annual report
to the
nasa
administrator
by the
aerospace safety
advisory panel

part I—apollo soyuz test project

section 2—summary of information developed in the panel's fact-finding activities

february 1975

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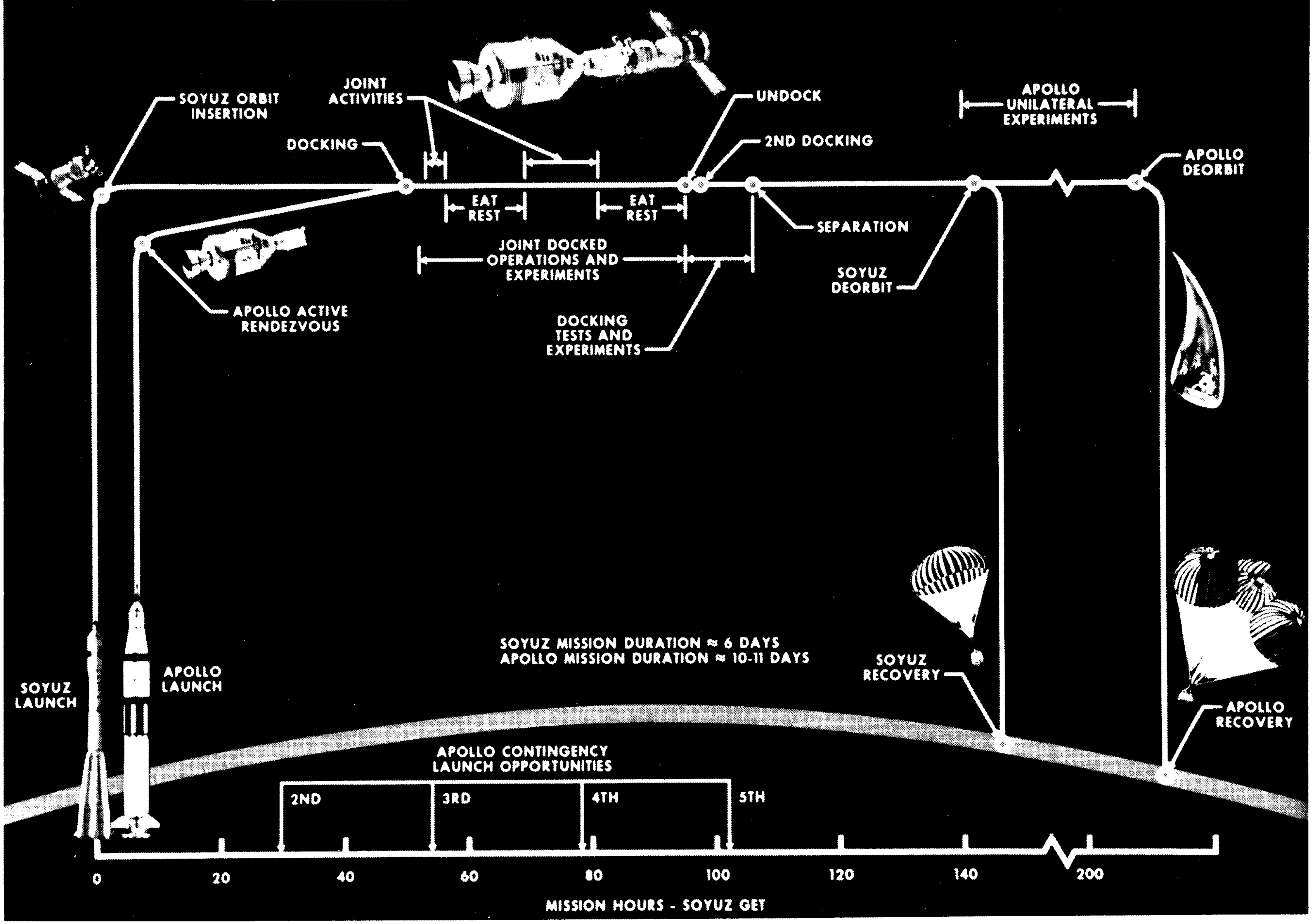
APOLLO SOYUZ TEST PROJECT MISSION PROFILE



ANNUAL REPORT TO THE NASA ADMINISTRATOR

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AEROSPACE SAFETY ADVISORY PANEL

PART I - APOLLO SOYUZ TEST PROJECT

Section 2 - Summary of Information Developed in the Panel's Fact-Finding Activities

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SECTION 2 - SUMMARY OF INFORMATION DEVELOPED IN THE PANEL'S FACT FINDING ACTIVITIES

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ABBREVIATIONS

ASTP	Apollo Soyuz Test Project
ATS-6	Applications Technology Satellite
CSM	Command and Service Modules
DCR	Design Certification Review
DM	Docking Module
DS	Docking System
DV	Descent Vehicle (Soyuz)
ECS	Environmental Control System
FMEA	Failure Mode and Effects Analysis
IED	Interacting Equipment Document
JSC	Johnson Space Center, Texas
KSC	Kennedy Space Center, Florida
LM	Lunar Module
LSS	Life Support System
OM	Orbital Module (Soyuz)
RCS	Reaction Control System
SCR	Spacecraft Compatibility Review
SLA	Spacecraft Adapter
SM	Service Module

1.0 INTRODUCTION

1.0 INTRODUCTION

Section I provides the Panel's observations and conclusions on ASTP based on its fact-finding activities to date. Attachment 1 to that section lists these activities and the topics covered. Attachment 2 includes Dr. Charles D. Harrington's observation on the joint docking tests in Moscow and the ASTP Program's response to his recommendation.

This section, Section II, provides a summary of the information developed during these fact-finding activities and in a review of the extensive documentation used in the program. The information from the various on-site visits has been consolidated and organized in the same outline as Section I. Such a summary of data is necessarily a compromise between comprehensiveness, detail, and brevity. It's intent is to provide the reader with an idea of what the Panel has reviewed and a description of the program at this point. Attachment 1 includes an example of recent Panel questions and the Program's response as an indication of the continuing dialogue.

2.1 APOLLO

2.1.1 MANAGEMENT

A. Technical Management System

The program management systems used in the design and production of the Apollo spacecraft and Saturn vehicles for this mission were essentially the same systems used to produce earlier successful Apollo and Skylab flight systems. The Panel has monitored the evolution of these systems over the years. Since they have been described in previous annual reports these systems are not discussed here. These technical management systems have been adapted for the engineering and manufacture of the new Docking Module, Docking System, and experiments as well as modifications to the basic Apollo Saturn hardware.

There is a management program for monitoring and evaluating storage and age-life effects. Implementation of this system provided a controlled benign storage environment and assured detailed continuing inspection of the flight hardware. In addition, there is a systematic program for the replacement of items approaching or beyond their shelf-life.

B. Personnel

The key NASA technical and management personnel bring the experience of both Apollo and Skylab to ASTP.

The number of contractor personnel has been reduced to fit the needs of the program. Where necessary contractor management has provided additional work in related areas to maintain the proficiency and morale of the people on this program.

C. Review Systems

The technical review system is as extensive as the one used on Apollo and Skylab.

The CSM, DM, DS, and launch vehicle have been through the Design Certification Review process (DCR). Part I of the DCR examined the design of new and modified elements. Part II examined the results of action items from Part I and the results of major qualification and certification tests.

In addition, management has held the following special reviews:

1. A board of experts reviewed the extent of qualification by analysis. This board examined the following subsystems: SLA truss, SM experiment doors and mechanisms, DM thermal blankets, DM structure, DM hatches and mechanisms, and DM oxygen and nitrogen tanks. The results of the review were presented at a Panel session as well as at the DCR.

2. An ASTP Engineering Review Board was established for a "fresh look." The Board was composed principally of senior engineering directors from Apollo and Skylab. They reviewed the new flight systems and their recommendations have been implemented as appropriate. This resulted from a recommendation by the Skylab I Investigation Board. Such a review increases management's confidence that experience from prior programs, including Skylab, has been used in this program.

2.1.2 BASIC APOLLO HARDWARE

A. CSM

The prime vehicle is CSM 111. It was built as an Apollo Block II spacecraft and was modified for ASTP. These modifications incorporporate subsequent improvements as well as changes required for this mission.

These modifications have been evaluated during the Design Certification Review. Safety assessments were also made. No significant new hazards were identified.

The following discussion summarizes the major changes and the basis for confidence in them.

The CSM electrical system has been modified to provide the capability for transferring approximately 295 watts to the docking module. Circuit wiring has been added between the CM and DM for communications, instrumentation, docking system power and control, and experiment power and control. In addition, circuit wiring has been added between the CM and SM for experiment power and control, ATS-6 operation, RCS, and RCS thermal control system. Hazard and sneak circuit analyses indicate no additional hazards.

Environmental control system modifications include: ATS-6 amplifier coldplate in the SM, Dopper receiver coldplates in the SM, a coldplate for the electrophoresis experiment, and new fittings, valves and lines for the electrophresis coldplate. These modifications were certified based on analysis and similarity to prior systems. Heat flux densities were within demonstrated limits. Mounting provisions were similar to previous installations. The vibration environment is similar to that on Apollo and Skylab.

The telecommunications system was modified to accomodate the requirements of the ATS-6 relay system and Soyuz interface. The ATS-6 system is shown in Figure 1. The NASA system has been successfully tested. A compatibility test was conducted on an electrical equivalent of flight hardware at JSC. Pre-flight tests will be conducted at the launch sites in 1975. The compatibility test program provided the only opportunity to interface the above equipment prior to the mission. To protect against possible adverse affect on the Soyuz pyrotechnic system from Apollo high energy RF sources, a high-gain antenna scan-limit capability has been provided. It utilizes switches providing redundant antenna position indications to the HGA control system which contains the logic and the control output/input. Two magnetic reed switches have been added to the antenna. However, the results of recent Soviet tests may indicate that such HGA scan-limits are not necessary because RF energy from the HGA is sufficiently attenuated and will not trigger Soyuz pyros.

The body mounted attitude gyro in the CSM has experienced excessive gyro response time. Two gyros (CSM 116 and 119) had such a history and eighteen gyros exhibited this anomaly when tested for reuse. Failure analysis has been hampered by the lack of repeatability of this type of anomaly. Current data seems to indicate that the problem is internal to the gyro, and it appears only when the output axis is down. The following actions have been taken to improve program confidence. Two gyros have been subjected to teardown failure analysis, twenty-two gyros have been rebuilt, and six rebuilt gyros have already been delivered. The schedule calls for the CSM 111 unit to be available in February 1975, the CSM 119 unit and spares in March 1975.

B. Launch Vehicle

The prime launch vehicle, S-IB-210, is composed of the S-IB-10 first stage, an interstage, the S-IVB-210 second stage, and the S-IU-210 instrument unit. The Saturn I-B 209 launch vehicle is the backup unit.

This vehicle for ASTP was compared with the last vehicle used for launching Skylab 4. The data indicates:

1. The rigid body and propellant slosh stability characteristics for this vehicle are equivalent or better than SA-208.

2. There should be no POGO problems.

3. The S-IVB/IU deorbit procedure is the same as in Skylab and there are no known problem areas.

4. Age limited hardware has been examined in detail. There appears to be no concern with either flight or spares because of age.

5. Marshall and the stage contractors have reviewed all

stress corrosion susceptible materials. They have inspected the appropriate areas and reworked or replaced items as required. Stress corrosion inspection requirements have been instituted at KSC to assure visibility and control of any problems.

6. No mission peculiar hardware changes were required for ASTP.

7. There appear to be no problems with the ground support equipment.

C. Space Suits

The space suits to be used by the ASTP crew have been reviewed by JSC. This Pressure Garment Assembly (PGA) is basically an A7LB-CMP configured suit with the cover layer cross section changed from the Teflon-Beta aluminized film nylon ripstop configuration to Teflon-Beta PBI since no extravehicular activity is required. The boots are Skylab boots with heel clips. Intravehicular gloves, electrical harness, and pressure gauge have remained unchanged. The pressure relief valve has been deleted and a blank flange installed in its place on the right leg. Qualification has been accomplished by similarity to like items flown on the Apollo and Skylab programs. There have been no significant test failures during the process of certification. All ASTP suits will be within the age life allowable at the time of the mission. No new waivers were required for the ASTP suit.

D. Spacecraft Adapter Truss

The spacecraft LEM Adapter (SLA) Truss supports the Docking

Module inside the adapter during the boost phase of the mission as well as during transposition and docking with the CSM. Its truss is also a stabilizer for the SLA during boost. Figure 2 shows the truss within the SLA on top of the Saturn I-B launch vehicle. Docking Module truss support fitting and truss release mechanism are shown in Figure 3. Truss structure consists of extruded aluminum angles and I-beams, aluminum and titanium fittings and sheet metal. It uses the same attachment points and the same separation and thruster hardware as used for the LM. New structure is designed to avoid coupling with the low frequency launch vehicle body modes.

Induced stresses in structural members so designed are much lower than the allowable stress of the member. Consequently a test program to verify structural integrity of support truss was unnecessary. Instead, a proof test at 109% of design limit was conducted on production articles as part of acceptance of the hardware. Strength margins of safety and deflections will be determined by analysis, with deflection measurements being taken during proof tests.

2.1.3 NEW HARDWARE

A. Docking Module

Docking Module is used for crew transfer between Apollo and Soyuz spacecrafts and as a work area for experiments.

Design was sufficiently conservative to warrant a minimal qualification test program. However, module did undergo an extensive test program where appropriate. This program included a proof-pressure test, leak tests, gas storage tank proof pressure and leak tests, exterior thermal insulation vent test, breadboard system tests, environmental control and life support system, and development tests of DM/Soyuz electrical disconnect mechanism. Vibration tests were made on individual components such as caution and warning detectors. Communication tests of VHF transceiver, antenna and power divider were made under various temperature, vibration and pressure conditions. Thermal vacuum tests supported qualification of a number of items such as the multipurpose vent system, and environmental control and life support system. The remaining qualification or certification program was based on analysis and similarity.

Because of the significance for crew safety, the Panel gave particular attention to the following areas: structure, hatches and seals, thermal protection, electrical, and environmental and life support systems.

1. Structure

Docking Module was designed with a very strong structure. Constructed of 0.625 inch, 6061 aluminum plate, it possesses an inherent strength which is significantly greater than that required for any known mission loads. It was designed for a ground-level launch of the S-IB. The planned launch from a pedestal means structure will see only about 25% of the energy level it would have seen in a ground-based launch. Math models used to define DM structural response to the launch are the same as those used on Apollo and Skylab programs.

Analysis indicates that general stresses in DM structure are very low. An exception is the local area where DM cylinder, DM bulkhead, docking structure, and DM truss come together (Figures 4 and 5). Acceptability of this strucutre is based on detailed analysis. Extensive repairs were made in the ring-to-shell weld which is in the highest stress area of Docking Module. This was reanalyzed and is within limits.

There is no concern about fracture mechanics because of thickness of the DM outer shell and the massive size of a flaw required for failure. This is also true for the tanks.

The two gaseous oxygen and two gaseous nitrogen pressure vessels are made from Inconel 718 forgings. Sections in each vessel are joined by one circumferential electron beam weld. They operate at 900 psi with a safety factor of about four. These tanks are shown in Figure 6. There was some question on the safety factor of the joint where tank mounting structure attaches to DM. This safety factor was less than two. The results of a further study indicate that this is sufficient.

2. Hatches and Seals

The Docking Module hatches have a structure machined from a forging. Hatch mechanisms are those used on Apollo. The technique used for analysis of the hatches is the same one used on Apollo and Skylab. A tool for disassembly in flight, if necessary, is available. Seals between the Docking Module forward bulkhead and the Docking System (Figure 7) are critical. Therefore, they have received added emphasis to assure structural strength and insignificant leakage rates.

3. Thermal Protection

Thermal protection is basically afforded by thermal blankets placed over the module. Thermal vacuum tests were conducted at JSC between June and August 1974. Soviet observers were present. The test results demonstrated satisfactory thermal control performance. The data correlated with the predictions of the thermal math models.

4. Electrical System

The Docking Module electrical system derives its power from the Command and Service Module. Two 28 volt dc buses are fed power for distribution to those items shown in Figure 8. Electrical interface connects, between the Docking Module and the Command Module and between the Docking Module and Soyuz, are shown in Figures 9, 10, and 11. The pairs of connectors for each unit are identified to preclude inappropriate wiring connections.

It was noted that electrical connector pins carrying experiment furnace power to the Docking Module are adjacent to pins carrying the Command Module entry pyrotechnic circuits. Based on Apollo and Skylab experience this has been adjudged to be poor design. The ASTP program office considered redesign. However, they concluded it was impractical because pin reassignment would cause major modification to CM 111 panels and bundles. To make the modification in CM 119 would affect the interchangeability of the Docking Module.

A review was conducted to assure continuity and pin-to-pin isolation. There will be another review at KSC.

5. Environmental and Life Support System

In the prelaunch preparations and prior to each crew transfer, the Docking Module is configured for the safe entry of the crew. Instrumentation is available in the Command Module's Panel 101 to allow review of the total pressure and O_2 partial pressure prior to entry. Results of testing show that even with the "worst case" of air composition a viable atmosphere was established upon completion of the mixing cycle. Before and after manning of the Docking Module, crew suit hoses are placed in the Docking Module to support proper mixing. Astronauts will not enter the Docking Module if the oxygen partial pressure is less than 165 mmhg. Each crew transfer, to and from Soyuz, requires at least one pressurization using nitrogen. The hand-held absolute gage is the primary method of determining when the desired absolute pressure has been achieved in the DM. The DM cabin pressure meter, the hatch delta P gage and the CM cabin pressure gage provide backup capability. Soyuz instrumentation is also an acceptable backup to the hand-held pressure gage.

An oxygen sensor in the Docking Module is used to control the atmosphere in the Docking Module during pressure changes. This oxygen sensor consists of an electro-chemical cell, temperature compensating thermistor, potentionmeter, associated wiring, and a connector. Because of its use in a critical system, NASA and the contractor for the Docking Module have evaluated the effect of a failed ventilating fan on the sensor and the effect of water on the membrane of the sensor. They have also reviewed the procedures for crew entry into the DM to assure that the configuration of such items as power, instrumentation, atmospheric pressure, and N_2 concentration support safe entry.

A ventilation fan is installed at the midpoint of the equipment module. It draws gas into the equipment module through a perforated plate near hatch no. 2. The air is routed over two oxygen sensors and into a plenum where the air is guided to the inlet of the ventilation fan. This fan then distributes the air into the Docking Module. A ventilation duct is provided to direct gas flow from the fan to the DM/Soyuz interface while hatches Nos. 3 and 4 are open.

In case of a fan failure, the Soyuz to DM ventilation fan can be used. It delivers 25% as much flow as the DM vent fan which is sufficient to achieve the desired atmosphere mixing during the pressure adjustment time. However, during nitrogen pressurization, the oxygen partial pressure sensors will not have sufficient flow past them. Thus they will provide very low partial pressure readings. Similarly the carbon dioxide reading on the CO_2 sensor would be erroneous when the fan is inoperative. The thermal effects resulting from an inoperative fan appear to be negligible with respect to the overall DM atmospheric temperature. While the air cooled VHF-FM transceiver would operate at a higher temperature than desirable, it would still meet the needs of the mission.

On the whole the effect of the inoperative fan can be mitigated by factors such as: short crew transfer timelines, crew movement within the DM volume, use of crew suit hoses for the Soyuz fan during hatch open operation, and manual fanning by the crew. The operating life of the ventilation fan has been proven on the Skylab program where similar units have operated for over 200 days without failures. A spare fan has been added to assure crew safety.

Water condensation is not anticipated in the DM. However, if condensate should reach a level that affects the operation of the oxygen sensor, the excess condensate would evaporate as a result of the repressurization and/or purge cycle of the transfer. Based on the low expectancy of excess water condensate on the oxygen sensor, no design change or additional testing is to be done.

B. Docking System

The Docking System is designed to meet the following requirements:

1. Active Mode

   (a) Initial Docking:

   - attentuate impact energy
   - provide capture and alignment
   - provide sensory indications of actions or events

   (b) Final Docking:

   - pull Apollo and Soyuz together
   - align and compress the docking ring seals
   - provide structural and pressure integrity
   - provide sensory indications of actions and events

   (c) Passive Mode:

   - provide compatible interfaces for the active Soviet system
   - provide sensory indications of actions and events
   - provide backup undocking capability

Major elements of the Docking System are shown in Figure 12. Details of the interface seals are shown in Figure 13.

The Docking System went through a thorough component test program which included the latches, attenuators, seals, thermal paint, structure, cables, and gear boxes. After system testing it underwent joint compatibility tests with the Russian docking system both in the USA and USSR.

As expected in a development program, the Docking System had some anomalies but they were minor in nature. These anomalies and their resolution are shown in Table I.

The ASTP Engineering Review Group generally was satisfied with the design manufacturing and qualification program.

They noted that full extension of the guide ring had not been possible under some test conditions. It was a case where the "full-extension light" indicator as orginally located could indicate that an operable system was inoperable. A change to relocate the guide ring extend sensing indicator has been implemented. The qualification program has been completed and the system fully extends with the attenuators at realistic temperature conditions. In addition, the ASTP organization is investigating the possibility of using a 300mm lens with the 35mm camera as an independent method of determining guide ring extension.

Also, the Group noted that Apollo/Skylab experience has shown that metal springs should be reviewed to assure that the material is as specified. Review of the numerous springs in the Docking System showed that one spring utilized on the retract cable sectors (wheels) is subject to stress corrosion. The function of the spring is to prevent cable slack during docking. Table II shows the analysis of that particular spring and is typical of the review conducted by the contractor on all the Docking System springs.

They reviewed the swaged fittings on cables to assure their mechanical adequacy. This had been a problem on previous programs. Analysis showed that the cables on the structural latch system remain preloaded following their initial installation. Furthermore, the rigging of the structural latches is carefully monitored during acceptance test of the Docking System and swage failure would have been readily detected. Development and qualification systems were completed over a year ago and there is no indication of a change in the latch rigging due to metal creep.

The electrical system provides power for operation of six solenoids, three gearbox motors, statusing lights, test meter, and limit switches. Certification of this system is by analysis as well as qualification testing. This system has been successfully tested by itself and with the Soyuz unit.

A Docking System alignment pin and socket problem showed up when a cable retract gearbox stalled out approximately 0.75 inches from full retract during the -18° F. cold screening test. Three attempts at retracting stalled out. On the fourth attempt the pin and Docking System did retract. Investigation showed that a slight misalignment of the pin had been caused by the test fixture. Such a misalignment could happen during inflight docking. The pin was pushed into the socket on docking at an angle which caused metal to displace and to bind when retract was attempted. A new pin was designed with a better shaped head and a slight change in the socket. Tests have shown that this combination can better withstand misalignments. This was shown to Soviets in November while the compatibility tests were in progress and the pin and socket on the NASA hardware was changed. This problem is now considered resolved.

C. Experiments

Both life science and application experiments will be flown. The life science experiments include investigations of the radiation effects of heavy charged particles impinging on live cells and the effects of spaceflight on the human immune system. Application experiments will investigate such areas as the isolation of medically useful substances and the zero-g processing of materials. The location of the experiments is shown in Figure 13 and is listed in Table III. Safety analyses are proceeding on the following experiments:

1. MA-010 - Materials Process Furnace. Failure of the cool-down system line would cause loss of the Docking Module's internal pressure. A 0.5 inch diameter orifice has been added to the exterior vent line. An emergency pressure regulator limit has been set. In case of a system failure, such as a line break or open valve, Docking Module pressure will be maintained above 3.5 psia for

15 minutes by the inflow of O_2 from the emergency pressure regulator. Tests are to be completed by January 1975.

2. <u>MA-011 - Cryogenic Freezer</u>. This experiment includes a vacuum bottle containing eight pounds of liquid nitrogen. If it were to fail the bottle could emit nitrogen into the spacecraft atmosphere. The bottle is enclosed in a metal container. In October 1974 the weld integrity was thoroughly tested.

3. <u>MA-048</u>. The soft x-ray experiment has a pressurized gas supply of 15 liters of gas at 2500 psi. An orifice in the vent line prevents overstress of the girth rings in the SM structure if the gas is dumped.

