Communication System

The communication system equipment and configuration are identical to those of the basic Apollo. It is augmented by a speaker box and configuration changes to facilitate cluster operation. The unique Skylab requirement is again in the extended operating time for a portion of the communications system. This includes the audio center, unified S-band equipment, premodulation processor, and up-data link. These units all use solid-state devices, having 100 percent derating, and preusage burnin screening as well as equipment burnin of 100 hours. Based on this justified extrapolation of previously demonstrated operating life to meet Skylab requirements was possible.

Ordnance Systems

Of the numerous devices used on the CSM, the Panel's interest centered on the CM-SM separation system. This system is located external to the CM and between the aft heat shield of the CM and forward bulkhead of the SM. CM separation from the SM takes place during all abort phases and after orbital flight before CM reentry. The Apollo RDX type tension tie cutter did not pass the Skylab thermal vacuum verification test. Detonation energy available for cutting was low. The RDX was replaced with a HNS silver sheathed shaped charge. At the time of Panel review the replacement was undergoing test certification. Failure of the tension tie cutter to separate the CM and SM is critical, and a qualified tension tie cutter must be available. The closure of this item will be enclosed in the next report.

Based on the material presented to the Panel, management controls are still in effect to assure hardware of high quality.

ORBITAL WORKSHOP

Background Description

The orbital workshop is a two-floor structure providing accommodations for the crew and a primary experiment area. The first floor is divided into four sections: the sleep compartment, the waste management compartment, the wardroom, and the experiment work area. The biomedical experiments are performed in the experiment work area. The second floor is devoted primarily to experiments which require relatively large volumes or which use either of two scientific airlocks for external viewing or exposure. The remainder of the space is occupied by subsystem and storage compartments. These arrangements are shown in figures 18 and 19.

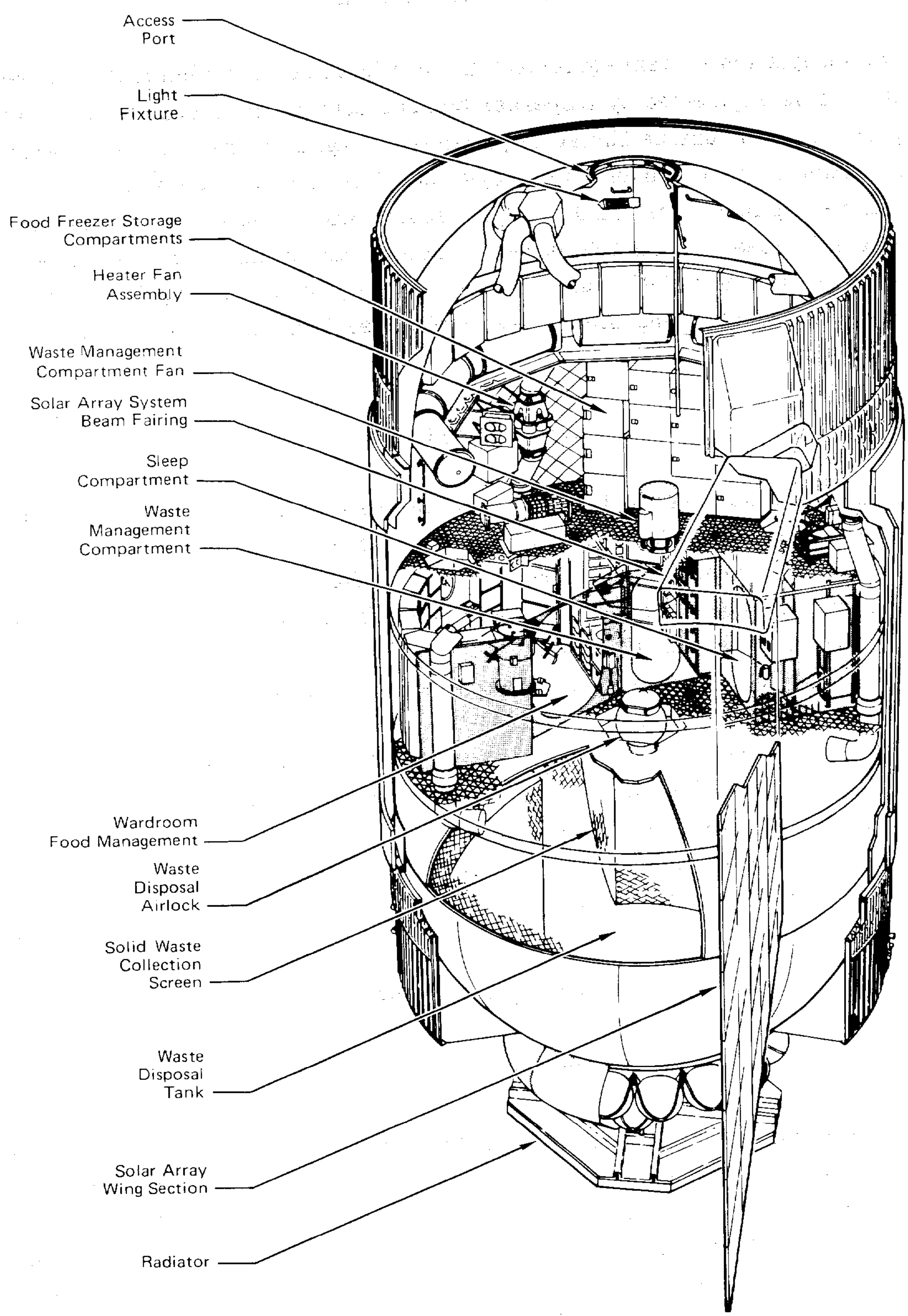


FIGURE 18 - ORBITAL WORKSHOP

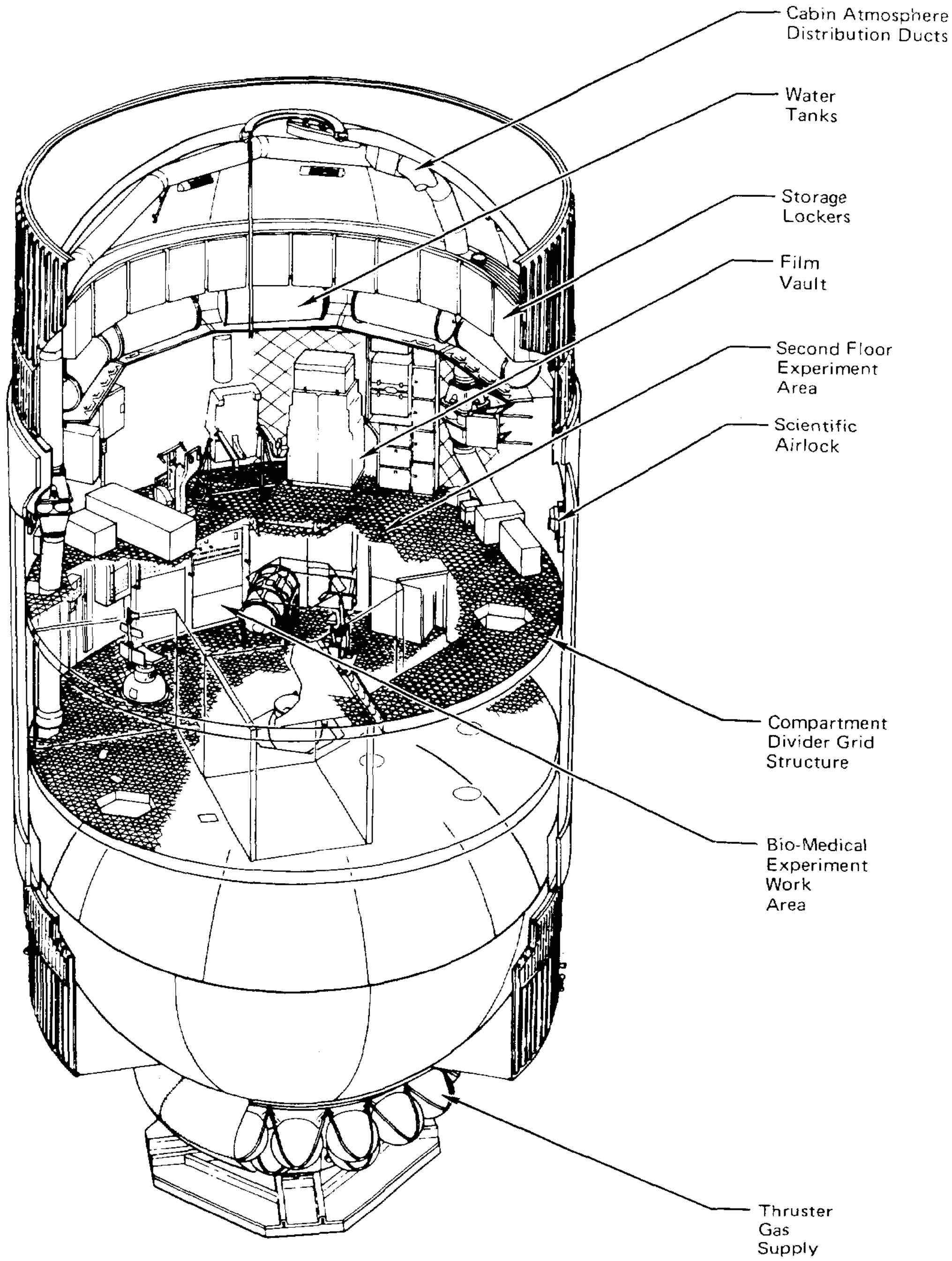


FIGURE 19 - ORBITAL WORKSHOP

The workshop also is the storage area for crew supplies, such as food, water, and clothing, as well as providing for personal hygiene and waste and trash disposal.

The OWS is an S-IVB stage of the Saturn V launch vehicle that is ground outfitted to be suitable for manned habitation.

The OWS structure provides for

1. Habitable environment with crew provisions and consumables
2. Capability for experiment installation
3. Support for conducting experiments
4. Propulsive capability for attitude control
5. Solar array power source, mounting provisions for the array, and routing of power to the airlock module
6. Storage for cluster waste material
7. Capability for orbital storage and reuse
8. Two scientific airlock installations, one on the cluster -Z axis (Sun side) and one on the cluster +Z axis (dark side)
9. Capability for television transmission via MDA video selector and CSM transmitt
10. No scheduled or planned activity requiring access into the habitable volume of OWS after closeout in the Vehicle Assembly Building

For launch, the OWS consists of an S-IBV/S-V forward skirt, S-IVB propellant tanks with preinstalled crew and experiment accommodations, and an S-IVB-S-V aft skirt and interstage. The forward skirt interfaces with the IU, the forward tank dome interfaces with the AM, and the aft interstage interfaces with the S-II stage. The in-orbit configuration is essentially the same. The only changes are that the interstage separates with the S-II stage, and the solar array and meteoroid shield are deployed.

Significant changes to the S-IVB structure have been caused by Skylab requirements. Provisions have been made for an OWS vacuum outlet, scientific airlock (SAL) and attachments for crew quarters, experiments, and equipment stowage. A waste dum airlock has been provided in the common bulkhead area for disposing of wet and dry waste through the common bulkhead from the LH_2 tank to the LOX tank.

A meteoroid shield is designed as a structurally integrated part of the OWS and protects the cylindrical portion of the tank. After deployment, the shield extends abou 6 inches radially from the outer surface of the LH_2 tank. Deployment is accomplished during orbit by a signal from the IU.

The S-IVB is divided into a two-level crew quarters by a structure serving as a floor/ceiling installed in the LH_2 tank, perpendicular to the longitudinal axis of the S-IVB stage. The section aft of the floor/ceiling provides the crew with accommodations for sleeping, food and waste management, hygiene activity, off-duty activity, da management, and the implementation of corollar experiments.

Astronaut mobility/stability aids have been installed to assist the astronauts in performing tasks associated with activation, crew habitation, experimentation, and d activation. These aids are of two basic types - fixed and portable. Fixed astronaut aids include handrails, tether attach devices, and the central handrail. They are permanently installed in locations throughout the LH_2 tank where it is expected that heavy traffic or task loading will occur. Portable astronaut aids include handholds, tether attach brackets, and foot restraints.

OWS interior lighting allows for crew equipment installations, normal and emergency crew activities, and experiment operations. The interior lighting system consists of initial-entry lights, general-illumination lights, emergency lights, and special-purpose lights. Orientation (running) lights are provided for determining the gross attitude of the passive vehicle and movement relative to a line of sight through the window of the docking vehicle. In addition, white floodlights will be used to illuminate the exterior of the cluster and the exterior of the AM within the thermal curtains. A portable floodlight is used by the astronaut during EVA.

The subsystems comprising the total OWS include the following for our purpose:

Panel examined in detail	Panel made cursory examination
Structures subsystem	Thruster attitude control subsystem
Environmental and thermal control subsystem	Solar array subsystem
Electrical power subsystem - (EMC and corona)	Ordnance subsystem
Communications and data acquisition system	Ground support equipment subsystem
Caution and warning subsystem	
Habitability support subsystem	
Crew equipment subsystem	

Three systems were reviewed on the following occasions: (1) MDAC-West, October 1971, (2) Marshall, April 1972, (3) PDTR, April 1972, and (4) DCR, October 1972. The Panel in its factfinding was interested in the evident effectiveness of the technical management systems, the maturity of the design, and the quality of the hardware. The following discussion is based on these factfinding reviews.

Note should be made that experiments and other modules are discussed here only as they present interface requirements. They are discussed in detail elsewhere.

Orbital Workshop Hardware

The OWS flight hardware checkout began November 6, 1971 with the start of continuity/compatibility testing. It continued through completion of the all systems test, electro/magnetic compatibility test, and residual subsystem retests August 16, 1972.

During this period, all subsystems, crew compartment fit and function (C^2F^2), and the combined all systems test and electro/magnetic compatibility (AST and EMC) test were performed.

The crew compartment fit and function was conducted in two increments. The first increment ran May 22 through 28, and the second increment August 12, 1972. Some C^2F^2 checkout remains to be accomplished at KSC primarily because of lack of hardware, notably in the stowage area.

The combined AST and EMC test was performed July 17 through August 7, 1972. This test functioned each OWS system on a simulated prelaunch, launch, and orbital time line to verify systems compatibility throughout the mission profile.

Further checkout activities included a mercury certification of the habitation area and calibration of the meteoroid shield strain gages. Major manufacturing activity focused on modification of the meteoroid shield and cleanup activities associated with final inspection. The spacecraft was moved to Seal Beach for thruster attitude control system proof testing on August 31, 1972. Final preparations for shipment followed at Huntington Beach.

Problems encountered during this checkout were documented on test problem reports. A summary of the closeout status of these reports is shown in table VI. Some test problems could not be closed at Huntington Beach because of unavailable hardware and unfurnished rework and testing. These are transferred to a recap test problem report which identifies the problem being transferred to KSC, the reason the problem was not resolved at Huntington Beach, and the applicable documentation (i.e., failure report, discrepancy report, inspection item sheet, original test problem report).

The retest outline is the document that identifies, at the time of shipment, open retest and/or test requirements of incompleted assemblies, discrepancy reports, failure reports, and removals and requires quality assurance verification for final buy-off. It contains three categories:

(1) Retest required as a result of assemblies, failure reports, discrepancy reports and removals that were worked after factory testing

(2) A listing of unworked assembly outlines, engineering orders, etc.

(3) A line item to identify the recap test problem report and associated test or rete requirements that must be transferred to KSC

All items associated with open work are listed in the data package contained as a part of the certificate of flight worthiness and DD250 form.

There were 27 OWS design certification review (DCR) review item discrepancies (RID's). Essentially all are closed at this time.

All test objectives have been satisfied except those noted in table VII.

Orbital Workshop Structures Subsystem

The OWS structures subsystem consists of the following major components:

1. Forward skirt which serves as structural continuation between OWS habitation area tank and the IU. It provides space for mounting electrical and electronic equipment as well as providing support for the solar array system wing assemblies. There appeared to be no unique fabrication techniques or new technology applied here. The major items requiring assurance were the SAS attachment provisions which support these most important electrical power generating components. At the time of the formal DCR there were no open items, waiver, or deviations associated with the forward skirt, and it complied with the MSFC hardware safety checklist. McDonnell Douglas-West expects little or no work to be done at the KSC on this item.

2. Thermal shield. The thermal shield, attached to the aft 34 inches of the forward skirt, functions as a radiator barrier to aid in stabilizing the habitation area temperature. There appear to be no constraints to mission or crew safety attached to this item.

3. Aft skirt and thermal shield. The aft skirt is a modified Saturn V/IVB aft skirt. Structural capabilities apparently were not changed by OWS modifications. The attachment of the aft thermal shield is similar to that for the forward thermal shield. This skirt also has attachments to support the SAS installation. The OWS flight loads are indicated as lower than those for the S-IVB aft skirt and there was no indication of any problems. During development of this structure, the thruster attitude control subsystem nozzles which are hard mounted to this structure had to be modified to a shock-mount to preclude damage to nozzle valves. Analysis and test results show no waivers or specification deviations required.

4. Aft interstage. This is a frustum-shaped assembly which transmits loads between OWS aft skirt and S-II stage and provides the OWS radiator assembly protection during launch. It remains with the discarded S-II stage. There appear to be no constraints caused by this item.

5. Thrust structure. This is a multipurpose structure using the basic S-IBV stage with modifications to support the thruster attitude control subsystem's nitrogen gas storage spheres and associated piping, the subsystem's meteoroid protection shield, and the refrigeration system radiator with its impingement shield and structural support. Some items of note are the single failure points associated with the thruster attitude control system.

(a) Rupture or bursting of the thruster attitude control subsystem's storage and manifold could jeopardize the safety of the crew.

(b) Radiator shield actuator assembly release mechanism failure could preclude jettison of radiator shield adversely affecting OWS thermal control system operation.

These single failure points appear acceptable based on the added manufacturing and quality controls imposed, tests and analysis conducted, and similarity to prior use on Saturn launch vehicles.

6. Meteoroid shield. This shield for the habitation area is composed of cylindrical sections. When deployed they act as the outer barrier with the OWS main tank wall as the inner barrier. The standoff distance of this meteoroid shield is approximately 5 inches. It is deployed on-orbit by severing tension straps with expandable ordnance tubes and moved outward by 16 links powered by independent torsion bars.

Meteoroid shield deployment was successfully demonstrated at NASA/MSFC. However, during pressure testing one of the shield hinges failed structurally. The hinge subsequently was redesigned and the strength capability verified by tests. These design changes have been incorporated into the OWS. The static test article (STA) is to be reworked and retested at NASA/MSFC during the October to November time frame and these test results should be verified.

Verification of the structures subsystem was demonstrated by the satisfactory completion of all subsystem testing.

A further deployment production acceptance test is expected to be conducted at KSC.

7. Habitation tank. This "habitation or crew area" consists of a forward dome, main cylindrical section with window and door openings, and an aft common bulkhead forming the "lower floor." The interior is insulated with polyurethane foam covered with an aluminum foil-fiberglass-teflon type liner. In addition, the external surface of the forward dome is covered with insulation consisting of some 95 layers of aluminized mylar with interspersed layers of separator sheets, while the cylindrical portion is coated with a reflective coating.

The Panel's interest here was the structure's ability to support onboard equipment particularly through the SL-1 launch period and to maintain onboard pressure within the allowable atmospheric gas leakage (OWC decompression). The allowable leakage rate has been set at no more than 5 pounds mass per day in orbit. Table VIII indicates the expected leakage allowances for hatches and penetrations. In line with this approach the Panel identified the following areas which are discussed here:

1. Scientific airlock. It is used with experiments S-063 and S-190B. The scientific airlock provides vacuum source and allows deployment of experiments outside the habitation area. There are two ports, one on the solar side and one on the anti-solar side.

2. Forward dome entry hatch. It is located at the apex of the dome and provides for workshop entry in orbit. It functions as a structural part carrying pressure loads during boost.

3. Side access panel. It provides ground access into the OWS module for installation and work on such items as experiments, water containers, food containers, etc.

4. Wardroom viewing window. It is of a double pane construction approximately 18 inches in diameter to allow simultaneous viewing by two crewmen. The design includes thermal and meteoroid protection when not in use.

