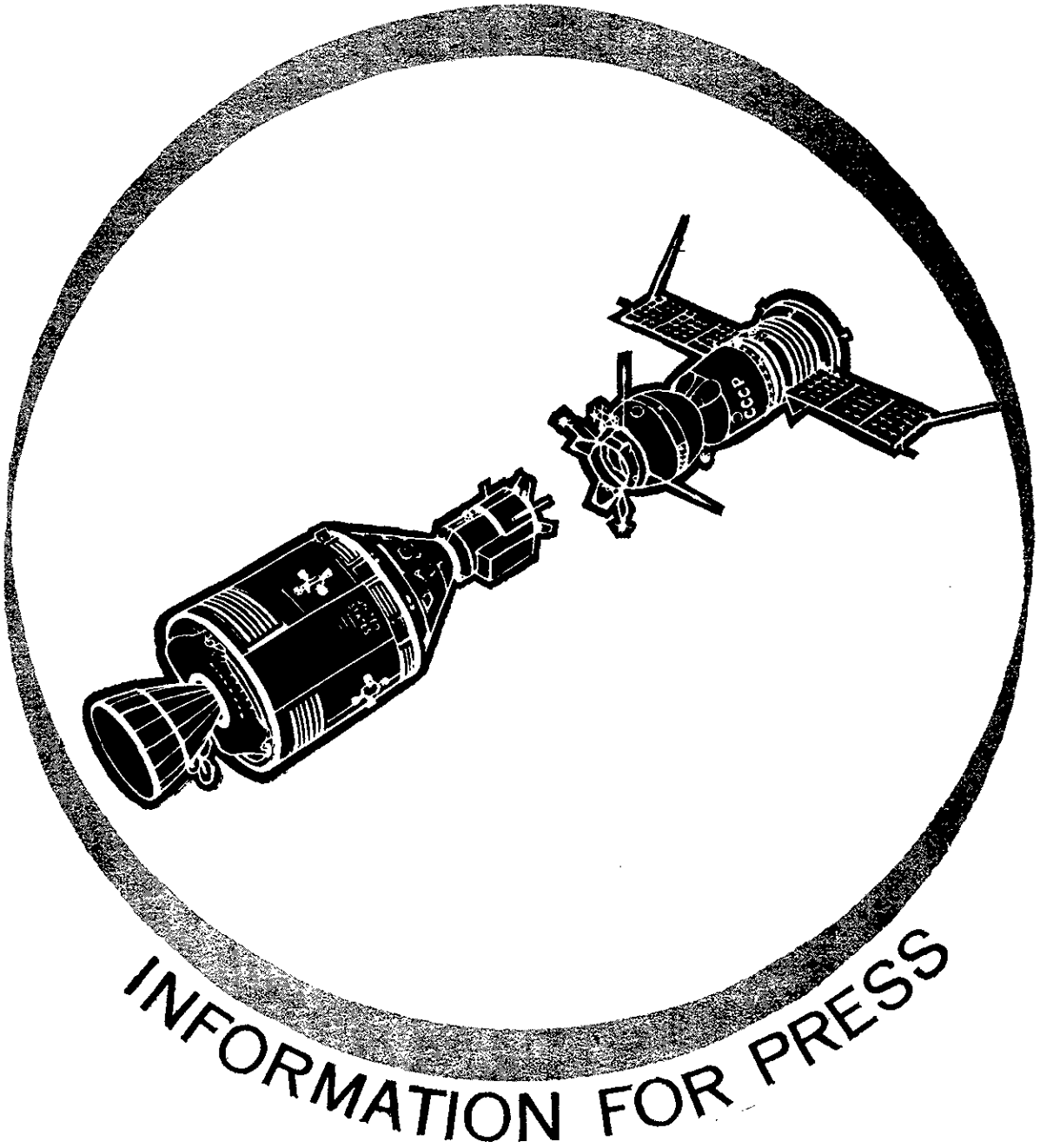


# APOLLO-SOYUZ TEST PROJECT



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## FOREWORD

The document contains materials on the Soyuz-Apollo test and consists of two parts, prepared by the USSR and USA sides respectively.

Both parts outline the purposes and program of the mission, the spacecraft design, the flight plan and information on joint and unilateral scientific experiments.

Brief biographies of the cosmonauts and astronauts, the joint mission crew members, are also presented. The document covers technical support activities providing mission control and gives information about the ASTP Soviet and American leaders.

As the USSR and USA parts of the document have been prepared independently, there might be duplication in the sections dealing with the joint activities.

The document is intended for press representatives and various mass information means.

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1.0 INTRODUCTION

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1.1 Background

Test flight of the Apollo-Soyuz test project (ASTP) is performed in accordance with the USSR/USA agreement on cooperation in the exploration and peaceful uses of space in order to develop compatible means of rendezvous and docking for the Soviet and American manned spacecraft and stations. This flight reflects the desire of both countries to create material basis with the aim of enhancing the objective of furthering the safety of manned space flight and supporting scientific experiments program in the future.

Since 1970 representatives of the USSR Academy of Science and the USA NASA have been discussing technical questions of the development of compatible rendezvous and docking systems of manned spacecrafts and stations. During the first joint meeting of the USSR and US specialists held in Moscow in 1970, October 26-27 both sides exchanged their views and information on the major directions to be followed in assuring compatibility of rendezvous and docking systems.

At this meeting working groups were set up to develop and approve technical requirements for compatibility of these systems.

Subsequent meetings were held in June and November 1971 to discuss technical requirements for spacecraft systems, approve basic technical decisions and guidelines for providing compatibility and discuss the possibility of carrying out the manned flights using existing spacecrafts in order to test the compatible means of rendezvous and docking in the middle of the 70's. The meetings of specialists of the Academy of Sciences, USSR and NASA, USA were held in Moscow and Houston alternately and were headed by the Aca-

demician B.Petrov, Chairman of Intercosmos Council, USSR Academy of Sciences and **R.Gilruth, NASA Manager**, Manned Spaceflight Center.

The Summary Document was signed on April 6, 1972 during the meeting of the representatives of the USSR Academy of Sciences and USA NASA. This meeting was held to discuss questions pertaining to the development of compatible means of rendezvous and docking of the USSR/USA manned spacecraft and stations. The document said that the test mission with the subsequent docking of the Soviet and American spacecraft was considered desirable in order to test the compatible means of rendezvous and docking.

On May 24, 1972, in Moscow, A.N.Kosygin, Chairman of the Council of Ministers of the Soviet Union and United States President R.Nixon signed an agreement between the two nations on cooperation in the exploration and peaceful uses of outer space. Both sides agreed to develop compatible means of rendezvous and docking and conduct in 1975 the first test mission in order to test the means by accomplishing docking of the Soviet Soyuz-type spacecraft and American Apollo-type spacecraft and the transfer of cosmonauts and astronauts (see fig.1.1). K.Bushuyev, a corresponding-member of the USSR Academy of Sciences, was appointed an ASTP Director from the Soviet side, and Doctor G.Lunney - from the American side.

Determination of the main objectives and stages of the mission, definition of the basic requirements for compatible and interacting systems were essentially completed during the meetings of specialists held in the second half of 1972 and in March, 1973.

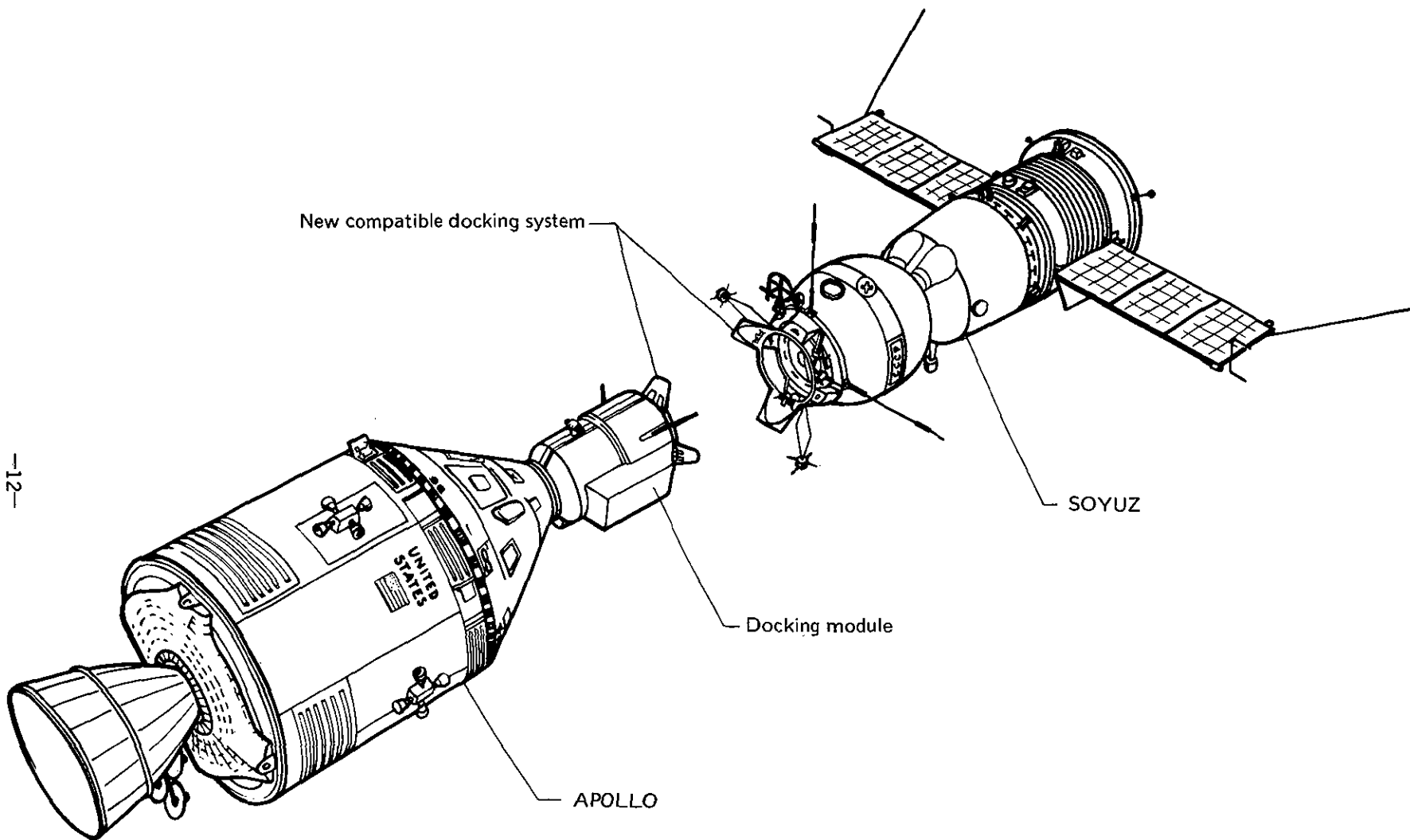


FIGURE 1.1 RENDEZVOUS AND DOCKING OF THE SOUYZ AND APOLLO SPACECRAFT DURING TEST FLIGHT

In October, 1972 the timing for carrying out the joint Apollo/Soyuz test mission was determined - July 15, 1975.

As technical requirements were determined development of the systems and technical documentation to be used for the manufacturing of compatible equipment was initiated.

From October, 1972 until April, 1974 the joint reviews of the compatible equipment were held to assure successful accomplishment of the mission.

Ground tests of compatible means started from October, 1973 in order to develop component designs and checking their performance.

The final tests of compatible means installed on the Soyuz and Apollo spacecraft are conducted completion at the launch sites.

## 1.2 Apollo-Soyuz joint test project objectives

The primary objective of Apollo/Soyuz joint mission is to check technical requirements and solutions for rendezvous and docking of future manned spacecraft and stations.

The performance of this mission includes the following:

- a) testing of a compatible rendezvous system in orbit;
- b) testing of androgynous docking assemblies;
- c) verifying the techniques of transfer of cosmonauts and astronauts;
- d) performance of certain activities of US and USSR crews in docked flight;

- e) gaining of experience in conducting joint flights by US and USSR spacecraft, including, in case of necessity, rendering aid in emergency situations.

The performance of Apollo-Soyuz joint test mission is a significant step in developing international cooperation in research and utilization of space for peaceful purposes.

## 2.0 COMPATIBILITY PROBLEMS

### 2.1 Spacecraft compatibility conditions and principal solutions, accepted for Apollo-Soyuz Test Mission

To accomplish manned spacecraft and stations rendezvous and docking it is necessary to meet three basic requirements:

First requirement - compatibility of docking units, that is of all assemblies which directly interface during docking. The docking units must be universal, active/passive, or as they are now called, androgynous, because either spacecraft can be the one waiting for assistance or rendering aid. For this purpose a basically new compatible androgynous docking system was developed for the Apollo and Soyuz spacecraft.

Second requirement - compatibility of the means of providing spacecraft ranging and rendezvous. The active vehicle using radio or optical means, must find the passive one (not excluding the ground facilities support) and approach it with the given accuracy using Reaction Control System; mechanical contact of the two docking systems should be ensured.

The passive vehicle usually assists the active spacecraft in tracking and rendezvous, using its radiosystem operating in transpond mode. That is why similar principles should be used when developing radiosystems of both spacecraft. They should also have the agreed to parameters.

It is also necessary to meet these requirements when providing voice communication between the crews. To provide tracking and rendezvous with the vehicle, not transmitting any radiation, a necessity arises to utilize the optical means of tracking and



ranging, or a radar operating on the basis of reflected signals. In the first case the unification of a number of elements is necessary, which provide optical measuring (unification of docking targets, agreement on vehicles surface light reflection and absorption coefficients) and use of optical measuring devices with unified characteristics.

For providing spacecraft visual detection and defining their mutual position the onboard unified flashing beacons and orientation lights must be used.

In the ASTP mission tracking and relative motion parameters measurements (radial speed and distance between spacecraft) are provided by the Apollo radiosystem with the transponding part installed onboard Soyuz.

Besides that, an optical system is used, by means of which the Apollo crew can track Soyuz during rendezvous at a distance of several hundred kilometers, and also determine spacecraft mutual attitude. For tracking in the darkness at a distance of dozens of kilometers the Soyuz is equipped with flashing beacons. At the final rendezvous phase (during approach) the spacecraft mutual position is determined visually by means of Apollo alignment sight and the Soyuz onboard orientation lights and docking targets.

All parameters measured are fed into the onboard computer, which provides data, necessary for guidance during rendezvous.

Third requirement - spacecraft habitable modules atmosphere parameters compatibility, specifically, compatibility of its components and pressure, because the crew cannot transfer from one spacecraft to another, if they have essentially different atmospheres.

The concepts of conditioning inside the habitable modules can be different but the environment parameters must be close.

In the previous flights Soyuz atmosphere practically corresponded to that of the Earth: pressure - 750-860 mm Hg, oxygen - 20-25%, nitrogen - 78-73%. Apollo atmosphere consists of pure oxygen with pressure of 260 mm Hg.

Crew transfer from Soyuz to Apollo without any special measures taken would result in decompression disturbances (itch, joint and muscle pain etc.), which are accounted for by rapid nitrogen excretion (bubbles can obstruct blood vessels and disturb blood circulation in different organs).

To avoid decompression disturbances it is necessary to gradually reduce pressure, preserving  $O_2$  partial pressure or to carry out the nitrogen desaturation (pure oxygen breathing for several hours to remove the nitrogen from blood). For the ASTP a special Docking (Transfer) Module is developed - a kind of an airlock with changeable atmosphere; after docking it is to be located between the habitable modules. The DM is inserted into orbit together with Apollo. During the crew spacecraft-to-spacecraft transfer the Docking Module atmosphere corresponds to the atmosphere of the habitable module with which free communication via internal hatch is established. To exclude such a process it was finally agreed to reduce the total pressure in Soyuz maintaining the same absolute oxygen content. Usage of Docking Module and reduction of pressure in Soyuz (to 490-550 mm Hg) practically exclude desaturation process and ensure fast and safe spacecraft-to-spacecraft transfer without complete compatibility of spacecraft atmospheres.

## 2.2 Compatibility of ground flight control personnel

Joint flight of Soyuz and Apollo spacecraft brought up a number of new problems of flight control to be solved by Soviet and American specialists.

Spacecraft flight control is a very complex process which involves the use of a wide network of tracking stations spread around the globe, several computation centers, a great variety of support equipment with complex interaction and participation of many specially trained specialists. All required information, from the data on the state of health of crewmembers up to the exact location of spacecraft, is routed thru the numerous communications channels to the Mission Control Center.

During the joint flight Soyuz and Apollo will be controlled by the Soviet and American Mission Control Centers respectively.

Such an approach towards flight control requires a strict coordination of activities of the USSR and US ground control personnel in the course of performing all operations in mission including spacecraft docking and crew joint activity.

The complexity of the mentioned problems is that each side worked out its own documentation in accordance with the principles adopted and established in its country.

Organization of the joint mission control required the formulation and adoption of shared principles of flight control which could become the basis for working out joint documentation specifying control personnel activities in nominal and contingency situations.

It was essential to overcome the language barrier, organize an exchange of information and allocate responsibilities in nominal and contingency situations.

Discussions and joint efforts have resulted in an agreement on interaction. Then the documents specifying joint activities of ground control personnel during flight were issued. These documents included all basic guidelines for the MCC interaction and details of specific activities of the US and USSR Mission Control Centers. Moreover, the documents contain time schedules for interaction of the Control Centers and standard formats for data exchange.

The language barrier was decided to be overcome thru interpreters on duty in MCC. For communication between Mission Control Centers, standard terminology will be used. Interpreters will use the same standard terms and phrases. Verbal reports will be transmitted in the receiving side language. Both American and Soviet interpreters will hear the reports in English and Russian. All verbal calls will be initiated with the identification of a called person followed by the identification of a calling person. Every working station in Control Centers will have standard identification.

### 2.3 Methodological compatibility

It is impossible to perform the joint spacecraft missions by different countries, without solving the problems of methodological compatibility. These are: terminology regulations, marks agreed, unification of coordinate systems and initial data for joint calculations and so on. A demonstrative example - reaching agreement in providing Apollo-Soyuz mission trajectory compatibility.

At the beginning of the joint work on the project there appeared some differences in understanding and use of some initial meanings and definitions by each country. These differences were mainly explained by traditions of each country in space research. So the joint work began from the agreement on the initial data and definitions. Coordinate systems were agreed upon. For describing the numerical characteristics the metrical system was accepted, and for preflight calculations the upper Earth atmosphere was taken as proposed by the USSR and the Earth gravity model, proposed by the USA (further they were called "the ASTP models"). This agreement ensured the compatible results of trajectory calculations performed by each country, and their identical understanding.

In some cases the traditional concepts were retained, if they did not principally effect the work. For example, it was decided to retain the orbital concept, traditional for each country, but both definitions of the word orbit were clearly given in the terms of both the USSR and the USA.

All this activity resulted in the common "Trajectory language" which proves useful in mutual understanding of specialists

working on this and future programs. In some cases compatibility was achieved by compromise decisions as was the case with agreement on Apollo and Soyuz launch time. After it was proved to be impossible to equally meet both countries launch time requirements, the American and Soviet sides refused to fully follow their traditional limitations and agreed on a compromised launch time.

For familiarization with and understanding of methods and approach, that the cooperating sides used in solving different problems of ballistics both sides exchanged brief mathematical description of the methods for defining and planning space objects motion: the US described procedures of Apollo rendezvous, and the procedures of the Soyuz forming the assembling orbit.

The trajectory compatibility was checked during joint experiments on tracking the Soviet spacecraft Soyuz-16 by the USA and USSR ground stations.

3.0 THE SOYUZ SPACECRAFT

3.1 The spacecraft purpose, brief data on "Soyuz" spacecraft flights

The Soyuz spacecraft is designed for solving a variety of objectives in the near space, among them:

- a) to develop autonomous navigation, guidance, maneuvering and rendezvous procedures and verify the concepts of designing and maintaining the Earth space stations;
- b) to study the space flight conditions influence on human organism;
- c) investigate possibilities of utilizing manned spacecraft for the Earth research for the benefit of the USSR national economy;
- d) to conduct some technical and scientific experiments in space.

During the period from 1967 to 1975 15 manned Soyuz spaceships accomplished their flight programs:

|         |             |      |            |   |
|---------|-------------|------|------------|---|
| Soyuz-1 | 23-24 April | 1967 | cosmonaut  | V.M.KOMAROV                                 |
| Soyuz-3 | 26-30 Oct.  | 1967 | -"-        | G.T.BEREGOVOI                               |
| Soyuz-4 | 14-17 Jan.  | 1969 | -"-        | V.A.SHATALOV                                |
| Soyuz-5 | 15-18 Jan.  | 1969 | cosmonauts | V.V.VOLYNOV<br>A.S.YELISEYEV<br>E.V.KHRUNOV |
| Soyuz-6 | 11-16 Oct.  | 1969 | -"-        | G.S.SHONIN<br>V.N.KUBASOV                   |

|          |              |      |            |  |
|----------|--------------|------|------------|--|
| Soyuz-7  | 12-17 Oct.   | 1969 | cosmonauts | A.V.FILIPCHENKO<br>V.N.VOLKOV<br>V.V.GORBATKO      |
| Soyuz-8  | 13-18 Oct.   | 1969 | "-         | V.A.SHATALOV<br>A.S.YELISEYEV                      |
| Soyuz-9  | 1-19 June    | 1970 | "-         | A.G.NIKOLAEV<br>V.I.SEVASTYANOV                    |
| Soyuz-10 | 23-25 April  | 1971 | "-         | V.A.SHATALOV<br>A.S.YELISEYEV<br>N.N.RUKAVISHNIKOV |
| Soyuz-11 | 6-30 June    | 1971 | "-         | G.T.DOBROVOLSKY<br>V.N.VOLKOV<br>V.I.PATSAEV       |
| Soyuz-12 | 27-29 Sept.  | 1973 | "-         | V.G.LAZAREV<br>O.G.MAKAROV                         |
| Soyuz-13 | 18-26 Dec.   | 1973 | "-         | P.I.KLIMUK<br>V.V.LEBEDEV                          |
| Soyuz-14 | 3-19 July    | 1974 | "-         | P.R.POPOVICH<br>Y.P.ARTUKHIN                       |
| Soyuz-15 | 26-28 August | 1974 | "-         | G.V.SARAFANOV<br>L.S.DEMIN                         |
| Soyuz-16 | 2-8 Dec.     | 1974 | "-         | A.V.FILIPCHENKO<br>N.N.RUKAVISHNIKOV               |

During these flights the following objectives were solved:

a) Soyuz-4 and Soyuz-5 performed automatic rendezvous, manual approach and docking of two manned vehicles, that assembled the first experimental space station with a total weight of 12924 kg on the Earth orbit. During the flight in docked configuration the 2 cosmonauts in space suits with individual life support systems performed the EVA and accomplished spacecraft-to-spacecraft transfer.

b) During Soyuz-6, Soyuz-7 and Soyuz-8 group flight scientific and technical experiments were accomplished, including different methods of welding tests using various metals in



low vacuum and weightless conditions, navigational tracking in flight, mutual maneuvering, spacecraft interaction and their communication with ground stations, located in different areas of the USSR and with ships of the USSR Academy of Science simultaneous control of 3 spacecraft flight.

c) Soyuz-9 performed a 424 hour flight during which an extensive program of biological and scientific experiments was accomplished.

d) Astrophysical observations and spectrography of some parts of the sky were conducted onboard Soyuz-13 using "Orion-2" telescope system.

e) Soyuz-1, Soyuz-3, Soyuz-10, Soyuz-11, Soyuz-12, Soyuz-14 and Soyuz-15 spaceships tested some onboard and new modernized systems both in independent flights and in the joint flights with Salut-type stations. Moreover, unmanned Soyuz-type spacecraft were launched to develop in flight certain subsystems and some elements of spacecraft.

f) According to the Soviet preparation plan for the joint Apollo-Soyuz mission two unmanned Soyuz type spacecraft flights were successfully accomplished (Cosmos-638 April 2, 1974,

and Cosmos-672 August 12, 1974). The Soyuz-16 with Filipchenko and Rukavishnikov on board performed its mission from 2 thru 8 Dec., 1974. The Soyuz-16 is a prototype of the spacecraft for the Apollo-Soyuz flight in 1975. During the 6 day flight the onboard systems modified according to the joint flight requirements were successfully tested. Tested were new docking unit and its automatics, orientation and guidance system, life support system.

In addition the crew activities and operation modes were checked during the flight, when solving the tasks identical to those for the future mission in 1975.

### 3.2 Soyuz spacecraft description

#### 3.2.1 General description of the Soyuz spacecraft

##### Main characteristics:

|  |                   |
|--|-------------------|
| Spacecraft maximum weight.....             | 6.8 tons          |
| Maximum length.....                        | 7.5 m             |
| Maximum diameter.....                      | 2.72 m            |
| Diameter of the habitable modules.....     | 2.2 m             |
| Solar panel span.....                      | 8.37 m            |
| Total volume of the habitable modules..... | 10 m <sup>3</sup> |

##### Soyuz constructive arrangement

The Soyuz spacecraft consists of three main modules:

- Descent Vehicle (DV);
- Orbital Module (OM);
- Instrument-Assembly Module (IAM).

General view of the Soyuz spacecraft is shown in Figure 3.1

The left part of the spacecraft consists of the docking system and Orbital Module, which is joined to the Descent Vehicle. The Descent Vehicle in turn is joined through a front heat shield to the Instrument-Assembly Module with solar panels installed. Mechanical connection of the spacecraft modules is performed using the pyrotechnic joints. Location of the main outer elements of the spacecraft systems is shown in the Soyuz space-

craft general view (Figures 3.1,3.2,3.3). The elements of compatible means inserted to support Apollo/Soyuz test project are outlined particularly.

The Soyuz spacecraft consists of the following main systems:

- attitude motion control system for flight and descent;
- rendezvous and correcting propulsion system;
- approach-orientation propulsion system;
- radio communication systems;
- electric power supply system;
- docking system;
- radio guidance system and system for providing rendezvous and approach using optical devices;
- parachute system and soft landing system;
- life support system complex;
- onboard equipment control system.

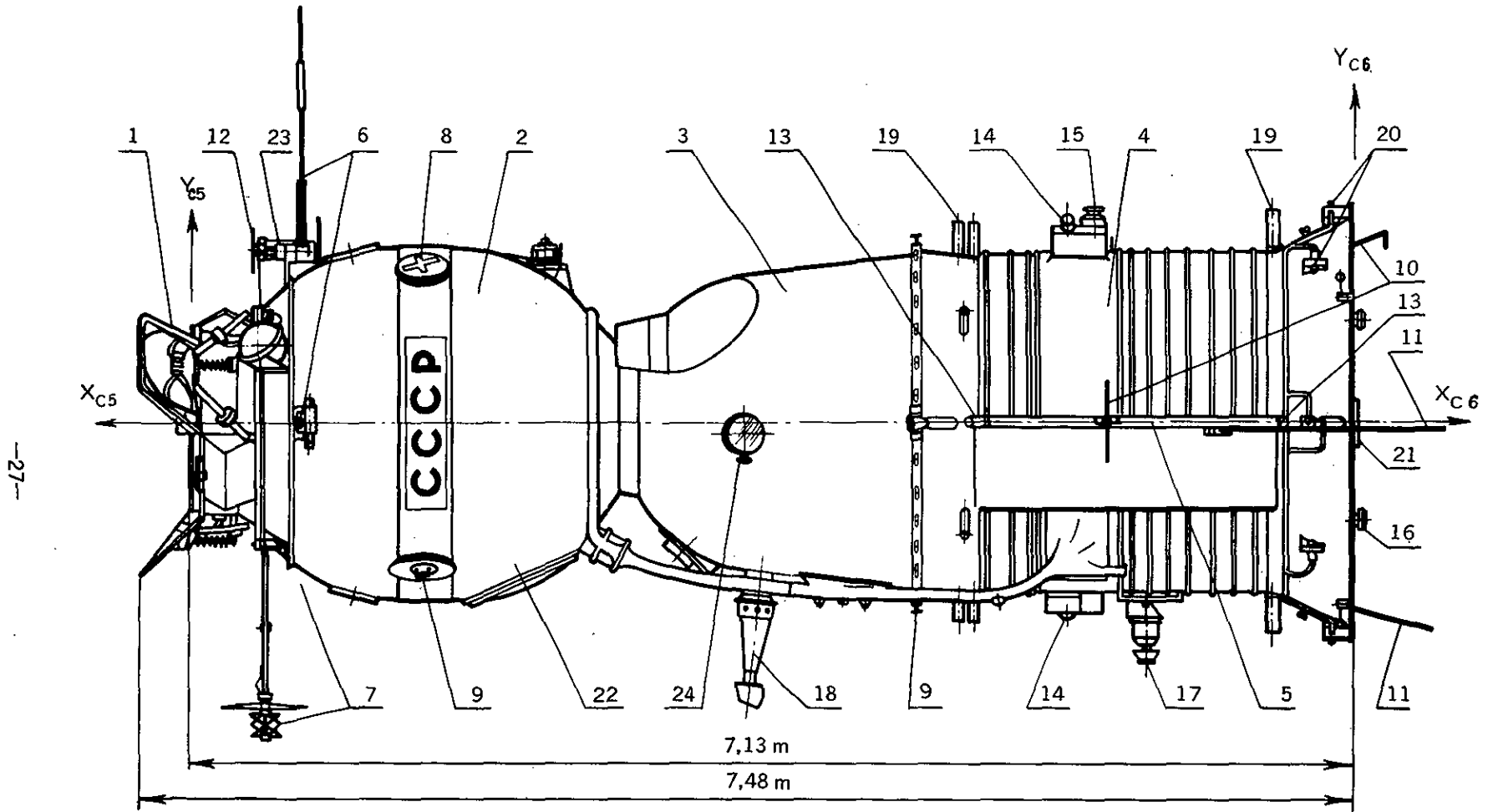


FIGURE 3.1 GENERAL VIEW OF THE SOUYZ SPACECRAFT (SIDE VIEW)

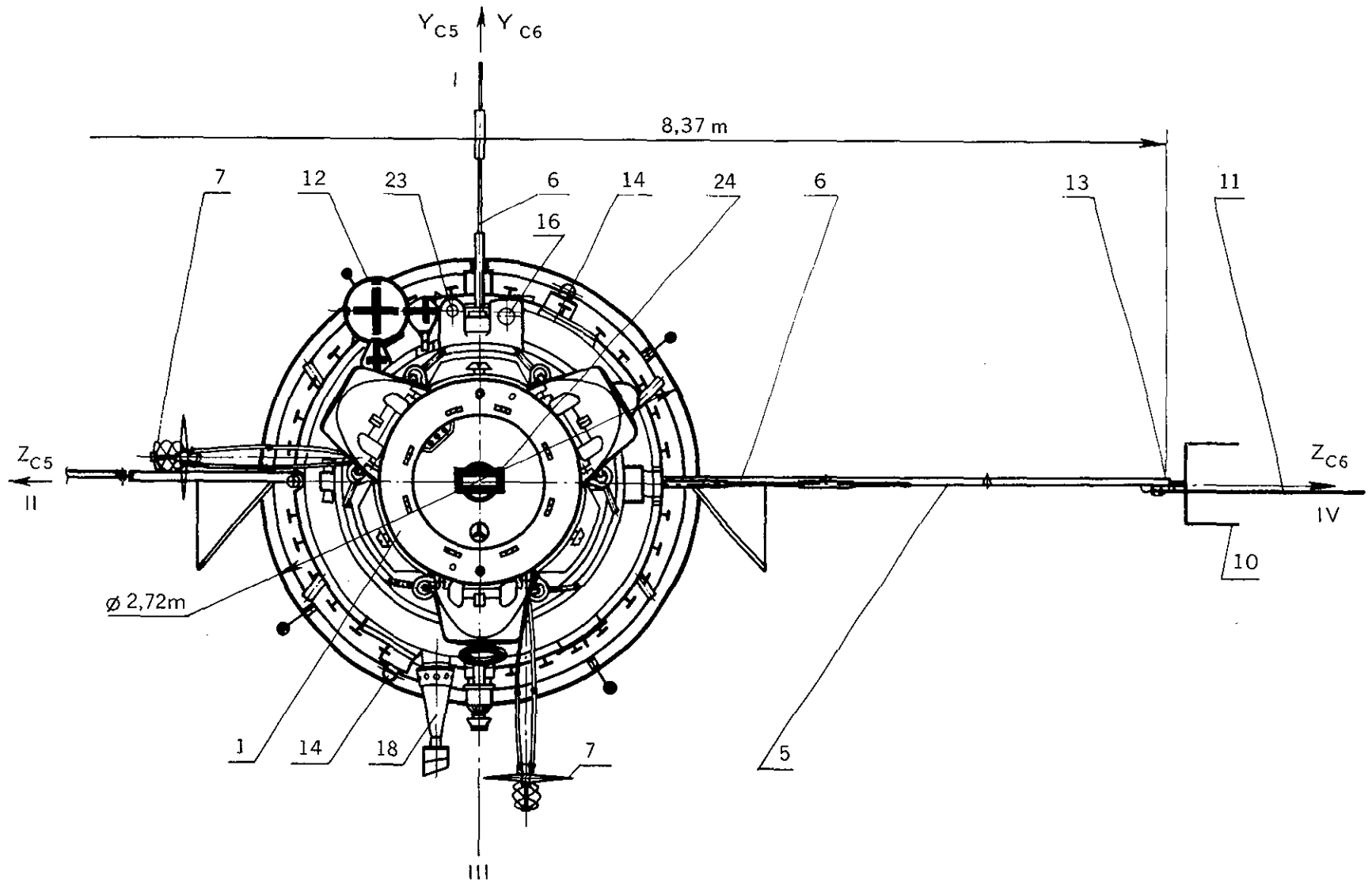


FIGURE 3.2 GENERAL VIEW OF THE SOUYZ SPACECRAFT (FRONT VIEW)

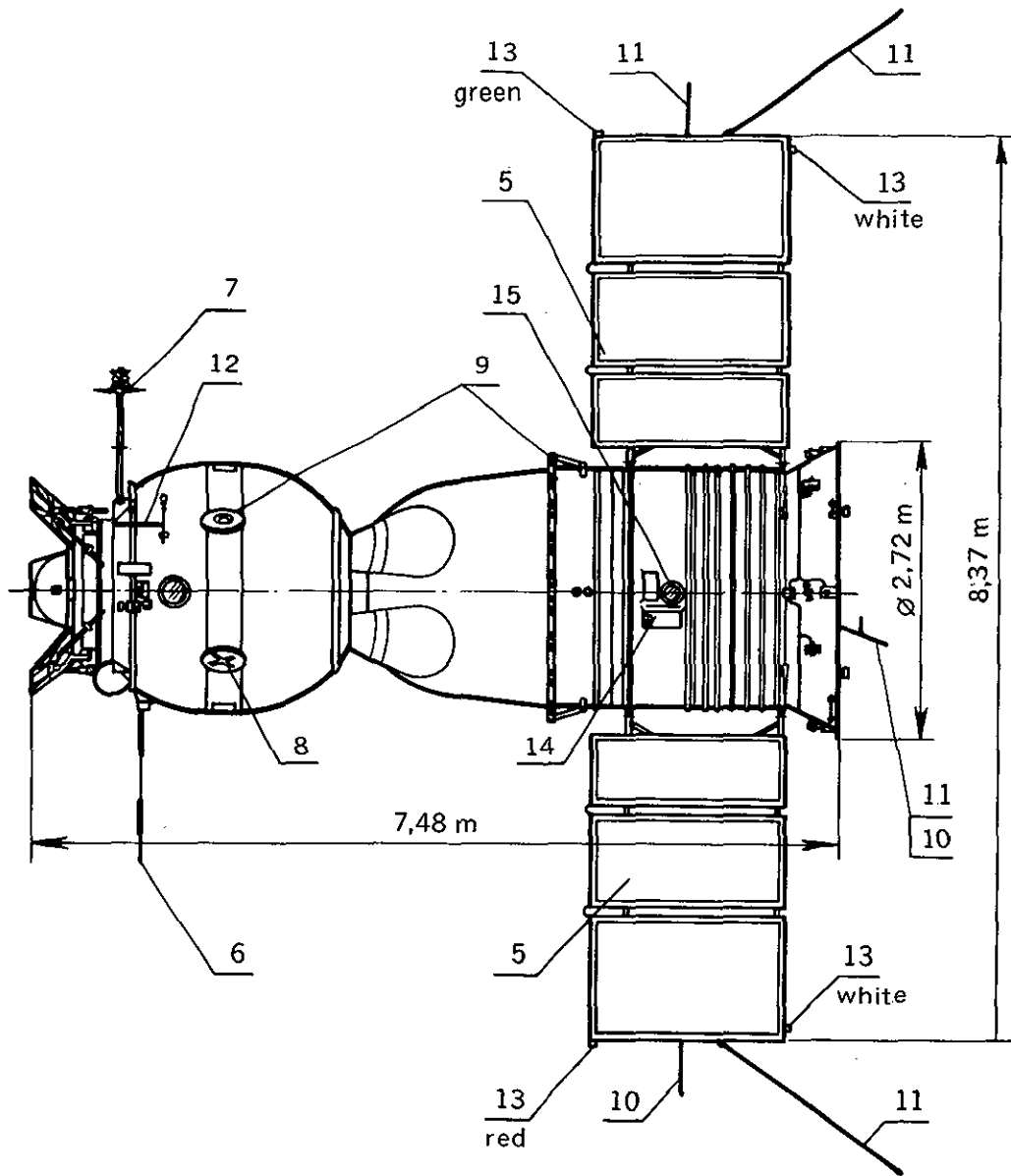


FIGURE 3.3 GENERAL VIEW OF THE SOYUZ SPACECRAFT (TOP VIEW)

- 1 - Androgynous peripheral docking system,
- 2 - Orbital Module,
- 3 - Descent Vehicle,
- 4 - Instrument-Assembly Module,
- 5 - Solar panels,
- 6 - VHF-radio station antennas on the frequency of 121,75 Mhz,
- 7 - Apollo VHF-radio station antennas on the frequencies of 259,7 Mhz and 296,8 Mhz,
- 8 - the antennas of the radio and television system,
- 9 - the antennas of the command radio link and trajectory measurements,
- 10 - the antennas of the radio telemetry system,
- 11 - the antenna used to communicate with Earth,
- 12 - docking target,
- 13 - onboard orientation lights,
- 14 - flashing light beacons,
- 15 - sun sensor,
- 16 - ion orientation sensor,
- 17 - infra red orientation sensor,
- 18 - optical orientator,
- 19 - approach and orientation engines,
- 20 - orientation engines,
- 21 - approach-correcting engine,
- 22 - the hatch for the crew ingress,
- 23 - external TV camera,
- 24 - windows.