4. <u>MA-088</u>. The helium glow experiment has a high pressure gas supply of 1.7 liters of helium at 1000 psia. The gas bottle is located in the SM. Intent here is to provide an adequate safety margin on the gas pressure bottle and/or the use of a relief valve with orifice.

5. <u>MA-089</u>. Batteries in the Doppler tracking experiment must have adequate venting of the cells and a means to prevent shorting paths.

In order to develop the experiments at minimum costs, documentation and testing were reduced where practical. This should not impact crew safety.

D. Apollo Hazard Review

Safety organizations at the Johnson, Marshall and Kennedy Centers are reviewing the spacecraft, launch vehicle and associated ground support equipment. This review includes an evaluation of the unchanged systems to assure that they are in fact as safe as before. They are reviewing both the history of the vehicles and the program for dealing with age-life and stress corrosion. Modifications and new equipment are, of course, also being evaluated. For instance, the safety analysis on the Docking Module was comprehensive enough to cover the following: location and depth of threaded fastener holes in the DM skin, examination of design and production drawings and the as-built vehicle, test results from development and qualification tests, correction of anomalies resulting from tests, analyses of the Docking Module from the point of view of safety, adequacy of the ECS valves to preclude malfunction during module separations from launch vehicle, analysis of relife valve operation, impacts of generic failures in potentially hazardous hardware, single failure point identification, acceptability of environment for a crewman to sleep in the DM, and pressure tanks (oxygen and nitrogen) for burst disc requirements and fracture mechanics.

A sneak circuit analysis is being done on the integrated Apollo spacecraft, Docking Module and Docking System.

Lightning tests have been performed to determine spacecraft and space vehicle susceptibility to lightning strikes and to an analysis of launch limitations. Work is continuing at this time. Shields and grounds have been designed and installed at the KSC on all exposed cables to reduce lightning effects. An insulated mast and ground wire system is being designed and tested for protection on the pad at KSC.

2.1.4 APOLLO MISSION DESIGN

A major portion of the Apollo mission is analogous to the Skylab CSM missions. The significant difference is the length of time the CSM remained docked to the Skylab cluster in a passive mode.

A comparison of trajectory and flight characteristics shows that:

1. The launch is made from Launch Complex 39 with the total vehicle standing on a pedestal. CSM interfaces for prelaunch and countdown operations are similar to those of Skylab.

2. Normal launch window for this mission is about 15 minutes. This is almost the same as it was for the first Skylab CSM launch.

3. ASTP Apollo will be inserted into a 150/167 km orbit coplanar to the Soyuz while the Skylab CSM was inserted into a 231/155 km orbit.

4. Orbit inclination for ASTP is 51.78 degrees as compared with 50.8 degrees inclination for Skylab.

5. Rendezvous and docking between Skylab CSM and workshop was between one-manned and one-unmanned vehicle while ASTP utilizes two-manned vehicles.

2.1.5. OPEN WORK

On the whole, challenges facing the program are not unusual for a manned program at this stage of progress. Typical open items to be worked off in the time ahead are:

1. Launch Vehicle

    (a) Continuation of planned inspections on accessible items that are susceptible to stress corrosion.

    (b) Monitoring the status of existing aft interstage reaction beam shear pin cracks on S-IV-B.

    (c) Replacement of the wet slug capacitor in flight control computer in the Instrument Unit.

2. CSM

    (a) Service Module experiement door bearing.

    (b) Design, installation and test of ATS-6 acquisition filter in the Hi-Gain Antenna system.

    (c) Completion of video system changes.

    (d) Completion flight acceptance tests for selected experiments.

3. Docking Module

    (a) Verification based on completion of the thermal-vacuum test.

    (b) Continued check of all accessible screws inserted into the main skin structure to assure they are locked in place.

(c) Completion of the formal report on analysis of the structural integrity of the Doppler antenna installation.

4. Docking System

(a) Review of the results of DS-5 and DS-7 tests conducted in Moscow for mate/leak/functional capability.

5. U.S. Hardware Certification Program

(a) Completion of certification by analysis and test of the thirty items open at the time of the Panel's review.

The Panel has not reviewed the work flow and test and checkout results on the flight hardware at KSC. The plan is to cover these areas at an appropriate time when major milestones have been accomplished and significant data will be available.

2.2 SOYUZ

2.2.1 MANAGEMENT

The following points were made by the NASA Working Group Chairmen and other engineering and management personnel most familiar with Soyuz. In general, Soyuz management systems provide program information comaprable to the data provided by NASA management systems.

They observed that the Soviets must have a working configuration management system because of their ability to know the designed vs. "as built" status of their hardware. They also have a detailed awareness of the differences between the basic Soyuz spacecraft and the modified ASTP Soyuz spacecraft.

The Soyuz management system does not appear to have safety functions organized formally in the same sense that NASA has. On the other hand, Soviet approach is to make safety and reliability the responsibility of the designers and to prove it in flight tests.

It has been indicated by the Soviets that they convene special investigation boards, similar to NASA's groups, to examine spacecraft accidents such as with Soyuz 11 and 15. Failure modes are defined and fixes implemented as a result of these boards examining the details of the mission and conducting necessary tests.

Soviets tend to have their flight and ground procedures developed by subsystem managers while ours are developed by NASA mission planners supported by technical personnel.

NASA Working Group Chairmen have a high respect for their counterparts basic technical knowledge and the application of that knowledge to their flight systems and mission operations. They stated that Soviet members of the Working Groups have demonstrated a marked capability for mathematical and logical analysis. They appear highly committed by self-interest to the success of the program.

Working Group Chairmen summarized their understanding of the test approach after witnessing some mockup, bread-board, and compatability tests.

Soyuz manufacturing, test and checkout, as described for the new and modified Soyuz hardware, flow provides for the following test program to meet the Apollo Soyuz Test Project requirements:

(a) Structural development tests of systems, subassemblies and components.

(b) Integrated tests of systems of development hardware.

(c) Flight tests.

(d) Integrated tests of flight systems and assembled spacecraft.

Each of these main stages of the development and qualification test programs are briefly described below.

1. Structural Development Tests.

These tests are performed during the manufacturing period on components, assemblies and systems to verify the adequacy of engineering designs, as well as of the materials and processes used in their fabrication. Where changes to the design or materials have been made, retesting is conducted where necessary. The degree of verification testing is greatest for spacecraft hardware systems and components that are new or have been modified for the ASTP mission. Those items and systems which are standard Soyuz equipment are subjected to the standard Soyuz verification tests.

2. Integrated Tests For Development Hardware.

One purpose of these tests is to obtain engineering data on major systems as life support, structures, and docking. They also verify operation under nominal and off-nominal conditions. These tests utilize such facilities as thermal-vacuum chambers to simulate flight conditions. During this period of testing, technical and flight crews receive a certain degree of "on-the-job" training, learning the real-life intricacies of the new and modified hardware. Ground test program for these integrated tests is shown in Table IV. An example of this type of testing is the compatibility tests on docking systems conducted in Moscow in November 1974. This work utilizes mock-ups as well as qualification test hardware.

3. Flight Tests.

Upon completion of the previous test stages, the Soyuz hardware is ready for flight tests. An example is the flight of Soyuz 16 in December 1974. During manned or unmanned flight tests, the objectives are to:

(a) Confirm the engineering design, fabrication and test procedures.

(b) Update the knowledge of natural and induced environments and their impact on the flight hardware.

(c) Verify the prelaunch ground procedures.

(d) Verify the adequacy of the hardware to operate properly both as an independent system and as part of the total Soyuz ASTP system.

During flight test the hardware is exercised to the degree it will be used on the actual ASTP mission. The exception is equipment requiring direct interface with the Apollo spacecraft, e.g., Docking System.

4. Final Integrated Systems Testing

Verification tests are conducted during the final stages of flight hardware manufacturing and its preparation for actual flight. These verification tests are conducted to assure proper hardware function and flight readiness. During final assembly at the manufacturing site and prior to integrated electrical testing of the total vehicle, the following major verification tests are made:

(a) Fluid line pressure integrity check.

(b) Functional verification of external deployable equipments, e.g., docking targets, antenna, etc.

(c) Electrical checks on individual systems.

During the integrated electrical testing of the total spacecraft, the interaction and total functioning of the electrical system is checked and verified. These tests include runs under nominal and off-nominal situations.

The spacecraft is then delivered to the launch site for the following tests:

(a) A final pressure integrity check of all fluid lines.

(b) Final verification of deployable hardware.

(c) Final integrated electrical verification of the total spacecraft with particular attention to the radio system.

Upon completion of the above tests, the spacecraft is prepared for mating to the launch vehicle and transported to the launch pad.

In accordance with joint agreements as documented in program IED's, there are a number of tests in which participation of both sides is worthwhile. The Soviet side considers it desirable that NASA specialists participate or be present when they conduct the following tests and verifications during preparation of the Soyuz spacecraft:

(a) Test activity on the mockup for development of compatibile arrangement of equipment.

(b) Compatible system testing during the preparation of the "nominal" Soyuz at launch area.

(c) Perform fit-check of the Apollo and Soyuz docking assemblies prior to installation.

(d) Test operations on mockup in connection with development of the life support systems.

Additional detail on the procedures used to prepare the spacecraft during manufacture and at the launch area are provided in Table V and Figure 15.

Compatibility tests conducted for the docking and radio communications systems indicate that the Soviet approach to both testing and the test facilities probably are comparable to NASA's approach. In the case of testing of the pyrotechnic devices, the Soviets apparently did not have an appropriate power source in the S-band frequency but they were able to meet the test requirements through other means.

The ASTP 20205 "Report on the Soyuz Habitable Modules Overpressurization and Depressurization Safety Assessment" describes the type of testing conducted on the Soyuz structure. All structural material is subjected to x-ray and ultrasonic checks to assure proper welds. It is also subjected to vibration and proof tests after manufacture, leakage tests, structural strength tests, vacuum chamber tests and integrated Soyuz vehicle tests. Valves, gas mixture supplies, and seals are all checked. Any item which had an anomaly in previous flights is also rigorously tested.

2.2.2 HARDWARE

A. General Description

The Soyuz spacecraft consists of four separate and mutually supporting elements: Docking Unit, Orbital Module, Descent Vehicle, and the Instrument Assembly Module. These are shown in Figure 16. The Soyuz spacecraft previously used by the Soviets was basically the same as the ASTP unit. This spacecraft incorporates the following new or modified features.

1. New systems.
    - (a) Docking and Internal Transfer System
    - (b) Ranging and Communication System for Rendezvous
    - (c) Apollo (USA) Radio Frequency Communication System
    - (d) External Lights System and Docking Target Assembly
    - (e) Cable Communication System
2. Modified Systems.
    - (a) Thermal Control System
    - (b) Life Support System
    - (c) Spacecraft structure to meet new and modified systems

Soyuz compatible docking system looks very much like the Apollo system since these units are androgynous and must fit together at the interface to achieve soft and hard dock conditions. The major difference in design is that the Soyuz unit uses motor-driven screws while NASA uses motor-driven cables. Each country developed and fabricated its own docking system independently. There are rigid interface requirements. Each country's docking system can serve either as an active or passive component in the docking operation. This hardware has been seen and worked on by USA personnel during tests in the USA and the USSR. For all practical purposes, this is the only flight hardware that has been so scrutinized.

The spherical Orbital Module is used principally by the crew as a work area for experiments as well as for rest and relaxation. Its hatches interface with the NASA Docking Module and the Soyuz Descent Module. The Orbital Module supports the Docking System, docking targets, and the TV/VHF antenna.

Descent Vehicle is the principal habitation and work area for the crew during launch, insertion into orbit, re-entry and landing. This vehicle has a hatch on its interface with the Orbital Module. Majority of controls and displays are in this segment of the total vehicle.

The Instrument Assembly module contains the structure for mating the Soyuz onto the launch vehicle. It contains the major components of such critical spacecraft systems as electrical power generation and control, environmental control, and propulsion.

To compare the Soyuz spacecraft with the Apollo spacecraft:

a. Apollo Service Module is similar to Soyuz Instrument Assembly Module.

b. Apollo Command Module is similar to Soyuz Descent

Vehicle and parts of Orbiter Module.

c. Apollo Docking Module is similar to Soyuz Orbital Module.

The size of the modules can be visualized from their internal free volumes:

a.	Soyuz Descent Module	3800 liters
b.	Soyuz Orbital Module	6500 liters
c.	Transfer Tunnel between a. and b.	400 liters
	TOTAL	10700 liters

d. For comparison the Docking Module has a free volume of 3500 liters.

B. Pre-dock Phase

For the sake of brevity, the systems discussed here are those used primarily during this period. These are the docking target system, stabilization and control system, propulsion system, radio communications system, and the Docking System.

1. Docking Target System.

Docking begins when the orbital parameters are approximately equal and the two spacecraft are in visual contact. It ends when the two docking units are hard docked. Docking alignment targets provide the necessary information for the crew to orient the vehicles to the proper position independently of the flight control instrumentation and visual displays. Primary sighting target is a deployable Apollo-type target mounted at the front end of the Orbital Module. A backup sighting device is mounted on the aft section of the Descent vehicle. There is an alignment target mounted on the Apollo Docking Module along the Soyuz line-of-sight for sighting from the Descent Vehicle periscope device (Figure 17).

NASA conducted target installation alignment tests in July 1974. Tests used the Soviet docking system qualification unit using a test fixture provided by the USA. Then the fixture was shipped to the USSR for target alignment tests by the Soviets on their own hardware at their own sites. Procedures for installation of the targets on the Soyuz and definition of the verification plan for docking alignment targets are found in IED 50502.2 dated August 15, 1974. Other IED's that apply are IED's 50201, 50004, 50202 and 50203.

Both Apollo and Soyuz have external lights along with color schemes to aid in the docking procedure. External lights on the Soyuz include a flashing light beacon, orientation lights and a flood light. The Apollo and Soyuz have external lights along with color schemes to aid in the docking procedure. External lights on Soyuz include a flashing light beacon, orientation lights, and a flood light. The Apollo floodlight is used to illuminate the passive Soyuz spacecraft so that the Apollo crew can determine the relative attitude existing between the spacecraft. Docking target on the passive spacecraft may also be illuminated by the floodlight. Orientation lights on Soyuz make it possible for the Apollo crew to determine the Soyuz's approximate attitude while maneuvering in its near vicinity.

2. Stabilization and Control

Soyuz attitude control system consists of three elements:

(a) Two sets of attitude control reaction system jets. Jets in one set have a 10 kg capability and the other jets have a 1 kg capability. Both use hydrogen peroxide as the propellant. They use common plumbing. When the control system is "off" gas pressurization electrovalves, tank propellant supply electro-valves, and individual jet valves are all "closed."

(b) Corrective engine system. Main engine is a single nozzle 419 kg thrust engine using 10 kg jets for attitude control. It utilizes bipropellant of hydrazine and nitric acid based oxidizer. There is a backup engine which has a dual chamber, dual nozzle set up with a maximum thrust of 411 kg, with throttleable jets for attitude control. These engines also have common plumbing. The electropneumatic tank pressurization and control valve pressurization valves are closed when no voltage is applied to them. The spring-loaded propellant feed-valves are also kept closed.

(c) The control system - with both automatic and manual control modes. Cosmonaut control panels contain input and display devices for stabilization and control events. Critical Command Unit activates the corrective engine system. There are two Command Signal Devices each with sixteen keys for mode and system selection. CSD units have a rotating drum with electroluminescent display windows to indicate the items selected. Digital Display Unit uses manual input for attitude and delta velocity maneuvers and indicates the backup corrective engine operation. In the operational mode, the Apollo vehicle normally is active and Soyuz passive. Soyuz will be able to perform stabilization and control functions in contingency cases during docked operations.

Test results of the Soviet control system have been provided by the Soviets and analyzed by the United States. These results indicate that the Soyuz control system provides adequate stability and controllability. The limits of acceptable control modes have been identified for various mission phases associated with joint operations. Soyuz vehicle is capable of providing control of the docked configuration, if necessary. It has the capability to hold inertial attitude, perform manual and automatic rotational maneuver, damp large initial rates, and provide some x-axis translations. Finally, the results indicate that the Soyuz does not produce excessive bending loads on the docking system interface.

Test plans and scope of tests are found in IED 50401. Apollo and Soyuz test results are contained in IED 50403. Usable control modes, as a result of the tests, are documented in IED 50405.

3. Communication System.

This system is used during the pre-dock period of rendezvous and ranging operations. The communications system components are shown in Figure 18. NASA's discussions with Soviet technical personnel and cosmonauts brought out the necessity for radio-silence during the period immediately preceding docking. In the Soyuz system where radio commands are used in the spacecraft attitude control system to energize and de-energize the circuits error protection coding and a closed loop "compare before execute" procedure provides protection against inadvertant command actions.

4. Television System.

The Soyuz television system also is used in rendevous and docking maneuvers. The TV system is capable of control both by the ground and by the onboard crew. A camera mounted on the outside of the Orbital Module is aligned with the vehicle x-axis. TV images are transmitted to both an on-board-viewer and a ground-viewer.

5. Docking System.

The Docking System is analogous to Apollo's. Principal difference is that where Apollo's system uses motor driven cables and hydraulic attenuators, the Soyuz system uses motor driven screws. This reflects only a difference in design philosophy. It is planned that during the initial docking the Apollo active system will capture the passive Soyuz system. In a subsequent docking exercise the active Soyuz system will capture the passive Apollo system. In both cases the Apollo spacecraft will be the active vehicle for approach and docking maneuvers. Both sides have agreed that successful completion of the docking compatibility tests on the flight hardware in November 1974 would "freeze" the interfacing hardware. Each country exchanged a data package containing the component manufacture dimensions that are critical to the interface of the two systems. Any waivers, changes or modifications to these dimensions or to the design requirements must be approved jointly.

The Docking System is designed to provide capture without the use of the reaction control system thrusters. If there is a docking problem, these thrusters can be used to assure reliable capture.

Soyuz docking functions are described in IED 50016 "Apollo Soyuz Docking System Sequence of Docking and Undocking." Figure 19 shows the sequence of normal operations for the phase when the Soyuz is passive and the Apollo is active. Figure 20 shows the sequence for the phase when these roles are reversed. Docking System is in a state of passive readiness when the guide-ring is fully retracted, structural ring-latch active-hooks are unlocked, and the body-mounted latches are locked.

IED 50006 "Apollo Soyuz Systems Thermal Interface" defines the thermal interfaces between the two spacecraft during joint mission phases.

Development and compatibility testing, as well as the material provided through the safety assessment reports, appear to provide evidence that the Soyuz system does meet the system requirements. Structural load histories for various contact conditions are contained in IED 50013 and associated Working Group No. 3 documents.

B. Docked Phase

For purposes of this report, the docked phase encompasses the time from hard-dock, through hatch-opening and joint-operations, and concludes with hatch-closing and preparation for undocking. Following areas are of particular significance for crew safety:

1. Seals.

After hard-docking the sealing of the interfaces between all modules of the combined Apollo/Soyuz vehicle must be assured. This area has been thoroughly tested and analyzed by both countries. The results of seal tests noted that they all met hardness, dimensional and leakage requirements at "worst case" simulated conditions. The force required to compress seals and achieve metal-to-metal contact, which exceeded requirements by 400 Kg, is provided by the docking system latches.

There is little information available on the seals and the manner of sealing the Docking System to the OM and the OM to the DV. In "Safety Assessment Report - ASTP 20205" there is a statement that tests are conducted on the whole Soyuz vehicle as well as on individual modules. There is also a statement that the DV ring plane is air-tight-locked by the OM ring at the time when the Soyuz spacecraft is assembled. The ultimate basis of confidence is that the Soyuz seals will be exposed to the flight environment long before the astronauts enter the Soyuz environment. Seals between modules may see new loads because of motion of the integrated Apollo/Soyuz vehicles. This is under review.

2. Atmosphere

The Soyuz atmosphere before transfer is defined in IED 50703 as:

Water Vapor Pressure Range	8 to 15 mmHg
Carbon Dioxide Partial Pressure	not over 10 mmHG
Temperature Range	15-25° C
Air Current Velocity	0.1 to 0.8 meters/second
Leakage rate at 520 ± 30 mmHg	7.5 grams/hour

After the crew transfer and with hatches of both Docking Module and Orbital Module opened, The Soyuz environment is:

Water vapor partial pressure	8 - 15 mmHg
Carbon dioxide partial pressure	Not in excess of 10 mmHg
Temperature range	15-25° C
Total pressure range	490 - 550 mmHg
Maximum total pressure	610 mmHg
Oxygen partial pressure range	150 - 220 mmHg but with a maximum of 40% by volume

As for toxic contaminants, the Soviets have described a four-step process to assure a safe environment. They screen materials to limit the residuals that would become contaminants in space. They evaluate all materials used in the spacecraft to assure that outgassing is within safety limits. They are conservative in using materials, if any, whose safety limits have not been defined as yet.

A chemical analysis of the contaminants and a toxicological evaluation of the atmospher is part of the life support system tests. Table VI shows the permissible concentration of assumed toxic materials.

Nitrogen is added to the Soyuz/DM atmosphere to adjust the oxygen percentage. Thus normal operation of the Soyuz atmosphere regeneration system maintains the 0_2 partial pressure within the acceptable range. Following volumes are used for analyses:

CM	8.97 cubic meters
CM/DM Tunnel	0.28
DM	3.50
DM/OM Tunnel	
DM Portion	0.25
OM Portion	0.15
OM	6.50
DV	3.80

3. Environmental and Life Support System.

Although NASA personnel have not seen the actual flight hardware or its production and testing, they have had the opportunity to review hardware that is described as identical to the ASTP Soyuz hardware. They have seen the location of this hardware in Soyuz mockups. In some cases the internal parts of the hardware are available for review. Elements which they have seen are:

(a) The oxygen generator and CO_2 removal devices in the descent vehicle.

(b) The oxygen generator, CO_2 removal unit, and gas analyzer in the Orbital Module.

(c) The condensing heat exchanger and fan system and instrument cooling heat exchanger and fan unit.

Figure 21 is a schematic drawing of the ECS, Figure 22 is a schematic drawing of the suit circuit gas supply system and Figure 23 is a schematic of the thermal control system.

Testing of the life support system conducted in Moscow was observed by USA personnel. The results met the objectives for a successful mission simulation and life testing of atmosphere regeneration. The tests showed there was a contingency capability for gross gas make-up to support crew transfers into the Apollo Docking Module. Biasing the Docking Module atmosphere constituent levels caused no adverse effect on the performance of the Soyuz life support system. Perturbation of operating conditions did not adversely affect the operation of the system although the cabin temperature remained warmer than settings. Radiator outlet temperature variations significantly affected cabin humidity and thus oxygen generator performance. The system was able to accommodate this. Supply voltage variations did not adversely affect the performance. Cabin pressurization system provided approximately thirty-five minutes of time at a habitable cabin pressure with a 5mm diameter hole in the hull. The life support system has redundant components in those areas critical to crew safety. These are shown in Figure 21.

The system is further described in IED 50723.

4. Cable Communications and Radio Communications.

The cable communications are designed principally for use by the visiting crewmen. The system provides a hardwired communication system between the docked Apollo and Soyuz spacecraft. This system consists of audio signal cables, power cables, and television video coaxial cables (Figure 24). Pressure sealed feed-through connectors are provided to ensure cable communications between docked vehicles without interfering with the hatch operations at the docking interface. The astronauts manually connect the interconnecting cables at the docking interface. Each country provides a junction box in its spacecraft for use by the visiting crewmen. The cable communication systems are electrically independent of the host spacecraft. Interface connector design and installation permits undocking of the spacecraft even if the connectors have been left connected. Wire sizes for these cables have been selected based on the current flow within each spacecraft. Circuit breakers have been selected using the same criteria. Circuit breaker acceptance criteria are shown in Figures 25 and 26.

5. Pyrotechnic System.

On the Soyuz vehicle, the pyrotechnic devices provide for these deployment and separations:

(a) Separation of the OM and DM through the use of pyrocartridges.

(b) Separation of the Apollo and Soyuz in the event of a contingency. Explosive bolts are used.

(c) Deployment of the Soyuz parachute system.

(d) Deployment of the external elements such as antennas and the primary docking target.

(e) Control of the hydro-pneumatic lines through the opening and closing of valves.

