# WSN SPACEFLIGHT HISTORY SPECIAL REPORT:

# SKYLAB NEWS REFERENCE: HARDWARE AND SYSTEMS

## SKYLAB HISTORY

The concept of using an empty rocket stage as an orbital "house", which is a cornerstone of the Skylab program, is many years old, and efforts to pin down its origin have not met with success. The first documented suggestion concerning the use of a Saturn S-IVB stage in that manner appears to have been in a report published by the Douglas Aircraft Company in November 1962. By early 1965 NASA was planning the "Apollo Extension Systems" and talking guardedly of a spent stage experiment in which it was envisioned that an S-IVB stage, once emptied of its propellants in orbit, could be outfitted and used as shelter for men in space.

This concept figured prominently in the early planning for the Apollo Applications Program (AAP). The foundation for AAP was the most efficient and economical use of surplus Apollo hardware. An office to manage this program, which absorbed the Apollo Extension Systems (AES) study program, was formally established on August 6, 1965. For the next year and a half, extensive study was made both within NASA and by NASA-hired firms. The Manned Spacecraft Center and the Marshall Space Flight Center both set up AAP management groups in July 1966.

The President's budget for space, presented in a press briefing, January 26, 1967, called for $454.7 million to bring the AAP from the design definition phase to full development. At that briefing, it was announced that AAP flights in Earth orbit would begin as soon as the Apollo missions shifted to the Saturn V launch vehicle, making the Saturn IBs available for other use. The orbital workshop missions, as the spent stage experiment came to be called, would fly in 1968, concurrently with the preparation for the first manned lunar landing.

According to that early plan, the so-called "wet" workshop would be the Saturn IB second stage (S-IVB), which would have its emptied hydrogen tank converted in orbit to a habitable volume. A second Saturn IB would launch a modified Apollo Command and Service Module (CSM) to carry the three-man crew and the major part of the mission expendables. Except for some of the major structural elements, all of the furnishings, crew accommodations, and experiments were to be carried in the Multiple Docking Adapter during launch and later taken into the workshop by the crew and set up for use.

Following the first mission, that crew would have returned to Earth and, six months later, a second pair of Saturn IBs were to have been launched - one carrying the second crew and the other a solar observatory. The plan was to have those two spacecraft rendezvous and dock with each other, then join the workshop.

Other AAP missions projected at that time included a one-year workshop mission, manned synchronous missions, and extended lunar exploration. Follow-on launch vehicle production was planned at four Saturn Vs and four Saturn IBs per year, and a six-man, land landing, reusable CSM was to be introduced.

The day following the briefing, plans for going beyond Apollo were swept aside by the Apollo fire and its aftermath. Later that year, Congress cut the AAP funding request by $200 million, beginning a series of budget trimmings that, together with readjustments of the Apollo schedule, led to the present schedule in which Skylab follows Apollo in sequence. The program was to benefit materially from the delay. Its content and potential came into clearer focus and it became possible to introduce a number of significant improvements. The most important of these, and the key to most of the others, was the shift to the Saturn V and the change from the "wet" to the "dry" workshop in which the S-IVB is not used as an active, fueled stage, hence it is dry. When Apollo 11 returned safely from the moon, it meant that a Saturn V could be diverted from its Apollo asignment, and in August 1969 the decision was made to abandon the "wet" workshop and shift to "dry", based on studies which had started out as concepts for later AAP missions.

Because the Workshop could now be outfitted on the ground, rather than by the crew in orbit, and because of the larger payload capacity of the Saturn V, additional highly sophisticated equipment and crew provisions could be accommodated. Also, almost all of the expendables for the entire mission could be carried on the initial launch, simplifying the demands on the CSM and reducing the changes needed to adapt it to the Workshop mission, with a corresponding reduction to its cost.

It was also possible to carry the Apollo Telescope Mount (ATM) as an integral part of the Workshop launch, vastly simplifying the operations associated with attaching it to the Workshop in orbit and more than doubling the time available for solar observation. Of equal importance was the ability to operate at a higher inclination for much greater Earth coverage and to add the Earth Resources Experiment Package (EREP).

From the hardware and mission planning viewpoints, the Skylab program has been relatively stable since the July 1969 decision to develop a Saturn V-launched "dry" workshop. Evolution of the cluster of spacecraft had, by then, been completed, and these were (and are) the major elements of the first U.S. space station:

The Orbital Workshop (OWS) provides the crew quarters, the majority of the expendables storage, a major experiment area, structural support for the large solar array, and the cold gas storage and thrusters for the attitude control system.

The Multiple Docking Adapter (MDA) provides the docking port for the Apollo Command/Service Module, houses the control panel for the Apollo Telescope Mount, provides a window for Earth resources viewing, and has other experimental capabilities.

The Apollo Telescope Mount (ATM) houses the solar experiments, the control moment gyros (CMG) installation and a solar array which provides electrical power.

The Airlock Module (AM) has an airlock for extravehicular experiments, main communication/data transmittal links, environmental/thermal system and electrical power control system.

The modified Apollo Command/Service Module (CSM) functions as the manned logistics vehicle for the missions and also provides certain communication functions to the Workshop.

In February 1970 the name Skylab was officially given to the Apollo Applications Program, to recognize and emphasize its role as an exploratory space station in the evolution of man's use of orbital flight for practical benefit.

## HARDWARE

Skylab is a cluster of four major units which will be launched by a two-stage Saturn V rocket into a near-circular Earth orbit with an altitude of 235 nautical miles and Command and Service Modules launched by Saturn IB rockets. The orbit will be inclined 50° to the equator.

The Saturn Workshop (SWS) consists of the Orbital Workshop (OWS), Airlock Module (AM), Multiple Docking Adapter (MDA), Apollo Telescope Mount (ATM) and related support structures and thermal and meteoroid shielding. A modified Apollo CSM, in which three astronauts are launched by a smaller Saturn IB rocket, will rendezvous and dock at the MDA. The instrument unit, mounted on the forward end of the OWS, serves the launch vehicle. The entire cluster in orbit, including the CSM, is sometimes called the Orbital Assembly (OA).

In orbit, the Skylab cluster will be 118.5 feet long and will weigh 199,750 pounds. The total work space in the OWS, AM, MDA and CSM will be 12,398 cubic feet.

Total weight of the payload at liftoff will be about 196,000 pounds. The height of the launch vehicle and payload on the launch pad will be 333.7 feet. Payload capability for the Saturn V at the proposed Skylab altitude is about 200,000 pounds.

In the launch configuration, the Skylab elements will be mounted directly above the second stage. A 26,000 pound Payload Shroud will cover the ATM, MDA and AM during the launch phase. The ATM is held forward of the MDA until the cluster reaches orbit and the shroud is jettisoned. The ATM is then moved by a deployment mechanism 90° to one side. This exposes the docking port on the forward end of the MDA, the port to which the CSM normally will dock. A port on the side of the MDA could be used if necessary.

**ORBITAL WORKSHOP** The Orbital Workshop uses hardware and techniques developed in the Apollo lunar landing program.

A Saturn IB second (S-IVB) stage was modified and outfitted on the ground as living and working quarters for three astronauts. It contains the majority of the expendables storage, serves as a structural support for a large solar array, and carries the cold gas storage and thrusters for the attitude control system. The stage's liquid hydrogen tank serves as a 10,426 cubic foot space laboratory. The OWS weighs 78,000 pounds.

NASA converted S-IVB-212 as the primary OWS. S-IVB-515 has been outfitted and checked out as the backup hardware. The OWS will have most of its operational equipment in place at launch. Some gear will be stored in the AM and MDA.

The S-IVB converted for Skylab has no engine or propulsive hardware other than the attitude control thrusters. A reusable access hatch replaced an existing manhole in the forward tank dome. A personnel hatch was also added to the side of the stage to permit workmen and technicians easy access during the checkout and prelaunch phase. This side hatch will be sealed before launch.

Aluminum open-grid floors and ceilings were installed in the tank to divide it into a two-story "space cabin." An aluminum foil, fire-retardant liner was placed on the inside tank surfaces and a meteoroid shield on the exterior. Two solar arrays are mounted on the outside.

Crew quarters are at the aft end of the tank. A ceiling grid separates the quarters from the laboratory area in the forward end. Solid partitions divide the crew quarters into a sleep compartment, wardroom, waste management compartment and an experiment compartment. Lighting fixtures are mounted on the crew quarters ceiling. The waste management compartment is sealed separately with walls and doors to retain odors and loose particles in the weightless environment. Crew quarters contain five radiant heaters. Three radiant heaters are in the forward compartment.

The wardroom has about 100 square feet of area; the waste management compartment has 30 square feet of floor space; the sleep compartment about 70 square feet; and the experiment area about 180 square feet.

The SWS's thermal control and ventilation system will give the astronauts a habitable environment with a temperature ranging from 60° to 90° F. A two-gas (oxygen and nitrogen) atmosphere will be used with internal pressure kept at five psi. Fans will circulate the artificial atmosphere.

Solar arrays on the OWS and ATM will provide electrical power for the cluster. The systems are cross-linked for flexibility in handling peak loads and for countering failures. The electrical power distribution system connects OWS areas with power sources in the AM and the solar cell assembly. Light fixtures have individual controls, and portable lights can be used for more illumination as needed.

The meteoroid shields will decrease the probability of hazardous punctures of the OWS. One is a 0.025 inch aluminum sheet held against the OWS outside surface during launch. Once in orbit, this shield is deployed by swinglinks (powered by torsion bars) and held five inches from the wall. The other shield is a fixed double-wall aluminum alloy cover over the Thruster Attitude Control Subsystem (TACS) cold gas spheres on the aft end of the OWS.

Water and food for Skylab's operational lifetime will be stored inside the OWS, the water in tanks in the forward experiments area and the food in compartments and freezers in that area and in the wardroom.

The wardroom has a window 18 inches in diameter in the middle of its wall. The window, double-paned and heated to prevent fogging, will face the sunlit side of the Earth during the mission.

The liquid oxygen tank of the S-IVB stage was converted into a waste container for OWS. An airlock was installed in top of the common bulkhead. The trash disposal section of the tank has 2233 cubic feet of space and the liquid dump area has 264 cubic feet.

Twenty-three spheres containing cold gaseous nitrogen for the TACS and pneumatics are mounted on the aft end of the OWS. These are protected by a thermal shield around the OWS circumference at the aft end and by the aft meteoroid shield. The radiator for life support system (LSS) refrigerators and freezers is mounted aft of the TACS spheres and shield. Two attitude control thrusters of three nozzles each are on the aft end on opposite sides of the OWS.

Two "wings" of solar panels are folded against the OWS on opposite sides for launch. Once in orbit, the arrays are deployed to expose almost 2355 square feet of solar cells to the Sun's rays - enough to produce as much as 10,500 watts of power at 131° F.

**FORWARD COMPARTMENT** The forward compartment occupies the greater part of the habitation area. It is separated from the crew quarters by an eight inch beam structure with an aluminum grid on each side. The forward compartment is divided into three main sections for ready identification of equipment locations, the experiments area, the stowage ring and the dome.

The main items in the dome section include the entry hatch and the ventilation control system mixing chamber and ducts. Other items include light fixtures, a fire extinguisher, electrical cables, handrails, an intercom box, power and instrumentation feed-through provisions, vent sealing devices and power outlets.

The stowage ring is at the point where the cylindrical forward experiments area joins the dome. Mounted on the ring are ten water tanks, each having a useable capacity of about 600 pounds of water. A portable water tank containing from 25 to 26.5 pounds of water is also available in the forward compartment.

Also on the stowage ring are 25 lockers containing supplies needed throughout the OWS - bundles of urine bags, portable lights and electrical cables, hoses, umbilicals, pressure suits, tape recorder, charcoal filters, fans, lamps and intercom boxes.

The forward experiments area contains food lockers and freezers, two Scientific Airlocks, and various items of equipment for performing a number of experiments. Major items include the ultraviolet panorama experiment, the body mass measurement device, contamination measurement equipment, photographic equipment, astronaut maneuvering equipment, EVA suits, film vault and scientific instruments.

Two Scientific Airlocks (SAL) are located in the forward compartment. They are bolted directly on a flange on the OWS wall over a hole 8.25 inches square in the tank wall. These SALs provide a method of deploying experiments through the wall of the OWS with depressurization.

Control and display units in the dome area include: OWS hatch and pressure equalization valve, intercom box, utility power outlets, solenoid vent port, pneumatic vent port and TV input station.

Control units in the forward area other than the dome include: utility power outlets; TV input station; two intercom boxes; two fire sensor control panels; experiment recorder control panel; water system pressure panel; and experiments T020, T027, T013, S019, S020, M509 and M172.

Water purification equipment is mounted on the wall of the experiments section. It consists of iodine containers, waste sample container, water samplers, reagent container, iodine injector, a color comparator and control devices.

**CREW COMPARTMENT** The crew compartment is separated into four basic areas: a wardroom, waste management compartment, sleep compartment, and an experiment compartment.

The **Wardroom**, with about 100 square feet of floor area, occupies most of the space in the -Z area of the crew compartment. It provides facilities for food preparation and serving, earth observations, and crew relaxation.

The wardroom has a window slightly left of the -Y axis. It is double-paned and heated to prevent fogging. An intercom station is located above and to the left of the window, and the flight data file is in a compartment below the window. The room has four general illumination light fixtures and emergency egress openings in the floor and ceiling.

The wardroom has 58 stowage compartments (lockers), a food chiller and two food freezers. In these containers are food, tissues and wipes, medical kits, off-duty equipment, clothing modules, towels, flight data files, trash bags and scientific equipment.

The food management table is located near the center of the room. The astronauts have three storage lockers available for temporary storage of cans of food, one compartment for storage of snacks and beverages, and a six-well empty food can disposal unit. Also in the wardroom is the compartment designed specifically for storing food trays during launch and the tray lids during eating periods.

Off-duty equipment is stowed in a corner cabinet. Mounted on the door are a tape player and two racks holding 48 tape cassettes. Items in the cabinet include headsets, microphones, batteries, playing cards, 36 paperback books, a dartboard and darts, balls, exercising equipment and binoculars.

Control panels in the wardroom include: control panel for water dump and window heater; control panels for S063 and M074 experiments; intercom box; food preparation table; three food tray outlets; a power outlet; and the water dump valve.

The **Waste Management Compartment** is a rectangular room with 30 square feet of floor space between the wardroom and the sleep compartment. It contains fecal and urine collection equipment, waste processing and urine management facilities, personal hygiene facilities, crewman restraint provisions and privacy and contamination control accommodations. Waste management and personal hygiene equipment and supplies are stored in the WMC.

The WMC has three general illumination light fixtures and a breakaway door for emergency egress. It has 15 stowage compartments, a urine holding compartment, a fecal/urine collector (toilet), a waste processor module, a urine freezer, a handwasher, foot restraints and overhead handrails, sample return containers, a vacuum cleaner and four mirrors, one fixed on the wall next to the wardroom, an articulating mirror mounted below the handwasher, and one each on the inside of the doors to compartments above and to the right of the handwasher.

Three individual personal hygiene modules (IPHM) are stored in the WMC, one for each astronaut. A typical hygiene kit contains shaving and dental equipment and supplies, soap, emollient, swabs, hair groom brush and cream, nail clippers, deodorant and expectorant collectors. Each kit occupies a separate locker. In the same row of lockers is one with washcloths and towels. Kits and towel/washcloth dispensers are color coded with a "Snoopy" emblem - red background for the commander, white for the scientist pilot and blue for the pilot. Towels and washcloths for the astronauts are also color coded.

On the wall opposite the handwasher are other containers, one containing a supply of soap, tissues and disinfectant pads. To the left of this row of lockers is a towel/washcloth drying panel.

The fecal/urine collector is mounted on the WMC wall. The collector, analogous to a toilet seat, is mounted in such a position that the weightless user appears to be sitting on the wall facing the floor.

Waste processing and urine management facilities include a waste processing chamber, urine holding compartment and urine freezer. Three insulated urine sample return containers are stowed in the OWS forward compartment until transferred into the CM for return to Earth. Specimen containers are bag assemblies that will be strapped to CM lockers for the trip to Earth.

Also located in the WMC are a vacuum cleaner with three different nozzles and a handwashing unit which has magnetic soap-holders (note: bars of soap containing steel bars are held in place by the magnetic holders), a pushbutton water dispenser, a washcloth squeezer, a waste water bag and a handrail.

Controls in the WMC include: WMC control panel; intercom box switches and displays; power outlets; circuit breaker panel for the waste processor; M074 experiment panel; fecal/urine collector controls; and water dump valve.

The **Sleep Compartment** is roughly triangular and is subdivided into three individual private rooms, each with supplies and equipment needed by an astronaut. The compartment provides noise abatement and light baffling provisions, sleep restraints, personal and mission equipment and supplies, individually controlled lighting and emergency egress provisions.

Each of the areas in the sleep compartment holds a sleep restraint, a sleeping-bag type arrangement into which the astronaut encloses himself to keep him from floating about the area while sleeping. The sleep restraints "hang" from the ceiling with the bases attached to the grid floor.

The sleep compartment has light baffles on the ceiling and overhead privacy curtains. The areas are separated by hard walls and fabric doors. A total of 22 lockers are in the sleep compartment. The top locker in each area has a personal hygiene mirror mounted on the inside of the door.

Facilities are provided for the performance of experiment M133, sleep monitoring. Control panels in this section are the three intercom boxes.

The **Experiment Compartment** occupies approximately half of the crew living and working section (crew compartment). This section is the experiments area and OWS control center. It has trash disposal facilities and mission and experiment equipment stowage facilities. It is lighted by 14 general illumination fixtures which can be supplemented by portable lights as needed.

The compartment has two fire extinguishers, one mounted on the wall separating the compartment from the sleep compartment and the other on the wardroom partition. Emergency egress openings are also provided. A remote Caution and Warning display panel is located in the area.

Major items of equipment in the experiments compartment include the trash disposal airlock, a rotating litter chair, lower body negative pressure device, an ergometer, metabolic analyzer and the experiment support system (ESS).

Six stowage lockers containing trash bags and other equipment are in the experiments area. Also in this section are the remote control WMC and Wardroom lighting panel, portable restraints and experiments compartment.

Facilites are provided to perform the following experiments: M071, Mineral Balance; M092, Lower Body Negative Pressure; M093, Vectorcardiogram; M131, Human Vestibular Function; M151, Time and Motion Study; M171, Metabolic Activity; and T003, Inflight Aerosol Analysis. The rotating chair will be used in M131, the ergometer in M093, M151 and M171, and the LBNP device for M092.

A replaceable Van Allen Belt dosimeter is located on the experiment compartment wall to permit ground monitoring of the radiation dosage rate to which the crewmen are exposed. (A spare unit is stowed in the OWS forward dome).

The experiments section has 30 control panels, six of which are directly related to experiments. Seven circuit breaker panels are for: refrigeration; high power and utility outlets; TV; lighting, experiments, caution and warning; habitability support system; thermal control system; electrical power system; and instrumentation system. Two panels are intercom boxes, five are fire sensor control panels, three are power outlets and one is the solar flare alert panel.

Astronauts will have tool kits, repair kits, a tool caddy, and spare parts for orbital maintenance.

The experiment compartment contains the tool kits, repair kits, tool caddies and selected spare parts for orbital maintenance. Many of the tools contained therein are duplicated within the cluster in strategic locations to facilitate maintenance and Skylab initial activation and deactivation tasks. Additionally, spare tools are carried in the event of inadvertent damage or loss.

**WASTE TANK** Engineers created a "trash dump" to be carried on Skylab because there is no such depository in space. The S-IVB liquid oxygen tank has been modified to serve as a storage container for solid trash and a dumping facility for waste liquids. It has a total volume of 2826 cubic feet.

The waste tank is divided into compartments by screen enclosures, the largest of which is for trash disposal. This volume of 2233 cubic feet is used to contain solid waste and bagged liquid.

Uncontained waste liquids enter the liquid dump compartment at three points. This compartment has a volume of 264 cubic feet. The unconfined liquid rapidly evaporates or solidifies and then sublimates so that it can be vented overboard as a gas. The tank is vented to space through two non-propulsive vents which are enclosed by screens (about 10 micron) to minimize the particulates vented overboard. This same type screen material is used to form a compartment around the liquid waste dump probes.

## MULTIPLE DOCKING ADAPTER

The Multiple Docking Adapter, or MDA, provides a permanent interface with the Airlock Module and a docking interface with the Command and Service Modules (CSM). The MDA permits the transfer of personnel, equipment, power and electrical signals between the docked module, the AM and the Workshop.

The MDA general configuration consists of a forward conical bulkhead and a cylindrical structure 17.3 feet long and 10 feet in diameter. It weighs 13,800 pounds and contains about 1140 cubic feet of volume. The MDA has a primary axial docking port at the forward end and a backup or rescue port at the +Z axis.

In orbit the MDA functions as a major experiment control center for solar observations; metals and materials processing; and the Earth Resources experiments. Once on station, the MDA will be positioned with the +Z axis pointing earthward to provide an orientation for the Earth Resources Experiment Package (EREP) or positioned with the -Z axis pointed toward the Sun for solar observations. The EREP equipment includes a multispectral photographic facility, an infrared spectrometer, a 13-band multispectral scanner, an L-Band radiometer and a microwave radiometer/scatterometer altimeter.

The Apollo Telescope Mount will be operated by the astronauts from the Control and Display (C & D) console in the MDA. There the crew will actively control the telescopes that will greatly increase understanding of solar physics. Repeated coronal observations will provide the ability to develop a three-dimensional structure of coronal forms by obtaining high resolution photographs of the corona. Three other telescopes will be operated from the C & D console to gather scientific data on photographic film mounted in cameras and stored in the film vaults occupying space in the MDA.

The "Materials Processing in Space" facility mounted in the module provides a furnace or vacuum work chamber with an electron beam generating device. A smaller yet important experiment controlled and operated from the MDA is the Nuclear Emulsion (S009).

The external surface of the MDA is covered by a radiator/meteoroid shield structure that stands 3 inches from the pressure skin. Items mounted on the outside of the MDA include: MDA vacuum vent; MDA/AM electrical feed-through cover assembly; ATM feed-through power distributor assembly (4); instrumentation signal conditioner (all covered by raised portion of the meteoroid shield); S192 10-band multispectral scanner; S191 infrared spectrometer; cover for the S190 experiment window; S194 L-band antenna; proton spectrometer; inverter lighting control assembly; and orientation lights. Associated docking lights and docking targets are mounted on the outside.

The MDA is structurally cantilevered from the AM and can withstand launch loads, docking loads, in-orbit stabilization maneuvering loads and internal pressure loads.

Although surrounded by ATM and Deployment Assembly members, the MDA does not interface structurally with either the ATM or the deployment assembly.

The MDA access hatch is at the aft end of the axial docking tunnel. A like hatch is in a similar position in the radial port. On the CSM side (outside) of the hatch are a pressure equalization valve and handle, a pressure gauge, a hatch opening handle, six latch connecting rods; a contingency tool kit for opening an inoperative hatch; like items, except for the connecting rods, are on the inside of the hatch.

The docking system is a means of connecting and disconnecting the CSM/MDA during a mission and of providing for intravehicular transfer between the two modules.

Docking is achieved by maneuvering the CSM close enough to the MDA so that the extended probe engages the drogue on the MDA. When the probe engages the drogue through the capture latches, the probe retract system is activated to pull the MDA and CSM together. Upon retraction, the MDA tunnel ring activates the 12 automatic latches and effects a pressure seal between the modules through the two seals in the CM docking ring face.

Following hard mate of the two modules and when the MDA pressure hatch is opened, providing a passageway between the two modules, the probe and drogue are transferred for stowage in the MDA.

Special tool kits and spare parts are contained in the MDA for selected types of orbital maintenance and activation/deactivation sequences to be performed by the astronauts.

Contingency hatch opening tools provide a combination of specially designed tools to be utilized in the event the MDA axial entry hatch is inoperable in the conventional manner. These tools are stowed on the MDA hatch (CM side) affixed to the hatch in a specially designed tool box.

These tools include: ring removal tool, pin removal tool, seal loosening tool and mallet assembly.

Activation/Deactivation tools provide a combination of tools to be utilized in the activation/deactivation sequences performed on initial entry and final exit of the Skylab. Also contained are tools necessary to open the OWS hatch in the event it is inoperable in the conventional manner. This tool box is located on a film vault in the MDA. These tools include: speeder handles, ratchet extension, socket wrenches, screwdriver bits, pinch bar, open box wrench, tool caddy, utility belts, leak repair materials, Phillips screwdriver and tape.

S190 Tool Kit provides a combination of tools specifically required for the operation/maintenance of Experiment S190. These tools are used frequently during the experiment operation and therefore are stowed within the S190 experiment envelope for ease of astronaut operation. These tools include: large spanner wrench, small spanner wrench, screwdriver, scissors and tape.

Spare parts are contained in the MDA for orbital maintenance. These spares are stowed on a special spares pallet and include such items as: TV input station, video switch, manual pointing controller, crewman communication umbilical, lightweight crewman communication umbilical and control head.

## AIRLOCK MODULE

The Airlock Module (AM) is the structural assembly between the OWS and the MDA. It is 17.5 feet long, weighs 49,000 pounds and has 622 cubic feet of habitable volume. It consists of a Structural Transition Section (STS), tunnel assembly, four truss assemblies, the lower truss of the Deployment Assembly, a flexible tunnel extension and a Fixed Airlock Shroud (FAS).

The STS connects the tunnel assembly to the MDA structure. The tunnel, a passageway for the astronauts, has an airlock and hatch to permit the astronauts to perform extravehicular activities without depressurizing the complete spacecraft. A flexible extension connects the tunnel assembly to the OWS to continue the passageway while isolating structural loads from the OWS forward dome.

The FAS which is a continuation of the OWS cylinder, provides a shroud around the aft portion of the AM and structural mounting for the AM and MDA modules, the ATM Deployment Assembly and the Skylab oxygen supply tanks. It supports the Payload Shroud, the ATM, AM and MDA during boost.

The truss assemblies attach the AM to the FAS and provide exterior mounting structures for battery, electronic, thermal and experiment equipment.

Some of the basic requirements provided to Skylab by the AM are: oxygen and nitrogen storage for atmosphere supply; thermal control for Skylab atmosphere; purification of Skylab atmosphere; OWS/AM electrical power control and distribution; lock, hatch and support for extravehicular activity; instrumentation for real time and delayed data transmission; caution and warning displays and tones; command link with ground network; ranging link for CSM rendezvous; tracking lights; teleprinter; experiment support; equipment stowage.

**STRUCTURAL TRANSITION SECTION** The STS is at the forward end of the airlock tunnel and is physically secured to the MDA. It provides the structural transition from the MDA to the airlock tunnel and its trusses. It is constructed as a welded aluminum cylinder of stressed skin in a semimonocoque configuration. Four double pane glass viewing ports, one in each quadrant, are provided for visibility.

Contents of the STS include: AM data file; STS control panel; six 10-watt instrument panel area lights; eight 10-watt STS area lights; a circuit breaker panel; the ECS supply duct to the MDA; the teleprinter paper stowage container; a spare stowage container (removable); molecular (mol) sieve; cabin heat exchanger module; ATM tank module; oxygen/nitrogen control panel; water tank module; condensate module; STS intravehicular activity (IVA) station; and carbon dioxide sensor module.

**AIRLOCK TUNNEL ASSEMBLY** The AM tunnel assembly provides the passageway from the MDA/STS to the OWS. It is constructed of aluminum and is cylindrical in shape. The tunnel is divided into three compartments by two internal bulkheads equipped with hatches. The forward hatch leads to the STS via the forward tunnel, and the aft hatch to the OWS through the tunnel extensions. The center (or lock) compartment includes a crew hatch for EVA. It is essentially the same as the hatch used on Gemini spacecraft, the first from which astronauts emerged to "walk in space." The hatch is roughly trapezoidal in shape and curved to match the wall of the AM. It has internal and external hatch handles and a window and is kept closed and sealed by 12 latches. When unlatched, the hatch swings outward on a hinge somewhat like a piano hinge. A rod on the inside of the hatch holds it open.

The two AM internal hatches are quite similar in appearance and function. Both are circular and both swing outward from the lock compartment. Each has a hatch opening of 47.3 inches in diameter. Each hatch has a window 8.5 inches in diameter with a stainless steel grid shield, pressure equalization valve, stiffeners and nine latches. The latches are the same type used on the EVA hatch.