To Fig. 3.1, 3.2, 3.3.

## DESCRIPTION OF THE SPACECRAFT MODULES

The Descent Vehicle (Figure 3,4) is intended for crew location during insertion into orbit, orbital flight, controlled descent through the atmosphere, parachuting and landing. The descent vehicle is a hermetically sealed compartment, provided with two viewing windows on its sides and one window with sighting device. The shell of the compartment is covered with heat shielding material on its outside, and thermal insulation and decorative materials on its inside. Cosmonauts' panel spacecraft control handles equipment of the main and supporting systems, containers for the scientific equipment to be returned and emergency kit for the crew are also located in the descent vehicle.

For the ASTP there is an additional control panel in descent vehicle to provide compatible radio-stations and external lights control. Special lights and additional brackets for TV camera mounting are installed to provide colour TV transmission.



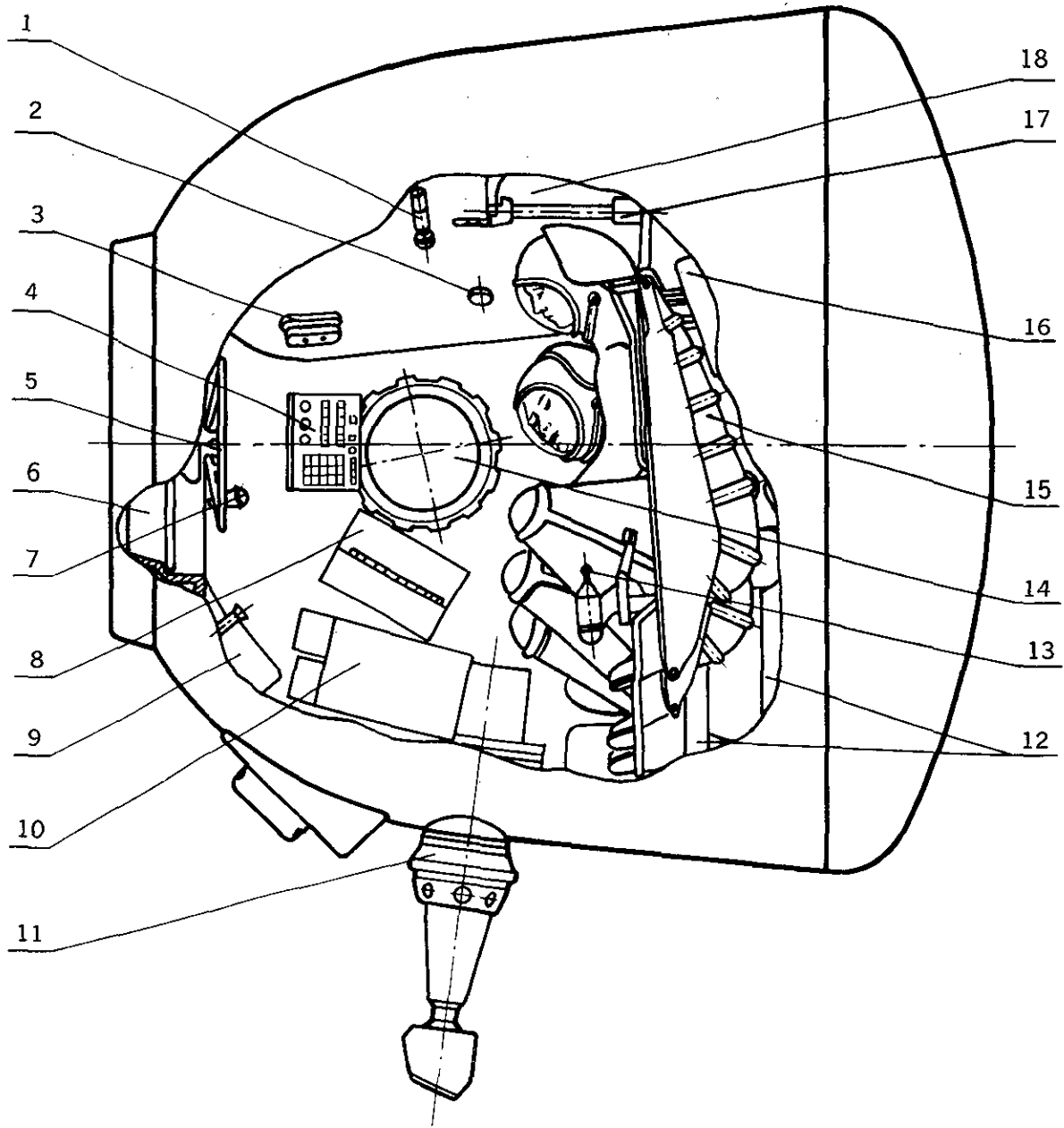


FIGURE 3.4 THE DESCENT VEHICLE ARRANGEMENT

- 1 - Portable light with autonomous power supply,
- 2 - Loud speaker,
- 3 - Working light,
- 4 - VHF-radio-stations control panel,
- 5 - Hatch wheel,
- 6 - Hatch, cover,
- 7 - Special illumination lamp,
- 8 - Command-signal device,
- 9 - TV camera,
- 10 - Instrument panel,
- 11 - Sighting device,
- 12 - Equipment,
- 13 - Control handles,
- 14 - Window,
- 15 - Cosmonaut couch,
- 16 - Equipment,
- 17 - Couch leg,
- 18 - Parachute container.

Fig. 3.4

The Orbital Module (Figure 35) is intended for conducting scientific experiments, for crews spacecraft-to-spacecraft transfers and for the rest of the crew.

The orbital module consists of two hemispheres connected by a cylindrical insert.

The androgynous peripheral docking mechanism with an internal hatch, having a cross-sectional diameter of 0.8 m is mounted on it. The orbital module has two viewing windows. The third window is in the cover of the docking mechanism hatch. At the bottom of the module there is a hatch connecting the Orbital Module and the Descent Vehicle, as well as a side hatch for the crew to enter the spacecraft on the launch pad.

The interior of the module consists of a sideboard and a "Sofa", which contain control panel, instrumentation and equipment of the main support systems. Scientific equipment is also located in the Orbital Module.

To the joint Apollo/Soyuz mission the following equipment is provided in the Orbital Module:

- transponder of the Apollo VHF-radio-station with antennas and autonomous power supply for it;
- junction box for connecting the communication or television equipment transferred by astronauts from Apollo to Soyuz during transfers;
- additional VHF transceiver;
- compatible system automatics unit.

Special lights and additional brackets for TV cameras and cine and photography equipment are installed in the module to provide colour TV transmission to Earth and movie and picture shooting.

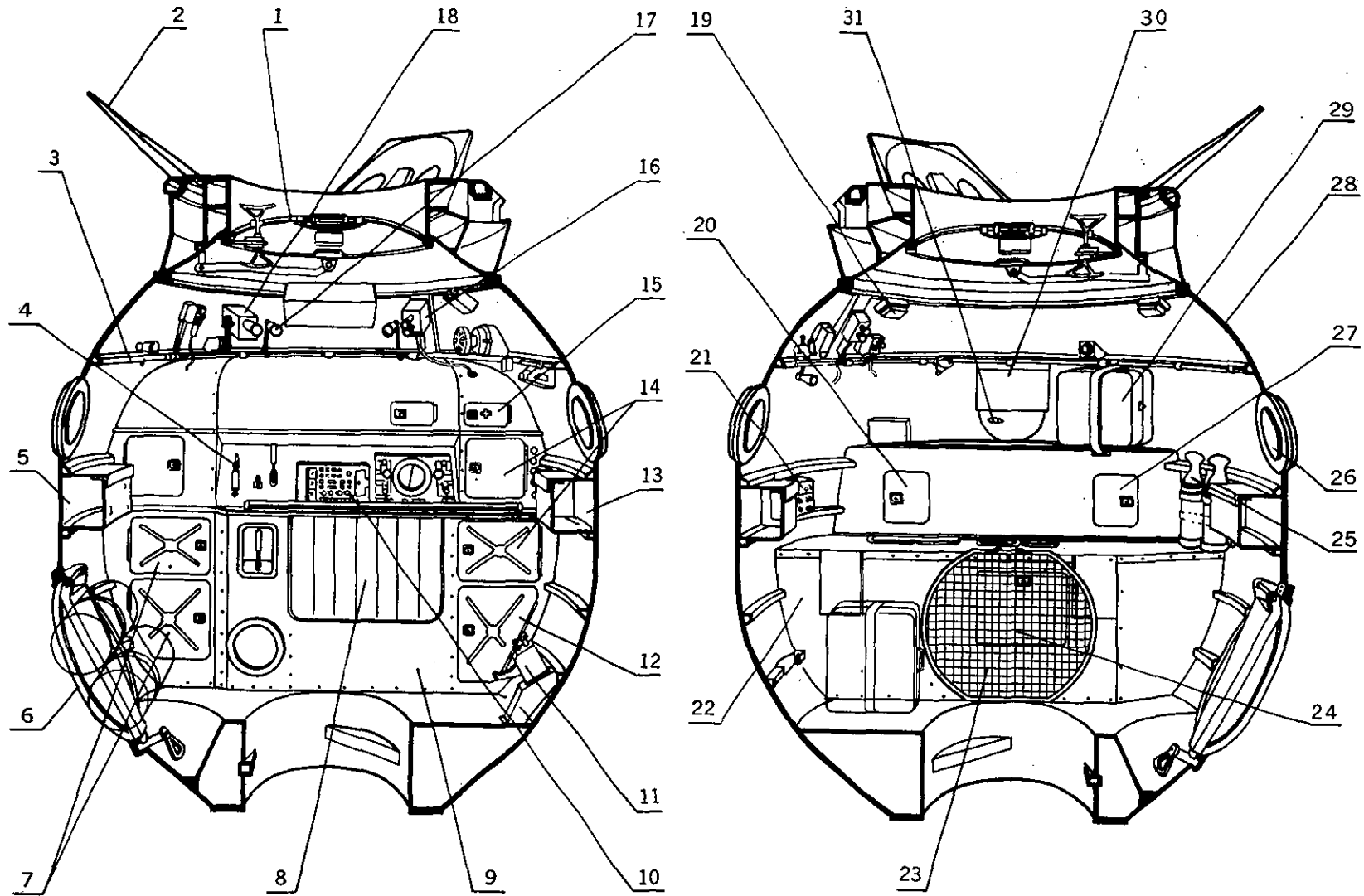


FIGURE 3.5 THE ORBITAL MODULE ARRANGEMENT

- 1 - Hatch cover,
- 2 - Docking mechanism;
- 3 - Hand-rail,
- 4 - Water dispenser,
- 5 - Waste container,
- 6 - Access hatch,
- 7 - Waste collector,
- 8 - Folding table,
- 9 - "Sideboard",
- 10 - Systems control panel,
- 11 - TV camera,
- 12 - Tools, communication cables,
- 13 - Container for scientific equipment,
- 14 - Food container,
- 15 - Medical kit, headset,
- 16 - TV camera,
- 17 - TV light,
- 18 - Apollo TV-camera
- 19 - Working lights,
- 20 - Container for onboard documents,
- 21 - Junction box,
- 22 - "Sofa",
- 23 - Cover,
- 24 - Container for stowage of cine and photography  
equipment, pressure suits and sleeping bags,
- 25 - Fire extinguishers,
- 26 - Window,
- 27 - Container for pressure suits hoses,

- 28 - Decorative covering,
- 29 - Container for transferred equipment,
- 30 - Gas analyzer,
- 31 - Handle of the valve of the module pressurization system.

Fig. 3.5

Antennas of compatible VHF-radio-stations, antennas of radio and television system, main and additional docking targets for approach and docking in a manual control mode are located on the module exterior in the vicinity of the external TV camera.

The Instrument-Assembly Module is intended for carrying the principle apparatus and equipment required for orbital flight. This module structurally consists of intermediate, instrument and assembly sections.

The intermediate section which joints the descent vehicle with the instrument section has a truss structure.

The engines with a thrust of 10 kg each, propellant tanks and propellant feed system of the approach and orientation engines system, are installed in this section.

On the intermediate section exterior there are:

- the small radiator of the thermal control system;
- front attachment points of the solar panels;
- antenna of the command-radio link.

The pressure-sealed instrument section has the shape of a squat cylinder with two ends. The equipment of the attitude motion control system, spacecraft onboard equipment control system, radio communication system, program-timing device, radio telemetry system, electric power supply system are located in the instrument section. The infra-red orientation sensor and sun sensor are mounted on the instrument section outer surface.

The assembly section is of a cylindrical shell design which is connected with a conical shell which ends with the base

mounting ring for the spacecraft installation on the launch-vehicle.

On the outside of the assembly section there are a radiator of the thermal control system, 4 approach and orientation engines with a thrust of 10 kg each, 8 orientation engines with a thrust of 1 kg each, and rear attachment points of the solar panels.

The rendezvous-correcting propulsion system is located in the assembly section. It consists of a main engine, a back up engine, propellant tanks and bipropellant feed system. In addition to that, the radio communication and telemetry antennas, the ion sensors of the orientation system and some of the batteries of the electric power supply system are installed in the vicinity of the base ring.

The instrument-assembly module also contains solar batteries in the form of two "wings", consisting of three panels each. Antennas for radio communication and telemetry in the VHF range and short-wave band and onboard color orientation lights are located on the end panels of the solar batteries.

For the Apollo/Soyuz test project the following elements of the compatible rendezvous system are mounted on the instrument-assembly module:

- flashing light beacons;
- an element of the additional docking target (on the instrument section);
- onboard color orientation lights (on the ends of solar panels).

The retroreflectors for joint ultraviolet absorption experiment are mounted in the orbital and instrument-assembly modules.



The Soyuz modules are externally protected with shield vacuum heat insulation of green color. Moreover, the Soyuz spacecraft is covered with a jettisonable nose fairing equipped with an emergency recovery propulsion system to protect the spacecraft during the phase of passing lower atmosphere layer.

### 3.2.2. Androgynous Peripheral Docking System (Fig.3.6)

#### Purpose.

The androgynous peripheral docking system (APDS) is designed to provide spacecraft docking and undocking and is one of the main compatible means for the spacecraft rendezvous and docking, that will be tested during the ASTP mission. The APDS is a modified docking system, which differs from previous versions developed according to the "pin-cone" schematic, and used for docking both the USSR and US spacecraft.

The Docking System performs the following functions:

- impact energy absorption;
- initial mechanical connection;
- spacecraft alignment and retraction;
- spacecraft hard mechanical connection and docking interface sealing;
- spacecraft undocking and separation.

Docking can be performed under the following conditions:

- spacecraft approach rate is 0.05-0.3 m/sec;
- longitudinal axes displacement up to 0.3m;
- pitch, yaw and roll misalignment up to  $7^{\circ}$ ;
- angular velocities: for an active spacecraft up to  $1^{\circ}$ /sec;
- for a passive spacecraft up to  $0.1^{\circ}$ /sec;
- lateral relative velocity up to 1.0 m/sec.

APDS configuration provides an inner tunnel for the crews to transfer from one spacecraft to the other.

When docking, APDS can be configured in either active or passive mode. The cosmonauts are provided with information on APDS primary units operation.

### APDS Development.

During the first meeting of the Soviet and American specialists in October 1970 the both sides provided data to develop a principle structure scheme of docking system.

It was necessary to develop an active/passive system capable of docking with any spacecraft of the given type (androgynous type). The US and USSR specialists provided different schematics of docking system. In addition, an androgynous principle was defined (the so called principle of reverse symmetry).

The second meeting was held in June, 1971 in Houston, USA. For this meeting the USSR side had prepared a new draft of "Technical Requirements for Docking Systems". The draft was used as a basis to determine technical requirements for development of the systems.

By the meeting in the fall 1971 the both sides had prepared their own drafts for a principle structure scheme. As the result of the discussion the joint features of the scheme, which was to meet the compatibility requirements were worked out. It was also agreed upon that each side would develop its own system, and these systems could differ from each other. Most of the Soviet proposals on the principle scheme had been adopted.

It was decided to provide to the USSR and US docking systems compatibility by using a common principle structure scheme and standardizing main dimensions of interacting elements when fulfilling the technical requirements for the structure. In addition, loads, temperatures and some other similar parameters were regulated.

In the course of development and fabrication docking system of each country was thoroughly worked at and tested separately and jointly by each side.

First the USSR and US DS scale mock-ups were tested jointly; then their full-scale mock-ups development tests were performed as well as testing of docking systems, practically identical to those to be used during the mission. And at last the preflight mate check of USSR and US flight DS was performed. Moreover, the USSR Docking System was installed on Soyuz-16 and thoroughly tested during the space flight. In this flight, a special ring simulated the Apollo docking ring. Main docking and undocking operations, including the functioning of latches which provide rigid connection of spacecraft have been checked

#### APDS Design.

The docking system consists of the following principle assemblies:

Docking system base is the main structural member to which main docking system assemblies are attached.

On the front end of the base there is a structural ring, the other end of the base has a flange for attachment to the spacecraft orbital module. The base is the pressure-tight construction and consists of a cylindrical part, forming a tunnel with a hatch which is locked from inside.

Guide ring consists of a ring, hollow in cross-section and three guides located  $45^{\circ}$  to the longitudinal axis of the docking system. The guide ring is installed on six supporting rods, attached in pairs. Supporting rods attachments are the kinematic connections between the rods and provide for the guide ring lateral displacement and roll during attenuation (three degrees of freedom).

The guide ring supports three capture latches with undocking drives.

Body mounted latches together with capture latches perform spacecraft docking. They are installed on the docking system base

and are equipped with solenoids to perform unlatching by a passive spacecraft.

Rods support the guide ring and connect it with the guide ring drive and docking system base. The rods are ball screws, that convert the stroke of the screw rod into rotary motion of the nut and vice versa. The rod configuration allows to change its length relative to the attachment points. The rods are attached to the base through joints with three degrees of freedom which transmit the rotary motion of the rods to the base assembly. The rods are attached to the guide ring at three points through rod connecting joints which provide kinematic connection between the crews.

Guide ring drive together with differential assembly performs two basic functions. The first function is to provide for rotation of the guide ring about lateral axes (pitch and yaw) during the impact attenuation. The second function is to retract and extend the guide ring. The guide ring rotation is accomplished through misalignment of the length of three rod pairs. The misalignment is accomplished by two gear differentials. The impact energy is absorbed by spring loaded mechanisms, which also serve to return the guide ring to its initial position. The supporting rods are moved by a drive, having two motors and an additional differential.

Structural ring latch provide hard, pressure-tight connection of the spacecraft. They consist of eight active and eight passive hooks, electrical drive installed on one of the latches and closed-loop cables connecting them. Each active hook has a cam operated mechanism, which performs its opening and tightening. Corresponding hooks of the passive docking system are captured by active hooks. The passive hook has a stack of preloaded bellville springs providing a definite force for the docking interface preloading.

Each passive and active hook is equipped with a pyrobolt to provide, if necessary, practically instantaneous undocking.

Guide pin together with the socket is designed for the spacecraft exact alignment during the final phase of retraction. When the DS is in active mode the pin can move radially to compensate for thermal and structural distortion of the structural ring. When the docking system is in passive mode, the guide pin is automatically locked in its central position.

The structural ring is also equipped with docking interface seal contact sensors and sensors indicating the interface seal compression.

Spring thrusters are located on the docking ring and provide spacecraft separation when the latches are opened.

Docking interface seal will provide pressure integrity of the docking interfaces. Docking interface seal consists of two concentric rubber rings seals on each system. The sealing is performed according to a "seal-to-seal" type.

The manhole cover is a part of the docking system and is used to close the transfer tunnel of the spacecraft.

The manhole locking/unlocking is manually performed by the crew. The manhole is sealed by a sealing mechanism, which has eight eccentric type latches, the latter being connected with each other by means of closed cable connection. In case the cover sealing mechanism fails, several or even all hooks can be opened or closed by means of its disassembling and subsequent assembling. The Docking System is equipped with alarm and meter system which provide all data about DS operation.

#### APDS operation during docking/undocking

During the mission the Soyuz docking system will first

operate in a passive mode, and during redocking in an active mode. Spacecraft docking schematic is given in Fig.3.7

Prior to docking the active DS guide ring is extended into forward position, and the passive DS guide ring is retracted to its most rearward position.

During approach the spacecraft are oriented relative to each other so that the DS guides of one spacecraft be approximately opposite the DS hollows of the other.

During spacecraft contact (impact) the guides of one DS slide along the guides of the other one, thus absorbing the spacecraft impact energy; then the active DS guide ring contacts with the passive one, and initial capture and spacecraft alignment is accomplished. Then the spacecraft retraction and their rigid coupling is performed.

Attenuation of spacecraft relative motion is realized by the guide ring's moving in any direction (on all six degrees of freedom) and energy absorbing units (springs and brakes). The ring movement in all direction is provided by changing the length of the six rods.

The initial capture is performed by three capture latches on the guide ring, which capture body-mounted latches of the passive system.

The spacecraft alignment is achieved by spring mechanisms, located on the guide ring and on the drive.

In case the spring energy is not adequate for alignment, the active DS ring is extended into its most forward position (till stop) by means of the drive, and the spacecraft are aligned approximately.

The guide ring retraction is performed by means of the drive after the spacecraft alignment. During the last phase of retraction the guide pins and sockets, located on the structural ring, perform spacecraft final alignment. When retracting and extending the guide ring electromagnetic locks, which prevent the guide ring misalignment, can be activated.

Spacecraft rigid docking. After the docking interface touching structure latches perform rigid docking and interface sealing. Then the docking interface and spacecraft tunnel leak tests are performed. The docking process is completed.

Undocking is performed by an active spacecrafts capture latches release and then by opening the structure latch hooks. If necessary, undocking can be performed by a passive spacecraft by body-mounted latches release and opening the structure latch passive hooks.

Spacecraft separation is performed by spring thrusters, symmetrically located on the structural rings of both systems, after the latches release.

All principal operations including structural latch operation during docking and undocking are redundant. Capture latch undocking as well as structural latch active and passive hooks opening is provided by pyrotechnic devices.

The docking system can perform all operations during docking/undocking automatically or each operation separately by initiating appropriate commands by cosmonauts or via command radio communication link. The system operation monitoring is performed by cosmonauts control panel indication and by the ground personnel (telemetry).



DOCKING SYSTEM ACTIVE

DOCKING SYSTEM PASSIVE

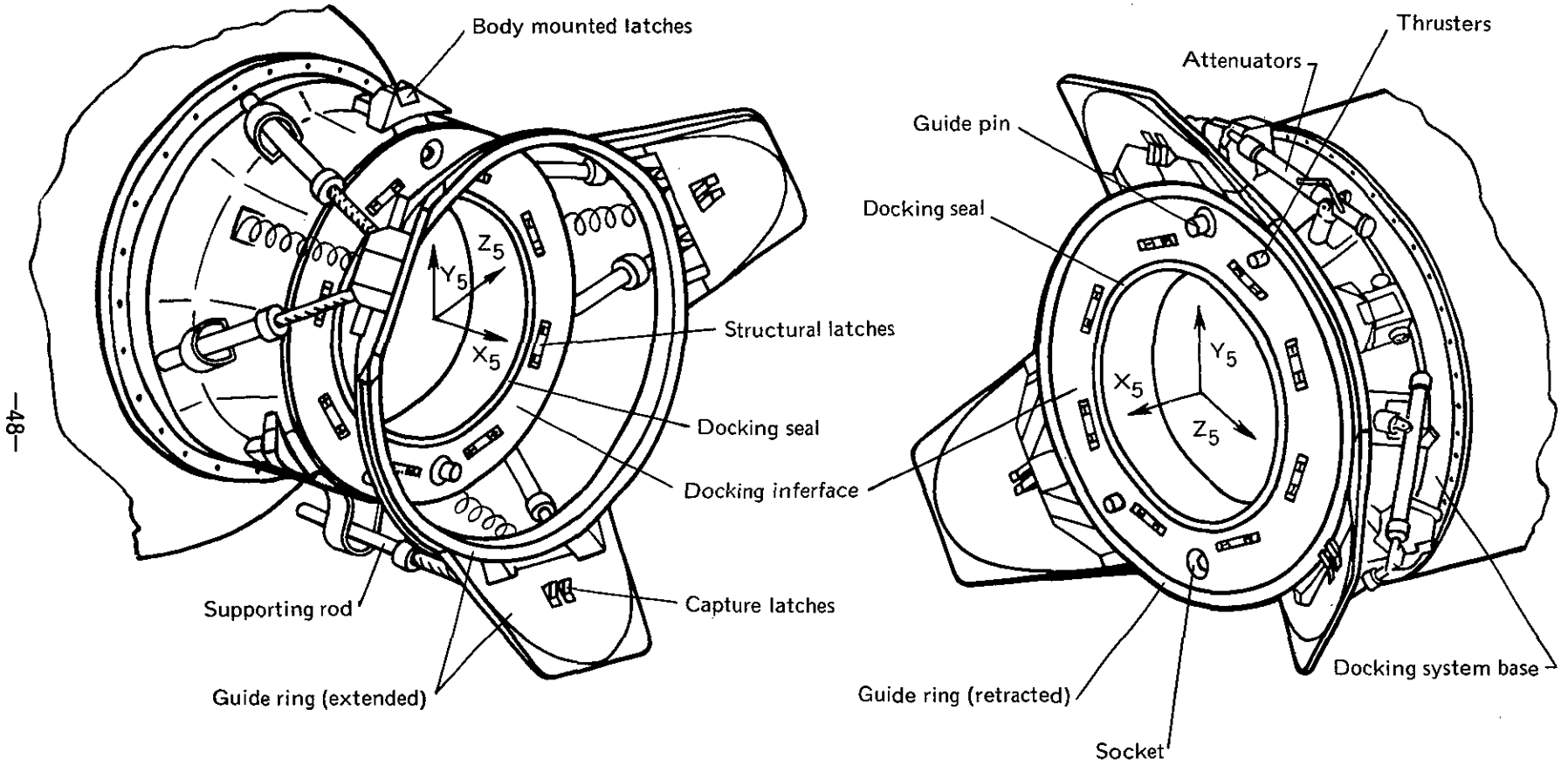
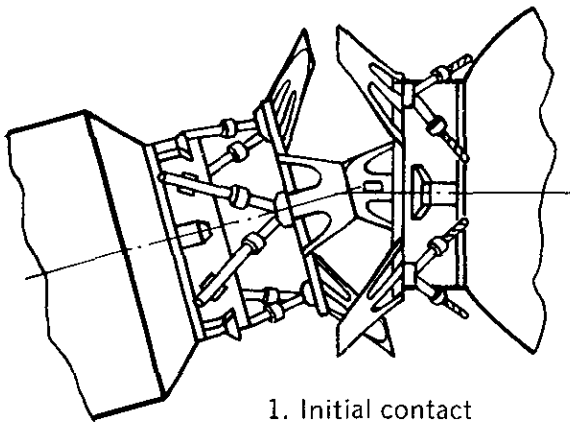
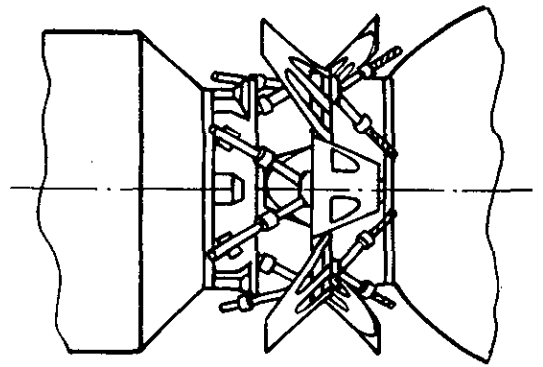


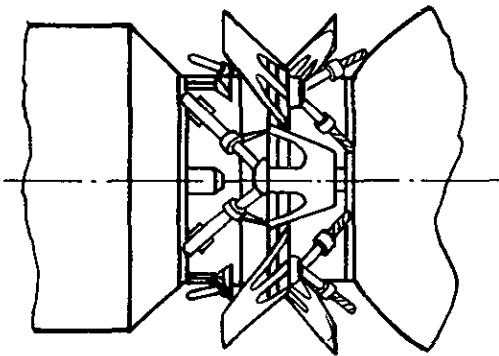
FIGURE 3.6 DOCKING SYSTEM



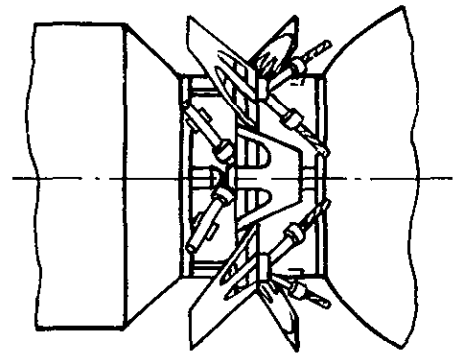
1. Initial contact



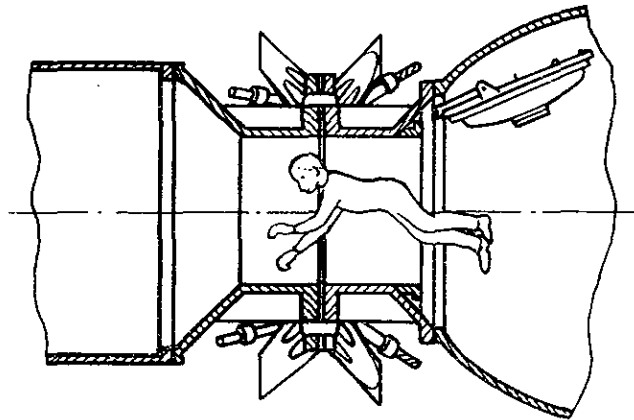
2. Guide ring mate and capture



3. Mutual alignment and retraction



4. Hard and pressure-tight coupling



5. Cosmonauts' transfer

FIGURE 3.7 SOYUZ/APOLLO SPACECRAFT DOCKING SCHEMATIC

## The difference between the Soyuz and Apollo Docking Systems

The USSR and US docking system designs have considerable differences. The differences are primarily based on previous experience of each side specialists and utilization of different structural procedures in manufacturing structural elements.