5. Trash disposal airlock. It is a passthrough chamber built into the waste tank common bulkhead. A failure poses both a potential pressure loss and microbial contamination problem.

6. Water bottles and stowage container support structure. It provides for large mass loads subject to static and launch acceleration loads. This is a good representation of all such structural loads.

The scientific airlock has a window which is the refurbished Apollo window and its failure, as with the scientific airlock doors, would jeopardize the safety of the crew. The inboard face of the scientific airlock has an opening which can be sealed by an experiment or a window cover. Because of this the Panel feels that procedures for both flight and ground operations must be explicit in the use of the scientific airlock. For example, flight procedures should specify that the crew must be certain that the experiments are indeed tightly situated against the scientific airlock to preclude leakage as the experiment becomes a part of the airlock pressure vessel.

Since the inner and outer surfaces of the assembly have highly effective antireflective coatings, special care is required during ground operations.

The low temperatures on the anti-solar side made a desiccated repressurization necessary to preclude humidity problems. Recent authorization for this resulted in a new design which is still undergoing qualification tests. These are scheduled for completion in November and to date indicate no problems are expected.

Precise alinement of the individual scientific airlock is apparently difficult because of deflections due to thermal, gravity, and pressure environments. Alinement must be done at KSC.

KSC is aware of the measurement work which they have to accomplish. In reviewing the scientific airlock structure it appears that it is capable of meeting its design requirements.

However, an item to be noted is that some scientific airlock components were made from material which had relatively low stress corrosion threshold levels. Stress corrosion analysis indicate susceptibility of the scientific airlock's aluminum 2014-T652 housing and aluminum. The 2024-T4 supports will possibly experience stress corrosion cracking, but since the housing and struts will be under a compressive load, the cracks should have little impact on the scientific airlock's operations. It was indicated that if cracks develop to the point where leakage occurs the scientific airlock integrity could be maintained with the outer door closed. There is also a possibility of closing any such leaks by using aluminum pressure sensitive tape or polybutane sealant putty indicated as part of OWS in-flight kit.

Subsequent to the completion of the forward dome entry hatch a rodent bearing failure during vibration was discovered. The failure apparently did not affect operation of the hatch. Failure analysis is still continuing; indications point to the cause being an improperly adjusted link (human error). Inspection of the spacecraft links is scheduled during subsystem checkout at KSC. A further check will result from integrated checkout requirements which specify a functional test with 25-pound maximum handle loads. If the hatch does not operate properly, tools are available in the tool kit. Procedures and tools have been verified on the test hatch. Leakage through the hatch seal has been analyzed. Prior proven application materials and special controls indicate that it is an acceptable single failure point.

Based on the analyses and test results presented to us, the side access panel as well as the opening into which it fits are structurally adequate. Tests indicate that no excessive leakage problems.

Two leakage problems were encountered. They were the wardroom window cover and the SAS wing cavity. Both are currently being redesigned and are identified as open work at KSC.

The protective cover leakage exceeded the allowable rate. Window redesign incorporates an O-ring seal in the cover plate (discussed subsequently) as well as on the support ring and window frame. When complete this will be installed and tested at KSC. With regard to the viewing window installation, the only major problem encountered involved the type of vent system used to vent the cavity between glazings to relieve the pressure. When the vehicle is launched, the cavity is sealed with an internal pressure of 14.7 psia. When the vehicle reaches orbit the differential pressure across the external glazing would be essentially 14.7 psi. There would be a pressure of about 10 psi across the inner glazing. Optical requirements dictate a pressure of no more than 6 psi. The original automatic one-way check valve provided a 5 psi pressure differential from the cavity to the cabin. Furthermore, analyses conducted by both the contractor and the NASA Center showed that should the valve "chatter" or freeze open a 26 psi differential could exist across the outer glazing. Eventually this would result in glass failure. To preclude this the window vent area was redesigned with a positive seal on the glass-to-glass cavity along with a manually operated valve. A removable metal cover plate was installed over the inside of the inner or cabin side glass window to carry the 26 psi OWS atmosphere during launch. This cavity between the new metal protective plate and the inner glass also required a similar manual vent valve. It is this cover plate that must be sealed to prevent leakage. This is an example of the extent of effort necessary to (1) meet the design requirements for both safety and mission utilization and (2) maintain the structural integrity of the basic OWS shell and reduce or eliminate hazards.

During factory checkout of the SAS wing cavity or support structure on the basic OWS, it was noted that there was excessive leakage of pure gas. If this occurred during KSC operations and launch it could lead to contamination within the cavity. It also means a chance of moisture. It was indicated that redesign was underway that would seal most leak paths. A leak test is then to be performed at KSC prior to SAS mating. This is not assumed to be a significant problem. One of the questions for the phase III review is whether moisture can or has seeped in and could when frozen impact the deployment mechanism. The closure of this question will be identified in the phase III or final report.

The trash disposal airlock is perhaps one of the most important items of operational hardware in the orbital workshop. It is in daily use and failure would most likely compromise primary mission objectives. Development and qualification tests were completed satisfactorily. They verified the structural integrity of the item (e.g., proof and burst pressures, leakage, vibration, etc.). Problems and corrective action are noted in table IX. One item noted by the Panel was that the hatch lid lock handle forces appeared high. It was understood that while the specification called for forces up to 25 pounds it requires as much as 45 pounds on the inboard hatch. The handle operating load for the outboard hatch is some 35 pounds.

The water container support structure (WCSS) provides support for ten 600-pound capacity stainless-steel containers within a circular ring structure. Stowage container support structure provides support for some 25 containers in a circular ring structure attached to the WCSS forward frame. The test results from the OWS dynamic test article and static test article, as well as analytic results, indicate adequate factors of safety and structural integrity.

Environmental and Thermal Control

The environmental control system (ECS) consists of the ground thermal conditioning subsystem (GTCS), the ventilation control subsystem (VCS), and the thermal control subsystem (TCS). The GTCS maintains the proper environmental conditions within the OWS while Skylab is on the launch pad. The TCS maintains the proper environmental conditions during all orbital operations. The VCS provides the proper ventilation during manned orbital operations. Figures 20, 21, and 22 indicate the general arrangement of the hardware involved.

In general, quality testing on the ECS/TCS has been successfully completed. Components still under test are in the refrigeration subsystem and condensate dump line to the waste tank.

OWS
PRESSURIZATION AND PRESSURE
CONTROL SYSTEM

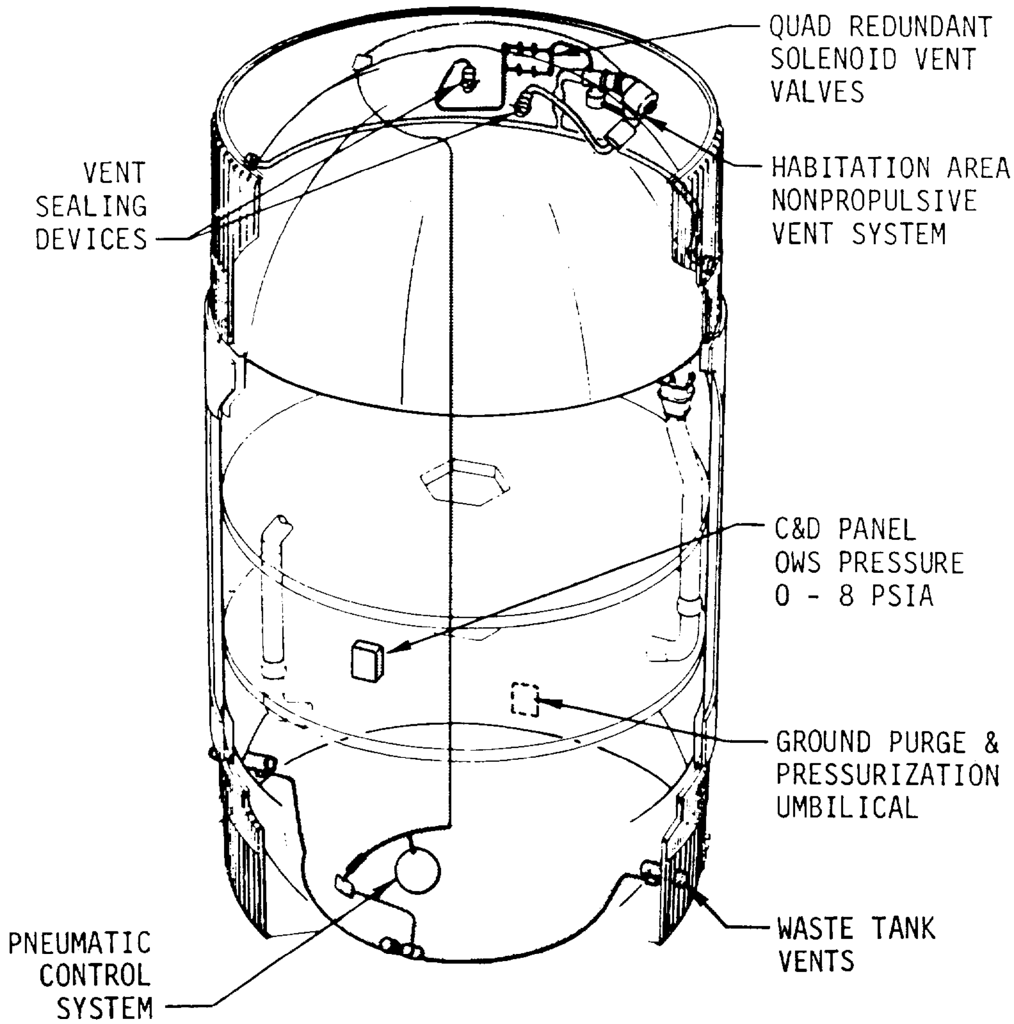


FIGURE 20

OWS
REFRIGERATION SYSTEM

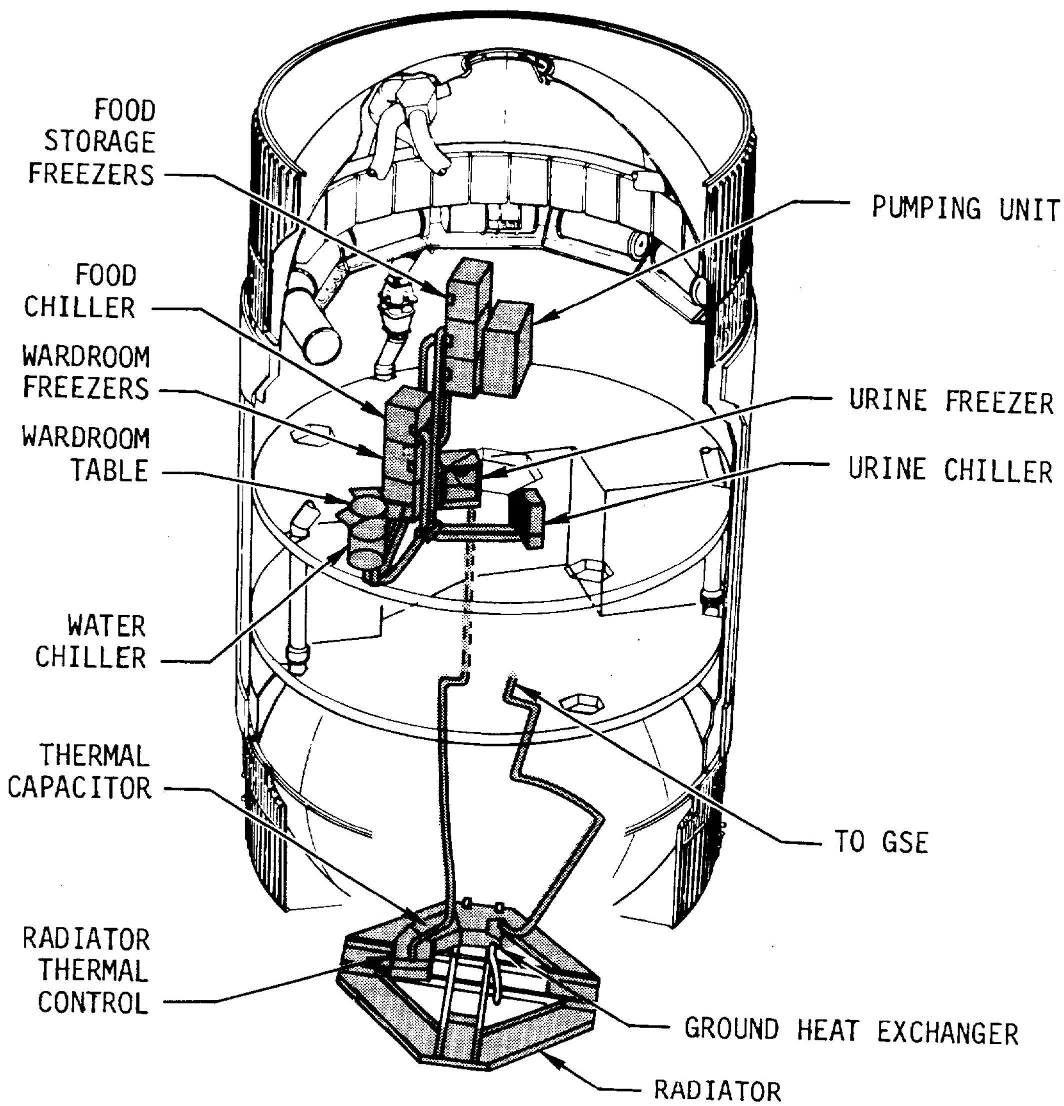


FIGURE 21

OWS
ATMOSPHERE CONTROL SYSTEM

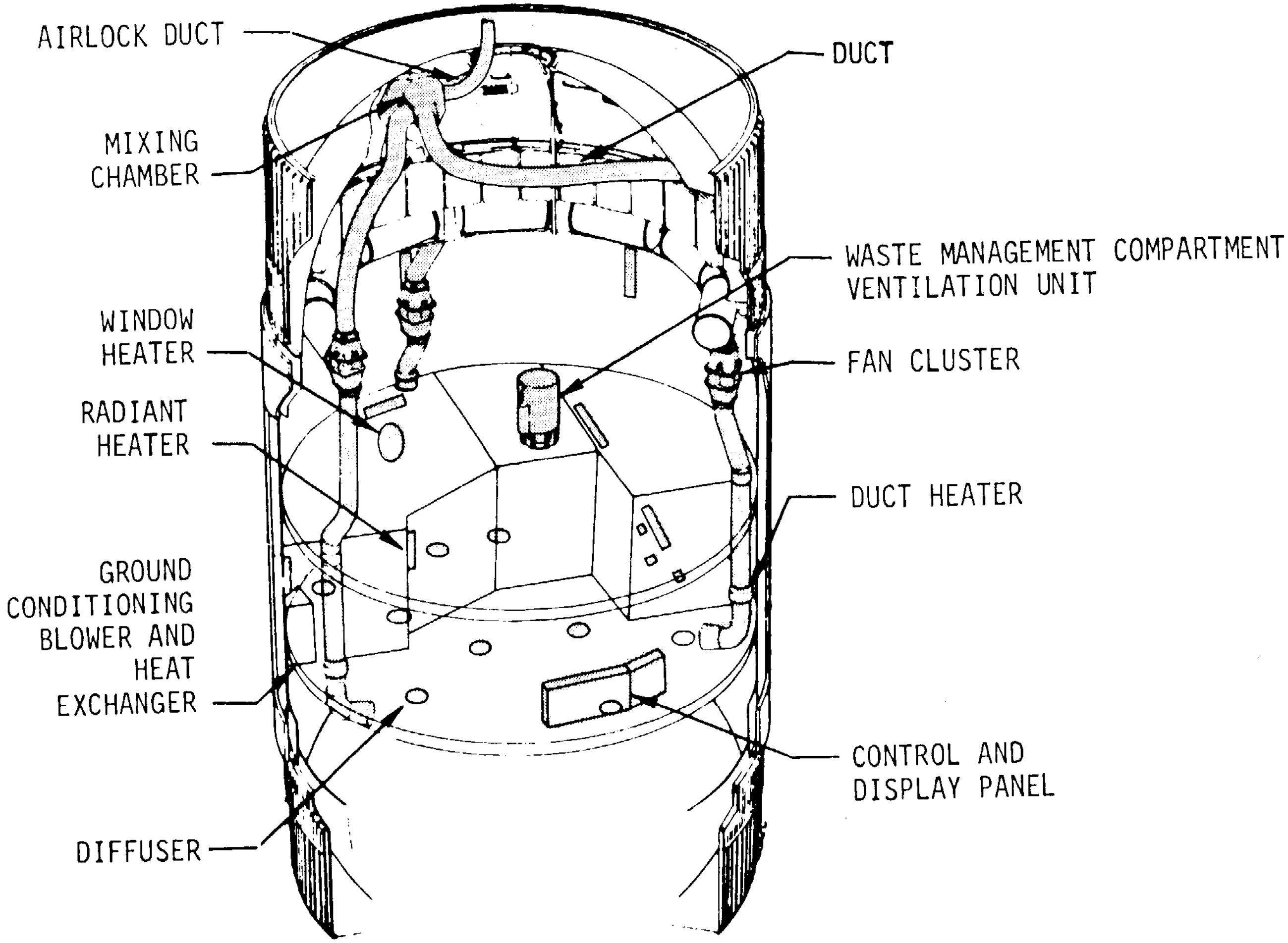


FIGURE 22

Panel interest in those subsystems directly related to crew operations has been emphasized throughout this review. Consequently, all aspects of the ECS were examined. As a result this section covers the following:

1. Habitation area atmosphere control
2. Waste tank as affects pressure control system
3. Thermal control ventilation and odor removal
4. Thermal control system
5. Refrigeration system
6. Ground conditioning and purge

The qualification test program for the remainder of the ECS equipment appears to have been successfully completed. There were numerous qualification tests, development tests, all systems' tests, etc., whose results were used to substantiate the qualification of the components.

Habitability area atmosphere control. - This portion of the ECS comprises the (1) vent system to provide overpressure protection during ground and flight operations, (2) pressurization provisions includes plumbing and pneumatic supplies for prelaunch pressurization from a GSE source and for in-flight pressurization from the AM supply, and (3) leakage control which herein is an extension of the material presented under OWS structures section.

The minimum allowable habitation area pressure during launch is 22 psia, based on structural requirements with a one-engine-out malfunction. Maximum pressure for the habitation area is 26 psia. Higher pressure will produce excessive discontinuity stresses in areas of the tank where reinforcement is required for floor, ceiling, and other equipment attachments. Prior to liftoff, the habitation area is to be pressurized with nitrogen from a ground source to between 23 and 26 psia.

The habitation area when in orbit is pressurized to 5 psia with oxygen by the AM pressurization system. The OWS part of the system consists only of the connecting lines from the AM/OWS interface to the gas inlet port located in the electrical feedthrough collar. Initial pressurization occurs through a system separate from that used to supply oxygen and nitrogen during habitation. This procedure permits flow of oxygen only and assures accurate knowledge of the oxygen and nitrogen concentrations for initial occupation. Pressurization will be initiated by ground command at about 1.6 hours after liftoff and will require about 9 hours to reach 5 psia. A pressure integrity check will be conducted prior to Skylab-2 launch.

During the 28-day Skylab-2 mission the AM pressurization system will control the habitation area pressure at 5.0 ± 0.2 psia with an oxygen partial pressure of 3.6 ± 0.3 psia.

At termination of the Skylab-2 mission, the solenoid vent port sealing device will be removed by the crew. The ground will then command the solenoid vent valves open to vent the orbital assembly from 5 to 2 psia to prevent condensation of water vapor during storage. Leakage will tend to reduce the pressure. Prior to reaching the minimum allowable of 0.5 psia, the ground will command the pressurization system on until the pressure is 1 psia. This sequence will be repeated as required. Prior to Skylab-3 launch the habitation area will be pressurized to 5 psia. Procedures for deactivation after Skylab-3 and activation prior to Skylab-4 will be identical.