Each hatch swings toward the lock compartment to close. A seal bead around the hatch rests in a molded silicone rubber seal when the latches are closed. Drawing a vacuum inside the lock compartment, as when depressurized for EVA, tends to reinforce the seal against leaks. The hatches are held in place by Velcro straps when open.

Although relatively small, the AM tunnel contains dozens of items of equipment and supplies. The small aft compartment contains stowage provisions for the Experiment M509 tank, a 10-watt light and handrail assembly, a crossover duct to the OWS, the inlet muffler assembly for the OWS, and the aft instrument panel.

Between the two tunnel hatches, the lock compartment contains four 20-watt tunnel lights, ATM film tree support, environmental control system (ECS) duct, aft compartment vent valve, life support umbilical (LSU) stowage, EVA panels 1 and 2, center instrument panel, umbilical end stowage, ATM film tree support, EVA hatch and cabin pressure relief valve.

The forward tunnel contains the spare molecular (mol) sieve fan and replacement liquid/gas separators, tape recorder module, portable timers and spare batteries, spare 10-watt and 20-watt lightbulbs, and spare teleprinter head.

**FIXED AIRLOCK SHROUD** The Fixed Airlock Shroud (FAS) is a circular structure that joins with the IU and extends forward to surround the AM aft compartment and about two-thirds of the lock compartment. It serves as a structural support for the ATM, AM, MDA and Payload Shroud (PS) and supports mounts for oxygen tanks.

Also carried on the FAS are two discone antennas which are deployed away from the OA once in orbit. The antennas are stowed for launch in the +Y+Z and -Y+Z quadrants halfway between the trusses. Pivot/attach points are on the inside of the FAS wall. Each antenna is in two sections. The sections are folded together at a rotary joint which rests against the AM. In orbit the antennas are deployed; one is 45° from -Z toward -Y and the other is 45° from -Z toward +Y.

**TRUSS ASSEMBLIES** The four AM truss assemblies located outside provide the longitudinal support for the AM between the FAS and STS. They provide mounting support for experiments, consumable containers and other hardware. The four trusses are located symmetrically around the tunnel assembly. A single point on each truss attaches the assembly to the FAS. Truss 1 is at +Y, truss 2 is at -Z, truss 3 at -Y, and truss 4 at +Z. Two nitrogen spheres are mounted in each of trusses 2, 3, and 4. Two umbilical stowage spheres are between trusses 1 and 4. Battery modules are mounted on the forward ends of trusses 1 and 2. Sample panels for experiments D021 and D024 are mounted atop truss 4. Electronic modules and equipment and thermal control equipment are also mounted on the truss assemblies.

Thermal curtains cover the trusses and surround the AM from the octagon ring at the aft end to the STS. Meteoroid curtains cover the battery modules and extend from the FAS to the aft end of the AM. The EVA hatch is not covered because it must be opened by astronauts for EVA activities.

## APOLLO TELESCOPE MOUNT

The Apollo Telescope Mount (ATM) is the first manned astronomical observatory for performing solar research from Earth orbit. In addition to accommodating telescopic equipment for the solar investigations, the ATM has a solar array which generates about half of Skylab's electrical power, and the ATM structure houses primary stabilization and attitude control components for the total spacecraft.

The ATM weighs 24,656 pounds, is 14.7 feet tall, and measures nearly 20 feet across with the solar arrays folded (prelaunch and launch position) and 102 feet across with the solar arrays extended (orbital configuration). The operational ATM system consists of five major hardware elements: the cylindrical experiment canister which houses the solar astronomy experiments; the Attitude Pointing and Control System; the solar array wings; the Control and Display (C & D) console which is in the MDA and which provides the capability for astronaut operational control and monitoring; and the rack assembly, a large octagonally-shaped structural frame which surrounds the canister and provides structural attachment points for the solar and thermal shields, outrigger assemblies, solar arrays, Deployment Assembly, experiment pointing control-roll positioning mechanism and numerous subsystem components.

The aluminum rack is made up of two large octagonally-shaped rings separated by eight vertical beams attached to the eight corners of the rings. Equipment-mounting panels are provided in seven of the bays between the vertical beams. One bay is left open for the astronaut work station to provide access to the canister's MDA-end film doors. The opposite end of the rack includes attachment points for mounting the solar shield assembly and the acquisition Sun sensor. The solar shield assembly protects the ATM rack mounted equipment from direct solar radiation and includes a work station for access to the experiment package's Sun-end film retrieval doors. The MDA end of the rack provides the attachment points for the thermal shield. Four outrigger assemblies on the sides of the rack provide structural support of the ATM by the Payload Shroud during launch.

The experiments canister consists of the Spar, the MDA and Sun-end canister halves and the canister girth ring.

The spar is a cruciform structure constructed of three one-inch thick insulation covered aluminum plates which provides structural support of the experiments and experiment pointing control components (fine Sun sensor, rate gyros, etc.). Girdling the center of the spar is a girth ring which provides the structural interface between the experiments canister and the rack mounted experiment pointing control-roll positioning mechanism. The girth ring provides attach points for the canister halves which enclose the spar mounted experiments to provide a contamination-free environment for the experiments.

The MDA end canister includes four film retrieval doors which are used for in-orbit experiment film retrieval and replacement. The Sun-end canister half contains two film retrieval doors and ten aperture doors on the Sun end bulkhead. These aperture doors cover the fine Sun sensor and experiment apertures during non-operating periods to prevent optical contamination. The experiments canister includes the EPCS and an active thermal control system to provide a stable thermal environment for the experiments.

Mounted on the ATM are major elements of Skylab's Attitude and Pointing Control System (APCS) that provides three-axis attitude stabilization and maneuvering capability for the orbiting vehicle. It also provides the capability of pointing experiments at desired locations, such as the Sun, the Earth and other targets of interest.

The APCS is comprised of the Instrument Unit/Thruster Attitude Control Subsystem (IU/TACS), Control Moment Gyros Subsystem/Thruster Attitude Control Subsystem (CMGS/TACS) and Experiment Pointing Control System (EPCS).

The EPCS maintains fine attitude pointing and control about two axes for the ATM instrument package. The third axis (roll) is controlled from the C & D Console. The ATM instrument package can be manually pointed to any desired location on the solar disk or its outer perimeter.

Vehicle attitude information is derived from strapdown reference computations in the ATM Digital Computer (ATMDC) using rate gyro information, and, during orbital daytime only, Sun sensors. The ATMDC processes the sensor signals to generate the CMG gimbal rate commands. The astronaut has the capability of manually controlling the CMGS through his keyboard on the ATM C & D Console.

The ATM CMG consists of an induction-motor-drive constant-momentum rotor, gimbal supported to provide two degrees of freedom. Associated with each CMG is an Electronics Assembly (CMGEA) for positioning the gimbals and controlling the gimbal rates, and an Inverter Assembly (CMGIA) for providing power. Each CMG has an angular momentum storage capability of 2300 foot-pound-seconds.

Three double-gimbaled CMGS hardmounted at 90° angles to the ATM actuate the system. A CMG is basically a spinning wheel that provides the forces required for vehicle control.

The EPCS provides fine pointing control and stability for the ATM experiments, further isolating them from any disturbance torques from the Skylab assembly. This system provides control to within 2.5 arc seconds for periods up to 15 minutes, utilizing fine pointing Sun sensors for attitude reference. The experiment package can be off-set pointed within a ±24 arc min square centered on the solar disc. It can also be rotated to any desired roll orientation throughout ±120 degrees.

To help maintain stability and alignment for the scientific instruments, a thermal control loop is incorporated within the skin of the experiment canister to circulate liquid coolant. This active thermal control system is self contained within the canister. The water/methanol cooling fluid transfers heat absorbed from cold plates to radiators on the exterior side of the experiment canister, where it radiates into space. This active coolant system maintains an average temperature within the canister of approximately 53° F. Each experiment also has its own thermal control heaters, designed to maintain its temperature within about ±1° F throughout the length and width of the instruments. Precautionary measures have been taken to avoid any fluid leakage which could contaminate the optical elements of the scientific instruments. All fluid lines and components are on the outside to avoid leakage inside. In addition to the active thermal controls for the experiments, a passive system regulates the temperature or the ATM supporting rack structure and the components mounted on it. The thermal shield attached to the Sun end of the canister and rack minimizes solar heating of system components when the ATM points directly at the Sun for data acquisition.

As a part of the ATM control and displays, two selectable video presentations will be available to the astronaut conducting the experiments. Pictures of the Sun can be displayed in various wavelengths from several of the solar instruments; thus a crewman onboard the spacecraft will be able to assure proper identification and tracking of solar events of interest and point the instruments with a high degree of accuracy or spatial resolution (1 arc second corresponds to about 434 statute miles) on the solar disk. The presence of the astronaut at the C & D console will permit rapid response to transient events on the Sun, such as the initial phase of an explosive solar flare.

The ATM solar array consists of four individual wing assemblies which are stowed in a folded configuration during launch and deployed in orbit at 90° to each other to expose a total of 1200 square feet of solar cell surface to the Sun. Each individual wing assembly weighs 1071 pounds and consists of four and one half solar cell panels (total of 18 panels for all wings), electrical cabling and the wing support structure, which includes the ordnance-activated decinching mechanism, and the motor driven deployment mechanism. Three solar arrays include telemetry and/or command antennas at their tips.

The solar cell panels are made up of a framework of rectangular aluminum tubing mounting solar cell modules. The four outboard panels of each wing mount 20 modules. The inboard panel mounts 10 modules on the outboard portion of the panel.

Each solar cell module consists of an aluminum honeycomb sandwich covered by a fiberglass insulation and mounting silicone solar cells with quartz cover slides. Cover slides are provided to protect the solar cells from micrometeoroid and radiation damage.

The ATM is mounted on the ATM Deployment Assembly (DA) which provides in-orbit structural support between the ATM and the Fixed Airlock Shroud (FAS) and deploys the ATM upon reaching orbit. The DA also provides a mounting fixture for some experiments, acquisition lights, VHF ranging antenna and wire routing from the ATM to OWS. The Deployment Assembly consists of upper and lower tubular truss assemblies, a release ordnance system, a rotation system and a means to latch the DA in the deployed position. The upper truss assembly, attached to the ATM, includes a rigidizing assembly which prevents ATM launch loads from being imposed on the DA. It provides structural rigidity between the ATM and DA following Payload Shroud (PS) separation (ATM launch loads are supported by the PS during launch).

## PAYLOAD SHROUD

The Payload Shroud (PS) is a smooth structure which surrounds and protects the ATM, MDA, AM and associated hardware during the launch and climb-out phase of the mission. The principal requirements are to provide an aerodynamic and environmental protection cover for Skylab elements and structural support to the ATM during the prelaunch and launch phases. Once in orbit, the PS is split into four sections or quadrants by pyrotechnic devices and jettisoned. Each quadrant has a cylinder section, aft cone, and forward cone. One quadrant also has a nose cap at the end of the forward cone. The four shroud sections are joined with "shear" rivets and latching link mechanisms.

Two ordnance systems are used for separation and jettisoning, the discrete latch system and the longitudinal separation system. With the SWS in a nose down attitude, signals from the IU cause detonation of ordnance. This creates a pressure that retracts pins in the latch actuators and circumferentially unlocks the quarter sections. Seconds later an IU signal is sent causing longitudinal separation into four segments by expandable bellows with a linear explosive inside. When longitudinal separation is initiated, the bellows are expanded by the internal pressure buildup from the linear explosive causing the longitudinal separation joint rivets to shear. The bellows continue to expand, imparting a velocity to the PS quarter sections causing them to move away from the payload at a rate of about 20 feet per second.

The total PS is 21.7 feet in diameter at the aft end (interface locking ring), 56 feet long and weighs 26,000 pounds. The forward cone tapers at a 25° angle and the aft cone at 12.5°. The nose cap is a structural shell made of aluminum and stiffened with rings and intercostals. The aft cone and cylinder section are structural shells stiffened by rings.

## COMMAND AND SERVICE MODULE

The Skylab Command and Service Module is basically the same CSM (J-type) used during the Apollo program. Numerous modifications and certain deletions have been made to accommodate the unique mission requirements of the Skylab missions. CSM 116, 117 and 118 will be flown on SL-2, SL-3 and SL-4 respectively. CSM 119 will be used as backup or rescue vehicle if required.

Major modifications include addition of a 12-tank reaction control system (RCS) propellant storage module, with a total of 1500 pounds of propellants to more than double the former RCS propellant capacity, expansion of the spacecraft's thermal control system, addition of a 50-gallon water tank to eliminate water dumps, addition of three descent 500-ampere-hour batteries, deletion of one of the vehicle's three fuel cells, and deletion of two of the four service propulsion system (SPS) propellant tanks and one of the two helium tanks.

CSM system changes have been: Deletion of high gain antenna which is not needed for Earth orbit missions. Addition of a capability to switch all S-band omni antennas from the ground. Pyrotechnic batteries (0.75 ampere-hour) deleted and replaced with entry/postlanding-type 40 ampere-hour batteries giving a total of five entry-type batteries. Proven life of the entry batteries is 140 days, as opposed to the 36-day life of the pyro batteries. Several blanket heaters added to various systems for thermal control during the prolonged solar-inertial attitudes of the OA. Addition of electrical power transfer umbilicals to supply OWS power to the CSM during the powered-down phase, after fuel cell shut-down. Addition of oxygen and hydrogen nonpropulsive vent valve to prevent propulsive torques. Additional stowage capacity has been provided by increasing locker size and configuration on the aft bulkhead.

**COMMAND MODULE** The Command Module will transport 3 crewmen and between 1000-1500 pounds of stowed equipment to and from Skylab, serve as the primary communications vehicle and command station for the SWS, provide backup attitude control, and have the capability of being reactivated after 56 days of semi-dormancy in space.

**COMMUNICATIONS AND INSTRUMENTATION** The CSM high bit rate telemetry will be the normal mode of operation. Data for the Circadian Rhythm experiments (S071/S072) will be dumped by ground control via the CSM real-time TM link.

The CSM tape recorder will not normally be used to record routine systems data, with the exception of the periods from launch through activation and deorbit through reentry. The recorder is required for radiation experiment (D008) operations during the initial 2 weeks at approximately 6 to 7 hours per day.

All voice transmission will be through the CSM communication system. The CSM is an integral part of the intercom system and will also be used for downlinking real-time voice on S-band, with VHF backup.

**GUIDANCE, NAVIGATION, AND CONTROL** The CSM guidance and navigation system will be powered down and the command module computer will be maintained on standby during orbit activities. Unless operationally required, the Inertial Measuring Unit (IMU) will not be aligned periodically during the CSM quiescent mode.

**ENVIRONMENTAL CONTROL** At launch the CSM cabin atmosphere will contain 60% oxygen and 40% nitrogen. Lithium hydroxide (LiOH) cartridges are changed after 12 hours of use or if CM carbon dioxide pressure exceeds 5.5 mm mercury pressure.

LiOH cartridge replacements are stored in the MDA and deployed in the CM. The LiOH system is operative only during CSM use and during molecular sieve bakeout deactivation.

The CSM fuel cells remain on hydrogen cryogenic supply for approximately 13 days or until the supply is depleted. Residual hydrogen will be vented to space and excess oxygen will be vented through the cluster or vented overboard.

**ELECTRICAL POWER** Entry and post landing batteries (A and B) will be turned on five minutes prior to an SPS burn and turned off immediately after completion of the burn. The batteries will be charged immediately after docking.

**SPACECRAFT LM ADAPTER** The Spacecraft Lunar Module Adapter, or SLA, is a large truncated cone which connects the CSM and second stage of the launch vehicle. For Skylab flights SL-2, SL-3 and SL-4 the adapter contains only a stabilizing device for providing structural support to the outer shell.

**SERVICE MODULE** The Service Module is a cylindrical structure which serves as a storehouse of critical subsystems and supplies. It remains attached to the Command Module from launch until just before Earth atmosphere entry. Its main propulsion engine is used to perform deorbit burns for return to Earth.

**LAUNCH ESCAPE SYSTEM** The launch escape system will take the CM containing the astronauts away from the launch vehicle in case of an emergency on the pad or shortly after launch. The subsystem carries the CM to a sufficient height and to the side, away from the launch vehicle, so that the drogue chutes and three main parachutes can operate to lower the spacecraft and crew safely.

**SATURN V** Saturn V vehicle AS-513 has been designated SL-1 for the first Skylab launch. The S-IC and S-II stages of the launch vehicle are essentially the same as those used in the lunar landing missions. From the S-II stage forward, the vehicle is considerably different. The Apollo launch vehicle had an S-IVB stage, IU, SLA, LM, CSM, and LES. On the SL-1, the S-IVB is replaced by the Orbital Workshop (OWS). Forward of the OWS is the IU, AM, MDA, and ATM; all except the IU are enclosed in the PS. The LES is not required since SL-1 is not manned. Total weight of the SL-1 launch vehicle and payload is approximately 6,222,000 pounds. Height of the total assembly is 333.7 feet. Payload capability is near 200,000 pounds. The S-IC and S-II propulsive stages of the launch vehicle are each 33 feet in diameter. The S-IC is 138 feet feet long and the S-II is 81.5 feet long.

Several major changes were to meet requirements of the Skylab mission. The boost acceleration limit was increased to 4.7 g for Skylab. On Apollo missions the limit was set at 4 g because those vehicles were manned. Since the SL-1 mission is unmanned, the restriction on g-force is not as great.

The S-IC engine cutoff sequence for Apollo missions was center engine first and then the outboard engines. On SL-1 the center engine will cut off first, followed by cutoff of two opposing outboard engines and then the remaining two outboard engines. The 1-2-2 cutoff sequence was programmed to gradually reduce slowdown instead of initiating it suddenly. Cutting off all four outboard engines at once would subject the ATM to a dynamic load that could cause problems.

On Apollo missions, the terminal stage was the S-IVB; on SL-1 it will be the S-II. Therefore, a number of changes had to be made to the S-II. First, provisions were made for S-II engines to be cut off by guidance signal instead of by propellant depletion. This enables cutoff precisely at the desired velocity. Also, provisions were made to separate the S-II from the Skylab payload in such a manner as to preclude recontact. (Analyses have verified that the nearest the S-II will approach the Skylab after initial separation is about 4659 feet nominal. Provisions were also made for making the S-II stage inert almost immediately after separation to assure that it remains intact. The safing sequence will be initiated by a timer 3.5 minutes after separation.

The IU will provide the initial payload attitude control signals and events sequencing to enable systems activation and checkout functions. These include: jettison payload shroud; initiate ATM deployment; acquire solar inertial attitude; activate the Attitude and Pointing Control System (APCS); and transfer attitude control to the ATM (switchback capability will exist only through IU lifetime).

The IU also will disable its functional interfaces at the end of its active lifetime (about 7.5 hours). These include: OWS switch selector inhibit; electrical power depletion through normal loads; fourth battery loads depletion through the Command and Communications System (CCS) transponder and an added heater; and gas and liquid (nitrogen and water) normal depletion. The structural lifetime of the IU has been increased to eight months instead of the few hours required of it during Apollo missions. (Adhesives have been verified by thermal and vacuum testing and structural integrity verified by analysis and test).

Changing the launch azimuth from 72-100° on Apollo missions to 40.88° for Skylab made it mandatory to revise vehicle maneuvers at liftoff. On Apollo launches, the launch azimuth was slightly north of due east. A yaw maneuver caused the vehicle's boattail to move toward the launch tower in a direction slightly west of due north. This aimed the vehicle slightly east of South, causing it to move away from the tower as it rose. On the SL-1 launch, a yaw maneuver alone would move the boattail northwest and aim the vehicle southeast, which would not result in sufficient clearance of the tower for safety. Therefore, a pitch maneuver will be combined with the yaw to cause the boattail to move directly northward toward the tower, aiming the rising vehicle southward away from the tower.

The Emergency Detection System (EDS) on Apollo launches was on a closed loop, providing abort capability and retention of telemetry of critical functions. On SL-1 the EDS will be on an open loop which will eliminate the abort feature but retain critical functions on telemetry. On SL-1 the only abort command possible must be initiated by the range safety officer. He can destroy the unmanned vehicle if it presents a hazard to inhabited areas.

A preliminary analysis of control, stability and dynamics for SL-1 shows that the control wind limit is greater than 90 meters-per-second at all altitudes, probability for a successful launch is 98%, and Skylab engine out capability is less than that for Apollo. SL-1 capability to withstand winds has been verified at 56.5 knots with damper attached and free-standing and 38 knots during vehicle launch release. This is slightly less than the 64 and 39 knots, respectively, on Apollo.

The safing sequence for the second stage is as follows: separation from OWS at 9.5 minutes GET; safing sequence initiated at 13 minutes GET; start tank and helium control tanks safe at 23 minutes; liquid hydrogen tank safe at 58 minutes; and liquid oxygen tank safe at 1 hour and 13 minutes.

## SATURN IB

The SA-206, -207, and -208 launch vehicles which will carry the three Skylab crews into orbit and rendezvous with the Skylab cluster are basic Saturn IB vehicles with modifications to update them to the SA-205 configuration which was manned. (SA-206, -207, and -208 were originally configured for unmanned flight.)

The three launch vehicles were modified to incorporate changes to adapt them for the Skylab mission.

Each of the three Saturn IB vehicles consist of the S-IB and S-IVB (first and second propulsive stages, respectively), the Instrument Unit (IU) and the payload.

The SL-2 launch vehicle, SA-206, is made up of the S-IB-6, S-IVB-206, S-IU-206, and CSM-116. The payload, derived from a modified Apollo Block II Command and Service Module (CSM), includes a Command Module (CM), Service Module (SM), Spacecraft and Lunar Module Adapter (SLA), and the Launch Escape System (LES). The SL-3 launch vehicle, SA-207, consists of the S-IB-7, S-IVB-207, S-IU-207, and CSM-117. The SL-4 launch vehicle, SA-

208, consists of the S-IB-8, S-IVB-208, S-IU-208, and CSM-118.

Each launch vehicle with payload stacked stands 224 feet tall and weighs about 1,300,000 pounds. The payload capability for the launch vehicle is 35,300 pounds for SA-206, 35,400 pounds for SA-207, and 35,800 pounds for SA-208.

Each Saturn IB will be launched from Launch Complex (LC) 39 at KSC. LC-39 is normally used only for launching the larger Saturn V vehicle. The Saturn IB will rest on a 127 foot tall pedestal on the launch platform. The pedestal will hold the vehicle at the proper height above the platform to use existing tower swing-arms with fueling, power and instrumentation facilities.

Most of the changes made to the Saturn IB were a part of the continuing effort to improve the vehicle. Some changes, however, were necessary to support the Skylab program. A number of changes eliminated single-point electrical failures and provided redundancy. Engine thrust was uprated to improve the payload capability. Other changes improved the vehicle's reliability by eliminating possible problems, such as leaks and corrosion. One change provided a means of dumping residual fuel through the J-2 engine of the second stage. Other changes added sensors to collect needed data.

Engine cutoff circuits in both propulsive stages were redesigned to eliminate inadvertent engine cutoff. Two vibration sensors and one pressure measurement device were added for evaluation of possible longitudinal oscillations ("Pogo") and load responses if such should occur in flight.

Each of the eight H-1 engines was uprated from 200,000 pounds to 205,000 pounds thrust to increase the payload capability. Total stage thrust was increased from 1,600,000 pounds to 1,640,000 pounds.

In the hydraulics system, a number of standard "O" rings were replaced with Quad-Bond seals because the latter resist spiraling. Spiraling of "O" rings in the past has resulted in leaks that caused failures in some components.

Additional instrumentation was added to provide measurements to identify low frequency vibration levels experiences during flight.

In the pneumatic system, the Pneumatic Power Control Module was replaced with a dual regulator and Actuation Control Module to eliminate marginal system performance and provide specified actuation pressure for the S-IVB J-2 engine start tank vent and relief valve.

The $LH_2$ tank relief and latching bypass valves in the S-IVB propellant system were replaced with a latching vent and relief valve. The open latch feature provides tank safing beyond the life of stage batteries. The "LOX Depletion Timer" was removed to eliminate a single-point failure. Safe engine shutdown using LOX depletion was demonstrated which made protection by the timer unnecessary.

Redesign of LOX and $LH_2$ prevalves improved reliability, and redesign of the directional propellant contol valve eliminated materials subject to stress corrosion. An orbital safing system was installed to provide the capability of dumping residual LOX and $LH_2$ and engine pneumatics through the J-2 engine. The tanks will be safed through their respective vent systems.

Redesign of the LOX and $LH_2$ low pressure fed incorporates multi-ply bellows and features which increase resistance to flow induced vibrations. An alternate propellant loading capability was added to the S-IVB for improved loading accuracy and reliability in alternate loading mode.

Structural changes include the addition of a drag-in cable door in the S-IVB aft interstage and another such door in the forward skirt so that LC-39 can be used for launching Saturn IB vehicles.

In the Instrument Unit, redesign of the inverter detector will reduce its susceptibility to negative transients, and modification of the flight control computer will minimize cracking of solder joints over an extended period.

Redesign of circuitry in the power distributor minimizes voltage transients of short duration momentarily interrupting coolant pump number 1 operation. The flight control computer was isolated from coolant pump noise on the +6D41 bus to avoid erroneous engine movement signals. Redundant power has been provided to the IU switch selector and S-IB stage to insure operation in case of +6D10 or +6D30 battery failure.

In the Environmental Control System (ECS), a hydraulic snubber assembly was installed between the ECS coolant pump outlet and pressure transducer to prevent the transducer from responding to dynamic pressure fluctuations from the coolant pump.

Four relays were added to the IU Emergency Detection System (EDS) circuitry to allow the dumping of propellant through the J-2 engine by inhibiting EDS cutoff from turning off engine control power. In conjunction with this change, a third EDS cutoff signal was added to the S-IB for a 2 out of 3 voting logic in the S-IB.

Redundant power was provided for the ST-124 platform stabilized system, and the command decoder was redesigned to improve aging characteristics and overcome a possible problem of cracked solder joints.

Two sensor panels were added to the exterior of the IU to provide data to evaluate short-term stability of the optical properties of the thermal control coatings (AS-206 only).

Other telemetry changes made will reduce electrical noise of the IU and vehicle affecting the telemetry system, improve launch range coverage for Skylab missions, and increase the capability to detect a battery failure.

Increasing the size of GHe storage spheres provided more storage volume for longer missions and reduced total weight.

The methanol/water coolant in the thermal conditioning system was changed to Oronite Flo-Cool 100 because the latter is less susceptible to corrosive galvanic currents and will reduce the alkaline content which reacts with the cooling system as compared to methanol/water.

The capability has been added to deorbit the S-IVB/IU stages of SL-2, SL-3 and SL-4 by dumping residual propellants through the J-2 engine to alter the vehicle's trajectory. By controlling the vehicle's attitude and the time and duration of the dump, the S-IVB/IU can be impacted in an ocean. The maneuver will be commanded in real time after considering vehicle trajectory, condition and capability. Sending the spent stage into the ocean eliminates the hazard of space debris impacting a populated land area.

## RESTRAINTS AND MOBILITY AIDS

Crew restraints and mobility aids include open grids, foot restraints, handrails and handholds, tethering devices, and thigh, sleep and waste management restraints. Equipment restraints include straps, bungees, towel holders, universal mounts, liquid cooled garment hangers, Velcro and snaps.

The grid structure for walls and ceilings is predominant throughout the OWS. Some sections have covers on one side that keep articles from passing through and other sections are uncovered or "open grid" structures. The open grids are handy for restraints. The triangular openings are uniform and sized to fit triangular plates fastened to the soles of shoes. A crewman wearing the shoes can insert the plate or "cleat" into a grid opening and turn his foot to lock himself into place. These grids are placed at points in the OWS and MDA where crewmen will be working with their hands but will need to be held in place. The stowage ring in the forward section of the OWS also has cleat receptable holes.

Astronauts will have other devices for holding their feet in place. One is a pliable arrangement similar to the straps on shower "clogs" placed at various points, such as three pairs on the floor of the wardroom at the base of the food table and a pair in the WMC on the floor beneath the handwasher. A third type of foot restraint consists of toe bars and heel fittings fastened to the floors or walls. These can be moved wherever needed.

Handrails and handholds are used extensively in all components of the OA, both inside and outside. Most of these are fixed but crewmen will have a number of detachable handholds they can move to various locations. They will use the handrails and handholds to propel themselves about the station and hold themselves in position temporarily. They will use an extensive system of rails in performing EVA.