One of the principle differences of docking systems involve those in attenuation system and guide ring systems.

Unlike the Soyuz docking system electromechanic system of the Apollo is equipped with autonomous gyro attenuators and electric drive with cable connection.

Another essential difference it that the Soyuz docking system has electric drives for capture and body-mounted latches and pyrodevices for redundant undocking.

However, despite the difference in docking system designs, the fulfillment of agreed upon principles and requirements provided their compatibility and made Soyuz/Apollo docking possible.

### 3.2.3 Attitude and motion control system

#### Attitude and motion control system function and structure

The Soyuz attitude and motion control system is to provide the spacecraft attitude control.

This is: build-up of orientation modes; long-term maintenance of the spacecraft specific orientation - attitude hold; spacecraft attitude hold with the generation of a reaction pulse of the approach - correcting propulsion system (ACPS); approach control during the spacecraft rendezvous.

AMCS includes: command sensors; converting and switching devices; monitoring and attitude control aids and spacecraft controllers; reaction jet microengines, approach-correcting propulsion system.

The spacecraft attitude control may be conducted both automatically and manually. The crew can select a control mode. Automatic modes can be initiated by ground radiocommands. During automatic orientation sensing devices supply data on the spacecraft attitude and rotation rate. The onboard logic device converts these data into on-off commands for thrusters which control the spacecraft turns.

The manual control loop enables the crew to orient the spacecraft to the Earth, Sun or stars. During the orientation mode the crew is sighting these reference points using optical devices or spacecraft position transducers. The spacecraft orientation accomplished by means of hand controllers which provide on-off signals to orientation engines.

#### Command sensors

Infra-red horizon sensor senses the Earth and atmosphere infra-red radiation and provides the spacecraft orientation towards the Earth center.

Ionic sensors respond to the counter flow of ions which are the atmosphere "traces" at these altitudes. These sensors generate control signals when the spacecraft longitudinal axis deviates from its velocity vector during the spacecraft orbital motion.

Sun sensor is used during the spacecraft orientation towards the Sun. The sensor has two side search zones and the central

field of view. The Sun is usually acquired at first by one of the sensor search zone, and then it is "carried" to the sensor midpoint.

Angular-rate pickups are electronic/gyroscopic instruments to measure the spacecraft rotation velocity. The instruments converting units integrate velocity signals and issue control signals proportional to the spacecraft rotation angles.

Onboard the spacecraft there is a gyropackage comprising two gyros. This assembly maintains the spacecraft set orientation and allows to perform programmed turns.

#### Vision devices, orientation monitors and controllers

Vision and orientation monitoring devices and controllers are located at the crew stations in the descent vehicle.

Cosmonaut's sighting device is an optical device designated for visual observation of the Earth or the other spacecraft during its approach. It has a central and peripheral field of view.

The earth edge position in peripheral zones allows to orient the spacecraft towards the Earth centre.

Ground speed in the central field of the sighting device is used when performing its yaw orientation.

On the outside of the DV windows shade gauges are located. The cosmonaut performs the spacecraft orientation towards the Sun by the shadow on the gauge screens.

Using the controllers the cosmonaut provides the spacecraft rotation or translational maneuvers.

The cosmonaut's panel include data display facilities and the spacecraft control systems. The panels with two command-sig-

nal devices and the DV instrument board are used during the AMCS operation.

#### Soyuz docking targets

The main orbit-deployed docking target is located on the outside of the orbital module near the docking system.

It comprises a cross placed in front of the screen which is the target base. There is also a cross pattern available on the base screen.

With both crosses aligned the Soyuz X-axis is directed towards the observer. Besides the main target the orbital and instrument-assembly modules carry fixed plates with marks which serve as an additional target.

#### Onboard orientation lights

Onboard orientation lights - red, green and two white lights - are mounted on solar batteries. They allow to approximately determine the approaching spacecraft mutual position.

The Soyuz spacecraft will carry two flashing light beacons. They are to detect and identify the spacecraft during the mission dark phase at the initial stage of approach (early approach). The beacons flashing light will help to identify the spacecraft against the star background.

#### AMCS jet thrusters and approach-correcting propulsion system

The attitude and motion control system, control jet thrusters and approach correcting propulsion system comprise 14 approach and orientation engines (AOE) each of 10 kg-thrust and 8 orientation engines (OE), 1 kg-thrust each.

These thrusters are fired in various combinations according to the spacecraft control logics.

They either provide control moments and make the spacecraft turn about its mass centre or they enable translational maneuvers.

The descent vehicle also carries 6 control thrusters which are fired during the vehicle descent phase.

The approach-correcting propulsion system (ACPS), which is designated to generate a correcting and a rate-damping reaction pulse, has a one-chamber approach-correcting engine (ACE) of 417 kg-thrust and a two-chambers backup correcting engine (BCE) with steering nozzles of 411 kg-thrust.

The ACPS has self-contained bipropellant tanks, a propellant-feed system for each engine and appropriate automatic systems.

#### AMCS modes

The Soyuz flight program provides for the spacecraft different orientation and attitude hold at each mission stage. The priority of these procedures is defined by concrete purposes.

Orientation modes - both automatic and manual - begin with searching reference points. The spacecraft rotates with constant speed until a specific reference point is acquired by the sensor or the cosmonaut's sighting device. Then the sensor central axis is aligned with the reference point direction.

The orientation sensors are fixed rigidly on the spacecraft modules. Their alignment with celestial bodies selected provides the spacecraft orientation relative to these bodies. After that the spacecraft attitude is maintained.

Automatic orbital orientation is performed using ionic sen-

son and infrared horizon sensor.

When using the IR-sensor the spacecraft Y-axis (lateral axis) is directed towards the Earth centre. The ionic sensor aligns the spacecraft X-axis with the orbital plane. The spacecraft can be transferred from its orbital orientation to any specific position in reference to celestial reference points using programmed turns.

To perform this procedure the gyros are uncaged at the desired moment and store the reference position for any specific turns.

The Soyuz control system allows to perform programmed turns without using gyros of a gyro package. In this case angular-rate pickups and their integrating devices are used.

The gyro package and angular-rate pickups allow to maintain the spacecraft attitude. To maintain the orientation the spacecraft needs compensation of disturbing moments due to the effect of the atmosphere and the Earth gravitational field.

The gyro package and angular-rate pickups illustrate functional redundancy when performing orientation of one definite type.

The different approaches in solving similar problems increases the spacecraft control system reliability and its "survivability".

The spacecraft one-axis orientation towards the Earth is provided by the infrared horizon sensor, while its orientation along the motion direction is performed by use of ionic sensor.

On generating a reaction pulse by the approach-correcting assembly the spacecraft will be stabilized and maintain its attitude unchanged.

The spacecraft attitude stabilization is provided by the AMCS. The special device of this system measures the velocity



increments and upon achieving a specific value shuts off the propulsion system.

During the spacecraft sun-orientation the onboard-automatic device provides the spacecraft rotation and exposes solar batteries to the sun radiation. When the proper position is achieved, it can be maintained by means of two ways, namely by twist, during which the spacecraft maintains its attitude like a top, and by vibrations about the Sun direction.

The cosmonaut may perform the spacecraft orientation of any type both in manual and automatic modes.

During automatic modes, which are of great importance, the cosmonaut usually monitors the process using the display, sighting device or signalling system on the cosmonaut's panel.

The right controller is used by the cosmonaut to ensure the spacecraft control through each of the three channels, setting the spacecraft rotational speed up to 3 degrees per second.

In the precision mode the controller enables the cosmonaut to use some pulses of control jet engines which provide the spacecraft minimum rotational speed and fuel consumption.

#### AMCS operation during rendezvous, approach and docking

Two revolutions prior to docking the Soyuz crew manually turns the spacecraft to perform its orbital orientation. During this orientation the spacecraft X-axis aligns with its velocity vector, while one of its Y-axis is directed towards the Earth centre. On accomplishing orbital orientation it is maintained automatically using the spacecraft AMCS. Upon detecting "Soyuz" with "Apollo" optical devices the spacecraft begin their approach.

To facilitate "Soyuz" detection and identification during early approach at the orbital dark phase the Soyuz instrument-assembly module carries body-mounted flashing beacons. The flashes of the white light allow to detect the spacecraft at a distance of hundreds of kilometres.

The onboard coloured orientation lights located on solar batteries are used to visually determine the spacecraft attitude. In case of need the crew may establish communication between the spacecraft by switching on and off the onboard lights, should the radio communication between the spacecraft be not established for some reasons.

The Soviet spacecraft docking target can be observed from "Apollo" at a distance of 200 meters.

With the distance of a few dozens meters, the target allows to determine the spacecraft attitude and distance. The precise alignment using the target is performed at a distance of approximately 10 meters.

During approach and docking the Soyuz spacecraft changes its orientation mode. After that it maintains its constant orientation relative to celestial bodies.

To observe the docking target it is convenient to automatically maintain such inertial orientation, since the conditions of the target illumination do not change during the spacecraft approach.

When in the vicinity of "Apollo", the Soyuz spacecraft turns about its X-axis and sets into position fit for docking.

The orientation system stores and maintains this position. The DM contact sensors respond to the spacecraft contact and disable the Soyuz attitude and motion control system.

#### 3.2.4 Life support systems. Purpose and composition

The main function of the Soyuz life support systems (LSS) is to provide life supporting conditions during the flight for the crew to perform transfers and joint activities with the Apollo crew.

The LSS provide and maintain the required atmosphere, temperature and sanitary conditions. The LSS also provide the crew with food and water.

Functionally the systems can be divided as follows:

- gas composition supply system;
- pressure suit set;
- thermal control system;
- food and water supply systems;
- furnishings and hygiene facilities.

For the Soyuz/Apollo flight the gas composition support system was modified to provide a possibility of establishing an atmosphere with pressure of 490-550 mm Hg.

The high limit was taken close to maximum which excluded the necessity of performing desaturation; the low limit was taken to ensure safety (the oxygen volumetric contents not more than 40%).

The Soyuz atmosphere high oxygen percentage and cosmonauts' staying in the Apollo oxygen atmosphere made necessary to perform additional fire safety certification of the most part of the Soyuz equipment and assemblies, and in some cases the materials used were replaced.

The joint flight required that the thermal control system should also be developed: the provisions are made to protect the Soyuz structural elements from the Apollo engine plume heating during the docking, a heat-exchanger in the form of a bracket was developed for the Apollo transceiver installed in the Orbital Module.

#### Gas composition support system

Gas composition support system is designed to provide in the Soyuz spacecraft (and in the docking module when transfer tunnel hatches are open) the required life supporting atmosphere composition and pressure, oxygen and carbon dioxide partial pressure and hazardous impurity contents required. The GCSS provides module pressure equalization and depressurization both during the space-

craft autonomous and joint flights, monitors module pressure integrity and atmosphere contents. If necessary, the GCSS provides gas leakage make-up and maintains the suit pressure required.

In the first orbits the Soyuz spacecraft pressure slightly exceeds the atmospheric pressure because of the module additional pressurization with oxygen performed at the launch site. The additional pressurization will provide the normal oxygen contents for the subsequent depressurization to 490-550 mm Hg. Following the completion of the joint activities with the Apollo crew the Soyuz pressure is increased to atmospheric as a result of the air pressurization from a specially-designed tank.

The removal of carbon dioxide and hazardous impurities excreted by the crewmen as well as the replenishment of the oxygen consumed during breathing are performed by the regeneration facilities installed in the Descent Vehicle and the Orbital Module. The operating principle is as follows: air is supplied to the regenerators by means of fans; in the regenerators containing potassium superoxide the air is purified and enriched with oxygen, when the regenerator is inoperative or the CO<sub>2</sub> concentration increases up to the high level, the air is supplied to the CO<sub>2</sub> absorber.

The DV regenerator is used only at the phase of insertion and during the autonomous flight.

The DV regenerator is controlled by the crewmen from the DV panel. The OM regenerator operation is performed automatically in response to commands of the gas analyzer. The regenerator control can also be performed from the DV and OM panels.

The monitoring of the atmosphere composition maintained by the regeneration facilities is performed by two gas analyzers

installed in the Descent Vehicle and the Orbital Module.

When  $O_2$  and  $CO_2$  contents exceed allowable values, the DV gas analyzer produces warning signals.

A pressure-and-vacuum gauge and a pressure integrity check unit, producing signals when leakage is more than 70-90 mm Hg/hr, are installed in the OM to verify the habitable module, transfer tunnel and interface integrity.

Should leakage occur, it may be compensated from the air storage tank designed for module pressurization during a period of time required for the crew to don their pressure suits.

Oxygen-nitrogen mixture (40% oxygen) can be supplied to the pressure suit both manually and automatically for a period of time required for the spacecraft descent and landing.

A pressure control unit is available onboard the spacecraft to maintain the module pressure within the specified limits.

#### Pressure suit set

The set comprises two pressure suits, four ventilation systems, two inflight bags, pressurized collar, two sets of flight garment and two headsets. The pressure suit is a soft pressure shell with a built-in soft helmet. The helmet is rigidly fixed with an opening window. The pressure suit is provided with removable gloves. The crewmen have their pressure suits on during the Soyuz orbit insertion, docking and undocking with Apollo, and descent. During the other flight phases the pressure suits are stowed in the bags in the Orbital Module.

During the suited operation the necessary life supporting conditions are established by ventilating the pressure suits with cabin air using ventilation facilities installed in the DV. Each

pressure suit is ventilated separately by its ventilation system. Should one of the DV ventilation system fail, another ventilation system provides ventilating of both pressure suits. If necessary, pressure suits can be ventilated with gas mixture supplied by the spacecraft onboard system.

The activation of the gas mixture supply system as well as deactivation of pressure suit ventilation systems are automatic. These operations can be performed manually as well.

The pressure suit donning and doffing are performed in the Orbital Module; during donning and doffing the pressure suits are ventilated with cabin air by means of the ventilation systems installed in the OM. These ventilation systems are used for the suits drying. Pressure suit drying involves two phases: two pressure suits are being dried simultaneously, then each pair of gloves is being dried. One pair of gloves is connected to a ventilation system using a special device which is stowed in a kit with tools.

After drying the pressure suits are stowed in the in-flight bags.

After the spacecraft landing the crewmen egress the DV with their pressure suits on.

In case of the DV splashdown or emergency escape a cosmonaut without doffing a pressure suit will don a pressurized collar and leave the DV.

## Thermal Control System

The Soyuz Thermal Control System provides the following:

- habitable module temperature within the range of 15-25°C, habitable module relative humidity within the range of 20-70%; instrument bay temperature within the range of 0-40°C;
- set temperature of equipment and different components of the design including APDS components and Apollo radio set installed in the Soyuz spacecraft;
- module atmosphere ventilation.

During the orbital flight the spacecraft structural elements are heated from external and internal heat sources: the Sun, Earth, equipment and crewmen. Besides, during the spacecraft joint flight the Soyuz is additionally affected by the Apollo attitude-control engine plume heating rates and heat transfer through the Docking Assembly. The heat generated by the spacecraft external surface is absorbed by space with temperature close to absolute zero.

The Soyuz Thermal Control System is designed to minimize the spacecraft unregulated heat transfer through its external surface to space environment, on one hand, and, on the other hand, to take excessive heat from the spacecraft internal heat sources and dissipate it in space environment.

The Thermal Control System comprises thermal insulation and hydraulic system.

The shield-vacuum thermal insulation is placed on the spacecraft external surface and allows to minimize heat exchange between the spacecraft and space.



The hydraulic system (Fig. 3.8) The circulating fluid accumulates the heat from internal sources and dissipates it in space.

The hydraulic system comprises units for heat collection, moisture collection, hydraulic system control, heat rejection and air ventilation within the modules.

The hydraulic system operates as follows.

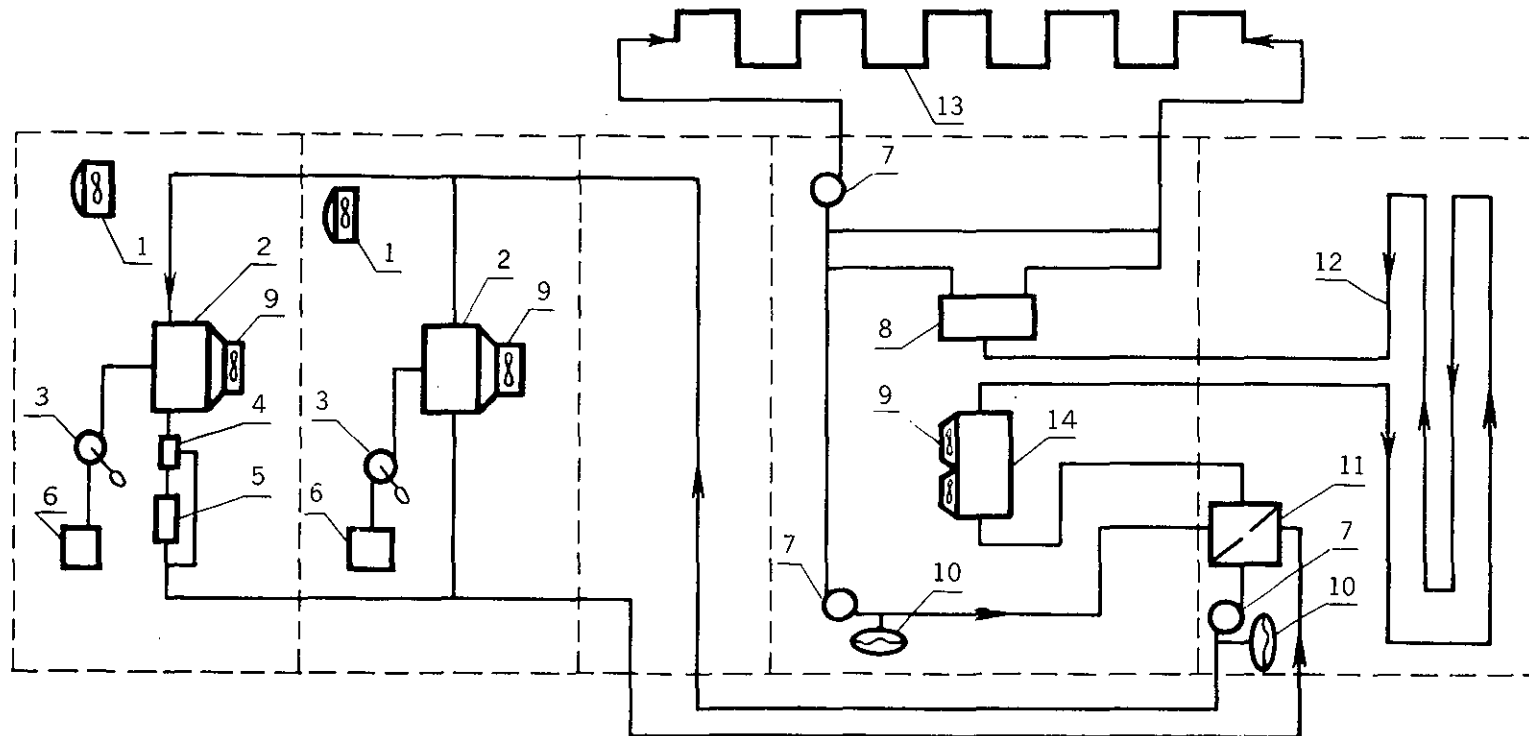
The heat generated by the equipment and crewmen is transferred to the air circulating within the modules. Air circulation within the modules is performed by fans. The heated air is supplied to the habitable module heat exchanger-condensers and instrument bay gas-to-liquid heat exchanger where it is cooled by the hydraulic system liquid.

The liquid temperature within the hydraulic system is maintained by regulator changing flow rate of the liquid going to the radiator to be cooled.

The habitable module air temperature required is maintained automatically by changing flow rate of air supplied to heat exchangers to be cooled. When the air is being cooled in the habitable module heat exchangers the air water vapors condensate on heat exchanging surfaces. The moisture condensated is pumped out by a pump into the moisture collector.

In addition to air cooling, the cooling is performed by the hydraulic system liquid passing through the channels of the structural elements (for example, cooling of the Apollo radioset mounting bracket).

The hydraulic system consists of two hydraulic circuits: habitable module circuit and instrument bay circuit which is con-



HEAT ACCUMULATION ELEMENTS: 2 — Heat exchanger-condenser; 11,14 — Heat exchanger; 5 — Transceiver bracket

MOISTURE ACCUMULATION ELEMENTS: 3 — Moisture removal pump; 6 — Condensate collector

HYDRO-SYSTEM CONTROLLERS: 7 — Hydraulic pump; 8 — liquid flow regulator; 10 — Compensator; 4 — By-pass valve

HEAT- DISPOSAL ELEMENTS: 13 — Radiator.

VENTILATION ELEMENTS: 1 — Fan; 9 — Heat exchanger fans;

FIGURE 3.8 THERMAL CONTROL SYSTEM SCHEMATIC

nected to the radiator-emitter. The circuits are connected by liquid-to-liquid heat exchanger. The excessive heat of the habitable module circuit is transferred in the heat exchanger to the instrument bay circuit with lower temperature and the excessive heat of the instrument bay circuit is dissipated as a result of radiator-emitter surface radiating to space environment. The circuit liquid circulation is performed by pumps.

Throughout the Soyuz flight the Thermal Control System is operating automatically. The only operation performed manually is a regular condensate pumping out from DV and OM heat exchangers.

The docking system thermal mode is provided by the shield-vacuum and fiber thermal insulation of DS surface as well as by the covers with certain optical characteristics (placed on uninsulated surfaces).

### Food Supply System

A cosmonaut's daily food-ration comprises various natural food products packed into aluminum tubes and tin cans. The food ration also involves a wide variety of bread packed in cellophane (Borodinskiy, Rizhskiy, Stolovy, Honey cake) and as a desert candied peels, refractory chocolate, sweets, ship's biscuits, etc.

All these products are very nourishing. Food nourishment value of daily ration per capita is 2700-3000 Cal that fully covers daily energy losses of the organism.

During the flight the crewmen take food four times every 24 hours.

The menu is made up to every crewmen's taste (three different menus, each repeated every fourth day). The following is the menu of the 3d day:

I. Breakfast. Meaty paste, Borodinskiy bread, sweets Praline, coffee with milk.

II. Launch. Cottage cheese cream with black currant purée, a honey cake.

III. Dinner. "Kharcho" soup, chicken meat, Stolovy bread, prunes with nuts.

IV. Supper. Meaty purée, Stolovy bread, Rossiyskiy cheese.

The overall nourishment value of the third day ration is 2843 Cal with protein contents - 126 g, oil contents - 130,5 g, carbohydrate contents - 271,1 g, water contents - 670,5 g.

It should be noted that the menu of the third day (dinner) comprises cottage cheese cream with black currant purée. It is very tasty food product made of a high-quality cottage cheese. It is mild and has a faint taste of black currant jam. It's nourishment value is 413 Cal.

Prunes with nuts are also very tasty. The combination of prunes and nuts is not so dry and more tasty.

The first courses, some meat products (bird purée, meaty purée), coffee with milk are less tasty when cold than when warmed up. Taking this fact into consideration a heater is provided aboard the spacecraft. The heater allows to warm up tubes with food stuff.

Three sets of dinner are provided aboard the Soyuz spacecraft for the US astronauts. The dinner comprises first courses, canned meat, bread, prunes with nuts, sweets.

The daily ration food stuff is enclosed in individual packages labelled in Russian and English to indicate the date of food taking.

Aboard the Soyuz spacecraft there is a folding table on which the cosmonauts and astronauts using hold-down facilities may

place their food stuff to have a meal.

### Water Supply System

The function of the Water Supply System is to store and supply potable water..

The portable water is stored in a storage tank installed in the Orbital Module. The ball-shaped storage tank has two cavities: one for water, the other - for air. There is a diaphragm to separate the water and air cavities.

When the water cavity is being charged with water the diaphragm is bent thus expelling all the air from the air cavity of the ball-shaped tank. Water expelling is performed by the diaphragm at an excessive pressure in air cavity. The excessive pressure (compared with the environment pressure) is created by the hand pump.

The accepted daily value of water consumption per capita is 1,7 l.

The difference between the tank potable water and ordinary potable water is that the first contains silver ions permitting storage of water in the tank for a few months; an throughout the storage period the tank water doesn't acquire an unpleasant odor, taste and remains transparent.

The receiving device is designed to receive water from the storage tank. It has a valve and a socket to install an individual mouth-piece. Individual mouth-pieces are provided in the OM for the cosmonauts and visiting astronauts.

For ease of water consumption three "space glasses" are provided in the Descent Vehicle. The body of the glass is like a bellows: it is folding up as water is being consumed. In the upper part of each glass there is a button-type by-pass valve to open

the water cavity, and a receiving tube to consume water. When a glass is empty, it can be refilled with water from the tank.

### Clothes

The Soyuz cosmonauts' suits are made of thermal resistant fabric specially manufactured for ASTP mission.

The suit of sports style (a jacket and trousers) will not restrict movements and will ensure convenience in work. The pockets of the suits are large enough to hold all necessary things (note-books, pencils).

If required, the cosmonauts may put on a wool cardigan under the jacket.

The constant wear garment (a part of the inflight clothing) is made of cotton-flax knitted linen with good physiological and hygienic properties: hygroscopicity, air permeability, steam permeability, water absorption.

The cosmonauts' light leather boots are protected by covers made of linen Lola.

The inflight clothing as a whole ensures comfort for the cosmonauts to stay in the Soyuz and Apollo spacecraft.

### Personal Hygiene Facilities

The personal hygiene facilities comprise damp and dry napkins and towels, combs, hair brushes and nail-files.

Damp and dry napkins are made of gauze, they are convenient for use and have a pleasant smell of jasmine. Damp napkins are damped with lotion. Damp and dry napkins are used for face, hands and mouth cavity hygiene.

Damp and dry napkins are provided for sponging a body.

Towels are made of linen.

For every day's toilet the cosmonauts use an electric razor equipped with a specific hair collector.

Each cosmonaut has an individual toilet set.

#### Waste Management System

The Waste Management System is placed in the Orbital Module. The operating principle is based on transferring liquid wastes (urine) by air flow to a collector where the particles are divided into liquid and gaseous phases. Solid wastes (feces) are collected and stored in pressure-tight volumes. The system prevents solid and liquid waste unpleasant odors and impurities to penetrate into the atmosphere of the spacecraft.

### 3.2.5 Radio/Electronic Equipment

The Soyuz spacecraft radio/electronic equipment includes radio/telephone communication system, TV-system, cable communication equipment, command radio communication line, telemetry system and orbit parameter measurement system.

The spacecraft radio/electronic equipment together with the ground radio equipment (the ground station and MCC equipment) provide voice communication with the Soyuz/Apollo crews, observation of the crew activities via TV-communication lines, TV-transmissions from space, the spacecraft systems remote control from the ground, the spacecraft system/assembly operation monitoring and determination of the spacecraft trajectory.

Radio/telephone communication system. The Soyuz voice communication system provides HF/VHF communication with the ground and also with the Apollo.

VHF range is used for communication with the spacecraft in sight of the VHF-ground stations. HF range utilization provides air/ground communication with the spacecraft out of the ground stations sight.

A compatible voice communication system which operates in VHF range at two American frequencies and at one Soviet frequency, was developed for the joint flight. This system provides the Soyuz/Apollo communication during rendezvous phase and after docking, and also that with the USA ground stations when the two spacecraft are in these stations AOS (acquisition of signal). Similar equipment in the Apollo spacecraft provides Apollo communication with the Soyuz crew and the USSR ground stations (Figure 39) when the two spacecraft are in the USSR stations AOS.



Joint examination of the rendezvous system compatibility problem concluded that it is impossible to develop in a short time an international radio system which provides the spacecraft relative attitude and motion parameters determination. Therefore it was proposed that the voice communication system be used to measure range between the spacecraft. For this purpose the Soyuz was equipped with the USA VHF transceiver to provide voice communication and besides serve as a transponder or provide reception, conversion (to increase noiseproof feature) and retransmission of "measurement signals" radiated by the Apollo VHF system. Range between the spacecraft is measured by comparing phases of "measurement signals" radiated by Apollo and of those retransmitted by Soyuz. Range is measured automatically without interrupting spacecraft-to-spacecraft voice communication.

The voice communication system includes the following:

- two transceivers supplied by the USA and the USSR and operating at American and Soviet frequencies respectively to provide spacecraft-to-spacecraft communication;
- VHF/HF transceivers for communication with the ground;
- speaker box and audio signal amplifiers;
- microphones, dynamics, headsets;
- antennas.

Radio communication system control is accomplished through the cosmonaut control panel.

Volume controls for signals received via voice communication are also built in this control panel. There are three individual volume controls at each cosmonaut station to control volume of signals of the air/ground, Soyuz/Apollo and internal communication lines.

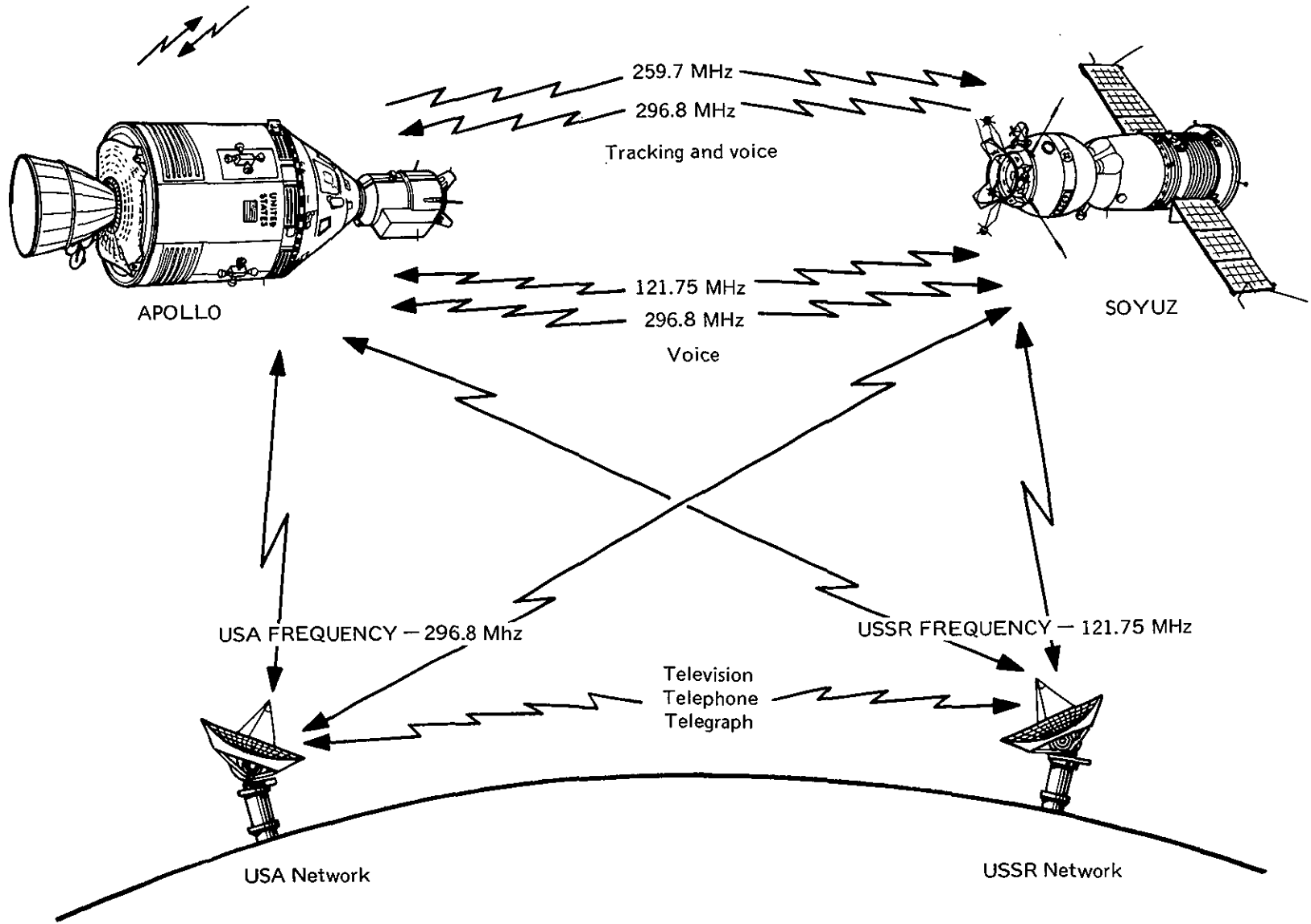


FIGURE 3.9 APOLLO SOYUZ TEST MISSION COMMUNICATIONS LINES

The selected transmitters are switched on via PTT (push-to-talk) built in the cosmonaut seat arms and the control panels or mounted on cables attached to headsets.

The Soyuz spacecraft is equipped with two sets of antennas for spacecraft-to-spacecraft communication. The antennas are mounted on the orbital module. Omnidirectional radiation pattern is practically provided by these antennas which is very important for the spacecraft arbitrarily positioned in space relative to each other.

TV-system. A four camera TV-system is used in the Soyuz spacecraft. Three cameras are installed inside the spacecraft: one in the descent vehicle and two in the orbital module. One camera, mounted outside, looks at the docking system. Two of the internal cameras provide color transmission.