The habitation area configuration during periods of leakage control is the normal manned orbital configuration (i.e., OWS/AM hatch open, and pneumatic and solenoid vent port plugs installed). There was a proposal to leave the solenoid vent port unpluggec A change to the specification permitting habitation area pressures below 22 psia during launch and a common bulkhead ΔP larger than 7.5 psia were being considered. The closure of this problem will be identified in the phase III or final report.

All habitation area penetrations use current state-of-the-art techniques to prevent leakage. Induction brazed fluid and gas lines are used wherever possible. Conoseals are used on large static components and in many cases are backed up by use of a sealant. Standard O-rings and B-nuts are used in other areas. There appear to be no new materials nor state-of-the-art advancements in this system.

The pneumatic system provides the means for opening and closing the habitation area vent valves, opening the waste tank vents, and jettisoning the refrigeration system radiator protective shield. The system consists of a 4.5 cubic foot pneumatic supply sphere from the S-IV-B. It is pressurized to 450±60 psia with nitrogen.

There are four S-IV-B actuation control modules for redundancy. One actuation control module supplies pneumatics to open the vent valve. Another actuation control module also supplies pneumatics to open the vent valve and serves as a pneumatic system vent. The third actuation control module is used for the waste tank vent duct cap release. The fourth actuation control module is used for the refrigeration system radiator protective shield jettison.

The pneumatic sphere is pressurized prior to launch. Following completion of all pneumatic functions but prior to the end of IU lifetime, the pneumatic sphere will be vented or dumped to safe the system. Failure to safe, however, is not considered critical since the 450±60 psia operating pressure is well below the sphere safety limits.

The method of calculating the orbital leakage rates based on ground tests conducted near ambient pressure and using a variety of gases (nitrogen, helium, and so on) may prove to be a difficult correlation. The Panel feels this area, being basic to consumable flow, should be thoroughly understood.

There appear to be no time/life critical components in this system, and most potential leak paths are of a static nature.

Waste tank as affects pressure control system. - The waste tank receives liquids and gases dumped through probes and penetrations through the common bulkhead. The waste tank is first pressured to 22 psia, then to 26 psia during launch, and finally vented to space once in orbit.

A problem that is apparently still open deals with the AM condensate dump line which transfers excess water collected in the AM from the OWS atmosphere. The dump system is shown in figure 23. Freezing during dumping of the airlock condensate has occurred during tests. Tests were then conducted to understand cause and solution. The cause is lack of driving pressure during two-phase flow - approximately 50 percent gas - 50 percent H_2O by volume. The current solution is to provide a pressure of at least 3 psia at the dump valve. Many approaches are being evaluated in order to select the best system for minimum impact on hardware, qualification testing, and crew timelines.

Thermal control ventilation and odor removal. - The ventilation control system (VCS) consists of the air supply duct, air circulation ducts, fan clusters (one per duct, four fans per cluster), a mixing chamber, distribution plenum, floor diffusers, and portable fans. The VCS transports revitalized air which has been purified and dehumidified from the airlock module (AM). It mixes the air with the OWS atmosphere and circulates the mixture throughout the habitable area. Revitalized air is brought from the AM to the dome of the OWS via the AM/OWS interchange duct. This duct is attached to the mixing chamber (plenum) located in the forward compartment near the OWS dome. Three OWS ventilation ducts are routed from the mixing chamber to the plenum chamber, which is between the crew quarters and the waste tank. The air flow is produced by fan clusters mounted in each duct. The crew quarters floor is equipped with adjustable diffusers which allow the air to circulate through the crew quarters and back to the forward compartment. A portion of that air then goes to the AM for revitalization.

Each ventilation duct contains four Apollo postlanding ventilation (PLV) fans. They are mounted in a baffled cluster assembly. Portable fans are included in the OWS. They consist of three of the postlanding ventilation fans mounted in central fixtures which can be located anywhere on the OWS grid, on handrails or the fireman's pole, and can be connected to utility outlets for electrical power.

Odor removal in the OWS is provided by the waste management compartment (WMC) ventilation unit. This unit is mounted on the forward compartment floor. The assembly is composed of a fan, charcoal bed, filters, and sound suppressor assembly. The fan is an Apollo postlanding ventilation fan. It is replaceable. The charcoal cannister, which contains activated charcoal, is also replaceable.

Removal of particulate matter, hair, and lint from the OWS atmosphere is provided by the combination of a fine and coarse filter at the inlet to the assembly. The fine inlet screen is upstream of the coarse inlet screen. The upstream restraining screen for the activated charcoal is 60 mesh. The downstream restraining screen is a 10-micron filter. All of the atmosphere flowing through the waste management compartment is drawn in through the circular diffuser in the floor of the waste management compartment, passes through the fan/filter assembly, and is discharged into the forward compartment.

The thermal control subsystem design is based principally on passive thermal con-

OWS
WASTE TANK DUMP PROVISIONS

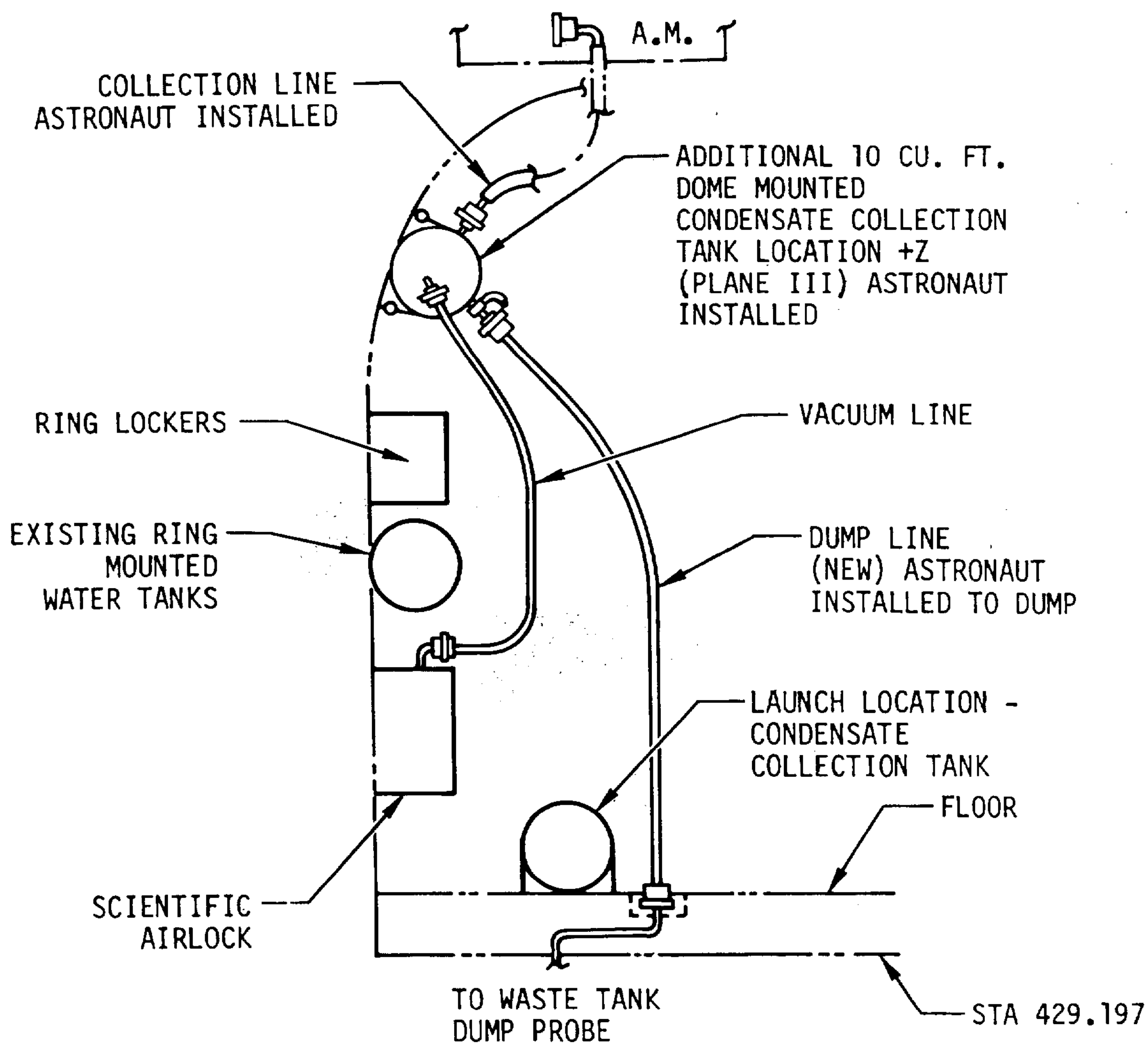


FIGURE 23

trol of the OWS environment. It is augmented by convective heating and cooling of the atmosphere during manned phases. Radiative heating of the internal structure due to the lack of atmosphere is the main thermal aspect to be controlled during unmanned phases. The thermal control subsystem is thus made up of two basic subsystems and a passive thermal control subsystem.

The active thermal control subsystem provides continuous control of the OWS internal environment during periods of astronaut habitation. The cabin gas temperature is controlled by cabin gas heat exchangers in the airlock module (AM) and by convective heaters in the three ventilation control system ducts. Reconstituted air from the airlock module is mixed and recirculated air in the OWS. Prior to habitation, radiant heaters maintain temperatures above the minimum levels that satisfy food and film storage requirements.

The passive thermal control subsystem consists of optical property control of the OWS interior and exterior surfaces. Also included in the passive system is the high performance insulation (HPI) blanket on the forward dome, polyurethane insulation lining the inside of the OWS pressure shell, and heat pipes attached to structural penetrations of the interior insulation. The exterior surface finishes and the high performance insulation blanket control the net energy balance between the OWS and the external space environment. The heat-transfer rates from the habitation area to the meteoroid shield and from the forward and aft dome areas are regulated by surface finish control. The interior habitation area wall temperatures are made more uniform through optical property control of these surfaces and use of heat pipes.

A functional checkout test was performed on the OWS, thermal control subsystem, and the ventilation control system, including spares. This served to (1) verify functional performance of the thermal control subsystem duct and radiant heaters, thermal control subsystem thermal control assembly, ventilation control system duct and portable fans, and the fan filter assembly, (2) verify fit of the spare charcoal cannisters, inlet filters, and heaters and fans, (3) demonstrate adjustment capability of the ventilation control system diffusers and dampers, and (4) verify manual and automatic control of the thermal control system. The test was initiated on April 21, 1972, and the final test was completed on June 20, 1972. There were three significant hardware problems encountered during the test. A duct flowmeter reading was out-of-tolerance on the low side. This was solved by a redesign of a section of duct to provide a more uniform contour at the flowmeter inlet. Floor diffuser dampers were binding preventing actuation. This required rework of the damper to provide more clearance from the diffuser sidewall. A heat exchanger relay drive module failed to turn on the heat exchanger indicator light. A redesign of the module was required. All retest of the modified hardware has been completed.

Problems under consideration at the time of the Panel's review are included here. The closure of these problems will be identified in the phase III or final report:

1. Flowmeters are currently undergoing life tests for 5700 hours with an estima completion date of February 17, 1973.

2. The relationship of inoperative vent fans versus the possibility of a CO_2 prob particularly in and around the sleep compartments, is being investigated.

3. It is understood that during SMEAT unexpected odors surfaced, and the sour(the odor was identified as insulation material.

4. SOCAR indicated an area where further data might be needed. Data may be : quired to substantiate that cabinets, lockers, and vaults had adequate vent area/ structural strength to preclude inadvertent opening.

Thermal control system. - Heat pipes are defined as a closed structure contain a working fluid which transfers energy by means of liquid vaporization at a high tem ture source, vapor transport driven from high to low temperature, and vapor conde: tion at a low temperature source with a subsequent return of the condensate by capi: action to the evaporator point. Heat pipes represent first-time applications (Freon as working fluid, out-of-plane bends) of a technology that has flown before in differe configurations. The Panel does not have information on prior use. Since the perfoı ance of the thermal control system as a complete system is based solely on analysi, and heat pipes do not normally operate in a one-G environment, the temperature mo ing of these pipes may be worthwhile during orbit.

Internal water condensation at any time during mission is of concern. If there operating conditions that can cause this condition they should be fully investigated.

Refrigeration system. - The refrigeration system is a low-temperature therm: control system that uses Coolanol-15 in a closed-loop circuit dissipating heat throu ground heat exchanger cooled by GSE during prelaunch operations and through an ex radiator in orbit. This system has dual coolant loops and redundant components wh necessary.

The refrigeration subsystem provides for chilling and freezing of urine, chilliı potable water, and chilling and freezing of food during all OWS operational modes including prelaunch and orbital storage (see table X).

The refrigeration subsystem has successfully completed checkout and all syste test (AST). All elements of this subsystem have been verified for thermal and func performance in both manual and automatic logic controlled modes of operation. Tl subsystem has been proven leaktight. Checkout for the refrigeration subsystem cc sisted of the following tests:

Refrigeration system electrical preparations
Refrigeration subsystem service
Refrigeration system activation, operating, and securing
Refrigeration subsystem
Refrigeration subsystem service flight

The refrigeration system qualification test has been underway in the McDonnell Douglas Space Simulation Laboratory since August 4, 1972. The system has performed within specification under all orbital conditions imposed to date. This includes the hot orbital mode and the coldest orbit, a 3σ case at the highest specified Beta angle of 73.5°. Full radiator operation under orbital conditions has been achieved. No subsystem problems are anticipated in the balance of this test since the performance in worst-case conditions has already been verified.

Nonetheless, the following components are still under test or tests have recently been completed. Therefore, the Panel was not familiar with all results as of this writing.

Pump assembly (1B79778) life test
Radiator bypass valve (1B79878) qualification test
Pressure relief valve (1B89613) qualification test
Full and drain valve assembly (1B93271) qualification test
Redesigned thermal capacitor (61A830371) qualification test
Redesigned thermal control assembly with cold plate (1B92904) qualification test
Redesigned thermal control assembly with housing radiator control valve qualification test

The major problems encountered during production acceptance testing and qualification testing have been corrected. There are now described:

1. Thermal capacitor leak. The original thermal capacitor failed during thermal cycling in January 1972. This was a result of expanding undercane (wax) being unable to force a flow path to ullage when the unit was tilted. A redesign was undertaken at McDonnell Douglas-East which resulted in a successful honeycomb configuration which places distributed ullage in each individual cell. The new capacitor assembly is installed on the spacecraft.

2. Radiator control valve. A mixing valve formerly used to regulate Coolanol temperature to the OWS showed a tendency to oscillate at high temperature and pressure differentials. Bellows leakage of the temperature control element was also a major problem during its development. Concern over these problems resulted in the adoption of an alternate method of temperature regulation by either diverting flow through the radiator or bypassing it. The mode was based on the temperature range sensed coming out of the first segment of the thermal capacitor. This "bang-bang" temperature control was proven successful in the test facility and in checkout and was adopted as the baseline configuration, thus eliminating the radiator control valve.

The major problems encountered during checkout operations have been corrected. They are as follows:

1. Pump start anomaly - A pump start anomaly was encountered during checkout loop switching verification in the refrigeration subsystem checkout. The primary pump did not start when commanded. This occurred one time out of a maximum of 147 pump starts accomplished during checkout. Questionable start torque margin was found during

off module investigation. This problem has been attributed to the current limiter in the inverter. The inverter will be redesigned to provide a 100 percent margin.

2. Food freezer frost buildup - During factory and AST operations, frost was observed in several spots on the food freezer exterior. The occurrence of frost has since occurred in testing. The problem will not present a problem in flight.

Ground conditioning and purge. - The ground thermal conditioning and OWS interior test performed a functional checkout of the GTCS to (1) verify the hermetic integrity of the plumbing and components, (2) validate the operation of the onboard heat exchangers and fans, and (3) confirm restart and purge capability of the ground environmental control system. The test was initiated on March 3, 1972, and it was completed on March 28, 1972. No major vehicle hardware problems were encountered and no retest was required.

The ECS portion of the AST verified proper operation of the GTCS fans and heat exchanger, the thermal control system control logic, and ventilation control system fans. The ECS equipment was functioned as required by the simulated mission timeline. The only significant AST ECS problem was in the GTCS. The pressure switch on one of the fan-heat exchanger assemblies failed to hold the electrical circuit energized. The pressure switch was tested and found to be within specification. A design change was made to add a tube from the existing high pressure static pressure tap on the fan heat exchanger assembly to the exit of the fan. The design change increased the ΔP sensed by the pressure switch by adding velocity pressure to the high pressure side of the switch. The new design was tested successfully. There are no open problems or items against the ECS resulting from the AST.

The ground support equipment required by the ECS includes the OWS interior ground thermal conditioning system kit and the environmental control distribution system. The OWS kit is the ground ventilation air distribution duct that is installed in the OWS during VAB operations. The installation and flow balance test is complete and there were apparently no problems encountered.

The environmental control distribution system is the ground thermal conditioning unit that supplies the coolant to the onboard head exchanger and controls the fan heat exchanger unit. The unit functioned properly and all fit checks were accomplished without encountering any problems. A modification is planned to add switch guards to the fan control switches on the manual control console (MCC) panel.

The ground support equipment required by the refrigeration subsystem are the ground thermoconditioning system, the refrigeration system service unit, vacuum pumping unit, mechanical test accessory unit, and the refrigeration test set. All units were verified with the exception of an out-of-tolerance flowmeter frequency controller module on the ground thermoconditioning system. The frequency controller is to be replaced as soon as procurement of a replacement module can be obtained through the supplier, North American Rockwell. Exchange is planned after delivery to KSC.

Thruster Attitude Control System (TACS)

The Panel reviewed this area to a lesser degree than those systems which directly interfaced with the crew. Consequently, our remarks here are limited to the qualification test area and SFP's which could compromise crew safety. The TACS high pressure storage spheres and adjunct lines were discussed in the structures portion of this section.

The qualification line item tests for the subsystem have been completed except for the following:

1. TACS valve panel tests have been completed with the exception of thermal vacuum testing. The TACS valve modules have demonstrated satisfactory performance during qualification testing. The number of cycles completed is in excess of 32,000.

2. A bonded metal sheath has been applied externally to the temperature transducer body in order to have a redundant leak seal to the miter weld. Development testing of the new configuration, with a known weld leak, to 8000 psig has been successfully completed. Proof and leak test of the flight hardware on OWS-1 was satisfactorily accomplished at Seal Beach.

3. The pressure switches were redesigned to eliminate a potential diaphragm leakage problem. All vehicle switches have been replaced. Development testing including cycle and burst testing have been completed. The flight hardware was successfully proof, leak, and functionally tested at Seal Beach.