Tethering devices are simply straps with hooks which crewmen can attach to themselves and fixed points to keep them from drifting too far. Thigh restraints are bars which extend from the food table. Each has two other bars that form a double "T" at the end. Astronauts put one leg on each side of the main bar and between the other two bars. Sleep restraints are similar to sleeping bags. The astronaut gets into the bag and zips up the front. Attached at the floor and ceiling, the bag holds the crewman in place while he is sleeping. Waste management control restraints consist of handholds and foot restraints. Astronauts will also have a handy device for moving from one section of the OWS to another - the "fireman's pole," which is removable and collapsible. All handrails and fixed handholds are painted blue for ease of identification.

Straps of varying lengths and stretchable bungees are stored on the OWS for use in holding and putting pressure on equipment to keep it in place. Rubber cylinders with a cross cut in the end are used to hold washcloths and towels. Universal mounts can be moved to sites needed and snapped into place to anchor equipment. Temporary restrainers include Velcro material and a uniform snap pattern.

## BACKUP HARDWARE

An identical set of hardware will be available the day the flight hardware for Skylab is launched. The backup hardware has two prime purposes: It can be used in place of the flight hardware in case of a failure of the latter; and it can be used for trouble-shooting, confidence testing and systems engineering during the Skylab mission. Backup hardware will be kept available at least through completion of the second manned visit.

NASA will have the capability to launch the backup Skylab within 12 to 15 months after a decision is made to do so. The launch vehicle for a backup launch would be Saturn V vehicle AS-515 composed of S-IC-15, S-II-15 and S-IU-515, now in storage at KSC.

The backup Workshop will not be given post-manufacturing test and checkout unless required for flight, and experiments will not be installed. It will be stored at the McDonnell Douglas plant in Huntington Beach, California.

Manufacturing test and checkout was completed on the MDA before it was shipped to the McDonnell Douglas plant at St. Louis for mating with the AM. The mated AM/MDA was tested through simulated flight test, a confidence test program in support of SL-1, instead of post-manufacturing and pre-delivery checkout. The unit is at the St. Louis plant ready for use in duplicating conditions of possible problems encountered in the flight hardware during the mission.

## SYSTEMS

### LIFE SUPPORT SYSTEM

The Skylab Life Support System encompasses environmental control provisions to decontaminate, deodorize, dry, heat and circulate a two gas atmosphere; food and water management equipment to store, preserve and prepare palatable food and drinking water; waste management equipment to collect, process, and dispose of body wastes and mission trash; sleep provisions to provide restraint and privacy during sleep periods; personal hygiene arrangements to maintain personal health and comfort; microbial control precautions to assist in maintaining crew health and comfort; Inflight Medical Support and Medical Accessory Kit equipment to enable remedial activities in the event of illness or injury; and operational biomedical equipment to monitor physiological parameters during critical tasks such as EVA.

**ENVIRONMENTAL CONTROL** Skylab is the first U.S. manned spacecraft pressurized with a two gas atmosphere.

The Environmental Control System (ECS) provides for distribution and purification of the atmosphere in Skylab, control of pressure, ventilation, cooling and heating of the atmosphere, and cooling and heating for the crew during EVA. The ECS is comprised of the Gas Distribution and Pressure Control Subsystem, the Ventilation and Atmosphere Control Subsystem, and the EVA/IVA Support Subsystem.

Skylab uses a gas distribution and pressure control subsystem with a total gas pressure of 5 psia, an oxygen partial pressure of

3.6 psia nominal, a nitrogen nominal partial pressure of 1.4 psia and a circulation velocity of 15 to 100 feet per minute. The oxygen is stored in six 45-inch diameter, 90-inch long cylindrical steel-lined fiberglass tanks at 3000 psia, mounted on the internal portion of the Fixed Airlock Shroud. The nitrogen is stored in six 40-inch diameter titanium spherical tanks at 3000 psia, mounted on the external AM trusses.

The two-gas control system supplies either oxygen or nitrogen to the Skylab cluster. Oxygen is supplied until the partial pressure of the oxygen reaches 3.7 psia and the nitrogen is supplied until the partial pressure of oxygen drops to 3.5 psia. Potential over-pressurization of the space vehicle is prevented by three pressure relief valves located in the AM.

Prior to launch, the AM/MDA/OWS is pressurized with nitrogen. During ascent the nitrogen from the MDA/AM is allowed to bleed down through two MDA vent valves until a timed command closes the valves. Nitrogen from the OWS is vented through its own vent valve system during and following ascent. Nitrogen from the waste tank is vented through its own system also, after orbit is attained. It has been estimated that 1.3 psia of nitrogen will be left in the MDA/AM/OWS when the valves are closed. The waste tank is allowed to vent to vacuum. A ground command is then used to open oxygen system solenoid valves, allowing oxygen to flow into the habitable volume until a total pressure of 5 psia is reached. After the solenoid valves are closed, the oxygen/nitrogen makeup system reverts to a demand basis.

During the unmanned storage periods the orbital assembly pressure is vented to 2 psia and then allowed to decay by normal leakage to a minimum pressure of 0.5 psia, after which it is repressurized by command as required.

Skylab uses the ventilation and atmosphere control subsystem to limit contamination and to maintain safe and comfortable levels of $CO_2$, humidity and temperature. Fans in the MDA, AM and OWS are used to circulate the atmosphere for crew comfort. Three cabin heat exchangers in the AM Structural Transition Section (STS) provide cooling to the MDA/STS region and four heat exchangers in the aft AM provide cooling to the OWS. Fans direct the flow of cool air through OWS, MDA and AM areas.

Humidity, heat, carbon dioxide and odors are removed from the atmosphere by one of two redundant molecular sieve assemblies, A or B. Each assembly contains two screen filters, two compressors, two heat exchangers, two molecular sieve beds and one activated charcoal canister. During operation of the molecular sieve assembly, atmosphere flows from the AM through the screens which filter large particle contaminants. The compressors force the atmosphere through one of the condensing heat exchangers which cools the atmosphere and removes some water. Part of the atmosphere then flows into one of the two molecular sieve beds where water and carbon dioxide are removed. The rest of the flow goes through either the activated charcoal canister where odors are removed, or through a bypass. Under the control of valves in each molecular sieve bed, atmosphere flows through one molecular sieve bed while the other is exposed to space vacuum to remove most of the water and $CO_2$ which has been absorbed by the molecular sieve bed. The beds are cycled every 15 minutes, automatically, so that one bed is active while the other is exposed to space vacuum. The space vacuum water removal method does not, however, remove all the water, necessitating the use of a 12-hour 400° F bake-out cycle after approximately 28 days of sieve operations.

The Environmental Control System provides thermal control and a supply of dry oxygen for suit pressurization, ventilation and breathing to the crewman performing EVA or suited IVA. Suit pressure is maintained for EVA at 3.6 psia with a variable controlled rate. Used oxygen is rejected to space through a controller in the suit. A pressure relief valve in the space suit prevents over-pressurization. One IVA $O_2$ supply station is in the forward section of the AM and two EVA/IVA $O_2$ supply stations are in the lock portion of the AM. During EVA operations the airlock is depressurized and $O_2$ is provided to the EVA crewman. After the EVA the AM airlock is repressurized to 5 psia by gas from the atmosphere.

Active cooling is provided to the crewmen through a water cooled undergarment. The water cooled system is a closed loop system, the water being re-cooled in the EVA heat exchanger in the AM.

**WATER MANAGEMENT** Unlike the Apollo spacecraft, which generated sufficient potable water as a by-product of fuel cell activity, Skylab contains enough stowed water at launch to serve all of the needs of three men for 140 days of operation. This water is stowed and managed by the OWS water subsystem. The OWS water subsystem provides for storage pressurization, distribution, purification, thermal control and conditioning, and dispensing of the water. The water is provided principally for food reconstitution, drinking, crew hygiene, housekeeping and urine separator flushing, if needed. Water is also provided for the Life Support Umbilical/Pressure Control Unit (LSU/PCU), the AM EVA/IVA cooling loop, the ATM C & D Panel/EREP cooling loop, the M512 facility experiment and the OWS shower.

Water is stored in ten stainless steel storage tanks in the forward compartment area of the OWS. The water tanks (WT) each having a useable capacity of about 600 pounds are identified as 1 through 10 and are assigned to particular water networks: WT 1, WT 2, WT 3, WT 4, WT 5, and WT 10 are assigned for wardroom use; WT 7 and WT 8 are assigned to the WMC water network; and WT 6 and WT 9 are provided as contingency water tanks in case of excessive water usage or failure in the water supply, in either the wardroom or the WMC. The capacity of one of the ten water tanks could be lost without decreasing the water supply below mission requirements.

Each water tank is a stainless steel cylinder with a sealed metal bellows inside. Each tank is an independent unit, supplied with a nitrogen gas pressurant to maintain water supply pressure. The sealed bellows assembly forms a nitrogen gas chamber and provides a constant pressure during use. The bellows extends as water is withdrawn from the tank. Two water tank heater blankets are used on each tank to keep water temperature at approximately 60° F during all mission phases. Each water tank contains water tank servicing equipment to facilitate ground filling and to permit water purification. Purity of the water is maintained by using iodine as a biocide. The water is periodically sampled on-orbit by use of the sample port valve. If the on-orbit sample analysis reveals a need to purify the water, iodine will be injected into the tank through the iodine injection port, with mixing from operation of the agitator pump.

The three water distribution networks are the wardroom network, the WMC network and the urine flush network, if needed. Each distribution network is designed as a totally independent system to prevent cross contamination.

The wardroom network distributes water to the food table where the water is chilled or heated for food reconstitution and drinking. The network consists of two water hoses, a water supply line, a filter, relief valves, a water heater which heats the water to 152° F, and a water chiller which chills the water to 45° F.

The wardroom has two water dispenser valves, one cold and one hot, for reconstituting dehydrated foods and beverages. The water chiller, in the table pedestal, provides chilled water to the cold wardroom water dispenser valve; the internal table-mounted water heater supplies hot water to the wardroom hot water dispenser valve.

Water is distributed to three color coded water guns for drinking purposes. They are located on the food table pedestal adjacent to each eating station. The water guns, fitted with replaceable drinking mouth-pieces, discharge chilled water in small, drinkable quantities.

The WMC water network distributes water to the water heater in the WMC, where the water is heated to 127° F, and routed to a dispenser for body cleansing and housekeeping purposes. The network is composed of two hoses, a supply line, relief valves and a water heater.

The network supplies water to a WMC water dispenser valve in the hand washer. The dispenser is provided hot water from the WMC heater. The dispenser contains a plunger which, when depressed, expels three jets of water in a continuous stream into the crewman's hand-held washcloth.

The urine system flush water network distributes water from the tank to the flush equipment in the WMC corner stowage compartment. This equipment is used only if needed to flush residual urine from the urine separators in the fecal/urine collector. The network is composed of a water hose, a water supply line and a filter.

The wardroom water dump provides for wardroom water network evacuation into the waste tank. Dumping is through quick-disconnects, flexible hoses, tubing, a hand valve, and a heated waste tank discharge nozzle (dump heater probe).

The WMC water dump provides for evacuation of the WMC water network, urine system flush water network (if used), washcloth squeezer bag and the condensate control system into the waste tank.

The portable water tank is independent and completely portable. It accommodates a self-contained pressurization unit and a 26 pound capacity water supply and is mounted in the OWS forward compartment on a wall bracket below WT 1 and WT 2. It may be taken to or near the area needed if one of the water networks fails. The quick-release fastener on the tank permits retention on any grid surface.

**FOOD MANAGEMENT** The meals on Skylab are more palatable than those of previous manned programs, due primarily to advancements in technology which allow the inclusion of frozen and canned foods.

The Skylab food system must meet the rigid requirements and objectives of medical experiments which demand precise knowledge of nutrient intake and must fulfill the experimental objectives of the M487 Habitability experiment.

The food system provides the energy requirements of each individual astronaut based on his body weight and age. The ration will insure a daily intake of between 750 and 850 mg of calcium, 1500 to 1700 mg of phosphorous, 3000 to 6000 mg of sodium, 300 to 400 mg of magnesium and 90 to 125 g of protein. Each astronaut will maintain a constant level of intake of these controlled nutrients within two percent. The diet is baselined to provide at least the dietary allowances of carbohydrates, minerals, vitamins, and fats recommended by the National Academy of Science.

About 2100 pounds of food and accessories for all three manned visits is stowed aboard the workshop prior to launch. The frozen food items will be secured in the five food freezers which have a combined stowage space of 10.6 cubic feet and the other food items are stowed in lockers on the floor of the workshop at launch and later placed in assigned locations during the activation period by the SL-2 crew. The 11 food lockers have a combined storage area of 88.3 cubic feet.

The more than 70 food items provided in Skylab have been taste tested by crew members. The items aboard the OWS will meet the following criteria: the food is a familiar kind; the food portions are processed to be prepared, served and eaten in a familiar manner; and the prepared food is satisfactory with regard to taste, aroma, shape, color, texture and temperature.

The Skylab menu includes the following food types:

**Dehydrated** - ready to eat rehydratable foods with a moisture content reduced to less than 3%.

**Intermediate Moisture** - precooked, thermally stabilized, or fresh food with the moisture content partially reduced so that the final moisture content is approximately 10 to 20%.

**Thermostabilized** - precooked, thermally stabilized or fresh food with the temperature reduced below -10° F prior to launch to retard spoilage.

**Frozen** - precooked fresh food with temperature reduced below -40° F before launch to retard spoilage and maintained in freezers in the OWS.

**Beverages** - rehydratable drinks including: black coffee, tea, cocoa, cocoa flavored instant breakfast, grape drink, limeade, lemonade, orange drink, grapefruit drink, cherry drink and apple drink.

The crewman assigned to duty of chef for the day consults the day's menu to determine what food and beverages are required for the next meal. He removes the items from the food lockers and carries them to the OWS food table for preparation. One portable food tray is provided for each crewman. The food trays have eight food cavities - four for large food cans and four for small cans. Three of the large cavities are heated. Foods which require heating are placed in those cavities. The astronaut sets the timer and turns on the warmer. A removable tray lid is used when the food is heating and is stowed in the food tray stowage area when not in use. Each of the trays and lids are color coded. Magnets hold the utensils to the tray until used. At the end of each meal, the food trays are filled for the next meal and the heater timers set for the appropriate interval.

Foods which require rehydrating are prepared at mealtime by each astronaut through the use of the cold or hot water gun in the center of the food table. The food table pedestal houses the water chiller and the wardroom water heater.

A plastic membrane is installed inside each food can to prevent spillage in the zero-g environment. The membrane is fitted with a one-way spring loaded valve for rehydratable food which permits the addition of water without leakage and prevents the escape of contents during and after lid removal and mixing. The crewman slits the membrane with his knife and the membrane retains the balance of the contents until consumed.

Rehydratable beverages are packaged individually in collapsed accordion-shaped beverage packs which vary in length according to the type of beverage. These packs expand in length as the cold or hot water is added to the beverage powder.

The astronauts sit at the food table in special thigh restraints with their feet in portable foot restraints.

**WASTE MANAGEMENT** The management of body wastes for three men and the mission trash from 140 days of manned operation posed a challenging problem for NASA design teams. To complicate the situation, body wastes are required as samples for a group of experiments conceived to assess the muscle and bone changes in crewmen exposed to weightlessness over a long period (M071, Mineral Balance, and M073, Bioassay of Body Fluids).

A collector module in the Waste Management Compartment (WMC) of the OWS performs the same function as an Earth toilet, but in a different manner. The collector module is used by a crewman in a seated position facing the compartment floor. This collector permits one crewman to defecate and urinate simultaneously while seated, using a lap belt and two handholds to hold himself in place. The urine receptacle, which is connected through the centrifugal separator to the urine inlet valve of the urine bag, is also a convenient height for standing urination. A pair of light-duty foot restraints in front of the fecal/urine collector permits standing urination and allows the crewman to conduct maintenance on the fecal/urine collector.

The fecal/urine collector is a rigid, wall-mounted unit. It contains one fecal bag for collection of a single defecation and three urine drawers, one per crewman, to collect each urination and to store the urine in a chilled state for 24 hours. A fecal/urine collector blower unit provides a gravity substitute airflow (suction) to draw and retain the waste material into the fecal collector and into the urine drawer during waste collection. The airflow is filtered to remove odors prior to its recirculation back into the cabin by the blower unit. The fecal bag is removed from the fecal collector after each defecation and replaced immediately with a new bag. The fecal bag with its contents is weighed on a mass measuring device and then vacuum dried in a waste processor to facilitate on-orbit storage.

The waste processors preserve, in collection bags, those organic and inorganic constituents of vomit and feces required to support the medical experiments. Six independent waste processors are wall-mounted in the WMC. Each processor uses mechanical pressure, an electric heating element and venting to the waste tank vacuum to dry the waste material. Each processor will accommodate one fecal bag or one contingency fecal bag. Each is controlled by individual control and display panels which include a timer, manually set by the crewman to automatically initiate and terminate the drying cycle. The drying time is selected as a function of the waste material's mass. After processing, the collection bags are removed and transferred to a storage area in the WMC for eventual return to Earth.

Three urine drawers are at the base of the fecal/urine collector, one assigned to each crewman. The drawers are used for collecting, storing for 24 hours, and measuring and sampling the urine. Each drawer contains the facilities to accept the urine, to separate the air, to collect and store the urine, and to withdraw a urine sample once daily. Each drawer is serviced with refrigeration subsystem coolant to refrigerate the urine bag and cool the urine separator. Each drawer is provided with a gravity substitute airflow from the collector's blower unit. Cabin air, used to collect the urine, is removed by the separation device through centrifugal action prior to freezing the samples.

The urine freezer, immediately below the waste processors, provides interim low-temperature storage of urine samples for return to Earth at the end of the mission. The 120 ml urine samples in sample containers are retained in urine trays which hold 42 sample containers (2 weeks accumulation) in partitioned segments. Two urine trays, with an integral thermal capacitor of dodecane wax, are stacked in the freezer at all times. The wax, after being thermally conditioned in the freezer, keeps the sample containers below 14° F during the return to Earth in a urine sample container.

Any item that is biologically active after its use (clothing, filters, food cans, urine bags, sleep restraints, hygiene kits, tissues, wipes, towels, washcloths, etc.) is considered trash and disposed of in the waste tank in trash collection bags. Controlled venting via the trash bags prevents excessive waste tank pressures and minimizes the formation of large ice crystals, which may collect on and clog the screens in the waste tank. Two types of trash collection bags are provided: trash bags that serve as trash receiving stations within the OWS, and disposal bags for use in bagging large items. Eight trash containers are located in the OWS; one in the experiment compartment, two in the wardroom, one in the WMC, three in the sleep compartment (one in each sleep area), and one in the OWS forward compartment.

The trash bags in the wardroom and the WMC are replaced daily, others weekly. When a trash bag is removed from the trash container, a bag-mounted, adhesive-backed diaphragm cover is sealed into place over the diaphragm to seal-off the opening. Filled trash bags are put into the waste tank through the trash disposal airlock.

Disposal bags are used for large items (urine bags, sleep restraints, food overcans, charcoal filters, etc.) which do not fit into the trash bags. When a large item is to be disposed of, a disposal bag is obtained from one of the stowage compartments and transferred to the work area. The bag is secured near the work area by the bag's Velcro lining or its snaps. "Stays" in the bag opening maintain the bag open or shut. After use, the bag is sealed shut by a tab on the bag and put into the waste tank.

The trash disposal airlock is located in the center of the crew compartment floor. The airlock will be used about five times a day.

**SLEEP PROVISIONS** Sound sleep periods of sufficient length are vital to enable crewmen to continue functioning under the stresses of long duration missions in weightlessness. The provisions for Skylab are consequently more elaborate than those of earlier, shorter duration flights. During sleep periods, each crewman is provided with an individual compartment for privacy and isolation from illumination and noise. Each compartment contains a removable sleep restraint, storage compartment for personal items and a removable light baffle for the ceiling.

The sleep restraints provide for a variety of sleep positions, including the fetal position, and also thermal comfort during sleep periods. The restraints are vertically mounted on a frame attached to one of the sleep area partitions. This frame is strapped to the floor and ceiling grid to provide rigidity. The neck opening is used for normal ingress and egress and for emergency egress. The restraint also has openings for crewmen's arms. The total sleep restraint is replaced every 14 days but individual components such as the headrest and blankets may be replaced at the discretion of the crewmen. Replacement restraints, headrests and blankets are stowed in the sleep area stowage compartment.

Crewmen place four light baffles on the ceiling grid of the sleep areas for light abatement during sleep periods.

**PERSONAL HYGIENE** On relatively short flights, the lack of personal cleanliness constitutes an acceptable annoyance. On longer missions personal hygiene becomes necessary to support good health and comfort. Consequently, Skylab has been equipped with a partial body cleanser, a whole body shower and personal hygiene items.

A partial body cleansing facility is provided in the form of a handwasher in the WMC. Crewmen will dispense water to a wash cloth and use a squeezer to wring excess water from cloths. The handwasher installation includes a waste water bag which collects the water from the squeezer. Four magnetized soap holders in the handwasher retain bars of soap, each of which contain a metallic insert. In using the handwasher, crewmen will position themselves in front of the module in the foot restraints.

For the first time in space, crewmen are able to take a shower using a "wet-soap-rinse" ritual. Once a week they shower using an allotment of three quarts of water. Crewmen enter the shower, raise the enclosure and attach it to the ceiling grid. Water is delivered by flexible hose from a portable water bottle to a push-button shower nozzle. A vacuum head on a flexible hose draws the used water into a disposable bag, which is later deposited in the waste tank.

**MICROBIAL CONTROL** The longer duration of Skylab missions makes the control of microorganisms in space an important consideration. The microbial control program includes: the collection and disposal of organic trash; personal hygiene measures with periodic changes of clothing; air drying of Liquid Cooled Garments (LCG) and Pressure Garment Assemblies (PGA) after use; periodic replacement of components highly susceptible to the collection of microorganisms; scheduled wipe-downs of susceptible areas with disinfectant; sampling and purification of potable water; decontamination of water distribution lines; and clean up of organic matter and water spills.

Certain microorganisms are shed from the crewmen's skin surfaces into their clothing. Skin cells and moisture provide an ideal environment for their growth. Consequently, all articles of personal clothing are disposed of after use.

The PGAs are dried after each EVA by inserting the boots into portable foot restraints near one wall of the OWS, securing the neck to the water ring grid in the forward compartment by straps, and blowing warm air through the PGA oxygen inlet quick-disconnects. The LCGs are passively dried by placing them on hangers and restraining the legs to the floor grid.

Equipment which readily collects microorganisms but is difficult to decontaminate by wiping with disinfectant or by cleaning is replaced periodically. Components and areas of Skylab which are particularly conducive to microbial growth (in regions with optimum temperature and availability of oxygen, moisture, and nutrients) are wiped down periodically with disinfectant wipes.

The potable water contains iodine in solution as a biocide at launch. Iodine, maintained above two parts per million, is an acceptable method of preventing microbial growth. The crews use the equipment to periodically draw samples from the tanks, to add a reagent, to determine the iodine concentration by comparison to a color chart, and to add iodine when necessary.

To prevent the growth of microorganisms in the wardroom water distribution network, the lines are filled with an iodine solution, allowed to soak for one hour, and flushed clear. The iodine injector is used to inject 100 parts per million of iodine into the portable water tank for transfer to the wardroom water lines. This decontamination is performed during deactivation of SL-3 and SL-4.

To limit the nutrients and moisture necessary for microbial growth, organic debris and moisture are cleaned up as required. Some equipment is cleaned periodically. Any spills of organic material or water are immediately cleaned up by the use of the vacuum cleaner.

**INFLIGHT MEDICAL SUPPORT SYSTEM** The Skylab Inflight Medical Support System (IMSS) provides an extensive inflight diagnostic and treatment center for emergency medical care of an "outpatient" nature. The IMSS consists of three basic groups of equipment:

diagnostic, laboratory, and therapeutic - which crew members have been trained to use. The equipment supplied is normally standard off-the-shelf medical items. The IMSS provisions are made up of kits, modules, and a work table stowed in locker compartments W706 through W709. The kits are diagnostic, therapeutic, dental and bandage, stowed together in the medical kits module. All of the kits are portable and are fitted with snaps which attach to a portable work platform or to other snap locations in the OWS. Medications and supplies with limited shelf life will be resupplied on each mission.

For diagnostic purposes the IMSS is supplied with the standard clinical tools the physician uses to perform a physical examination. The kit includes a stethoscope, a blood pressure measuring device, neurological examination instruments, and eye, ear and oral examination equipment. The kit also contains an ophthalmoscope and a headmount light. Altogether the diagnostic kit contains more than 20 items.

The laboratory equipment module provides the equipment to perform inflight medical analysis through the use of an incubator, a microscope kit, a slide stainer, a microbiology kit and a hematology and urinalysis kit.

The incubator is permanently mounted in locker compartment W708 and is used to grow cultures for analysis in isolating microorganisms to aid in diagnosing the probable cause of crewmen's illnesses. A slide drying compartment is provided as part of the incubator for rapid fixing of the stains onto tempered glass slides for microscopic analysis.

The microscope kit includes a portable microscope, lens tissue, tempered slides and slide treatment equipment. The slide staining equipment functions as a self-contained and totally enclosed fluid system for staining slides for microbial analysis and for blood smears to perform white blood cell identification.

The microbiology kit provides equipment to perform antibiotic sensitivity testing as a diagnostic aid. The kit also contains equipment to collect microbial samples from crewmen at the time of illness for inflight analysis, and to obtain environmental and crew microbial samples throughout the mission for post-flight analysis at MSC.

Supplies and equipment for performing urinalysis (the urinalysis kit) include a specific gravity refractometer. The hematology kit supplies the equipment, including a hemoglobin meter, to obtain white blood cell and hemoglobin information.

The locker module containing the laboratory equipment has a hinged, sheet metal surface for use as a laboratory workstation platform. Operational areas are provided on the workstation for mounting the microscope and for securing slides and associated equipment for processing cultures while analysis is being conducted. When not in use, the workstation platform folds into the module.

The therapeutic kit contains items such as injectable medications, syringes and a laryngoscope which operates on batteries. For therapeutic purposes the kit contains a wide variety of medications, both oral and injectable, for the treatment and prevention of infection, disease, and allergies. Minor surgery tools for the care of injuries are also included.

Several dozen types of medicines are in separate medication cans (two supplied per mission) stowed in W706 in the OWS. Prior to launch, the pills for SL-2, SL-3, and SL-4 are individually packaged and placed in the cans which are then sealed and opened when required. About 190 separate packages of pills, ointments, injectors and other medicines are aboard Skylab. Cans which have been opened and their unused contents will be disposed of at the end of each mission.

A catheterization kit is in a pocket inside the therapeutic kit. The equipment in the kit serves to relieve urinary blockage and to aspirate a crewmember's stomach if necessary.

Two treatment kits for minor surgery, containing more than 15 items each, are provided in the minor surgery module. The sterile surgical kits, in cylindrical cans, provide the necessary equipment to permit extraction of small foreign items from the skin or for creating and or closing small lacerations and puncture openings. The module also contains such surgical items as scissors, forceps, hemostats, scalpels and retractors.

The bandage kit contains more than 20 various configurations of bandages, swabs, dressings, gauze and associated equipment for treating minor injuries and fractures.

In the event any crewmember has a toothache or for some reason requires repair or extraction of a tooth, a 20-item dental kit provides the necessary equipment to cope with inflight dental emergencies.

The resupply and return container is used to carry medical supplies to Skylab and return samples to Earth.

**MEDICAL ACCESSORIES KIT** The Medical Accessories Kit (MAK) provides the crew with all medical supplies and bioinstrumentation accessories necessary for the Command Module (CM) portions of the Skylab mission. The MAK is stowed in the CM and is for use only in the CM. Designed as a rucksack for easy accessibility, it contains a variety of medications that can be generally categorized as antibiotics, anti-motion sickness medicines, pain relievers and antihistamines. Also, normal first aid equipment is provided, such as bandages and ointments. Space bioelectrodes and bioelectrode paste are also in the MAK.

**OPERATIONAL BIOINSTRUMENTATION** The purpose of the Operational Bioinstrumentation System (OBS) is to provide a means of transmitting to ground in real time certain critical physiological information during launch and recovery, EVA and on demand, as necessary. With such data at its disposal, the medical staff will be able to maintain a constant surveillance of health and physiological condition throughout selected phases of the Skylab mission.