The location and types of pyro devices are shown in Figure 27 and Table VII. Table VIII is a comparison of the Apollo and Soyuz pyrotechnic initiators. Soyuz pyrotechnics are of the bridge-wire type. The Soyuz explosive bolt consists of a steel body with external thread and an internal cavity for the bridge-wire type detonator. Characteristics of the pyrocartridges are:

Bridge resistance (ohms)	0.6 to 1.2
Safe current (amps)	0.2
Operating current for sure-fire amps	2.0
Pyrocartridge self-actuation temperature (°C)	275
Operating temperature (°C)	±60
Permissible shock overloads (g's for 5-10 millisec)	100

The characteristics of the explosive bolts are:

Bridge resistance (ohms)	3-8
Safe current (amps)	0.05
Operating current (amps)	0.6 to 0.8

Explosive bolt self-actuation temperature (°C)	275
Operating temperature (°C)	±60
Permissible shock overload (g's)	100

Chairman of Working Group No. 4 has told the Panel that the Apollo and Soyuz cabling, control, and circuit protection have been jointly reviewed and are considered safe. The characteristics of Apollo and Soyuz pyro-device have been reviewed to limited extent. However, particular attention has been given to assuring there is no potential hazard of RF energy igniting the pyros. Russian tests made in November appear to have been successful in proving that their pyros will not fire when subjected to the equivalent of a 20 to 30 db margin in RF radiated power.

2.3 JOINT APOLLO/SOYUZ

2.3 JOINT APOLLO/SOYUZ

2.3.1 Working Group

A. Organization

The five working groups have the responsibility for technical and management integration of the Apollo and Soyuz programs. Working Group No. 1 has the responsibility for requirements, plans and procedures for a joint mission profile, crew and mission control centers' activities, contingency planning, and simulation and training. Working Group No. 2 has the responsibility for docking aids, guidance and control. Working Group No. 3 has the responsibility for the operational compatibility of the two docking systems. This involves a number of joint test activities, including one at which a Panel member, Dr. Charles D. Harrington, was an observer. Working Group No. 4 has the responsibility for integrated radio communications between Apollo and Soyuz spacecraft and the Mission Control Center. This includes the EMI impact of one radio system on the flight systems of the other spacecraft. Working Group No. 5 has the responsibility for life support and crew transfer systems and procedures during both nominal and off-nominal situations. There is a sixth "working group" that is the forum for the Program Managers.

B. Process

Methods were established in document ASTP 2000 and have evolved as the two communities have learned to work together, to exchange information, and to understand the particular design or operational philosophy of each community. Working Group chairmen are permanent appointees. Membership changes as the work changes to include the appropriate engineering or operation specialists. Most working groups have held an average of three to four meetings a year. These include the two plenary sessions when all groups meet simultaneously. Problems identified by one group as not within their province are referred to the appropriate group for work. Communications to support these meetings is almost continuous as documents and test results are exchanged, evolving issues are discussed and agendas are established. The Soviets apparently have shown a willingness to exchange information as it can be demonstrated to be needed for a safe joint operation while maintaining their proprietary rights in other areas.

Interpreters used by the USA are not full-time NASA employees. They come from industry and universities and have some technical background. These individuals have become accustomed to the technical systems and are fully aware of the need for exact interpretation when dealing with technical areas in the joint working groups. Along with the Soviet interpreters, they are involved in writing the US version and USSR version of joint documentation. In Working Group No. 2 the Soviet personnel read, speak, and write English well enough that most of their joint meetings are conducted in English.

C. Documentation

The results of this process has been extensive documentation of detail in joint areas.

1. Project Level.

These documents contain general description, organization agreements, schedules, public information plans, glossary, etc. Of major importance are the Safety Assessment Reports which evaluate the flight safety aspects of Soyuz and Apollo hardware.

2. Mission Documents.

These cover the actual operation and conduct of the flight. They include trajectories, crew flight plans, and training.

3. Interacting Equipment Documents (IED).

These Apollo Soyuz Test Project documents are closely related to interface documents used on Apollo and Skylab between the NASA centers and between contractors. In this case, these documents specify the interfaces between the USA and the USSR hardware. Currently there are some 125 IED's in existence and a 109 or more of them are complete. IED's generally follow a set format for each major interface area. As an example, the document tree for the docking systems cover:

IED 50001 - Technical requirements for compatible docking systems

IED 50002 - ASTP docking system development plan

IED 50003 - Test plan for scale models of ASTP docking system

IED 50004, 50005, and 50006 - Physical, load and thermal interfaces

IED 50007 - USSR ground support equipment/USA docking system equipment, mechanical and electrical interface requirements

IED 50008 - USA ground support equipment/USSR docking system equipment, mechanical and electrical interface requirements

IED 50009 - Joint development test plan for docking systems

IED 50010 - Qualification test plan

IED 50011 - Preflight compatibility verification test plan

IED 50012 - Results of Apollo/Soyuz docking system scale model tests

IED 50013 - Results of Apollo/Soyuz systems development tests

IED 50014 - Results of qualification tests

4. Working Group Papers.

Currently NASA has developed close to 300 internal working papers to support activities of the Working Groups. The Soviets have prepared well over 200 papers.

D. Joint Reviews

The Spacecraft Compatibility Review (SCR) is a joint operation between the USA and the USSR. Its purpose is to review each country's installation design against the IED requirements. Dates for the SCR are found in the latest issue of ASTP 30000.

The Equipment Acceptance Review (EAR) completes the assessment of each country's exchanged equipment. This is held after completion of all joint and integrated testing. Based on this review the decision is made to certify the equipment as suitable for flight.

Configuration of interfacing hardware is jointly controlled after joint qualification/compatibility tests, and the joint equipment acceptance review. In addition, each side assesses their own hardware to meet their own total mission plan. Dates for the FRR are designated in the latest edition of ASTP 30000.

The Joint Flight Readiness Review provides the opportunity for flight hardware, joint assessment of the supporting equipment and operations to assure they support launch schedules and mission operations.

2.3.2 MISSION DESIGN

Mission planning is described in varying detail in the Mission Operations Plan (ASTP-40400); Control Centers Interaction Plan (ASTP-40401); Joint Crew Activities Plan (ASTP-40301); and Onboard Joint Operations Instructions (ASTP-40600). What is chosen for a brief review here are those areas of particular significance for crew safety. These areas include: (1) development of the command structure for situations both nominal and contingencies, (2) analyses of hazards and development of appropriate contingency planning, and (3) training for ground controllers and flight crews.

A. Command Structure

1. Nominal

The rules for "command and control" during nominal situations can be summarized as follows:

(a) Flight operations are directed by flight directors according to joint documentation.

(b) Communications between control centers will consist of voice, teletype, facsimile, and TV transmissions.

(c) Each side will appoint a groups of technical specialists to assist in the other country's center.

(d) Joint training of crew and ground personnel, including simulations will be conducted.

(e) Each side is responsible for its own spacecraft.

(f) A possibility must be provided for communication with a country's spacecraft through the other country's network.

2. Examined Contingencies

These are situations or equipment failures that could occur based on prior spacecraft operational experience. These contingencies are reviewed and a procedure is developed for coping with it. The general approach or ground rules include the following:

(a) Responsibility for identifying the occurrence of a significant failure lies with those responsible for that spacecraft or control center.

(b) Decisions made by the flight directors in contingency situations will be coordinated over the voice communication channels. Subsequently, the decision will be confirmed by a document containing the agreed upon decision transmitted through the facsimile system.

(c) A decision to abort the flight or cancel the launch may be made at any time by either country if there is a failure of any system directly affecting crew safety. Necessary measures will be taken to insure that one country's action does not create a situation which could threaten the safety of the crew of the other spacecraft.

(d) If early mission termination is required or continuation to another mission phase cannot be accomplished, every effort will be made to satisfy as many objectives as possible consistent with crew safety and remaining systems capability. After launch, if systems and time permit, crew transfer will be accomplished regardless of the total joint activities time available; docking will be performed even if crew transfer is not possible; and rendezvous will be completed as planned while troubleshooting is progressing.

3. <u>Contingencies Which Have Not Been Anticipated</u>.

The ground rules for dealing with such "surprises" include the following:

(a) There is no overall mission commander. Each commander is responsible for his spacecraft.

(b) In case the control center identifies an unexamined contingency situation on board its own spacecraft not requiring immediate action, the control center works out the necessary measures, coordinates them with the other country's control center and subsequently carries them out.

(c) If the control center identifies an unexamined contingency situation on board its own spacecraft requiring immediate action, this center may work out and implement the necessary course of action unilaterally without coordinating them with the other control center, with due regard for the safety of the other country's crew, and subsequently will notify the other country's control center.

(d) If the crew identifies an unexamined contingency situation not requiring immediate action, the spacecraft commander reports to the control center and acts in accordance with instructions.

(e) In case the crew identified an unexamined contingency situation requiring immediate action, the spacecraft commanders act according to a mutually agreed plan and inform the control centers.

(f) In case the crew identifies an unexamined contingency situation requiring immediate action, and coordination between the spacecraft commanders is not possible, the decisions are made by the spacecraft commanders independently, with due regard to the safety of the other spacecraft's crew. Subsequently, the spacecraft commanders inform the control centers.

B. Hazard Analyses

The identification of hazards during the joint phase begins with the joint safety reports. These reports were prepared by each country, on its hardware, and provide the other country with an assessment of the safety and hazards. These assessments cover the following areas: docking and ring latches, propulsion and control, fire, pyros, and pressurization and communications. As the working groups evolved, additional information became available and this enabled NASA to prepare more detailed analyses. The scope and conclusions of these expanded safety studies prepared by NASA and as presented to the Panel are summarized here.

1. Pyrotechnic Devices.

A review of Soyuz-Apollo interfaces show that the failure of any Soyuz device to function will not compromise crew safety. The safety assessment also considers the hazard of premature firing, through such possibilities as inadvertent crew operations, auto ignition capability, firing circuit failure, spurious signals, high shock level and ignition from an Apollo source. Their conclusion at this time is that there are sufficient safeguards against a firing being induced by Soyuz malfunctions. Compatibility of Soyuz devices in the Apollo environment can be established after a complete review of the results from the completed full scale tests. Soyuz pyro-devices will be considered safe for the joint mission upon the acceptable presentation of the full scale test results by the USSR at the January Joint Meeting.

2. Propulsion and Control.

JCS's Safety Office reviewed the capability of Soyuz to support predocking maneuver requirements, to maintain attitude for guide ring contact and capture, and to perform contingency attitude control. They also investigated failures that could cause loss of maneuver capability, loss of attitude hold capability, inadvertent thruster firing, or loss of docking capability. Finally, they considered the functional redundancies in sensors, control mode selection, thruster selection, and propellant supply. Their assessment concludes that the Soyuz control system has functional redundancy to maintain a stable attitude for guide ring contact. They have not identified any single functional failures that would cause loss of attitude control. A single functional failure could result in an inadvertent thruster firing but the thruster manifolds can be isolated. Functional redundancy exists for the Soyuz sensors, control mode selection, and propellant supply. A thruster failing in the "on" mode would cause loss of that thruster. However, there is functional redundancy for nominal docking and docked contingency attitude control.

The open items to be closed at the January Working Group meeting include documentation on tank safety factors and further detail on the relay voting for dropout of faulty signals.

3. Electrical Power System.

There is no interchange of power between spacecraft. Soyuz is powered down while docked. The analysis of the electrical power system shows that the Soviet design approach provides for safety through two-wire distribution circuits, venting of battery hydrogen, flame retardant cable casing, safety guards on switches to critical circuits to prevent inadvertent actuation, voting logic in automatic controls, overload protection, current limiting resistors in pyrotechnic circuits, and series redundancy switching to prevent short-circuit actuation. The general conclusion at this time is that the safety approach is satisfactory. Open items to be resolved in the January meeting include control of the charging current, criteria for circuit protection and testing for component grounding.

4. Controllable Penetrations.

JSC's Safety Office evaluated Soyuz valves exposed to the vacuum of space and controllable by crew actions or system operations. Their assessment also covered the depressurization detection system and the capability for atmosphere replenishment. Given the redundancy in the valves and detection system, as well as the operational procedures, their conclusion is that there are no constraining concerns or open safety issues.

5. Environmental Control System.

The elements of the atmosphere maintenance system have been reviewed. These elements include the subsystems for atmospher regeneration, gas analysis, pressure integrity check, pressure venting and equalization, module pressurization, gas mixture, and expansion bladder pressurization. The conclusion of the Safety Office is that hazards have been reduced to an acceptable level. Their assessment of the thermal control system is that the hazards here have also been reduced to an acceptable level. No hazards were identified in the water and waste management systems. Hazards in food supply and personal hygiene are considered to be minimal and acceptable. A review of the Soviet toxicity test and control program leads NASA to conclude that concentrations of contaminants will be kept below harmful levels. Therefore, there are no constraining concerns or open safety issues in the environmental control system.

C. Mission Safety Assessment

JSC's Safety Office traditionally prepares a mission assessment to support the flight readiness review process. Such an assessment is being prepared by ASTP. Their review considers previous Apollo spacecraft anomalies, modifications to the spacecraft, Docking Module and other new systems and experiments, Soyuz hardware and operations, operational procedures, and special analyses and test anomalies. The report will be updated as the program progresses. This summary of what was presented to the Panel is limited to the Soyuz spacecraft. Where the hazard analyses consider possible failures in a spacecraft, the fault tree approach used here postulates major events affecting crew safety and looks for credible causes. This technique was used on the Apollo and Skylab programs to ensure that no serious hazards were overlooked and is used here for the same purpose.

1. Failure to Separate.

Failure of the Soyuz vehicle to separate from the Docking Module following docked operations could prevent Soyuz's reentry and would result in an off-nominal reentry configuration for Apollo. This event could be caused by electrical malfunction of the Docking System circuitry and mechanical malfunction of the docking latches. The Safety Office's conclusion is that there is no direct hazard to the Apollo crew. The primary separation system is redundant. Apollo hardware alone can accomplish all separations. The backup Soyuz pyrotechnic separation system is available.

2. Attitude Control Loss.

Loss of Soyuz attitude control would prevent Soyuz from providing contingency attitude control and docked x-axis translation, and would require Soyuz crewmen to transfer to Apollo for reentry. This event could be caused by electrical malfunctions in the propulsion command system, failure of sensors and manual command devices, or mechanical failure causing loss of propellant. Their conclusion is that there is no direct hazard to the Apollo crew. The Soyuz attitude control system is passive during docking operations. Multiple failures would be necessary before there would be loss of Soyuz control.

3. Uncontrolled Thrusting.

Uncontrolled firing of the engines could result in undesired attitude or rotation and prevent the crew from performing critical functions. This even could be caused by electrical failures that turn on the thrusters or by mechanical failures that turn on the valves. The Soyuz propulsion system is passive during docked operations. Multiple failures would have to occur for undesired thrusting. The Apollo spacecraft is prime for control of the docked attitude. Control authority from the Apollo reaction control system will override any Soyuz uncontrolled thrusting.

4. Decompression.

Uncontrolled or rapid loss of pressure in the Soyuz could result in loss of Apollo crew. This event could be caused by pressure seal leakage, inadvertent actuation of Soyuz cabin penetrations, pressure hull failure or premature vehicle separation. Their assessment is that the Soyuz contains equipment to detect cabin pressure reduction. Significant seal leakage would be detected in prelaunch checks or during mission phase prior to docking. Docking seals are extensively tested and their integrity is verified in flight. All lines exposed to vacuum contain redundant isolation. Multiple failures or inadvertent operations are required for actuation of cabin penetrations. The OM and DV pressure hull are proof tested to 1.65 and 1.8 atmospheres, respectively, and inspected for flaws. System malfunctions could not increase internal pressure beyond structural limits. Separation system design and operation is adequate to prevent premature module separations. The only additional information needed are the results of Soyuz testing to verify that the module separation system pyrotechnics are not overly sensitive to RF energy.

5. Electrical Shock.

Electrical shock could cause injury or loss of crewmen. This could be caused by contact with exposed or faulty electrical equipment. However, as noted before, Soyuz utilizes a floating dual wire DC power distribution system. Non-conductive covering over a large percentage of Soyuz Orbital Module interior decreases chances of exposure to shock. Most electronics equipment is located outside the inhabited areas. Soyuz electrical circuits and components are verified prior to launch. Additional information is required on component grounding tests before the analysis can be completed.

6. Explosion.

Explosion of Soyuz pressure vessels, batteries or pyrotechnics could cause crew injury or decompression of the inhabited area. Their assessment concludes that the relief and safety factors on the pressure vessels are adequate. Batteries are vented to prevent internal pressure buildup. Soviet analyses indicate no excessive buildup of explosive gases from batteries. Pyrotechnic design and operations are adequate to prevent inadvertent firings. Mission plans do not call for firing of any Soyuz pyrotechnics during joint activities. Pyrotechnics are reported to be self-contained. In order to complete this assessment the results of the Soviet tests on the sensitivity of the pyros to the Apollo RF energy have been formally requested. Additional information is required to determine the capability of battery vent system to accommodate off-nominal conditions. Finally, additional information on tank safety factors has been requested.

7. Debris from Explosion on Inadvertent Pyro-Firing.

Apollo contact with Soyuz generated debris could result in vehicle damage. This debris could come from Soyuz separation from the launch vehicle, from the pyros fired during separation, and from explosion of a pressure vessel. Their assessment is that contact with Soyuz separation debris is remote due to relative orbital positions. The use of pyros for undocking is a contingency operation. It would release no high energy debris. Relief and safety factors for the pressure vessels are adequate. As noted above, additional data is needed on tank safety factors to conclude the analysis.

8. Collision or Structural Contact.

Undesired structural contact could result in spacecraft damage or depressurization. This event could be caused by uncontrolled thrusting at docking or by loss of visual contact. Their assessment notes the following as a basis for confidence that the risk is minimal. The vehicles hold a narrow attitude dead-band for docking. Soyuz systems contain sufficient safeguards for undesired thrusting. Both Apollo and Soyuz monitor closing rate. Abort criteria have been developed for contingencies during docking. Docking guides will automatically align vehicles. The slow closing rate minimizes possibility of high energy contact. Apollo controls the closing rate and alignment during active and passive docking.

9. Radiated Energy Effects.

Radiated energy from one spacecraft or its ground stations could affect the other spacecraft systems or pyrotechnic devices. Analyses and testing on Apollo systems do not indicate any adverse effects from Soyuz generated RF energy. Soviet analyses and component testing indicate Soyuz pyros are not overly sensitive to RF energy. Information needed to complete the analysis is the results of specific system tests. These tests will verify that the pyros have acceptable safety margins and the Soyuz receivers are not overly sensitive to RF energy.

10. Toxicity.

Toxic contaminants could cause illness or loss of crew. Such an event could be caused by malfunction of the Soyuz contaminant control system or by off-gassing of materials. Their assessment concludes that the testing and control program for exposed material is adequate to establish the safety of these materials. The contaminant control system is adequate. A warning system is provided to indicate any leakage from coolant loop or out-of-tolerance concentration of O_2 or CO_2. The cosmonauts are exposed to the Soyuz atmosphere for fifty-two hours before astronaut exposure.

11. Fire.

Fire, regardless of origin, is a critical crew hazard requiring immediate and correct response. Fire in the Soyuz vehicle, as in the Apollo, could result in loss of critical equipment, cabin pressure integrity, and injury or loss of crew. Based on experience, maximum effort has been focused on the essential ingredients for fire: electrical ignition sources, non-metallic materials, Soyuz atmosphere, and internal configuration. Detailed analyses of available data indicate that:

(a) Soyuz atmosphere is less conducive to the start and continuance of a fire.

(b) Floating ground (two-wire electrical system) reduces the chance of ignition from short circuit.

(c) Essential electrical circuit protection is provided for all systems except the abort and reentry systems. These systems are not covered by breakers or fuses because of their critical nature. Therefore, they use current limiting resistors and series switching redundancy.

(d) Main batteries and most electrical equipment are located outside of the crew areas.

(e) Soviet analysis shows that battery hydrogen levels are maintained below hazardous levels.

In addition to analyzing the causative factors and the ability to control them, NASA is also developing "fire procedures." NASA's intent is to train the crew to react instinctively to fire by being thoroughly familiar with the fire sensing/alert system, the characteristics of fire in the Soyuz, as well as Apollo, and the fire suppression and evacuation procedures. Several additional points are noteworthy. The Soyuz does not contain fire suppression equipment as such. In case of fire or smoke in the OM the crew will evacuate to either DM or DV and suppress the fire by dumping the OM atmosphere. Thereafter, the OM could be repressurized if it were safe to do so. The Soviets do not consider the initiation of fire in the DV a credible failure.

NASA, as a part of its continuing examination of the fire hazard in Soyuz has requested additional information on characteristics and control of Soyuz flammable material to assure a complete analysis. In addition, JSC is continuing its studies of hydrogen gas generation from Soyuz silver-zinc batteries and the control of hydrogen peroxide from any leakage in the fuel line.

D. Contingency Planning

The basic principal of contingency planning is to maximize crew safety and then, secondly, achieve mission objectives. Planning for contingencies is an integral part of the mission planning process. The first step is to develop the basic plan which meets the specified requirements of a nominal mission. The second step is to identify the events which are critical to the success of the plan and identify potential contingency situations related to these events.

Several fundamental categories of problems are considered: problems related to limited consumables, problems of events not occurring or occurring in the wrong time and place, and system malfunctions. In the third step, these situations are evaluated. Some situations can be eliminated with modifications to the basic plan and hardware. Some situations can be corrected with procedures. Some situations have trivial consequences or a low probability of occurrence. Some situations have to be worked until the hard core problems are reduced to a minimum or acceptable level.

As a consequence of the iterative contingency planning process, nominal plans will provide for adequate margins of critical consumables. The maximum allowable usage for each consumable as a function of time will be established. Thus real time monitoring will provide consumables status in terms of these limits so that corrective action can be taken if the usage rate is excessive. As for problems with the non-occurrence of events or occurrence at the wrong time, the nominal plan is written to provide adequate margins. Alternate plans are provided as appropriate. As for system problems, backup and malfunction procedures are written for each system as required. This requirement is based on the impact of the loss, design of the system plus previous experience, redundancy, and the ability to take corrective action.

Used in this work are such documents as ASTP 50500 "Contingency Plan," IED 50724 "Analysis of Non-nominal Situations Involving the Soyuz Life Support Systems and Apollo Environmental Control Systems," ASTP 40301, ASTP 40401, ASTP 40600, and WG4-353.

As an example of the work being done, backup procedures are being developed for situations involving Apollo active and passive docking, rapid loss of pressure, and crew transfer.

Planning and operations personnel participate in the preparation and review of the hazard analyses and unilateral safety reports. Items which result from these activities will be integrated into the mainstream planning and training as they are identified.

In response to a request by the Panel, a briefing was provided on studies on the possible use of EVA during the ASTP mission. The material covered included: (a) crew transfer sequences, (b) toxicity and fire considerations, (c) seal and structural reliability, (d) environmental control and life support systems, and (e) system redundancy and reliability.

The studies showed that crew safety considerations are satisfied without EVA capability, and EVA capability would, in fact, complicate the joint operations without an attendant improvement in crew safety. For example, if loss of Docking Module pressure is caused by a valve failing open and the valves cannot be closed, the emergency DM oxygen pressure regulator will maintain the cabin above 3.5 psia for a minimum of fifteen minutes. This should be sufficient time for the crew to equalize pressure between the DM and the CM, transfer to the CM, and isolate the CM from the DM. Also, there are no single failure points in the hatches which would require an EVA.

E. Training.

The Panel reviewed the approach to training mission control personnel and flight crews in both nominal and contingency situations.

1. Training of Flight Controllers.

NASA flight controllers trained in Moscow in September 1974. The twenty member group included a full team of flight controller, communication specialists, technical specialists and interpreters. Training for Soviet controllers at the NASA mission control center also began this year. Additional control center tests and simulations are scheduled for March, May, and June/July. There will most likely be NASA observers at Soviet sites and vice versa during these tests. These observers will be technical specialists who will support the flight control team as well as the on-going working group efforts.

2. **Training of Flight Crew.**

Joint training will provide the crews an opportunity to: (a) familiarize themselves with Soyuz and Apollo spacecraft systems supporting the flight, (b) study the joint crew documents, (c) review contingency planning, and (d) develop working relationships.