After docking a color TV-camera can be transferred from Soyuz and connected to the Soyuz cable system in Apollo.

The TV-cameras are switched on from the Soyuz. Both cosmonauts and astronauts will be participating in the TV-reporting. During reporting, pictures will be simultaneously transmitted to a Soyuz onboard TV-screen and to the ground.

Besides transmission of TV scenes, the TV equipment provides monitoring the Soyuz system parameters. The equipment control is accomplished by commands from the ground or directly from the spacecraft.

#### Cable communication system

Following the spacecraft docking, the docking system elec-

trical connectors, which provide spacecraft-to-spacecraft voice and TV cable communications, are manually mated.

The cable communication system equipment including J-boxes to connect headsets and TV cameras were specially designed for this test project.

Command radio system. Command radio system provides uplink transmission from the USSR ground control stations to the Soyuz of commands to remotely control the spacecraft systems. After being received by the Soyuz onboard receiver a command switches on or off various onboard systems or changes the systems' mode of operation. Commands which have to go into effect when the spacecraft is out of the USSR ground control station AOS shall be delivered to a special memory device where they are stored until the appointed time and then delivered to the spacecraft automatic controls.

The command radio communication line provides downlink transmission of signals which confirm reception and execution of commands transmitted to the spacecraft and also verification of the board and ground time.

Onboard telemetry system. Onboard telemetry system provides the spacecraft system operation remote monitoring on the ground. Onboard system operation parameters are automatically measured, coded and transmitted to the ground.

Information received on the ground is automatically decoded and processed so that the flight managers and specialists can at any time have on request any information on the measured parameters they are interested in.

Real time transmission of telemetry data is accomplished when Soyuz is within the USSR measuring station AOS. When the Soyuz is out of the USSR measuring station AOS, telemetry information is stored in special memories.

Orbit parameters measurement system. The Soyuz onboard radio system in conjunction with the ground measurement facilities provides accurate measurement of the spacecraft orbit parameters.

### 3.3 Basic data on the Soyuz spacecraft launch vehicle

The Soyuz spacecraft launch vehicle (Figure 3.10) has 3 stages.

I stage consists of 4 side units, each of which is 19m long, about 3 m in diameter and equipped with the four-chamber engine and two steering chambers having a total vacuum thrust of 102 tons.

II stage is a central unit of about 28 meters, with maximum diameter of 2.95 meters, equipped with the four-chamber engine and four steering chambers having a total vacuum thrust of 96 tons.

III stage is a unit of 8 meters in length with a diameter of 2.6 meters, equipped with four-chamber engine (with steering nozzles), generating a vacuum thrust of 30 tons. Launch weight of the launch vehicle (with the Soyuz spacecraft) is ~ 300 tons.

At launch the engines of the I and II stages are ignited simultaneously. The operation of the second stage continues following the jettisoning of the 4 side units. The third stage is operative following the cut-off of the II-nd stage engines.

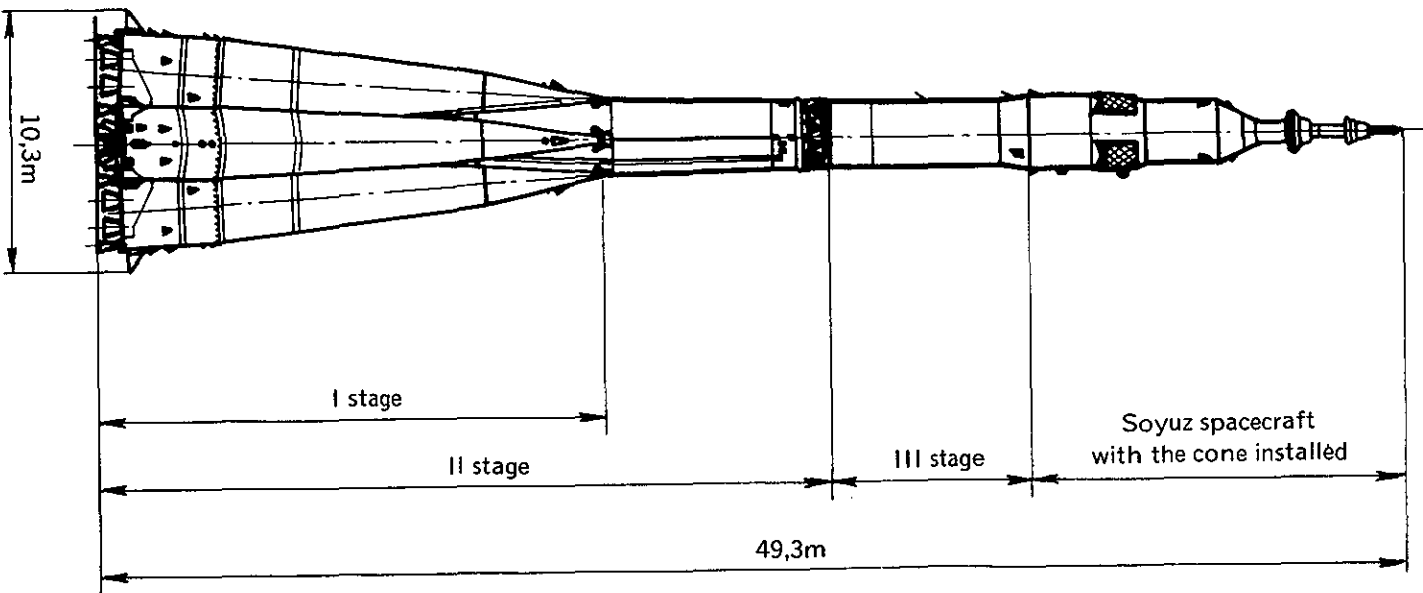


FIGURE 3.10 SOYUZ LAUNCH VEHICLE

Oxygen-kerosene propellant is used for all stages of the launch vehicle. The full length of the launch vehicle (with the Soyuz spacecraft) is ~ 49 meters. Maximum diameter is 10.3 m (stabilizers).

#### 3.4 Biomedical requirements

The spaceflight biomedical requirements imply all means and measures used at the various stages of design, preparation and flight implementation to prevent illness or functional disturbances which may hinder realization of the flight program.

On designing the Soyuz spacecraft for the joint mission with Apollo the first biomedical problem solved was the choice of gas atmosphere to exclude human decompression disturbance during cosmonauts' transfer from the Soviet spacecraft to the USA spacecraft.

Much attention was paid to the cosmonauts' rational work/rest regime to maintain a high level work capacity. During the period of crew activities time is allowed for rest, eat period, hygienics procedures, active rest period. These procedures alternate with work periods to avoid overstrain and to schedule the most responsible actions for periods of the maximum work capacity.

For the purpose of disease-prevention provision is made for Soyuz and Apollo crew members' partial isolation before the flight. The fact of the matter is that for some preset time period the crewmen of both sides will have primary contacts with a limited number of persons. In view of the flight short duration the main procedures and the crews' joint activity will be performed under conditions of severe weightlessness adaptation.

As is generally known, during the first days of human being under weightlessness conditions some disagreeable feeling (specifically, with abrupt motion) and objective changes may occur which usually disappear on the 5th or 7th day of the flight. That is why the crewmen will be under regular surveillance of the ground medical personnel and all their activities should be planned with regard to medical requirements.

For the purpose of medical monitoring the crewmen reports on their state will be used along with registration of physiological parameters (electrocardiogram, respiratory rate) and spacecraft environment inflight characteristics.

Concurrent with medical monitoring dose monitoring will be conducted to determine the level of radiation effect.

Radiation safety service will also predict radiation level in the spacecraft inhabited modules and in the mission trajectory and forecast solar activity (flares).

One more specific feature of Soyuz/Apollo experimental joint flight is that five cosmonauts and astronauts will be in space at a time. This will provide a great quantity of preflight and postflight data on human state during space flight. Due to the spacecraft different flight duration it will be possible to reveal characteristic features of organism weightlessness adaptation using flight data of medical observation and human postflight response assessment.

For this purpose it is necessary to simultaneously carry out the both spacecraft crew's pre- and postflight basic examination using similar or identical methods of investigation and functional test, conducted according to unified procedures.



In so doing crewmen state of health is evaluated and potential latent diseases or functional anomalies are revealed which require remedial or preventive intervention.

Preflight and postflight medical data together with preflight examination allow to evaluate general human response to space factors and to study readaptation behaviour under conditions of terrestrial gravity force with the process of weightlessness adaptation not accomplished.

Preflight and postflight examination program for the both spacecraft crews comprises the following procedures: medical examination, individual drug response testing, clinical and laboratory investigation, biochemical investigation, cardiovascular system observation when in rest and during functional test, vestibular and immunologic examination. Both Soviet and American specialists have agreed upon procedures and time schedule for the Soyuz and Apollo crewmen primary pre- and postflight examination.

The crews preflight examination is to be conducted 30, 15 and 7-10 days prior to the flight according to the full program, while just before the flight only partial medical examination will take place.

The crews' postflight examination will be carried out mainly on the day the mission is accomplished, then on the 1st and 3d day after the flight. Should some abnormalities be revealed, this examination will be periodically repeated.

## 4.0 MISSION DESCRIPTION

### 4.1 Nominal mission model (Fig. 4.1)

Soyuz is launched to the Earth orbit by a launch-vehicle from Soviet launch complex at 15.20 Moscow Time (12.20 GMT) on July 15, 1975. The Soyuz is inserted into a 188 by 228-km orbit at an inclination of  $51^{\circ}48'$ , with orbiting period of about 88.6 min. Following the Soyuz insertion the Soviet tracking stations calculate the real insertion orbit. The results are used to calculate the correcting impulses and the required data is transmitted to the spacecraft. During two days of the flight the Soyuz performs a number of maneuvers to transfer to the circular assembly orbit with an altitude of 225 km, that is, the orbit for performing the docking operations. In the 5<sup>th</sup> orbit when passing the USSR station coverage zone the Soyuz orbit parameters are once more radio measured and a decision is taken to launch Apollo. At 7 hr 30 min after Soyuz launch the Apollo will be launched from the Cape Canaveral launch site, USA. After the orbit insertion the Apollo will extract the docking module and perform a number of maneuvers required for the spacecraft rendezvous. The docking will be made in the 36 orbit when the two spacecraft assume the required mutual location (51 hr 55 min\*) after the Soyuz lift-off). From this moment on, the joint two-day flight of the docked spacecraft starts. The crews make sure that the DM systems function normally; the crews transfer from one spacecraft to the other. The first transfer is performed by American astronauts and during the two days of the docked flight each member of the Soviet and American crews will visit the other spacecraft. Soviet and Ame-

\*) Here and further times are given for the nominal plan. Actual flight times can differ from those given.

rican crews will conduct joint scientific experiments and radio-TV transmissions from the spacecraft.

During the docked flight the spacecraft are oriented so that the required Apollo thermal mode and the required position of Soyuz solar panels are ensured.

At 95 hr 42 min after Soyuz lift-off the spacecraft undock but there are still some joint experiments to be conducted. The experiments which need the orbital maneuvering of the spacecraft, redocking and re-undocking are conducted after the undocking. After final separation of the two spacecraft each will continue its own activities independently.

The Soyuz retro-rocket is fired during the 97th orbit and the Soyuz DV is separated after the braking. The DV enters the lower atmosphere layer and performs the controlled descent. After that the parachute develops and the Soyuz lands. The landing will be performed in the given area of Kazakhstan at about 142.5 hr GET. The Apollo will continue in orbit for approximately 3 days after Soyuz landing. 9 days after the Soyuz lift-off the Apollo will splash down in the Pacific ocean west of Hawaiian Islands. Thus the joint ASTP program will be accomplished.

#### Launch of a second Soyuz

To increase the probability of completing the joint mission the Soviet side will have a second Soyuz spacecraft available which will be launched in the following cases:

- a) a contingency causes a premature landing of Soyuz prior to its docking with Apollo;
- b) Apollo is not inserted into orbit during 5 days after Soyuz launch.

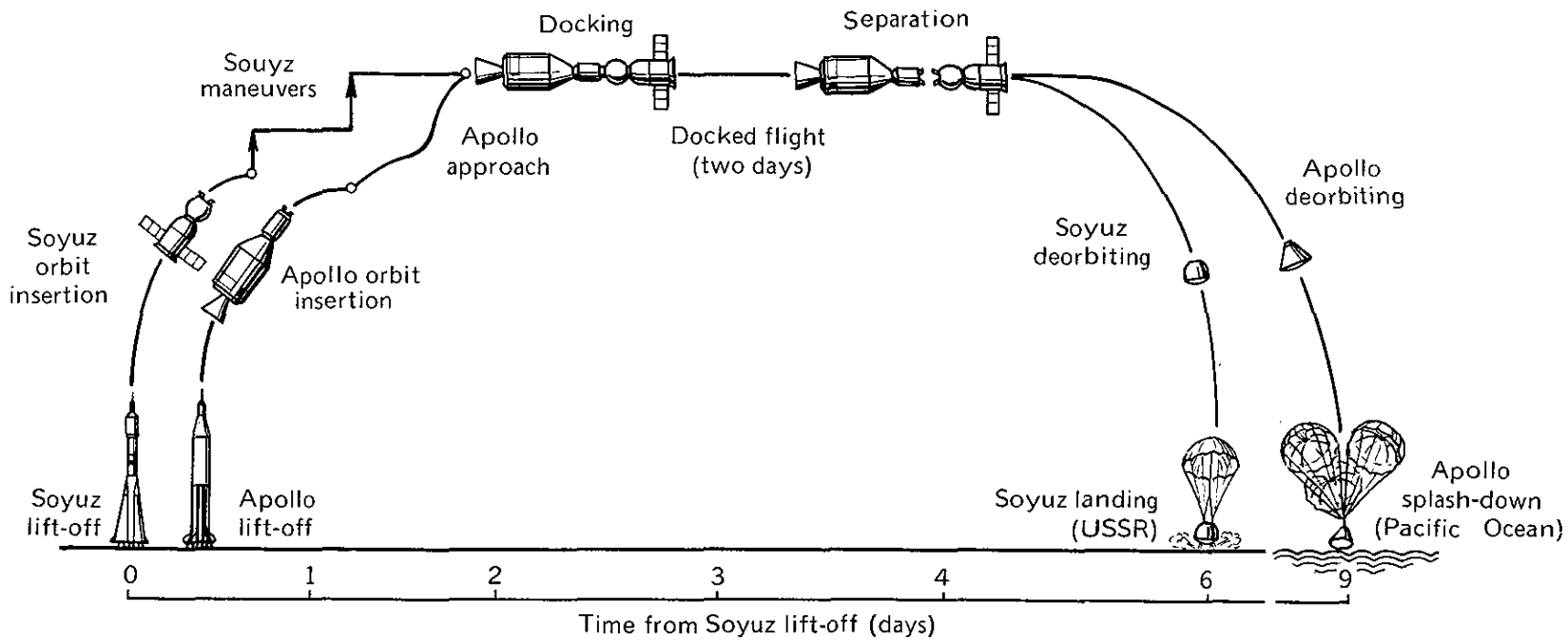


FIGURE 4.1 FLIGHT TRAJECTORY

Second Soyuz flight profile will be basically similar to that of the first Soyuz. Differences will be determined by the circumstances of a second Soyuz insertion.

#### 4.2 Explanation of the preferred mission profile. Launch windows

Every flight is preceded by a trajectory analysis which aim is to choose a flight profile. A flight should meet different constraints and requirements determined by peculiarities of the launch vehicle insertion zone, requirements for the spacecraft landing, flight goals, spacecraft design peculiarities and many other factors. A specific flight profile and launch time can be chosen only after the joint analysis of all the above-mentioned requirements.

Spacecraft of two different countries designed for different purposes will be participating in this joint mission, that is why the constraints and requirements for the two spacecraft are so different. The ASTP mission profile, launch windows and launch times are chosen so as to maximally meet the requirements of both sides.

#### The spacecraft launch sequence

The chosen spacecraft launch sequence takes into account a possible change of the launch azimuth of Soyuz and Apollo launch vehicles and the effect of the launch date shift of the spacecraft landing conditions.

During the spacecraft insertion into Artificial Earth Satellite (AES) orbit and maneuvering some motion parameters can

deviate from the calculated. That can be caused by random errors in functioning of the spacecraft and launch vehicle control systems, inaccurate current parameters of the Earth atmosphere and other errors. These errors cause so-called orbit parameter spread. As a rule such spreads are not great but nevertheless they should be taken into account when launching the second spacecraft since the orbital planes of the two spacecraft should coincide. Orbital planes can be adjusted by changing the launch azimuth of the second spacecraft. If Apollo is launched first then the launch azimuth, if necessary, will have to be changed by Soyuz and this is not admissible. Soyuz insertion zone corresponds to the populated territory of the Soviet Union. Since the launch vehicle stages are jettisoned onto the Earth the location of populated areas should be carefully considered when choosing the launch azimuth and insertion program.

According to the adopted profile Soyuz is launched first and Apollo will have to make the necessary correction of the active portion which is admissible since Apollo has its insertion zone over the ocean. Following the first spacecraft orbit insertion there can arise a necessity to postpone the second spacecraft launch, - this was also considered when choosing the spacecraft launch sequence.

With the Soyuz launched first the Apollo launch delay would only better the Apollo splash - down conditions. If Apollo is launched first the Soyuz launch date shift would worsen its landing conditions. The above-mentioned and some other considerations determined the preferred launch sequence for the spacecraft.

### Launch windows

A launch window is a period of time during a launch which ensures the fulfilment of the mission tasks and meets the given constraints.

The Soyuz launch time is chosen so as to meet the following conditions during the first daily orbit on the landing day.

a) Prior to the Soyuz retrorockets engagement cosmonauts should have a possibility to manually operate the orientation system. To satisfy this requirement the spacecraft during the required period should pass over the lighted side of the Earth.

b) Soyuz DV landing must take place at least one hour before sunset in the landing area. This is necessary for the spacecraft rescue following its landing.

The desirable time of day for Apollo launch is determined by the following consideration involving the requirement of having daylight in the splash-down area for the DV rescue.

The splash-down in case of an abort after lift-off or the splash-down in the Pacific at the conclusion of the mission must take place at least 2-3 hours before sunset in the landing area. To meet these requirements the spacecraft launch windows were determined for every launch date during 1975. If these launch windows had a common range a compromise decision with respect to the USA and USSR constraints would be reached by choosing a launch time from this range.

However different geographical location of USSR and USA launch complexes and different requirements resulted in no such common range, that is why it appeared impossible to simultaneously meet the constraints of both sides.

The discussion of this problem resulted in a compromise decision based on the following moderated constraints of both sides:

1) Soyuz launch windows for the period from March, 1 through October, 1 are determined so as to ensure the nominal landing in the 3d orbit of the nominal and reserve landing days; for the other periods - in the 2nd daily orbit.

2) Nominal "daylight" time for Apollo rescue is reduced by 25 minutes for the period from March, 1 through October, 1; for the other periods - by 50-90 minutes.

The launch windows determined on the above-mentioned basis meet the constraints of the American and the Soviet sides; these launch windows were used to determine the nominal launch time.

Nominal launch time and launch windows for several dates are given below (Moscow Time) in Table 4.1.

| Launch date   | July,<br>1 | July,<br>15 | August,<br>1 | August,<br>15 | Sept.,<br>1 | Sept.,<br>15 |
|---|------------|-------------|--------------|---------------|-------------|--------------|
| Upper limit of the<br>launch window                               | 15.44      | 15.30       | 15.08        | 14.40         | 14.09       | 13.38        |
| Nominal launch<br>time and lower<br>limit of the<br>launch window | 15.34      | 15.20       | 14.58        | 14.30         | 13.59       | 13.28        |

Spacecraft launch time

Soyuz may be launched any time, provided that it is within a launch window. For this particular mission the Soyuz



launch time was determined so as to provide the landing conditions for a second Soyuz, if it has to be used.

Apollo launch time is determined by Soyuz launch time since the Apollo must be launched into the Soyuz orbital plane. For the first time such an opportunity occurs at 7.5 hours after Soyuz launch (it is called the first launch opportunity).

The Apollo will be launched at 22 hr 50 min in Moscow Time, 19 hr 50 min in Greenwich Time, 14 hr 50 min in Houston Time.

Since the Earth makes one revolution around its axis per 24 hr and the spacecraft orbital plane in space changes relatively slowly the spacecraft trajectory every 24 hours passes over the same regions of the Earth surface. This provides Apollo with additional launch opportunities. They occur once per 24 hours during four days and each launch opportunity starts 25 minutes earlier than the possible launch time on the day before. The Soyuz flight profile remains the same for all 5 launch opportunities of Apollo, except for the docking time and the duration of the docked flight.

#### Assembly orbit

An assembly orbit is an orbit of an Artificial Earth Satellite (AES), an orbit of the spacecraft docking. Assembly orbit parameters for the joint mission were determined with respect to the mission tasks, spacecraft design capabilities and peculiarities. Thus these parameters were determined so as to ensure such a mutual attitude of the spacecraft at the time of Apollo insertion which is acceptable for their rendezvous.

### Soyuz maneuvers

During the flight the Soyuz will perform several maneuvers. Their aim is to make up for errors which can occur during the spacecraft insertion, to form a circular assembly orbit for Soyuz and Apollo docking and to ensure such a mutual attitude of the spacecraft at the time of Apollo insertion which is necessary for rendezvous. These maneuvers are performed either by the crew or by commands from Earth.

Trajectory correction data - the time, the duration of propulsion system operation and the thrust vector orientation during a maneuver - is determined using the results of actual orbit measurements and is transmitted to the spacecraft when it is in the coverage zone of a Soviet tracking station.

### Soyuz landing

First three orbits of every day (first daily orbits) occur (due to the Earth rotation) approximately over the same regions of the Soviet Union where the Soyuz landing must take place, that is why these particular orbits are used for the spacecraft deorbiting. If necessary the Soyuz landing may be performed in the first daily orbits of the following (reserve) day.

#### 4.3 Soyuz independent flight

Soyuz independent flight begins from Soyuz insertion into AES orbit and ends with Soyuz and Apollo rendezvous (accomplishment of rendezvous maneuvers).

During this flight the Soyuz insertion into an elliptical 188 by 228 km orbit with an inclination of  $51.8^{\circ}$  will be

performed and during the first and second days of the flight (which correspond to 4th and 17th orbit), a circular assembly orbit with an altitude of 225 km will be established.

The Soyuz crew will reduce the pressure in the living modules to 520 mm Hg, verify radio and TV communication and conduct the planned scientific experiments.

The sequence of main flight operations and crew activities is given below.

| Orbit     | GET   | Main events  |
|-----------|-------|--|
|           | 00:00 | 1975, July 15/12:20 GMT (15:20 MT) - Soyuz launch from the launch complex at Baikonur  |
| 1st orbit |       | Orbit insertion. Separation from the launch vehicle. Deployment of solar panels and antennas.  |
| 3d orbit  |       | Verify voice communication modes:<br>2 hr 51 min communication of the USSR MCC with Soyuz spacecraft via USA communication network;<br>2 hr 53 min communication of the flight controller in the USA MCC with Soyuz. |
| 3d orbit  |       | Dinner (40 min)  |
| 4th orbit |       | Perform the first maneuver to form a circular assembly orbit with an altitude of 225 km  |

| Orbit     | GET          | Main events   |
|-----------|--------------|---|
| 5th orbit | 7 hr         | Orient solar panels to the Sun<br>Report from the USSR MCC to the USA MCC on the Soyuz readiness status based on the results of the first maneuver.   |
| 5th orbit |              | Conduct experiments:<br>"Zone-forming fungi" - (observe and photograph the ZFF);<br>"micro-organism growth" - (observe the micro-organism growth);<br>"First embryonic development" - (unstop Biocat- device, secure it in OM). |
| 7th orbit |              | Supper; prepare for sleep period.   |
| 8-9 orbit | 8-10 hr      | Begin 1st rest period.<br>Sleep period (8 hours).   |
| 14 orbit  |              | Morning toilet. Breakfast (30 min).<br>Spacecraft systems check.  |
| 15 orbit  |              | Conduct experiments:<br>Micro-organism growth (observe the micro-organism growth)<br>"ZFF" (observe and photograph the ZFF)   |
| 16 orbit  |              | Lunch (30 min)  |
| 17 orbit  |              | Perform the second maneuver to establish a circular assembly orbit with an altitude of 225 km   |
| 18 orbit  |              | Orient solar panels to the Sun  |
| 19 orbit  | 28 hr 11 min | Verify TV communication lines between Soyuz and the USA MCC   |

| Orbit    | GET          | Main events   |
|----------|--------------|---|
| 19 orbit |              | Dinner (40 min)   |
| 22 orbit |              | Conduct experiments:<br>"ZFF" (observe and photograph the ZFF)  |
| 23 orbit |              | Supper (30 min). Individual time.<br>Evening toilet.  |
|          | 34 hr 20 min | Begin the second rest period. Sleep<br>(8 hours)  |
| 32 orbit |              | Conduct experiments:<br>"ZFF" (observe and photograph the ZFF);<br>"Micro-organism growth" (observe the<br>micro-organism growth) |
| 33 orbit |              | Orient to the Earth for "braking".<br>Conduct experiments:<br>"Photography and visual observation of<br>daylight horizon".        |

#### 4.4 Spacecraft rendezvous and docking

Soyuz/Apollo rendezvous and docking will take place during the 3d day of Soyuz flight (with the Soyuz inserted into a circular orbit with an altitude of 225 km and an inclination of 51,8 degrees); the Apollo will conduct a number of maneuvers to approach the Soyuz.

This maneuvering will result in the spacecraft docking. A pressure-tight interface will link the spacecraft. The following compatible means are used for rendezvous and docking: external orientation lights, beacons, USA and USSR VHF-radiostations, an optical sighting device and docking targets.

The sequence of Soyuz main flight operations and crew activities is given below:

| Orbit    | GET   | Main events   |
|----------|-------|---|
| 33 orbit | 48:34 | Apollo performs a maneuver to ensure the required difference in altitude between the spacecraft for Apollo onboard navigational measurements. Distance between the spacecraft is approximately 480 km and reduces in the progress of rendezvous. The Soyuz is in the orbital orientation mode |
| 34 orbit | 48:43 | Distance between the spacecraft is about 441 km. Apollo crew begins visual tracking of Soyuz using a sextant; the crews check the compatible VHF - communication means. Prior to entering the darkness in the 34th orbit the Soyuz crew switches on the beacons.                              |
|          | 49:18 | Distance between the spacecraft is about 269 km. Apollo performs a correction maneuver to control the phasing and plane differentials between the spacecraft in altitude and angle.   |
|          | 49:26 | Distance between the spacecraft is about 241 km. Soyuz transponder and Apollo transceiver are on. Apollo starts tracking of the Soyuz using VHF-radiomeans.   |
|          | 49:55 | Distance between the spacecraft is 150 km. Apollo transfers into co-elliptical orbit (the orbit with constant difference in altitudes referenced to the Soyuz orbit); this brings about constant difference in altitude between   |

| Orbit    | GET   | Main events   |
|----------|-------|---|
|          |       | the spacecraft. The Soyuz crew begin preparation for docking and transfer at the beginning of the 35th orbit: perform necessary manipulations with equipment and systems, required for the docking and transfer, don pressure suits, inform the MCC and Apollo on rendezvous operations and get the required information. |
| 35 orbit | 50:54 | Distance between the spacecraft is about 39 km. Apollo starts transferring into interception trajectory.  |
|          | 51:52 | Distance between the spacecraft is 2 km. Apollo retards, reduces its relative velocity and flies around the Soyuz for assuming the initial position prior to approach.  |
|          | 51:31 | Distance between the spacecraft is 30-50 m. Apollo station-keeping relative to Soyuz, the docking systems are facing each other.  |
| 36 orbit | 51:40 | The Soyuz crew is in DV, the hatch between DV and OM is closed.   |
|          | 51:45 | On the Apollo request the Soyuz rolls for ensuring the required orientation of Apollo high - directional antenna to the communication satellite which will transmit to Earth the information on the rendezvous and docking progress.<br>After the roll the Soyuz maintains the mode of inertial attitude hold.            |

| Orbit | GET   | Main events   |
|-------|-------|---|
|       | 51:50 | After the final check of the spacecraft systems Soyuz and Apollo crews confirm their readiness for docking. Apollo approaches the Soyuz using the optical sighting device, installed aboard the Apollo and the docking target mounted on the Soyuz. The crew maintain the radio communication exchanging the information on the progress of the main operation accomplishment. The Soyuz external survey TV camera is activated to control the Apollo motion; Soyuz crew perform photography of the approaching Apollo. |
|       | 51:55 | The docking systems of the two spacecraft are captured and retracted; the interface is sealed. Apollo maintains the orientation of the docked spacecraft. The crews report to Earth on the complete docking and prepare for transfer from one spacecraft to the other.  |

#### 4.5 Crews joint activity in the orbit

Soyuz/Apollo crews joint activity can be specified as follows:

1. Spacecraft rendezvous;
2. Approach and docking;
3. Docked flight;
4. Undocking, redocking and final undocking;
5. Joint experiments during separate flight of the spacecraft;



## 6. Separation of Soyuz and Apollo.

Main events of cosmonauts and astronauts joint activity are referenced to ground elapsed time (GET), i.e. time from the Soyuz lift-off.

### Spacecraft rendezvous

The crew of Soyuz and Apollo perform maneuvers to bring the spacecraft (they are in different orbits) as near as 30-50 m, they also establish spacecraft to spacecraft radio communication and check all the systems involved in it.

| Orbit    | GET   | Main events  |
|----------|-------|--|
| 33 orbit |       | Start joint activity in orbit. Prepare the orbital orientation systems.<br>Conduct "Photography of daylight horizon" experiment.<br>Establish Soyuz orbital orientation so that solar panels are properly lighted; this is necessary for tracking of the Soyuz using the Apollo sextant. |
| 34 orbit | 49:05 | Establish radiocommunication with Apollo and verify systems of radiocommunication between the spacecraft.  |
|          | 49:26 | Activate VHF ranging   |
| 35 orbit | 51:00 | Prepare Soyuz inertial attitude hold system.   |
|          | 51:18 | Prepare docking system for operation.  |

Approach and docking phase

Apollo approach to the Soyuz (Soyuz is in the inertial orientation mode), spacecraft contact, as well as rigid coupling of two spacecraft and docking interface sealing are performed during this phase.

---

| Revo-<br>lution | GET              | Main events   |
|-----------------|------------------|---|
| 36              | 51:45            | Establishment of the Soyuz inertial orientation prior to docking                |
|                 | 51:55            | Docking   |
|                 | 51:57<br>-52:13  | Soyuz system monitoring and rough pressure integrity check of OM and DV         |
|                 | 52:13            | Cosmonauts transfer from DV to OM.  |
|                 | 52:18-<br>-52:40 | Exact pressure integrity check of Soyuz and interface volume between spacecraft |

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Phase of the flight in docked configuration (fig.4.2)

Crew back-to-back transfers, joint scientific experiments, TV coverages and film and picture shooting are performed during this phase.