The OBS is an electronic system including sensors, signal conditioners and telemetry interfaces. Also included as a part of the system is the Electrical Harness Assembly into which the signal conditioners are placed and which each crewman wears.

The system returns the following data via telemetry: electrocardiogram (ECG); heart rate (cardiotachometer - CTM); respiration rate (Impedance Pneumogram - ZPN); Subject Identification (SID). The various hardware elements of the system are:

**Signal Conditioners** - There are three signal conditioners, one each for ECG, CTM and ZPN. These are small electronic devices, the purpose of which is to electronically prepare (or condition) the incoming signals from the various sensors to interface with the telemetry system and on-board readout devices.

**DC to DC Power Converter (DDC)** - The DDC accepts the current-limited spacecraft power and converts it to an isolated balanced power supply for each signal conditioner.

**Biosensors** - The biosensors are electrodes that are affixed to the crewman's body. They sense the bioelectric potentials associated with heart action (ECG and CTM) and chest cavity expansion and contraction (ZPN) and send them through their attached leads to the appropriate signal conditioner. These electrodes are similar to those used in association with Medical Experiment M093.

**Subject Identification Module (SID)** - The SID is an electrical device that emits a unique voltage output for each crewman.

**Electrical Harness Assembly (EHS)** - In addition to providing a means of affixing the signal conditioners to the body as already described, the EHS includes the wiring between the sensors and their conditioners and between the DDC and the conditioners and SID. It also provides the electrical interface connectors to spacecraft power and telemetry system.

**Portable $CO_2$/Dew Point Sensor** - This device provides the crew with a reliable means of measuring $CO_2$ concentration, humidity and ambient gas temperature anywhere within the Skylab cluster. This device will serve as supplementary instrumentation to the fixed Skylab instrumentation which is supplied as a part of the environmental control system. Such adjunct instrumentation is required because it is anticipated that there will be areas of static or nonconvective gas masses due to the circulatory pattern of the Skylab fans. The device is designed as a portable hand-held unit utilizing components of the Apollo Dew Point Hygrometer System and the Apollo Portable Life Support System $CO_2$ Sensor for its measurement functions. It measures gas and dew point temperatures from 40° to 100° F and carbon dioxide partial pressures from 0.1 to 30 mm Hg. The portable sensor is completely self-contained, requiring no spacecraft support. It is designed to physically lock into the floor grid so that it can be placed in a fixed position when desired.

## THERMAL CONTROL

Thermal control within Skylab is maintained by the combined influences of the passive system, which limits heat fluxes through the compartment sidewall, and the active systems which dissipate atmospheric and cold-plate heat loads to the radiator heat sink, provide refrigeration and suit cooling, and heat components during storage.

**ACTIVE THERMAL CONTROL SYSTEMS** The AM active thermal coolant loop removes and dissipates waste heat which is due to cluster equipment operation and metabolic heat loss. Active cooling is provided to the EVA/IVA suit cooling module, condensing heat exchangers, three tape recorder cold plates, oxygen heat exchanger, ATM Control and Display (C & D) panel heat exchanger, battery modules and six electronic modules. A bifilar (each loop split into two parallel passes) radiator and a thermal capacitor (charged with tridecane wax) immediately downstream of the radiator are used for heat rejection. The capacitor absorbs heat from the coolant while the vehicle is on the sunny side of the orbit, and adds heat to coolant on the dark side.

The ATM C & D/EREP cooling system provides single-loop water cooling by circulating water through a heat exchanger that interfaces with both loops of the Airlock Module coolant system. The fluids of the C & D panel cooling system (water) and the AM coolant system are isolated by heat exchanger walls.

The suit cooling system provides astronaut cooling for EVA and IVA by circulating water through umbilicals and liquid-cooled garments (LCG). The system consists of two identical subsystems (one subsystem per AM coolant loop). Each subsystem can deliver a minimum of 200 pounds per hour of water. The water flowrate through each LCG is controlled by an adjustable flow divider valve.

During the 7.5 hours that the IU equipment is required, the IU-mounted equipment is thermally controlled by an active thermal control system. Flow Cool 100 coolant is circulated by a centrifugal pump and heat rejection capacity is provided by a sublimator, using stored-water supply.

The active Thermal Control System for the ATM is a closed-loop fluid circulation system designed to maintain the methanol-water at the ATM canister inlet at a temperature of 50° ±3° F. Two parallel flow paths contain eight cold plates each. The cold plates are on the internal circumference of the canister; two cold plates are connected in series in each quadrant on the MDA end, and two cold plates, also connected in series, are in each quadrant on the Sun end.

The heat picked up by the fluid while in the cold plates is rejected to space by radiators on the exterior of the ATM canister. Temperature control of the cold plates is obtained by using a modulating flow control valve, which proportions the fluid flow between the radiator and the heater flow passages.

A refrigeration subsystem is provided aboard the OWS for food refrigeration, potable water chilling, food freezing and urine-sample freezing. Also, this subsystem provides temperature control during the initial storage period through a range of 39° to -14° F. A single-phase liquid refrigerant, Coolanol-15, circulates through the low-temperature storage units and accepts heat, which in turn is delivered to an external radiator and rejected to space.

The wardroom food freezer provides low-temperature storage 0° F maximum for 100 pounds (a 56-day supply) of frozen food, 40° ±5° F storage for up to 50 pounds of perishable food, and the required food-chilling capability (from room temperature) for beverages, desserts, etc.

The food storage freezer provides low-temperature storage 0° F maximum for 150 pounds (an 84-day supply) of frozen food at a pressure of 1 psia minimum. The low temperature is maintained by transferring heat from the freezer to the refrigeration subsystem coolant loop.

Heat is rejected from the food compartments to the refrigeration subsystem coolant loop. Valving, pressure-tight covers, seals and transducers are provided to maintain the required food pressure and to provide pressure readout. Transducers are provided for temperature readout.

A water chiller is provided to satisfy the requirement for chilled drinking water at 40° +5° F.

The chiller can hold 10 pounds of chilled drinking water. Only 5 pounds of chilled water can be extracted at one time. Once this amount has been extracted, it takes approximately 1 hour to rechill the incoming water. The refrigerant is controlled to an inlet temperature of 39° ±3° F.

Electrical heaters are provided to maintain SWS wall temperatures at an acceptable level during storage-mode operation and to prevent freezing in the water storage container plumbing, suit-cooling, and ATM C & D panel cooling systems during the unmanned phase of the mission.

**PASSIVE THERMAL CONTROL SYSTEM** The passive thermal control system employs appropriate surface coatings and thermal insulation to maintain the internal walls and truss-mounted equipment within acceptable temperature limits. Due to the dependence of passive system performance on the external radiative exchange, temperatures are influenced by the vehicle orientation.

The external surface thermal coatings are black and white paints. The radiator on the MDA and STS uses a white paint (zinc oxide) with a low ratio of solar absorptivity to surface emissivity to provide low effective sink temperatures and higher heat-rejection rates. The design value used for the radiator surface is slightly higher than values measured for a clean surface to account for degradation during the mission caused by exposure to ultraviolet radiation, meteoroids, exhaust plume impingement, etc. Black paint is used for the forward skirt, IU, FAS and MDA.

Rack-mounted equipment has surface thermal coatings to maintain operable temperatures by radiation heat transfer. The canister lip and the Sun shield prevent direct solar radiation from striking the rack-mounted equipment in the nominal mission attitude. Reradiation from the Earth and the surrounding portions of the cluster is balanced by radiation from the rack-mounted equipment to space, thereby maintaining the components within the upper operable, low-power and orbital-night periods of the mission.

Passive protection against solar radiation or cold space for crewmen during EVA is provided by a thermal garment consisting of seven layers of aluminized mylar separated by layers of spacers.

## ELECTRICAL POWER SYSTEM

The human body is kept alive and well by the proper flow of vital force throughout the complex circulatory system. Likewise, Skylab is kept alive and functioning by the flow of electric current throughout the complex power distribution systems.

Skylab's electric supply is provided by three electrical power systems: IU EPS; SWS EPS; and CSM EPS (SWS refers to the mated OWS, ATM, MDA, AM and IU). Each system has a specific function and operating profile for which it was designed.

The IU EPS is required only during countdown, launch and orbital insertion. The IU initiates automatic, programmed signals which control critical Skylab functions during that period. The maximum required operating life of the IU EPS is 7.5 hours. This electrical power system is independent of the other electrical power systems.

The IU EPS consists of the following major components: four batteries, one platform AC power supply, one 56 Vdc power supply, one 5 Vdc power supply, seven distributors, one power transfer switch. The four batteries are silver-oxide-zinc 20-cell dry charge type with a capacity of 350 ampere-hours each. Activation of each battery before launch is through addition of potassium hydroxide electrolyte. A connector with jumpers to connect 18, 19 or 20 cells is provided on the battery case to match the battery output to its load.

The Platform AC Power Supply converts unregulated 28 Vdc power to three-phase, 400 Hertz, 26.6 Vac. This power is fed to the Control Distributor for use by the Platform electronics.

Both the 56-volt power supply and the 5-volt power supply are DC to DC converters whose outputs are fed to the Control Distributor and the Telemetry System, respectively.

The seven distributors include a Power Distributor, two Auxiliary Power Distributors, one Control Distributor, one Emergency Detection System Distributor and two Measuring Distributors. The pressurized distributors serve as junction and switching boxes distributing 28 Vdc power to IU components and housing the various necessary electrical hardware.

The sources of primary electrical power for the SWS cluster are solar cell arrays on the ATM and the OWS. These arrays collect and convert incident visible sunlight into electrical power. This power is then made available to recharge batteries and is power conditioned before distribution to designated loads.

The ATM EPS and AM/OWS EPS are operated in parallel and are capable of delivering power to, or receiving power from, each other, as well as delivering power to the CSM EPS.

The end-of-mission average per orbit power requirements of the two EPSs are:

| | SOLAR INERTIAL | Z-LV-RENDEZVOUS | Z-LV-EREP |
|---|---|---|---|
| ATM | 3716 W | 1300 W | 3000 W |
| AM/OWS | 3814 W | 1300 W | 3000 W |
| TOTAL | 7530 W | 2600 W | 6000 W |

The CSM EPS consists of the following major components: two fuel cell power plants (Bacon type); 3 solid state inverters; three entry/post-landing batteries (40 amp-hour); two pyrotechnic batteries (40 amp-hour); and three descent batteries (500 amp-hour).

The fuel cells are capable of supplying up to 1420 W. When CSM power is required after fuel cell life, it is supplied by the batteries or by the SWS EPS (during the docked mode). CSM power is provided by the fuel cells up to and after docking for a maximum of 13 days. Just prior to fuel cell depletion, the CSM EPS is connected to the SWS EPS and power for CSM loads is provided by the SWS until undocking.

During deactivation, prior to undocking, the descent batteries are operating. The SWS EPS is paralleled with the CSM EPS during switch-over. The parallel operation periods are about four minutes.

When docked, the CSM main buses are connected to the AM transfer buses through circuit breakers and motor driven switches with power connections in the MDA docking ring umbilical.

**POWER GENERATION** Solar cell power generation system differences exist due to individual supplier design and assembly preferences, and each is considered capable of satisfying all mission requirements.

The raw power capability, prior to power conditioning at the beginning of the mission, of the as-launched solar cell arrays is:

**ATM** - 10,480 watts at 55° C, solar angle = 0°
Illumination = 1400 W/m$^2$

**AM/OWS** - 12,400 watts at 77° C, solar angle = 0°
Illumination = 1400 W/m$^2$

The difference between the total generated power capability of about 23 kilowatts and that available to spacecraft loads is due to power conditioning losses and cable resistances. Further reduction in solar array output is caused by the dependent influences on the solar cells such as UV exposure, solar flare charged particles, and temperature cycling fatigue of materials due to the more than 4000 day-night periods imposed by the mission. Other factors include the seasonal Sun distance effect on illumination intensity, orientation angle with the Sun and shadow patterns from vehicle protuberances.

The above factors and many others have been considered in assuring that Skylab load requirements will be satisfied at all times.

**POWER CONDITIONING AND ENERGY STORAGE** The ATM uses 18 Charger Battery Regulator Modules (CBRMs) while the AM/OWS uses 8 Power Conditioning Groups (PCGs). A CBRM and a PCG perform essentially the same functions.

Each CBRM is designed to operate at various power levels which are determined partly by the amount of energy supplied by its associated solar cell panel. The CBRM conditions the power by converting the higher solar array or battery voltage to the lower 28 Vdc level required by Skylab power buses. The maximum capability of each CBRM is 415 watts at an efficiency of 92%. The output of the CBRM is fed to two buses.

A portion of the solar array power is required to replace the energy removed from the batteries during the dark part of the orbit. The function of the charger is to optimize the power available from the solar panel. It distributes power to the load regulator and the batteries when required. The charger output is connected to the battery only when charging power is available and is disconnected when either the battery is fully charged or when the available solar array power is too low to charge the batteries.

The regulator provides regulated 28 Vdc power to appropriate buses within the ATM. The regulator can receive power from either the battery or the solar panel directly. The average and maximum steady state power levels delivered by the regulator are 235 W and 415 W respectively.

The operational modes for the AM are similar to those stated for the ATM CBRM except that the control limits are different. Charge termination results when the battery thermal switch opens at 125° F, and/or when the array cannot supply sufficient power.

The voltage regulator regulates power to both the EPS control and regulated buses. This power is supplied in one of four ways: from the battery charger only; from the battery charger and battery in parallel; from battery only; from SAG only.

Fuses are provided for each regulator to isolate malfunctioning systems from the remaining normal regulators on the same bus.

The OWS/AM EPS is provided with a Shunt Regulator on each EPS Control bus to restrict over-voltage transients resulting from voltage regulator malfunctions. This is accomplished by providing an additional current path until circuit interruption occurs in the malfunctioning circuit.

**POWER DISTRIBUTION SYSTEMS** Both power distribution systems have their negative returns connected to a single point ground in the AM when the CSM is not docked and to the CM vehicle ground when CSM is mated with the SWS.

**POWER CONTROL** Control of the SWS EPS is normally automatic but manual or ground control is also possible. Various ground command systems can be used for remote control of the SWS EPS.

ATM power-up/power-down may be accomplished by activating or deactivating each CBRM independently or by activating all simultaneously.

Both the ATM EPS and the AM/OWS EPS are designed to operate while interconnected. This provides for power sharing between the two EPSs. The SWS EPS in turn is parallel with the CSM EPS. This paralleling provides power to the CSM when required. In this paralleled condition the EPS with the highest bus voltage will supply the major portion of the total power requirement. Balanced power sharing is an important capability of this configuration.

**MONITORING SYSTEMS** On-board monitoring capabilities for the SWS EPS are contained in various types of readout devices. Also, the telemetering system permits status information to be displayed on the ground.

**SYSTEM CIRCUIT PROTECTION** Protective devices for the cluster's electrical power system consist of fuses and circuit breakers. Their function is mainly to protect system wiring, being placed ahead of associated components and as near as practical to associated feeder buses. The design of the protection system is such that individual failures will not affect remaining normal loads.

**LIGHTING** Lighting of Skylab was somewhat of a challenge to engineers because they had to be sure "every nook and cranny" had sufficient light, but at the same time, not place too great a drain on the power supply. Another consideration was the weight factor - too many lights would raise the OWS total weight significantly. Still another factor was types of lighting for various purposes. Also, special provisions had to be made for mobility of some light fixtures, shading and protection against breakage.

Skylab lighting requirements are internal and external. The internal lighting system is for normal operations of the spacecraft and for conducting experiments. The external lights are for docking, rendezvous tracking and EVA.

**EXTERNAL LIGHTS** Four strobe lights are mounted on the ATM

Deployment Assembly near the pivot points, two each at -Y and +Y. These serve as tracking lights as they flash regularly. These lights cast a cone of brilliant light 45° from the +X axis of the Skylab, giving a 90° spread of light. The light would appear as a third magnitude star if viewed from an Apollo Command Module window at a distance of 144 nautical miles or through a sextant at a distance of 629 nautical miles.

All eight docking lights are 20-watt incandescent bulbs protected by grid enclosures. Two are red, two white, two green and two amber. Four are mounted on the forward end of the MDA, the white at +Z, red at +Y, amber at -Z and green at -Y. The four mounted on the forward end of the FAS are placed with colors matching those coordinates of the MDA lights, resulting in a cross of lights when viewed from ahead of the OWS. As the Command Module approaches the forward docking port, the two white lights will be "up," the two amber lights "down," the red lights to the right and green lights to the left. Two other lights will be visible during the docking maneuver. Four 0.7 watt white bulbs protected by a transparent dome will be shining at the tip of each of the two discone antennas.

**INTERNAL LIGHTS** Interior lighting of Skylab uses 78 fixed lights and five portable spares. General illumination light fixtures include 24 in the crew quarters, 18 in the OWS forward compartment and 8 in the MDA. In the crew quarters, the wardroom has four general illumination lights (numbered 1 through 4 in the illustration, Figures II-63 and II-64), the WMC has three (1-3), the sleep compartment three (1-3) and the experiments compartment 14 (1-14). In the forward compartment, 10 lights are on the upper wall (1-10) and eight on the dome (1-8). Four general illumination lights are in the forward end of the MDA and four in the aft section.

Handrail lights and tunnel light fixtures are used in the smaller spaces. Four handrail lights are in the forward part of the Airlock Module's Structural Transition Section (STS) and four in the aft section of the STS. Six handrail lights illuminate the instrument panel in the STS, and six of the lights are in the AM aft compartment. Four tunnel light fixtures are installed in the AM lock compartment. Of these interior lights, certain ones have been designated as emergency and initial entry lights. One general illumination light in each end of the MDA, two in the OWS dome, two on the OWS forward compartment upper wall and four in the OWS experiment compartment fall into this category, as do two handrail lights in the STS and one tunnel fixture in the AM lock compartment.

High intensity lights are used in conducting many of the experiments. Four of these lights are in the OWS forward compartment, one at the +Y-Z quadrant near the M509 experiment bottles, one at the -Z-Y quadrant for the T013, M151 and S149 experiments, one at the +Z-Y quadrant next to the M172 experiment, and one at the +Y+Z quadrant next to the M509 experiment.

The four high intensity lights in the OWS forward compartment are fixed. Two spare high intensity lights are stowed for use if needed. They can be plugged into any high power outlet. Three portable hand lights, stowed for use as needed, are powered by any available utility outlet.

## ATTITUDE AND POINTING CONTROL SYSTEM

The Saturn Workshop (SWS) Attitude and Pointing Control System (APCS) provides three-axis attitude stabilization and maneuvering capability of the orbiting vehicle. It also provides the capability of pointing experiments at desired locations such as the Sun, the Earth and other targets of interest. The APCS is comprised of the Instrument Unit/Thruster Attitude Control Subsystem (IU/TACS), Control Moment Gyros Subsystem/Thruster Attitude Control Subsystem (CMGS/TACS) and Experiment Pointing Control Subsystem (EPCS).

The IU/TACS provides control and maneuvering of the SWS from insertion to control transfer (switch-over) to the CMGS/TACS. Switchback to IU/TACS control capability is provided; however, the IU/TACS lifetime is limited to launch plus approximately 10.5 hours.

The CMGS/TACS provides control, maneuvering and offset pointing of the SWS and OA commencing with control transfer from IU/TACS. This subsystem utilizes three primary control modes (solar inertial, Z local vertical and experiment pointing) with the control forces provided by the CMGS augmented by TACS firing as required.

The EPCS provides highly accurate pointing and stabilization of the ATM experiment package along with limited offset pointing from Sun center in the pitch and yaw axes and roll axis positioning over a wide range. The EPCS is activated as required to meet experiment objectives.

The TACS APCS is activated at orbital insertion (S-II cutoff). The OWS thrusters accept commands from the IU Launch Vehicle Digital Computer (LVDC) after orbit insertion to maneuver the SWS for Payload Shroud jettison and then to the solar inertial (SI) attitude. The SI attitude points the vehicle -Z axis to the center of the solar disk and places the X-principal axis near the orbit plane. CMG spinup is initiated and vehicle control is switched to the CMG control subsystem (TACS augmented). Shortly thereafter, the complete CMG control program is enabled, including automatic management of the Skylab momentum.

The APCS can be commanded by manual inputs from the astronauts using the ATM C & D Console in the MDA or from the ground via the vehicle Digital Command System. System redundancy is provided by using component backup units or by operating the system in an alternate configuration, e.g., although three CMGs are used in maintaining vehicle control, two can provide this function if one fails. The APCS can receive commands and control input data from ground operations through the Command System. The Telemetry System is used to transmit APCS information to the ground for operational support and evaluation.

Six control modes are addressable by C & D Console switches and also by the DAS and DCS system for APCS operation. Two of the six modes, Solar Inertial (SI) and Z Local Vertial (Z-LV), are the attitudes used most of the time during the mission. All vehicle attitudes other than SI or Z-LV are attained by maneuvering or offsetting from SI or Z-LV. The attitude used most of the time for Skylab is SI.

The six modes are:

**Solar Inertial Mode** - During orbit daytime, this mode is used for maintaining the vehicle's minimum moment of inertia axis (X-principal axis) near the orbital plane and the Z-axis parallel to the sunline. During orbit "nighttime," it is used to perform gravity gradient momentum dump maneuvers for desaturating the CMGs.

**Z-Local Vertical (Z-LV) Mode** - This mode is entered during the rendezvous phases of the mission or when Earth pointing experimentation periods are required.

**Experiment Pointing Mode** - This mode is identical to the SI mode except that the EPCS is automatically activated each orbital sunrise and deactivated each orbital sunset.

**Attitude Hold (CMG) Mode** - In this mode, the vehicle can be maneuvered to any inertial-oriented attitude and held using the CMGs only.

**Attitude Hold (TACS) Mode** - This mode is used to maneuver the vehicle to any inertial-oriented attitude and held using the TACS only.

**Standby Mode** - Used when vehicle control is not required of the APCS, e.g., during CSM control of the OA.

The pointing accuracy and stability requirements are as follows:

| CMG SYSTEM | ACCURACY | STABILITY |
|---|---|---|
| Solar Inertial X, Y | ±6 arc-min | ±9 arc-min/15 min |
| Z | ±10 arc-min | ±7.5 arc-min/15 min |
| Z-LV (EREP) X, Y, Z | ±2° | |
| Z- LV (rendezvous) X, Z | ±6° | |
| Y | ±12° | |
| EPC SYSTEM | | |
| X, Y | ±2.5 arc-sec | ±2.5 arc-sec/15 min |
| Z | ±10 arc-min | ±7.5 arc-min/15 min |

**THRUSTER ATTITUDE CONTROL SUBSYSTEM** The IU/TACS provides for attitude control of the Skylab about all axes following separation from the boost vehicle. Upon activation of the CMGS, the TACS augments the CMG Control Subsystem. When both the CMGS and TACS are enabled, TACS is used when the vehicle's total system momentum exceeds a defined limit. The vehicle is controlled by TACS only when redundancy management disables CMGS control, CMG control is inhibited via DAS/DCS, or the Attitude Hold (TACS) Mode is selected when the attitude error exceeds 20° during CMG operations.

**CONTROL MOMENT GYRO SUBSYSTEM (CMGS)** Vehicle attitude information is derived from strapdown reference computations in the ATM Digital Computer (ATMDC) utilizing Rate Gyro information. The Acquisition Sun Sensors provide data for updating of vehicle attitude information for the X and Y control axes. Switching from the orbital daytime to the orbital nighttime configuration and vice versa is performed automatically upon command from the ATMDC. Orbit nighttime commences either at sunset or at the start of momentum desaturation maneuvers, whichever begins first.

The minimum period of the commanded nighttime configuration is 35% of the orbit. Orbit daytime commences either at sunrise or at the end of the momentum maneuvers, whichever ends later. The ATMDC processes the sensor signals with the CMG control law to generate the CMG gimbal rate command (control forces). The astronaut has the capability of manually controlling the CMGs by means of the Digital Address System (DAS) keyboard on the ATM C & D Console.

Three double gimbaled CMGs hardmounted at 90° angles to each other on the ATM provide the control forces. A CMG is basically a large spinning wheel that provides the forces required for vehicle control by changing the orientation of the wheel's spin axis. The momentum is monitored and managed by the ATMDC. The CMGs also have the ability to store a certain amount of force or momentum. When they have absorbed the maximum amount they are saturated and the accumulated momentum must be reduced to desaturate the CMGs. The momentum stored in the CMGs is reduced by special maneuvers which reorient the CMG wheel spin axes. These are performed automatically during orbit nighttime.

**EXPERIMENT POINTING CONTROL SUBSYSTEM (EPCS)** The EPCS is used to maintain pointing and stabilization of the ATM experiments package. The package is provided with an independent control system to isolate it from perturbations due to disturbances on the vehicle.

The EPCS provides automatic control of the experiment package X and Y axes. Manual positioning of the two axes and offset pointing of the experiment package are provided by the Manual Pointing Controller in conjunction with the Fine Sun Sensor (FSS). The FSS is used for sensing ATM experiment package pointing errors, with rate gyro sensing rates. The Experiment Pointing Electronics Assembly (EPEA) conditions the sensor signals to provide command signals to the actuators.

The experiment package can be offset pointed using the FSS in the X and Y axes over a range of ±24 arc-minutes, with the center of the solar disk being the zero position. The actuators allow approximately ±2° of experiment package rotation about the X and Y axes. The Roll Positioning Mechanism (RPM) provides ±120° rotation about the Z axis. The solar north pole is the experiment package zero roll reference position.

The RPM is commanded by the astronaut via rate switches on the ATM C & D Console. Once the experiment package is positioned, the RPM will hold the location until a repositioning command is received. The astronaut uses the ATM EVA Rotation Control Panel during EVA to reposition the canister for experiment retrieval.

**CONTROL MOMENT GYRO (CMG) ASSEMBLY** The ATM CMG consists of an induction-motor-drive constant-speed wheel, gimbal supported to provide 2° of freedom. Associated with each CMG is an Electronics Assembly (CMGEA) for positioning the gimbals and controlling the gimbal rates, and an Inverter Assembly (CMGIA) for providing power.

The actuator pivot contains a DC torque motor, gear train, output shaft and rate-feedback tachometer. The sensor pivot assembly contains a ball-bearing mounted pivot shaft, a resolver assembly and a flex lead assembly. The resolver assembly provides gimbal position information for gimbal caging, control law computations and momentum management.

Each CMG has an angular momentum storage capability of 2300 foot-pound-seconds. The rotor is driven by two identical double squirrel cage, 3-phase induction motors. A single motor is capable of maintaining rotor operating speed. The CMGs are sized so that vehicle attitude control can be maintained with any two CMGs with minimal use of TACS.

**STAR TRACKER** The ATM Star Tracker function is to provide star position inputs to the ATMDC for calculating the roll reference angle and the orbital plane error. The roll reference angle provides an experiment pointing reference with respect to the solar disk for roll positioning, telemetry and experiment file recording.

The Star Tracker consists of an Optical-Mechanical (OM) Assembly and a Star Tracker Electronics (STE) Assembly.

**FINE SUN SENSOR** The Fine Sun Sensor (FSS) provides the highly accurate attitude information for the X and Y axes of the EPCS. The FSS is comprised of four separate components: an OM Assembly, Preamplifier Electronics Assembly, Control Electronics Assembly and the FSS Signal Conditioner.

The two primary and two redundant Sun sensor channels of the FSS are housed in the OM Assembly. Similarly, redundant electronics are housed in the other three components. If a malfunction occurs in the primary system, the complete redundant system is switched in. An offset pointing capability for each axis is also provided.

**ACQUISITION SUN SENSOR** The Acquisition Sun Sensor (consisting of an optical and electronics assembly) provides attitude information for the X and Y control axes of the vehicle. These data are used to update the strapdown computation in the ATM Digital Computer during orbital daytime. Both Acquisition Sun Sensors are active in the vehicle control loop under normal operating conditions but either unit may be selected.

The system provides electrical analog signals proportional to the solar pointing error of the SWS and a Sun presence signal to indicate when the Sun is in the field-of-view of the error sensors.

**RATE GYRO PROCESSOR** The gyro is a floated rate integrating type gyro. Each component contains a gyroscope and associated electronics. Nine rate gyro processors are used in the CMGS/TACS and two per axis in the EPCS.

**EXPERIMENT PACKAGE CAGING AND GIMBAL ASSEMBLY** The ATM experiments are hardmounted and attached to a 3° of freedom caging and gimbal assembly. The EPCS maintains attitude control of the experiment package. The experiment package is provided with a separate control system to isolate it from vehicle disturbances and provide fine pointing.