Joint flight crew training hours will approximate 640 hours during the period July 1974 to April 1975 period. Total training for the astronauts in both Apollo and joint phases will be in the neighborhood of 2187 hours per crewman. This compares with some 1285 hours for each member of the Apollo 7 crew. Language training has been intensified to assure complete understanding of phrases and acronyms as well as normal conversation and reading materials. A good number of Soviet personnel have a working command of the English language.

Each crew has flown in the others trainers. The NASA trainer has a mockup of both the Apollo and Docking Module cabins while the Soyuz trainer has a mockup of the descent vehicle and

Orbital Module. In each case flight effects are created by visual aids. These trainers are used for both training and simulation. Training assures knowledge of hardware and its operation but does not necessarily duplicate mission conditions. Simulation recreates the actual mission and includes both nominal and non-nominal conditions.

Simulations to date are using the nominal flight procedures. Procedures for non-nominal situations will then be introduced.

3.0 ATTACHMENT - 1

Attachment No. 1

AEROSPACE SAFETY ADVISORY PANEL

QUESTIONS OF DECEMBER 1974

Question:	1.	What is the written ground-rule for mission management in the event of the loss of all nine long lines between Moscow and Houston during mission?
Answer:		We currently plan to continue the joint mission as planned while troubleshooting progresses.
Question:	2.	What is the situation where a fire in the Orbital Module results in retreat to the Descent Vehicle and depressurization of the Orbital Module? Would NASA want to repressurize the Orbital Module and transfer our crewman back to the Command Module? Could there be an toxic material remaining in the Orbital Module? What if fire was to destroy wiring to repressurize system, etc.?
Answer:		The question of repressurizing the Orbital Module to complete a return transfer is still under consideration and must be discussed further with the USSR. The alternative is to return in the Soyuz Descent Vehicle. This course of action would also be required if the fire precluded repressurization.
Question:	3.	What is the status on taking a fire extinguisher into the Orbital Module? Early meetings indicated that we would not take or use a fire extinguisher into the Orbital Module. Current groundrules indicate we would.
Answer:		Under nominal conditions, we currently do not plan to take a fire extinguisher into the Soyuz. However, we do have contingency procedures by which a member of the Apollo crew would stand by with the DM fire extinguisher in event of a fire in the Orbital Module. This subject including the potential use of the DM extinguisher in the DM will be discussed with the USSR in January.

Question: 4. What is the adequacy of the data base for the conclusion that there are no hazards associated with the Soyuz electrical system?

Answer: The data base is as provided in the unilateral system safety report for Soyuz electrical power system for the ASTP. Some additional questions have been defined as a result of the review of this report and these will be discussed with the USSR in January. In addition, one hazard, the potential for an explosive mixture existing in the descent batteries if a short occurs, will be further explored in January.

Question: 5. How does the safety of ASTP compare with the safety of the Skylab CSM? What is the basis for this conclusion?

Answer: The safety program for the US ASTP hardware is the same as that for the Skylab CSM. Based upon our overall approach to joint mission, i.e., planning to ensure a static and benign environment, and assuming satisfactory resolution of current open Soyuz safety questions, we feel the safety of the overall mission is comparable to that of the Skylab missions.

Question: 6. To what extent and in what areas are the mission rules significantly different than those for prior Skylab flights? What are the associated hazards, if any?

Answer: Major areas of difference are as follows:

a. Some rules related to joint mission provide for coordination between US & USSR control centers prior to implementation.

b. There is no overall spacecraft commander - the Soyuz commander is responsible for Soyuz and Apollo commander is responsible for Apollo.

c. New mission rules developed for Docking Module/Docking System operations.

d. Mission rules to cover transposition, docking and extraction of DM.

e. Experiment unique mission rules.

Question: 7. What is the current plan for translating the results of the hazard tree analyses, etc. into contingency planning and joint crew training in contingency procedures?

Answer: Planning and operations personnel are an integral part of the preparation and review of the hazard analysis and unilateral safety reports. Items which result from these activities will be integrated into the mainstream planning and training as they are identified.

Question: 8. What provision has been made for evaluating the age-life effects and reliability of the launch escape system on the CSM?

Answer: The age-life analysis for the launch escape system and the CSM have been completed and all components are within age-life limits.

Question: 9. What were the results of Soyuz 16? Were there configuration differences that would qualify the results?

Answer: Based upon preliminary telephone reports from the USSR, the Soyuz 16 spacecraft achieved the ASTP target orbit, depressurized to 10 psi, and exercised the Docking System successfully. Based upon previous discussions, we do not believe that there were any configuration differences which would negate the results of the flight. A more detailed evaluation cannot be made until after the January meeting.

Question: 10. What is the suit-donning time and the ability of the crew to transfer to their spacecraft?

The nominal 4th transfer time is 110 minutes. We have defined a quick return 4th transfer procedure which requires approximately 28 minutes. Once in the CSM, 15 to 30 minutes are estimated to don and pressurize the suits.

Question: 11. What assessment has been made of sharp projections in Apollo, DM and Soyuz? Is there a hazard to the crew?

Answer: Based upon our mock-up familiarization and training activities we have found no crew hazards due to sharp projections in Apollo, DM or Soyuz.

Question: 12. What were the results and problems, if any, of this December's "ground personnel procedures checkout," including the adequacy of the communication systems?

Answer: The test results were considered satisfactory.

4.0 TABLES AND FIGURES

TABLE I

DOCKING SYSTEM DEVELOPMENT PROBLEMS

	Problem	Resolution
1.	Capture latches failed to capture at -100°F. (flight predicted -58°F.).	Grease in bearings changed to F-50 oil. Screen latches at -100°F.
2.	Structural latch failed to reset at -31°F. (not a normal flight condition).	Definitive cause not established. Reset cable rigging revised and low temperature system screen implemented.
3.	Attenuator leakage detected.	Contamination in seals. Refurbished attenuators still show some leakage in quality test. Monitor leakage and replace if required.
4.	Indicator switch movement during quality and acceptance vibration test.	Redesigned switch mounting and conducted delta quality test to assure adequacy.
5.	Capture latch assembly shifted during quality vibration test.	Redesigned latch mounting for positive positioning (not dependent on friction) and incorporated in qualification test.
6.	DS-1 retract cable frayed following initial thermal/vacuum test.	Completed qualification test with frayed cable. Probable cause identified as rigging error which damaged cable. Inspected flight system.
7.	Intermittent capture identification.	Design permits intermittent operation; indicator is used as cue to terminate thrust for capture. Understand and accept.
8.	Tunnel insulation debonded during thermal/vacuum test.	Redesigned using beta cloth blanket and retained velcro and mechanical fasteners. Completed verification.
9.	Screws backed out during DS-5 vibration test.	Analysis of all screw installations. Reverification of critical applications. Disassembled gear boxes retorqued.
10.	Retract cable slack during acceptance test.	Redesigned to reduce sensitivity to cable slack.

TABLE II

CONTRACTOR ANALYSIS OF HARDWARE FOR ASTP DOCKING SYSTEM (TYPICAL)

Part:	Spring-motor, gear-box, cable-retract-system
Application:	To provide tension on cable during initial capture
Material:	PH15-7 Mo Cond A CRES Sheet - RH1075 Temper
Stress:	Residual stress arises from loading in the wound position at a calculated 69.5 in. lb. torque Calculated stress = 108,000 psi Stress corrosion threshold = 85,000 psi 85,000 ÷ 1.5 safety factor = 56.67 KSI (threshold)
Evaluation:	Stress Level: greater than threshold Consequence of Failure: criticality 3 - not adverse Environment: atmospheric air - adverse Surface Protection: passivated - not adverse Category: AC (one factor adverse - stress corrosion remote)
Rationale:	Function is strictly convenience - mission not impaired by failure. No corrective action warranted.

TABLE III

USSR AND UNITED STATES EXPERIMENTS

Astronomy

MA-048	Soft x-Ray
MA-083	Extreme UV Survey
MA-088	Helium Glow
MA-148	Artificial Solar Eclipse
MA-151	Crystal Activation

Earth's Environment

MA-059	UV Absorption
MA-007	Stratospheric Aerosol Measurement
MA-136	Earth Observations and Photography
MA-089	Doppler Tracking
MA-128	Geodynamics

Radiation Effects

MA-106	Light Flash
MA-107	Biostack
MA-147	Zone Forming Fungi

Immune System

AR-002	Microbial Exchange
MA-031	Cellular Immune Response
MA-032	Polymorphonuclear Leuko Cyte Response

Medical Applications

MA-011	Electrophoresis Technology
MA-041	Electrophoresis

Material Applications

MA-010	Multi-purpose Furnace
MA-028	Crystal Growth

TABLE IV

USSR ASTP GROUND TEST PROGRAM

Orbital Module structure static test.

Dynamic tests of Orbital Module structure.

Final development layout of compatible equipment in living compartments and of the exterior elements (target, etc.) in mockup.

Development of the Life Support System incorporating new and modified equipment.

Orbital Module thermal conditions development.

Spacecraft antenna mockup.

Docking dynamics development.

Docking system development and interface pressure integrity control check in the thermal/pressure chamber.

Bench set for docking system structure components development and verification.

USSR/USA nominal docking system fit check.

TABLE V

SOYUZ FACTORY CHECKOUT SEQUENCE

MODULE AND HYDROPNEUMATIC LINE PRESSURE INTEGRITY CHECK AFTER INSTALLATION ONBOARD THE SPACECRAFT

PYROS CIRCUIT CHECK

DOCKING SYSTEM AUTONOMOUS CHECK OF OPERATION

CHECK OF RF COMMUNICATION LINKS AND ANTENNAS

CHECK OF EXTERNAL DEVICE DEPLOYMENT MECHANISM AND ACCURACY OF INSTALLATION, INCLUDING DOCKING TARGET ALIGNMENT

SENSORS AND MEASUREMENT SYSTEMS EQUIPMENT CHECK

AUTONOMOUS ELECTRICAL VERIFICATION TESTS OF SPACECRAFT SYSTEMS

TEST ACTIVATION OF RADIO TELEMETRY SYSTEMS

TEST ACTIVATION OF LIFE SUPPORT SYSTEM, EVERYDAY USAGE EQUIPMENT, MOVIE AND PHOTO EQUIPMENT, ORIENTATION LIGHTS AND FLASHING BEACONS

INTEGRATED TESTS (ELECTRICAL)

PREPARATION FOR TRANSPORTATION

TRANSPORTATION TO TECHNICAL SITE OF THE LAUNCH COMPLEX

TABLE VI

PERMISSIBLE CONCENTRATIONS OF CONTAMINANTS IN THE SPACECRAFT ATMOSPHERE

a.	Carbon monoxide	0.01 mg/1
b.	Ammonia (and amines)	0.002 mg/1
c.	Acetone	0.04 mg/1
d.	Aldehydes	0.001 mg/1
e.	Acetic acid	0.001 mg/1
f.	Hydrogen sulfide (and mercaptans)	0.0015 mg/1
g.	Total organic oxidizable impurities	0.150 mg/1
h.	Helium	not more than 0.5% of the volume
i.	Hydrogen	not more than 1% of the volume

j. The following cleaning agent solvents, or chemicals must not be used in or around the spacecraft or during manufacture of its components:

Mercury

Materials containing organic-phosphorus compounds and other substances which may prove to be allergenic or carcinogenic.

Carbon tetrachloride

Chloroform

Trichloroethylene

TABLE VII

THE SOYUZ PYROTECHNICS

No.	Function	Type	Quantity
1.	APDS passive hooks' jettison	Explosive Bolt	8
2.	APDS active hooks' jettison	Explosive Bolt	8
3.	APDS latches' jettison	Explosive Bolt	3
4.	OE-ODE lines backup control	Pyrocartridge	11
5.	Service prop. backup pressurization	Pyrocartridge	2
6.	Unblocking of pressure unit	Pyrocartridge	1
7.	Control Unit of DV Control System	Pyrocartridge	11
8.	Sight jettison	Pyrocartridge	2
9.	OM-IAM cable path separation	Pyrocartridge	8
10.	DV-OM separation	Explosive Bolt	6
11.	DV-OM separation	Pyrocartridge	6
12.	Feed-through jettison	Pyrocartridge	4
13.	DV-IAM separation	Pyrocartridge	6
14.	Cover jettison, primary parachute container	Pyrocartridge	24
15.	Cover jettison, backup parachute container	Pyrocartridge	18
16.	Breathing vent unblocking	Pyrocartridge	4
17.	Front Shield separation	Pyrocartridge	12
18.	Arming of couch shock absorbers	Pyrocartridge	4
19.	Firing of soft landing engines	Pyrocartridge	4
20.	Cooling System line control	Pyrocartridge	4
21.	Antenna Control	Pyrocartridge	4

(No pyro devices to open solar panels, antenna and docking target are listed in the above table)

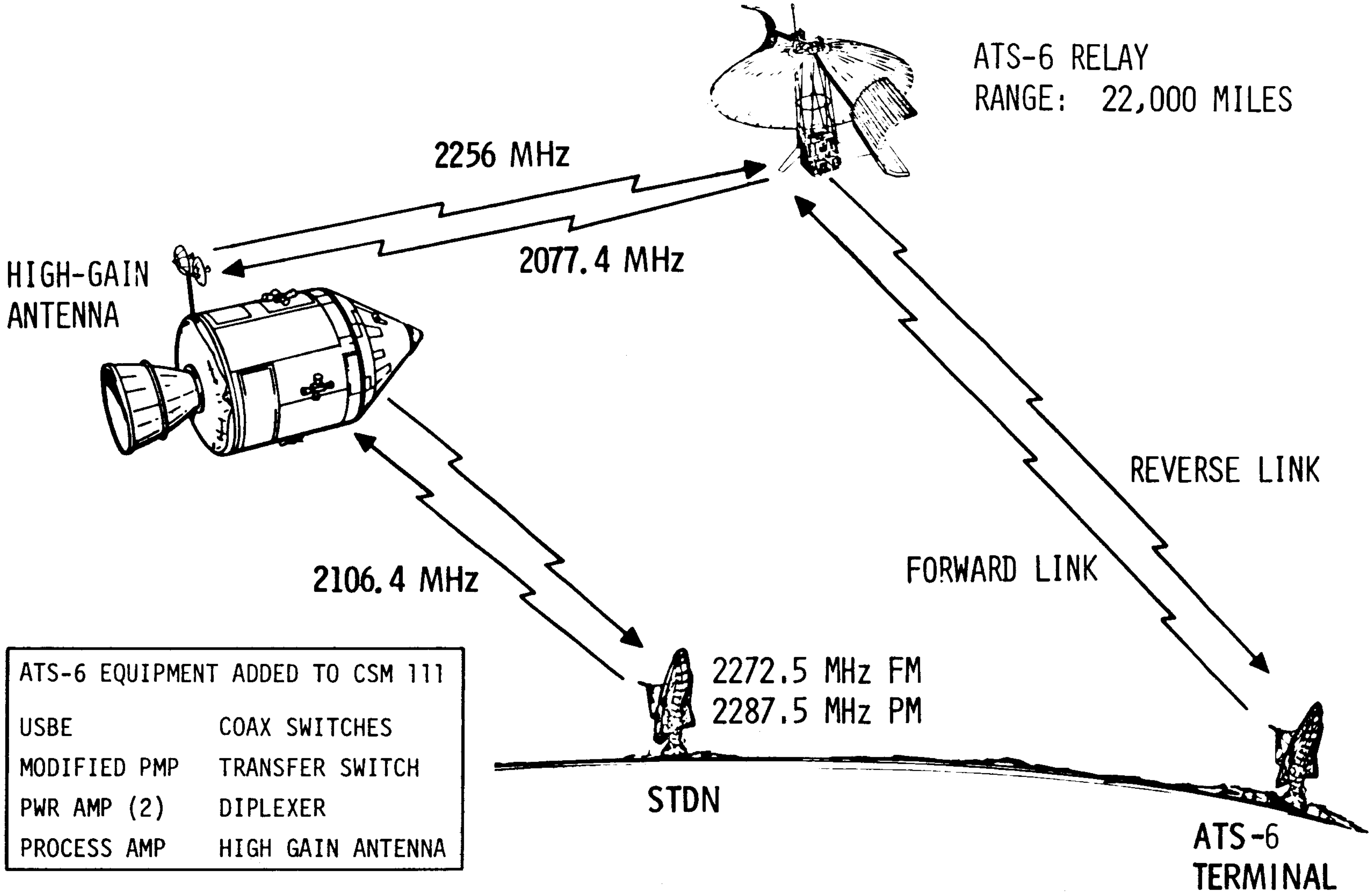
(APDS = Androgynous Peripheral Docking System)

TABLE VIII

COMPARISON OF APOLLO AND SOYUZ PYROTECHNIC INITIATORS

CHARACTERISTIC	SOYUZ	APOLLO
INITIATOR TYPES	USE TWO TYPES OF INITIATORS 1. Dual bridgewire cartridges 2. Pyrotechnic bolts	USES STANDARD SINGLE BRIDGEWIRE INITIATOR FOR ALL FUNCTIONS (SBASI)
PYROTECHNIC MATERIALS	UNKNOWN	ZIRCONIUM AND POTASSIUM PERCHLORATE
DC SAFE POWER LEVEL (NO-FIRE LEVEL)	$\approx$1.5 MILLIWATTS/50 MILLIAMPS	$\approx$1 WATT/1AMP FOR 5 MINUTES
DC FIRE LEVEL	$\approx$ 400 MILLIWATTS	$\approx$3.5 WATTS
RF FIRING LEVELS	SAME AS FOR DC: PIN-TO-PIN MODE ONLY	VARIES WITH FREQUENCY: PIN-TO-PIN AND PIN-TO-CASE MODES
CIRCUIT SHIELDING	CONTINUOUS FROM FIRING RELAYS TO INITIATOR. 360° CONNECTION AT INITIATOR BACKSHELL	SHIELDING HAS DISCONTINUITIES AT BULKHEAD CONNECTORS. 360° CONNECTION AT INITIATOR BACKSHELL
TWISTED PAIR WIRING	YES	YES
CIRCUIT GROUNDING	FLOATING FIRING CIRCUITS	GROUNDED/SHORTED FIRING CIRCUITS WHEN SAFED

ASTP/ATS-6 RELAY



ATS-6 EQUIPMENT ADDED TO CSM 111	
USBE	COAX SWITCHES
MODIFIED PMP	TRANSFER SWITCH
PWR AMP (2)	DIPLEXER
PROCESS AMP	HIGH GAIN ANTENNA

Figure 1

DM ON TRUSS IN SLA

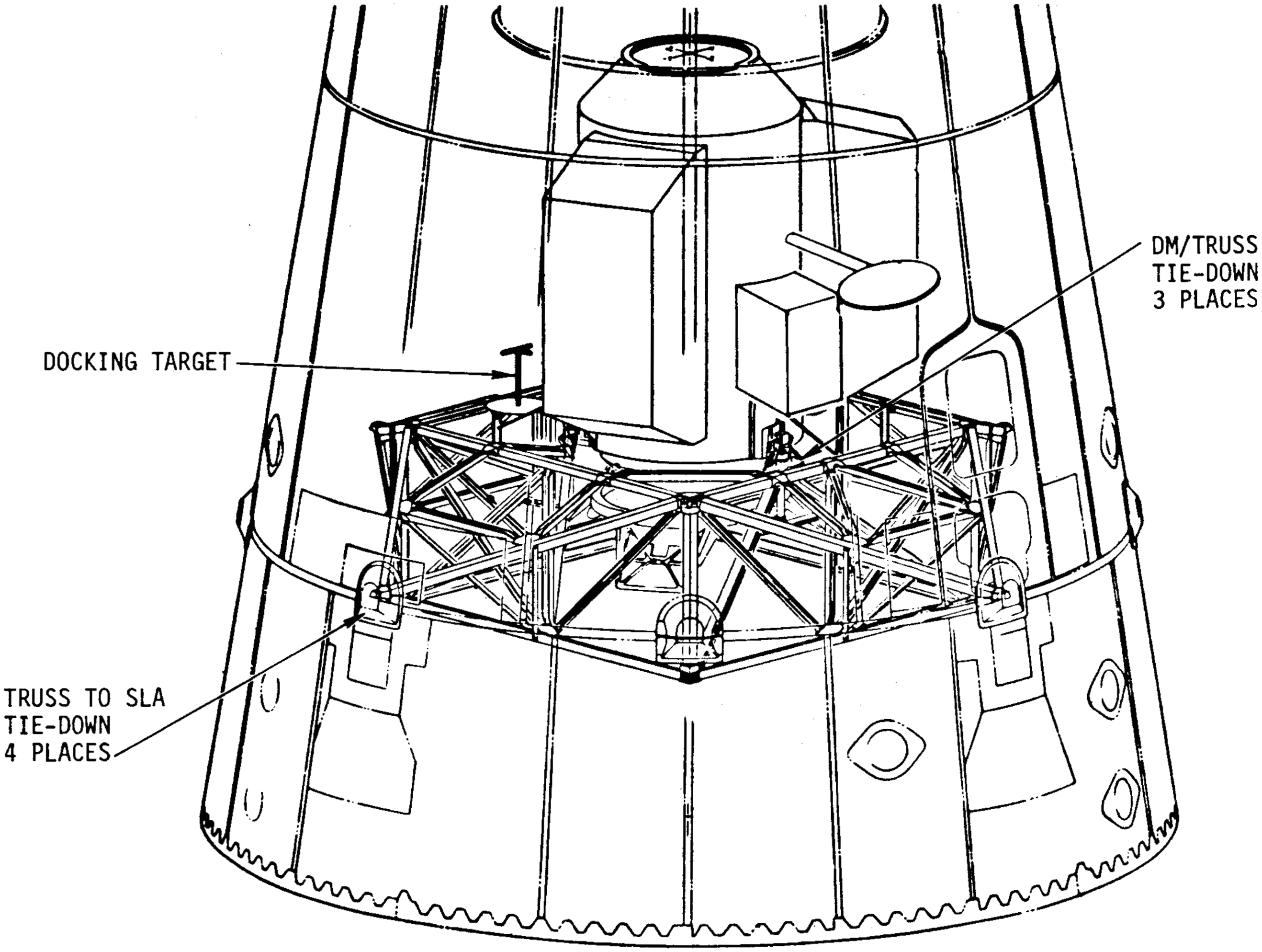
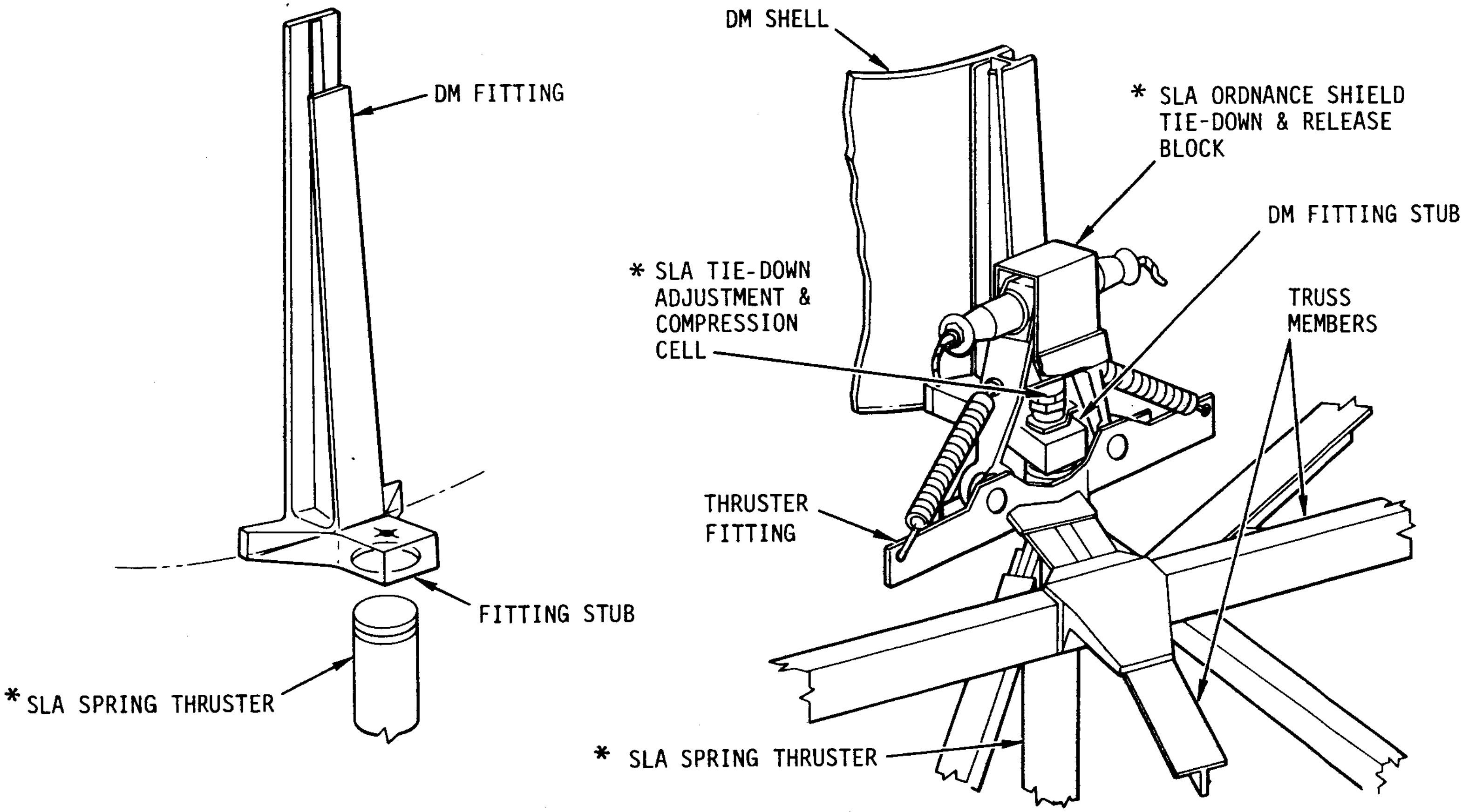