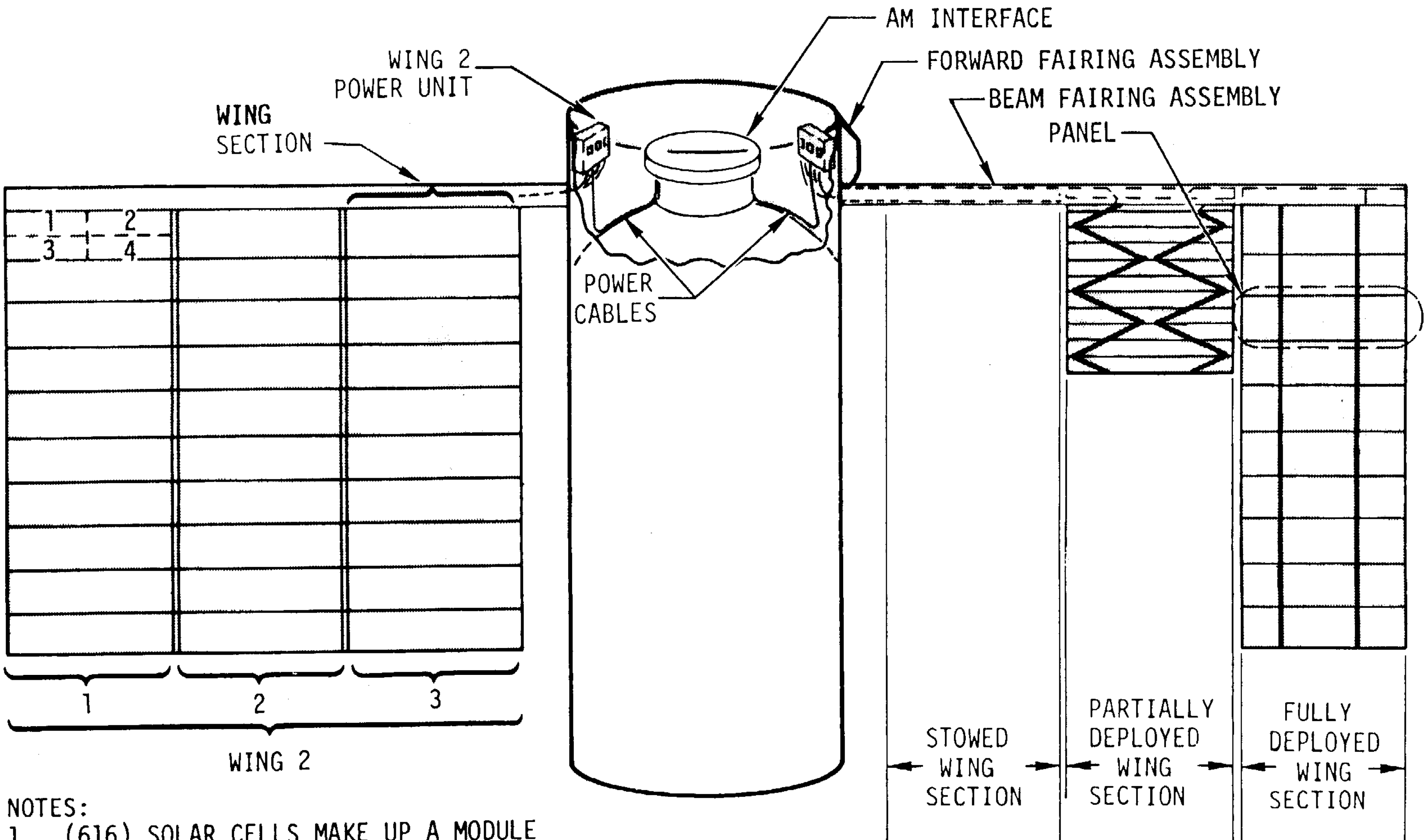
Solar Array Subsystem (SAS) (fig. 24)

The solar array subsystem (SAS) consists of two wing assemblies. The major components include the forward fairings, beam/fairing, deployment mechanisms, power units electrical harnesses and instrumentation, and three wing section assemblies per wing. The wing sections are composed of 10 panels with solar cells. There is a total of 147,840 cells for the OWS supplying an average of 10,496 watts during sunlight portions of orbit. The SAS is manufactured and tested by TRW, Inc.

The SAS has been qualified for flight by a testing program which included component as well as a system qualification test. The component testing was done on solar cells, solar panels, actuator/dampers, deployment mechanism, and the vent module.

System testing was accomplished on a wing assembly complete except for the thermal baffle and environment seals; the two forward bays had dummy masses simulating the wing sections. System testing included dynamics, deployments, and structural testing under induced worst case environments. All tests appear to have been completed satisfactorily.

OWS SOLAR ARRAY SYSTEM



NOTES:
1. (616) SOLAR CELLS MAKE UP A MODULE
2. (4) MODULES MAKE UP A PANEL
3. (10) PANELS MAKE UP A WING SECTION
4. (3) WING SECTIONS PLUS BEAM FAIRI"G MAKE UP A WING

FIGURE 24

From a structural standpoint a number of items are of interest. Design modification of the actuator/dampers was required in the spring of 1972. The time required in the specification for full deployment changed. It originally was to be deployed in 6 to 9 minutes at 20 minutes after liftoff. This was changed to 10 to 14 minutes at 105 minutes after liftoff.

The beam fairing release and deployment system and the wing section release and deployment system are considered mission critical functions. These have received concentrated attention, both analytically and empirically. No major or unresolved problems are currently known.

From the point of electrical power generation there have been some problems. The following have all been resolved or the condition found to be acceptable:

1. Qualification solar array panel exhibited open circuits in solder joints between cell "prayer" tabs. Such open circuits could result in significant reductions in module power output. This problem was resolved by improved soldering methods, tab-to-tab joints inspected by mechanically "tweaking" them, and replaced long turn-around ribbon with ribbons having stress relief loop.

2. Actuator/damper storage test to be conducted at McDonnell Douglas-West. The actuator/damper is at KSC and will be returned to McDonnell Douglas in January 1973 for inspection.

Electrical Power Subsystem (EPS) (fig. 25)

The OWS is considered a load for power supplied from the AM. Such power is distributed by the OWS power distribution system. The primary function of the power distribution system is to provide circuit protection and switching capability for the various loads within the workshop. Circuit protection is provided by circuit breakers and fuses. Their primary purpose is to protect wiring from exceeding the maximum temperature limits specified to prevent fires and excessive outgassing within the OWS. Circuits are designed to provide the necessary redundancy and to limit the voltage drop within the system to prescribed levels. This is necessary to prevent the OWS loads from receiving voltages below their minimum operating voltage levels.

The distribution system provides power to operate internal OWS subsystems such as

Thermal control system
Internal lighting system
Experiment support system
Habitability support system
Communication system
Caution and warning system
Urine dump heater system
Refrigeration system

OWS
ELECTRICAL POWER DISTRIBUTION SYSTEM

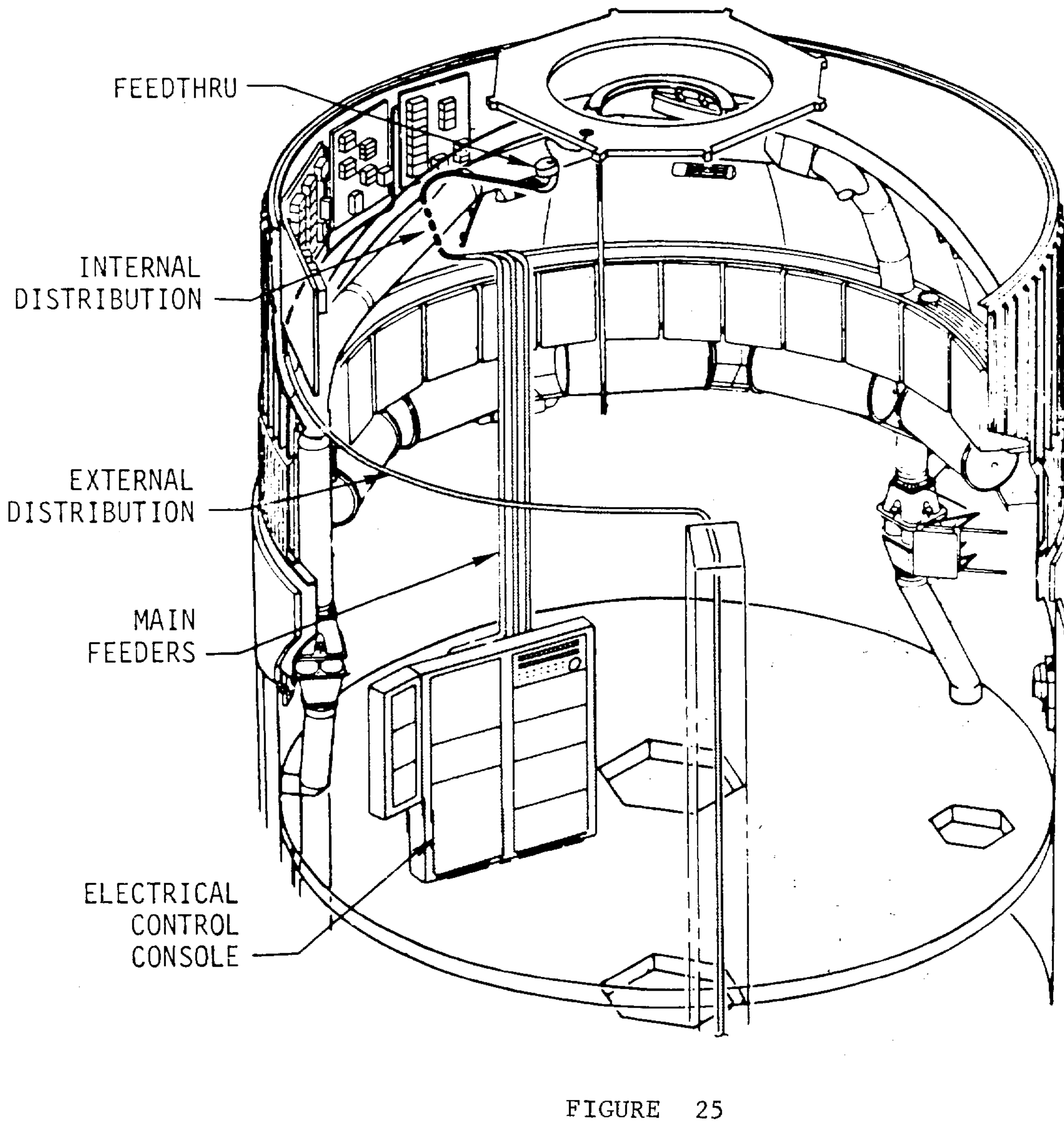


FIGURE 25

Viewing window heater system

Utility outlets

Essentially all wiring is installed external to the pressurized compartment for the following equipment and systems:

Instrumentation system

SAS

TACS

Meteoroid shield system

Switch selector

Airlock module umbilical requirements support system

The OWS receives 28 + 2, -2.5 volts dc from the AM at the OWS/AM interface.

All development and qualification testing has been completed. This includes such tests as the following:

Continuity/compatibility

Umbilical/AM interface checks

Power setup, I/C scan, power turnoff

Power distribution acceptance test

Electrical bus isolation

Crew compartment fit and function

All systems test - preparations and securing

EMC - Preparations and securing

All systems test - prelaunch, boost, and preactivation

All systems test - activation, orbital operations, and deactivation

Areas that require particular management viability and control include the following:

1. Individual wire identification was deleted to save cost and buildup time. There is the possibility that testing and work done at KSC may be hampered to some degree by this lack of identification.

2. Circuit breakers have been a source of failure during qualification tests. There are some 215 such units on OWS and malfunctions could cause spacecraft damage if another failure (circuit overload) occurred in the circuit.

3. The Panel understands that there are some exceptions to the protection of wires in the pressurized or inhabited section of OWS. These appear to be at the number 1 and 2 buses where wires are electrically unprotected between the circuit breakers and the bus. The length of wire is apparently very short and internal to the OWS panel.

4. The Panel noted there was a possible conflict between OWS specification and cluster specification over voltage requirements.

5. The wire harness running from the IU to the OWS and S-II stage interface are considered single failure points. The harness from the IU to lower stage may affect S-II performance if open or shorted. The harness from the IU to the OWS may affect

venting of waste tank if open or shorted. These have been identified as "critical hardware for Skylab" to ensure careful handling and will receive checks at KSC for integrity.

At the time of turnover there was no open work pending on this subsystem. Thus, a complete, functional subsystem was to be shipped to KSC. The subsystem hardware (i. e., wiring, circuit breakers, switches, etc.) presently installed in the OWS is flight-qualified equipment. All interim use material was removed and replaced with flight equipment prior to beginning the AST. In addition, all subsystem hardware changes authorized during factory checkout (e.g., replacement of switches, circuit breakers, and meters due to low insulation resistance; replacement and/or thermal cycle of modules due to encapsulation separations) have been completed.

The OWS data acquisition system provides both real-time and delayed-time monitoring of OWS subsystem flight parameters. This includes biomedical and scientific experiment data sent to ground tracking stations of the spaceflight tracking and data network (STDN). Designed as an integral part of the airlock module data system, it consists of high and low level multiplexers, signal conditioning, transducers and umbilical prelaunch instrumentation.

All interim use material was removed and replaced with flight hardware prior to the AST. Subsystem hardware presently installed in the spacecraft is flight-qualified equipment.

All qualification testing has been completed except for the following test line items:

1. Absolute pressure transducer life test. Anticipated completion date is November 1972.

2. Flowmeter transducer life test. Anticipated completion date is April 1973.

The following checkout procedures have been performed to establish the integrity of this subsystem:

Signal conditioning setup

Power setup, IC scan, power turnoff

DAS calibration, OWS

DAS, acceptance test procedures

All systems test - preparations and securing

All systems test - activation, orbital operations, and deactivation

All systems test - prelaunch, boost, and preactivation

EMC setup and system reverification

Crew compartment fit and function check

The only open work transferred to KSC relates to a number of measurements that could not be functionally verified end-to-end at Huntington Beach because they were either not installed (i.e., SAS, meteoroid shield, etc.) or the subsystem/parameters were not exercised functionally (i.e., water system, digital clock, etc.).

Communication and Television Subsystems (fig. 26)

The OWS communication system is designed as a functional part of the orbital assembly (OA) audio system for the Skylab program and provides

1. Direct voice line between the OWS and STDN via the command module (CM) S-band
2. Biomedical data to STDN through the AM PCM telemetry system
3. Intercommunication line between astronauts
4. Audio and visual displays of warning tones generated by the caution and warning system
5. Control for the operation of the voice and data recording system in the airlock module

Subsystem hardware presently installed in the spacecraft is flight-qualified equipment. There were no test plan line items prepared by McDonnell Douglas-West for development testing of components used in this subsystem.

The speaker intercom assembly is provided as government furnished property (GFP), and it is qualified by McDonnell Douglas-East.

There were no major problems encountered during checkout of this subsystem and there is no open work being transferred to KSC.

The OWS television subsystem is an extension of the orbital assembly television system and provides video coverage of crew activities, equipment operation, and experiments. Transmission to STDN is made through the command service module unified S-band. The subsystem hardware presently in the spacecraft is flight-qualified equipment. The updated configuration is to be installed, but not tested, at Huntington Beach. There were no requirements for development testing of television subsystem components. The television input station is provided as government furnished property and is qualified by Martin-Marietta Company, Denver. There were no major problems indicated. The only noted open work transferred to KSC relates to the testing required as a result of replacing the television input station with the latest configuration after AST. The KSC test requirements have been defined in the KSC test and checkout requirements, specification, and criteria document.

The instrumentation subsystem, while integral to this system, has been discussed elsewhere in the report.

The SOCAR team in reviewing test results indicated a desire for improvement of the general audio quality of the audio subsystem. This involved modifying lightweight headset to provide greater signal level and high output impedance. We understand this improvement has not been completed.

OWS
COMMUNICATION SYSTEM

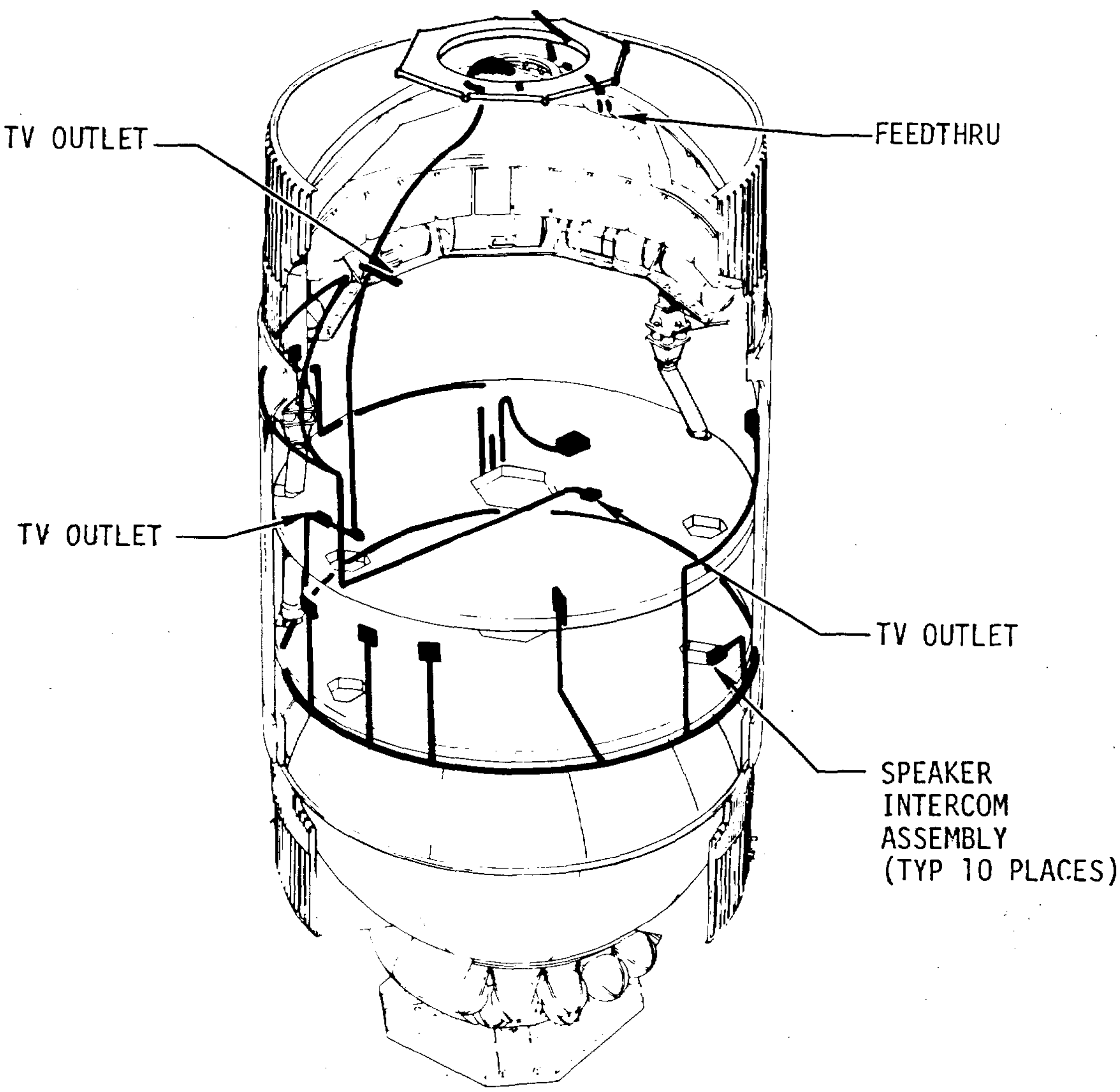


FIGURE 26

Caution and Warning Subsystem

The OWS caution and warning (C&W) system is a part of the cluster C&W system. It is completely redundant and not affected by a single failure point. The OWS portion of C&W inputs signals to and receives command signals from the AM C&W logic unit.

It consists of completely redundant monitor and repeater circuits to identify caution, warning, and emergency parameters. The parameters monitored throughout the cluster are annunciated by audio/visual alarms and indicators as required. The parameters monitored by the C&W are categorized as either emergency, warning, or caution. The criticality and crew response used to determine the category of a parameter is defined as follows:

Emergency. Any condition which can result in crew injury or threat to life and requires immediate corrective action, including predetermined crew response.

Warning. Any existing or impending condition or malfunction of a cluster system that would adversely affect crew safety or compromise primary mission objectives. This requires immediate crew response.

Caution. Any out-of-limit condition or malfunction of a cluster system that affects primary mission objectives or could result in loss of cluster system if not responded to in time. This requires crew action, although not immediately.

Solar flare activity which is monitored through the multiple docking adapter (MDA) solar flare panel is also annunciated within the OWS by an audio tone annunciator.