This electromechanical system, comprised essentially of two large concentric rings, provides the torquing capability for the fine pointing servo system in pitch and yaw. Roll control is provided in an open loop fashion. The astronaut can rotate the experiment package to align optical axes of the experiment as required for data taking or during EVA for film retrieval. A caging system constrains both rings when the experiments are inactive. The launch locks are removed with pyrotechnics once orbit is achieved.

**MANUAL POINTING CONTROLLER** The Manual Pointing Controller (MPC) is used by the astronaut to either offset point the ATM instrument package or to manually search for a desired star.

The MPC control handle can be tilted from a center null position to a left/right position for yaw, to an up/down position for pitch, or a combination of both positions. The MPC consists of a spring loaded two-axis gimbal control handle and mechanism, two linear transducers and a housing with connectors for the input/output wiring.

**EXPERIMENT POINTING ELECTRONICS ASSEMBLY (EPEA)** The EPEA contains the electronic circuits for amplifying, shaping and mixing the outputs of the ATM Experiment package sensors to obtain error signals for driving the Experiment Pointing Control Subsystem (EPCS) actuators (DC torque motors). Interface circuitry between the MPC, the FSS and the Star Tracker is also included in the EPEA.

Caging of the EPCS is done with orbital locks for the pitch and yaw axes and by a brake mechanism for the roll axis.

**ATM DIGITAL COMPUTER/WORKSHOP COMPUTER INTERFACE UNIT** The ATMDC/WCIU subsystem provides high speed general purpose computing capabilities along with a multipurpose, flexible input/output capability. It accepts from several sources analog and discrete signals which are used to perform calculations under the direction of a stored program. It also provides analog and discrete outputs to several devices. The subsystem consists of two identical ATMDC units and a single WCIU unit.

The computer accepts signals from the vehicle and the ATM experiment package sensors, commands from the ATM C & D Console, including the DAS, and the DCS. The computer sends commands to the system actuators and information to the ATM C & D Console and to the telemetry system.

**MEMORY LOAD UNIT (MLU)** Two ATMDCs are included in the ATM APCS. During the ATM mission, only one ATMDC is powered up and operating at any one time. If the operational ATMDC fails, switchover (automatic or commanded) will occur. The Memory Load Unit makes it possible to load ATMDC flight programs in flight from the onboard tape recorder or from the ground via the ATM RF command uplink.

**THRUSTER ATTITUDE CONTROL SUBSYSTEM (TACS)** The OWS mounted TACS consists primarily of: cold gas propellant (nitrogen) utilized in a blowdown system (capacity of 61,000 pound-sec minimum); twenty-two propellant storage spheres on the thrust structure of the OWS; two thruster modules of three thrusters each on the aft skirt of the OWS at position planes I and III; quad-redundant valves for each thruster; Power and Control Switching Assemblies (PCSA).

The nitrogen is stored at 3100 ±100 psia at 100° F in the 4.5 cubic foot titanium spheres and plumbed to a common manifold connected to the two thruster modules. Propellant is supplied to each of the six thrusters through quad-redundant (series-parallel) control solenoid valve. The location of the thrusters was chosen to satisfy vehicle control and thermal requirements. A passive thermal control system is used, consisting primarily of insulation over the propellant supply lines.

The Power and Control Switching Assemblies receive command signals from either the Saturn V Instrument Unit (IU) Launch Vehicle Digital Computer (LVDC) via the IU Flight Control Computer (FCC) or the ATM Digital Computer (ATMDC).

## COMMUNICATIONS

The Skylab communications system provides a transfer of voice and instrumentation data between the SWS and the Spaceflight Tracking and Data Network (STDN) during all phases of the mission, in addition to providing an intravehicular communication network between crewmen in the Skylab.

The CSM system is basically identical to that of Apollo with slight modifications, primarily in the audio/intercom, antenna and video downlink areas. There will be no high-gain antenna on the CSM, and the omni antenna will all be selectable via ground command. The ground will be able to select video downlinking using the CSM frequency modulation transmitter.

The AM communication system consists primarily of modified Gemini equipment. The audio/intercom system will use any three of four VHF transmitters for downlinking real-time data, delayed-time recorded data or recorded voice.

The AM has three tape recorders (replaceable in flight) for recording systems, experiment and voice data. Command capability to the AM will be through redundant UHF receiver decoders.

Modified Saturn hardware is being utilized in the ATM communication system. This data system has two VHF transmitters for downlinking real-time and delayed-time data. It has two non-replaceable recorders and related interface equipment to provide for the recording systems and experiments data.

During the manned phases of the mission, the communication system provides the following: voice communication between crewmen in the Skylab and the spacecraft communicator in the MCC; indications of a caution and warning alert; range information between the CSM and SWS; hard-copy printed messages from MCC to the crew; and transmission of television data to STDN.

Operation of the communication system is divided into six subsystems: audio, television, teleprinting, ranging, caution and warning, and photography.

**Audio** The SWS will use the CSM S-band equipment as an integral part of the audio/intercom system. The system has two channels - one to be used for downlinking real-time voice or as an intercom (I/C) channel, the other being used for recording experiment voice data.

All real-time and SWS intercom voice will require the use of the CSM S-band system with the CSM VHF equipment serving as a backup. Voice recording will normally be accomplished by using one of the voice channels and the AM recorders.

Voice may also be recorded on the CSM data storage equipment (DSE) and downlinked via the CSM S-band system during later passes. The crewmen, when required, may voice record through any of the 13 speaker intercom assemblies (SIAs) throughout the SWS.

In addition to the 13 SIAs, the audio subsystem consists of EVA panels, one IVA panel, two load compensators (ALC), three CSM audio centers (A/C) and a CSM speaker box.

The SIAs provide the voice communication capability for crewmen in an unsuited mode throughout the SWS. This is accomplished via a speaker and microphone or through a headset and Crewman Communications Umbilical (CCU). The intercom system also provides audio tones and visual displays for Caution and Warning.

The two EVA panels and the IVA panel provide the voice communication capability when crewmen are wearing their pressure suits.

The audio load compensators provide automatic compensation for varying audio loads by supplying regulated audio signal levels.

The CSM audio center consists of headsets and communication umbilicals and provides the voice capability when crewmen are unsuited within the CSM. The CSM speaker links a crewman in the CSM with those in the SWS via the internal communication system.

The rescue voice mode does not utilize the CSM equipment but is to be used in the case of a CSM failure. When operating in this mode, audio communication from the vehicle is one-way only via the AM VHF transmitter. STDN must utilize the AM teleprinter for uplink messages. The basic system is designed with redundant components and buses to minimize loss of audio communication.

**Television** The Skylab TV Subsystem provides television coverage to Earth of internal and external Skylab scenes during manned and unmanned mission periods. A TV signal from one of five ATM black and white TV cameras or from a portable color TV camera can be selected by the crew for radio transmission to a ground station using the FM transmitter in the docked CSM. When out of contact with STDN, a selected TV signal can be recorded on the Video Tape Recorder (VTR) for subsequent playback during ground station contact. During recorded playback to the ground, real time TV signals can not be transmitted.

The ATM TV cameras are fixed-mounted and are an integral part of the experiment. The cameras provide real time monitoring of the experiment operations. Sync signals are inserted into the video signal by redundant sync generator and switcher processor elements to provide commercial standard TV signals on two channels, ATM-1 and ATM-2. However, the aspect ratio is 1:1, instead of the standard 4:3.

The portable color TV camera will be used to cover scenes of experiment performance and crew operation and habitation activities, both within and outside of Skylab. This camera, which weighs about 12 pounds and measures 11 by 6 by 4 inches, is similar to that used on Apollo missions. The camera controls include focus, iris, zoom and light sensitivity. The camera is used with a small TV monitor to assist the crewman in scene composition and focusing. The camera is connected to the TV subsystem with a 30 foot cable at any one of five Television Input Stations (TVIS). The camera operates on 28 volts power from the TVIS and provides a field sequential color TV signal. This is converted to commercial broadcast format on the ground. The camera may be hand-held by a crewman or fixed-mounted on a universal mount. External viewing is accomplished by connecting the camera at the TVIS in the Airlock for EVA, by mounting on the experiment S191 Viewfinder Tracking System, or by deployment through the Scientific Airlock (SAL) on the T027 Experiment Universal Extension Mount. In this latter mode, the camera focus, iris, zoom and orientation are controlled remotely by crewmen from within the OWS.

Three TVISs are in the OWS, one in the AM and one in the MDA. These stations accept the portable TV camera signal and condition it to modulate the CSM transmitter or be recorded by the VTR. The TVIS gain adjustments are individually set prior to launch.

The Video Selector Switch (VSS) is in the MDA. It permits manual selection of the portable color camera or ATM-1 or ATM-2 TV signals to be transmitted or recorded. The VSS contains electronics to condition ATM-1 and ATM-2 channels to modulate the CSM transmitter.

The VTR in the MDA can be controlled manually or by ground command except for the playback function which can only be initiated from a ground station. The VTR can record up to 30 minutes of TV signals from any source as selected at the VSS. The playback rate is the same as the recording rate. During recording, the VTR can accept voice signals from the Audio Subsystem and multiplex this voice signal with the TV signal being recorded. The voice signal is later recovered after recorder playback by demultiplexing at the ground station.

The docked CSM accepts the conditioned TV signal, either real time or recorded, and routes it to the S-band FM transmitter. The signal is broadcast while in ground station contact using the one of four CSM omni antennas that provides optimum coverage for that pass.

A spare portable color camera, TVIS, VSS and VTR are provided.

Real time coverage of television will be provided by STDN stations at Goldstone, Corpus Christi and Merritt Island. The TV signal will be recorded and routed at the end of the day to MSC over NASCOM. For special events, real-time video will be made available to MCC. Other STDN stations around the Earth will record the signals received routinely and mail the tapes to MSC.

**Teleprinting** Teleprinter messages to the Skylab crew will provide updates in detailed flight planning, experiment schedule activity and general mission information. Messages will originate at MCC, and remote sites will pass these messages up during site passes. Daily uplink time will be about 9 minutes; however, when EREP passes are scheduled, this may be lengthened to 12 minutes.

Teleprinter messages are limited to 30 characters per line. Messages with 50 lines or less can be uplinked as one load; those of greater length will require an appropriate number of loads to accommodate the message length (50 lines per load).

The uplinked messages will be received in the teleprinter printout in the SWS. Some 156 rolls of spare paper are aboard the SWS.

**Ranging** Tracking adequacy is important to SL-2 launch and rendezvous support. For the SL-2 launch, there are only eight passes over sites which have C-band skin tracking capability (CRO and MIL). Six of these passes have elevation angles less than 10°. Therefore, the CSM command and communications (CCS) USB beacon will be powered to include the entire rendezvous sequence. The SWS ranging subsystem, which utilizes the CSM ranging subsystem with the SWS ranging antenna, VHF transceiver and a range tone transfer assembly, facilitates rendezvous of the CSM with the SWS. The CSM sends a range tone to the SWS. The SWS receives the tone and, through its range tone transfer assembly (RTTA), returns a signal to the CSM. The CSM ranging subsystem uses this to compute and display range and range rate.

The C-band support for SL-3 and SL-4 launch targeting and rendezvous is thought to be adequate since there is a long period of undisturbed coasting flight during which accurate tracking can be established on the SWS.

**Caution and Warning** The Caution and Warning (C & W) System will monitor the performance of itself (voltage only) and systems and alert the crew to hazards or out-of-limit conditions which constitute or could result in jeopardizing the crew, compromising primary mission objectives, or if not responded to in time could result in loss of a system. Parameters monitored by the C & W System are categorized as either **EMERGENCY**, **WARNING**, or **CAUTION**. Criticality and/or crew response will be used to determine the category. The categories are defined as follows:

**EMERGENCY** - Any condition which can result in crew injury or threat to life and which 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. Immediate action by the crew is required.

**CAUTION** - Any out-of-limit condition or malfunction of a Skylab system that affects primary mission objectives or could result in loss of a system if not responded to in time. Crew action is required although not immediately.

The number of monitored parameters must be consistent with effective monitoring. When any of the monitored parameters reach the predetermined out-of-tolerance level, appropriate visual and acoustical signals will be activated.

**OA C & W System** - The OA Caution and Warning System consists of C & W Systems installed in both the Saturn Workshop (SWS) and the Command and Service Module (CSM). Each system provides the crew with visual displays and audio tones when selected parameters reach out-of-tolerance conditions. In the docked configuration, the two C & W Systems interface by means of discrete contact closures to provide for cluster-wide monitoring of selected parameters.

**SWS C & W System** - The SWS Caution and Warning System monitors the performance of specified vehicle systems and alerts the crew to hazards or out-of-limit conditions. The SWS C & W System utilizes two independent subsystems, a Caution and Warning Subsystem for monitoring various system parameters and an Emergency Subsystem for detecting fire or rapid loss of pressure.

Fifteen separate panels are provided in the SWS for control, display, operation and testing of the Caution & Warning and Emergency Subsystems. Three of these panels are used for control and display of both subsystems; the remaining twelve are used primarily for control of the fire detection portion of the Emergency Subsystem.

**Control and Display Panel 206** - The major power and control switches for the SWS C & W System are on Panel 206. The panel is in the STS. The master alarm telelight switch, which is colored aviation red, is illuminated when either a caution, warning or emergency parameter is activated. The memory recall telelight switch has an amber lens and is used to indicate that parameter(s) which activated the C & W Subsystem have been stored in memory. Three power switches are provided for powering the SWS C & W System. One is used to control power to the C & W Subsystem and the other two are used for the Emergency Subsystem. Four test switches are provided for testing the C & W Subsystem electronics, audio tone and visual displays. Three volume controls are also provided for controlling the intensity of the emergency, warning, and caution tones.

**Display and Inhibit Switch Panel 207** - The parameter identification lights and inhibit switches are on Panel 207 which is in the STS. Forty parameter identification lights are used to help the crew identify which parameter or system has gone out-of-tolerance. Each display has two bulbs for redundancy with each bulb being driven by separate power sources. Each parameter monitored by the C & W System has a corresponding inhibit switch on Panel 207. The inhibit switches are used to disable a malfunctioning circuit or input signal without disabling other active parameter inputs.

**OWS Repeater Panel 616** - Panel 616 is in the Experiment Compartment of the OWS. The panel contains one master alarm reset telelight switch which contains two bulbs.

Ten parameter identification lights are used in helping the crew identify various parameters or systemsthat have gone out-of-tolerance. Each display contains two bulbs for redundancy; each drawing current from separate power sources.

**Fire Sensor Control Panels** - The Fire Sensor Control Panels provide the controls for operation and test of the Fire Sensor Assemblies. Each panel has the capability of controlling two sensors. Two power switches are provided, one for each sensor, which allow manual selection of one of two normally energized buses capable of supplying power to the respective sensor. A master alarm reset/test switch is provided for testing the sensor(s) and resetting the SWS C & W System. The bulbs and lenses on the panels and the panels themselves can be replaced in flight. Two panels (complete with lenses and bulbs) and eight lens and bulb assemblies, are stowed in the OWS for inflight replacement.

**C & W Subsystem Operation** - The OA C & W Subsystem encompasses the SWS C & W Subsystem and the CSM C & W Subsystem. The CSM C & W Subsystem monitors preselected caution and warning parameters in the CM and SM. An out-of-tolerance condition produces an audio tone and the illumination of visual displays in the CM. The SWS C & W Subsystem monitors preselected parameters in the ATM, AM and OWS and, through the CSM C & W Subsystem, monitors the performance of critical systems in the CSM. An out-of-tolerance condition in the SWS or CSM will produce a tone in the MDA, the AM and the OWS and illumination of display lights on the SWS C & W control and display panels and the SIAs.

**Emergency Subsystem Operation** - The Emergency Subsystem monitors fire and rapid spacecraft pressure loss conditions. An out-of-tolerance condition produces audio tones and visual displays. Also, signals are telemetered to the ground indicating the type of emergency situation. Fire sensors are located throughout the SWS to detect fires. Two rapid change of pressure sensors are in the Structural Transition Section (STS) of the Airlock Module.

**16 mm Data Acquisition Camera (DAC)** - This camera is used to obtain sequential photographic data. Unlike typical movie cameras, this camera has independent shutter speeds and framing rates. The DAC can be hand-held or bracket-mounted, can operate from spacecraft or portable battery power, and can accept various lenses and assorted accessories.

The camera's manufacturer is J.A. Maurer, Inc. It weighs 1.7 pounds and measures 6 x 3.75 x 2.4 inches. Its volume is 54 cubic inches. Power requirements: 28 ±4 VDC at 0.6 amps nominal from spacecraft or DAC Power Pack. DAC incorporates self-resetting overload protection circuit and replaceable power line fuse. The sequencing frame rate is settable to 1 (or 2), 6, 12, or 24 frames per second (fps) and time exposure.

Automatic modes [1 (or 2), 6, and 12 fps] are initiated by depressing and releasing camera front button and continue uninterrupted even if sequencing rate is changed among automatic modes. Camera operation is stopped by depressing and releasing front button or by switching to the time exposure or 24 fps mode settings. Green operate light will flash at frame rate.

Additional DAC accessories are 140 foot film magazines, six types of lenses (5 mm, 10 mm, 18 mm, 25 mm, and 75 mm), right angle mirror, fuse assembly, power cables, film cassette (400 foot) and transport mechanism.

**35 mm Nikon Camera** - Two motorized 35 mm Nikon cameras, modification of commercial Nikon equipment, are supplied for the S063 and T025 Experiments. The camera body incorporates reflex viewing and through-the-lens coupled light metering along with motorized film advancement. For the experiment operations, a visible lens and an ultraviolet lens are used.

The camera weighs 3.66 pounds without film or lens and measures 6.55 x 6.16 x 2.8 inches. Its volume is 112.9 cubic inches. The included focal plane shutter has the following settings: T (time), 1, ½, ¼, 1/8, 1/15, 1/30, 1/60, 1/125, 1/250, 1/500, and 1/1000 second. A standard connector for X-synchronization with the shutter at 1/60 sec or lower shutter speeds is provided. The camera accepts lenses with the commercial Nikon mounting. The 55 mm, f/1.2 visible lens and the 55 mm, f/2 UV lens are intended for use on this camera body. The visible camera viewfinder shows the full through-the-lens coverage, shutter speed setting, and the light meter needle and matching indicator. The viewfinder can be removed easily to permit waist-level camera operation or replacement.

Nikon camera accessories include two 55 mm lenses (UV and visible), film cassette assemblies and battery assembly.

**Hasselblad Data Camera** - The Hasselblad Data Camera (HDC) is a rugged version of the commercial electric Hasselblad camera, 500 EL, and is used for medium resolution, photogrammetric photography. This camera incorporates a glass reseau plate positioned immediately in front of the film plane. The reseau plate places a pattern of precision crosses on each photograph to facilitate photogrammetric utilization of the photography.

The camera weighs 3.1 pounds (with batteries) and measures 5.75 x 3.86 x 4.77 inches. Its volume is 106 cubic inches. The HDC has a 4 mm thick glass plate rigidly mounted in the rear opening of the camera. An array of 25 reseau crosses is engraved on the rear surface of the plate to facilitate precision geometrical calibration of the film and of the camera and lens optics. The glass plate also incorporates a fine rim on each vertical edge to provide minimum but positive contact with the film.

The following HDC accessories are stowed aboard the OWS: 70 mm film magazines, 80 mm lens, nickel cadmium cell batteries and a ring sight.

**Earth Terrain Camera** - The Earth Terrain Camera (ETC) is the major system component and includes an outer lens cone/mount assembly, the lens cone itself comprising the lens and the camera electronics, a control box and the camera body which houses the ETC magazine.

The ETC is designed to obtain high resolution photographs of the Earth during the performance of Skylab Experiment S190B (EREP). The functional capabilities of the ETC permit automatic operation for overlapping topographic coverage and manual operation for single photographs of selected scenes.

The ETC is manufactured by Actron Industries, Inc. of Monrovia, California. It weighs 77 pounds with ETC magazine, without film - launch configuration; or 82.5 pounds with film. The ETC measures 28.31 x 11.25 x 13.45 inches, and its volume is 4280 cubic inches. The ETC's electrical power requirements are supplied through a cable from the spacecraft. AC Power - 115 Vac, 400 Hz, 3 phase is for all camera drive motors - shutter, film transport, and forward motion compensation (FMC). DC Power - +28 (+2, -4) is for camera control circuits and relay operation. The camera power ON/OFF switch is located on the camera control box. The film format is 4.5 x 4.5 inches with the use of a 0.75 x 0.75 inch area at one format corner for data recording. The lens type is color corrected, f/4, 18 inch focal length. Field-of-view is 14.2° x 14.2°; 20° diagonal; for 235 nautical miles; altitude - 58.7 x 58.7 nautical miles.

The ETC camera system also includes film magazines and film canisters.

The Scientific Airlock Assembly provides the interface between the Skylab OWS anti-solar Scientific Airlock (SAL) and the ETC. The assembly incorporates a precision optical window that is matched to the ETC lens optics and maintains the pressure integrity of the SAL.

The assembly is manufactured by Actron Industries and weighs 12.1 pounds, measuring 11.65 x 12.32 x 3 inches. Its volume is 430 cubic inches. The front (square) side of the Window Assembly installs in the interface flange of the -Z (anti-solar) SAL. The back (round) side of the Window Assembly attaches to the ETC outer lens cone/mount assembly by means of a toggle latch ring (Marman) clamp incorporated on the Window Assembly. Protective metal covers are attached to the front and the back interface surfaces of the Window Assembly during handling and stowage. The front cover is secured with two self-contained spring latches. The back cover is secured with the Marman clamp of the Window Assembly.

Other crew equipment items include: spotmeter (and batteries), chronograph watches, two speed mechanical timers, ball point pens, mechanical pencils, marker pens, and general and all purpose adhesive tape.

## CREW EQUIPMENT

**WEARING APPAREL** Skylab crews inside the OWS will wear gold colored shirts fabricated from fire resistant PBI (polybenzimidazoic) fabric and trousers and jackets made of fire resistant woven Durette fabric. Enough of these items, including socks and underwear, are provided so that crewmen can change clothing regularly - trousers once a week and socks, shirts and underwear every two days.

The clothing for the three manned flights is in 15 Clothing Modules, each holding enough clothes to supply a crewman for 28 days. Each crewman on SL-2 will have a 28-day Clothing Module; while crew members on the 56-day missions SL-3 and SL-4 will each have two 28-day modules. Also, two contingency Clothing Modules are stowed in the OWS prior to launch. The contingency modules contain clothing sized for backup crew members.

More than 700 clothing items will be stowed in the OWS prior to launch. Among these items are: 3 jackets, 53 trousers, 58 shirts, 15 boots, 15 pairs of gloves, 4 union suits, 199 T-shirts, 47 half union suits, 34 jockey shorts, 102 boxer shorts, 16 knee shorts, 128 pairs of socks and 7 constant wear garments.

The 28-day Clothing Module is a fabric rucksack made of 14 mil Armalon fabric, sized such that when filled with clothes it will fit in the standard OWS stowage locker, 16 x 11.4 x 9.8 inches. It is sectioned into seven main areas for each of identification (through labeling) and access to each specific clothing item.

The Skylab **jacket** is a contoured, custom fit, waist-length jacket made of fire resistant woven Durette fabric. Three snaps on the waistband attach to the trousers. The jacket has a front, full-length zipper. The American Flag emblem is on the upper left arm, the NASA emblem on the upper right front section and the crew emblem and name tag on the upper left front section.

The **trousers** are custom fit, waist-to-ankle, and made of fire resistant woven Durette fabric. The legs are removable above the knee by zippers for easy conversion to shorts. The trousers have an adjustable waistband for stability and sizing comfort, and a concealed, zippered front closure.

The Skylab **shirt** is a short-sleeve pullover of fire resistant knitted PBI fabric. It incorporates a raglan sleeve design and a mock turtleneck collar. The shirttail is a straight cut side-slit design long enough to be kept in the trousers. A utility pocket with zipper is in the upper left front section.

Shirts are provided in various sizes ranging from extra small to large.

The Skylab **boot** is ankle high fabricated and comfort-lined with woven fire resistant Durette fabric. The inside sole comfort lining is made from simplex knitted Durette fabric. The boot is lightweight and designed to completely cover the foot and ankle without discomfort from tightness or material bunching and with minimum degradation to mobility.

A pair of wrist-length **gloves** made of deerskin and fire resistant simplex knitted Durette fabric are provided for each crewman. The glove is five-fingered, unlined and lightweight. The palm and front of the gauntlet, thumb and fingers are seamless deerskin, and the remaining portions are Durette fabric.

Four different types of **underwear** sets are in the 28-day Clothing Modules.

Set 1 is Full Union Suit with integrated socks and without an opening in the seat. It is a white 100% cotton "off-the-shelf" item.

Set 2 is a Half Union Suit ending at the waist. It has integrated socks and no opening in the seat. The other half is a standard pull-over T-shirt. Both are white 100% cotton "off-the-shelf" items.

Set 3 is T-shirts, shorts and socks. The short styles include jockey, knee and boxer. The T-shirts and shorts are white cotton. The socks are white cotton with reinforced heels and stretch tops, with one size to fit sizes 10 through 13.

Set 4 is a white cotton Apollo Constant Wear Garment (CWS).

Any combination of clothing articles contained in the 28-day Clothing Module may be packed in the contingency module as long as specified weight and volume requirements are not exceeded. The clothing sizes of the backup crewmen will be compared to the clothing sizes of the prime crewmen. If a backup crewman cannot wear a particular article of the prime crewman's clothes, this article, in the backup crewman's size, will be packed into one of the contingency modules.

If the backup crewman can wear all of the prime crewman's clothes, the backup crewman may choose extra clothing subject to the same weight and volume limitations. The two contingency modules will contain all the contingency clothes for the SL-3 - SL-4 backup crew.

Construction of the contingency clothing module is identical to the 28-day rucksack, except that no valet kit is provided and there are only three compartments. It may contain any combination of the following types of items: jackets, shirts, trousers, underwear, boots or gloves.

The 28-day clothing modules are stowed in OWS wardroom lockers W718 through W722, and W730 through W734. Used clothing is placed in the waste tank after use. The two contingency clothing modules are stowed in OWS wardroom lockers W723 and W729.

**A7LB SUIT** Skylab crew members will use the Extravehicular Mobility Unit (EMU) for all operations which require pressure suits. The primary components of the EMU are the Apollo A7LB pressure garment assembly (PGA), the Liquid Cooling Garment (LCG), the pressure helmet, the Skylab Extravehicular Visor Assembly (SEVA), EVA gloves and the Astronaut Life Support Assembly (ALSA). Each crewman wears his A7LB suit in the CM at launch.

The PGA provides an oxygen environment for the crewman not only for breathing but also for spacesuit ventilation and pressurization. It is supplied with electrical provisions for bioinstrumentation and communications. After each use, the PGAs are placed in the suit drying station before they are again used.

The LCG, which is worn under the PGA, is made up of a network of water-carrying tubes that provide body cooling. Cold water is routed through the tubing, circulated about the crewman's body and returned to the SWS for heat rejection.

The helmet is a transparent, detachable enclosure and is supplied oxygen from the PGA to pressurize and ventilate with a provision to diffuse the oxygen about the crewman's head.

The SEVA attached to the helmet provides micrometeoroid and thermal protection while filtering out the harmful light rays of the sun.

EVA gloves are worn during EVA to provide additional thermal and micrometeoroid protection of the hand and forearm area. Three pairs of gloves are launched in each CM and each pair is stowed during flight in the SEVA stowage bag near the suit donning station.

The ALSA receives water, oxygen and electrical provisions through its Life Support Umbilical (LSU) and regulates and/or distributes them to the spacesuit by a Pressure Control Unit (PCU). An additional oxygen supply is furnished through a Secondary Oxygen Pack (SOP).

The LSU is 60 feet long and is marked at 5-foot intervals to aid in visually tracking the deployed length as the crewman exits the AM. The LSU is connected to a panel which provides the required water, electrical power and oxygen.

The only other activity requiring a pressurized suit besides EVA is a portion of the M509 astronaut maneuvering unit performance. With the exception of launch, undocking and separation the crewmen will be in a "shirt sleeve" mode throughout the mission.

Following rendezvous and docking, the pressure suits will be dried at the drying station in the OWS and then stowed in the CM. The crew will retrieve the suits for EVA. After EVA, the suits will again be dried and returned to stowage in the CM.