Figure 2

DM/TRUSS SUPPORT FITTING AND TRUSS RELEASE MECHANISM



* SLA INDICATES PARTS USED FOR LM/SLA TIE-DOWN ON APOLLO MISSIONS

Figure 3

DOCKING MODULE
PRIMARY STRUCTURE

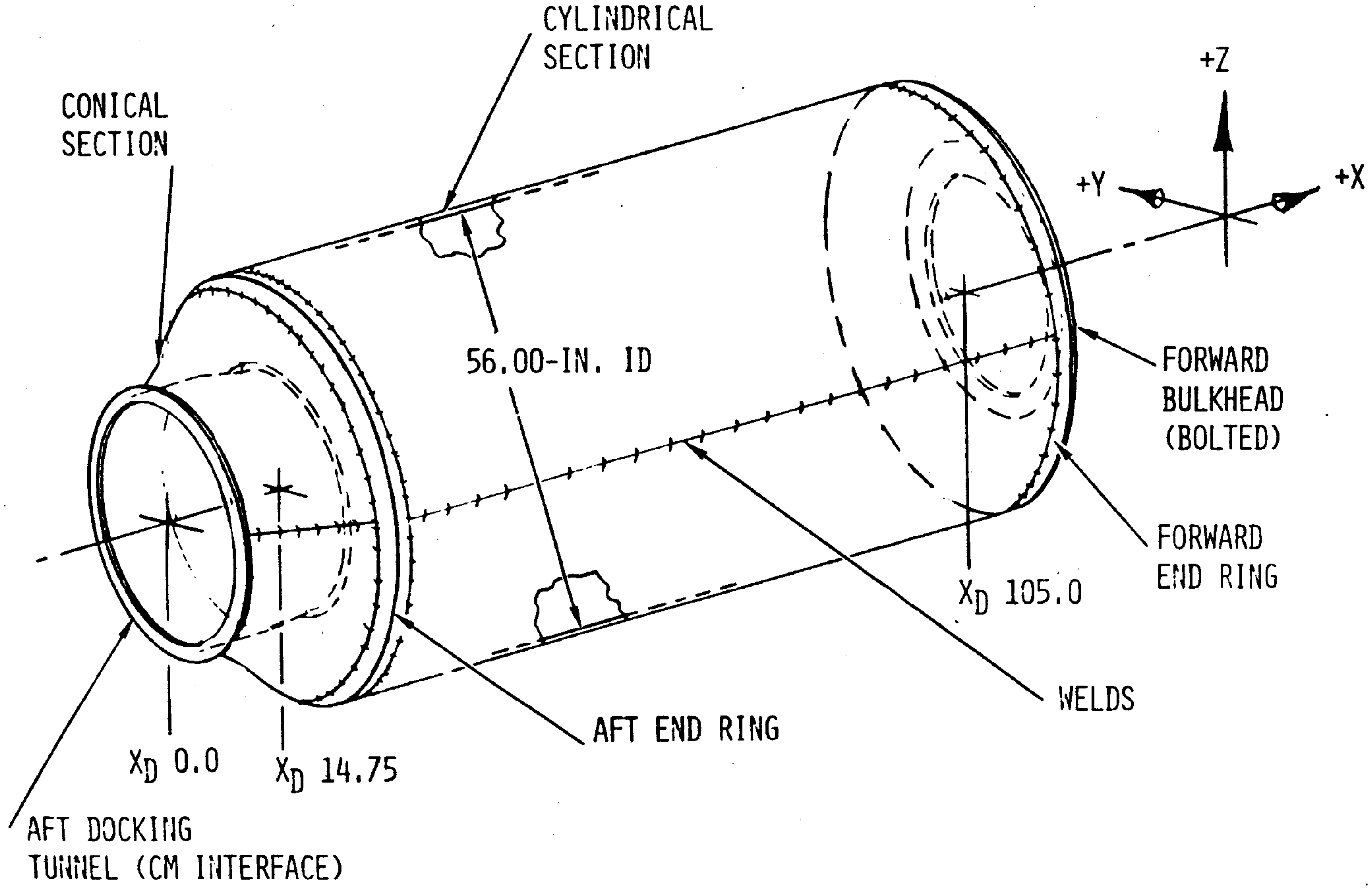


Figure 4

DM IN-FLIGHT STOWAGE CONFIGURATION

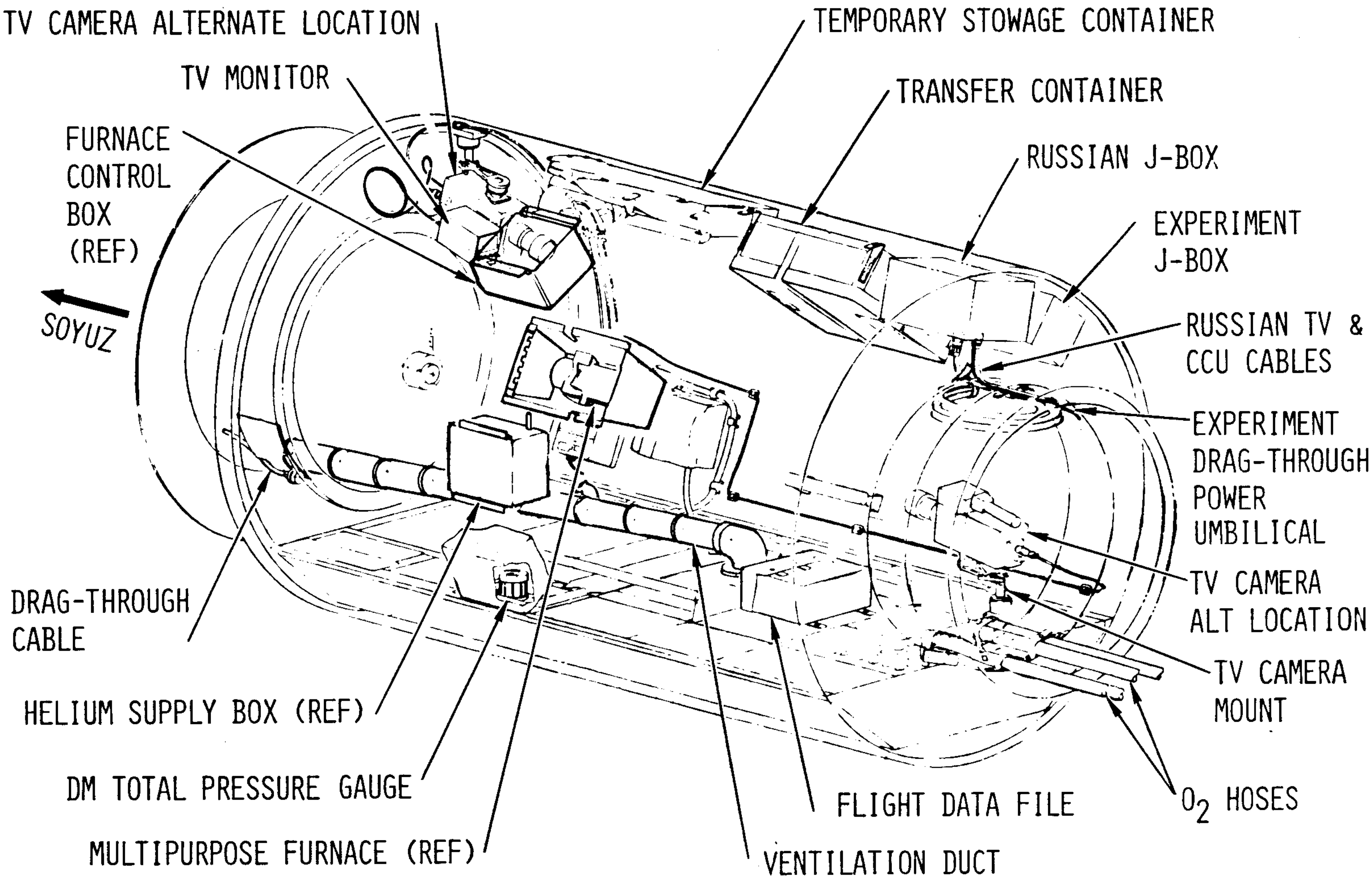


Figure 5

DOCKING MODULE
GAS STORAGE TANK

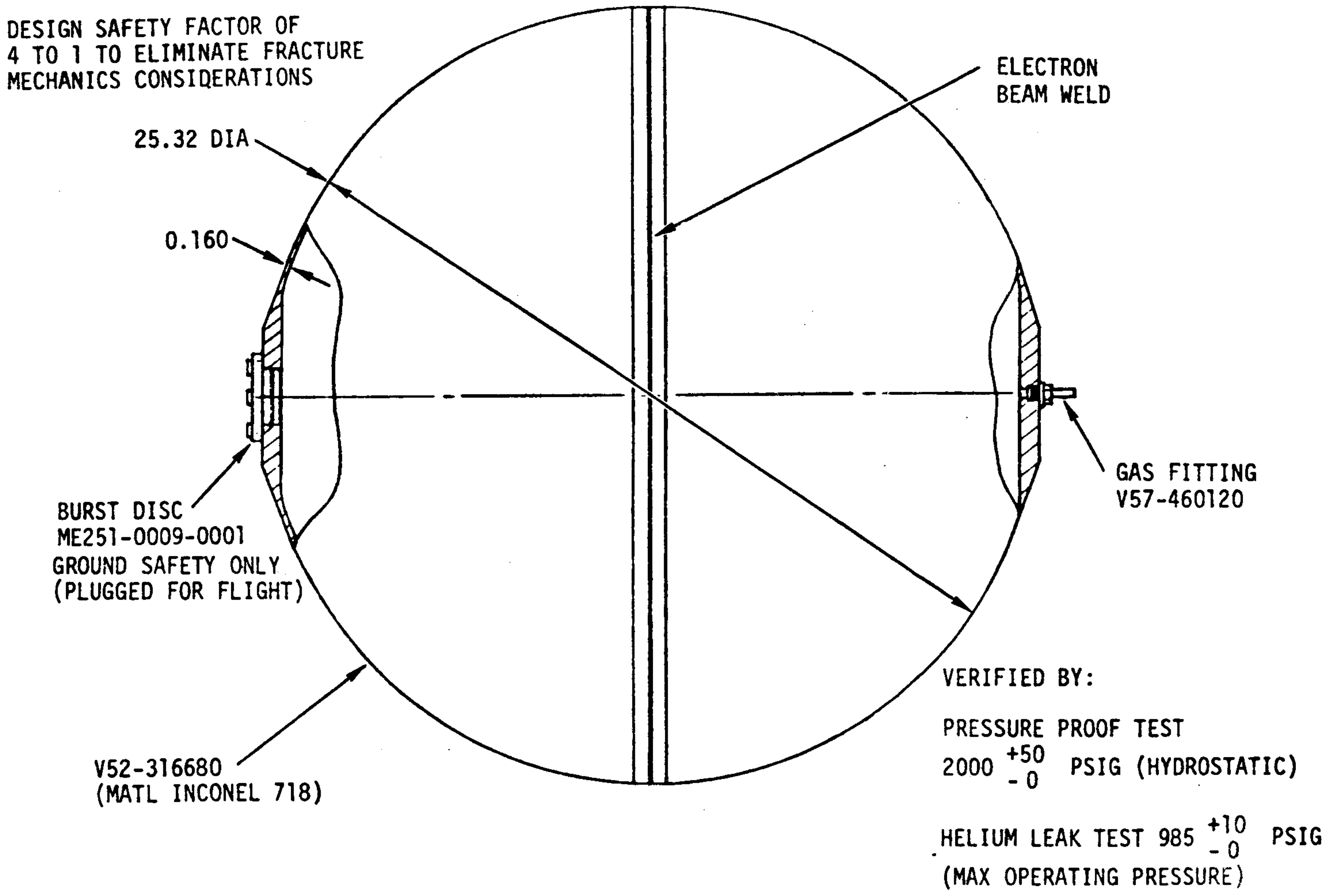


Figure 6

DOCKING MODULE

DOCKING SYSTEM AND FORWARD BULKHEAD JOINT SEALS

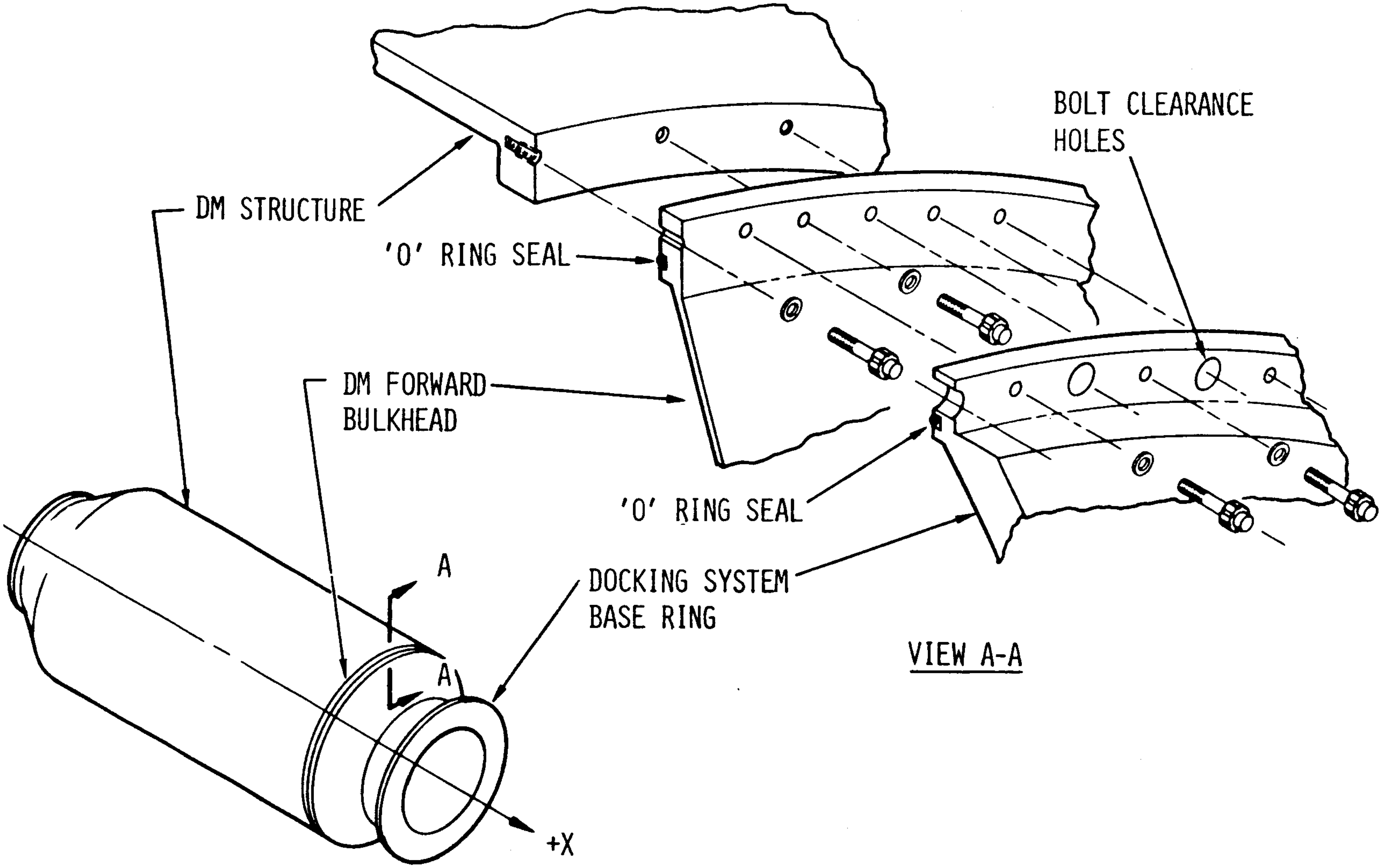


Figure 7

ASTP DM ELECTRICAL POWER SYSTEM
CM/DM POWER DISTRIBUTION AND CONTROL SCHEMATIC

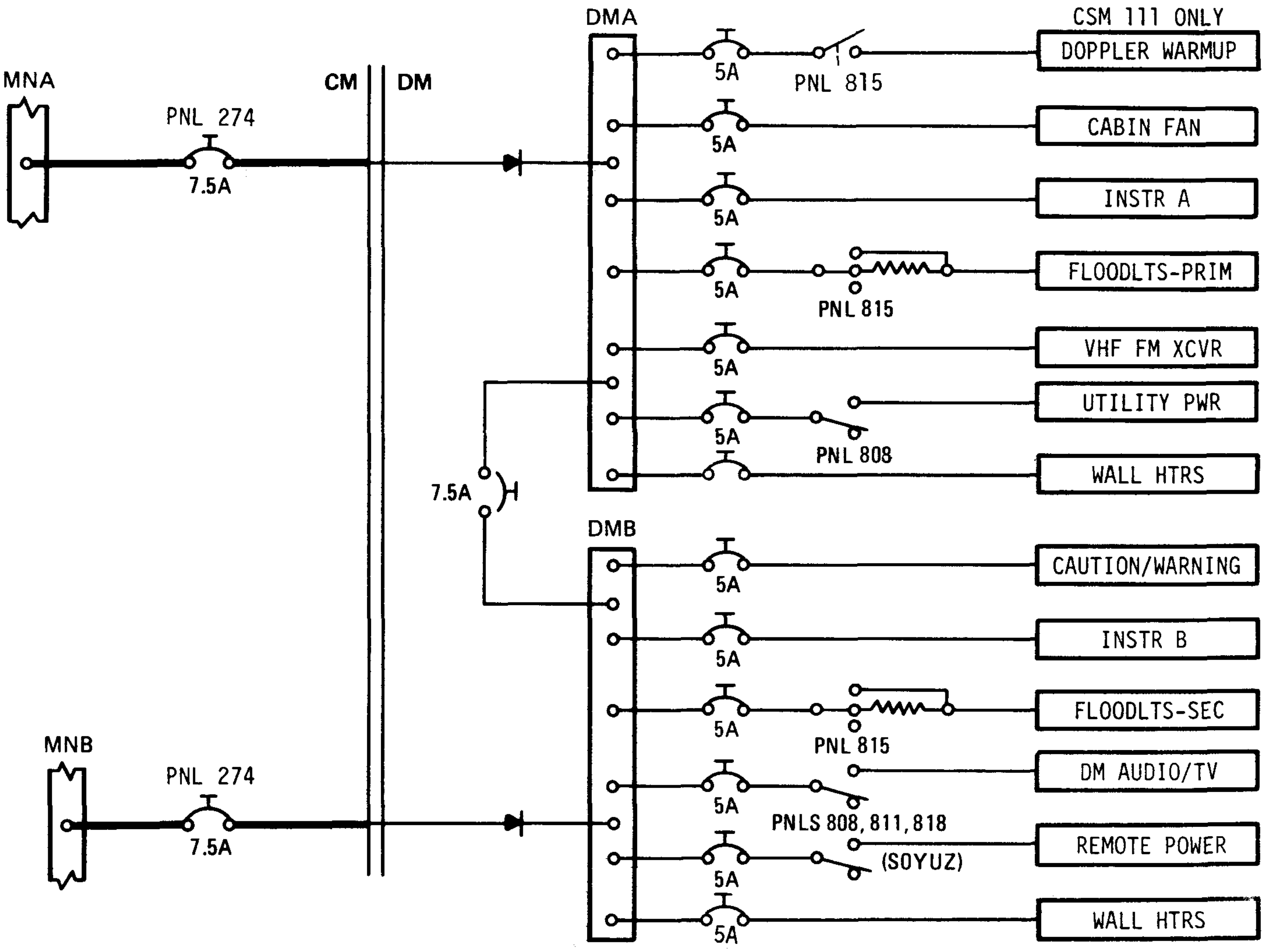