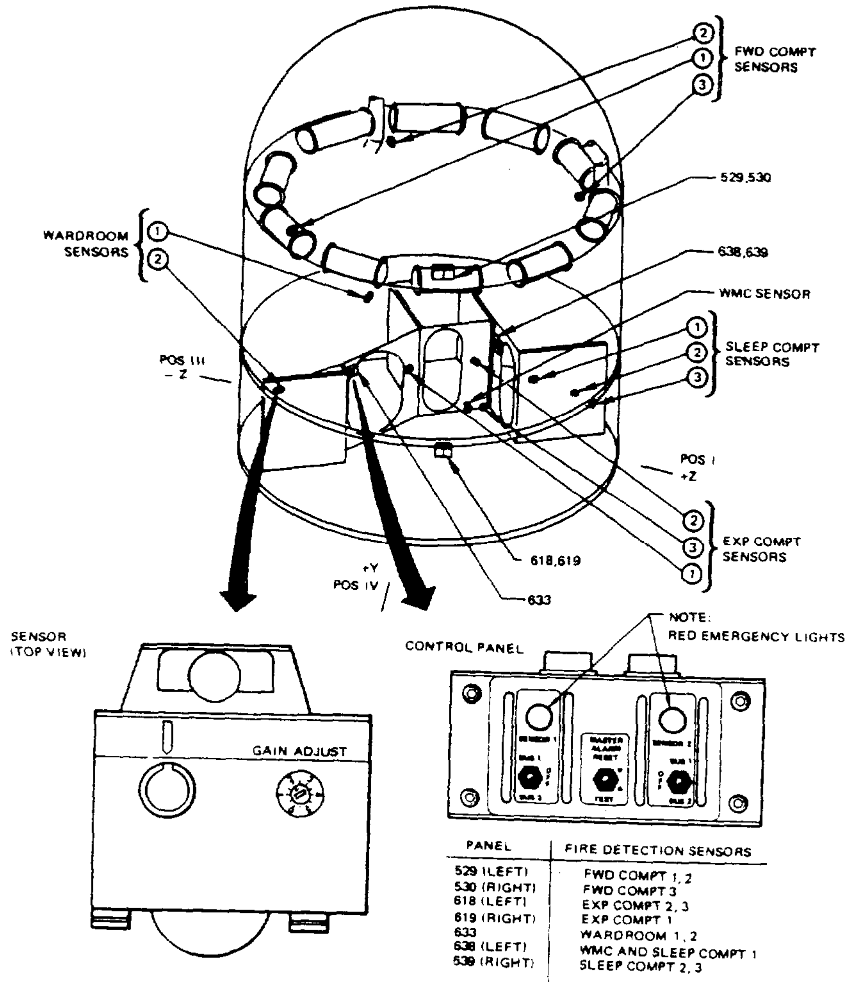
Specifically, the system is to provide warnings with respect to fire (table XI), rapid decompression, low pressure conditions, and OWS bus voltage changes. The fire sensors cover about 85 percent of the OWS volume and about 92 percent of the outer walk between aft floor and water bottle ring on top of the forward compartment. There are 12 ultraviolet sensors in the OWS, located as follows (fig. 27):

OWS forward (top compartment)		3
OWS crew quarters:		6
Wardroom	2	
Waste management compartment	1	
Sleep compartment	3	
OWS experiments		3
Total		12

The design of the OWS C&W system appears to be based on proven design practices which should preclude human errors.

The rapid ΔP alarm system is designed to alert the Skylab crew and the flight controllers to a decrease in cluster pressure at a rate equal to, or greater than, 0.1 psi per minute.

SKYLAB - ORBITAL WORKSHOP
FIRE DETECTION SYSTEM AND
PANELS 529, 530, 618, 619, 633, 638 & 639



PANEL	FIRE DETECTION SENSORS
529 (LEFT)	FWD COMPT 1, 2
530 (RIGHT)	FWD COMPT 3
618 (LEFT)	EXP COMPT 2, 3
619 (RIGHT)	EXP COMPT 1
633	WARDROOM 1, 2
638 (LEFT)	WMC AND SLEEP COMPT 1
639 (RIGHT)	SLEEP COMPT 2, 3

FIGURE 27

The first question that would naturally be raised is the possibility of an inadvertant fire alarm due to ultraviolet light from a nonflame source (e.g., through a window). Two methods were applied here to prevent that. The windows were coated to delete ultraviolet from solar radiation, and a time delay was added to avoid false triggering. A system constraint was added for the three fire sensors in the OWS forward compartment which must be powered down during operation of experiment SO63, ultraviolet air-flow horizon photography. Tests were performed in the McDonnell Douglas-West hi-fidelity mockup to simulate energy conditions. These tests showed that such a modification was necessary to preclude false alarms. The rationale which permits this includes the fact that crew members are in the immediate vicinity of these powered-down sensors.

The fire sensors and fire sensor control panel are provided as GFP and are qualified by McDonnell Douglas-East. The solar flare alert is provided as GFP. These checkout procedures have been performed to establish the integrity of the subsystem:

Caution and warning subsystem test

EMC setup and systems reverification

All systems test - preparations and securing

All systems test - Activation, orbital operations, and deactivation

Ordnance Subsystem

The ordnance subsystem for the following systems are of diverse configurations:

Meteoroid shield release (figs. 28 and 29)

Solar array beam/fairing release

Solar array wing section release

S-II retrorocket ignition

S-II/OWS separation

The Panel understands that underlying this diversity were common design guidelines and criteria. These were greatly influenced by the operational success of the McDonnell Douglas-West launch vehicle stage hardware. Some typical examples of these concepts are given. All ordnance systems should use (1) a high-energy exploding bridge wire-type initiation for crew and pad safety, (2) common ordnance components, (3) minimum quantities, and (4) redundant ordnance trains.

Because the installation of all ordnance components has been planned for KSC, checkout and AST activity at Huntington Beach was limited to verification of electrical circuitry on the OWS. Checkout for the ordnance subsystem consisted of the following two tests:

EBW subsystem, meteoroid shield, and solar array

All systems test (AST)

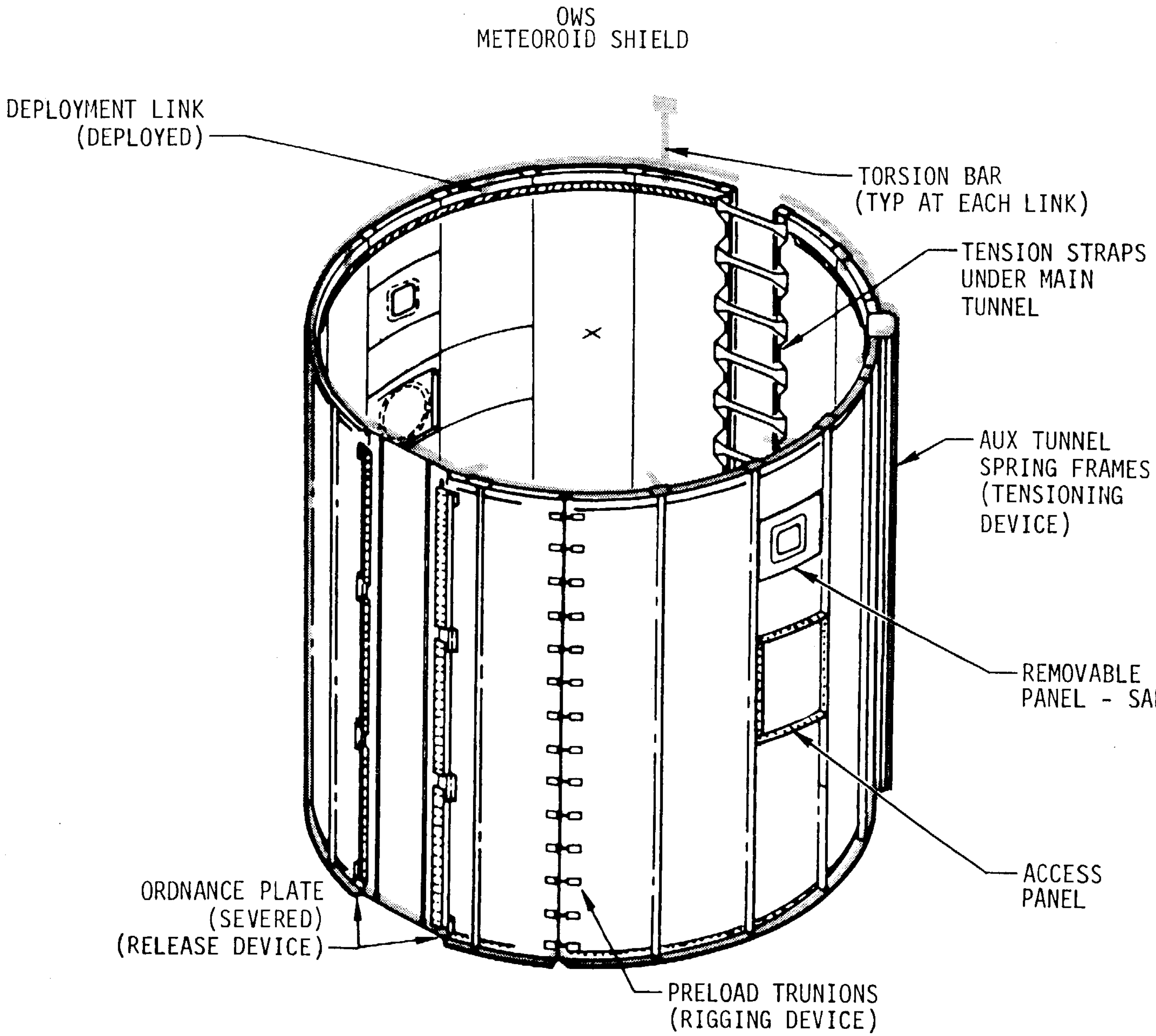

OWS
METEOROID SHIELD
DEPLOYMENT LINK
(DEPLOYED)
TORSION BAR
(TYP AT EACH LINK)
TENSION STRAPS
UNDER MAIN
TUNNEL
AUX TUNNEL
SPRING FRAMES
(TENSIONING
DEVICE)
REMOVABLE
PANEL - SAL
ACCESS
PANEL
ORDNANCE PLATE
(SEVERED)
(RELEASE DEVICE)
PRELOAD TRUNIONS
(RIGGING DEVICE)

FIGURE 28

OWS
METEOROID SHIELD RELEASE ORDNANCE

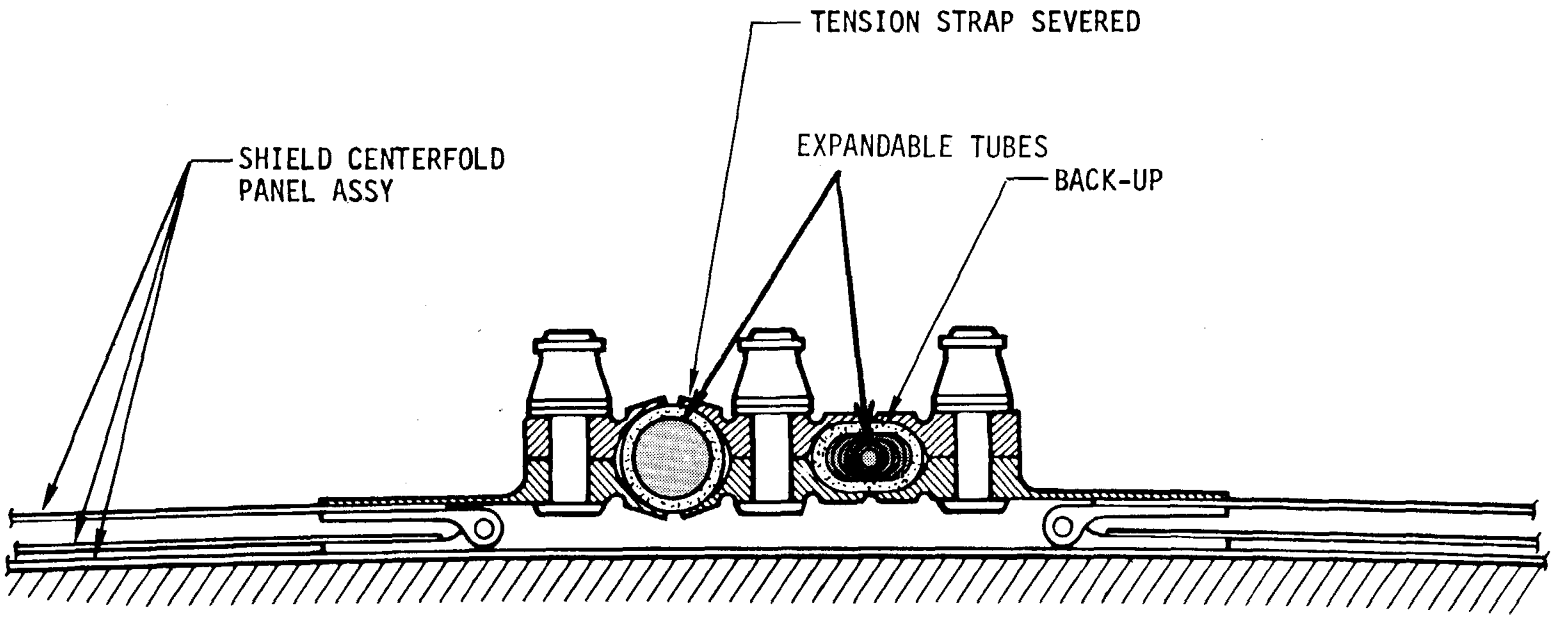


FIGURE 29

Problems encountered during this checkout were resolved, and there are no unresolved problems. Currently all ordnance qualification tests appear to have been completed satisfactorily. Major areas of qualification were the following:

1. Full-scale meteoroid shield deployment. This was accomplished at MSFC on the static test article. The meteoroid shield release system had been redesigned after a factory deployment test in May 1971. An expandable tube ruptured and released gas and debris. Reported testing has verified the performance of the redesign.

2. Solar array system. These factory deployment tests qualified both the solar array beam-fairing release and wing section release systems. All individual deployments were successful. The only ordnance system anomaly was the breaking off of small metal tabs along the fracture line of the tension straps during firing. This problem has been completely solved with a dual tapewrap that has been satisfactorily tested in SAS production acceptance tests. These tests, which incorporated flight ordnance, showed that all broken tabs were completely retained by the tape.

Habitability Support Subsystem (HSS)

Habitability support encompasses a number of vital crew related systems because they sustain the crew on a day-to-day basis and are susceptible to the most subjective study and comment; the Panel examined this area in some detail. During the actual mission the public would probably relate most to an area in which they themselves are daily confronted. For our purposes the HSS consists of the following:

1. Waste management system. This provides for the collection, processing, storage, and/or disposal of the feces, urine, and vomitus as well as debris, particulate mater, and free water from the atmosphere. It also provides support for experiments MO71 (mineral balance) and MO73 (bio-assay of body fluids). At the end of each orbiting stay period this system provides for transferring of processed and identified samples to the CM for Earth return.

2. Water subsystem. This provides for storage, pressurization, distribution, purification, thermal control and conditioning, and dispensing of water. Water is provided for such items as food reconstitution, drinking, crew hygiene, housekeeping, urine separator flushing, life support unit used in EVA, ATM C&D Panel, EREP cooling loop, M-512 facility experiment, and the shower.

4. Food management subsystem. This provides specially selected foods, mineral supplements, fecal marker capsules, wardroom food preparation table, and galley.

5. Illumination subsystem. This provides interior lighting for normal and emergency crew activities, and experimental operations in the forward and crew quarter compartments. The fluorescent floodlight assembly is flight replaceable.

The habitation subsystems, of course, interface with other systems within the OWS. In this section the Panel limits itself to equipment not covered in other areas and which are primarily considered an integral part of HSS.

Waste Management

As is true of most all systems on board Skylab, the hardware capability must endure nominally for one 28-day and two 56-day manned mission periods during an 8-month time span. The waste management system components and general location are shown in figure 30 and 31.

The waste processor consists of six identical processing units capable of individual operation. They vacuum dry and thereby preserve fecal and vomitus collections for medical analysis.

The processor demonstrated its capability based on a series of detailed development and qualification tests. The significant problems have either been resolved or accepted based on their low order of impact on safety and/or mission success.

1. A processor chamber heater plate temperature was found to be out-of-tolerance. A waiver was submitted to the test and checkout requirements, specifications, and criteria (TCRSC). The specification requirement is 105° F maximum to conform to touch temperature requirements, since this heater plate exceeded the requirement by 5° F. This condition was considered minor and the hardware change has been made.

2. The processor indicator lights also exceeded touch temperatures by some 15° F. Since the lights are recessed in a protective cover to prevent access, a waiver was requested.

3. The processor drawer timer tended to "skip" in 1/2-hour increments during qualification tests. Voltage surges from the test setup apparently damaged the timer units. Timers were reworked and successfully retested.

The fecal/urine collection units are considered open items. Prior to the SMEAT, component qualification tests were still to be completed on the urine separator, fecal/urine collection module, urine volume determinator, chiller compartment, and urine bladder. These were essentially system performance and life cycle tests. They involved such factors as size and residual in separator.

There was a problem in achieving the accuracy required of the urine measurement device. Test results indicated that the original method of vertically calibrating the pressure plates resulted in error greater than ±2 percent allowed by specification. Horizontal calibration results indicate significant improvements. Spacecraft pressure plates will be removed and horizontally calibrated before flight.

WASTE MANAGEMENT SUBSYSTEM

THE WASTE MANAGEMENT SUBSYSTEM PROVIDES THE HARDWARE ITEMS NECESSARY FOR SAFE, EFFECTIVE, AND HYGIENIC COLLECTION, PROCESSING, RETURN, AND/OR DISPOSAL OF WASTE PRODUCTS (FECES, URINE, VOMIT, AND DEBRIS) FOR THREE CREWMEN.