Facilities are furnished within the OWS to service the various components of the life support system as well as dry the pressure suits between uses. In addition, stations are designated in the OWS for suit donning and doffing.

The crew members don and doff their suits using the portable foot restraints in the forward compartment near the suit drying station. The drying station suit dryer on the ring section is used to blow air into the PGA to remove the accumulation of water after each use.

**OFF DUTY ACTIVITIES EQUIPMENT** The flight plan provides daily recreation time and regularly scheduled "off duty" days in addition to more than ten hours per day of work activities per crewman. On SL-2 the crew has three days off, the SL-3 crew has seven days and the SL-4 crew is scheduled to have eight days off duty.

The crew has an Off-Duty Activities Equipment module outfitted with exercise gear, reading material, taped music and games. Each crew member had a hand in selecting the type of music and books and in testing the items before flight.

The Off Duty Activities Equipment (ODAE) locker is in a corner wall of the wardroom. The interior of the locker is divided into three stowage areas.

In addition, three tape players are stowed separately, one in each of the sleep compartments in lockers S909, S921 and S931.

The door of the ODAE locker is a rigid hinge-mounted unit to which is affixed the tape player and speakers and shelves holding 60 tapes, four decks of playing cards and 16 ear pieces for use in four stereo headsets. The tape player and speakers are commercial grade and the taped music may be played through the speakers or through the headsets, which may be plugged into special jacks on the locker door.

Power for the player is provided by the OWS power outlet or by dry cell batteries, 112 of which are in the locker door unit.

The four decks of cards are made of fire resistant paper, and the 16 headset ear pieces are foam pyrel. Special flexible magnetized straps and retainers are included to prevent the cards from floating in zero-g.

The recreational unit of the ODAE, an L-shaped unit built into the locker, contains the following: individually selected off-the-shelf paperback books in eight stowage compartments; three library book covers of fire-resistant Teflon/Beta material; three card deck retainers; three card retainer hand holders; six hand exercisers constructed of Fluorel-coated sponge rubber; and three hand balls of different sizes (one fluorel coated commercial ball, one pyrell Nerf-ball dipped in ammonium-dyhydrogen phosphate and coated with Fluorel, and one commercial toy ball coated with Fluorel).

Three tape player Power Cords for playback of tapes are in the ODAE, as are four stereo headsets for listening to cassette tape playback; twelve darts (six blue, six gold), made of Fluorel with heads covered with Velcro hook and a dart board 11½ by 15 inches, the front of which is covered with Velcro pile. The board is mounted in front of the library section.

Other recreational supplies include: three commercial grade Exer-Gyms; two commercial monaural microphones to be used by the crew for recording their comments on the cassette tapes; and one set of binoculars (10 x 40).

The ODAE is stowed in the wardroom in corner wall locker W714.

Containers with Velcro pile and hook latches are provided for stowage of equipment. These are kept in place during the mission by spring retainers.

**PERSONAL HYGIENE KIT** The Personal Hygiene Kits provide each crewman with an individual supply of articles for personal hygiene use during the Skylab mission. These items are packed in Personal Hygiene Kits 1 and 2.

One Kit #1 is provided for each crewman for the initial 28-day mission. Six #2 kits are provided for use by crew members of subsequent missions. One resupply kit is furnished for all missions. Each kit bears the name of the crewman to whom it is assigned.

Kit #1 is a semi-rigid, rucksack shaped and sized to accommodate the personal hygiene articles for each crewman. The rucksack is five-ply layup construction, consisting of sandwiched layers of Teflon-coated Beta cloth, asbestos aluminum and Armalon. Hinged flaps provide kit closure, and other flaps inside the kit furnish stowage for personal hygiene articles. A pull tab is provided for opening the flaps. A Velcro hook is attached to the base of the kit, when in use, for retention in zero "g." Contents of the kit are held in place by elastic keepers and pockets.

The rucksack for Kit #2 is identical in construction to that of Kit #1. Kit #2 contains the same items as Kit #1, except no wind-up razor is provided. The wind-up razor is transferred from Kit #1 to Kit #2 after the initial 28-day mission. A new head is provided for the razor from the six replacement heads stowed in the Resupply Kit.

The Personal Hygiene Resupply Kit is a semi-rigid rucksack shaped and sized to accommodate toothbrushes, toothpaste, a resupply of expendable articles and space shaving equipment for Skylab Mission 2, 3 and 4.

Provisions are made for stowing Kit #1 in personal lockers assigned to crew members of the initial 28-day mission. One Kit #1 will be stowed in each of three WMC lockers.

Six Kits #2 and one Resupply Kit will be stowed in the Sleep Compartment.

**SURVIVAL EQUIPMENT** Survival equipment, intended for use in an emergency after Earth landing, is stowed in two rucksacks (Rucksack 1 has survival equipment and Rucksack 2 contains a life raft) in the right-hand forward equipment bay of the CM. A lifevest for each crew member, which is to be worn during launch procedures, donned prior to reentry, and worn throughout recovery, is also stowed in the CM.

The three-man life raft is composed of a floatation tube with reversible, inflatable baffle and floor, three ballast buckets, and carbon dioxide and oral inflation systems. It is designed to support a load of 750 pounds for an extended period with an initial inflation pressure of 2 psig.

The raft is initially inflated by pulling a lanyard which simultaneously activates two cylinders, each charged with 375 grams of carbon dioxide. The raft is inflated in about 25 seconds.

The other rucksack contains a beacon transceiver, survival lights, desalter kits, machete, sun-glasses and water cans.

The radio/beacon transceiver is a signal and communications device (manufactured by Cubic Corporation) about 7 3/4 inches high, 4¼ inches wide and 2¼ inches thick, which weighs 6 pounds. The unit operates on a frequency of 243 mHz, and broadcast and reception are line of sight.

The transceiver, when operated continuously for 24 hours with a single Apollo Survival Radio Battery Pack, will give the following performance:

| | RECEIVER ALTITUDE | RANGE (N.M.) | WATTS OUTPUT |
|---|---|---|---|
| BEACON MODE | 10,000 feet | 125 | 1.25 |
| | 25,000 feet | 200 | |
| VOICE MODE: | | | |
| Transmission | 10,000 feet | 100 | 0.5 |
| Reception | 10,000 feet | 120 | |
| Transmission | 25,000 feet | 150 | |
| Reception | 25,000 feet | 200 | |

The combination Survival Light Assembly is a miniature survival kit, the function of which is self-explanatory. Components are: signal mirror, strobe signal light, flashlight, compass, a water-proof receptacle, 14 water purification tablets, a siren whistle, a knife blade, three needles, four fishhooks, a spool, heavy nylon thread, a flint striker and four cotton balls.

The Sunglasses especially designed for the Apollo Program will be used in Skylab. They satisfy the criteria for resistance to breakage, compactness and protection from harmful sunrays and glare.

The sunglasses have a soft fabric frame and are adjustable to head size and face contour. They are held against the face by elastic braids which are fastened together behind the head with hook and pile fastener.

The blade of the machete is high quality stainless steel; the handle is aluminum. The blade is ground and honed to a shaving sharpness. A sawing edge is opposite the cutting edge. It is sheathed.

Three Water Containers with 5 pounds capacity are in Rucksack #1. Two are similarly configured; the third is shaped for neat interface with the spacecraft stowage compartment. Each has an aluminum body and an aluminum cap with a neoprene gasket.

The Sun screen is a protective cream that may be rubbed on the exposed portions of the body to prevent sunburn.

Two survival knives are provided. They are standard three-bladed, all metal knives developed by the U.S. Navy.

The Utility Netting is 60 by 52 inches and is made of a standard fine mesh nylon material. The netting is intended primarily for protection from insects, but can be used as a fishing net if required.

Three pieces of Nylon-Mylar material 60 by 42 inches are provided. The material can be used for thermal protection and for signaling. The color of the inner surfaces is International Orange. The outer surface is aluminized.

## PROVISIONS AND STOWAGE

Outfitting and provisioning for 420 man days of living and working in the Skylab has resulted in the biggest packing job NASA has undertaken. More than 20,000 items have been stowed throughout Skylab.

Management of the Skylab "stowage list," has produced a Skylab Workshop Stowage numbering system with assigned items in each of the vehicles. Each of the stowage locations in the AM, MDA and OWS is again subdivided into series. Each stowage location has a label that contains the assigned stowage number, the items contained and their quantities. A label kit and marking pen permit crewmen to write numbers on the items to maintain control.

The items stowed aboard SL-1 range from 1200 aspirin and 2100 pounds of frozen and unrefrigerated foods to more than 150 rolls of teleprinter paper and 60 pounds of maintenance tools.

**MDA STOWAGE** In the MDA are four stowage compartments and four film vaults. The items stowed in the MDA include the film for the ATM cameras, lithium hydroxide replacement cartridges for the CSM, mission and data files, crewman communications equipment, mol sieve solids traps and CSM and SWS power and signal transfer cables.

The CSM LiOH cartridges, communication equipment, SWS activation equipment, flight data files and mol sieve trap spare parts are stowed in MDA lockers M125, M126, M157 and M168. All but M168 are permanently located on structures in the MDA. Stowage compartment M168 is launched in the AM and later transferred to the MDA.

The MDA film vaults (M124, M141, M143 and M152) provide stowage for the ATM film magazines and cameras. Each vault features aluminum shielding to supply radiation protection for the stored film. There are more than 175 film magazines stowed in the SWS.

**AM STOWAGE** Sixteen stowage compartments are in the AM, five in the STS, four in the forward compartment, two in the lock compartment and five in the aft compartment. Stowage in the STS is assigned (M) 200 series numbers, while the AM forward, lock and aft compartments stowage is assigned (M) 300 series numbers.

Supplies for the teleprinter, life support umbilicals, portable timers and spare parts are in compartments M201, M202, M301, M305, M310 and M311. All of the compartments are removable through use of Calfax fasteners. A compartment labeled M208 is reserved for inflight stowage of flight data material.

The M168 compartment is transferred to the MDA following crew activation.

The life support umbilicals (LSU) are mounted on the exterior of the lock compartment. One 60 foot LSU is in each spherical enclosure.

There are also two spare tape recorders, a speaker intercom assembly and a spare condensate tank module mounted on the walls of the AM.

**OWS STOWAGE** Stowage in the Orbital Workshop is provided on the Forward Compartment ring and in the Forward Compartment and Crew Quarters in the form of various sized compartments, dispensers, refrigerated and ambient temperature food stowage facilities, refrigerated urine stowage and a film vault. The OWS stowage and series numbers are: Forward Compartment F500, experiment E600, Wardroom W700, Waste Management Compartment H800, Sleep

Compartment S900, and forward dome stowage (25 containers) D400 series. OWS stowage items are: dispensers, food boxes, urine freezer, film vault, wearing apparel, EVA support and workstation provisions, off-duty equipment, trash and waste management, personal hygiene, maintenance equipment and spare parts, fire suppression equipment and Inflight Medical Support System.

Dispensers are stowed for waste management collection, bags, towels and trash containers. The waste management bag dispensers are stowed in H833 and are readily available to the crew in the WMC.

Towels are stowed in five compartments in the WMC. Each towel dispenser contains 18 towels.

Trash containers are in certain stowage compartments of the OWS. Trash is inserted directly into the bag through the opening in the trash container door.

Eleven food boxes provide launch and on-orbit stowage of ambient temperature foods for the SL-2, SL-3 and SL-4 missions. Five of the 11 boxes are permanently mounted in the OWS Forward Compartment on the grid above the wardroom. The remaining six food boxes are dispersed on the forward compartment floor to ensure structural integrity during launch. Upon SL-2 activation, the six dispersed foodboxes are unbolted from their launch positions and placed in permanent locations.

The entire mission supply of refrigerated foods is stowed in a three-chambered refrigerated unit in the OWS Forward Compartment and in one in the wardroom. The stowage freezer is divided into three chambers with each chamber containing a 28-day supply of frozen foods.

**FOOD STOWAGE** Food is stored in cans and beverage packs which are grouped in menu form in food overcans. The overcans are stowed in bundles in food boxes and the freezers. The food trays in the wardroom food table permit the temporary stowage of food when preparing meals and managing leftovers.

The food is in two forms - ambient and frozen. The ambient consists of dehydrated food and beverages, thermostabilized foods, dry bites and puddings. The frozen foods consist of thermostabilized food, some of which must be heated prior to consumption.

Ambient temperature foods (excluding beverages) and frozen foods are vacuum packed in single meal portions in food cans which come in types - large, small, and pudding. The food is prepared in the can, all of which have pull-top lids, and the can is used as the dish.

The food overcans contain 12 food cans or beverage packs which are packed and identified according to the menu for the particular crewman. The overcans, containing a mixture of large and small overcans, are stored in bundle form, two deep.

The overcans are stored in the 11 food lockers. Every seven days, a week's supply of food overcans is transferred from a food overcan bundle in one of the food boxes to the galley stowage trays.

The galley in the wardroom accommodates 22 galley trays, a week's supply of food readily available for meal preparation. The trays consist of five galley trays per crewman for their individual menu, one galley tray for the weekly pudding supply, one galley tray per crewman for snacks (dry bites) and one galley tray per crewman for beverages.

Each galley tray slides out on a track and may be removed from the galley. Each tray holds 20 items: large and small food cans, pudding cans or beverage packs in partitioned segments.

**URINE FREEZER** A urine freezer in the WMC stores and preserves up to a 56-day accumulation of urine samples from the three crewmembers. Urine samples are in portable urine trays. The freezer can stow up to four urine trays simultaneously.

**FILM VAULT** The OWS film vault, F510, is a shielded, drawered vault in the Forward Compartment which stores hand-held camera film cassettes used for experimentation. On-orbit the doors are secured closed with two dial latches. The doors and vault walls contain aluminum shielding to protect the unexposed film from radiation.

**SKYLAB FLIGHT DATA FILE** Skylab requires a comprehensive assembly of documents, charts and data for crew use in operating the spacecraft systems and experiments. The data collectively is known as the Flight Data File and consists of: flight plans (crew timelines), experiment and system checklists (condensed procedures), systems data, logs, maps and charts. Using this group of books the crewman knows not only what to do and when to do it, but also is provided supplemental reference data with provisions for real-time updating.

The Flight Data File for Skylab is formidable when compared to the FDF of Apollo. The Apollo FDF weighed 35 pounds. The Skylab FDF consists of 120 pounds launched in the workshop and 40 pounds launched in each CM. Basically, the workshop FDF consists of books pertinent to all three missions whereas the CM books are peculiar to the particular mission in question. Data file items that can be used again for subsequent missions are left stored in the SWS during the unmanned mission phase. Other books are either discarded in the SWS or returned in the CM for postflight use.

Flight data files are stored in four basic areas: the CM (R1, R2 and R3), the MDA (M126), the AM (M208) and the OWS workroom (W742, W743, W744, and W745). Special beta bag provisions are provided for large bulky maps and charts and for inflight stowage of books adjacent to experiment hardware.

**TOOLS** Tool box #1 has five drawers containing common usage tools, i.e., hammer, clamps, pinch bar, vise, standard slot screw drivers, Phillips screw drivers, Allen wrenches, 3/8 drive socket wrenches (deep well and standard), ratchet handles, speeder handles, torque handles (5-150 inch pounds), universal joint, ratchet extensions, open end/box wrenches, crow-foot wrenches, retrieval tools and mechanical fingers.

Tool box #2 has five drawers and a storage bin containing common usage tools and special repair items, i.e., channel pliers, needle-nose pliers, slip joint pliers, pocket knife, large crowfoot wrenches, tweezers, O-ring extractors, torque wrench (0-600 inch pounds), scissors and tape.

The repair kit contains five drawers of special patching materials, i.e., flat and blister patches, Teflon tape, sealant putty, Velcro strips, snip scissors and a leak detector. Adhesive tape, scissors and tweezers are used in repairing fabric material damage. Punctures in the pressurized structure caused by inadvertent damage are repaired using pliable, pressure sensitive blister and flat patches which are sized for specific leaks. These patches are made of aluminum sheet backed with a layer of polymeric compound to flow into the puncture. The aluminum provides a rigid surface upon which cabin pressure acts in applying the force necessary to maintain a pressure-tight seal.

Tool box drawers are designed to be removed by the astronauts and transferred to the maintenance area and attached to the structure using a universal mounting technique.

The tool caddy is attachable to a crewman's utility belt by four snaps. The caddy has elastic bands and pocket restraints for holding tools. It also has two boxes with clear windows on the front and flexible sides with slits. Small articles, such as nuts and washers, can be inserted through the slot and kept in view until needed.