---

| Revo-<br>lution | GET                   | Main events  |
|-----------------|-----------------------|--|
|                 | 52:47-<br>52:57       | Tunnel 2 pressurization and pressure integrity check (tunnel between the spacecraft).                      |
|                 | 37<br>53:00-<br>53:12 | Pressure Garment Assembly (PGA) doffing and PGA connection to the fan for the drying                       |
| 38              | 54:47                 | Flight engineer rechecks tunnel 2 pressure integrity after DM pressurization. Soyuz commander stows PGA's. |

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| Revo-<br>lution | GET              | Main events   |
|-----------------|------------------|---|
|                 | 54:48            | Hatch 4 opening   |
|                 | 54:50-<br>-55:03 | DM/Soyuz pressure equalization. Preparation of the astronauts and cosmonauts for TV coverage of the rendezvous in the orbit.  |
|                 | 55:01            | Hatch 3 opening and astronauts transfer to the Soyuz. Joint TV coverage of the rendezvous (greetings).  |
|                 | 55:38-<br>-56:44 | Joint activity period of the USSR and USA crews in the Soyuz; cosmonauts and astronauts exchange the flags of their countries, souvenirs and sign a joint document on the first international space docking. They perform film and picture shooting and have joint dinner.            |
| 39              | 56:44-<br>-57:10 | Transfer of the docking module pilot and Soyuz flight engineer into DM to conduct joint "Multipurpose Furnace" experiment. Flight engineer returns then into OM. Transfer kits for "Microbial Exchange" to DM. Exchange of "Rhythme - 1" devices. Apollo commander transfers into DM. |
|                 | 57:15            | Close hatches 3 and 4. Monitor tunnel 2 depressurization.   |
|                 | 57:24-<br>-57:30 | Pressure integrity check of hatches 3 and 4.  |
| 40              | 57:35            | Conduct experiments: "Microorganism growth", "Genetic studies", "ZFF".  |
|                 | 58:11            | Presleep systems checkout   |
|                 | 59:00-<br>-66:30 | Sleep period  |
| 46              | 66:30-<br>-67:30 | Individual time   |

| Revo-<br>lution | GET               | Main events  |
|-----------------|-------------------|--|
|                 | 67:30-<br>-67:45  | Postsleep systems checkout   |
|                 | 67:45-<br>-68:25  | Breakfast  |
| 47              | 68:42             | Second transfer initiation.<br>"Microorganism growth" experiment   |
| 48              | 69:22             | Cosmonauts open hatch 4  |
|                 | 69:29             | Hatch 3 opening.   |
|                 | 69:31             | Astronauts proceed to DM-Soyuz atmosphere<br>mixing  |
|                 | 69:36             | Command module pilot transfer and USA<br>equipment transfer into Soyuz   |
|                 | 69:48             | Soyuz commander transfer into DM (thus,<br>flight engineer and DM pilot stay in the<br>Soyuz)  |
|                 | 70:03             | Close hatches 3 and 4  |
|                 | 70:11-<br>- 70:17 | Apollo flight engineer and commander<br>check pressure integrity of hatches 3<br>and 4   |
|                 | 70:17-<br>-75:30  | Joint activity period of the flight engi-<br>neer and CM pilot in the Soyuz, when TV<br>coverages, films and pictures shooting,<br>dinner and Zone-forming fungi joint<br>experiment are performed |
|                 | 70:03-<br>-70:53  | Transfer of the Soyuz and Apollo comman-<br>ders from the docking module into the<br>Apollo command module   |

Revo-  
lution

GET

Main events

70:53-  
-74:40 Joint activity period of the Apollo commander, Soyuz commander and docking module pilot in Apollo, when TV coverages, films and pictures shooting, dinner and Multipurpose Furnace joint experiment are performed

51 74:40 Initiation of the Soyuz and Apollo commander transfer into Soyuz

52 75:28 Flight engineer opens hatch 4

75:36 After DM-Soyuz pressure equalization, Apollo commander opens hatch 3. Initiation of the DM-Soyuz atmosphere mixing

75:47 Soyuz commander transfers into OM

75:57 Command module pilot transfers into DM

75:59 Apollo commander transfers into OM

76:02 Flight engineer transfers into DM

76:08 Closing of hatches 3 and 4 (thus, Apollo and Soyuz commanders stay in the Soyuz)

76:15-  
-76:21 Pressure integrity check of hatches 3 and 4

76:22-  
-79:53 Joint activity of the Soyuz and Apollo commanders in the Soyuz, when TV coverages, films and pictures shooting  
Microorganism Growth and Microbial Exchange joint experiments are performed

76:22-  
-76:55 Flight engineer and command module pilot

| Revo-<br>lution | GET    | Main events  |
|-----------------|--------|--|
|                 |        | transfer in the Apollo, when TV coverages, films and pictures shooting, Microbial Exchange scientific experiment are performed |
| 54              | 78:54  | Flight engineer and docking module pilot transfer initiation into DM   |
|                 | 79:27  | Soyuz commander opens hatch 4  |
|                 | 79:30  | Docking module pilot opens hatch 3. Initiation of the DM-Soyuz atmosphere mixing.  |
|                 | 79:40  | Docking module pilot transfers into OM and Microbial Exchange experiment   |
| 55              | 79:55  | Docking module pilot returns into DM   |
|                 | 79:56  | Flight engineer transfers into Soyuz.  |
|                 | 80:14  | Parting of the cosmonauts and astronauts.  |
|                 | 80:24  | Apollo commander transfers into DM   |
|                 | 80:28  | Close hatches 3 and 4  |
|                 | 80:34- | Pressure integrity check of hatches 3 and 4  |
|                 | -80:41 |  |
|                 | 81:00  | Zone-forming Fungi experiment  |
| 56              | 81:30- | Supper   |
|                 | -82:10 |  |
|                 | 82:10- | Presleep systems checkout  |
|                 | -82:30 |  |
|                 | 82:30- | Individual time  |
|                 | -83:10 |  |

| Revo-<br>lution | GET              | Main events   |
|-----------------|------------------|---|
| 57              | 83:10-<br>-90:15 | Sleep period  |
| 62              | 90:15-<br>-91:30 | Individual time   |
|                 | 91:30-<br>-91:45 | Postsleep systems checkout  |
| 63              | 91:45-<br>-92:45 | Breakfast   |
|                 | 93:00-<br>-94:25 | "Microorganism Growth" experiment.<br>"Zone-forming Fungi" experiment and system<br>check |

Phase of the undocking, redocking and final undocking

Spacecraft undocking is performed during this phase. Soyuz docking assembly is set into the active position, and the Apollo docking assembly is set into the passive one. Then crews perform redocking, systems check after the docking, pressure integrity check of the interface volume and final undocking.

| Revo-<br>lution | GET              | Main events                      |
|-----------------|------------------|----------------------------------|
| 64              | 94:25-<br>-95:00 | PGA donning and transfer into DV |
|                 | 95:42:05         | Undocking                        |

| Revo-<br>lution | GET              | Main events  |
|-----------------|------------------|--|
|                 | 95:50            | Establishment of the Soyuz inertial orientation and the setting of the Soyuz docking system into the active position |
| 66              | 96:11            | Spacecraft recontact   |
|                 | 96:20-<br>-96:25 | Docking completion   |
|                 | 96:20-<br>-96:32 | System check   |
|                 | 96:45            | Flight engineer transfers into OM  |
|                 | 96:45            | Soyuz commander transfers into OM  |
|                 | 96:45-<br>-97:10 | Soyuz and interface volume pressure integrity check  |
|                 | 97:25-<br>-98:10 | Dinner   |
| 67              | 98:35            | Cosmonauts return into DV  |
|                 | 98:45            | Hatch 5 closing  |
|                 | 98:46            | System preparation for undocking   |
|                 | 99:06-<br>-99:08 | Final undocking  |



Phase of the joint experiments during the separate  
flight of the spacecraft

During the phase the Apollo spacecraft performs the Soyuz fly-by at different distances and in different planes, keeps the orientation that is necessary for Ultraviolet Absorption experiment and performs the TV coverage and photography.

---

| Revo-<br>lution | GET               | Main events   |
|-----------------|-------------------|---|
| 68              | 99:10             | Establishment of the orbital orientation.   |
|                 | 99:10-<br>-102:45 | Conduct the experiments "UV-absorption" and "Study the possibility of observation and identification of stars in the daylight part of the orbit". |
|                 | 99:20             | TV coverage   |
|                 | 99:24             | Open hatch 5  |
|                 | 99:24             | Cosmonauts transfer into OM   |
|                 | 99:30             | PGA doffing   |
|                 | 102:05            | Film the Apollo   |

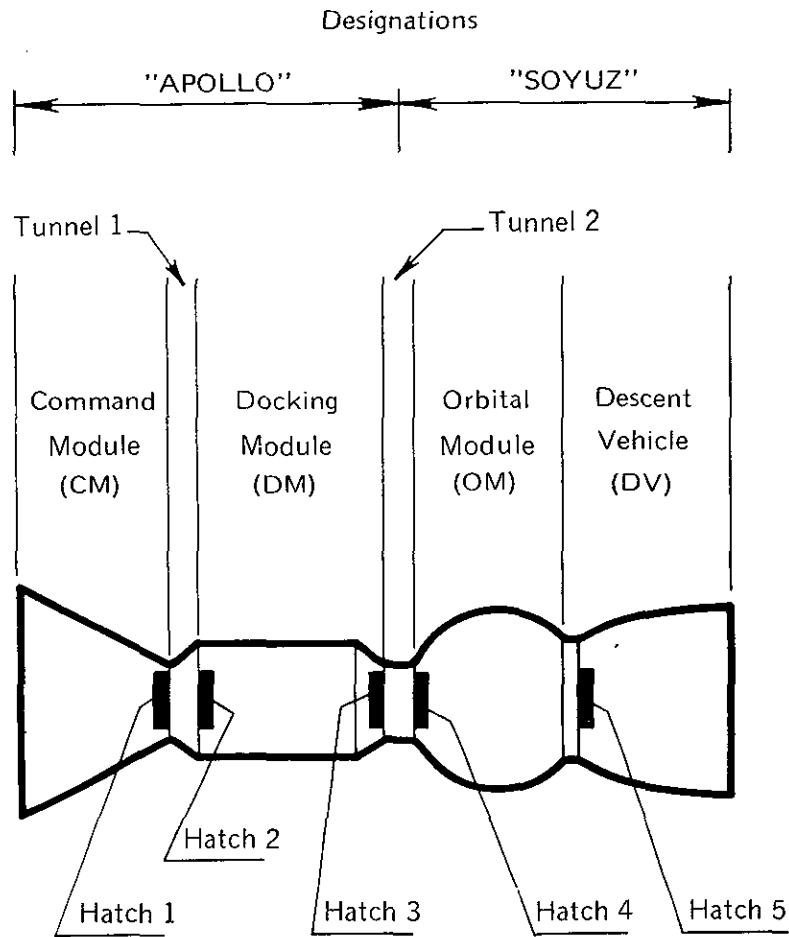
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Phase of the spacecraft separation

During this phase the Apollo performs orbit-transfer manoeuvre. After the completion of this manoeuvre the crews proceed to the autonomous phase of the flight.

| Revo-<br>lution | GET    | Main events   |
|-----------------|--------|---|
| 70              | 102:45 | Preparation of the Soyuz systems<br>for the spacecraft separation.  |
| 71              | 103:41 | Apollo orbit-transfer manoeuvre   |
|                 | 103:40 | Perform the sun orientation   |
|                 | 104:03 | Conduct the scientific experiments<br>"Genetic studies", "Microorganism<br>growth", "ZFF".<br>Complete "UV-absorption" experiment.<br>Photograph the Apollo spacecraft. |

The joint orbital activity of the Soyuz and Apollo crews on this phase of the flight is over.

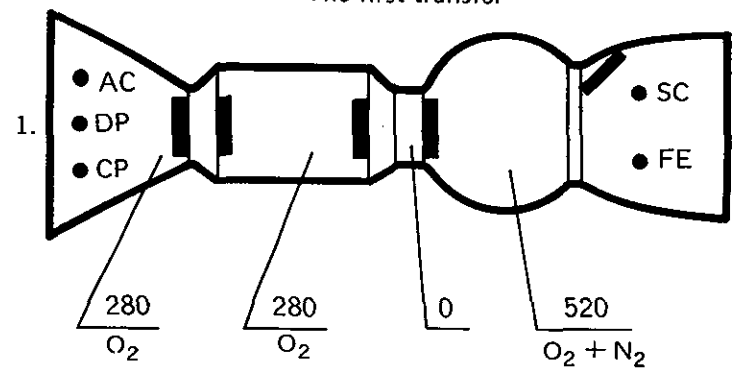


AC — Apollo Commander  
 DP — Docking Module Pilot  
 CP — Command Module Pilot

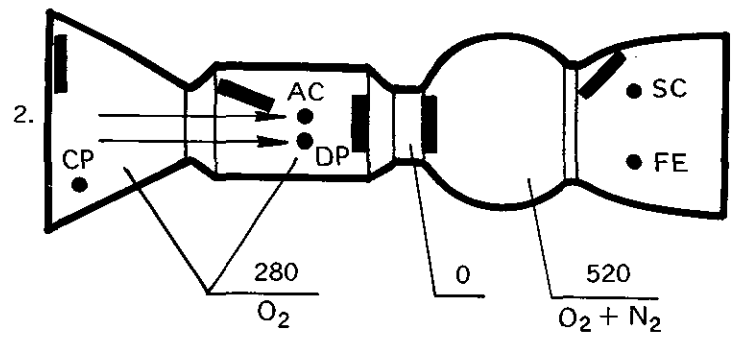
SC — Soyuz Commander  
 FE — Soyuz Flight Engineer

FIGURE 4.2 ASTRONAUTS AND COSMONAUTS VEHICLE-TO-VEHICLE TRANSFER DIAGRAM

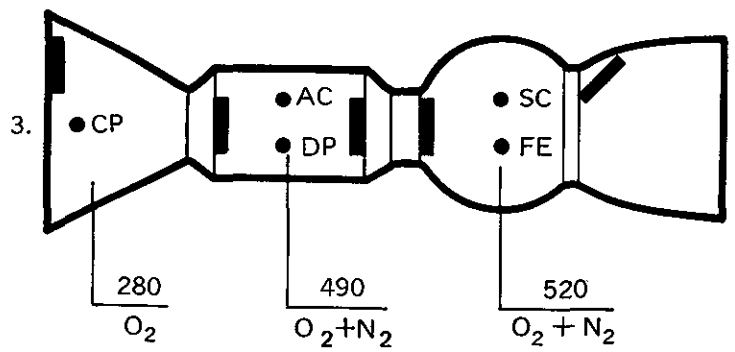
The first transfer



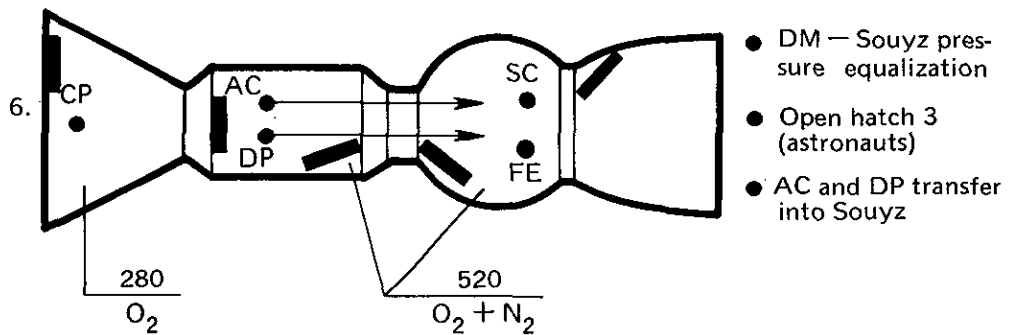
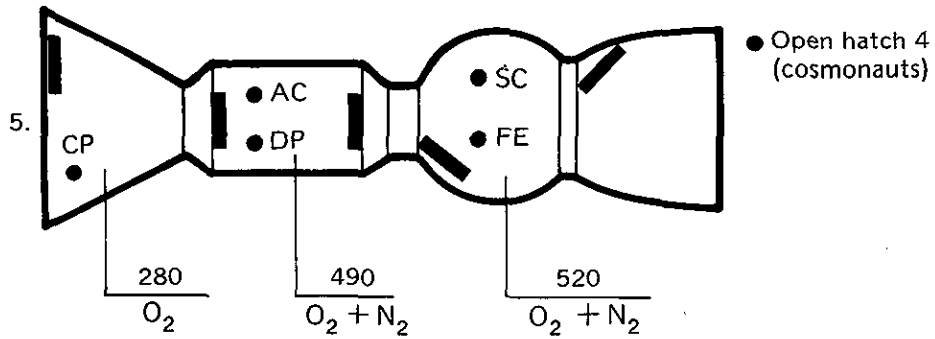
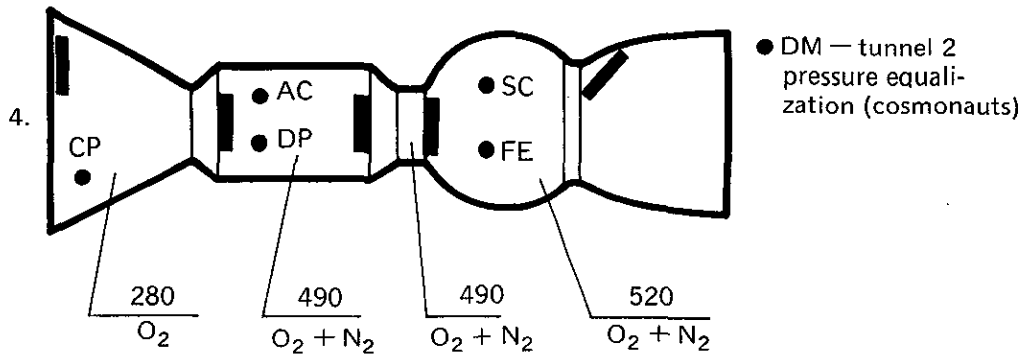
- Cosmonauts and astronauts location prior to transfer initiation

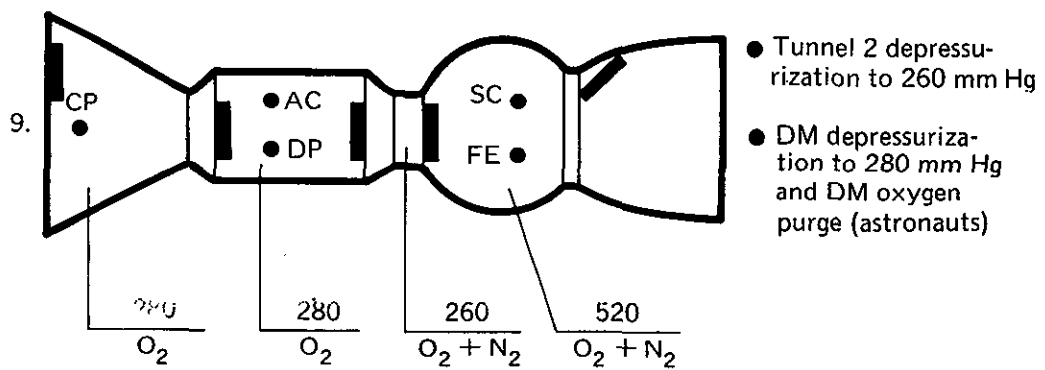
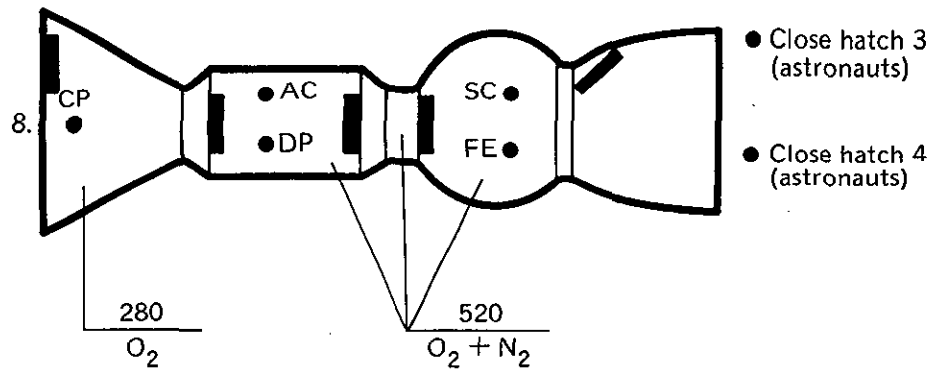
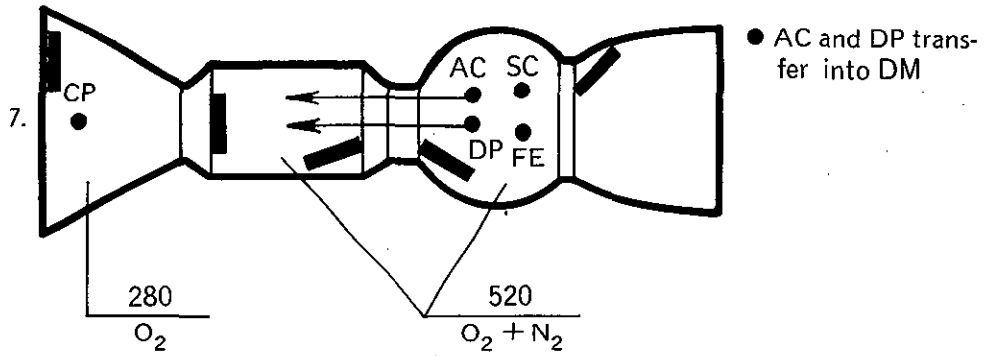


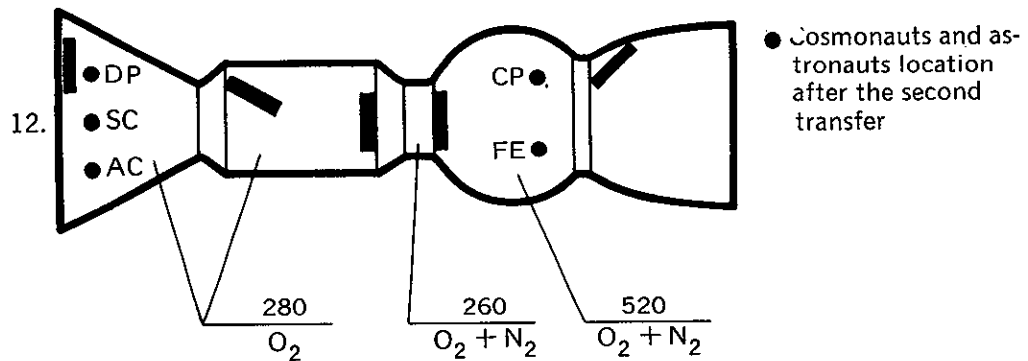
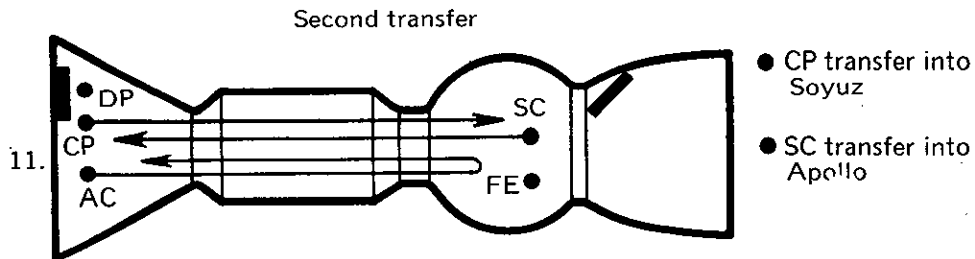
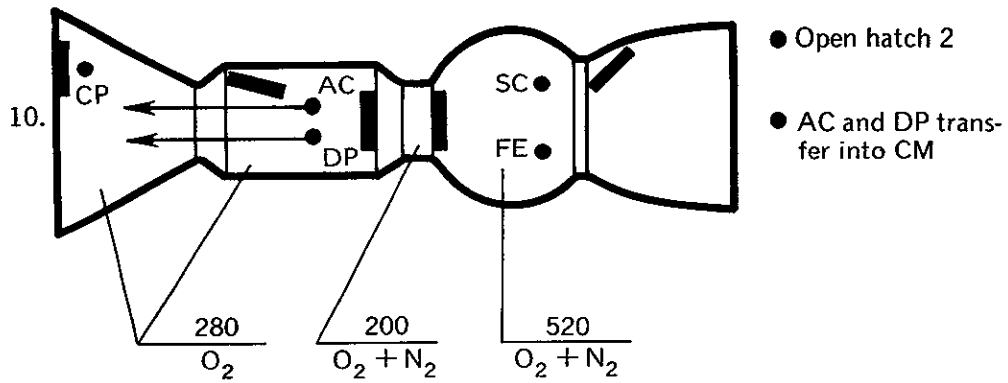
- Open hatch 2
- AC and DP transfer into DM



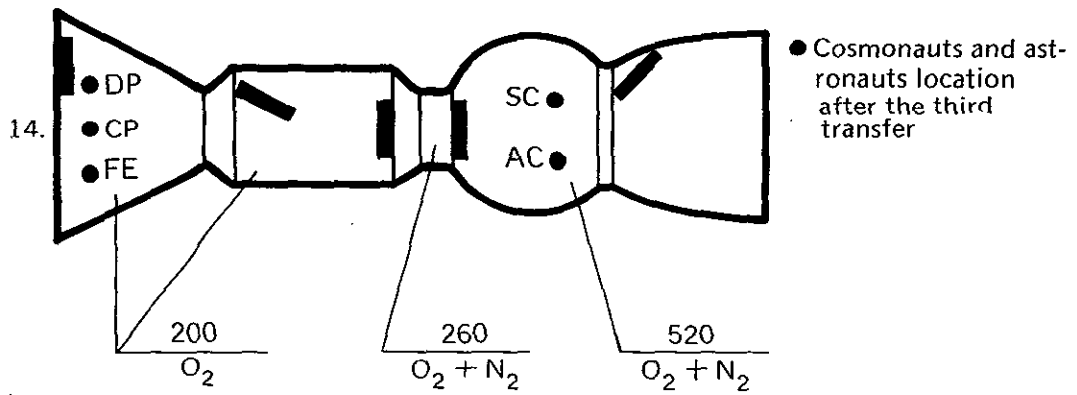
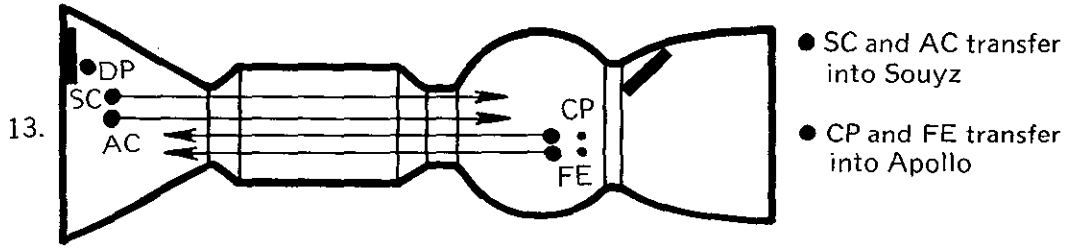
- Close hatch 2
- DM pressurization to 490 mm Hg (astronauts)





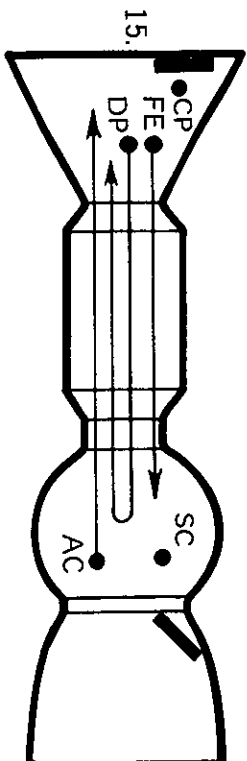


The third transfer

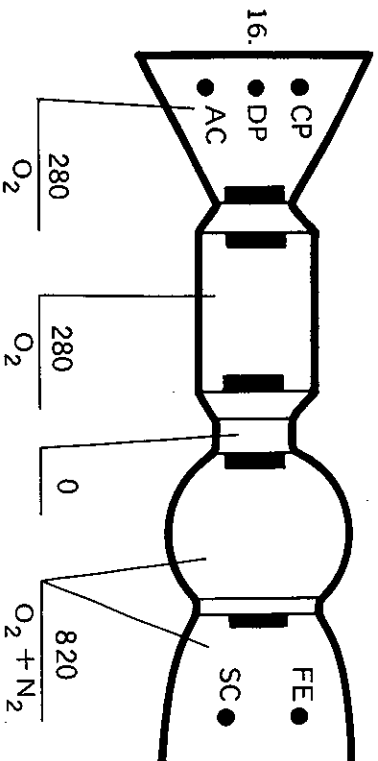




The fourth transfer



- FE transfer into Soyuz
- AC transfer into Apollo



- Cosmonauts and astronauts location after the transfer completion

Fig. 43 JOINT ACTIVITIES PLAN

17.7.75

| Soyuz orbit.                           |                            | Orbit 37        |   | Orbit 38 |   | Orbit 39 |  | Orbit 40 |                            | Orbit 41  |  |                        |
|--|----------------------------|-----------------|---|----------|---|----------|--|----------|----------------------------|---|--|------------------------|
| Ground elapsed time                    |                            | 52:00           | 53:00   | 54:00    | 55:00   | 56:00    | 57:00  | 58:00    | 59:00                      |   |  |                        |
| Soyuz crew                             | Soyuz commander (SC)       | Docking (51:55) | SC and FE transfer into OM and perform pressure integrity check                       |          | Doff and dry PGA's<br>Prepare for the astronauts rendezvous |          | Joint TV coverage of the rendezvous.<br>Souvenirs exchange.<br>Joint lunch.            |          | AC and DP transfer into DM | (Equipment transfer for the joint scientific experiments) |  | Sleep period (8 hours) |
|  | Soyuz flight engineer (FE) |                 |   |          |   |          |  |          |                            | SC and FE presleep systems check                          |  |                        |
| Television                             |                            | TV              | TV  | TV       | TV  |          |  |          |                            |   |  |                        |
| Apollo crew                            | Apollo commander (AC)      | Docking (51:55) | AC and DP remove CM/DM hatch and activate DM systems; transfer into DM with equipment |          | AC and DP transfer into Soyuz                               |          | AC and DP transfer into CM. Initiate furnace system experiment. Presleep systems check |          | Sleep period (8 hours)     |   |  |                        |
|  | Docking module pilot (DP)  |                 | Prepare for the transfer to the Soyuz.  |          |   |          |  |          |                            |   |  |                        |
| Command module pilot (CP)              |                            |                 | CP performs solar orientation   |          | Eat period  |          | Presleep systems check   |          |                            |   |  |                        |
| Ground elapsed time. Apollo revolution |                            | 52:00           | 53:00   | 54:00    | 55:00   | 56:00    | 57:00  | 58:00    | 59:00                      |   |  |                        |
|  |                            |                 | Rev. 30   | Rev. 31  | Rev. 32   | Rev. 33  | Rev. 34  |          |                            |   |  |                        |

18.7.75

| Orbit    | Orb. 47  | Orb. 48 | Orb. 49                      | Orb. 50                    | Orb. 51                              | Orb. 52                       |       |       |       |  |
|----------|--|---------|------------------------------|----------------------------|--------------------------------------|-------------------------------|-------|-------|-------|--|
| GET      | 67:00  | 68:00   | 69:00                        | 70:00                      | 71:00                                | 72:00                         | 73:00 | 74:00 | 75:00 |  |
| SC       | SC and FE postsleep systems check. Breakfast.  |         |                              |                            | FE and CP joint activity             |                               |       | Lunch |       |  |
| FE       | Sleep period (8 hours)   |         |                              |                            |                                      |                               |       |       |       |  |
| TV       | TV   |         | TV                           | TV                         | TV                                   | TV                            | TV    |       |       |  |
| AC       | Sleep period (8 hours)<br>AC, DP and CP postsleep systems check. Breakfast.<br>Perform solar orientation |         | AC transfer into DM          | AC and DP transfer into CM | Furnace system experiment completion |                               |       |       |       |  |
| DP       |  |         | AC, DP and SC joint activity |                            |                                      | Zone-forming fungi experiment |       |       | Lunch |  |
| CP       |  |         | CP transfer into DM          | CP transfer into Soyuz     |                                      |                               |       |       |       |  |
| GET Rev. | 67:00  | 68:00   | 69:00                        | 70:00                      | 71:00                                | 72:00                         | 73:00 | 74:00 | 75:00 |  |
|          | Rev. 39  | Rev. 40 | Rev. 41                      | Rev. 42                    | Rev. 43                              | Rev. 44                       |       |       |       |  |

18.7.75

| Orbit GET | Orb. 53  | Orb. 54                            | Orb. 55                            | Orb. 56                                   | Orb. 57  | Orb. 58   |                           |                        |       |
|-----------|--|------------------------------------|------------------------------------|---|--|---|---------------------------|------------------------|-------|
|           | 76:00  | 77:00                              | 78:00                              | 79:00                                     | 80:00  | 81:00   | 82:00                     | 83:00                  | 84:00 |
| SC        | SC and AC joint activity. Microbi-<br>al exchange experiment |                                    |                                    | SC, FE,<br>AC and<br>DP joint<br>activity | SC and FE have supper<br>and perform presleep<br>systems check |   | Sleep period<br>(8 hours) |                        |       |
| FE        |  |                                    |                                    |   |  |   |                           |                        |       |
| TV        | TV   |                                    | TV                                 |   |  |   |                           |                        |       |
| AC        | AC and SC trans-<br>fer into DM                              | CP and FE<br>transfer<br>into CM   | DP and FE<br>transfer<br>into DM   |   | AC and DP trans-<br>fer into CM                                | AC, DP and CP have<br>supper and perform<br>presleep systems<br>check |                           | Sleep period (8 hours) |       |
| DP        | AC and SC trans-<br>fer into Soyuz                           | CP, DP and<br>FE joint<br>activity | FE and DP trans-<br>fer into Soyuz |   |  |   |                           |                        |       |
| CP        | Microbial exchange expe-<br>riment                           |                                    |                                    |   |  |   |                           |                        |       |
| Rev. GET  | 76:00  | 77:00                              | 78:00                              | 79:00                                     | 80:00  | 81:00   | 82:00                     | 83:00                  | 84:00 |
|           |  | Rev. 45                            | Rev. 46                            | Rev. 47                                   | Rev. 48  | Rev. 49   |                           |                        |       |

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| Orbit    | Orb. 63  |       | Orb. 64   |       | Orb. 65  |       | Orb. 66  |       | Orb. 67                   |  | Orb. 68  |  |   |  |
|----------|--|-------|---|-------|--|-------|--|-------|---------------------------|--|--|--|---|--|
| GET      | 91:00  | 92:00 | 93:00   | 94:00 | 95:00  | 96:00 | 97:00  | 98:00 | 99:00                     |  |  |  |   |  |
| SC       | SC and FE perform postsleep systems check and have breakfast |       |   |       | Don spacesuit, transfer into DV and prepare for undocking. Artificial solar eclipse experiment |       | Undocking (95:42)<br>Perform orientation for docking     |       | Redocking (96:20 - 96:25) |  | SC and FE check systems operation; transfer into OM. Lunch |  | Orientation for film shooting. Apollo picture shooting  |  |
| FE       | Sleep period (8 hrs)   |       |   |       |  |       |  |       |                           |  | Undocking (99:03 - 99:08)                                  |  |   |  |
| TV       | TV   |       | TV  |       | TV   |       | TV   |       | TV                        |  | TV   |  |   |  |
| AC       | Sleep period (8 hours)                                       |       | AC, DP and CP perform post-sleep systems check and have breakfast |       | Orientation for undocking. Prepare for undocking. Artificial solar eclipse experiment          |       | Undocking (95:42)<br>Perform orientation for the docking |       | Redocking (96:20 - 96:25) |  | Lunch. Orientation for undocking                           |  | Orientation for film shooting. Perform ultraviolet absorption experiment. Apollo departure (106:41) |  |
| DP       |  |       |   |       |  |       |  |       |                           |  |  |  |   |  |
| CP       |  |       |   |       |  |       |  |       |                           |  |  |  |   |  |
| Rev. GET | 91:00  | 92:00 | 93:00   | 94:00 | 95:00  | 96:00 | 97:00  | 98:00 | 99:00                     |  |  |  |   |  |
|          | Rev.54   |       | Rev.55  |       | Rev.56   |       | Rev.57   |       | Rev.58                    |  |  |  | Rev.59  |  |

4.6 Independent flight of Soyuz after the spacecraft separation

Soyuz independent flight begins after the Apollo performs the maneuver to separate the spacecraft so that they do not collide.