Figure 8

ASTP/DM ELECTRICAL POWER SYSTEM
SIMPLIFIED DM HARNESS DIAGRAM

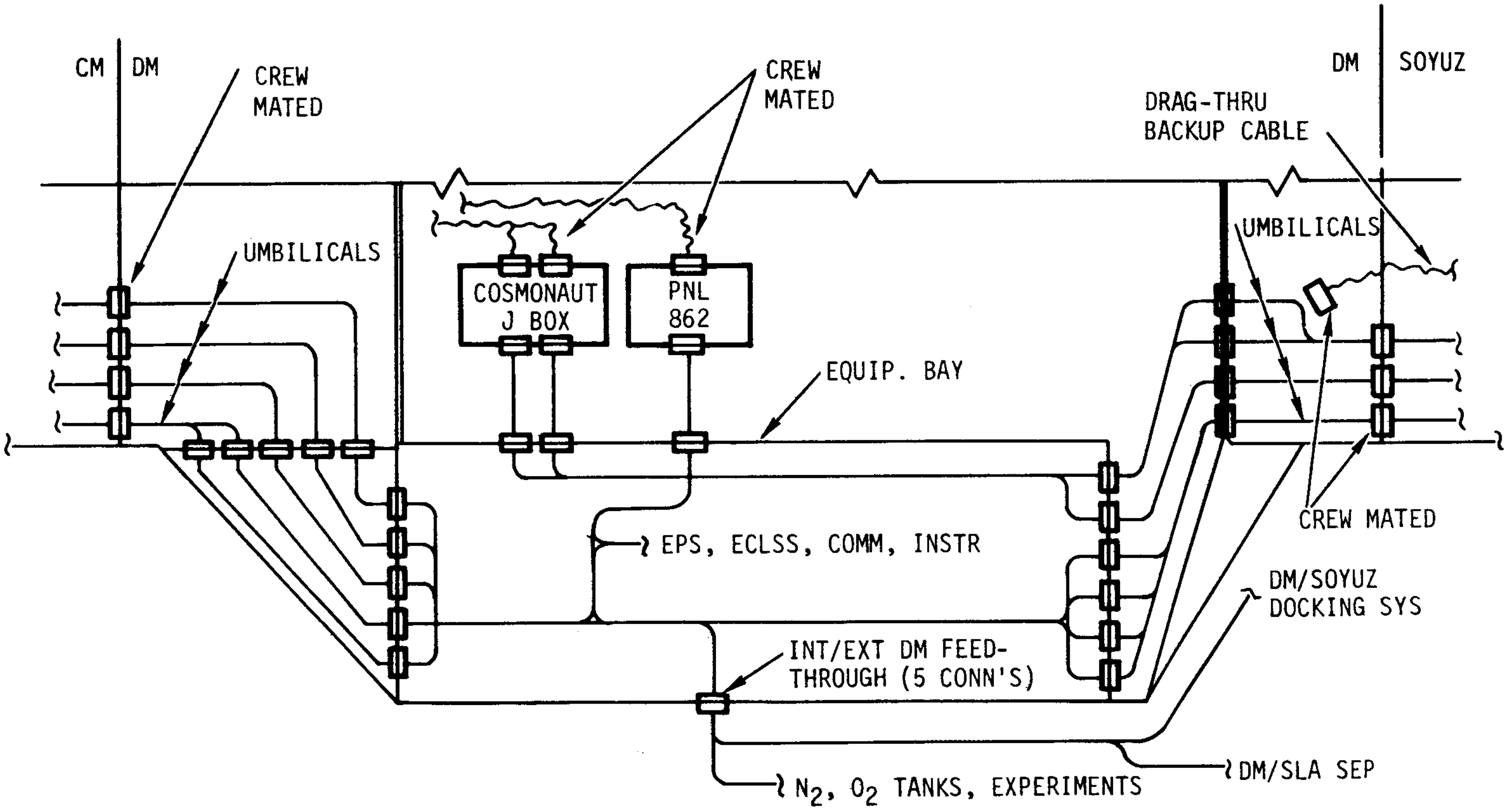


Figure 9

ASTP ELECTRICAL POWER SYSTEM
CM/DM UMBILICAL CONNECTIONS

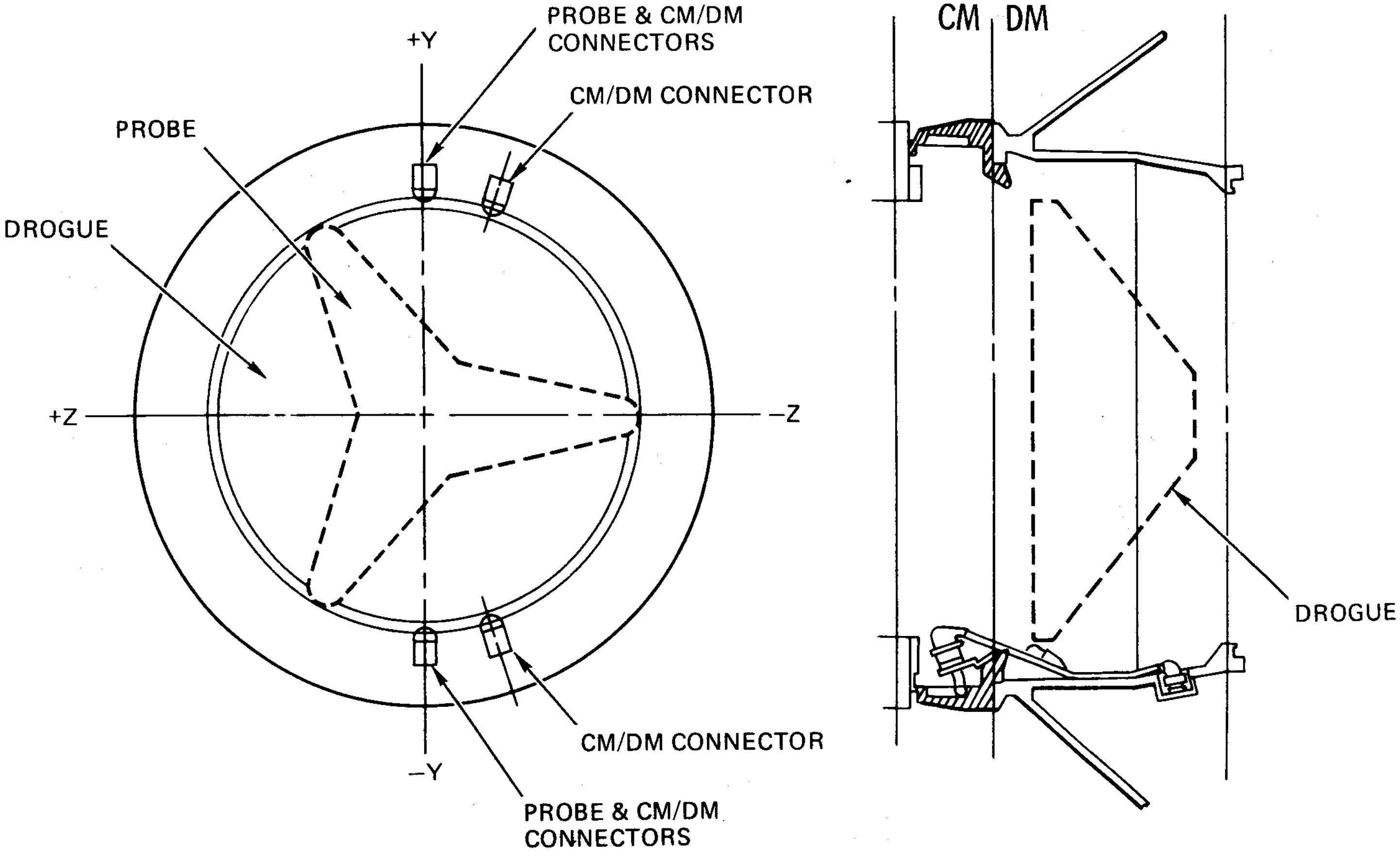


Figure 10

ASTP ELECTRICAL POWER SYSTEM DM/SOYUZ INTERFACE CONNECTIONS

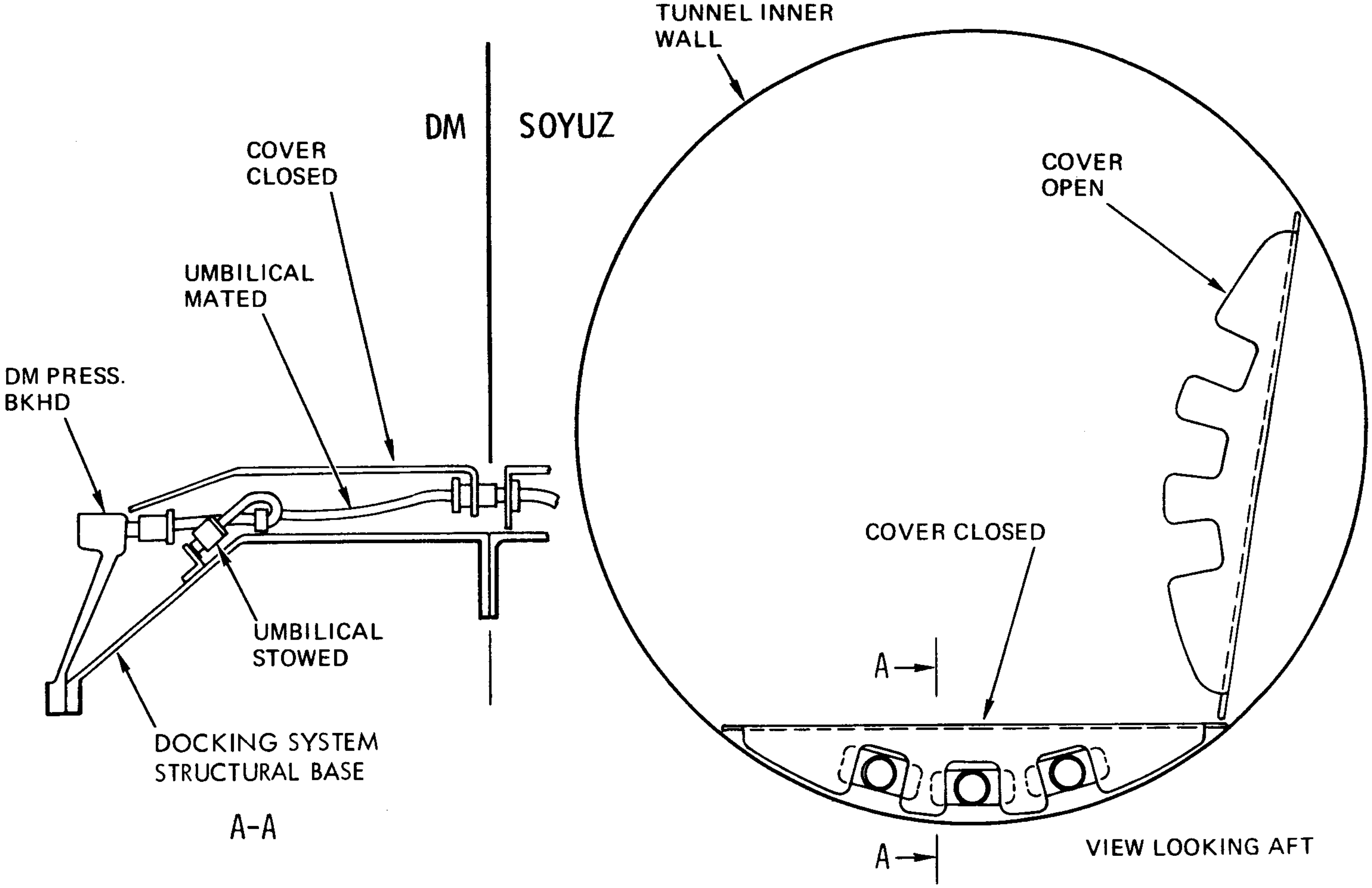


Figure 11

ASTP DOCKING SYSTEMS 5 & 7

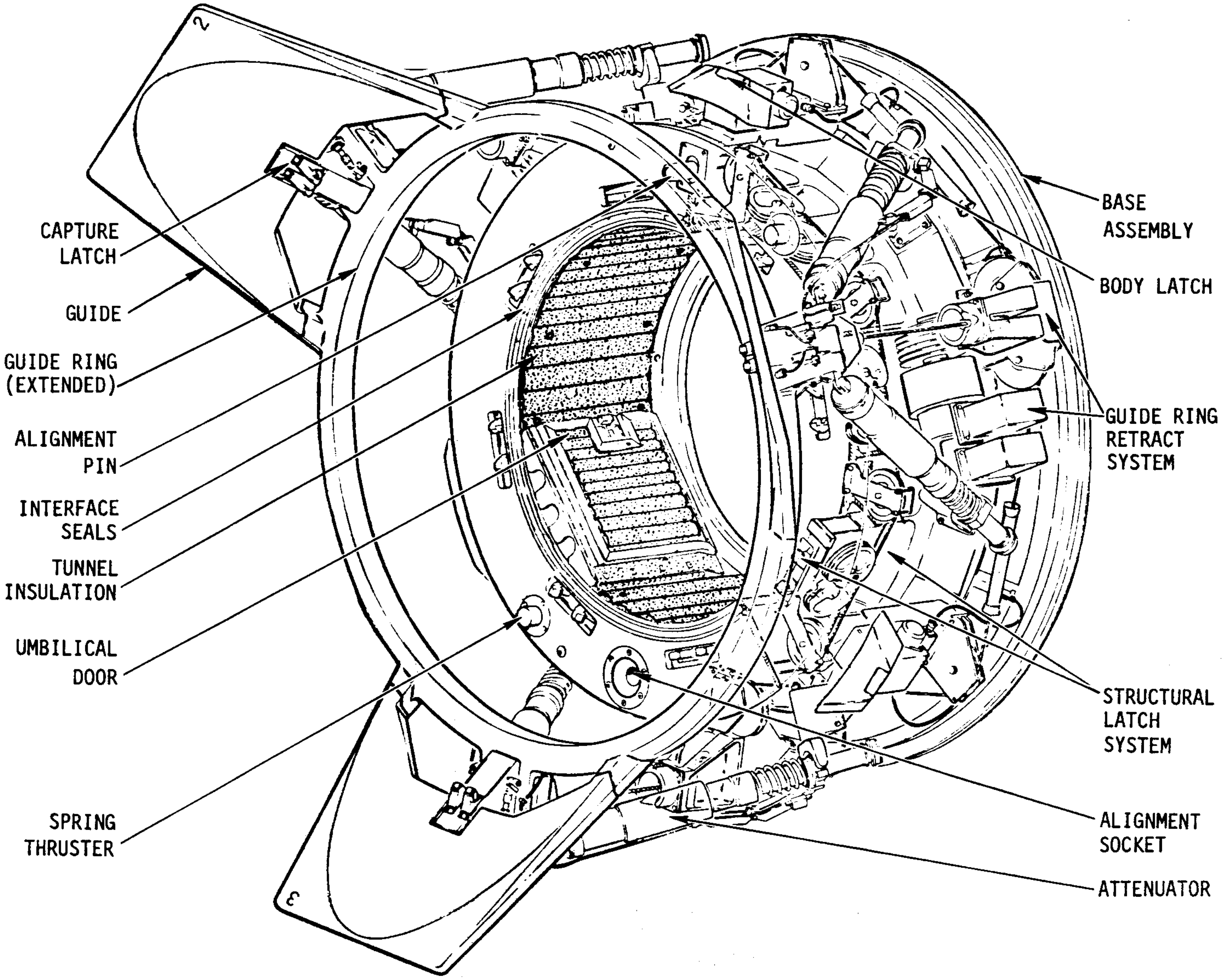


Figure 12

ASTP DOCKING SYSTEM
INTERFACE SEALS

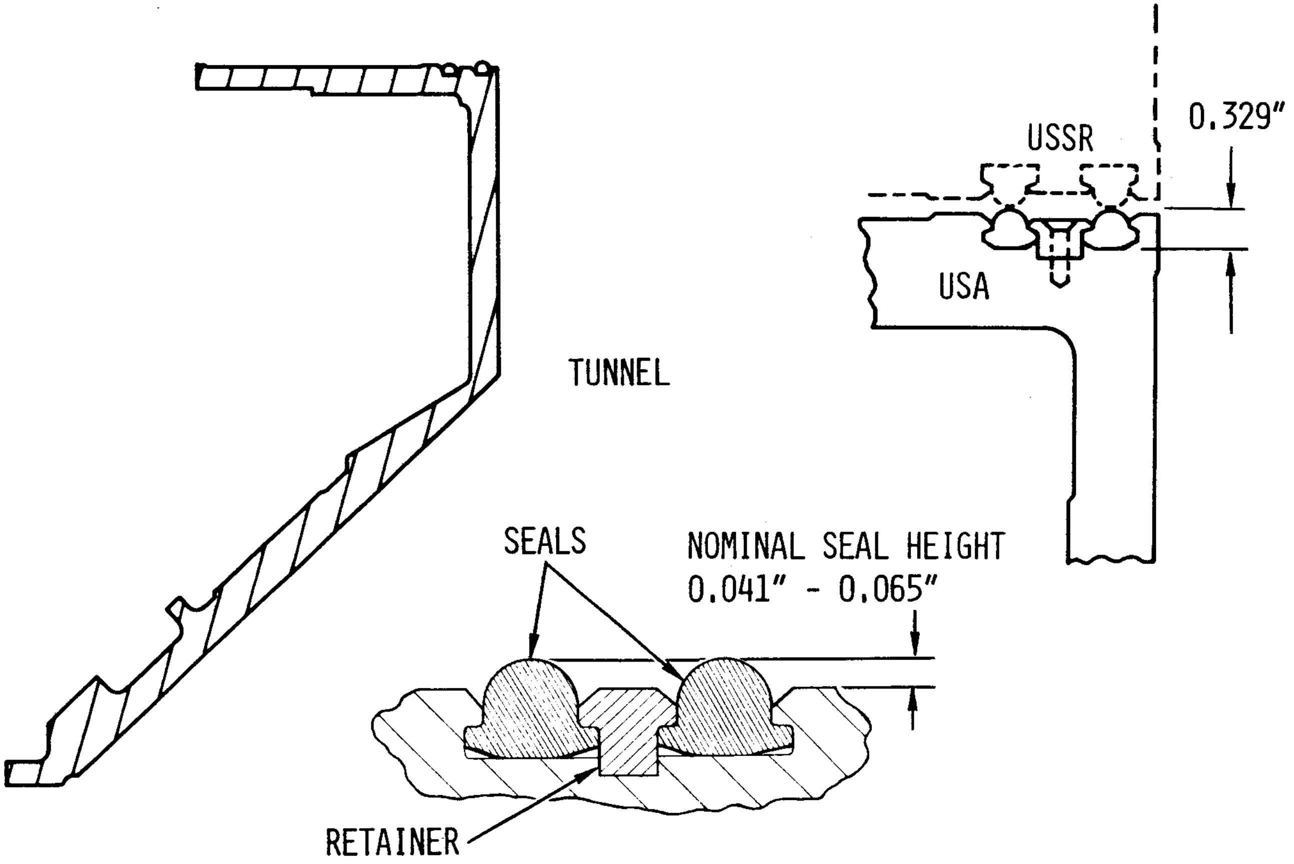


Figure 13

ASTP EXPERIMENT LOCATION

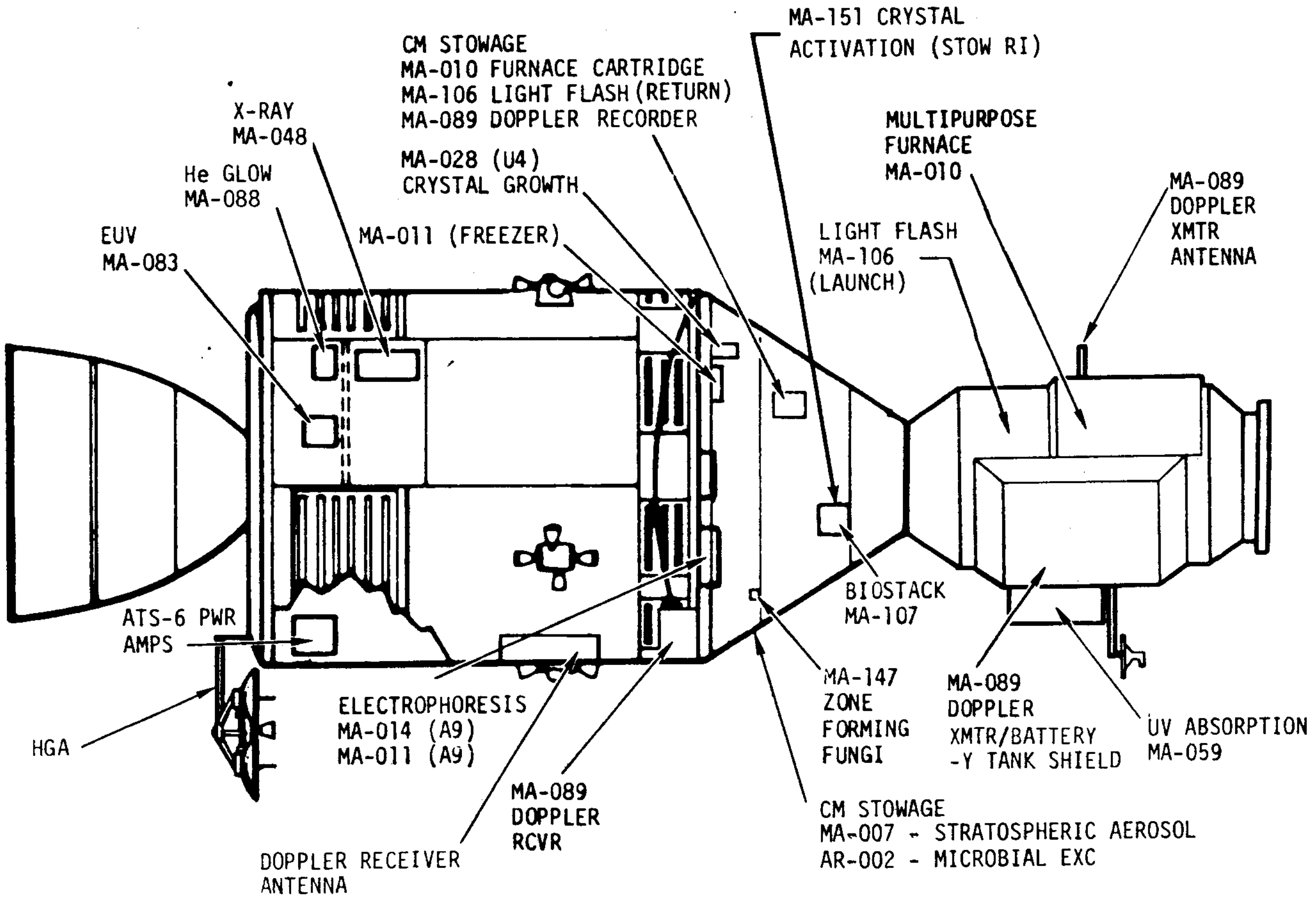
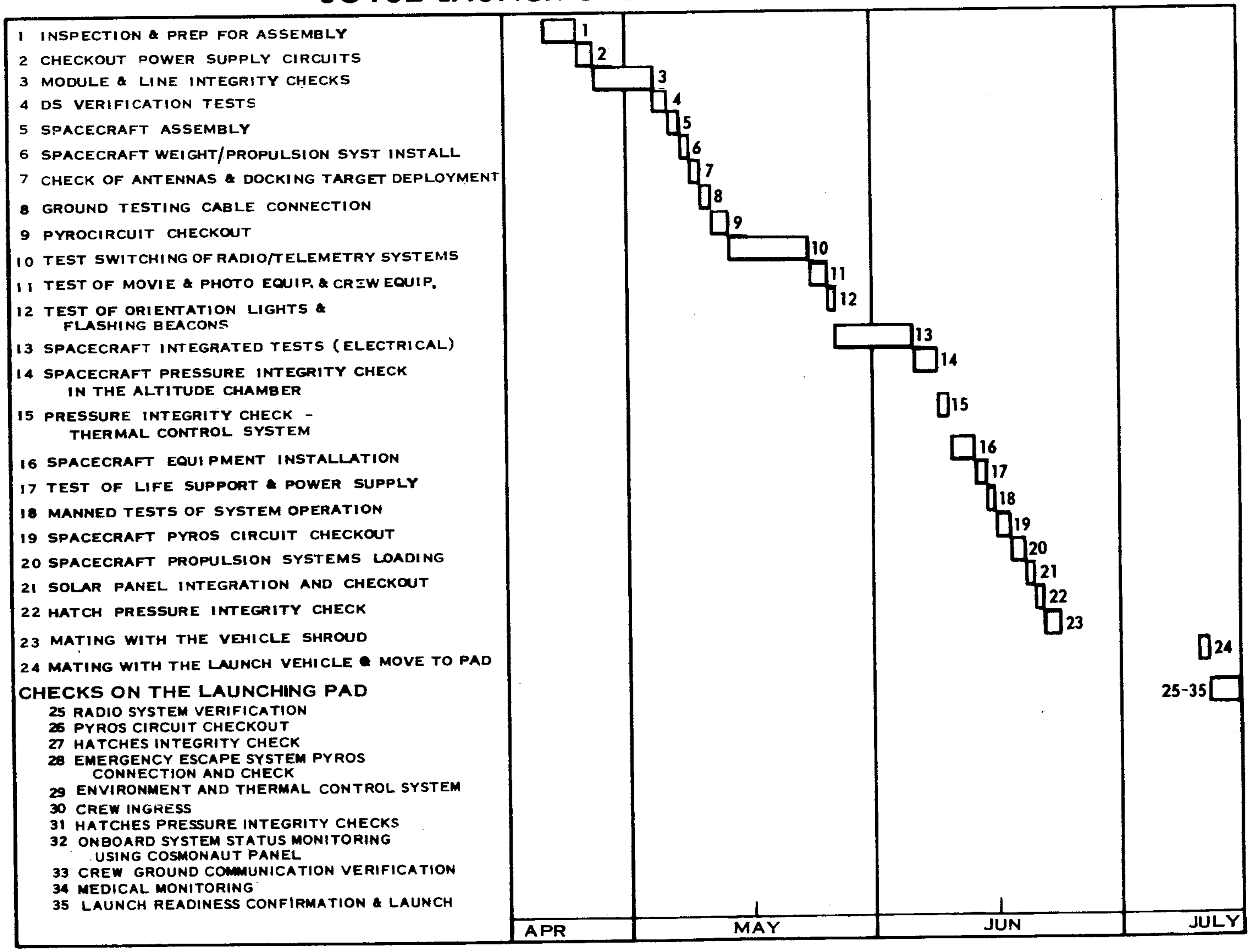