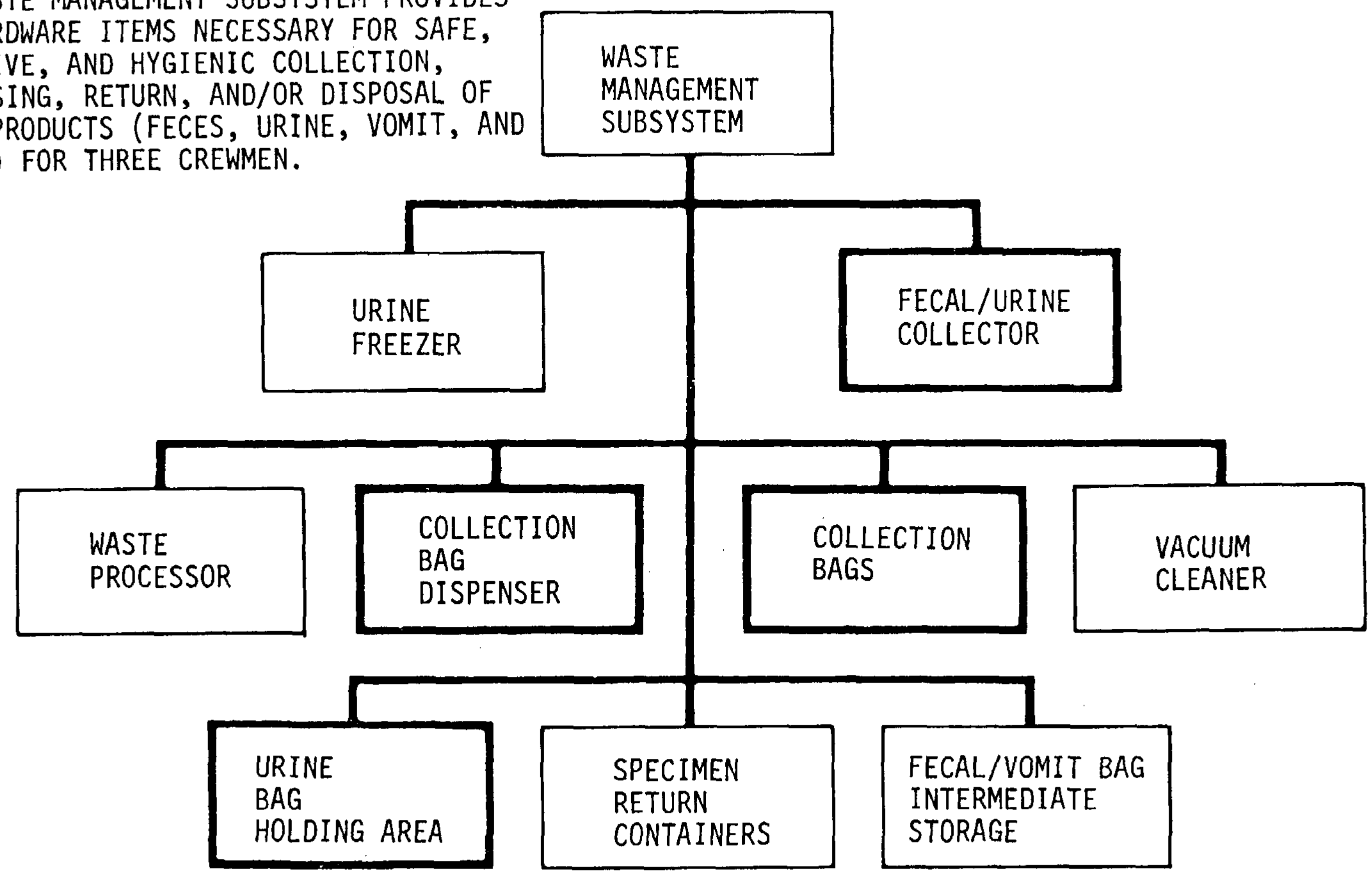


FIGURE 30

OWS
WASTE MANAGEMENT SUBSYSTEM

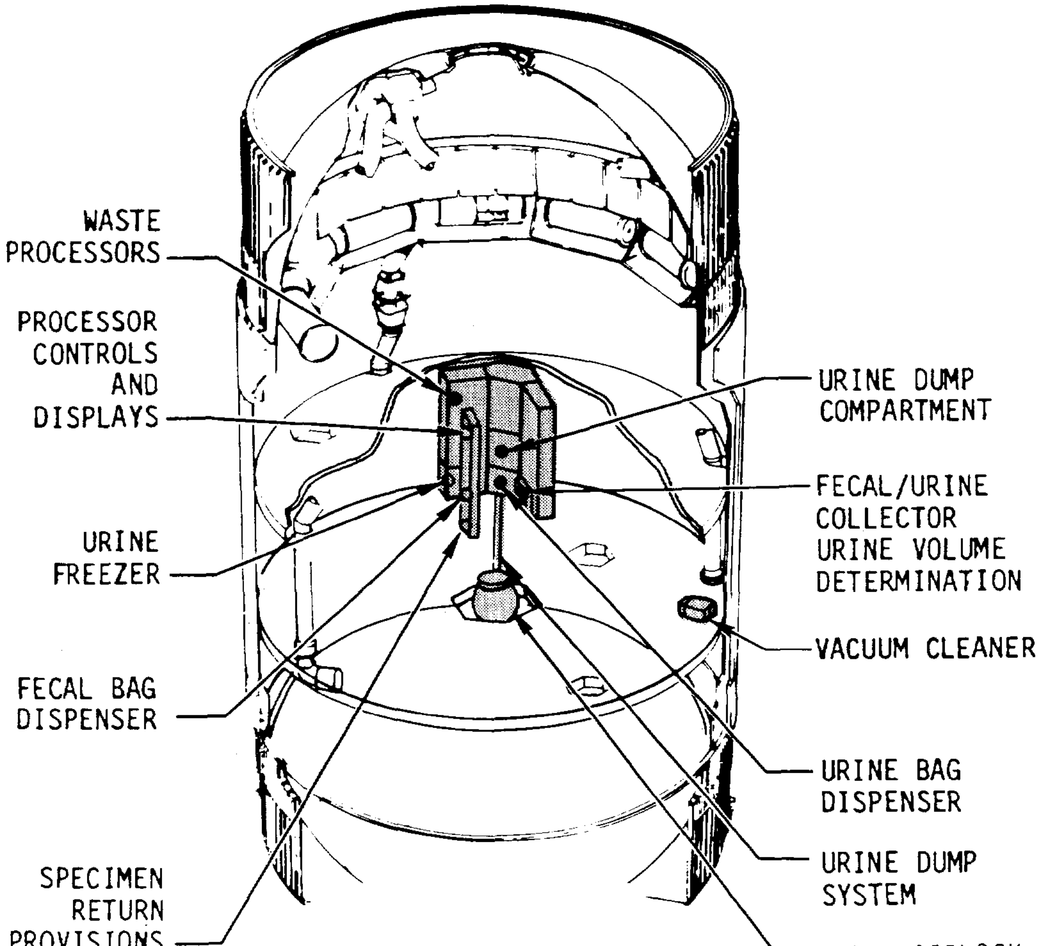


FIGURE 31

One significant problem in checkout was the stickly operation of the urine pressure plate. The pressure plate was redesigned by replacing the clock spring with a tension spring and the redesigned unit was reinstalled and verified in the spacecraft.

Minor items open at time of PDTR were the following:

1. Fecal and contingency bags tare weight. The bag tare weight was found to be discrepant during pre-SMEAT test operations. Three discrepancies and their solutions are as follows:

(a) Weighing equipment was inadequate at Fairchild/Dielectric. The bags will be reweighed.

(b) Testing indicated that moisture content of bags due to humidity was a small influence but must be accounted for. Reweighing fecal and contingency bag will be accomplished in a controlled environment.

(c) Green peel tape weight was not adequately accounted for. Statistical weighing of green peel tape is expected to prove tape weight dispersion is within tolerance.

2. The SMEAT test crew exceeded 2000-milliliter capacity of the urine system. The system is therefore being modified to increase the capability of the urine system to 4000-milliliter capability. Hardware and development testing is to be completed in January 1973. Qualification testing is to be completed in March 1973.

An objectionable odor in the fecal collector cabinet was noted during delta C^2F^2. The odor appears to emanate from the collector acoustic insulation. The insulation, which is not mandatory, will be removed from the cabinet.

The trash disposal system shown in figure 32 deals with collection, disposition, and storage of cluster wet and dry waste. Two areas are discussed here since they constitute either open work or a problem to be resolved. The trash disposal system uses 420 trash bags for collection, 349 disposal bags for trash airlock disposition into a 2195 number 3 waste tank, 28 bags for cardboard packing used during launch, and the remainder 46 bags for contingency. With respect to the collection bags the open item is a shelf-life test with an estimated completion date of November 30, 1972.

The nonflammable cardboard is used extensively in OWS lockers to alleviate vibration impacts. Two problems have arisen here: (1) the cardboard sheds particles, and (2) it must be removed from the lockers and stored. The closure of these problems will be identified in the phase III or final report.

Other waste management areas, such as the vacuum cleaner, are covered within the discussion on SMEAT.

OWS
TRASH DISPOSAL SUBSYSTEM

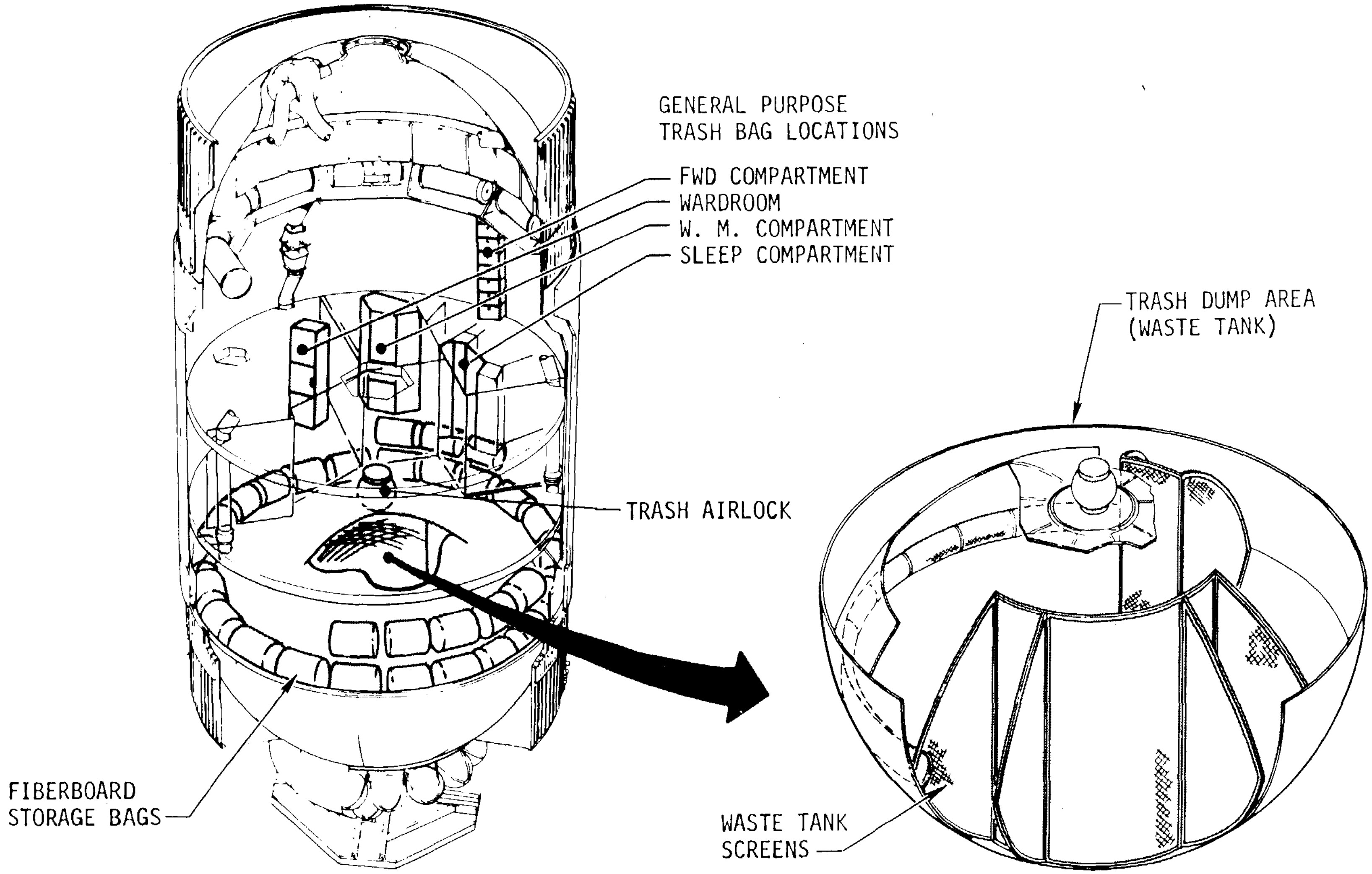


FIGURE 32

Water Subsystem (fig. 33)

The water system provides 6000 pounds of water, packaged in 10 tanks of GN_2 at 35 psig for pressure distribution. Iodine is the biocide.

The major problem during development testing occurred in the water deionization assembly test. It showed that the deionization resin absorbed an excessive amount of iodine from the water and the required iodine concentration levels could not be significantly increased by reducing the resin volume. The cartridge was redesigned to reduce the resin volume to 30 percent of the original design with influent iodine level at 8 ppm. Test completion is scheduled for April 1973.

System performance is being verified by the water subsystem qualification test. The estimated completion date is December 1972.

1. Leakage was observed from the valves in the iodine container, iodine injector, sampler, reagent container, and portable water tank. An investigation revealed that the food grade viton O-ring seals had taken a large amount of compression set. There are only two known food grade seals that can be used in the water system and are compatible with iodine, viton, and silicone. The silicone seals are known to have better compression set characteristics than viton. However, these are normally not used in dynamic applications because of poor abrasion and tear resistance. Tests have been conducted that indicate these seals are acceptable for low cycle, low pressure applications. All affected viton seals have been replaced.

2. Operation of the food reconstitution dispensers created a water pressure spike causing the relief valves to expel water. The problem was resolved by adding an orifice to each dispenser inlet and raising the relief pressure.

3. During life cycle testing of the iodine injector, water leakage was observed on the 38th cycle. The unit was disassembled and two cracks were found in the weld beads of the bellows assembly. The unit is being redesigned to add a pressure limitor to the bellows assembly.

During checkout for the water subsystem two significant problems were encountered. The water tank domes on several tanks were deformed. The problem was the result of the mechanical restraint method used for handling. The domes were reformed with gas pressure. The restraint system was redesigned to use a vacuum system. Temperature of water dispensed from the chiller was higher than the specification requirements. The CEI and Food ICD specifications and the TCRSC drawing were changed. Waivers or deviations to specifications had been given where touch temperatures had exceeded the specification on the personal hygiene water heater dump quick disconnect. However, further testing indicated that the original requirement of 105^0 F was in fact met and the deviations were not necessary.

OWS
WATER SYSTEM

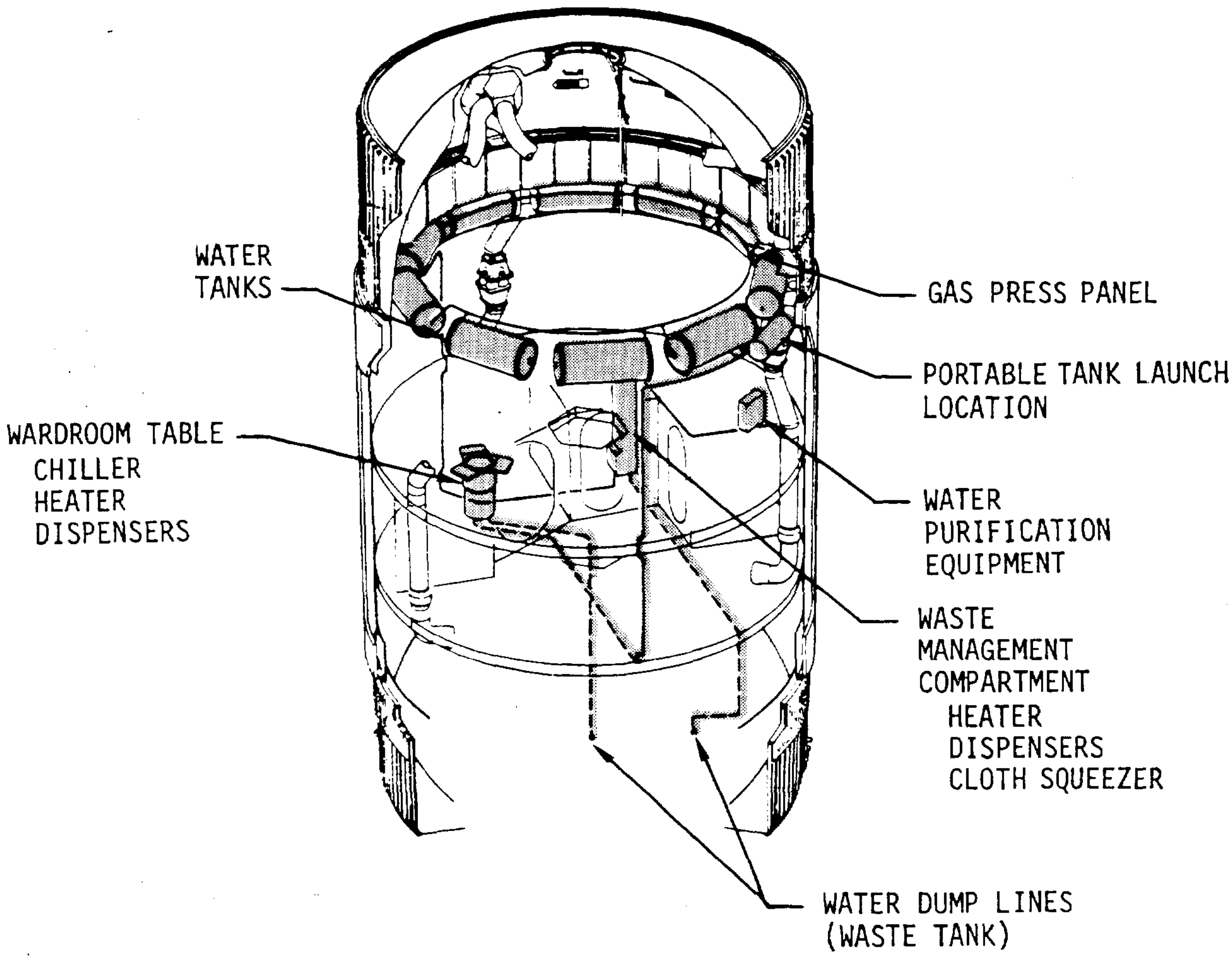


FIGURE 33

Food Management Subsystem

The Skylab food system appears to be still evolving. A reference menu, formulated some time ago as a driver for galley design, provided good engineering data. Galley design appears to be sensitive to the relative proportion of different food packages. The unique food safety problems of Skylab differ from Apollo in that the mission causes increased length of storage, food variation, new packaging, and medical experiments interface.

The basic system is shown in figure 34. The containers provide storage of 2200 pounds canned food and 252 pounds of frozen food. The food table has restraints and heating devices. This area is discussed in further detail under the OWS C^2F^2 activities.

Illumination System

The OWS illumination subsystem (see fig. 35) is comprised of that hardware which is involved in providing lighting to support crew activities within the workshop (see table XII).

All development testing associated with this subsystem has been completed.

All Huntington Beach postmanufacturing checkout procedures associated with establishing the integrity of this subsystem have been completed. Checkout for the illumination subsystem consisted of the following tests:

Illumination subsystem acceptance test

Photography

Television

Crew compartment fit and function

All systems test - preparations and securing

EMC-preparations and securing

All systems test - activations, orbital operations, and deactivation

There were no major anomalies encountered during testing. All checkout problems have been resolved and all applicable test requirements have been satisfied.

The only open work still pending at the time of the PDTR is a modification to the two GFP portable high intensity photolamps to incorporate EMI filters. In addition, all subsystem hardware changes authorized during factory checkout (e.g., replacement of lights due to inconsistent low mode starting) have been completed.

The GSE internal test lighting kit was verified during postmanufacturing checkout but was not used during the balance of VCL testing. Facility lighting was used instead during all postmanufacturing checkout. There were no major problems encountered during the checkout of this item of ground support equipment.