During this flight the Soyuz crew conduct ASTP scientific experiments, verifies the functioning of the spacecraft systems, stores and packs the equipment which is to be returned to Earth.

During this flight the Soyuz crew conduct TV-transmissions from the spacecraft in the USSR MCC coverage zones.

Following is the sequence of the main events:

| Orbit       | GET | Main events  |
|-------------|-----|--|
| 71 orbit    |     | Supper (30 min)<br>Prepare for sleep period  |
| 72 orbit    |     | Sleep period (8 hours)   |
| 78 orbit    |     | Morning toilet<br>Breakfast (30 min)<br>Spacecraft systems check   |
| 78-80 orbit |     | Verify the functioning of the spacecraft systems operational during the descent  |
| 80 orbit    |     | Orient solar panels to the Sun   |
| 80-82 orbit |     | Conduct scientific experiments:<br>"ZFF" (observe and photograph the ZFF, transfer and stow in DV).<br>Fish embryonic development (transfer and stow Biokat-3 device). |

| Orbit       | Get | Main events   |
|-------------|-----|---|
| 83 orbit    |     | Individual time. Dinner (30 min)                                  |
| 84 orbit    |     | Conduct the experiment: "Photography of the sunrise".             |
| 85-86 orbit |     | Stow the equipment to be returned to Earth                        |
| 86 orbit    |     | Individual time. Supper (30 minutes).<br>Prepare for sleep period |
| 87 orbit    |     | Sleep period (8 hours)  |

#### 4.7 Preparation for descent; Soyuz descent

The Soyuz descent begins after the crew rest period on the last flight day. The crew don pressure suits, transfer to DV and close the DV hatch from the DV side; release OM pressure by 150 mm Hg to make sure that the DV hatch is pressure-tight, orient the spacecraft for "braking". The retrorocket is activated at the given time following the commands of the onboard automatics. After the retrorocket deactivation the spacecraft modules are separated and the DV performs a controlled descent into the given landing area. The sequence of major events is given below:

| Orbit    | GET | Main events  |
|----------|-----|--|
| 94 orbit |     | Morning toilet.<br>Breakfast (30 min).<br>Check spacecraft systems |

| Orbit    | GET | Main events  |
|----------|-----|--|
| 94 orbit |     | Don pressure suits.<br>Crew transfer to DV.<br>Close hatch DV-OM   |
| 95 orbit |     | 150 mm Hg pressure drop in OM.<br>Make sure the DV hatch is pressure-tight   |
| 95 orbit |     | Make sure the pressure suits are pressure-tight.<br>Prepare for descent  |
| 96 orbit |     | Orient spacecraft for "Braking".<br>Activate retrorocket.<br>Module separation.<br>Parachute deployment.<br>DV soft landing. |

#### 4.8 Crew recovery

After completion of the technical and scientific experiments program in AES orbit the cosmonauts will be returned to Earth. DV will land in a pretermind area of the Soviet Union. The DV is designed for landing but it is also equipped with special systems, ensuring the cosmonauts security in case of a splash-down.

In the landing area the cosmonauts will be met by a specially-trained rescue team. The group will consist of technical experts, doctors, flight record Certification Officers. The rescue team will be equipped with everything necessary to arrive in time to the landing



site and render the required aid to the cosmonauts. Planes, helicopters, ships and landrovers will be used for rescue. Technical experts and doctors of the rescue team are usually well-trained parachutists and underwater swimmers. The doctors of the rescue team will be provided with the required medicaments and equipment which can be used in the field under any weather conditions. During the descent and after the landing the cosmonauts and the rescue team will maintain the 2-way radiocommunication.

After the DV landing the cosmonauts will open the hatch covers and prepare the containers with scientific equipment and filming for transportation.

If necessary they may use the emergency kit which contains the camp outfit, warm clothes, swimming means, communication means, food, water etc. After the cosmonauts land and leave the DV they doff pressure-suits and don their flight-suits. Containers with scientific equipment and filming are handed to the specialists of the rescue team. At the landing site the cosmonauts will be subjected to the first postflight medical examination. In case the DV splashes-down, the cosmonauts will stay in the DV till the arrival of a rescue team. In this case the cosmonauts will doff their pressure-suits, prepare the swimming means, communicate with the rescue service and wait for arrival of one of its team.

## 5.0 Scientific experiments

The program of scientific experiments scheduled for Soyuz mission provides for unilateral and joint experiments.

### 5.1 Unilateral scientific experiments

Unilateral scientific experiments involve astrophysical and biological experiments.

Astrophysical tests are based on the metrophotography approach, that is on the use of calibrated photometric films which make it possible to perform light measurements. Moreover, it is important that each photo-picture should be exactly time-referenced. These experiments are conducted with the use of the same automatic camera with a command unit that is used in the Artificial Solar Eclipse experiment (ASE). Given below is a brief description of astrophysical experiments.

#### Photography of the solar corona and zodiacal light against the background of the night sky

The experiment envisages a number of shots of the night and dusk sky with the Sun at different angles behind the horizon of the Earth, that is under conditions of solar eclipse by the Earth.

This experiment, carried out in addition to the joint ASE experiment, will be an attempt to find coronal rays at large angular distances from the Sun in order to corroborate a hypothesis of extensive solar corona. Visual observation by the Soyuz crew will serve the same aim.

Coronal rays will be identified or singled out among possible structural formations of atmospheric origin by the absence of their visible shift against stars.

Investigation of refraction and transparency of the upper layers of the atmosphere

The aim of the experiment is to measure atmosphere refraction and solar light absorption by the atmosphere. The experiment, in particular, will assist to experimentally determine altitude distribution of air density in the stratosphere and troposphere which is of great importance for the solution of the problems of meteorology and atmospheric optics. Moreover, the experiment will make it possible to obtain initial data for the development of equipment for autonomous astronavigation and orientation of spacecraft.

The experiment involves photography of the Sun when it rises or goes behind the horizon of the Earth. The referenced pictures will make it possible to obtain the altitude distribution of atmospheric layers.

Refraction of the atmosphere is determined from the solar disc image flattening. Atmospheric absorption (vs. altitude) is determined in terms of the film darkening both for each image and for the whole set of solar disc pictures obtained for different positions of the Sun above the Earth's horizon. The shooting will be carried out in the narrow spectrum with the use of band-pass filters to prevent the blurring of the Sun's pictures due to atmospheric dispersion of the light.

Some of the aims of this experiment will be gained additionally by photography of setting stars. In this case, "deformation" of the portion of a sky of stars ("star grid") in the course of its going behind the horizon will give atmospheric refraction, and the measurement of the darkening of the setting stars will determine atmospheric absorption.

### Photography of daytime and dusk horizon

This experiment is divided into two independent procedures:

- Photography of daytime horizon,
- Photography of dusk and night horizon.

The aims of the experiment are to determine characteristics of light-scattering by atmospheric air, investigate stratospheric (at altitudes from 15 to 25 km) and mesospheric (at altitudes from 40 to 60) layers of aerosol, make an attempt to discover and investigate noctilucent and nacreous clouds, and analyse dependence of altitude aerosol distribution on geographical and meteorological factors. Moreover, the theory available makes it possible to use photographic data of dusk horizon to quantitatively assess atmospheric scattering within the altitudes from 30 to 150-200 km.

Daytime and dusk horizon is shot with the use of band-pass filters.

The program of astrophysical experiments scheduled for the Soyuz flight in the joint mission involves applied technical experiments as well. In particular, the program envisages visual observation and photography of light effects in the vicinity of the spacecraft, and investigation of the possibility of the observation and identification of stars with the spacecraft on a daytime portion of an orbit.

In this experiment the window is protected from the Earth's high lights by the same sunshade that is used in the Artificial Solar Eclipse experiment.

### Biological Experiments.

The biological experiments are conducted to study the effect of weightlessness, space radiation and Earth's magnetic field on the growth, development and heredity of different organisms. Peculiar feature about these experiments is that they are conducted in thermostats and the organisms develop mainly during the flight. To make the organisms develop during the flight the cultures are placed into the nutrient medium, the seeds are wetted, the shoots and developing fish are fixed onboard the spacecraft.

Thermostatic control of a biological object is provided by "Biokat" - biological thermostatically controlled capsule maintaining the given temperature to an accuracy of  $\pm 0.5^{\circ}\text{C}$ .

The device consists of a casing and a power supply unit. The casing contains the central cylindrical passage surrounded by the elements ensuring thermostatic control; and the inserts with biological objects are placed into the passage.

There will be three thermostats onboard the Soyuz. They are intended for conducting the following experiments: "Micro-organisms growth", "Fish embryonic development", and "Genetic studies".

#### "Micro-organisms Growth"

The aim of the experiment is to study the effect of space-flight factors on the rate and character of the micro-organism growth, mobility of bacteria cells. Possible changes in morphology, genetics, survivalability and radio-sensitivity of cells will be determined. The experiment will use the culture of protea vulgaris, which is characterized by high mobility in solid and liquid nutrient media. The insert has the form of a capsule and is made from transparent material. The butt end of the capsule has the button:

of the inoculation device under which an ampule with the micro-organism culture is located. The cavity with the ampule in is connected to special chambers filled with nutrient media containing the indicator which changes its colour when effected by micro-organism wastes thus forming the visual growth boundary.

#### "Fish embryonic development "

The aim of the experiment is to study growth and development of water animals under the weightlessness conditions. The experiment will reveal embryonic and genetic changes and peculiarities of formation of the vestibular apparatus of developing fish.

Two inserts-aquariums are placed into "Biokat", one of the aquariums will be used for the preservation of the developing fish at the completing phase of the flight. The fish from the other aquarium and the preserved material will be brought back to Earth. The experiment will use well-known aquarium fish - Danyo Rerio or Cardinal. The inserts with fertilized roe of these fish will be installed onboard the Soyuz immediately prior to the lift-off.

#### " Genetic experiment"

The aim of the experiment is to study the weightlessness effect on the cell division, genetic structures and radiosensitivity of different biological objects:

- chlamydomonada zygotes which do not germinate in darkness for a long time. Peculiarities of the chlamydomonada cell division when effected by space flight factors will be studied;
- seeds of crepis and arabydopsis will be steeped during the flight; the shoots will be fixed. In the dividing cells of the shoots the frequency of chromosome

restructures will be studied. The effect of the spaceflight factors on radiosensitivity of the dry seeds of these species, the frequency of embryonic and chlorophyllous mutations will be studied.

All these objects in the appropriate capsules will be also placed into one of the Biokats.

Along with the flight experiment a number of laboratories in this country will also conduct control experiments maintaining the same temperature conditions as in the "Biokat" devices.

Following instructions from the MCC the scientists will conduct experiments in the same manner as the cosmonauts will conduct theirs in the orbit.

Note: Unilateral experiment program may be changed depending on the specific conditions.

## 5.2 Joint scientific experiments

### Artificial solar eclipse experiment (Fig 5.1)

Artificial solar eclipse experiment was proposed by the USSR side. This experiment requires the participation of both spacecraft during docking and undocking. The experiment is to obtain from onboard the Soyuz a series of photographs of the solar corona and "atmosphere" around Apollo while the Sun is eclipsed by Apollo. This flight gives the opportunity for testing new methods of studying the solar corona and the "atmosphere" around the spacecraft. It is the first solar eclipse scheduled by man. It will occur on July 19, 1975 at midday universal time.

Solar eclipse . The interest it presents for scientists.

Solar corona is the most external, extremely rarefied layers of solar atmosphere. Practically, it consists of fully ionized hydrogen plasma, i.e. protons and electrons. Its temperature reaches 1 million degrees. Solar corona stretches for great distances and the Earth is in its external part.

High-energy particles and electromagnetic radiation which effect the earth atmosphere and cause practically all geophysical effects are formed in solar corona. In the visible part of spectrum the solar corona shows itself as a weak glow which is nothing else but sun light scattered by the electrons of coronal plasma. Self-radiation of solar corona takes place in the invisible part of spectrum, in the general, in the shortwave part. Corona brightness million times as weaker as the brightness of solar disk and usually corona is not seen on the background of bright day sky. Corona becomes visible from the Earth only in case of total solar eclipse, while the solar disk is fully eclipsed by the Moon and the sky brightness decreases million times. It is precisely this happy circumstance that has allowed for the solar corona to be detected at the remote past. However its' physical nature was discovered only



during last decades.

Total solar eclipse is a very rare phenomenon. So, total solar eclipses may occur at the same geographical point, in average, once in 300 years. The duration of the full phase of the eclipse usually does not exceed 1-2 minutes. The total time of observations performed during the whole history of total solar eclipse observations using optical instruments does not exceed two hours. However, the most important discoveries in astrophysics as well as in geophysics were made based on these observations. Corona may be investigated out of the eclipse, for example, in short-wave spectral range. However, for some reasons it is impossible to get the total and reliable information using only these methods. The single way to conduct out-of-eclipse solar corona observations in visible part of spectrum is to create artificial solar eclipse. This principle is used as the basis for so called out-of-eclipse coronagraph. Artificial solar eclipse is realized in the device itself: the image of solar disk is shut by non-transparent screen of larger diameter. As the level of atmosphere background brightness is high under the ground conditions, the observations of solar corona using these coronagraphs are possible in close vicinity to the edge of solar disk (the range not more than tenth parts of angular radius of the Sun). At the same time the observations of corona up to dozens of angular radii are of great interest. In general, the observations out of atmosphere should enable to perform this kind of observations. However, the installation of out-of-eclipse coronagraphs aboard the spacecraft increase insignificantly the possibility for solar corona to be studied in comparison to the ground conditions. Artificial solar eclipse experiment provides more reliable conditions to study solar corona. It is reached by eliminating the errors caused by the light reflected from the Earth, effects of diffraction on the

edge of artificial "moon" and effects of the Soyuz atmosphere (Soyuz is in shadow), i.e. factors that limit the possibility to carry out onboard investigations using coronagraphs. The other merit of the method to be used in this experiment is the employment of rather simple and compact recording equipment.

About spacecraft "atmosphere". Spacecraft atmosphere is another object of study. Under conditions of space vacuum, continuous evaporation (sublimation) of different materials from the spacecraft surfaces takes place.

At first absorbed gases, water and other volatile substances will leave the spacecraft surface. Microformations - "dust particles" - may also leave the spacecraft surface. Additionally the failure of surface layers of the structure itself occurs. All materials, as well as metals, are subjected to the destruction but to a different degree. Organic materials and different kinds of coatings are especially unstable. Micrometeorite particles, cosmic and solar radiation intensify this process. All products of "depreciation" leave the locality of the spacecraft not simultaneously. So, at present it is considered that there is a peculiar atmosphere around spacecraft. This atmosphere is enriched by the outgassing of sealed compartment and especially by exhaust products of reaction engine.

Contamination around the vehicle under orbital flight conditions is effected by the incident flow of the Earth residual atmosphere, pressure of sun light and so called "solar wind". So the vehicle with the "atmosphere" around looks like comet. But we must take into consideration that the terms "atmosphere" and "comet" are used only as graphic phrases. **Actually, they describe rare medium which differs from the undisturbed space medium. It is necessary to take into account this difference as all observations**

are conducted inside the "comet". The components of this "atmosphere" change physical characteristics of the environment and, consequently, may result in operation of important vehicle systems and instruments. They may also introduce errors into scientific information. "Atmosphere" around the vehicle causes appreciable changes into optical characteristics of the environment, therefore optical instruments are especially subjected to its effect. Effect of the contamination around the vehicle may result in increasing induced illumination and in disturbance of useful light signal by the cloud components as well as in changing optical characteristics of the instruments as the result of contamination effect on unprotected optical surfaces. So it is impossible to conduct complicated experiments in space and to develop and improve important systems of vehicles without taking into account different effects concerning the change of physical characteristics of the environment around the vehicle. But to take into account all these effects it is necessary to study them in conjunction with all space factors which couldn't be created at the laboratory. Artificial solar eclipse experiment provides reliable possibilities to perform this kind of investigations. This experiment gives the opportunity for registering the general pattern of light aureole ("atmosphere") around the spacecraft to be obtained from the other spacecraft under reliable conditions, while this spacecraft is in the shadow of the first one.

Experiment description. The experiment idea is rather simple, but the high techniques, precise piloting and cooperation of all spacecraft crew activities are required to perform this experiment. Artificial solar eclipse experiment will be performed as follows. Before undocking the spacecraft link of Apollo and Soyuz spacecraft is oriented with high accuracy by placing the longitudinal axis to-

wards the Sun (Apollo from the side of the Sun) and stabilized in this position. Separation will be performed according to the schedule. After undocking control systems of both spacecraft will keep the initial orientation mode. The separation rate of the spacecraft is to be approximately 1 meter per second along the Sun-Apollo-Soyuz line. When performing orbit translation both spacecraft will go away along this line.

During the separation the Apollo spacecraft will occult the Sun creating for Soyuz onboard observer the artificial solar eclipse conditions. The separation will continue until the relative distance of 220 m is reached. At this distance angular dimensions of artificial "moon" (Apollo spacecraft) for Soyuz onboard observer will be twice as great as dimensions of solar disk. When the distance of 220 m is reached the direction of translational motion along the Sun-Apollo-Soyuz line reverses in order to return into position for redocking.

The experiment will be performed along the sunrise part of the orbit to crossing the terminator in order to eliminate the Earth induced illumination of the Soyuz hatch window and the part of the Apollo spacecraft visible from the Soyuz. At this part of orbit the Sun is raised for both spacecraft but there is night in that part of the Earth where spacecraft flies at this time. A special baffle installed on the Soyuz will provide additional protection from the dawn light for Soyuz hatch window. Scheme and schedule for the experiment are given in figures.

During the artificial solar eclipse the photography of solar corona and "atmosphere" around the Apollo will be performed through the Soyuz docking hatch window. The photography will be performed with the help of automatic photcamera with programmed control unit. Photometrically calibrated highly sensitive film

will be used. Apollo crew will perform film-shooting of the Soyuz spacecraft in order to receive data required to analyze (after the flight) conditions for Soyuz window occultation. This experiment attempts to find coronal rays on the background of night sky, i.e. when the Sun is eclipsed by the Earth. Additionally synchronous ground-based observations of the Sun will be performed to determine the interaction between the structure of the outer corona and active features of the solar disk and limb.

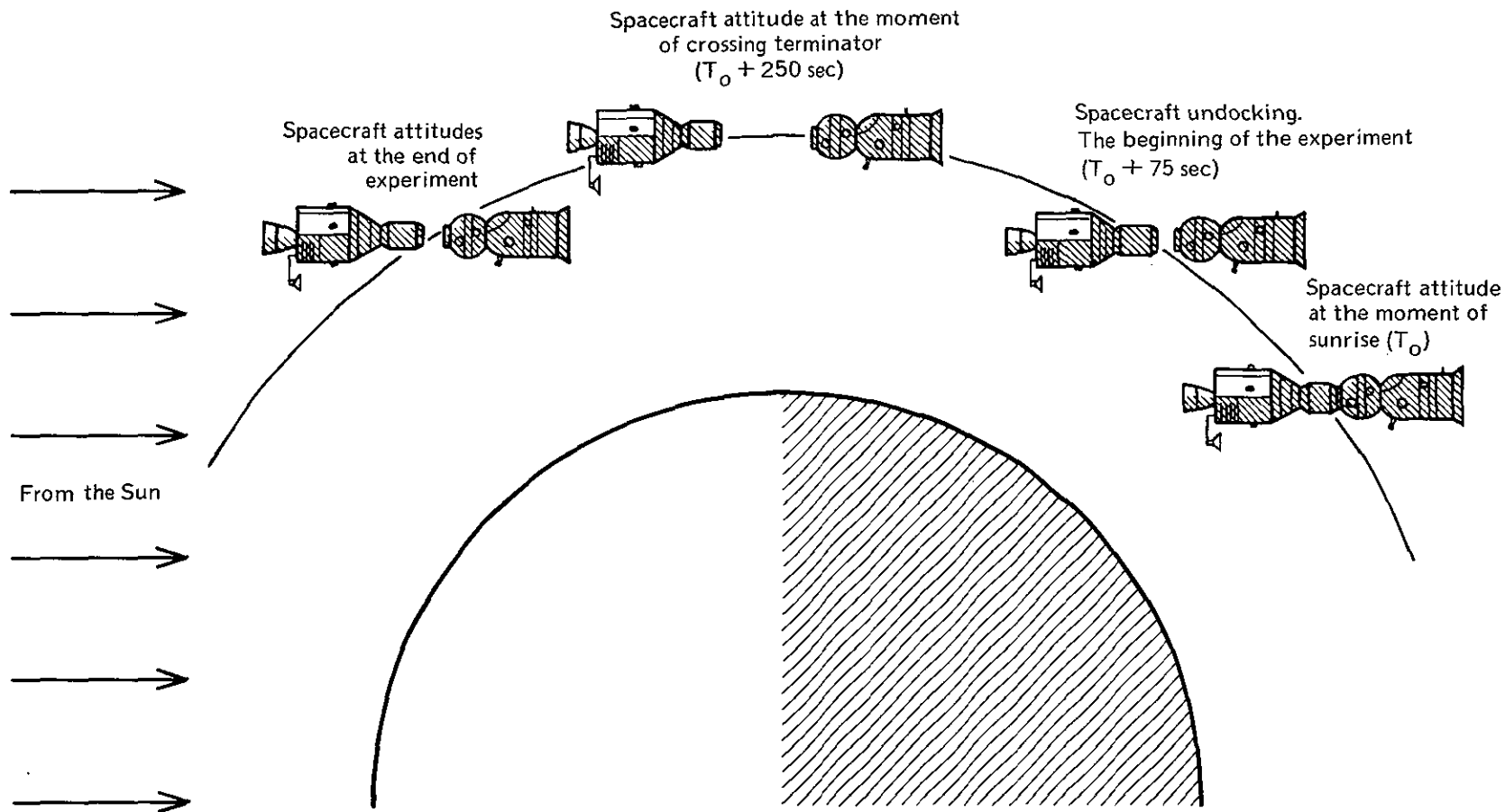


FIGURE 5.1 SOYUZ AND APOLLO ATTITUDES FOR "ARTIFICIAL SOLAR ECLIPSE EXPERIMENT"

## Ultraviolet absorption experiment (Fig.5.2)

Experiment objective. The objective of the experiment is to measure the concentration of atomic oxygen and nitrogen in space at the altitude of the flight. At present time the density of atomic oxygen remains uncertain, and the density of atomic nitrogen has never been significantly obtained. This experiment attempts to measure the O density and the N density down to  $5 \times 10^6$  Atoms/cm<sup>3</sup> at 220 km.

Scientific value of the experiment. Different types of mass-spectrometers will be the main instruments to be used during investigation of chemical composition of the outer atmosphere of the Earth. All types of mass-spectrometers reliably register molecular and inert gases, such as O<sub>2</sub>, N<sub>2</sub>, Ar, Ne and do not register atomic oxygen and nitrogen. These components recombine quickly, i.e. turn into O<sub>2</sub> and N<sub>2</sub>. The method of resonance absorption within ultraviolet spectrum allow to determine reliably the density and composition of any components of the outer atmosphere.

The determination of the density of atomic oxygen and nitrogen will help to solve many indefinite physical problems concerning the outer atmosphere of the Earth. Ultraviolet absorption experiment gives the opportunity to compare the results received in this experiment with the data obtained using mass-spectrometer methods.

Experiment description. During the experiment the degree of signal absorption within UV-range will be measured. These signals correspond to the resonance frequencies of atomic oxygen and atomic nitrogen. For this purpose the signals from resonance sources at the defined range will be sent by the mirror of the spectrometer

installed in the DM of the Apollo. These signals are directed towards the retroreflector installed on the Soyuz and returned back to the spectrometer of the Apollo.

To eliminate Doppler effect during data taking period the line-of-sight is to be perpendicular to the orbital velocity vector within solid angle of  $\pm 15^\circ$ . The axis of solid angle is normal to the velocity vector.

The measurements of the concentration of atmospheric species around Soyuz spacecraft are taken to evaluate the effect of "atmosphere" around spacecraft arising from the outgassing of the compartments and attitude control thruster burn. These measurements will be made while Soyuz flies along the Apollo track. Soyuz spacecraft is to be within the solid angle of  $\pm 8^\circ$  with its axis directed along the orbital velocity vector.

The concentration of atmospheric species will be measured at some designed distances between spacecrafts. The distances up to 500 meters will be determined by accelerometers of the Apollo spacecraft; for a separation distance greater than 500 meters radio system will be required. This system will be used during rendezvous before spacecraft docking. The experiment will be conducted in 68-71 orbits, after final undocking of the two spacecraft. A calibration of the device must be made by Apollo in darkness prior to the first data measurement. The measurements of the concentration will be made within  $\pm 20$  latitude of the equator, at nominal distances of 150, 500 and 1000 meters. The duration of each measurement is up to 8 minutes. During measurements, Soyuz must be in the orbital plane and Apollo will be oriented with its longitudinal axis towards Soyuz. The optical axis of the spectrometer will be pointed at the retroreflector installed on Soyuz. Measurements of



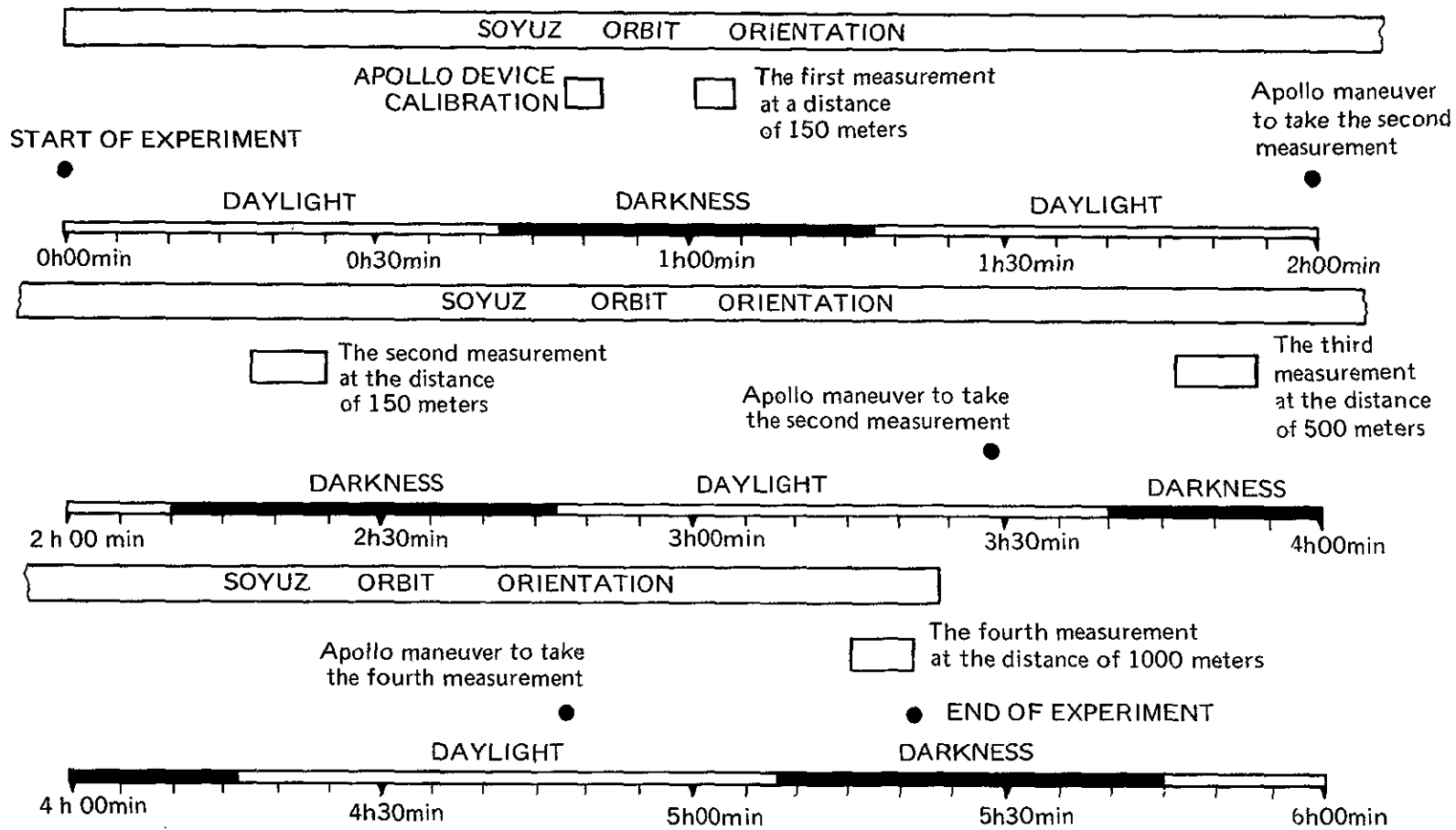


FIGURE 5.2 SCHEME FOR UV ABSORPTION EXPERIMENT

particles concentration around Soyuz will be taken at high latitudes, at a distance of 150 meters between the spacecrafts. The duration of measurements will be 5 minutes. The Apollo crew will be required to perform maneuvers to provide necessary orientation for both spacecraft during the experiment.

Equipment and its characteristics. Three retroreflectors installed on Soyuz along longitudinal and transversal axes are the part of the spectrometer assembly required to conduct the experiment.

To increase the measurement accuracy it is necessary to obtain the highest reflectivity for optical surfaces of the reflectors. It makes some difficulties for manufacturing and performing preflight preparation. The fact is that the reflectivity of special mirrors made of glass and coated with a layer of pure aluminum does not exceed 0.8 for wave-lengths at UV range (1200 to 1356 Å). Taking into account that the reflected signal is to be returned in the direction of the incoming beam the retroreflector is specially designed. Each retroreflector cube consists of 3 mirrors at exactly  $90^{\circ}$  angles with respect to each other. At this design the incoming light makes 3 reflections on the mirrors and thus the net reflectivity is not more than 0.512. To prevent the formation of aluminum oxide that decreases the reflectance of aluminum, mirror surfaces are coated with thin film of magnesium fluoride. This film must be sufficiently thin to be properly transparent at specified wave-lengths.

Any contaminations of optical surfaces (moisture, drops of oil and solvents, etc., effects of corrosive gases produced by thrusters) result in sufficient decrease of reflector sensitivity.

Taking into account this fact, each of three retroreflec-

tors is furnished with sealed protective cover, which is to be opened just before the experiment initiation. The reliability for the covers to be opened is checked out under ground conditions during independent tests and after retroreflector installation aboard the Soyuz spacecraft.

Special measures must be supported to provide protection of optical surfaces from external contamination.

Spectrometer assembly is installed on Apollo. It consists of Ebert-Fastie spectrometer, telescope - the device for retroreflector tracking, light sources - for generation of resonance electromagnetic vibrations with the following wave-lengths: 1200 Å; 1304 Å and 1356 Å; transmitting and receiving optics, electronics unit.

Note: The experiment sequence can be changed to enable the Soyuz crew to visually control the Apollo maneuvering.

## ZONE-FORMING FUNGI EXPERIMENT

The investigation of the natural biological clock, affecting the main biological rhythms, constitutes an important part of the complicated biophysical process and the general theory of life system regulation. Growth periodicity, cell development and division, changes in activity and propagation, are considered to be the main rhythms. The basic data on different aspects of this problem have been determined. However, we are still far from the solution of the main problem. This problem is the correlation between the periodicity of the cell processes and different periodical factors external to the organism which are required to determine the main biological rhythms of the organism and its systems. It is necessary to study these questions in order to understand the most important general biological regularity. The answers to these questions are required for subsequent investigations of prophylaxis and the theory of decynchronosis, intensification of general reactivity and resistance, and selection of the optimum work and rest modes. The investigation of space factor effects on the Earth biosphere constitutes an important part of space biophysics. There is considerable data on the solar effects on the biosphere, for example, on a number of leucocytes and rate of different diseases of man, animals and plants. It has been shown that space radiation takes part in formation of space flight factor biological effects. The high biological effectiveness of hadrons and heavy nuclear particles of high and superhigh energy have been shown as well. Hadrons - particles capable of strong interactions.

It is necessary to study space particles effects on the organism to ensure biological safety during prolonged space

flights, especially beyond the limits of the earth radiation belts. The objective of the zone-forming fungi experiment is to study the effect of space flight factors (weightlessness, overload, space radiation) on the main biological rhythms.

The USSR proposed to include this joint experiment into the flight program. The Puschino strain of *Actinomyces levo-ries* (natural growth) is used as the object of study.

This fungus is cultivated using hard nutrient medium. The quality of the chosen object is the visually observed difference between correct round zones of mycelium growth (transparent rings) and spore-forming zones (protruding white band). In appearance fungi rings are like the cut of a tree. The other qualities of this fungus are the following: comparative resistance, sensitive to zone-forming synchronization when illuminated, synchronization during prolonged periods of time, suitable range of zone-forming periodicity - one zone (ring) per 1 day, capability of growing in Petri sealed dishes. Local death of some cells, delay in growth and development (caused, for example, by the damage of heavy nuclear particle) may be visually observed along the asymmetry line of formation or along the break line of the next spore-forming ring. The fungi zones are kept for one month or even longer periods.

The program of the joint Apollo-Soyuz flight will allow space investigations of biorhythms using the identical biological objects cultivated within different time belts. The time difference between the USSR and USA laboratories engaged in the pre-flight cultivation of fungal culture is approximately 9 hours. This experiment is conducted using the device "Rhythm-1" specially designed for these purposes by the USSR side. Two Petri dishes

with fungal cultures and a plastic detector to register the flow of heavy nuclear particles (hadrones), coming within fungus growth zone are installed in the device body.

The cultivating of fungal culture will be done by the USSR and USA laboratories 7 days before launch.

Approximately, 200 Petri dishes will be loaded with medium and fungi plated. Then Petri dishes will be placed into an incubator and cultivated for 3-4 days. The required zone-forming rhythm is provided by illumination of 100-200 lux: from 0900 to 2100 hours, local time (daytime) from 2100 to 0900 hours (darkness). The imposed rhythm is maintained for a long time including the period of flight and postflight processing. 24 hours before launch 16 round colonies with perfect rings (no breaks and asymmetry) are selected from Petri dishes. 8 devices with selected colonies in Petri dishes are assembled in a sterile box. The installation of the devices aboard the spacecraft is carried out 3-4 hours before launch. Two experimental and two control devices are selected. 4 backup devices will remain at the laboratory.