Figure 14

SOYUZ LAUNCH SITE CHECKOUT FLOW



1 INSPECTION & PREP FOR ASSEMBLY
2 CHECKOUT POWER SUPPLY CIRCUITS
3 MODULE & LINE INTEGRITY CHECKS
4 DS VERIFICATION TESTS
5 SPACECRAFT ASSEMBLY
6 SPACECRAFT WEIGHT/PROPULSION SYST INSTALL
7 CHECK OF ANTENNAS & DOCKING TARGET DEPLOYMENT
8 GROUND TESTING CABLE CONNECTION
9 PYROCIRCUIT CHECKOUT
10 TEST SWITCHING OF RADIO/TELEMETRY SYSTEMS
11 TEST OF MOVIE & PHOTO EQUIP. & CREW EQUIP.
12 TEST OF ORIENTATION LIGHTS & FLASHING BEACONS
13 SPACECRAFT INTEGRATED TESTS (ELECTRICAL)
14 SPACECRAFT PRESSURE INTEGRITY CHECK IN THE ALTITUDE CHAMBER
15 PRESSURE INTEGRITY CHECK - THERMAL CONTROL SYSTEM
16 SPACECRAFT EQUIPMENT INSTALLATION
17 TEST OF LIFE SUPPORT & POWER SUPPLY
18 MANNED TESTS OF SYSTEM OPERATION
19 SPACECRAFT PYROS CIRCUIT CHECKOUT
20 SPACECRAFT PROPULSION SYSTEMS LOADING
21 SOLAR PANEL INTEGRATION AND CHECKOUT
22 HATCH PRESSURE INTEGRITY CHECK
23 MATING WITH THE VEHICLE SHROUD
24 MATING WITH THE LAUNCH VEHICLE & MOVE TO PAD

CHECKS ON THE LAUNCHING PAD

25 RADIO SYSTEM VERIFICATION
26 PYROS CIRCUIT CHECKOUT
27 HATCHES INTEGRITY CHECK
28 EMERGENCY ESCAPE SYSTEM PYROS CONNECTION AND CHECK
29 ENVIRONMENT AND THERMAL CONTROL SYSTEM
30 CREW INGRESS
31 HATCHES PRESSURE INTEGRITY CHECKS
32 ONBOARD SYSTEM STATUS MONITORING USING COSMONAUT PANEL
33 CREW GROUND COMMUNICATION VERIFICATION
34 MEDICAL MONITORING
35 LAUNCH READINESS CONFIRMATION & LAUNCH

Figure 15

SOYUZ SPACECRAFT
КОСМИЧЕСКИЙ КОРАБЛЬ „СОЮЗ"

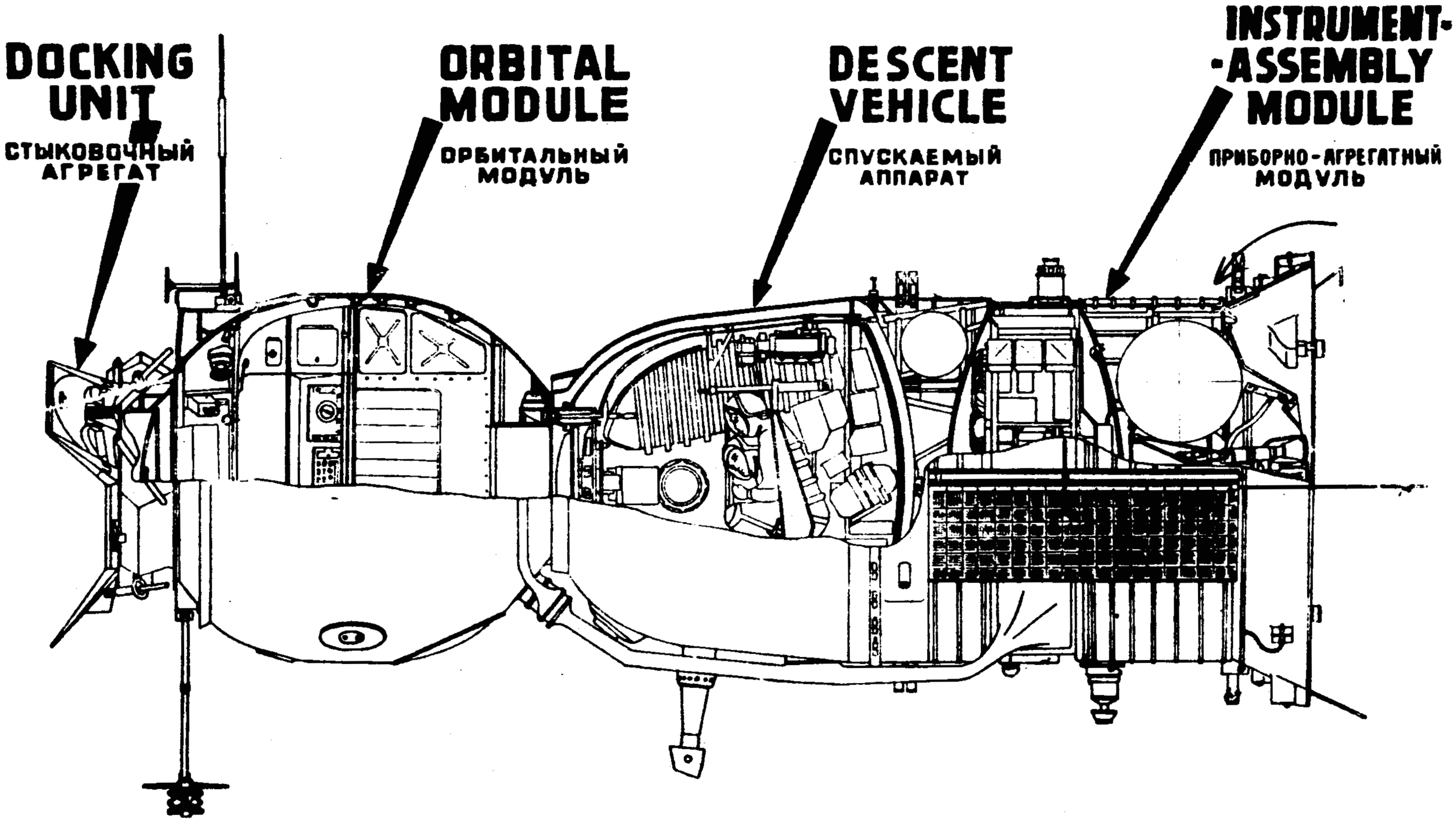


Figure 16

OPTICAL ALINEMENT AIDS FOR DOCKING

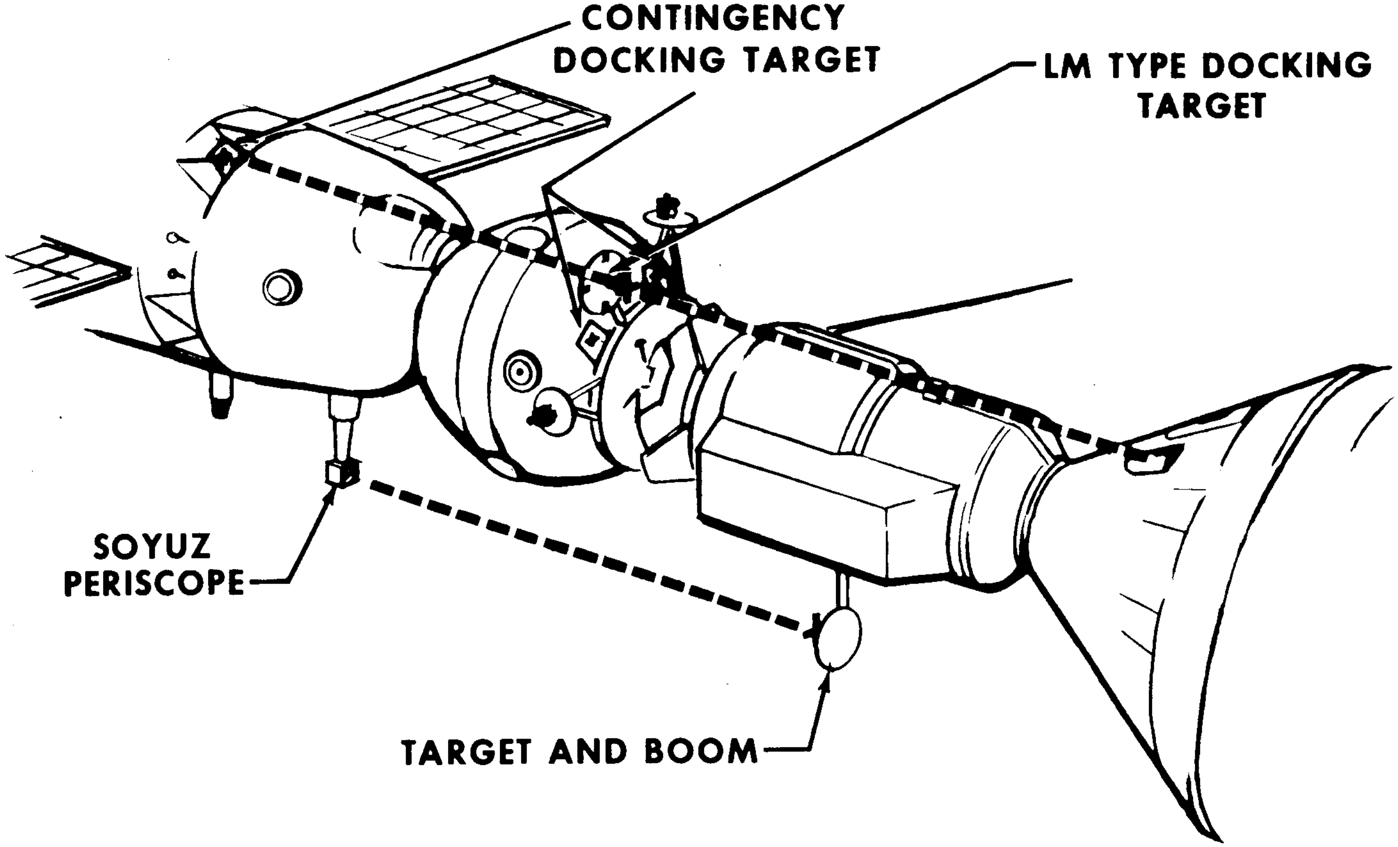


Figure 17

APOLLO/SOYUZ - MISSION RADIO COMMUNICATIONS LINKS

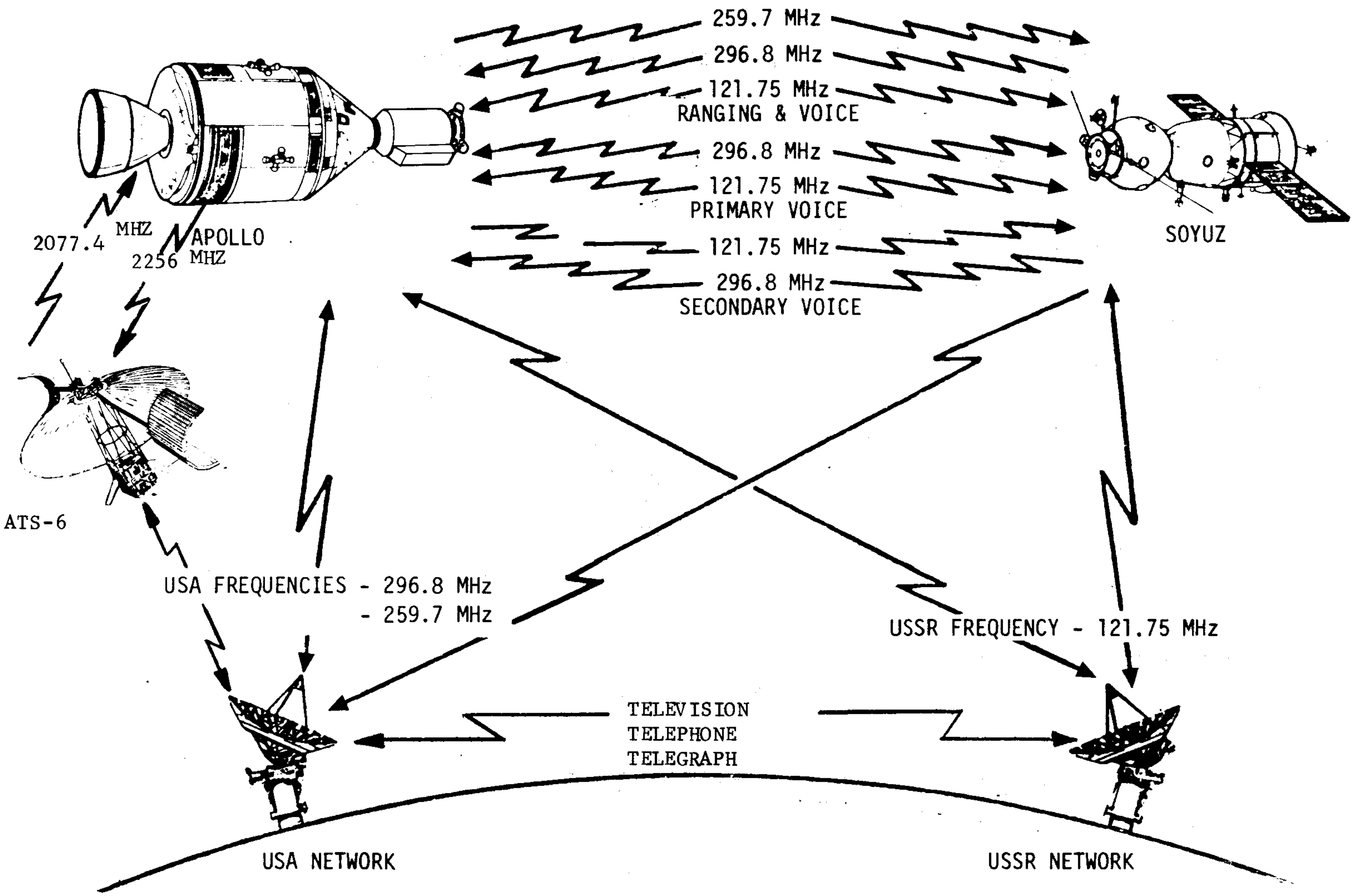


Figure 18

SEQUENCE OF NORMAL OPERATION APOLLO ACTIVE FOR DOCKING AND UNDOCKING

(ALL TIMES ARE APPROXIMATE)

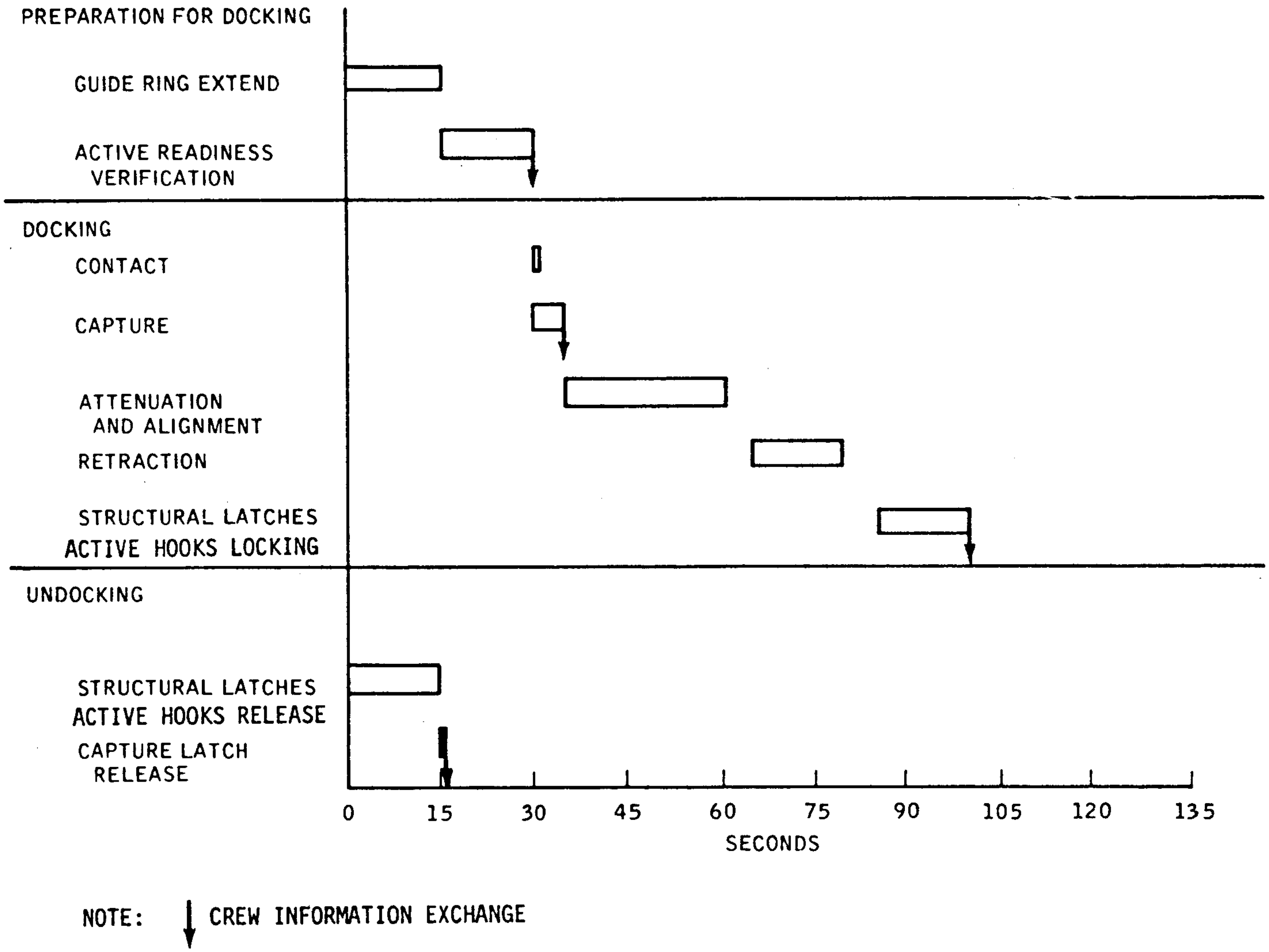


Figure 19

SEQUENCE OF NORMAL OPERATION FOR SOYUZ ACTIVE DOCKING AND UNDOCKING
(ALL TIMES ARE APPROXIMATE)