OWS
FOOD MANAGEMENT SYSTEM

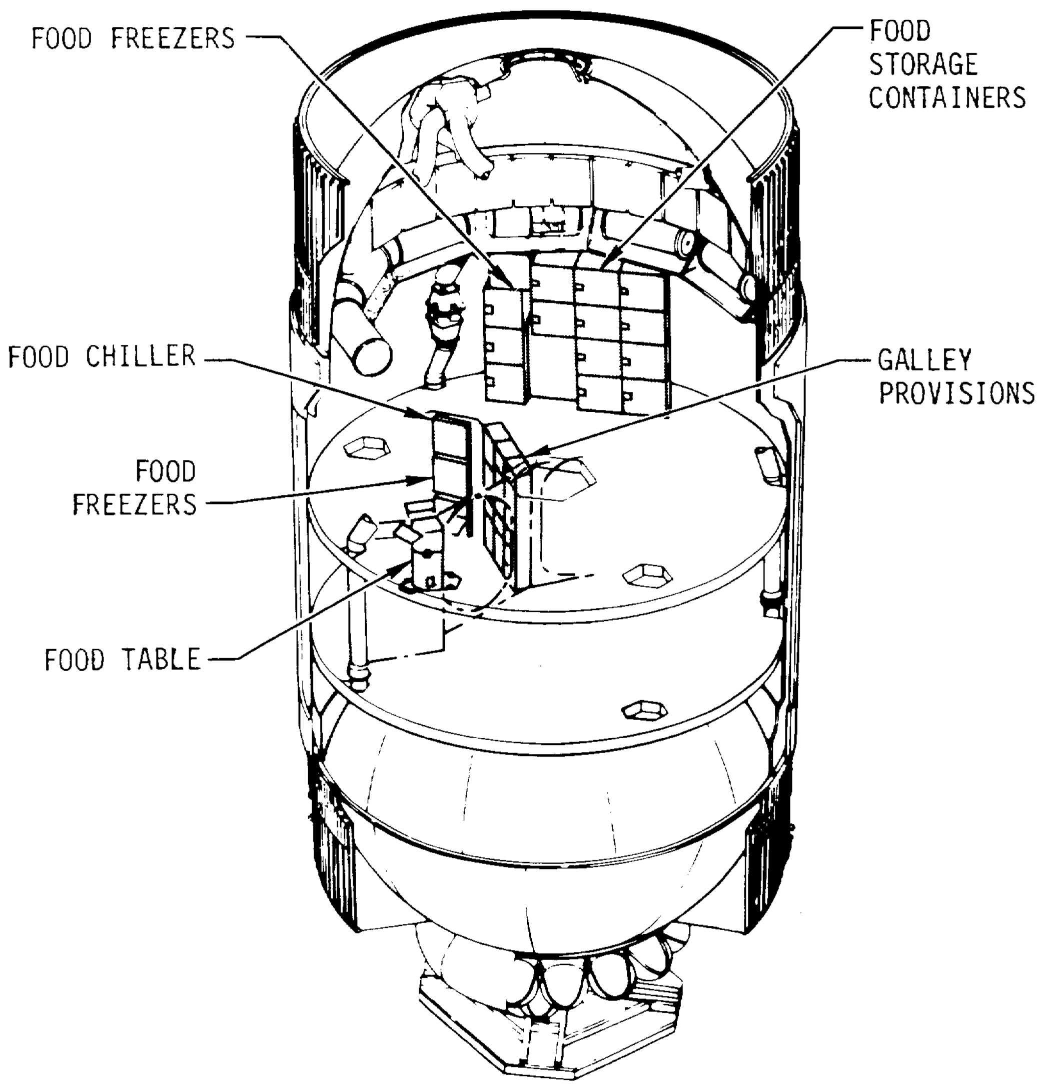


FIGURE 34

OWS
GENERAL ILLUMINATION SYSTEM

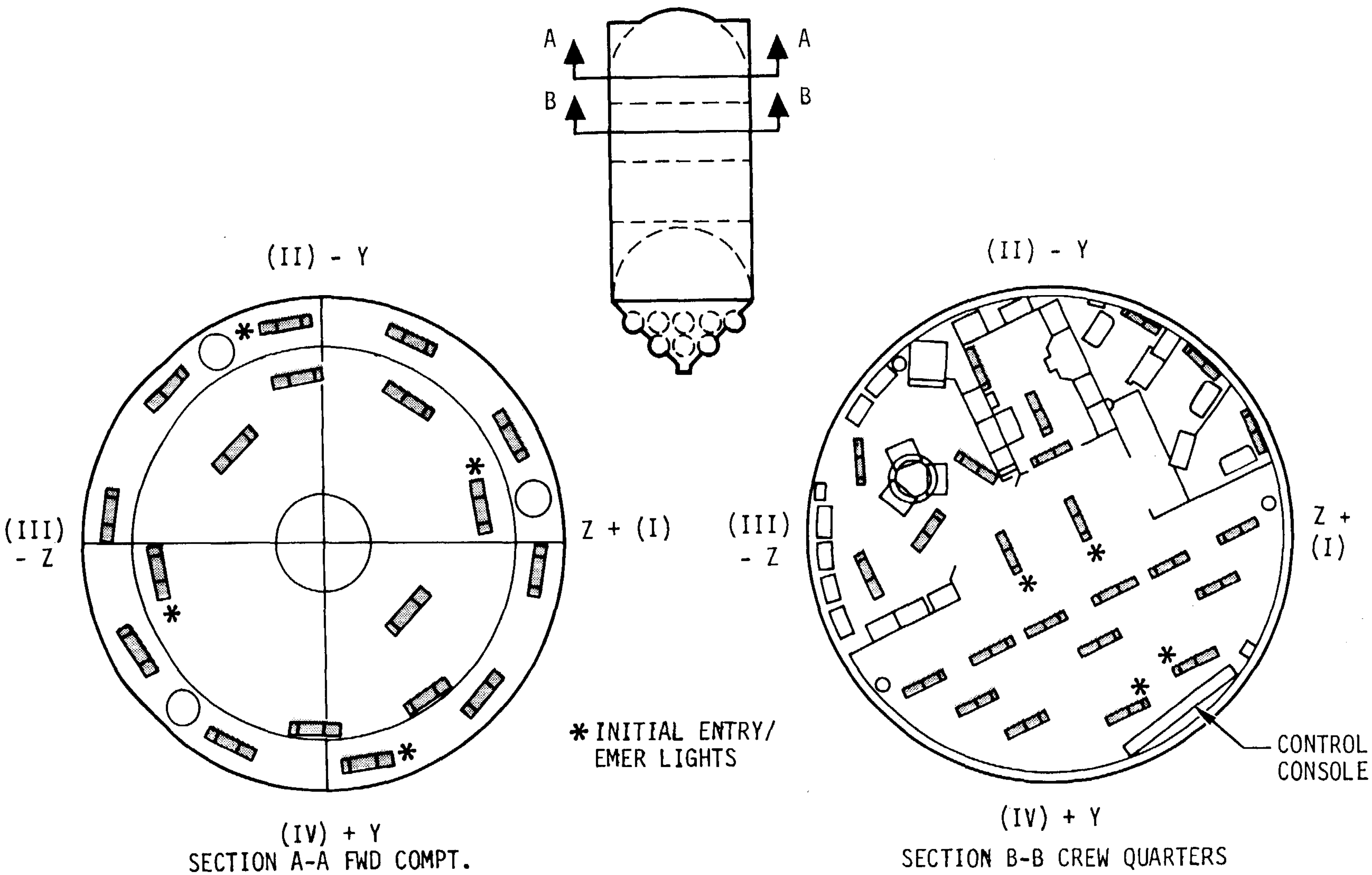


FIGURE 35

Crew Equipment Systems

Panel reviews in this area include discussions at MSFC, MSC, Headquarters, and the OWS contractor McDonnell Douglas-West. Of particular interest were the crew accommodations and stowage areas.

The Panel gave particular attention to the role of crew compartment fit and function activities in establishing design adequacy and mission readiness of the hardware. The materials control aspects are covered in the CLUSTER MATERIALS section.

Crew accommodations include the personal hygiene equipment, sleep hardware, and foot restraints (see figs. 36, 37, and 38). The stowage system (fig. 39) provides a total volume of 583 cubic feet.

Included in the stowage are two materials - nonflammable cardboard packing and mosite linings - which have been the occassion of much discussion. Cardboard was noted before as part of the trash control problem and will be covered in more detail under MICROBIAL CONTROL and MISSIONS OPERATIONS sections of this report. Mosite is discussed under the CLUSTER MATERIALS section of this report.

Problems under consideration at the time of the Panels review include the following:

1. The type of hook velcro used in the OWS may wear off and particles could float in zero-G.

2. Flight tools were getting worn as a result of use in C^2F^2.

The testing of the portable foot restraint (triangle shoes) and the sleep restraints have been deferred to KSC because late configuration definition prevented flight articles from being available at Huntington Beach. McDonnell Douglas-West noted that significant sections of the C^2F^2 test and checkout procedures were not performed at Huntington Beach because of hardware unavailability. Therefore, the following activities will have to be completed at KSC:

M487 experiment verification

M172 experiment verification

Stowage fit checks - sleep compartment

29 Stowage locations in other compartments

Crew systems required no unique GSE. The interfaces with the crew quarters vertical access kit, and the HSS equipment handling kit have been successfully demonstrated.

All crew systems qualification tests are complete except for the biocide wipe packaging.

This is an 8-month shelf-life test scheduled for completion in March 1973. It is to determine the stability of the Betadine solution used to prewet the wipes. The data after 73 days still show an acceptable iodine concentration. However, a consistent loss trend

OWS
PERSONAL HYGIENE EQUIPMENT

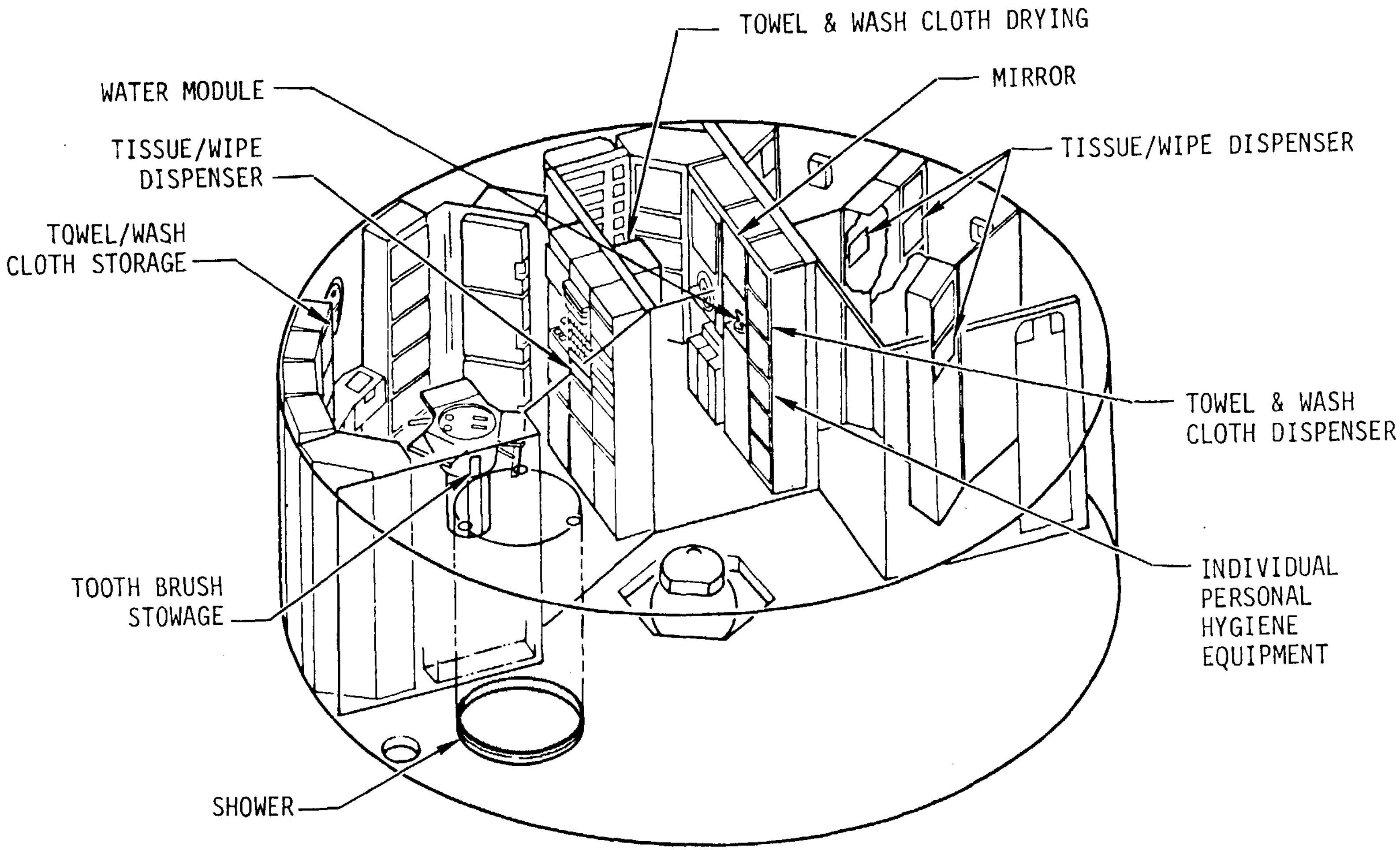


FIGURE 36

OWS
SLEEP COMPARTMENT EQUIPMENT

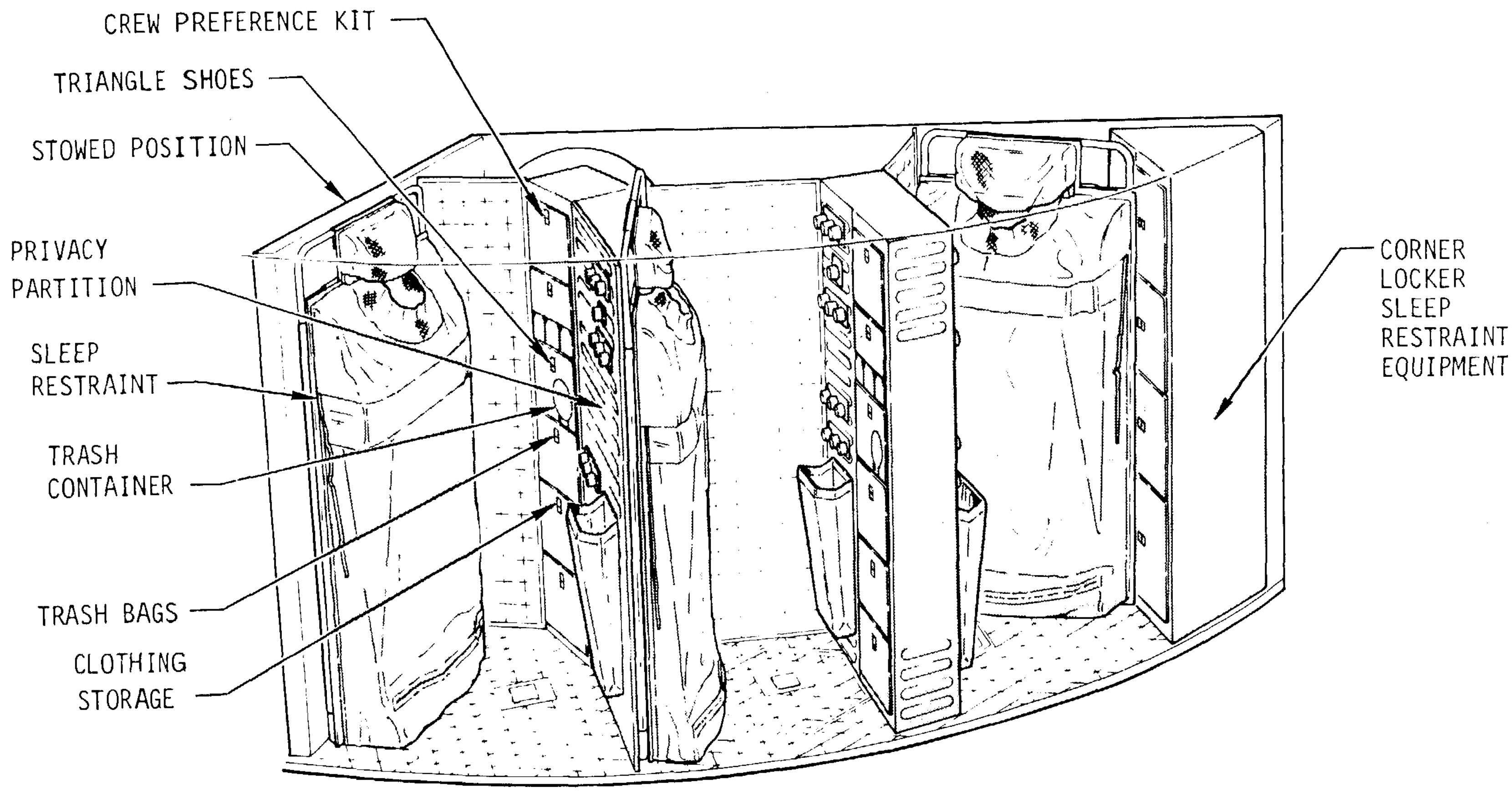


FIGURE 37

OWS
MAINTENANCE

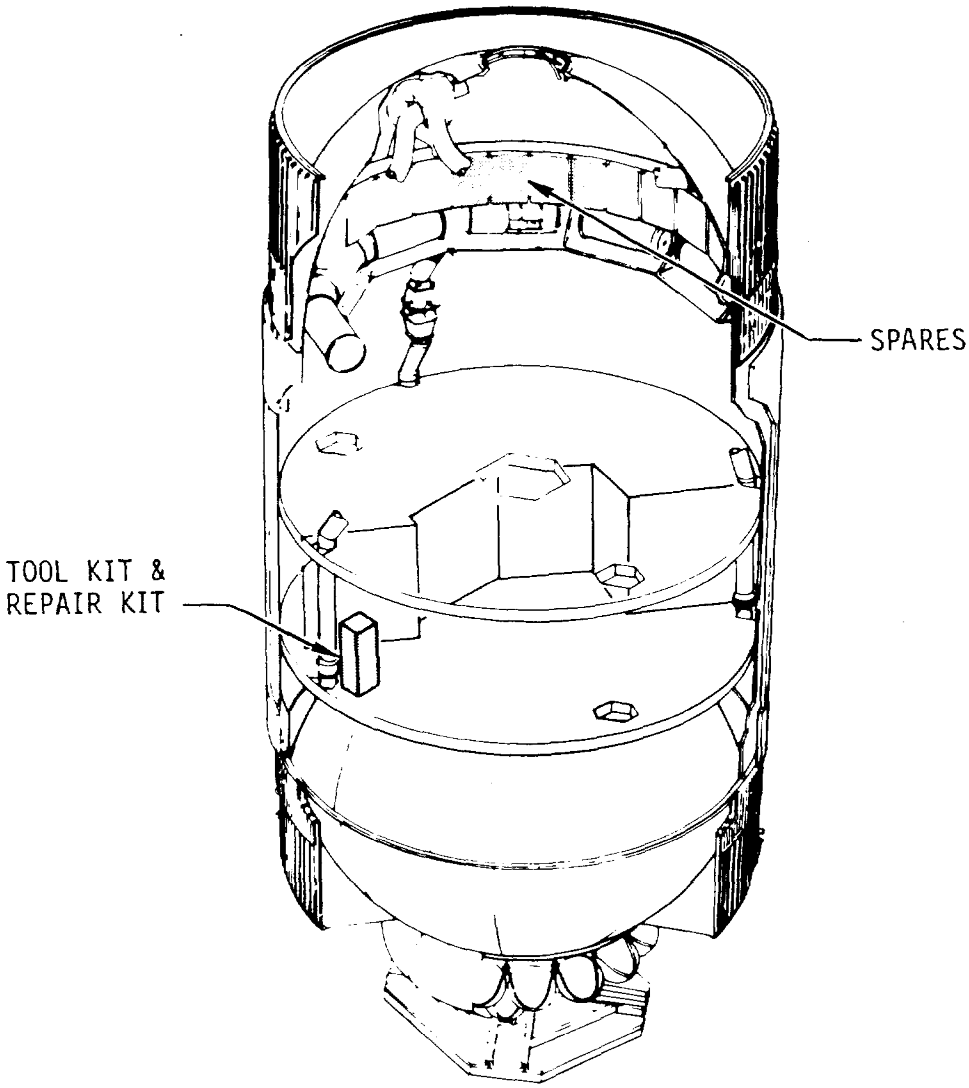


FIGURE 38

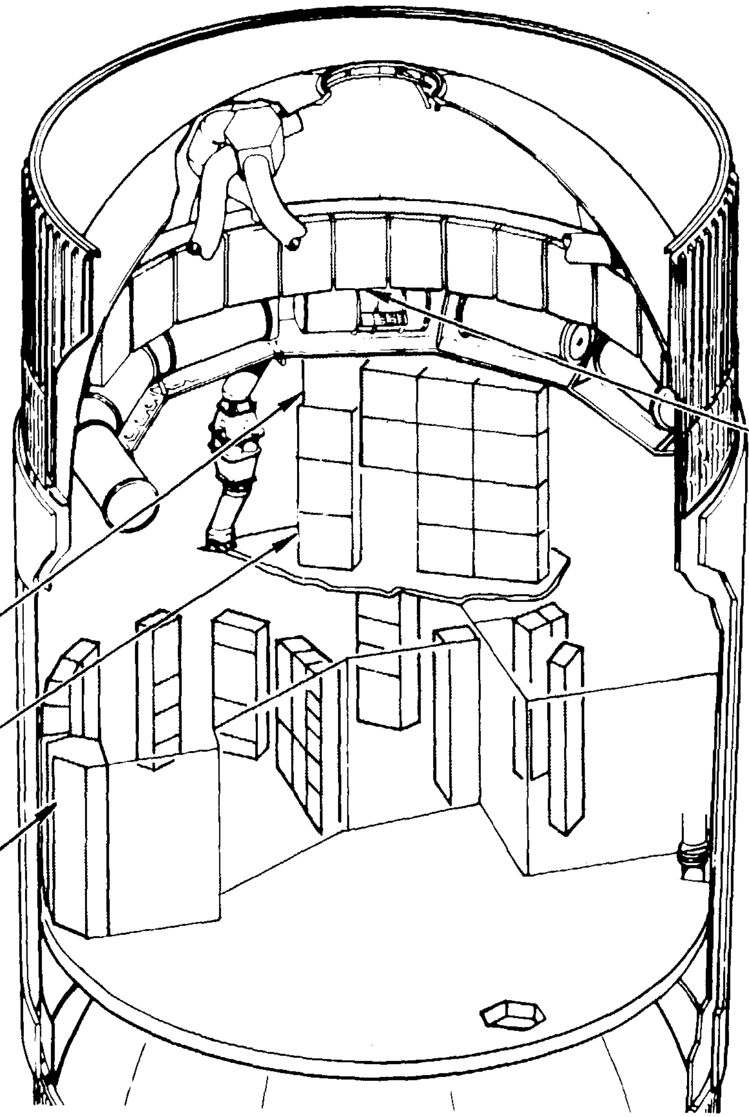

RING LOCKERS
FOOD
STOWAGE
CONTAINERS
FOOD FREEZERS
STANDARD
STOWAGE
LOCKERS

FIGURE 39

indicates that complete depletion will occur in approximately 160 days. If the trend does continue, one of the following solutions will be instigated:

1. Change the biocide to Zephyrin
2. Supply wipes for each mission

Checkout for the stowage accommodations and procedures dealt mostly with the experiments and waste system. All stowage locations were fit checked during checkout except for approximately 28 locations where equipment was not available. Checks will be completed at the KSC. In addition, equipment in 96 locations was unstowed and will then be restowed at the KSC. Twenty-five ring containers will be delivered to the KSC outside the spacecraft. Fourteen of the ring containers are fully stowed and five are partially stowed.