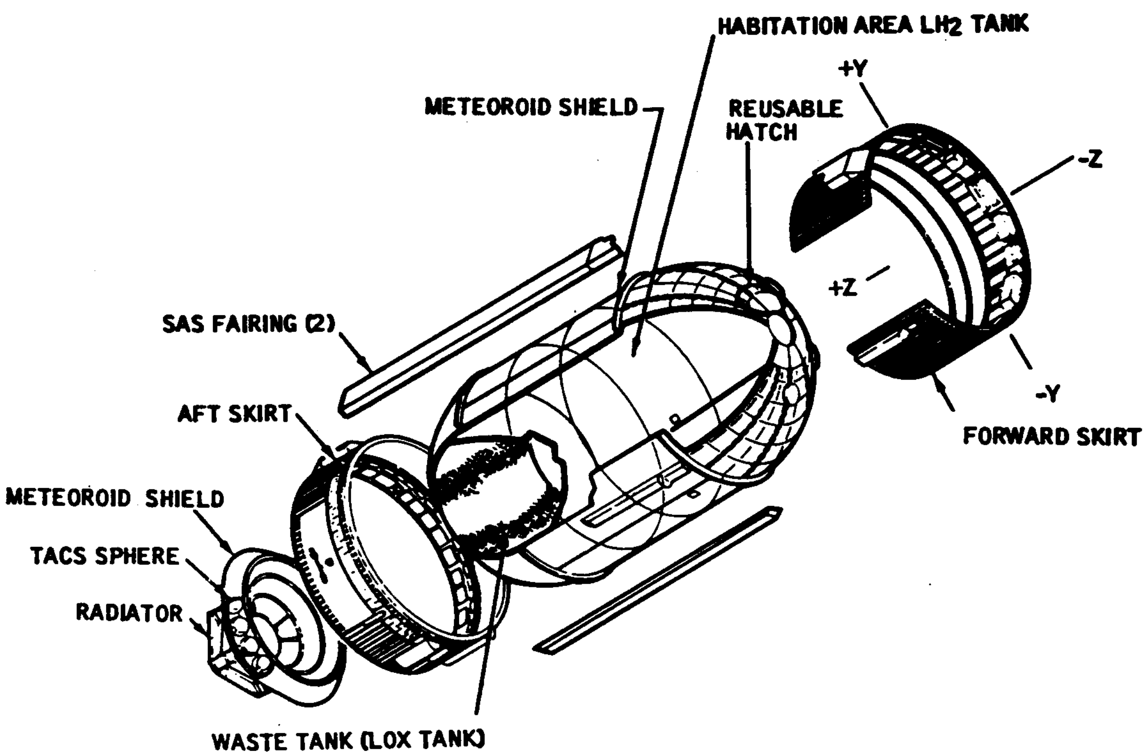



Figure I-3 — OWS Major Assemblies

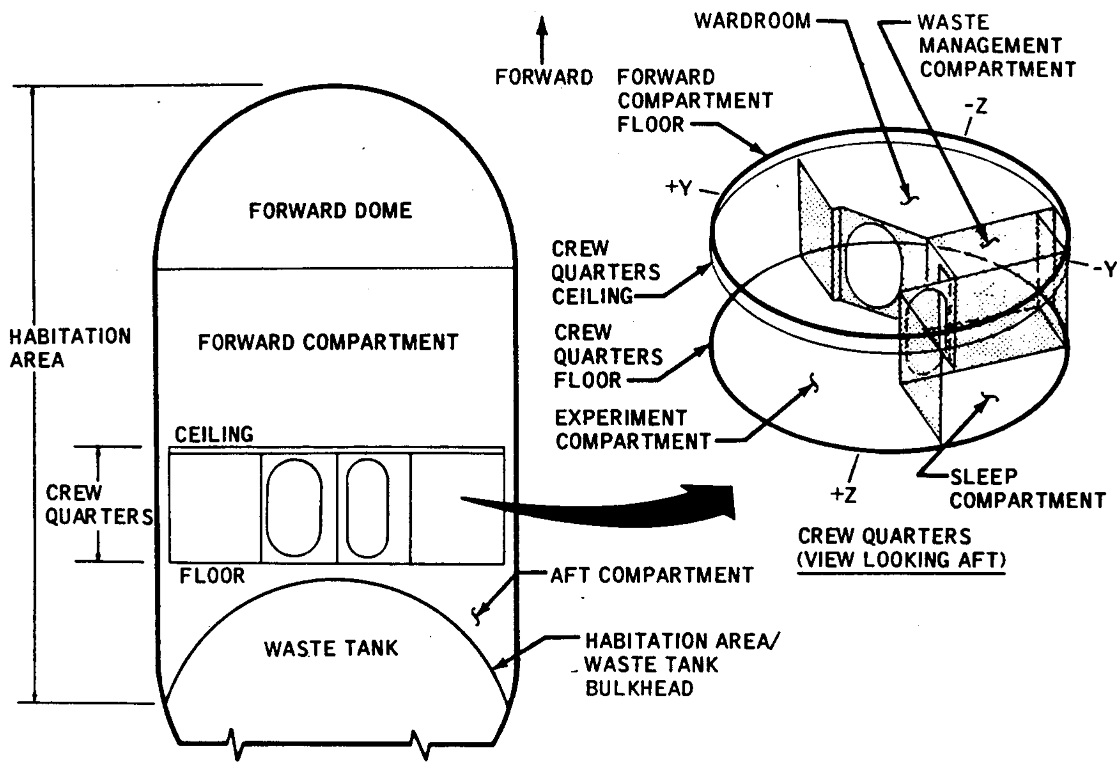



Figure I-4 — OWS Habitation Area

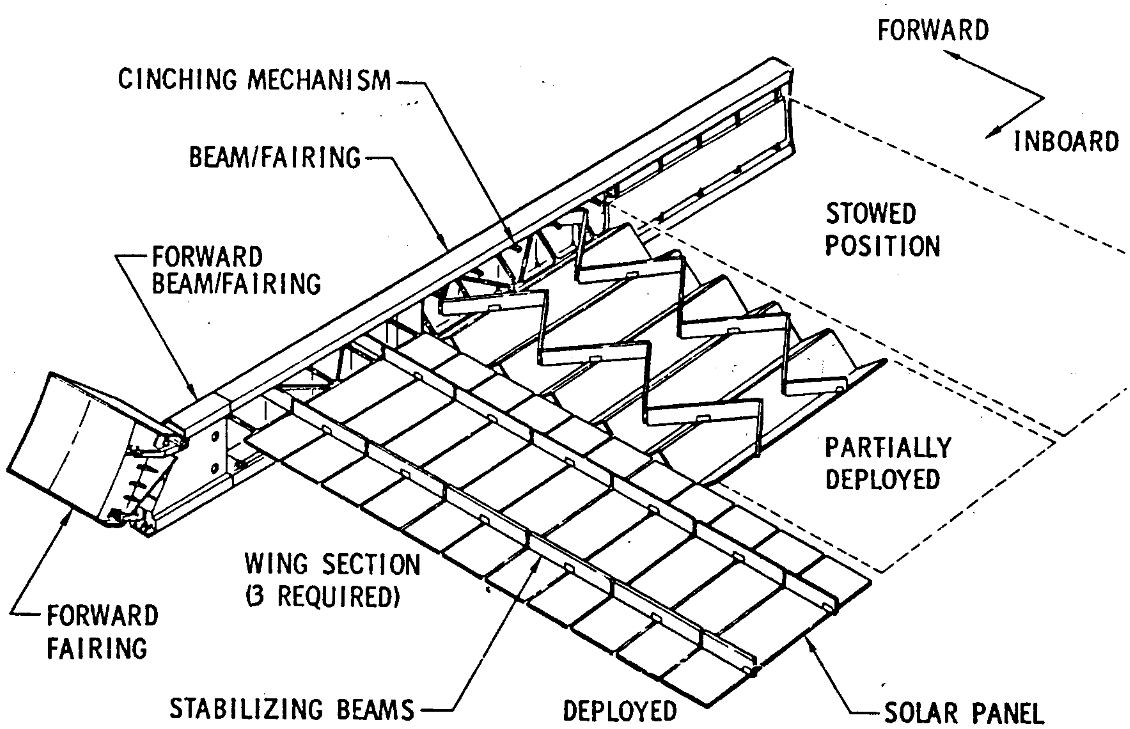



Figure I-5 — OWS Solar Array Wing Assembly

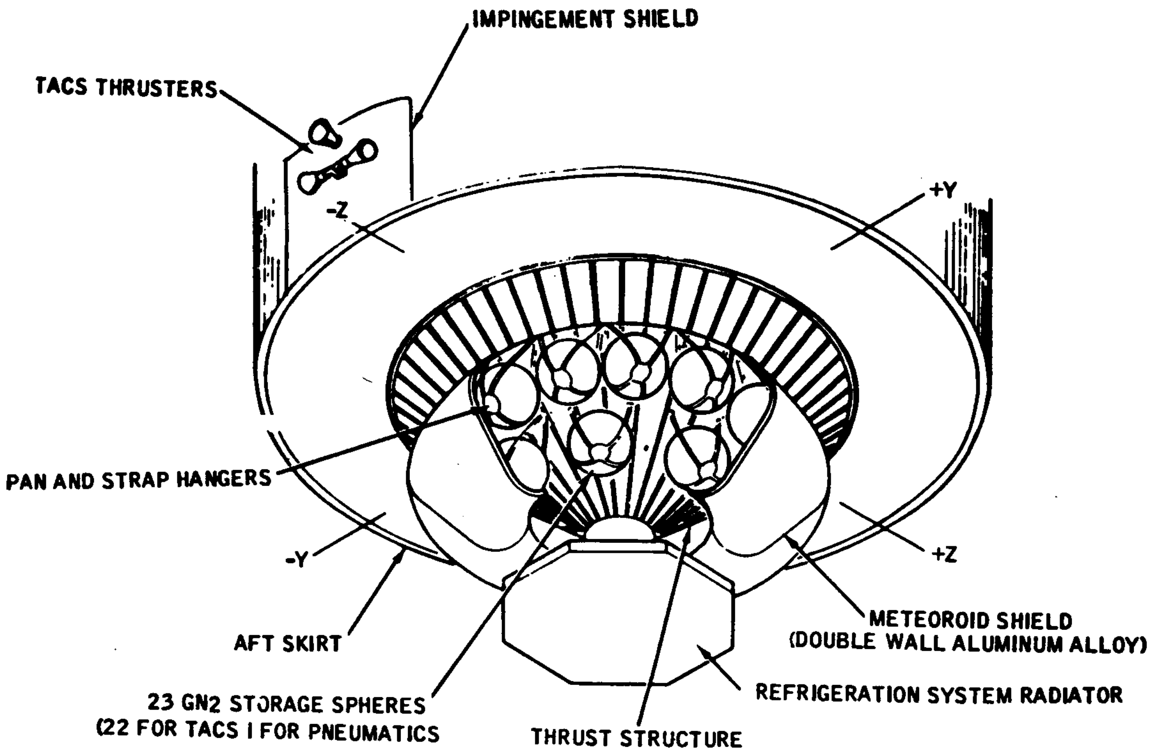



Figure I-6 — TACS Spheres, Meteoroid Shield

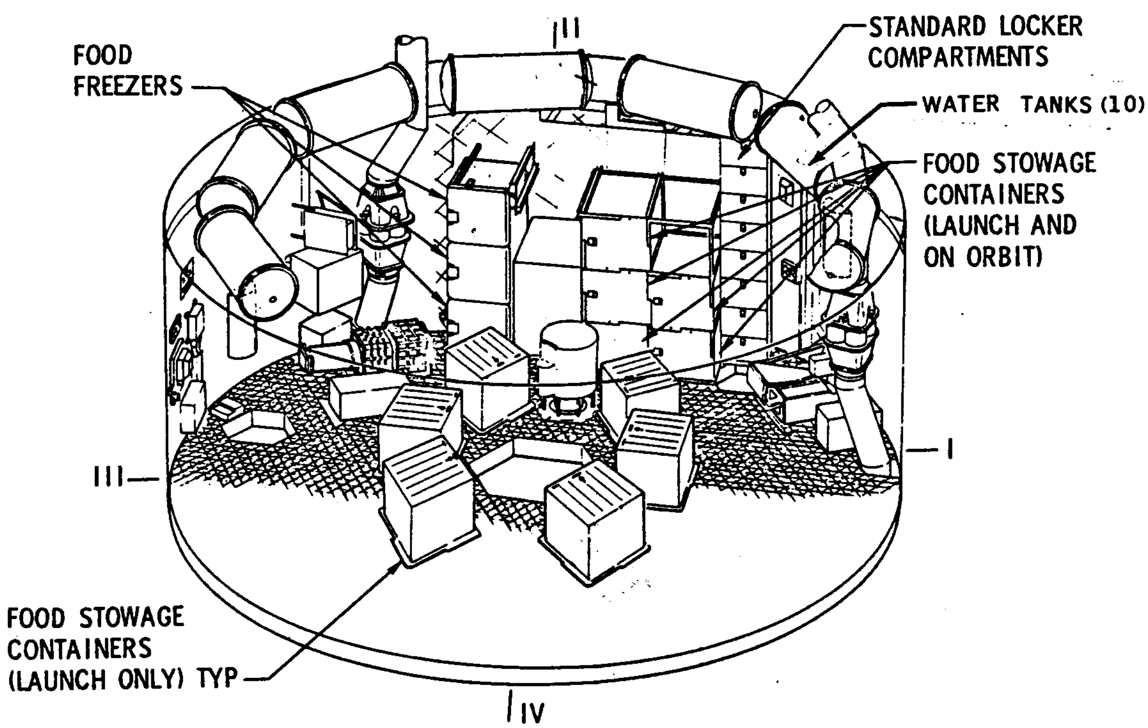



Figure I-7 — OWS Forward Compartment, Launch Configuration

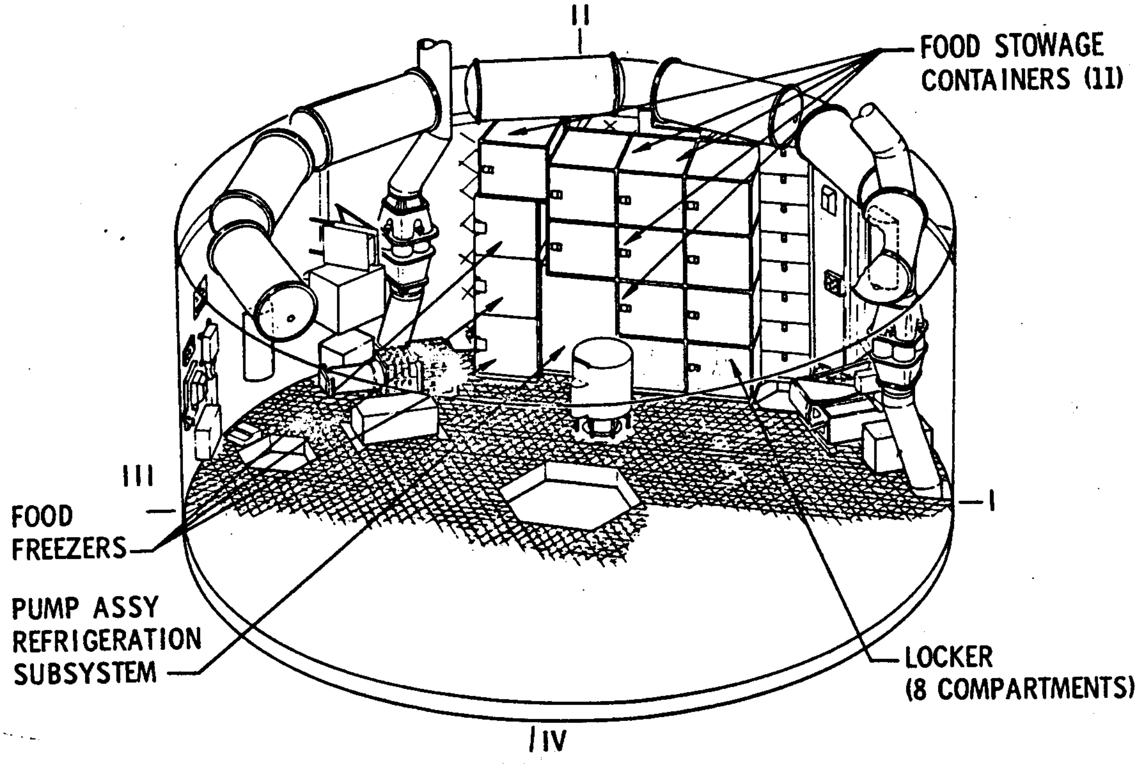



Figure I-8 – OWS Forward Compartment, On-Orbit Configuration

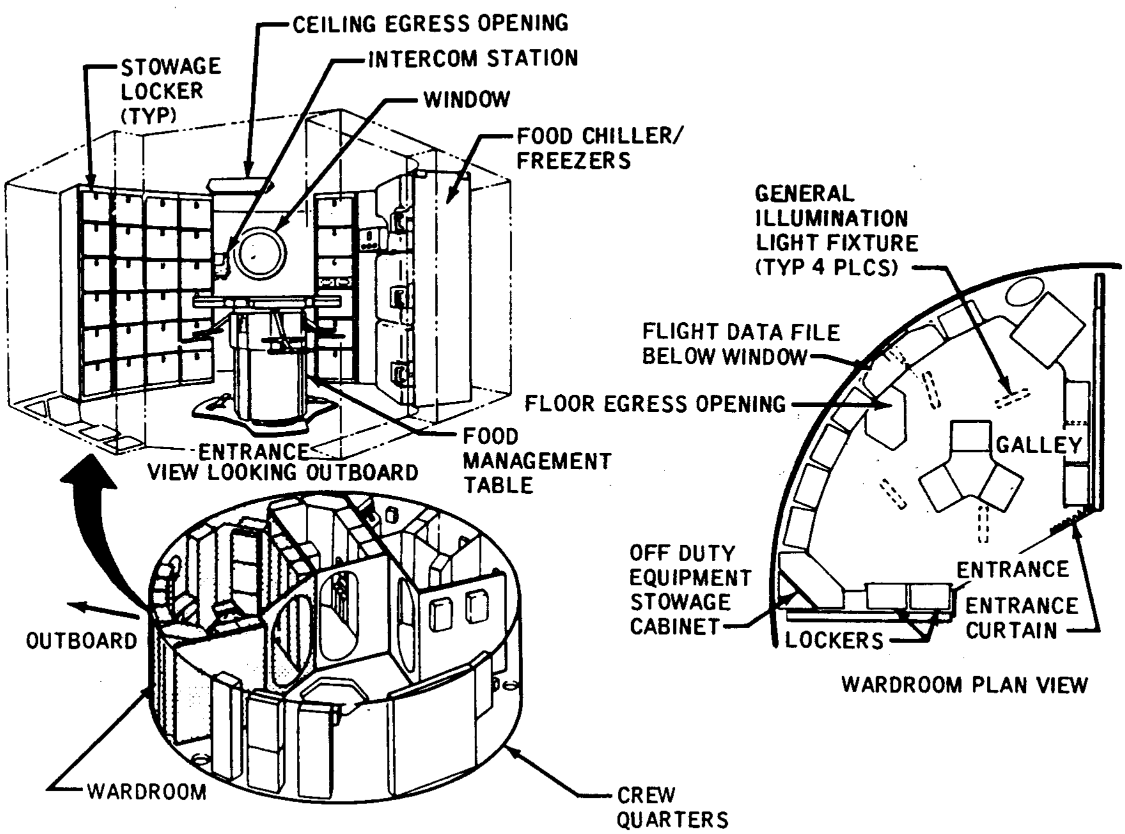



Figure I-11 – Wardroom Arrangement

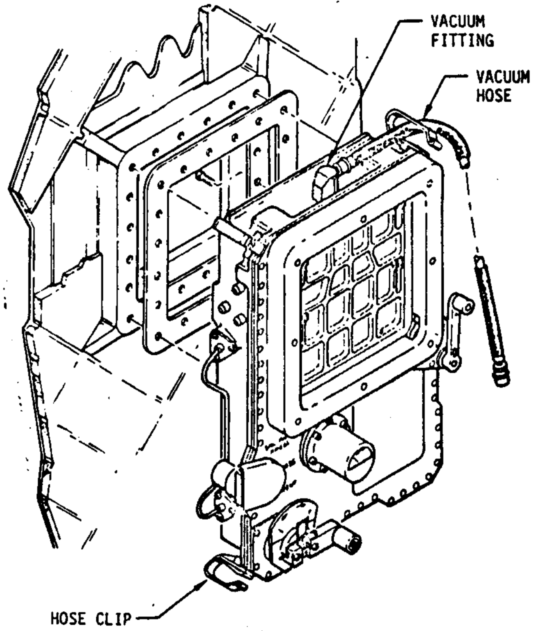



**Figure I-10 – Scientific Airlock**

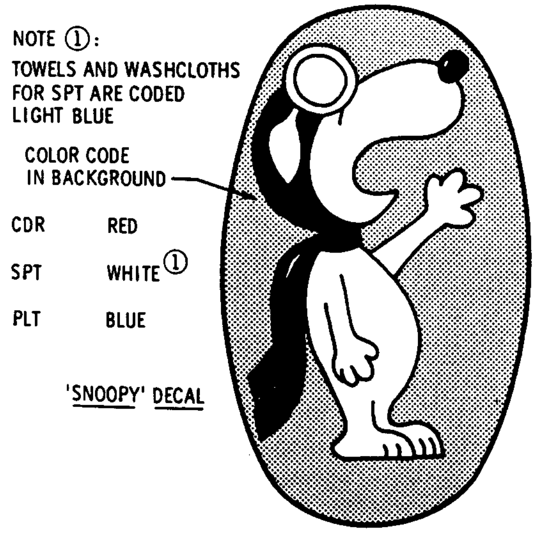



**Figure I-13 – Crewman Color Coding**

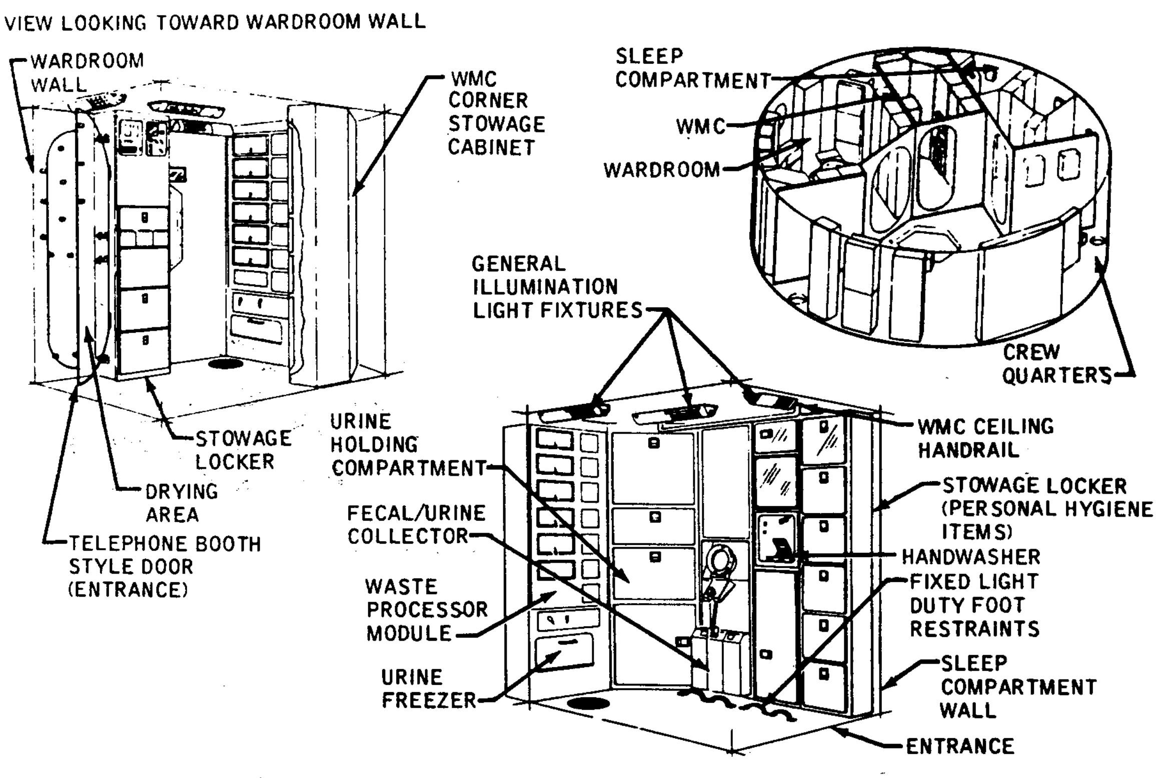



**Figure I-12 – WMC Arrangement**

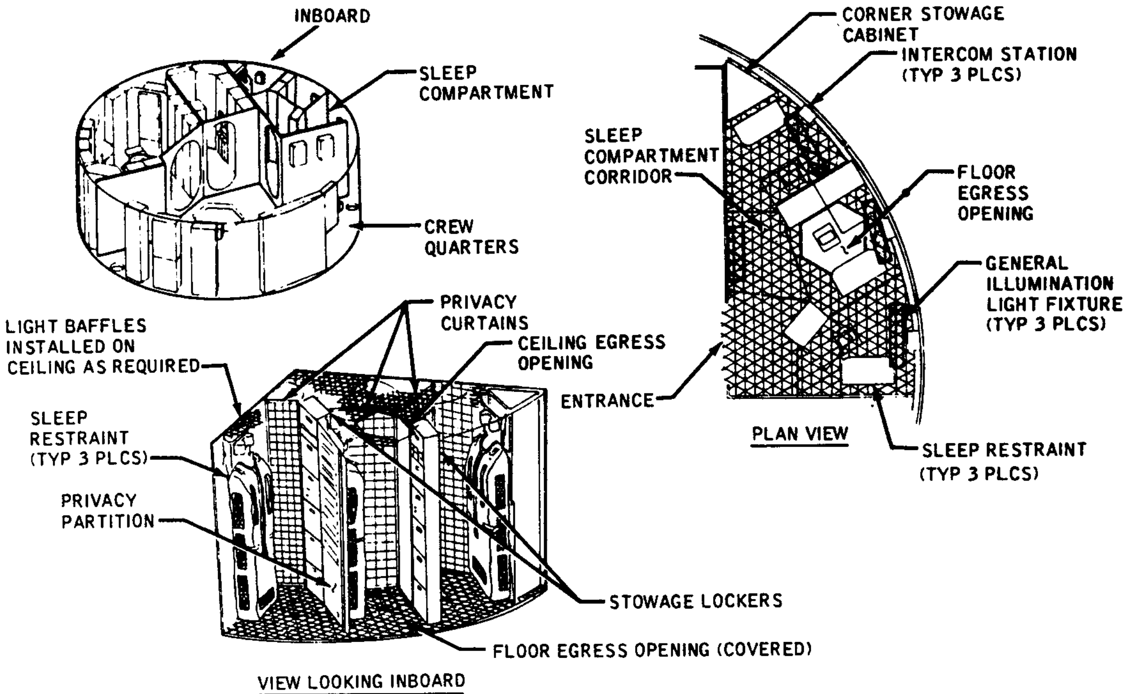



**Figure I-14 — Sleep Compartment**

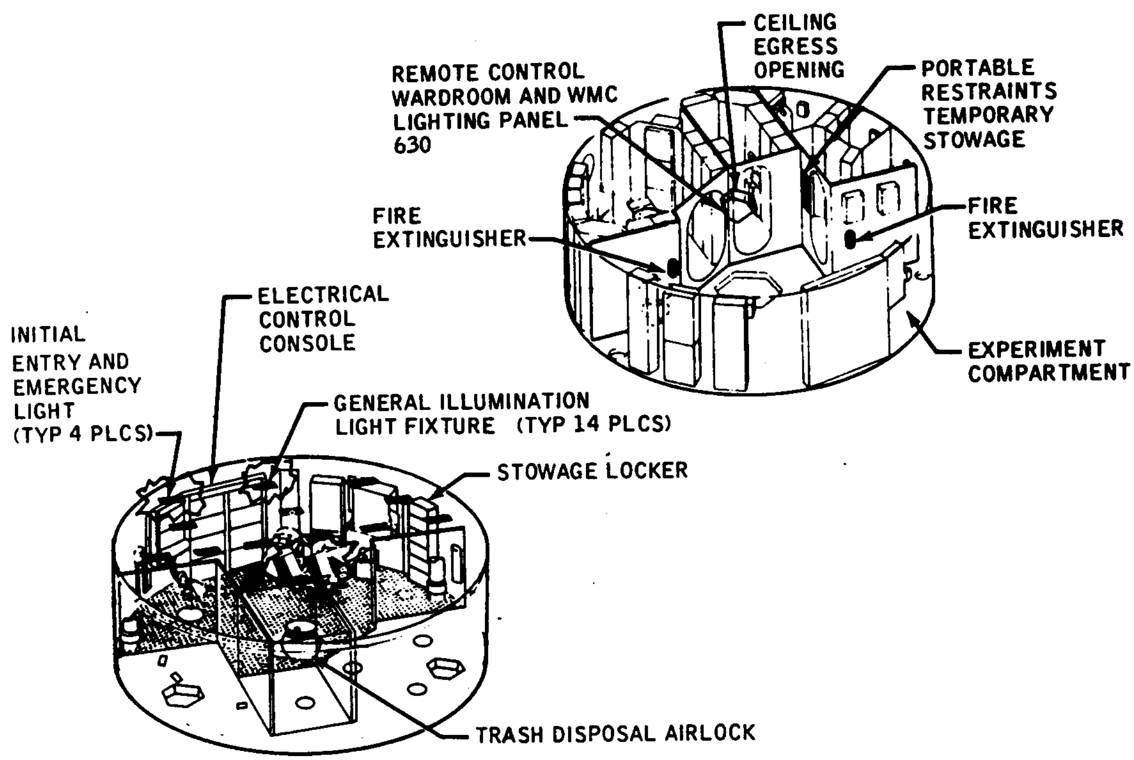



**Figure I-15 — Experiment Compartment**

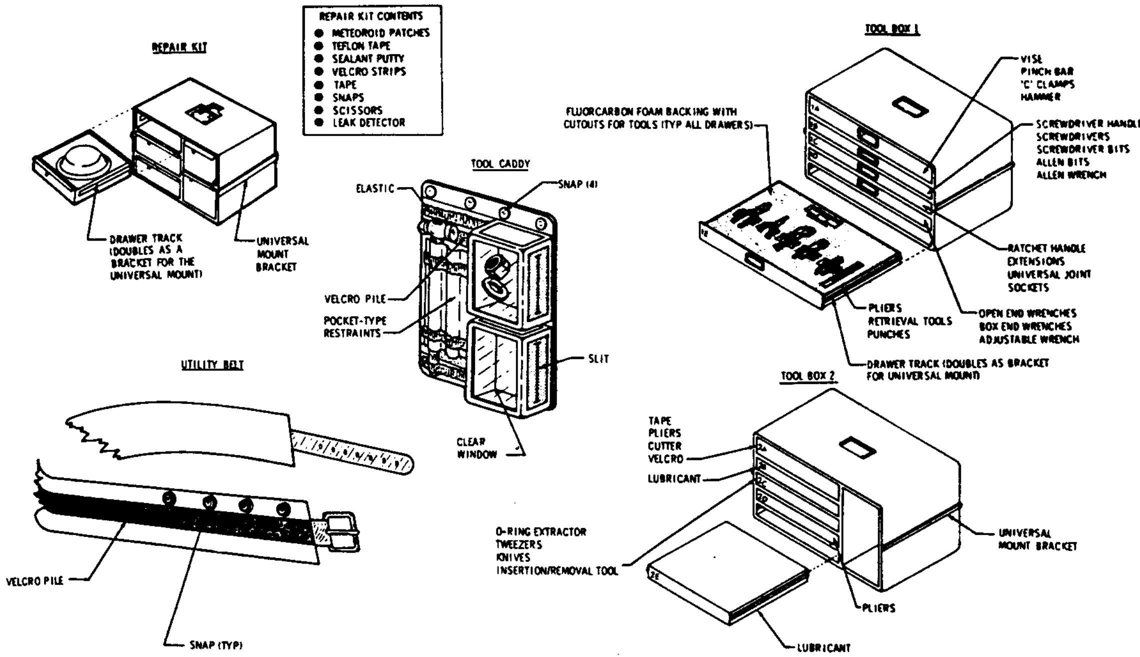



**Figure I-16 — OWS Maintenance Equipment**

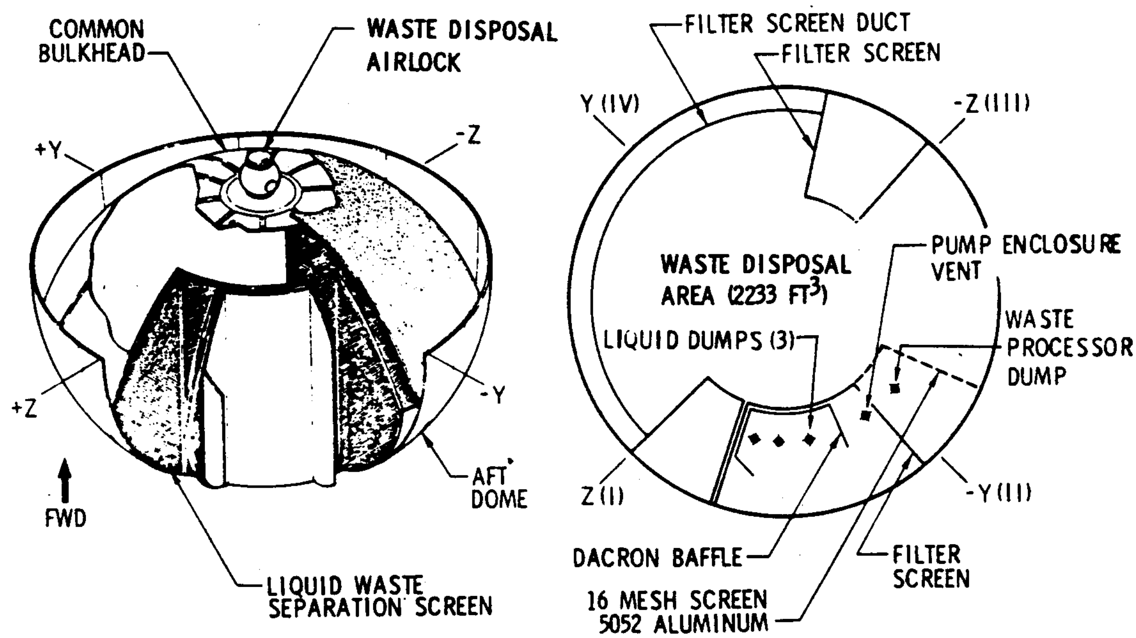



**Figure I-17 — OWS Waste Tank**

- PROVIDES CSM DOCKING CAPABILITY
- CREW WORK AREA
- PROVISIONS FOR EXPERIMENTS
- CONTAINS THE ATM C&D AND EREP PANELS
- ECS RADIATOR MOUNTS
- STOWAGE