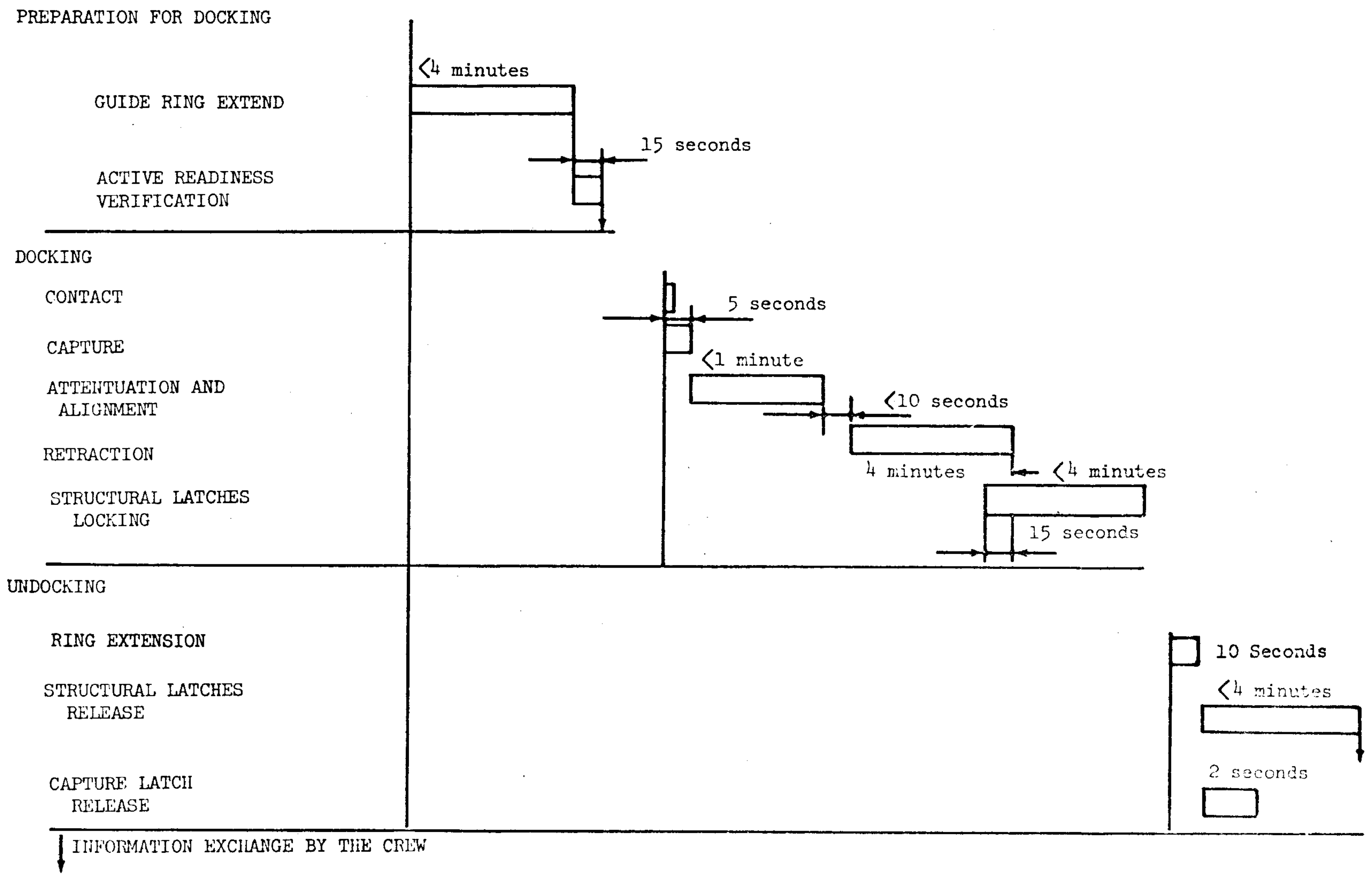


Figure 20

SOYUZ ECS SCHEMATIC

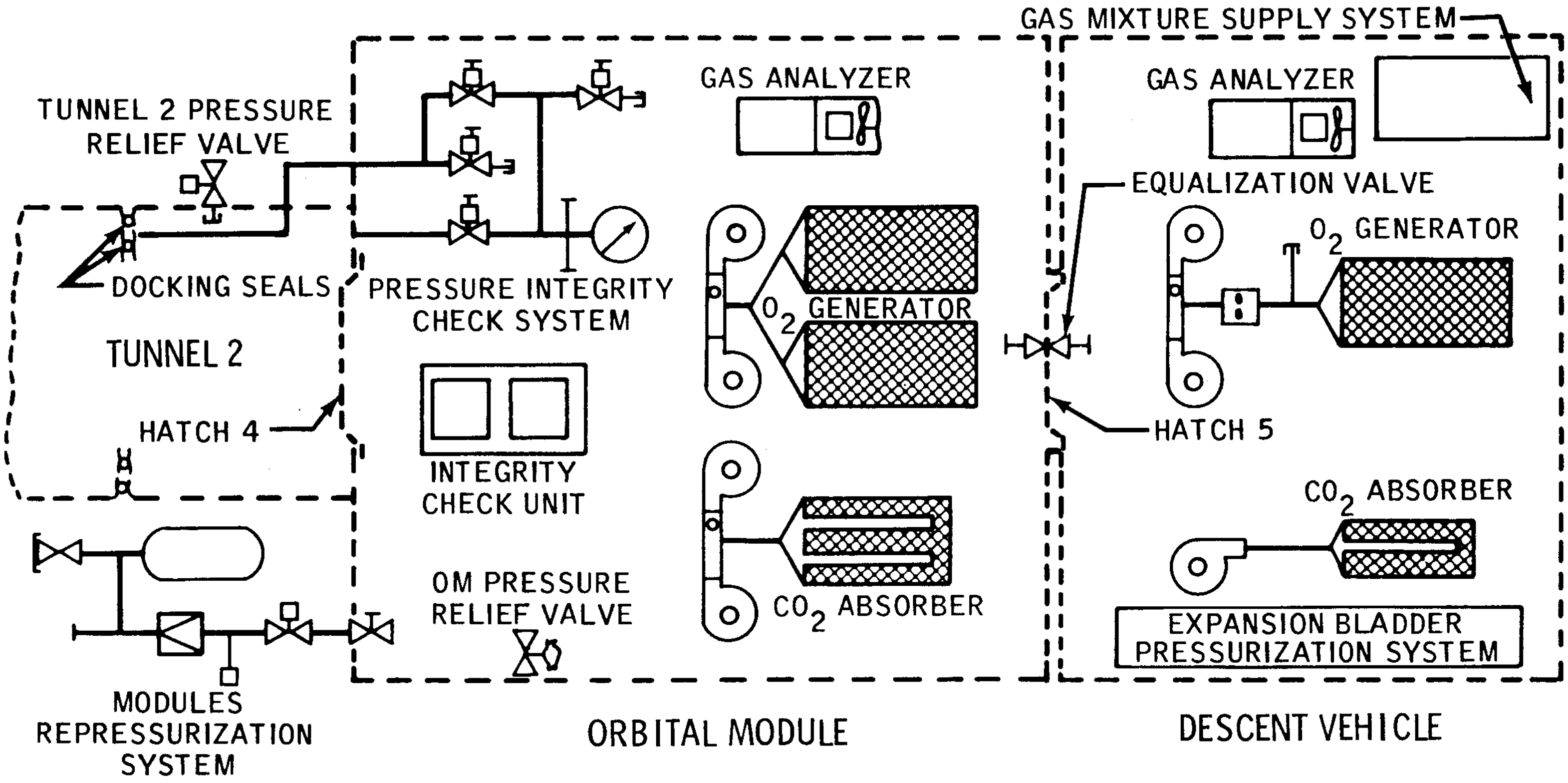


Figure 21

GAS MIXTURE SUPPLY SYSTEM

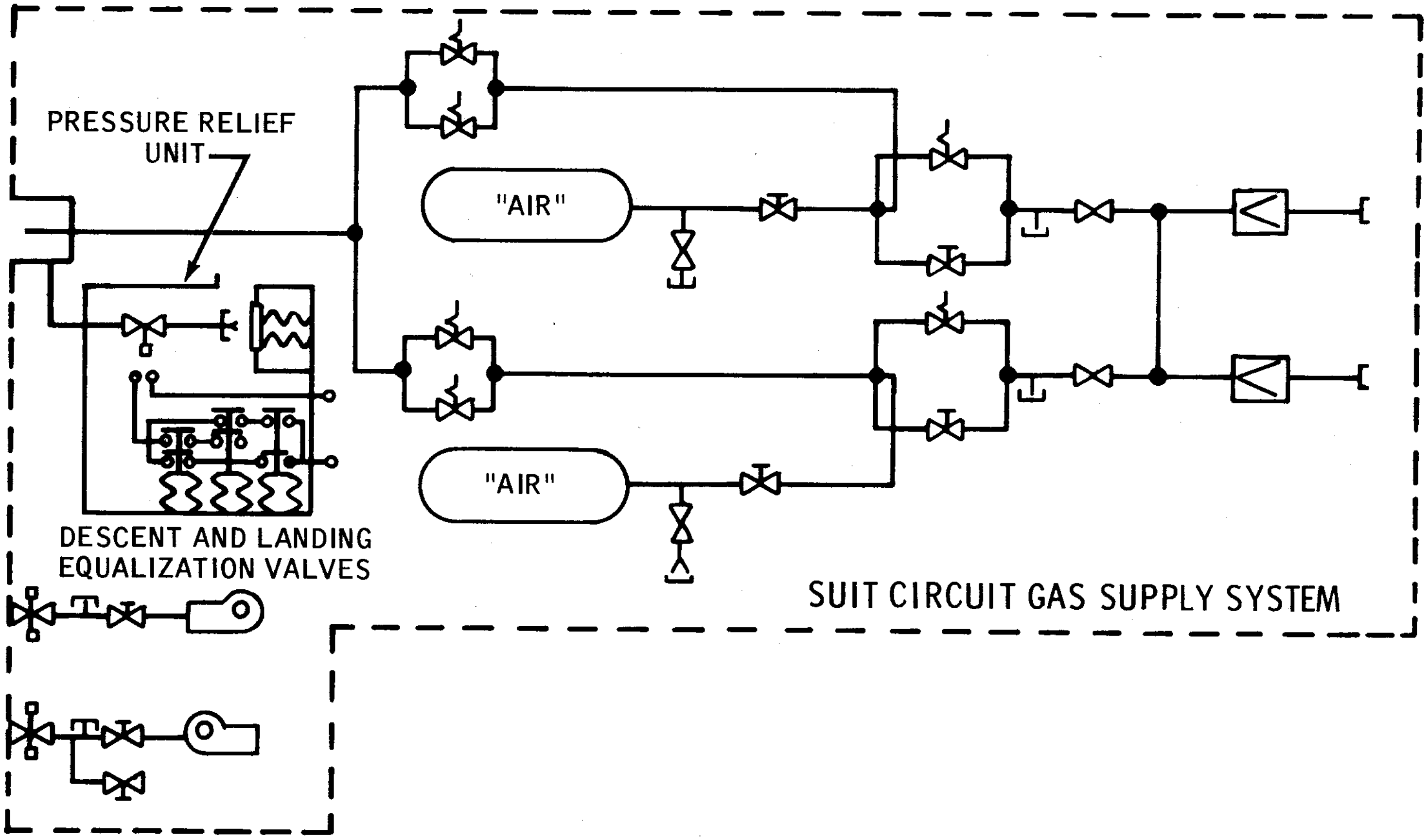


Figure 22

SOYUZ THERMAL CONTROL SCHEMATIC

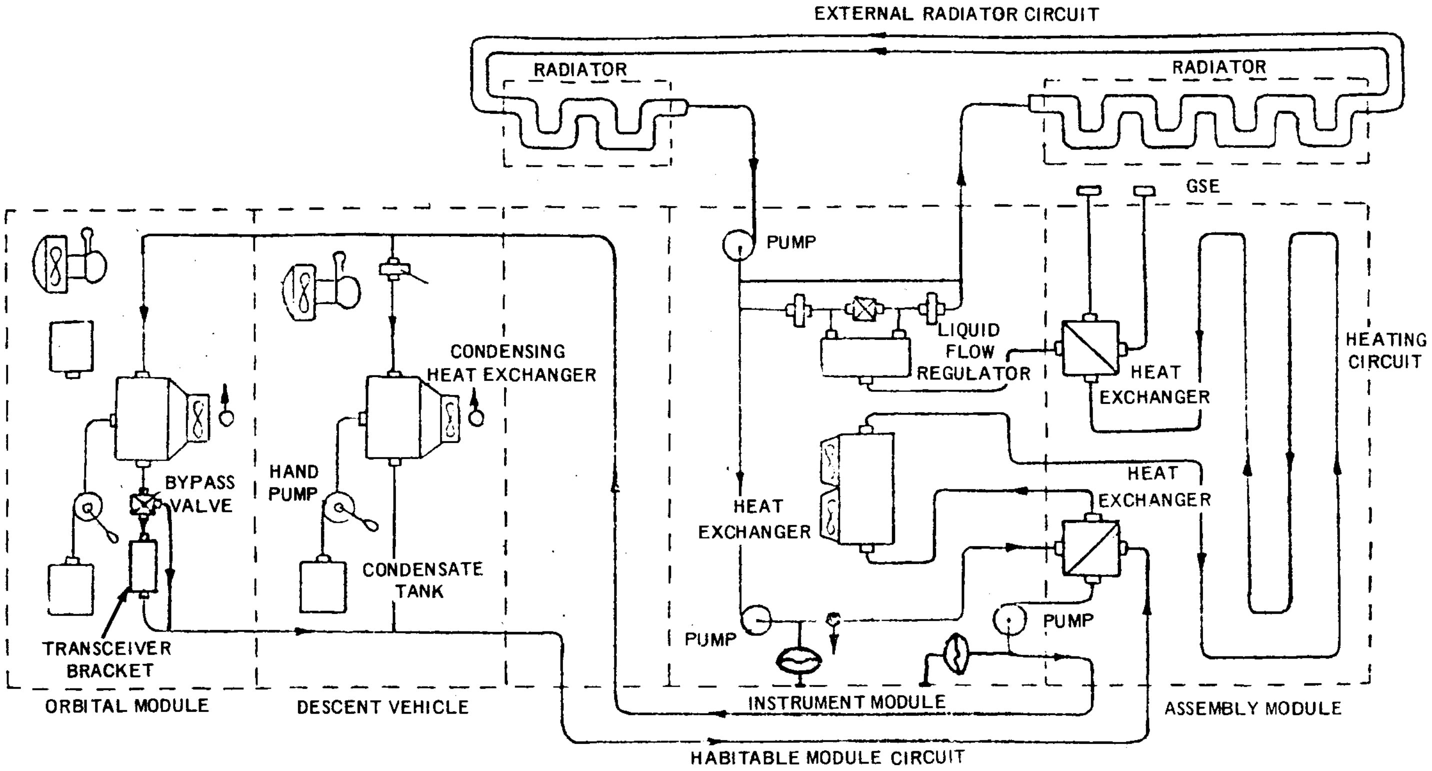


Figure 23

USA/USSR CABLE COMMUNICATIONS

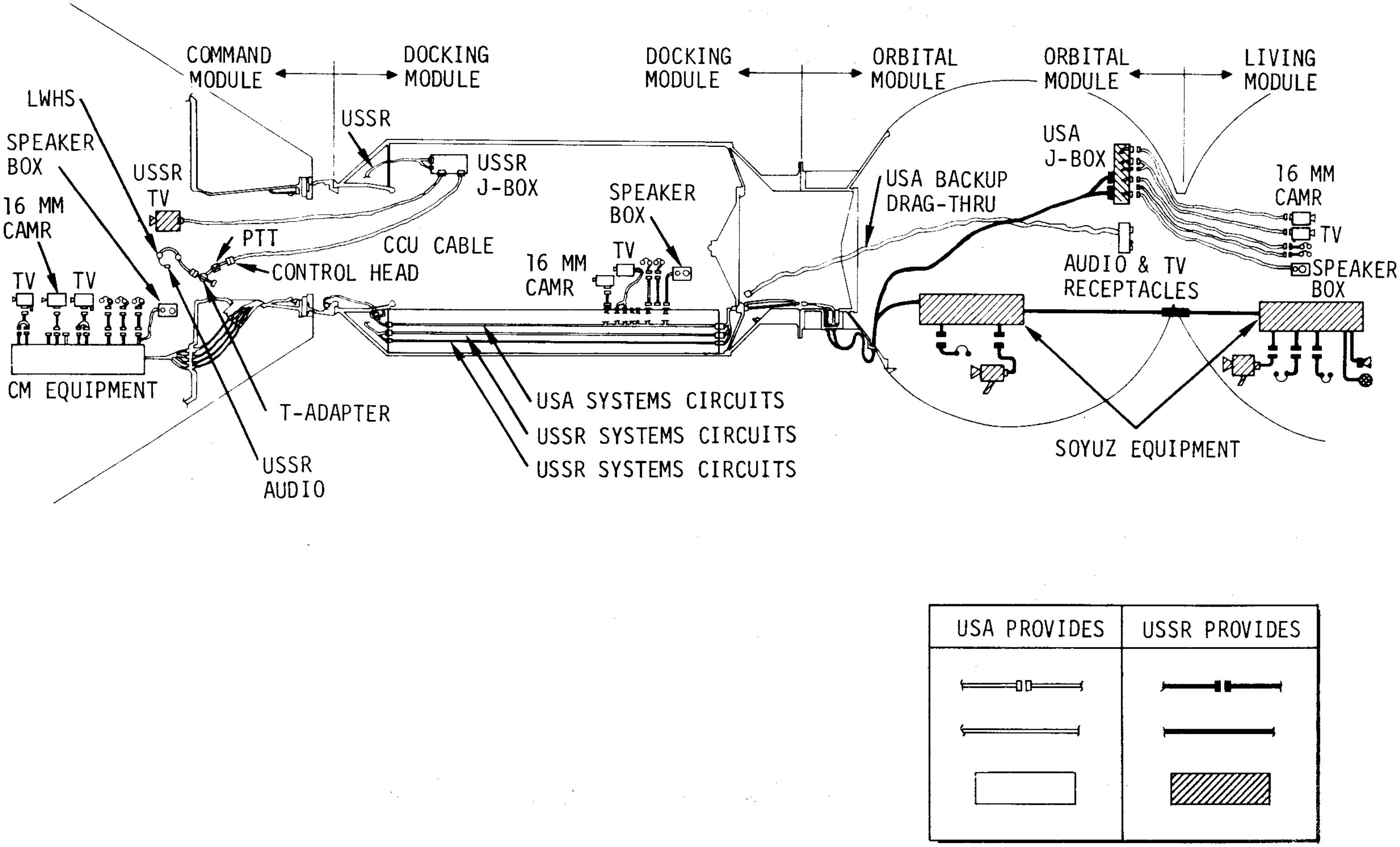


Figure 24

APOLLO CIRCUIT BREAKER ACCEPTANCE CRITERIA

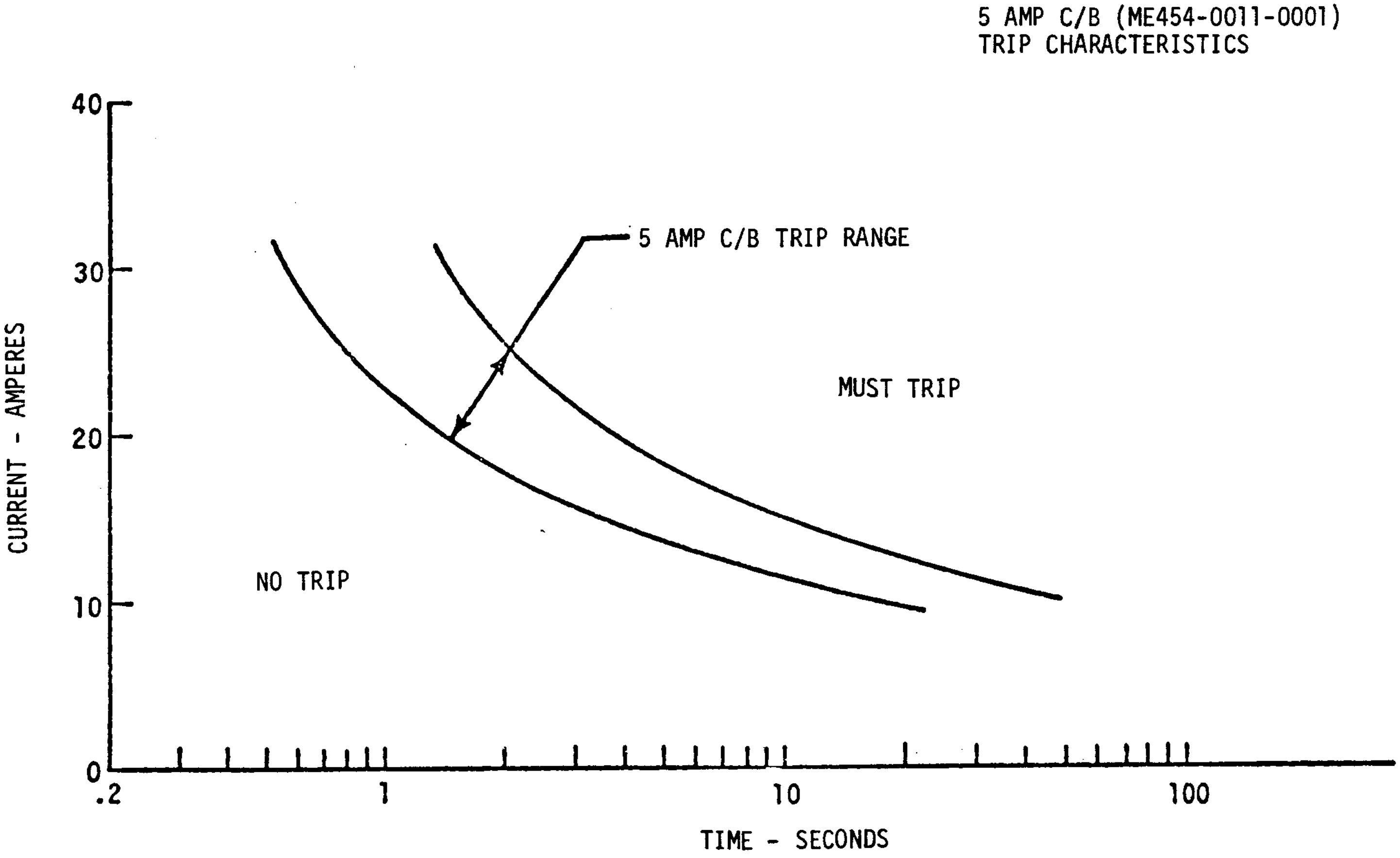


Figure 25

SOYUZ CIRCUIT BREAKER ACCEPTANCE CRITERIA

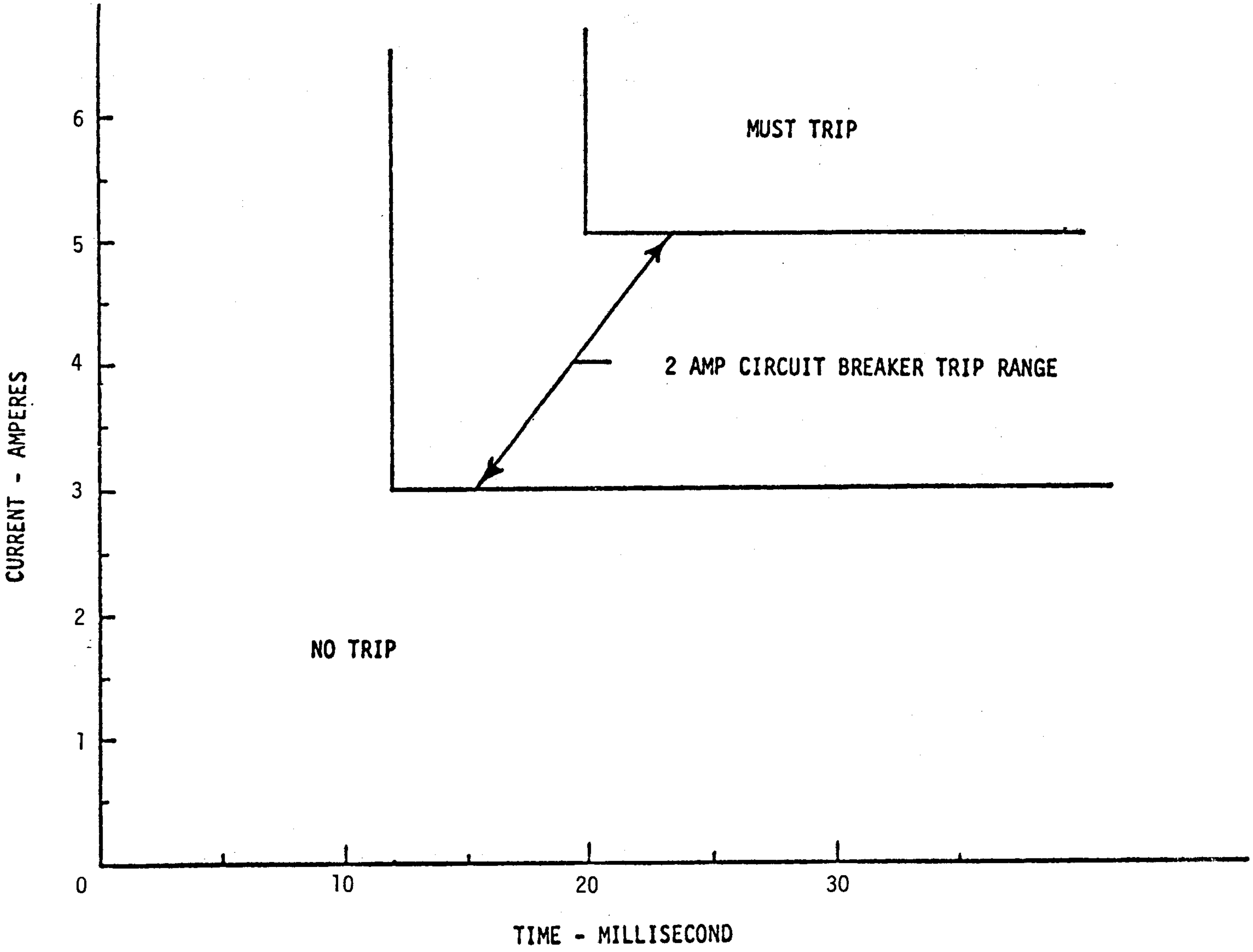
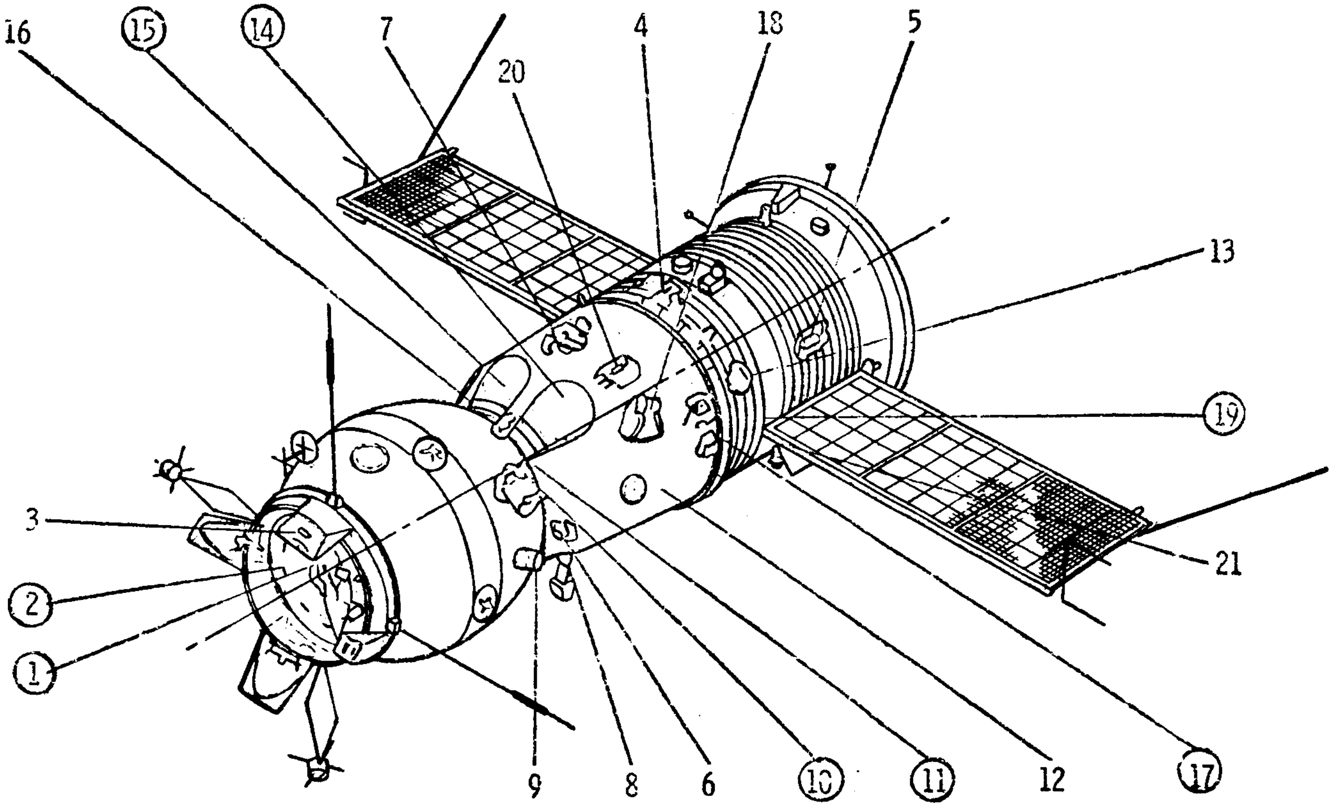


Figure 26

SOYUZ PYROTECHNIC DEVICES



Location of Soyuz Pyrotechnics

Figure 27