A list of stowage lockers not reviewed at McDonnell Douglas at PDTR and hardware not reviewed during OWS checkout at McDonnell Douglas are shown in table XIII.

Ground Support Equipment

The Panel has not had the opportunity to look into this area in depth. Based on the results of SOCAR and the OWS DCR and PDTR's it appears that OWS unique GSE including mechanical, electrical, and special handling has received a reasonably thorough examination. In most cases this equipment was used during the in-house development and qualification testing (all systems, dynamic test articles, subsystem tests, C^2F^2, and so on). It appears that where problems were encountered they have been resolved. Of interest at the KSC will be those items of GSE which are shipped incomplete or require further modification. A second point is the necessity of maintaining GSE, including separate cables and ducts, to the necessary cleanliness standards. Based on prior Apollo experience the Panel wishes to reiterate the necessity of having adequate GSE procedures and knowledgeable personnel to preclude overexcitation of flight hardware.

Current Assessment of Technical Areas

The Panel has observed factory buildup and test activities along with SOCAR, module DCR, PDTR, and cluster DCR reviews. These activities and reviews provide the basis for the Panel's assessment. This assessment identifies areas that require particular management visibility. Discussions of the individual systems follow.

1. Structure

(a) The thrust structure contains two single failure points. The TACS high pressure and storage spheres and one radiator shield jettison mechanism would jeopardize the mission and the crew if they failed. Furthermore, these components support not only the OWS but the total cluster and other individual module operations. It is important that these items be properly identified to the KSC test and checkout personnel to assure proper handling and control of ground excitation.

(b) The meteoroid shield deployment system was reworked; it was to be retested in the October-November 1972 time frame. Results of this test and further deployment tests expected at KSC should prove this system.

(c) The pressure integrity of the main habitation tank is subject to many perturbations during test, checkout, and while in orbit. Currently, the leakage problems are confined to secondary areas such as the wardroom window cover and SAS wing cavity. Nonetheless, there are so many structural penetrations and hatches that extreme care must be exercised during transport and handling as well as during test and modification activities. The Panel understands that the total OWS was not pressure tested. Pressure testing was limited to the original SIVB and each subsequent penetration.

2. Environmental and thermal control

(a) The waste tank receives fluids from the AM. In the case of condensates the fluid has frozen during dump tests.

(b) Thermal ventilation and odor removal subsystems are still under consideration.

(1) The results of the flowmeter life tests to be completed in ECD February 1973.

(2) The possible CO_2 concentrations because of inoperative ventilation fans in and around crew sleep compartments were covered in SOCAR and in the DCR, but the Panel did not have the results of the data presented.

(3) Objectionable odors emanating from feed collector (not from fecal matter) resulted in a determination that cabinet acoustic insulation caused the trouble. Solution was to remove it from cabinet. An assessment of the impact due to acoustic excitation with the insulation removed was under consideration.

(4) OWS head pipes use, for the first time in a space application, Freon-22 as the working fluid and out-of-plane pipe bends. The performance of the TCS as a whole is based on analysis; therefore, in-flight sensors are probably necessary for verification.

(c) Development tests continue on the suit drying station. The suit drying activity is significant because of its impact on the crew's planned activities and emergency egress.

3. Refrigeration system

(a) The inlet pressure of Coolanol-15 circulating pump is a "red-line" measurement. The Panel understands that the transducer currently in place is not operating properly and should be either replaced or bolstered with a redundant sensor.

(b) The following items are still undergoing life or qualification tests and test results should be monitored:

Pump assembly
Radiator bypass valve
Relief pressure valve
Fill and drain valve assembly
Thermal capacitor
Cold plate
Housing radiator control valve

(c) The inverter associated with the coolant pump was under redesign to assure adequate start torque margin. Tests at KSC should prove this unit. Hardware availability is December 1972.

4. Solar array system

This unit built by TRW for McDonnell Douglas-West is a complex structural, mechanical, and electrical unit. It requires special handling with a controlled environment while at KSC. Condensation in the stacked or stored configuration should be precluded for reasons of system deterioration and possible jamming of deployment mechanism. These subjects have been monitored by McDonnell Douglas and NASA, and the Panel has been assured that all precautions will be taken.

5. Electrical power system

(a) Wiring does not contain individual identification sleeves to depict their terminal points. This can hamper the KSC work effort if mods or test anomalies occur.

(b) Wire harness support and proper bend radii are of concern if modifications occur at the KSC in which wire bundles are moved, replaced, or operated on in any way. Procedures should assure that proper support and bends are maintained throughout test and checkout.

6. Caution and warning system

The rapid ΔP alarm system, unlike the fire warning system, does not indicate location of leaks. The alarm only indicates a rate equal or in excess of 0.1 psi per minute. Crew and flight controller procedures will have to be devised to support this system.

7. Habitability support subsystem

(a) SMEAT results will have a decided effect on the HSS areas of waste management, water, and food, while the specifics of SMEAT are discussed in that section devoted to it. The results include the following:

Urine collector system was redesigned to accommodate 4000-milliliter capability.

Fecal collector odor, noted in earlier tests as well as SMEAT, is determined to come from acoustic insulation which will be removed.

Current design of fecal bags is under consideration due to difficulty in using and closing them.

(b) Component qualification testing is in process or to be accomplished on the following:

Urine separator

Fecal/urine collection module

Urine volume determinator

Chiller compartment

Urine bladder

(c) Resolution of problems associated with disposal of cardboard used for packing appears to still be in process.

(d) The trash collection bag shelf-life tests are still in process. So far there are no problems.

(e) The water system has a number of component qualification tests in process on currently available hardware and redesigned hardware:

Food dispenser

Quick disconnect

Fluid filter

Iodine injector assembly

Water deionization filter assembly

8. Crew equipment systems

Most of the crew accommodation, storage, and C^2F^2 items are covered under other sections of this report (e.g., CLUSTER MATERIALS, MICROBIAL CONTROL, and RELIABILITY, QUALITY, AND SAFETY).

(a) The biocide wipe packaging is being subjected to an 8-month shelf-life test to assure maintenance of acceptable iodine concentrations. If depletion does occur, then the biocide will be changed or wipes will be supplied for each mission.

(b) Protective covers (also called "shop-aids") on OWS hardware and supporting equipment for use at KSC was discussed at the PDTR. There appears to be a need for either more covers or a better use of those currently available.

9. Ground support equipment

The majority of the GSE associated with the Skylab cluster modules and launch vehicles has been used in factory testing prior to shipment to KSC.

Where the equipment has not been used previously or is used in a different mode, it has been evaluated to assure usage compatability with the flight hardware. McDonnell Douglas-West and MSFC's general conclusion was that the few problems or descrepancies in hardware, documentation, and planning would not have a program impact.

An end-to-end functional assessment of all GSE systems operations was made during SOCAR using interface documentation, schematics assembly drawings, and other engineering planning documentation. All signal or operational paths associated with electronic and mechanical equipments were verified from initiating activity up through the first recipient function on the vehicle. The team also reviewed the impact of potential GSE failure modes on launch preparations, flight hardware, and personnel safety. Their conclusion was that there was low probability of failure in critical items because of demonstrated performance and no significant effect because of redundancy or adequate time to repair.

Risk Assessment and the Management System

For the past year MSFC has maintained a resident task team at McDonnell Douglas-West. This has included MSC and KSC personnel as required. The purpose was to assure the timely and proper resolution of both manufacturing and test problems in order to meet the Skylab schedule, funding limitations, and program design specifications. Because of such efforts the orbital workshop design reviews were well documented and the hardware presented for acceptance by NASA was reasonably "clean." In addition to the normal reviews, NASA had an OWS engineering "walk-through" inspection of the OWS on August 18, 1972 to inspect (with a team of MSC and MSFC specialists) wiring, sharp corners, and general fabrication techniques. The walk-through team expressed their satisfaction with the OWS spacecraft and were impressed with the overall condition of it, particularly the quality of construction. The routing of wire harnesses and tubing runs were especially well engineered and fabricated. This type of inspection will be repeated at KSC. The data packages used to support the turnover meetings were thoroughly reviewed by KSC quality engineering and quality assurance personnel.

McDonnell Douglas-West in support of this effort established an engineering test team with manufacturing expediting assistance to improve the development and qualification test schedule and establish engineering subsystems managers to work across the board from design through procurement, manufacturing, assembly, checkout, etc.

Essentially the task team members supplemented efforts of the NASA Resident Office in areas of individual specialties and could provide significantly improved communications regarding all types of problems and their timely resolution.

The OWS programmatic review cycle and methodology during the phase II Panel review period provided a measure of confidence that OWS hardware and software have been examined thoroughly and by a capable NASA/McDonnell Douglas-West team. The SOCAR system end-to-end analysis, pre-DCR's, and PDTR's provided open forums for frank discussions and surfacing of problems and their resolution.

Some concerns did arise on the management systems governing SFP's, use of backup hardware, control of retest requirements, and the control of contractor supplied data packs. The process by which SFP's are handled must be available to alert all concerned parties of their existence, background, and justification. This assures, for example, that the TSCRD would have a special note of such items and that the proper approvals are secured when a change is made involving SFP's. The Panel feels that a closed-loop system must be assured. The ability to use the Skylab OWS backup hardware for in-flight and on-the-pad anomaly resolution, similar to that done on the Apollo program, appears to be in question at this time and the extent of the problems probably needs further examination. The documentation and control of retest requirements, which are to be implemented at KSC, did not appear clear to the Panel although it may be under control.

Fire prevention and extinguishment. - The Panel was concerned with the possibility of fire because of the AS 204 and Apollo 13 incidents. The philosophy of the Skylab program is fire prevention. Thus, while there are significant consumables onboard (e.g., OWS wall insulation, Coolanol-15), there has been a careful and thorough attempt to minimize such materials or to define the rationale for their use, and to isolate ignition sources and propagation paths. MDAC noted that all materials were checked against a list of acceptable material and that all possible steps have been and will be taken to assure the risks are minimized.

Manufacturing, workmanship, and vendor control. - McDonnell Douglas-West had no direct experience in building such a complex manned spacecraft for the Skylab cluster. Thus, there was a learning curve which involved the manufacture of in-house piece parts and the development of in-house test procedures. The Panel feels comfortable with the quality of the hardware workmanship based on prior reviews and the NASA statements made during the DCR and PDTR's. McDonnell Douglas-West further tried to identify and use the relevant lessons from Apollo experience.

The "Lessons Learned on Apollo Spacecraft Reliability Program" was reviewed for applicability of its recommendations to the Skylab program. The recommendations have been generally implemented in the Skylab-OWS program. The exceptions are those cases where the task is considered to be applicable to a production or multivehicle program as opposed to the one-of-a-kind OWS.

"NASA/MSC Space Flight Hazards Catalog" describes 266 hazards which have been identified during prior space flight programs. The catalog was used by McDonnell Douglas's OWS departments and design technologies to voluntarily perform a comprehensive review. Results of the review have been incorporated into the systems safety presentations given to MSC and MSFC representatives. The final assessment and evaluation of all of the hazards was made by a special committee chaired by the director of system safety and product assurance.

The history on "Apollo Electrical, Electronic and Electromechanical (EEE) Parts Problems and Solutions" has also been used in a comprehensive review. This contributes to confidence that OWS electronics design has recognized prior pitfalls and will avoid or design around the conditions identified in the report. Concurrent with this review, McDonnell Douglas-West conducted independent but related studies relative to

McDonnell Douglas designed and manufactured electrical components. This study included a review of failure history, design analysis, manufacturing, and reliability considerations. The study concluded that the problems which had been identified and/or experienced on related programs had been given adequate consideration in the design, manufacturing, planning, and inspection of like OWS components.

Motivation. - In recognition of the human element and its vital influence on product quality, a positive and continuing vendor and in-house "awareness" program was planned and implemented. It features an OWS overview/orientation briefing. Some 1300 personnel from McDonnell Douglas and critical OWS suppliers attended. Primary emphasis during the orientation was devoted to the importance of each individual's contribution to mission success and the need for defect-free hardware that will operate reliably for the planned 8-month orbital mission. During the tour of the Crew System Evaluation Laboratory, the participants were shown the crew quarters and work areas, and they were briefed on several of the experiments to be performed in the OWS. The program has given OWS personnel a fuller appreciation of the application and importance of their work for OWS.

Other motivative aids have been introduced. Over 1000 plastic plastic pocket inserts with the designation "Skylab Team" were distributed to personnel working on the program. Approximately 500 1972/1973 Skylab calendar/facts pocket booklets have been passed out as have Skylab astronaut team photographs.

NASA and McDonnell Douglas produced films such as "Invitation to Confidence," "Anatomy of an Accident," "Quality Craftmanship," and "Human Factor." These have been widely shown at Santa Monica, Huntington Beach, and the Florida Test Center to further motivate OWS employees and acquaint them with the importance of the OWS mission. NASA and McDonnell Douglas Manned Flight awareness posters have been prominently displayed in all OWS work areas and changed as frequently as new posters were available. Posters and films have likewise been made available to suppliers. In addition, special OWS awareness stamps were procured and instructions prepared for all suppliers of mission/safety critical hardware to stamp all shippers, ship travellers, rejection tags, and any other inprocess paper "critical hardware for Skylab/OWS."

Hardware cleanliness. - Special precautions are being taken to maintain the required levels of OWS cleanliness. All items are and will be logged in and out of the vehicle. Such areas as the "crotch" (where the forward area meets the dome as well as where the floor meets the wall) were and will be X-rayed and fiber-scoped as well.

Acceptance testing. - Acceptance testing at both the manufacturer's site and at KSC have much in common and are vital to the receipt of known hardware at each site. The plan for carrying these acceptance tests at KSC for the OWS and ancillary equipment is shown in figure 40.

OWS
ACCEPTANCE TESTING
TEST SITES

KSC VAB CHECKOUT OPERATIONS

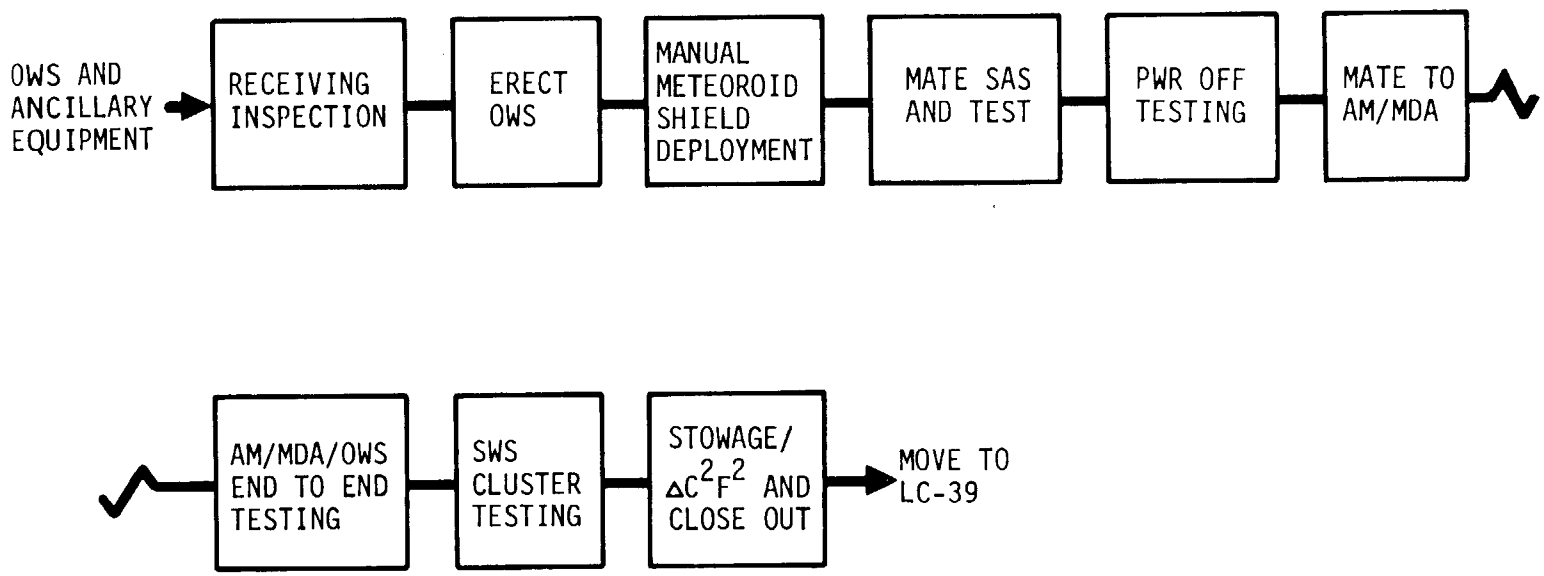


FIGURE 40

AIRLOCK MODULE

The airlock module (AM) is the module containing the hatch through which astronauts egress when performing extravehicular activity (EVA). It also contains systems for environmental control, instrumentation, electrical power, communications, and operational management for the orbiting assembly (OA) or cluster. It is attached to the forward end of the orbital workshop and provides structural support to all modules mounted forward of the OWS (MDA, ATM, CSM). The AM consists of two concentric cylinders with truss structures bridging the annular gap. This is illustrated in figures 41 to 44. The outer cylinder, or the fixed airlock shroud covering the high pressure gas bottles and encircling the outer AM structure, has the same diameter as the OWS (22 ft). The inner cylinder, or tunnel, contains the airlock and constitutes the passageway through which the Skylab crews move between the CSM and MDA on one side to the OWS on the other. The forward end of the fixed airlock shroud is the base on which the tubular structure supporting the ATM is mounted.

The airlock itself is the central portion of this module. It has two hatches that close off each end of the cylinder and a third hatch located in the outer wall that is the EVA hatch. Closing the two end hatches before opening the EVA hatch ensures that the atmosphere within the rest of the cluster is retained. High pressure gas containers store the oxygen and nitrogen which provide the internal atmosphere throughout the mission.

The payload shroud, covered in a separate section, fits over the AM as it does over the MDA and is supported on the fixed airlock shroud.

As with the OWS, the Panel has elected to discuss the AM from two points of view to better provide an assessment of the adequacy of management systems and their implementation. Thus, the first portion discusses management systems of the NASA Centers and McDonnell Douglas Astronautics Company, Eastern Division. The second portion discusses their implementation as mirrored in the technical aspects of the program.

Management

The basic system of management applied by NASA to the airlock program is similar to that used on other modules. Variations were necessary however due to the unique handling of the AM and MDA as a unit during the major phases of testing accomplished at the MDAC-East plant in St. Louis, Missouri. The airlock has more major interfaces than other modules. Last and certainly not least is the background of the MDAC-East organization. They have been involved in manned space flight through two programs prior to Apollo (i.e., Mercury and Gemini). The basic approach may be the same for each module contractor, but in the case of MDAC-East the emphasis was placed differently. Furthermore, there was a requirement to use existing hardware where possible. The