The devices will be photographed before installation to register the initial state of fungal cultures. The transportation of loaded devices at all stages of the experiment will be performed in special thermostatic containers designed by the USSR side.

During the flight both crews will regularly (approximately every 12 hours) take pictures of "Rhythm-1" devices in order to register fungal growth rates. When docked the crews will exchange devices (one of two installed onboard each spacecraft).

At the landing areas the research group specialists will take pictures of fungal colonies and provide their quick

delivery (not more than 2 days) to the USSR and USA laboratories. At the laboratory the specialists will analyse cosmonaut and astronaut notes, pictures and the type of the returned fungi. There will be also determined the number of rings, the time of their formation, zone width and localization of deformed areas. Detectors are removed, processed, analyzed using a microscope in order to find particles tracks. Particles are identified by their charge group and energy ranges. Local anomalies of zone-forming fungi rhythm are checked against particle track co-ordinates. Relationship between zone-forming rhythm anomaly and the values of particle charge and energy is analyzed. Similar investigations will be performed using control devices (not flown). Extensive plating will be done taking samples from unchanged and deformed ring sections. This is done to determine the possible changes in fungal properties, inherited by subsequent fungi generations. The results of the investigation conducted in space and laboratory conditions will be discussed at the special symposium and prepared for publication as joint works.

## MICROBIAL EXCHANGE TEST

At present sufficient data are available which illustrate that man's prolonged presence in sealed compartments and the effect of space flight factors on man's organism may result in diseases caused by the representatives of the "own" man's microflora (automicroflora). The course of these diseases is similar to that of "autoinfection". This means that microorganisms which "have lived peacefully" with the man - "host" earlier may cause suppurative diseases, quinsy and other diseases.

As a result of space flight factors the ability of a man to resist invasion by microorganisms may decrease. Diseases may be caused by the microorganisms contained on man's integuments which are unharmed under usual conditions but in space flight they acquire "aggressive" (pathogenic) properties.

There are some other reasons of crew diseases in space flight. The main reason is the transmission of infection by the people which are the pathogenic microorganisms carrier (staphylococci, meningococci, pneumococci, etc.). But susceptibility to these diseases may increase when infection resistance decreases. The mechanism of microbe transmission is the basis of the so called "cross infection" which is being studied now in hospitals and other medical offices.

At present "the cross infection" is considered to be the main reason of crew infection diseases during the space flight.

"Microbial Exchange Test" to be performed during the joint Apollo and Soyuz space flight attempts to evaluate the character and conditions of microbial exchange between crewmembers and crews of both spacecraft in space flight.



Organism infection resistance will be thoroughly studied during preflight and postflight crew members' examinations with regard to the fact that decrease in organism infection resistance may cause diseases during the space flight.

The main objective of the experiment - to determine the character and conditions of microbial exchange - will be achieved by studying qualitative and quantitative composition of the man's integuments and mucosa flora to be performed before, during and after flight. The detailed investigation of microbial types and isolation of different microorganism species will be performed to determine the peculiarity of different microorganism exchange.

It was decided that USSR and USA specialists would study different microbial groups in order to conduct investigation more successfully. But both sides will study those microbial groups in which they are especially interested at the present stage of space investigation.

In addition to cosmonauts' and astronauts' microflora microbial samples will be taken from all crew members and inner surfaces of both spacecraft. This will allow to assess the role of inner surfaces in microbial transfer under these specific conditions. A specific device was designed for taking samples from the different sites of the crew members' integuments and from inner surfaces of Apollo and Soyuz spacecraft during the flight. This device is also used for storage and delivery of microflora samples to the Earth where the analysis of these samples will be performed.

The device is a tube made of fluoroplastics with a screwing sealed cap. The end of the tube is a capillary which

is filled with specific maintenance fluid. A small cotton swab is placed on the free end of the capillary. During the storage the swab is continuously moistened with maintenance fluid contained in the capillary. The tubes are placed into specific cloth trays.

It was agreed that the USSR side would provide tubes for investigations to be performed before, after and during the flight.

The investigations have been already performed by USA and USSR scientists to determine maintenance fluid composition for different types of microorganisms. Maintenance fluid composition developed by the USSR side was chosen to maintain microorganisms sampled from crew members' integuments and from inner surfaces of both spacecraft. Maintenance fluid composition developed by the USA side was chosen to maintain microorganisms sampled from oral cavity and throat. All samples will be analysed at the laboratories of Moscow (USSR) and Houston (USA) in the presence of scientific representatives of both sides. All samples will be divided and sent to the laboratories of both sides to be studied there.

The results of "Microbial Exchange Test" will be documented as joint scientific works.

## FURNACE SYSTEM EXPERIMENT

In the near future the space will be not only the wide field of research but it will be used for numerous technological processes of production to be conducted.

Even at present the use in production process of such natural space factors as ultrahigh vacuum and weightlessness is of great interest for manufacturing of metals and semiconducting materials needed in some electronic, electric and instrument industries.

It presents great difficulties to create "space" vacuum under earth conditions and we are not able to maintain weightlessness for sufficiently long time. This is why it is impossible to perform and investigate numerous "space" new materials production processes of scientific and practical interest.

Weightlessness seems to be very much perspective for manufacturing new metal and semiconducting materials formed of elements with substantially different specific weights through their crystallization from liquid state.

Under ground conditions it is either impossible or very difficult to create such composite materials due to the so-called "weighty" element segregation which causes heavy elements to deposit.

It is anticipated that big semiconductor crystals manufactured under weightless conditions, including that formed of elements with sufficient difference in their specific weights, will possess such semiconductor properties which are infeasible under ground conditions.

Such crystals will enable us to design new semiconductor devices for electronics, computers, space radio systems, instrument engineering etc.

Weightlessness will allow to manufacture the so-called composite materials with fusible basis and more refractory and heavier second phase. We may preset the second phase material distribution under ground conditions with components solid phase and this distribution has to be maintained after the basis melting in weightlessness conditions.

When on the ground the heavy second phase will deposit after melting.

Calculations show that such composite materials fabricated under weightlessness conditions will possess unique mechanical, electric and other characteristics.

Of no less importance is a use of ball-formation of fused metals and semiconducting compounds in weightlessness conditions to fabricate perfect balls for bearings of different purpose, fabrication of semiconductor spheres and so on. We may also expect ball-formation of different powder systems when melting under weightlessness conditions. The investigation of this process is significant not only for material production under weightlessness conditions, but also for such space technological procedures as welding, treatment of biochemically active raw materials and so on.

During ground metallurgical procedures it is of significant importance to know actual rate such processes as solid metals high-temperature dissolving in various liquid systems, metal crystallization from liquid phases, new phases melt growing. Ground determination of such processes' actual rate is infeasible because of fluid convection flows due to gravitation.

The knowledge of actual rate values will allow to control ground metallurgical reactions more precisely.

While placing strong emphasis on space utilization and above all on weightlessness usage in scientific and technological purpose, during the Soyuz and Apollo joint mission Soviet and American scientists will perform a number of experiments to reveal weightlessness effect on some metallurgical and chemicrystallization processes in metals and semiconductors. The experiments were suggested by American scientists and generally titled as "Multipurpose furnace". The scientific program of these investigations was developed in the Institute of metallurgy of the USSR Academy of Sciences.

To investigate weightlessness effect on melting of metal compound consisting of metals with different specific weights and melting points aluminium was taken with tungsten balls impregnated and oriented in a special way. The compound is to be heated up to  $1100^{\circ}\text{C}$  under weightlessness conditions. In this case aluminium will melt and tungsten balls will partially dissolve in it.

This experiment will allow to learn basic possibility to fabricate composite materials with structure of elements with substantially different specific weights, using metallurgical processes under weightlessness conditions.

The experiment will also allow to determine actual rate of tungsten dissolving in aluminium and to evaluate convection part in this process.

Semiconductors monocrystallization from liquid melt was suggested to be studied using germanium containing Si 2% at.wt.

Due to convection melt flows fabrication of such Ge-monocrystals with silicon uniformly distributed all over the bulk is a problem of great difficulty.

Ball-formation in weightless conditions will be investigated through melting aluminium powder. This experiment will allow to reveal the processes of melting and powder materials crystallization in space.

The purpose of these joint experiments is also testing of the future technology of material production onboard long-term space stations.

This technology is based on raw production materials which are stored up on the ground and then they are supplied to the orbital plant-stations.

Upon completing of technological processes ready-made articles are transferred to the Earth.

This technology will be tested when performing Furnace System experiment.

Material samples prepared on the Earth and placed into special cartridges (Fig.53) are supplied onboard the Soyuz spacecraft to the orbit.

After the spacecraft docking the cartridges with samples are transferred into the docking module and placed by astronauts into a special automatic furnace. On completing technological cycle the cartridges are transferred to the Earth by the Soyuz crewmen.

The Apollo automatic furnace construction allows to simultaneously heat 3 cartridges up to  $1100^{\circ}\text{C}$ . Each cartridge contains 3 quartz ampoules with samples. Ampoule 1 contains aluminium impregnated by tungsten balls, ampoule 2 - germanium impregnated by silicon, ampoule 3 - aluminium powder. Ampoules and samples are fabricated by the Soviet side. The furnace maximum temperature range covers only ampoule 1 and partially ampoule 2. By

selecting graphite and copper inserts inside the cartridge temperature is slowly reduced towards the cold end of the cartridge.

When reducing ampoule 1 temperature in accordance with the program preset, solid-to-liquid phase interface in ampoule 2 with Ge-Si alloy encapsulated will be slowly shifted.

This method is used to obtain Ge:Si monocrystals under weightlessness conditions.

Ampoule 3 temperature is  $700^{\circ}\text{C}$  which ensures aluminium powder melting. Ampoule 1 maximum temperature is being maintained for 1 hour. The duration of the experiment from cartridges loading into the furnace to their extraction is 10 hours.

To investigate weightlessness effect during "Furnace System" experiment the USSR and USA scientists will conduct simulation experiments using the USA flight furnace in MSC prior to the Soyuz/Apollo joint mission.

Identical simulation experiments are performed in the Institute of Metallurgy of the Academy of Sciences of the USSR.

The above mentioned materials fabricated in ground conditions will be used to perform the entire program of scientific researches.

The results obtained will be further utilized during postflight analysis of metal and semiconducting materials fabricated under weightlessness conditions.

Thus, successful implementation of Furnace System program will allow to found the basis of future production technology to fabricate materials on space orbital plant-stations.

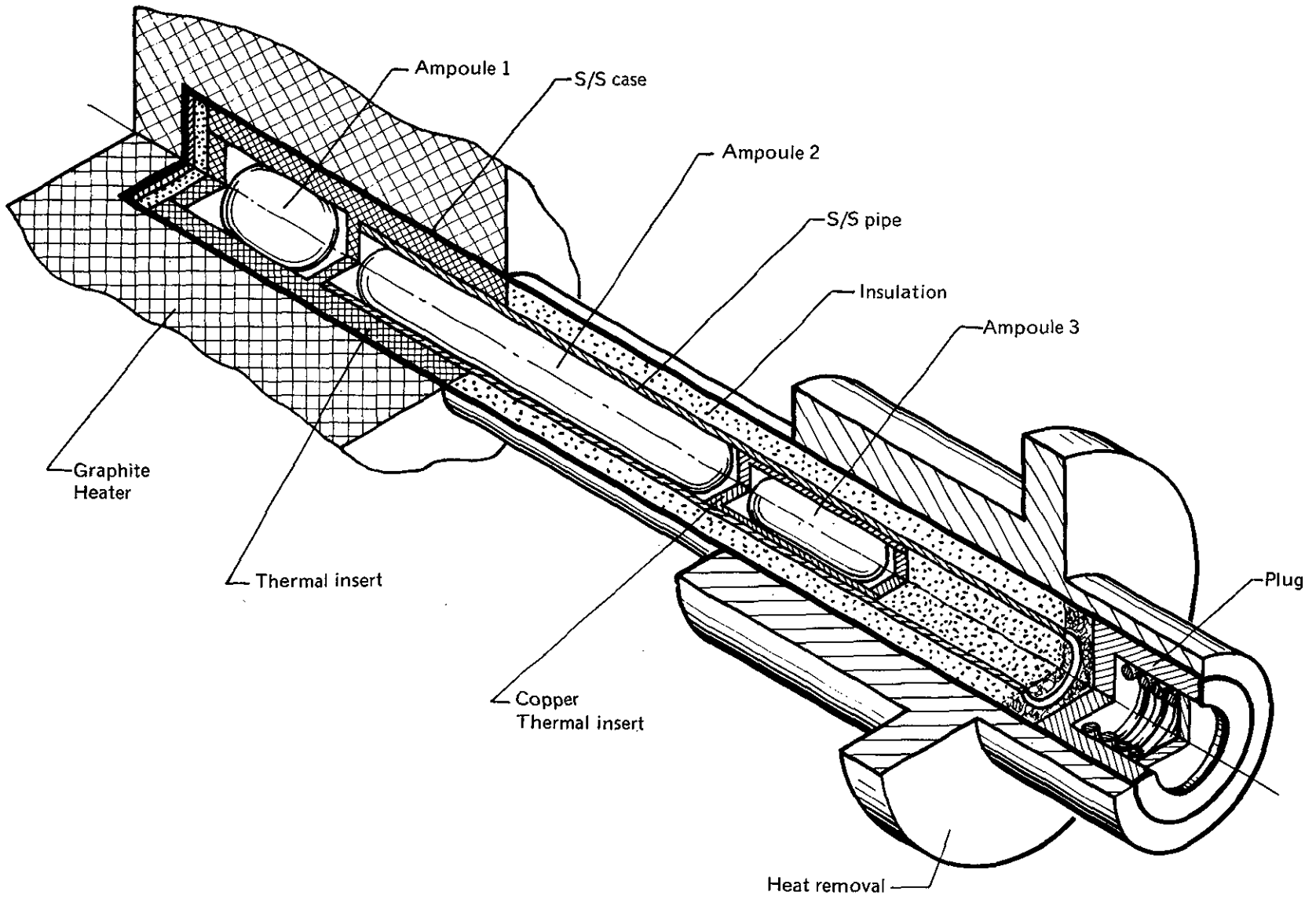


FIGURE 5.3 MULTIPURPOSE FURNACE EXPERIMENT CARTRIDGE



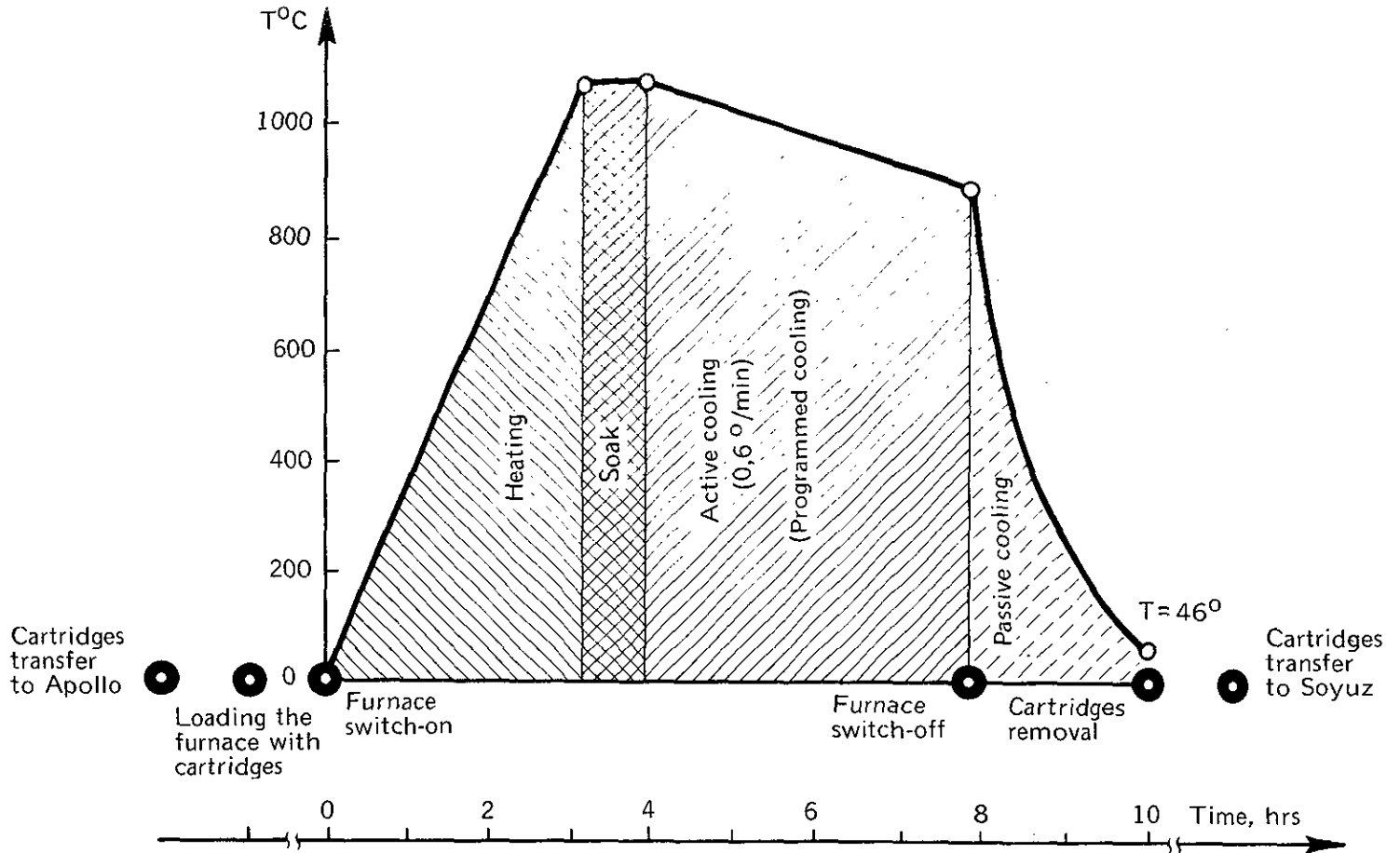


FIGURE 5.4 FURNACE EXPERIMENT DIAGRAM

## 6.0 TELEVISION PLAN

Onboard (using the Soyuz TV cameras) and ground based television transmissions are planned to inform public on the progress of the Soyuz and Apollo spacecraft joint flight.

### 6.1 Onboard television

Onboard television transmission will be carried out in accordance with the planned sequence of scenes to show activities of the crew:

- preparation for and performance of docking of the Soyuz and Apollo spacecraft;
- intervehicular transfer operations;
- joint activities (experiments, conversations etc.);
- docking/undocking tests;
- preparation for and undocking of the Soyuz and Apollo spacecraft.

During the Soyuz and Apollo spacecraft joint flight (from 48 hours GET through 108 hours GET) 23 onboard television transmissions are scheduled to be carried out, 4 being transmitted from the Apollo spacecraft.

The following TV cameras of the Soyuz spacecraft are used for onboard television:

- portable color TV camera of the Orbital Module (TK-1);
- fixed black-and-white TV camera of the Descent Vehicle (TK-2);
- portable colour TV camera to be used in the Soyuz and Apollo spacecraft (TK-3);

- external black-and-white TV camera (TK-4).

Control of the TV cameras (TK-1, TK-3 and TK-4) is provided via command radio link (GRL) and using the command-warning device (CWD). Control of TK-2 camera is provided via GRL only.

List, contents and times for the USSR onboard television transmissions are given in Table 7.1.

## 6.2. Ground based television

List, contents and time for the USSR ground based television transmissions TBD.

Table 7.1

THE USSR ONBOARD TELEVISION TRANSMISSIONS DURING THE SOYUZ AND APOLLO  
SPACECRAFT JOINT FLIGHT

| Step | Revo-<br>lution | Ground<br>elapsed<br>time<br>hrs:min | Index  | Scene   | Place,<br>TV camera    | TV trans-<br>mission<br>duration,<br>min | Contents  |
|------|-----------------|--------------------------------------|--------|---|------------------------|--|---|
| 1    | 2               | 3                                    | 4      | 5   | 6                      | 7  | 8   |
| 1.   | 34              | 48:50<br>48:56                       | TV-5   | Soyuz crew scheduled activities.                                | DV (TK-2)              | 9 min                                    | MCC comments on crew activity.  |
| 2.   | 35              | 50:23<br>50:29                       | TV-5.1 | Soyuz systems familiarization.                                  | DV (TK-2)              | 8 min                                    | SC and FE comments on Soyuz spacecraft systems.                               |
| 3.   | 36              | 51:56                                | TV-3   | General view of Apollo. Soyuz crew comments on docking process. | OM (TK-4)<br>DV (TK-2) | 9 min                                    | MCC comments on docking.<br>SC report on Apollo and Soyuz spacecraft docking. |
| 4.   | 37              | 53:29                                | TV-9   | Soyuz crew preparation for meeting.                             | OM (TK-1)              | 5 min                                    | SC and FE comments on meeting preparation                                     |

| 1  | 2  | 3     | 4       | 5  | 6         | 7     | 8   |
|----|----|-------|---------|--|-----------|-------|---|
| 5. | 38 | 55:02 | TV-9.1  | Hatch 3 opening. Meeting of crews with OM of the Soyuz spacecraft. | OM (TK-3) | 4 min | SC comments on hatch 3 opening and AC and DP transfer to OM. Greetings. |
| 6. | 47 | 68:12 | TV-9.2  | Soyuz crew activity after the first transfer. Eat period.          | OM (TK-3) | 8 min | Crewmen conversation around the table.                                  |
| 7. | 48 | 69:34 | TV-10   | Hatch 4 opening to initiate the second transfer.                   | OM (TK-3) | 3 min | SC comments on transfer preparation.                                    |
| 8. | 48 | 69:45 | TV-10.1 | SC transfers to Apollo.  | OM (TK-1) | 5 min | MCC comments on crew activity and SC transfer to DM.                    |
| 9. | 49 | 71:05 | TV-10.2 | Joint activities in Apollo during the second transfer.             | OM (TK-3) | 5 min | Familiarization with the Apollo CM systems.                             |

| 1   | 2  | 3              | 4       | 5  | 6         | 7              | 8  |
|-----|----|----------------|---------|--|-----------|----------------|--|
| 10. | 49 | 71:17          | TV-10.3 | Joint activities in Soyuz during the second transfer                 | OM (TK-1) | 5 min          | Familiarization of DP with the Soyuz systems                           |
| 11. | 50 | 72:33<br>72:38 | TV-10.4 | Joint activities in Apollo during the second transfer                | CM (TK-1) | 4 min<br>5 min | FE comments on the Earth observation                                   |
| 12. | 51 | 74:06<br>74:11 | TV-10.5 | Joint activities in Soyuz during the second transfer                 | OM (TK-1) | 4 min<br>4 min | "Mixed" crew comments. Conversation at table. Report on the space food |
| 13. | 52 | 75:39          | TV-11   | Crewmen activity in Soyuz during the third transfer. Hatch 4 opening | OM (TK-1) | 4 min          | MCC comments on crewmen activities                                     |
| 14. | 52 | 75:43          | TV-11.1 | Crew joint activity in Apollo during the third transfer              | DM (TK-3) | 5 min          | MCC comments on the SC transfer from DM to the Soyuz OM                |

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| 1   | 2  | 3              | 4       | 5   | 6                      | 7              | 8  |
|-----|----|----------------|---------|---|------------------------|----------------|--|
| 15. | 53 | 77:11          | TV-11.2 | Joint activities in Apol-10 during the third transfer | CM (TK-3)              | 5 min          | Joint press-conference of mixed crew in CM                 |
| 16. | 54 | 78:44          | TV-11.3 | Crewmen activities in Soyuz during the third transfer | OM (TK-1)              | 3 min          | Exchange of souvenir emblems and tree seeds.               |
| 17. | 63 | 91-54          | TV-12   | Soyuz crew activities after the fourth transfer       | OM (TK-1)              | 7 min          | MCC comments on completion of the crew program. Eat period |
| 18. | 64 | 93:15<br>93:27 | TV-14   | Soyuz nominal activities. Soyuz system check out      | DV (TK-1)              | 5 min<br>4 min | MCC comments on completion of the crew program             |
| 19. | 65 | 94:47<br>94:59 | TV-14.1 | Soyuz crew preparation for undocking                  | OM (TK-1)<br>DV (TK-2) | 4 min<br>5 min | MCC comments on docking preparation                        |
| 20. | 66 | 96:15<br>96:21 | TV-14.2 | Redocking   | OM (TK-4)              | 9 min          | MCC comments on redocking and APDS operation               |

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 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8  
 -----

|     |    |                |         |  |           |                |   |
|-----|----|----------------|---------|--|-----------|----------------|---|
| 21. | 68 | 99:21<br>99:26 | TV-15.1 | Cosmonauts report on re-<br>sults of the second un-<br>docking | DV (TK-2) | 4 min<br>4 min | SC and FE comments on re-<br>sults of the second un-<br>docking               |
| 22. | 69 | 100:53         | TV-18   | Cosmonauts activities<br>after undocking                       | DV (TK-2) | 5 min          | SC comments on completion<br>of the program                                   |
| 23. | 70 | 100:26         | TV-18   | Cosmonauts activities<br>after undocking                       | DV (TK-2) | 3 min          | FE comments on ULTRAVIOLET<br>ABSORPTION experiment per-<br>formed by Apollo. |



7.0 FLIGHT CONTROL. MAIN SUPPORTS: PURPOSE, FUNCTIONS AND INTERACTION

7.1 Flight control  
Control criteria

During the joint flight preparation the two sides agreed that the USSR mission control center (MCC-M) should control the Soyuz flight and the US mission control center (MCC-H) should control the Apollo flight, and that sufficient number of communications lines be provided between the MCC-H and MCC-M to coordinate joint activities of the centers.

Maximum flight safety is the main criterion of the joint flight control. Also, a number of organization criteria as a base of joint flight control implementation were developed.

Each MCC controls joint flight in accordance with mutually developed and agreed to documentation, and effective crew joint activity coordination is provided.

The Flight Directors control the joint flight and coordinate MCC activities. Correctness of decisions made in the course of flight control is the Flight Director responsibility.

Each country appoints a team of specialists to work at the other country MCC and to provide the required consultations for that country Flight Director.

Responsibility Assignment

Responsibility assignment in nominal and contingency situation was agreed upon.

The Soyuz flight control is the USSR MCC responsibility. The Apollo flight control is the US MCC responsibility.

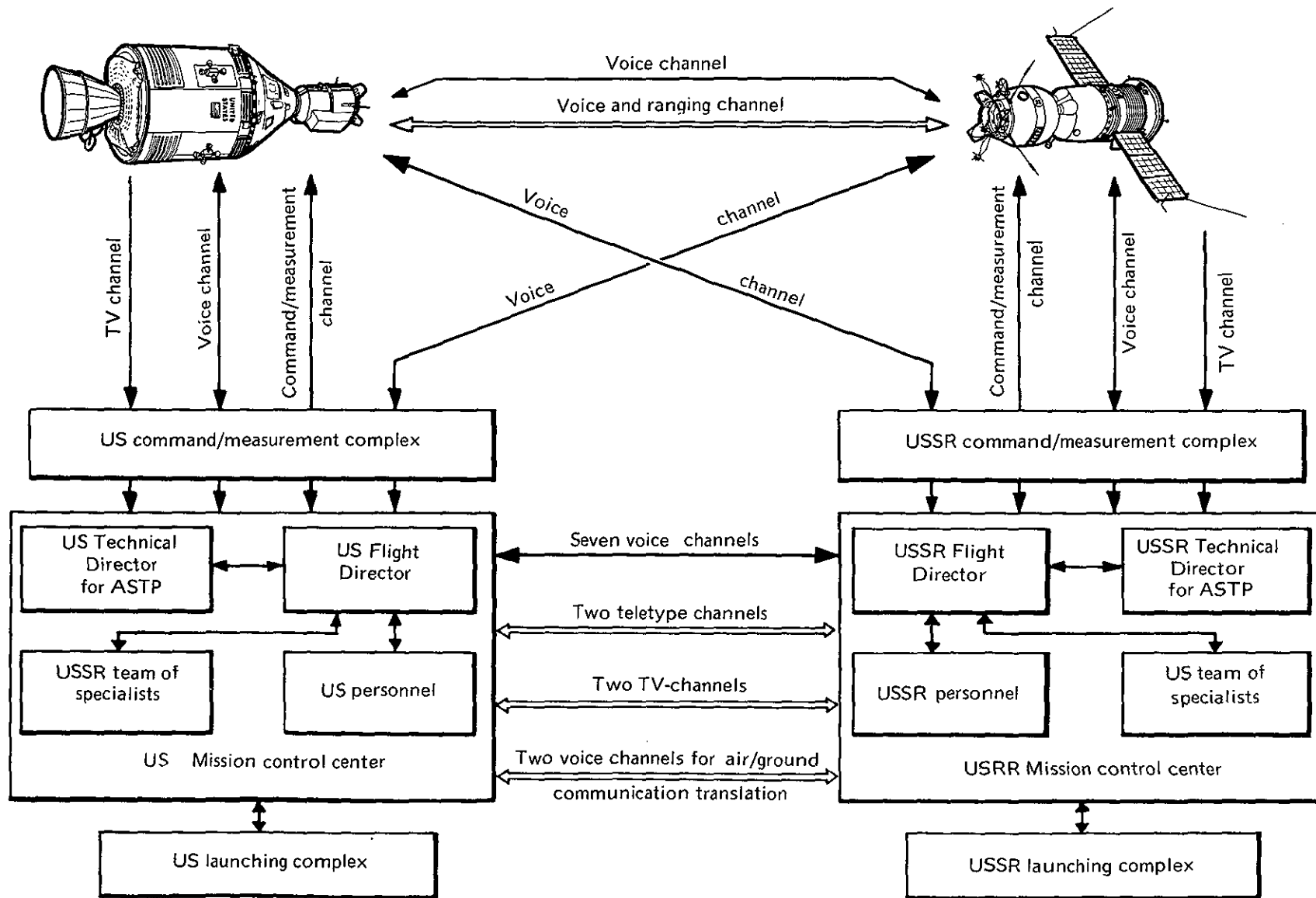


FIGURE 7.1 APOLLO/SOYUZ JOINT FLIGHT CONTROL SCHEMATIC

In accordance with the main flight control criterion, in case of a contingency in either spacecraft, the MCC which learns of the contingency first should immediately inform the other MCC and take actions to ensure the crew safety. If either crew finds out a contingency and no communications line to either MCC is available, the spacecraft commanders agree upon their action and come to a decision to proceed with the mission program.

#### Information exchange

Information exchange between the two MCCs is accomplished via the following communications lines: voice, TV, teletype and facsimile.

Command/program, trajectory, telemetry and TV information is exchanged between the MCCs during the flight. Transmission of schematics, facsimile and other graphic data is provided. A figure 7.1 below is a schematic of communications lines between the MCCs and the two spacecraft.

If need be, either MCC can communicate with its spacecraft flying over the other side ground station after the communication is agreed upon with the other side. Voice link can be provided either by remote keying from the MCC or through a designated specialist in the other MCC after permission is granted.

Also, the two sides agreed to exchange air/ground voice communication records.

#### 7.2 Mission control center (MCC)

##### Purpose, personnel and facilities, MCC

Mission control center functions to control manned space-

craft and automatic vehicles of "Moon", "Venus" and "Mars" type. Also, the flight control is supported by the USSR ground stations such as Djusali, Evpatoria, Ussuriysk, Ulhan-Ude, Kolpashevo, Tbilisi, Petropavlovsk-Kamchatskiy and research ships of the USSR Academy of Sciences in the Atlantic Ocean water areas and computation centers of the USSR Academy of Sciences.

The MCC responsibilities during the flight are as follows:

- collect, process and analyze the information (telemetry, trajectory and TV) arriving from the ground stations and research ships through ground and satellite communication links;
- update, change, if required, the flight program and implement this program;
- practically direct the activities of the ground tracking stations and scientific research ships of the Academy of Science;
- communicate with the computation center to provide the measurement data processing reliability;
- interact with the mockup and simulator setups and consoles;
- interact with the search-and-rescue complex.

The mission control center personnel includes:

- managers and cognizant specialists (whose stations are in the control room);
- USA consultative team (a room near the control room);
- support teams (whose stations are in the MCC building and who provide the control room with all the necessary information and preliminary proposals to control the flight).

The mission control center involves:

- computer complex;
- TV-equipment that provides reception and indication of TV-information transmitted from the USSR space launch area and the spacecraft, and also, indication of telemetry data and support team information on individual display facilities;
- voice communication equipment that provides the MCC personnel with all the necessary internal and external communication links;
- display facilities for individual and collective use to display all the necessary information to control the flight.

Communication lines between the MCC and the Moscow TV centers are provided.

#### Control room

The flight control is accomplished in the control room. The personnel activities in the control room are directed by the Shift Flight Director.

The following people man their stations in the control room:

- Shift Flight Director;
- cognizant specialists responsible for the primary spacecraft systems;
- cognizant specialist responsible for ground tracking station network normal functioning;
- cognizant specialist responsible for flight program time line working out;

- cognizant specialist responsible for complex analysis of onboard system operation;
- operator-cosmonaut who performs voice communication events with the crew;
- Project Technical Director representative;
- trajectory specialist;
- cognizant specialist responsible for scientific experiments;
- medical officer responsible for the crew-medical examination;
- MCC Shift Director and cognizant specialists responsible for the MCC primary systems (communications, information/computer complex, information display systems etc.).

All the specialists' stations are equipped with standard panels, data display facilities for collective and individual use, and communication facilities for the specialists to directly communicate with each other, Shift Director and support team outside the control room.

The personnel works in three 12-hour shifts with about an hour overlap for taking over-procedure. During the flight the take over procedure is performed without causing any delay in flight procedures.

#### Control room functions during the flight

The mission control center takes over the spacecraft control from the launching complex immediately after the spacecraft separation from the launch vehicle third stage.

Up to this time the control room personnel monitor onboard system operation via telemetry channels and observe the crew acti-

vities by TV-communication link and listen to the crew/launch control team voice exchange.

The central screen displays launch vehicle progress throughout the period of orbit insertion.

Following the spacecraft separation from the launch vehicle, the control room personnel monitor, via telemetry channels, the spacecraft antenna and solar battery deployment, establish communications lines to the spacecraft and start the onboard system operation checkout.

The cycle of operation described below is followed.

When the spacecraft reaches the ground station AOS (acquisition of signal) (the spacecraft progress is displayed on the central screen), transmission of command to the spacecraft is started in accordance with the flight program. The personnel in the control room monitor the command transmission and reception onboard the spacecraft. The appropriate onboard systems are switched on. The ground stations start reception and retransmission to the MCC of all the telemetry and trajectory information and also TV-retransmission from the spacecraft. The telemetry and trajectory information is automatically processed by the MCC computers and displayed in the control room at the rate it is being received.

Cognizant system specialists thoroughly analyse the telemetry information, assess each onboard system status and operation, and present the assessment results to the cognizant specialist responsible for the system complex analysis. Cognizant system specialists can communicate with the support team whose stations are outside the control room, and consult the latter, if required, or get additional information on the onboard system operation.

In case of deviations from the normal modes of onboard

system operation, the complex analysis specialist analyses the effect of the failure on each system, prepares his proposals to eliminate the failures and correct the scheduled modes of onboard system operation, and informs the Shift Flight Director of these proposals.

The medical officer responsible for the crew medical examination thoroughly analyses the biotelemetric data, evaluates the crew physical condition and informs the Shift Flight Director of the results.

As trajectory information is processed and orbit parameters determined by the computers, the trajectory data are automatically displayed on the alphanumeric board in the control room.

The trajectory specialist in the control room can communicate with the trajectory support team.

In flight the operator-cosmonaut performs voice exchange with the crew.

The specialist responsible for the ground station network monitors the station operation, informs the Shift Flight Director if deviations from the scheduled program are observed, and takes appropriate action to eliminate the deviations. He can directly communicate with the ground station personnel.

The Shift MCC Director monitors the MCC support teams activities and also informs the Shift Flight Director of any deviation, and takes appropriate action to eliminate the deviations.

The Shift Flight Director summarizes all the information and comes to a decision with regard to the progress of the flight.

If no deviations in the ground and onboard systems operation were observed, permission is released to proceed with the nominal program.



If program correction is required, this is accomplished by the specialist responsible for the program time-line.

Corrective actions can be taken during both the current and the subsequent events. The spacecraft model and the cosmonaut complex simulator can be utilized, if required, for failure identification and corrective action verification.

The worked out decisions are implemented by MCC transmitting radio commands to onboard systems and radio message to the crew.

During Apollo/Soyuz joint flight a consultative team of US specialists will support the flight from the USSR mission control center by providing (1) consultations for the USSR Flight Director on technical questions pertinent to the US spacecraft and (2) communication with the Apollo crew in the USSR ground station AOS, if required.

The consultative team is stationed in a special room (near the control room) equipped with standard panels and facilities, and provided with all the necessary data pertinent to the Soyuz spacecraft.

The US specialists in the MCC-M can communicate with the MCC-H at any time through voice and teletype channels or transmit/receive the necessary data by facsimile.

#### The control room support teams

Besides the specialists in the control room there are support teams in the MCC.

The specialists who support the control room activities work in separate rooms equipped with standard panels similar to those in the control room.

The support team responsibilities are as follows:

- provide information and computation data for the personnel in the control room to use it as a base in making decisions with regard to the flight program;
- consult the specialists in the control room and help them in analyzing the onboard system operation;
- provide implementation of decisions made by the Shift Flight Director;
- control the MCC facilities operation.

The support teams include:

The spacecraft onboard system specialists

- prepare and provide display of all the necessary additional information about onboard systems for specialists in the control room;
- consult the control room specialists and assist them in onboard system operation analysis;
- provide failure identification on the spacecraft model, if required;
- systematize the telemetry data processing results;
- change telemetry data processing computer program, if required;

Specialists responsible for flight program planning

- prepare changes in the flight program, if required, based on onboard system operation analysis results and the Shift Flight Director decisions;
- work out commands transmission plan for onboard systems and radio messages for the crew;
- provide and display the necessary information for the specialist in the control room responsible for the flight program working out;

### Trajectory specialists

- provide the necessary trajectory computation data in orbit determination, scientific experiments, AOS, the spacecraft coming into and going out of the shadow and the spacecraft maneuvers, and these data display;

### Air/ground communication specialists

- provide the MCC/spacecraft continuous communications via ground stations;
- provide voice channel keying from one ground station to another as the spacecraft passes them over;
- provide record of voice exchange with the crew;
- provide ground/air voice communication line for the US consultative team, if required;

### Ground station network operation coordination specialists

- provide information on the ground station operation for the specialist responsible for command/measurement complex in the control room;
- coordinate the ground station operation in accordance with the program;
- insert changes into the ground station operation program, if required;
- send commands to onboard systems through ground stations;

### MCC-M/MCC-H communication specialists

- provide all center-to-center communication lines proper functioning, and the required communication lines keying according to the established list of priority, if any channels fail;

### Search and Rescue Facilities Representatives

- communicate with SRF management;
- provide information on search status for Flight Director and display facilities.

The control room support teams work in two 13-hour shifts. The total number of the flight control people is 100.

### MCC Instrumentation/Computer Complex

The instrumentation/computer complex includes the following:

Computer Complex processes all numerical information in accordance with control tasks.

Primary, auxiliary, and special computers function in real time. The usual procedure is to use two primary computers for current center problems, the other two standing by. Each of the primary computers can provide processing of all of the TIM and trajectory data.

Processing results are routed to facilities of individual and collective use and to those of control. Only one of the computers is operative at a time; in case it fails the other computer takes over.

TV-equipment provides several TV-channels between the MCC and the country communication centers. In the MCC TV-information is routed to the display facilities and video tape recorders.

Recorded TV information can be fed into the display facilities. Flows of TIM information are routed from the control and distribution equipment output to the computer complex through the monitoring and conversion equipment.

Voice communication equipment provides the MCC with hundreds of voice and TLG communication lines to support the flight control.

Some of voice communication lines provide numerical data exchange between the MCC and ground stations, launch pad, simulation facilities, backup control centers and other users.

Other voice communication lines provide efficient command communication between the MCC personnel and the crews, ground stations and other facilities supporting flight control.

Voice communication lines connect the MCC-H and the MCC-M (eleven voice communication lines, two of these having both voice and facsimile capabilities; two teletype communication lines and two TV-channels).

The primary display facilities for individual use are the personnel station monitors of 625 and 1125 standard.

Monitors of two types are used to display ordinary TV pictures (625 lines) and documents requiring better image sharpness and higher resolution (1125 lines).

Display facilities in the control room include:

- alphanumeric display of trajectory information processing results, most important information on the flight plan and this plan progress, reference data, information from the timing system; the alphanumeric display is controlled by the computer complex with capability of manual data input;
- optical projectors to display in large scale screens maps the spacecraft trajectories and positions, ground station location and AOS, the vehicle prelaunch preparation program and that of injecting the vehicle into a satellite orbit in form of graphs and tables;

- large scale TV-projectors to display live transmission from the launch site and spacecraft, the spacecraft status and crew-condition analysis results, most important reference data on the flight program.

Also, installed in the MCC are:

- uplink command transmission remote system with capability of transmitting commands through ground stations;
- display facilities of individual use (displays) which provide efficient interaction of the specialists and the computer complex;
- teletype-writers to exchange data with the ground stations and other organizations.

### 7.3 MCC Personnel Training

The MCC personnel performs training sequence during the spacecraft flight preparation. In the training use is made of simulators, the spacecraft physical/mathematical model, equipment of the ground stations, the USSR computer center and scientific research stations. Participating in the training are the spacecraft crews and the ground station personnel.

During the training the flight program is practised in real time and also the MCC interaction with the ground stations and the computer centers of the USSR Academy of Science. Potential contingencies onboard the spacecraft and at the ground support facilities are considered during the training as well as efficient ways out of these contingencies - with the crew safety-provided.

During preparation for the joint Apollo/Soyuz flight it

is necessary for the MCC personnel, the Soyuz crews, the mock-up and simulator complex and the ground support complex to perform additional joint training sequence. Objectives of these additional trainings are as follows:

- familiarization of the USSR and US specialists with the USSR and US MCCs and these MCCs peculiar features;
- examination by the USSR and US specialists of the Soyuz and Apollo systems and these systems functioning during the joint flight;
- all the communications lines functioning checkout, the MCC-M/MCC-H information exchange procedure checkout;
- the MCCs operation cyclogram training;
- training in finding ways out of potential contingencies introduced by the flight trainers with the crew safety provided.

The training is performed under conditions very close to those of real flight.

## 8.0 CREWS TRAINING

The Soyuz crewmen training consisted of the crewmen self-dependent training and of the joint Soviet and American crewmen training.

Soyuz crewmen self-dependent training included: theory, flight, medical examination and physical training and also simulator training and practical course.

The purpose of Soyuz crewmen theoretical training was to study:

- Soyuz spacecraft design, power supply system and configuration;
- equipment structure and arrangement;
- spacecraft instruments and systems;
- flight scheme, ballistics and program;
- scientific and photography equipment;
- manual and automatic systems modes;
- space navigation theory.

The purpose of flight training was to develop cosmonauts professional qualities in conditions maximally approximating those of space flight.

Flight training included: flights using trainer aeroplanes and test-bed aircraft to train activities under short-termed weightlessness conditions.

Crewmen training of practical knowledge to control Soyuz system was conducted using Soyuz complex simulator.

Spacecraft motion simulation during visual observation was provided by electronic and optical devices.



The complex simulator comprises Soyuz descent vehicle and Soyuz orbital module.

During practical studies crewmen tried on flight suits and mastered their work stations in mock-ups and in the spacecraft, and also operated with scientific and photography equipment.

To purpose of medical training was to strengthen cosmonauts' resistance to some space factors (g-load, isolation, environment limited area, gas atmosphere and so on).

This included centrifugal and vestibular training, altitude chamber training with pressure and gas atmosphere increased and reduced similar to actual flight modes, as well as periodical medical examinations.

Physical training was aimed at maintaining cosmonauts' excellent state and physical readiness through generally strengthening and special exercises.

Crewmen joint training included:

- familiarization with Soyuz and Apollo systems ensuring the joint mission;
- study of documents on crews joint activities;
- ~~DM~~ mock-up contingencies training;
- crew interaction training in Soyuz and Apollo mock-ups;
- testing of radio communication between Soyuz and Apollo crews;
- crews joint training in Soyuz complex simulator (Gagarin Cosmonauts' Training Centre, USSR);
- crews joint training in Apollo mock-up and simulator in Johnson Space Centre (USA);

- crews familiarization with Apollo spacecraft and with two Soyuz spacecraft;
- cosmonauts' study of the English language and astronauts' study of Russian as well as study of American and Soviet space terminology.

Cosmonauts and astronauts joint training was carried out both in the USSR and the USA. The Apollo spacecraft and its systems were theoretically studied by cosmonauts in JSC (USA) in July 1973.

The Soyuz spacecraft was theoretically studied by astronauts in Gagarin Cosmonauts' Training Centre in November 1973.

Crewmen joint training in Soyuz mock-up and complex simulator was carried out in Gagarin Cosmonauts' Training Centre (USSR) in July 1974 and May 1975.

Crewmen joint training in Apollo mock-up and simulator was carried out in JSC (USA) in September 1974 and February 1975.

In February 1975 the crewmen were familiarized with Apollo spacecraft and in May - with two Soyuz spacecraft.

9. INFORMATION  
ON THE ASTP CREWS AND DIRECTORS

9.1. Information on the Soyuz crews

The First Crew.

Commander - Leonov Alexey Arkhipovich.

Colonel Alexey Arkhipovich Leonov, USSR space-pilot, Hero of the Soviet Union was born in 1934 in village of Listvyanka, Kemerovo region.

After World War II the Leonovs moved to the city of Kaliningrad. In 1953 a Komsomol member Leonov A.A. entered an aviation school. He graduated from it with an honours diploma and became a professional military pilot.

In 1957 he joined the Communist Party of the Soviet Union. The Headquarters highly appreciate Alexey Arkhipovich's skill, self-control, discipline. He is a well-trained parachutist - performed more than 100 parachute jumps of varying degrees of difficulty.

In 1960 with the first group of Soviet cosmonauts he began training for a space flight.

On March 18, 1965 he made a space flight in Voskhod-2 spacecraft (with Pavel Belyayev as the commander). On that flight Leonov went outside the ship. His walk into open space opened a new chapter in the history of space exploration.

All the subsequent years the cosmonaut continued his studies and training. He participated in preparation for all Soviet space flights. In 1968 he graduated from the Zhykovskiy Air Force Academy.

A.A. Leonov is a member of the Young Communist League Central Committee (YCLCC), and a deputy to Moscow Regional Soviet. He is a vice-president of the USSR-Italy Friendship Society, the Chairman of the Constituent Council of the Press and News Agency. He is an honorary citizen of towns: Kemerovo, Kaliningrad, Vologda, Kremenchug, Malchik, Belgorod, Drogobych, Sochi, Chuguev, Termez, Kapsukas, Sofia (PRB),

Perm, Ust-na-Labe (Czechoslovakia), Altenburg (GDR), Houston (USA).

A.A. Leonov has a passion for painting. He is a member of USSR painter's union. His paintings were exhibited in Moscow, Orel, Simferopol, Bratislava, Prague, Ottawa, Helsinki and in the Bjenal annual show. He is also keen in filming, hunting, water skiing, track and field athletics, parachute sport.

Rewards: Hero of the Soviet Union,

Hero of the DRV,

Hero of the PRB,

18 orders and medals, including 8 orders and medals of other countries and:

Tsiolkovski Gold Medal, Great Gold Medal of FAI, 1st degree diploma,

Great Gold Medal of Ch.SSR Academy of Sciences (For Services to Mankind).

Gold damask blade.

Leonov's wife, Svetlana Petrovna, graduated from a Teachers Institute, she is an editor. They have two daughters: Victoria, 13 and Oksana, 7.

Flight Engineer - Kubasov Valeriy Nikolaevich.

Valeriy Nikolaevich Kubasov, USSR space pilot, Hero of the Soviet Union was born in the town of Vyazniki, Vladimir region.

In 1952 Valeriy graduated from a secondary school with a silver medal and entered S. Ordzhonikidze Moscow Aviation Institute. After the graduation from the Institute Valeriy began working at a design bureau where he revealed comprehensive knowledge and aptitude for scientific research. In 1969 Kubasov received

candidate's degree in science. He is an author of a number of papers on computation of flight vehicle motion.

In 1966 V.Kubasov was named to cosmonaut corps. He underwent a comprehensive flight preparation program. In 1968 he joined the CPSU. In January 1969 V.Kubasov was cosmonaut Yeliseev's back up for Soyuz-4 and Soyuz-5 flight. In October, 1969 he was flight-engineer for the Soyuz-6 mission (the spacecraft commander - Georgiy Shonin). During the flight along with a number of other scientific experiments the first metal-welding experiment was conducted.

V.Kubasov is an honorary citizen of towns: Karaganda, Kaluga, Vladimir, Vyazniki, Houston.

Rewards: Hero of the Soviet Union,  
Tsiolkovskiy Gold Medal (USSR Academy of Science),  
medal "For valiant labour in commemoration of  
V.I. Lenin centenary",  
emblem "For active participation in Komsomol  
activities",  
Gold Medal of Yugoslavian Academy of Science,  
medal "For development of virgin lands", and a  
number of medals of other countries.

V.Kubasov has a passion for filming, hunting, fishing, skiing, water skiing.

Kubasov's wife, Lyudmila Ivanovna, graduated from Moscow Aviation Institute; she is an engineer at a machine-building plant. The Kubasovs have two children: Katya is 8 and Dima is 3.

The Second Crew.

Commander - Filipchenko Anatoliy Vasiljevich.

Colonel Anatoliy Vasiljevich Filipchenko, USSR space pilot, twice a Hero of the Soviet Union was born on February 26, 1928 in the village of Davydovka, Voronezh region.

He completed seven years of school, worked as a turner, studied at Air Force School. In 1947 he entered the Chuguevo Higher Pilot Training School; he graduated from it with an honours diploma. In 1951 A. Filipchenko was commissioned in Air Force. Prior to joining the cosmonauts corps A. Filipchenko had advanced from junior pilot up to senior inspector-pilot of a air division.

A. Filipchenko joined the CPSU in 1952.

In 1961 he graduated from the Air Force Red Banner Academy (now it is called the Gagarin Air Force Academy).

A. Filipchenko was named to cosmonaut corps in 1963. He continued to master his skill, piloted the supersonic planes and got the test-pilot proficiency. When preparing for the space flight A. Filipchenko studied thoroughly the theory and acquired practical skill for conducting scientific experiments. In January, 1969 he was Shatalov's back up for Soyuz-4 flight and in October, 1969 he was the commander for Soyuz-7 orbital flight. In June, 1970 A. Filipchenko was Nikolaev's back up for Soyuz-9 flight.

In December, 1974 A. Filipchenko with cosmonaut N. Rukavishnikov performed the orbital flight onboard Soyuz-16 as part of the preparation program for ASTP.

A. Filipchenko is an honorary citizen of towns: Karaganda, Kaluga, Sumy, Chita, Lipetsk, Ostrogozhsk, Davydovka, Arkalyk.

A. Filipchenko is an ardent sportsman and a shooter, he is fond of hunting and auto-tourism.

Rewards: two orders of Lenin,  
two medals "Gold Star",  
"Valor award",  
Order of the Banner with diamonds(HPR).  
Order "Star of the Republic, 5<sup>th</sup> degree(RPR),  
a number of Soviet medals and medals of other  
countries,  
FAI medal named after Gagarin.  
Tsiolkovski Gold Medal (USSR Academy of Science),  
Small Gold Medal of the ENEA.

The cosmonaut's wife Yelizaveta Alexandrovna is a housewife. They have two children: Alexander, 18, and Igor, 14.

Flight Engineer - Rukavishnikov Nickolay Nickolaevich.

The USSR cosmonaut, twice the Hero of the Soviet Union Nickolay Nickolaevich Rukavishnikov was born in 1932 in the town of Tomsk. After finishing school in 1951 he entered the Moscow Engineer-Physical Institute and graduated from it successfully in 1957. Results of Rukavishnikov's diploma papers were published in a scientific magazine.

After the Institute Rukavishnikov works at a machine-building plant. He works at the design, development and fabrication of spacecraft automatic and manual control systems.

In January 1967 Rukavishnikov was named to cosmonaut corps. In April 1971 he performed his first space flight as a reserch engineer during Soyuz-10 mission(commander Shatalov V.A, flight engineer Yeliseev A.S).



Rukavishnikov N.N. is a CPSU member from 1970.

In December 1974 Nickolay Nickolaevich Rukavishnikov participated in the Soyuz-16 mission, which was the ASTP precursor test flight.

Rukavishnikov is an honorary citizen of towns: Tomsk, Karaganda, Kaluga, Arkalyc, Kayhtiy, Suche-Bator.

Rukavishnikov N.N. is an amateur radio operator and a good driver.

Rewards: two orders of Lenin, two "Gold Star" medals of Hero of the Soviet Union, Order of Suche-Bator, Gold Star of Hero of the MPR, Gold Medal of Tsiolkovskiy ( from the USSR Academy of Science), Minor gold medal of ENEA Medal "For valiant labour in honour of Lenin's centenary. Gold Medal of the Ukrania SSR Academy of Science and others.

He is also entered in the book of Honour of IGLCC.

His wife, Nina Vasilievna, works at a machine-building plant. The Rukavishnikovs have a son Vladimir, born in 1965.

The Third Crew.

Commander - Džhanibekov Vladimir Alexandrovich.

Major Džhanibekov Vladimir Alexandrovich, the USSR cosmonaut, was born in 1942 in South-Kazakhstan region. After the war he and his parents moved to Tashkent. Having finished the Suvorov military school he entered the highaviation school in the town of Eysk in 1961.

In 1965 he got the diploma of pilot-engineer and stayed in the school as a pilot -instructor.

In 1970 Džhanibekov A.A. joined the CPSU. and was named to the cosmonaut corps.

Vladimir Alexandrovich is an amateur radio operator, and he has a passion for painting.

Rewards: the 20<sup>th</sup> Victory anniversary in the Great Patriotic War,  
the 50<sup>th</sup> anniversary of the USSR Armed Forces,  
for irreproachable service, III grade.

Džhanibekov's wife, Lilia Munirovna, has graduated from the Conservatoire and now she is a music teacher at school. The Džhanibekovs has two children: Inna, 5 years of age and Olga, who was born in 1974.

Flight Engineer - Andreev Boris Dmitrievich.

Cosmonaut Andreev Boris Dmitrievich was born in Moscow, 1940. After the school in 1968 he entered the Bauman High Technical school. When a student he took part in the activity of the student scientific-technical society, took English courses. After the High School beginning with 1965 he worked in a design bureau as an engineer, and

as a chief of the scientific-technical information department.

In 1969 he joined the CPSU. In 1970 he was named to cosmonaut corps. Boris Dmitrievich is a good skier, bicycle-driver, he likes hiking. He is also a good car driver.

His wife, Tamara Vasilievna, has graduated from the Bauman High Technical School and as an engineer.

The Andreevs have two children: Dima was born in 1969, Tanya - in 1972.

### The Fourth Crew

Commander - Romanenko Yuriy Victorovich.

Major Yuriy Victorovich Romanenko was born in 1944 in the village of Kaltubanovskay, Buzulukskiy district of Orenburg region. Soon his parents moved to Kaliningrad. After finishing school Yuriy worked as a fitter for a year. In 1962 he became a student of the High military aviation school in Chernigov. Yuriy graduated from the school with an honours diploma and stayed in the school as a pilot-instructor.

In February, 1965 Romanenko joined the CPSU.

In 1970 he was named to cosmonaut corps. In December, 1974 he was a backup-cosmonaut for Philipchenko A.V. during preparation for Soyuz-16 mission.

Y.V. Romanenko has a passion for underwater hunting and painting, he is also a good car driver.

Rewards: The Victory 20<sup>th</sup> anniversary in the Great Patriotic War.

" The 50<sup>th</sup> anniversary of the USSR Armed Forces "

"For irreproachable service, III degree".

Romanenko's wife, Alevtina Ivanovna, is a music teacher. Their son, Roman, is 6 years of age.

Flight Engineer - Ivanchenkov Alexander Sergeevich.

Cosmonaut Alexander Sergeevich Ivanchenkov was born in 1940 in the town of Ivanteevka, Moscow region. His father volunteered for the front in the war first days and perished in 1942 nearby Rzhev. His mother died soon after the war. Alexander was brought up by his father's sister.

Having finished school with the gold medal in 1958 he entered the Moscow aviation school. When a student he acquired skills in spacecraft design, participating in the students' design bureau.

After he graduated from the Institute Alexander worked as an engineer in a design bureau. He works at the choice of spacecraft design parameters by computers.

In 1970 he was named to cosmonaut corps.

In 1972 he joined the Communist Party of the USSR.

In December, 1974 he was a back-up cosmonaut for N.N. Rukavishnikov during preparation for Soyuz-16 mission.

Alexander Sergeevich is fond of tourism, basketball, mountain skiing.

His wife, Rimma Alexandrovna, is a doctor in the First Moscow Medical Institute. Their daughter, Tanya, is 6 years old.

9.2 Information about USSR directors for ASTP, Organization Scheme

Joint coordinated activity of the Soviet and American specialists were required to provide the Soyuz/Apollo spacecraft compatibility, to prepare for and conduct the joint mission.

To fulfill the task both sides agreed upon the ASTP program management and planned the joint activities for the period up to 1975.

ASTP organization scheme, presented below, was adopted. The USSR and US working groups met in Moscow and Houston. At the times between meetings communication between the groups was provided via voice and teletype channels, or by mail.

The meetings of separate and all working groups (plenary meetings) were held regularly at agreed upon time.

ASTP ORGANIZATION SCHEME

Academy of  
Science, USSR  
Project Techni-  
cal Director

NASA, USA  
Project Techni-  
cal Director

General technical Direction.  
Agreements approval and accom-  
plishment, activities coordi-  
nation.

Working groups

Principle functions  
Mission model and operation  
plans

Working groups

Mission model  
Mission plan  
Mission control  
Communications between  
control centers

No.2

Guidance and control

No.2

Requirements for tracking sys-  
tems during guidance and ren-  
dezvous

Support provisions for dock-  
ing

Optics and orientation lights  
Control systems

No.3

Mechanical structure of the

No.3

Docking system

No.4

Communication and tracking  
provisions

No.4

Air-to-air and air-to-ground  
radio-voice communication

Ranging equipment spacecraft  
cable communication

No.5

Life support system and crew  
transfer

No.5

INFORMATION ON THE USSR MANAGEMENT FOR  
ASTP

Boris N.PETROV - Chairman, "Intercosmos" Council USSR  
Academy of Sciences

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B.N.Petrov was born in 1913. He is a Doctor of technical sciences, professor, academician - secretary of the Mechanics and control processes division of the USSR Academy of Sciences, Member of the Presidium of the USSR Academy of Sciences.

B.N.Petrov is a great scientist, founder of the automatic control of industrial objects and new technical objects.

B.N.Petrov was made a valuable contribution to the organization of the international cooperation in peaceful use and exploration of space.

Petrov's work received the international recognition. He is a Member of the Academy of Sciences in ChSSR, GDR, HNK, and NKB. Member of the International of Astronautics, Chairman of the Technical Committee (control in space) of the International Federation on automatic control.



Konstantin D.BUSHUYEV - USSR Technical Director for ASTP

Born 1914, in Cherten, Mosalsk district, Kaluga region. In 1941 he graduated from the Ordjonikidze Moscow Aviation School.

For practical works on applied dynamics and strength K.Bushuyev got a doctor's degree in science. In 1960 he became a corresponding member of the USSR Academy of Sciences.

K.Bushuyev has been presented numerous government awards: the Hero of Socialist Labour, government and Lenin prizes, two Orders of Lenin and Order of October Revolution for his contributions to the space exploration.

As the USSR Technical Director for ASTP he was responsible for the technical management of ASTP from the Soviet side.

Vladimir A. SHATALOV - Soviet Cosmonaut Training Leader

Shatalov was born in 1927 in the town of Petropavlovsk of the North-Kazakhstan region. He graduated from the Kachino Air Force School in 1949 and the Order of Red Banner Air Force Academy in 1956 (now the Yu. A. Gagarin Academy).

V. A. Shatalov flew the Soyuz-4 and Soyuz-8 spacecraft in 1969 and Soyuz-10 spacecraft in 1971.

He is the Soviet cosmonaut training leader since 1972. In 1972 V. A. Shatalov was conferred the title of Hero of the Soviet Union (twice). He is also rewarded with many Soviet and foreign orders and medals.

Alexey S. YELISEYEV - USSR Flight Director

Born 1934 in Zysdra, Kaluga region. In 1975 he graduated from the Bauman Moscow Higher Technical School. In 1969 he participated in Soyuz 5 and Soyuz 8 missions and in 1971 - in Soyuz 10 mission. In 1972 he earned a doctor's degree in science.

For his contributions to space exploration Yeliseyev was twice awarded the title of Hero of the Soviet Union and got Order of Lenin and other orders of the USSR and other countries.

Under his supervision the questions of joint mission control were agreed, the USSR MCC personnel training was performed.

Vladimir A. TIMCHENKO - Working Group 1 Chairman

Born 1931 in Porkhov, Pskov region. In 1955 he graduated from the Ordjonikidze Moscow Aviation School.

For his contributions to the space exploration he was awarded "Badge of Honour" order in 1961 and Order of Lenin - in 1971.

V. Timchenko is USSR Deputy Director for ASTP and Working group 1 chairman. In his capacity he was in charge of questions on the mission purpose and task definition, the Soyuz spacecraft modification program and mission trajectory support development.

Victor LEGOSTAEV - WORKING GROUP 2 CHAIRMAN

Born 1931 in Moscow. In 1955 he graduated from the Bauman Moscow Higher Technical School. In 1959 he defended his thesis and earned a candidate's degree in science. Since 1965 he is an assistant professor of the Moscow Physical Technical School.

For his contribution to the development of national economy Dr. Legostaev was awarded the Order of the Red Banner, the Gold Medal of NEAE (National Economy Achievements Exhibition) and the Medal for Valiant Labour presented to him on the occasion of the 100<sup>th</sup> anniversary of Lenin's birthday.

Under his supervision for ASTP there were developed procedures and conditions for spacecraft approach, and compatible equipment for spacecraft acquisition, guidance and approach. Dynamic calculations of the Soyuz control system during approach were performed, and conditions for these operations performance were determined.

Vladimir S. SYROMJATNIKOV - WORKING GROUP 3 CHAIRMAN

Born 1933 in Archangelsk. In 1956 he graduated from the Bauman Moscow Higher Technical School. In 1968 after defence of his thesis he earned a candidate's degree in science.

Under his supervision a principally new androgynous perihperal docking system (APDS) was developed to be used for Soyuz/Apollo docking

V. Syromjatnikov was responsible for fabrication and development of all DS units beginning with DS design phase up to its flight testings.

Boris V. NIKITIN - WORKING GROUP 4 CHAIRMAN

Born 1919 in Novosibirsk. In 1941 he graduated from the Moscow Communication Engineers' School.

For his contributions to the space exploration he was awarded Badge of Honour in 1961.

Under his supervision for ASTP radio communication network between the spacecraft and the ground was determined, radiocommunication and ranging systems compatibility testing were performed, spacecraft radio frequency compatibility was verified, the possibility of Soyuz/Apollo TV and audio coverage when crews' visiting the other spacecraft was provided, pyro devices safety testing was performed.

Ilja V.LAVROV - WORKING GROUP 5 CHAIRMAN

Born 1920 in Moscow. In 1949 he graduated from the Bauman Moscow Higher Technical School. For his contributions to the space exploration he was awarded Orders of Lenin, Badge of Honour, Space Exploration Medal of the USSR Academy of Science.

Under his supervision there were developed provisions for Docking System and Apollo radio set, installed in Soyuz, thermal mode; provisions and materials for equipment and cosmonauts' suits fire safety in pure O<sub>2</sub> environment, and life support system was updated to meet compatibility requirements.



10. REFERENCE INFORMATION

U S / U S S R S P A C E A G R E E M E N T

Text of the agreement on cooperation in space  
between the United States and the Union of So-  
viet Socialist Republics signed in Moscow on  
May 24, 1972:

AGREEMENT

Between the United States of America and the Union of Soviet Socialist Republics concerning cooperation in the exploration and use of outer space for peaceful purposes,

The United States of America and the Union of Soviet Socialist Republics,

Considering the role which the USA and the USSR play in the exploration and use of outer space for peaceful purposes,

Striving for a further expansion of cooperation between the USA and the USSR in the exploration and use of outer space for peaceful purposes,

Nothing the positive cooperation which the parties have already experienced in this area,

Desiring to make the results of scientific research gained from the exploration and use of outer space for peaceful purposes available for the benefit of the peoples of the two countries and of all peoples of the world,

Taking into consideration the provisions of the treaty on principles governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies, as well as the agreement on the rescue of astronauts, the return of astronauts, and the return of objects launched into outer space,

In accordance with the agreement between the United States of

America and the Union of Soviet Socialist Republics of exchanges and cooperation in scientific, technical, educational, cultural, and other fields, signed April 11, 1972, and in order to develop further the principles of mutually beneficial cooperation between the two countries:

Have agreed as follows:

A r t i c l e 1

The parties will develop cooperation in the fields of space meteorology: study of the natural environment: the exploration of near Earth space, the moon and the planets: and space biology and medicine: and in particular, will cooperate to take all appropriate measures to encourage and achieve the fulfillment of the "summary of results of discussions on space cooperation between the US National Aeronautics and Space Administration and the Academy of Sciences of the USSR" of January 21, 1971.

A r t i c l e 2

The parties will carry out such cooperation by means of mutual exchanges of scientific information and delegations, through meetings of scientists and specialists of both countries, and also in such other ways as may be mutually agreed. Joint working groups may be created for the development and implementation of appropriate programs of cooperation.

A r t i c l e 3

The parties have agreed to carry out projects for developing compatible rendezvous and docking systems of United States and Soviet manned spacecraft and stations, in order to enhance the safety of manned flight in space and to provide the opportunity for c o n-

d u c t i n g joint scientific experiments in the future. It is planned that the first experimental flight to test these systems be conducted during 1975, envisaging the docking of a US Apollo-type spacecraft and a Soviet Soyuz-type spacecraft with visits of astronauts in each other's spacecrafts. The implementation of these projects will be carried out on the basis of principles and procedures which will be developed in accordance with the summary of results of the meeting between representatives of the US National Aeronautics and Space Administration and the USSR Academy of Sciences on the question of developing compatible systems for rendezvous and docking of manned spacecraft and space stations of the USA and the USSR, dated April 6, 1972.

A r t i c l e 4

The parties will encourage international efforts to resolve problems of international law in the exploration and use of outer space for peaceful purposes with the aim of strengthening the legal order in space and further developing international space law and will cooperate in this field.

A r t i c l e 5

The parties may by mutual agreement determine other areas of cooperation in the exploration and use of outer space for peaceful purposes.

A r t i c l e 6

This agreement shall enter into force upon signature and shall remain in force for five years. It may be modified or extended by mutual agreement of the parties.

Done at Moscow on the 24th of May, 1972, in duplicate in the English and Russian languages, each equally authentic.

For the United States of America

Richard Nixon

For the Union of Soviet Socialist Republics

Aleksei N.Kosygin