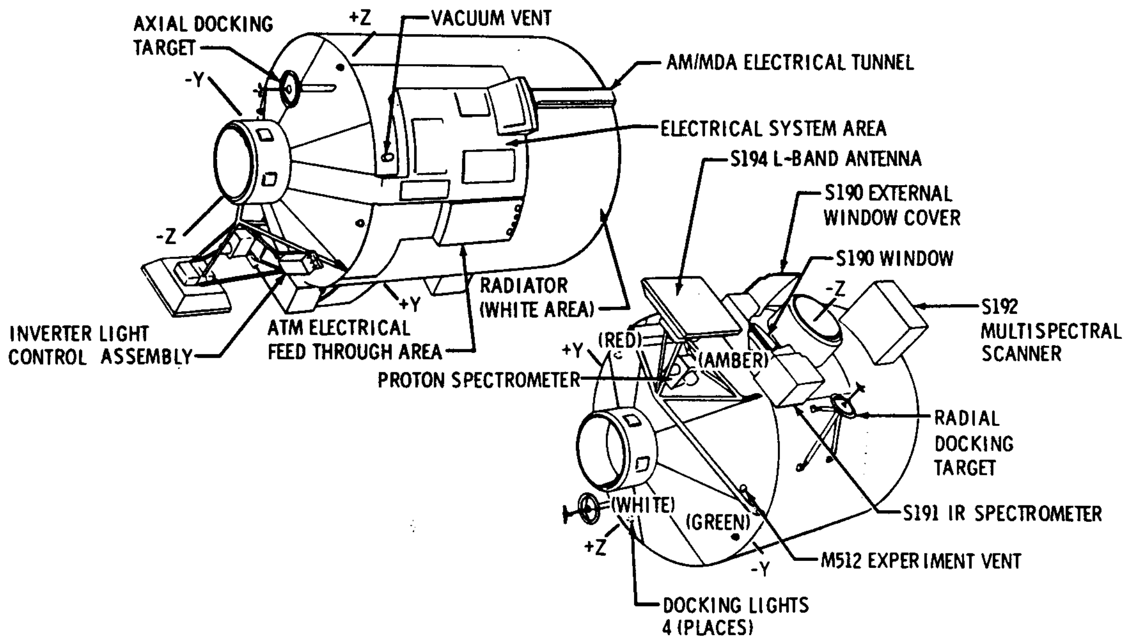



Figure I-20 — Multiple Docking Adapter

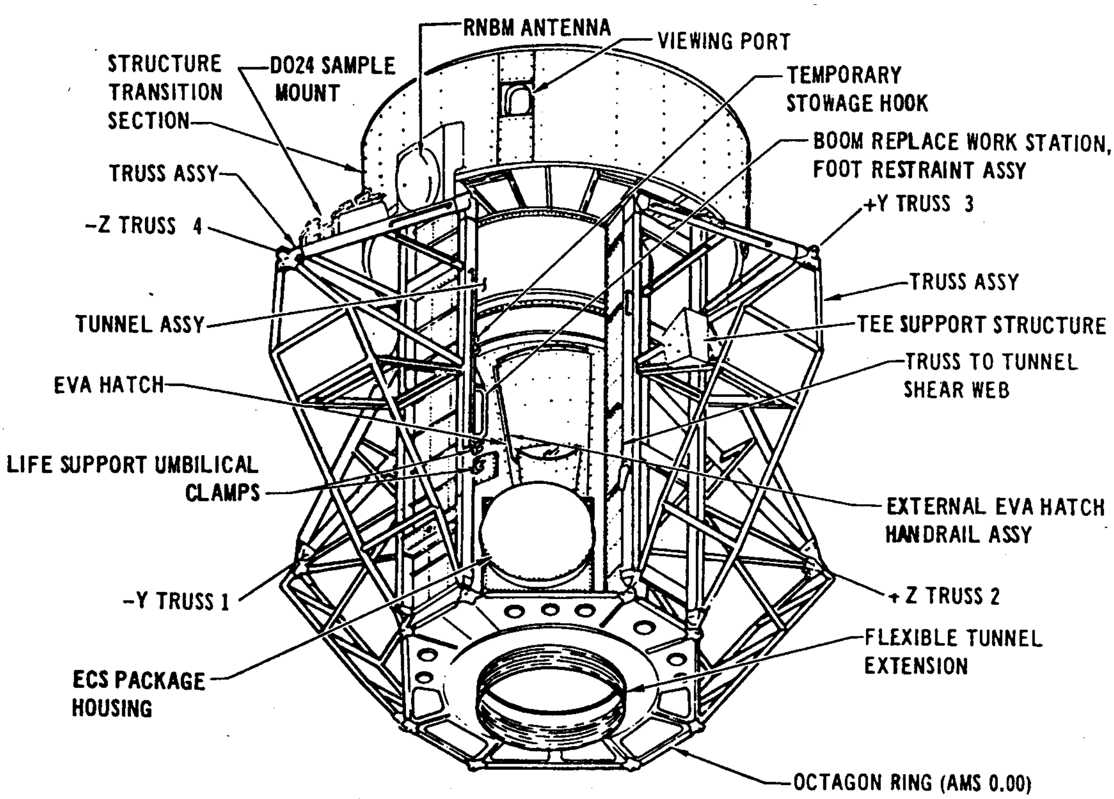



Figure I-25 — Airlock Module

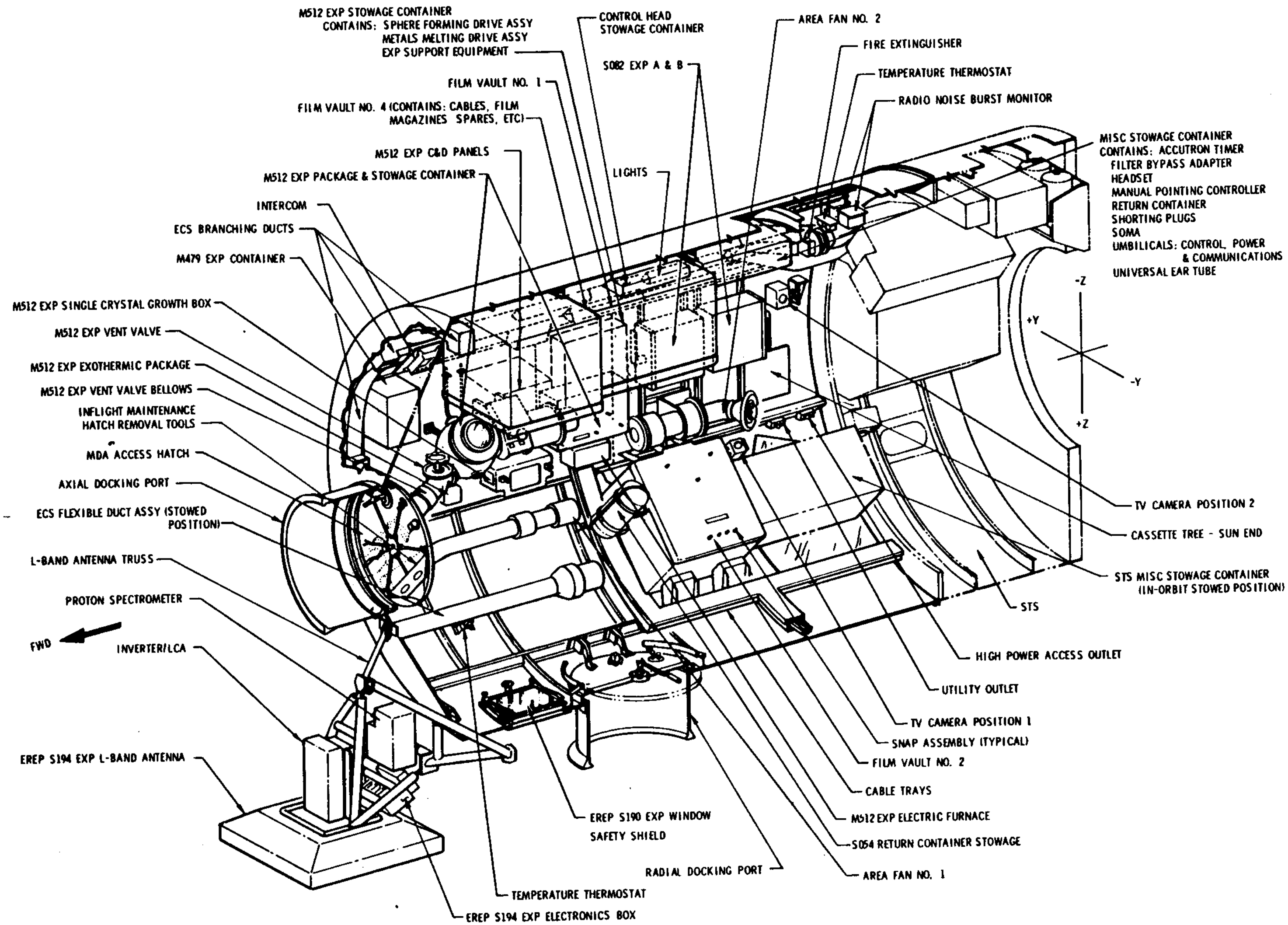



**Figure I-21 — MDA Internal View, +Y**

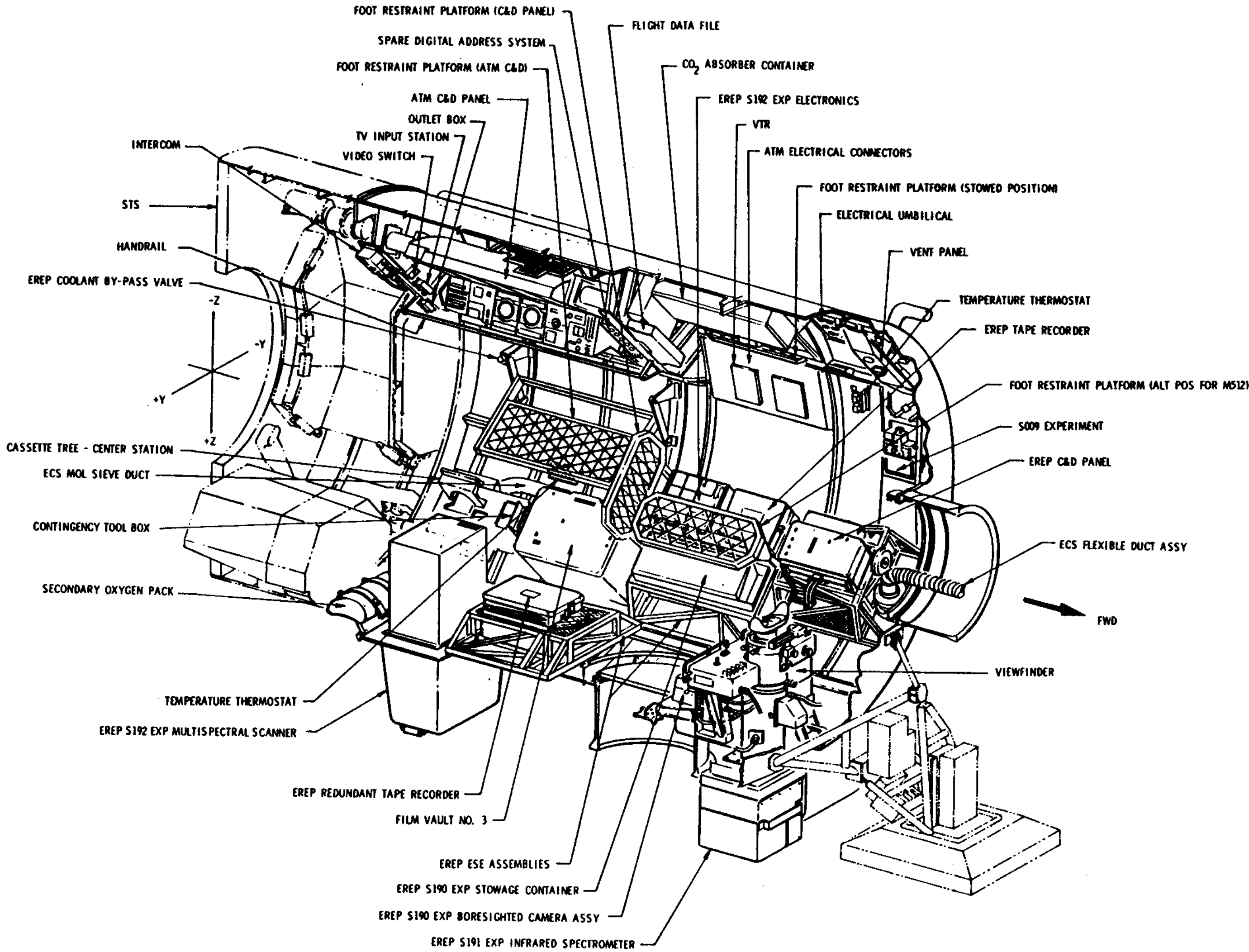



**Figure I-22 — MDA Internal View, -Y**

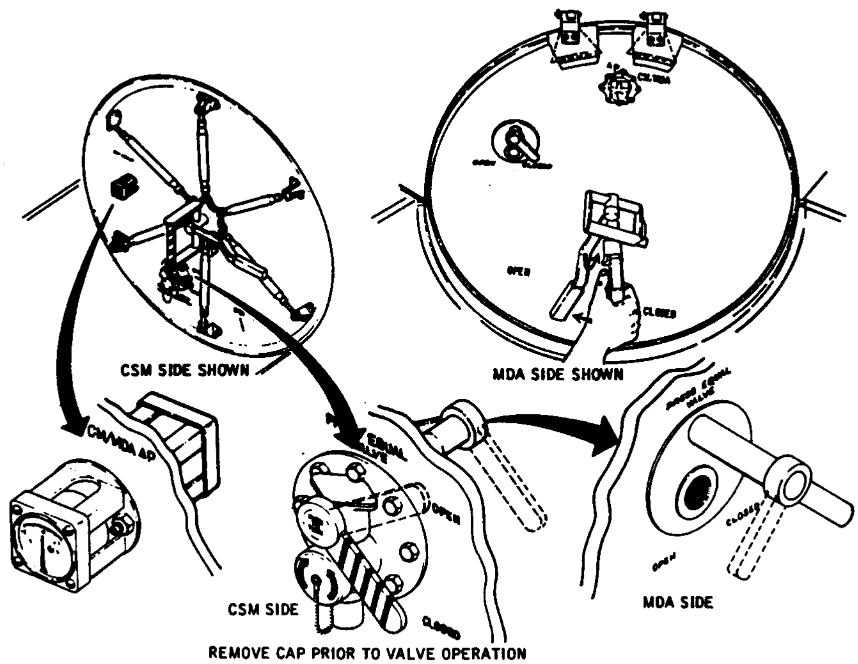



**Figure I-23 — MDA Hatch**

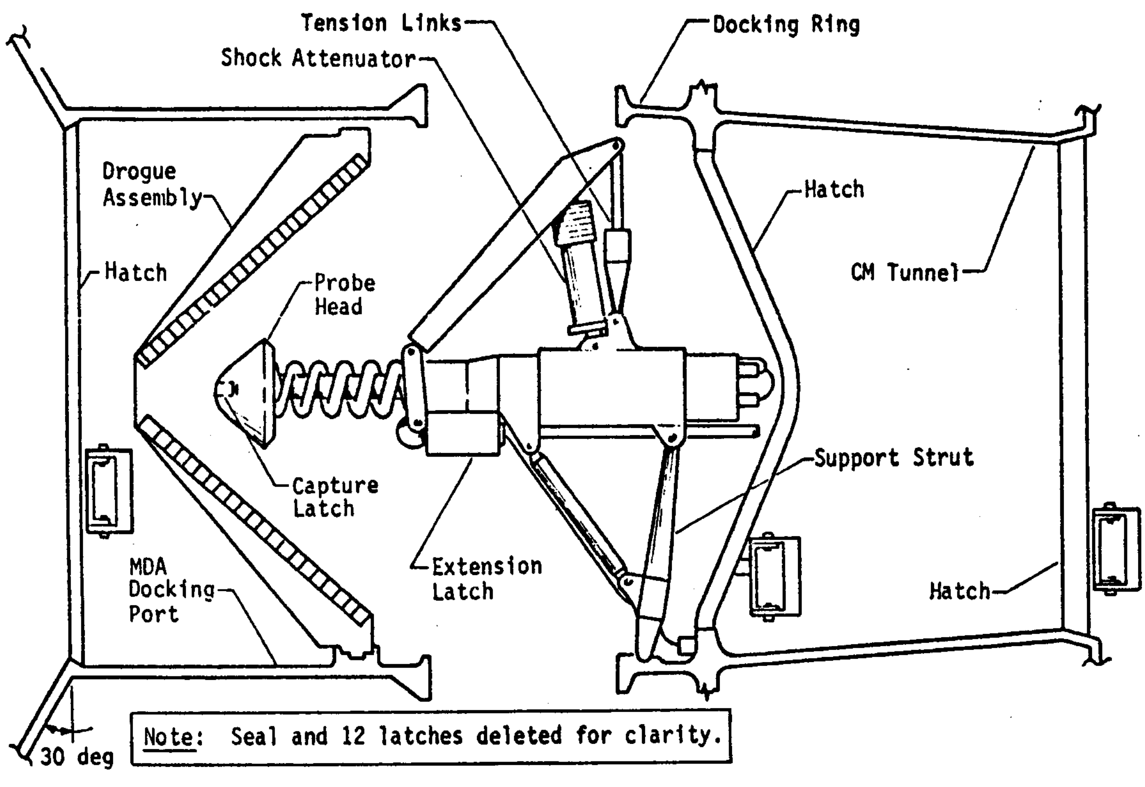



**Figure I-24 — MDA Docking Mechanism**

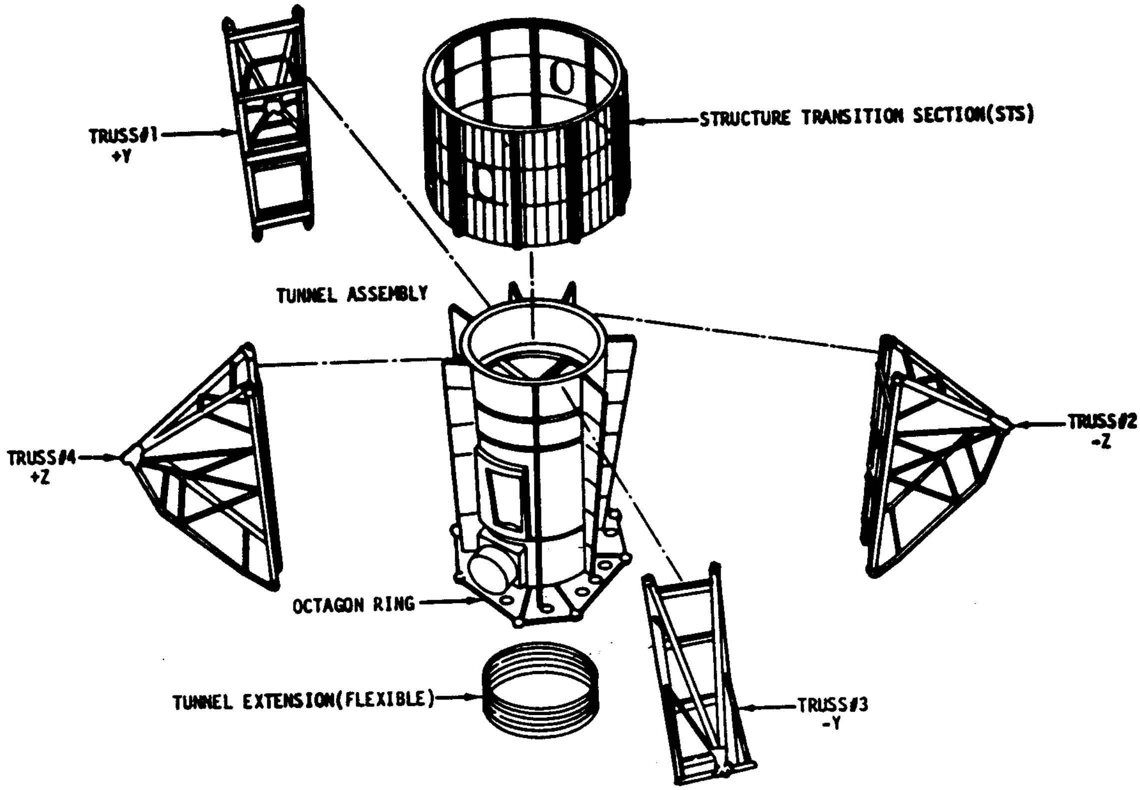



Figure I-26 — AM Structural Elements

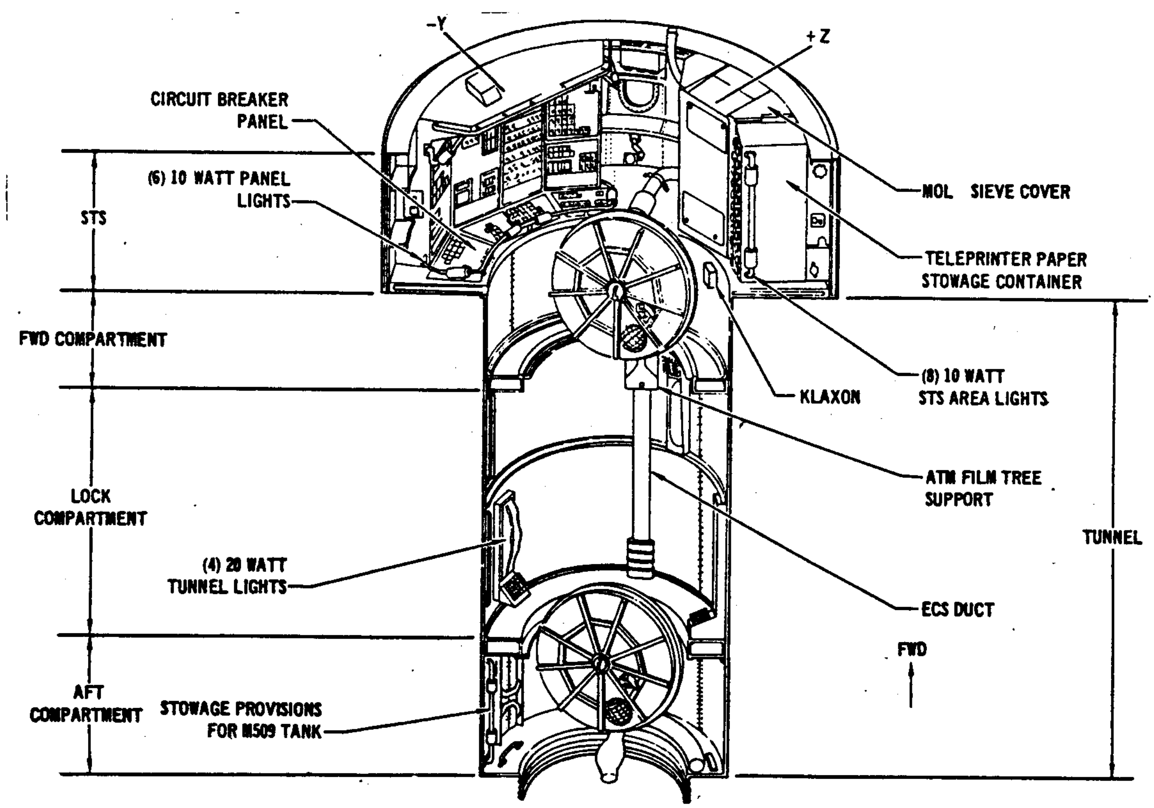



Figure I-27 — AM Interior, -Y+Z

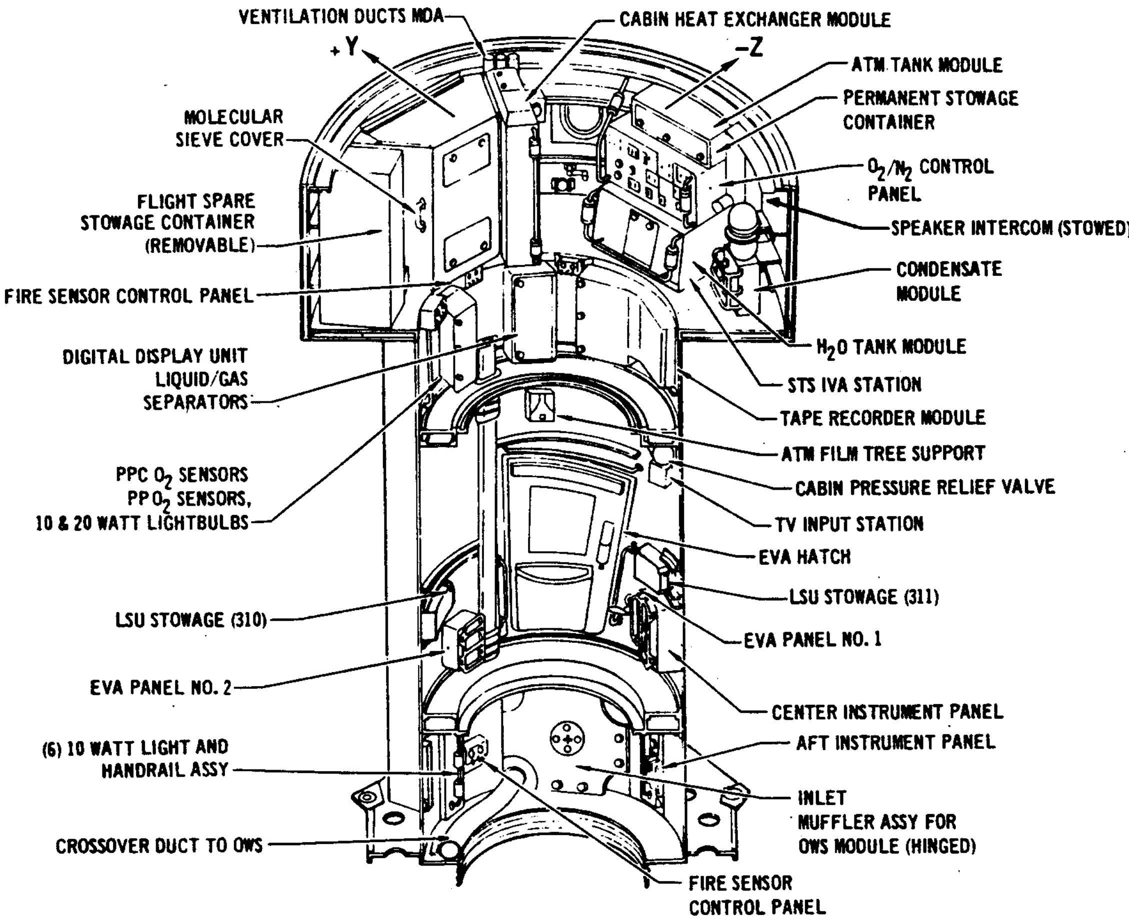



**Figure I-28 — AM Interior, +Y-Z**

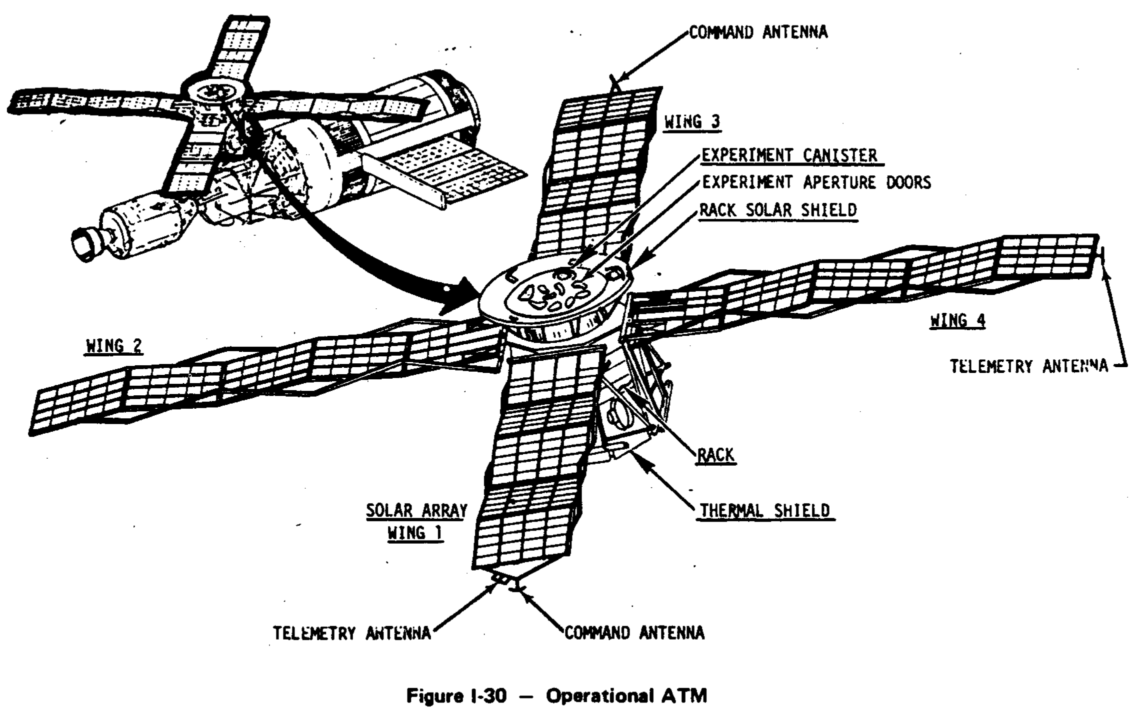



**Figure I-30 — Operational ATM**

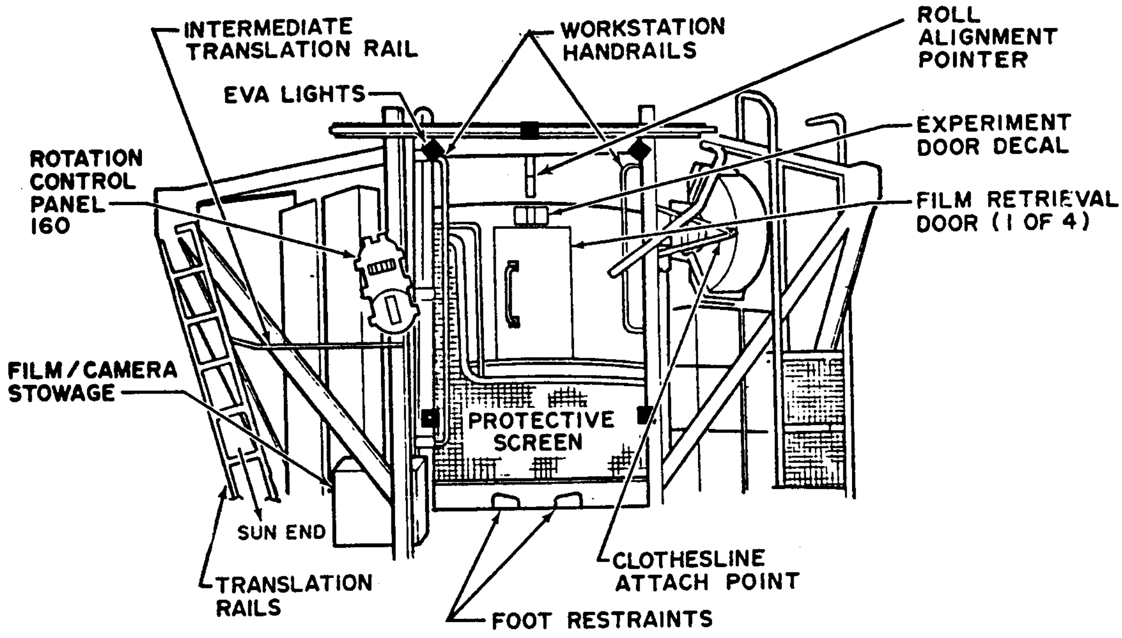



**Figure I-32 — ATM Center Work Station**

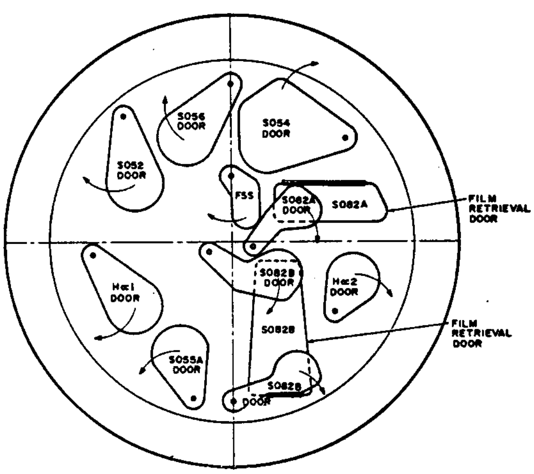



**Figure I-33 — ATM Sun End**

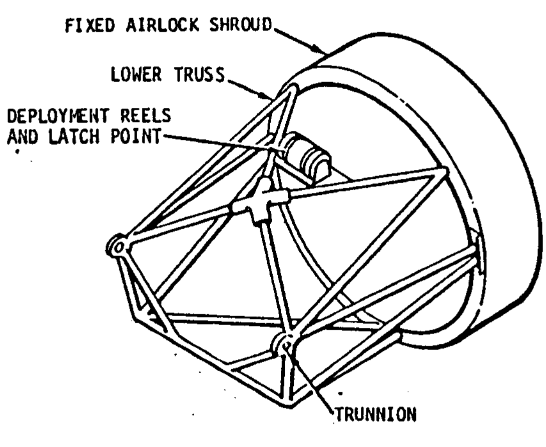



**Figure I-29 — Fixed Airlock Shroud, Deployment Assembly**

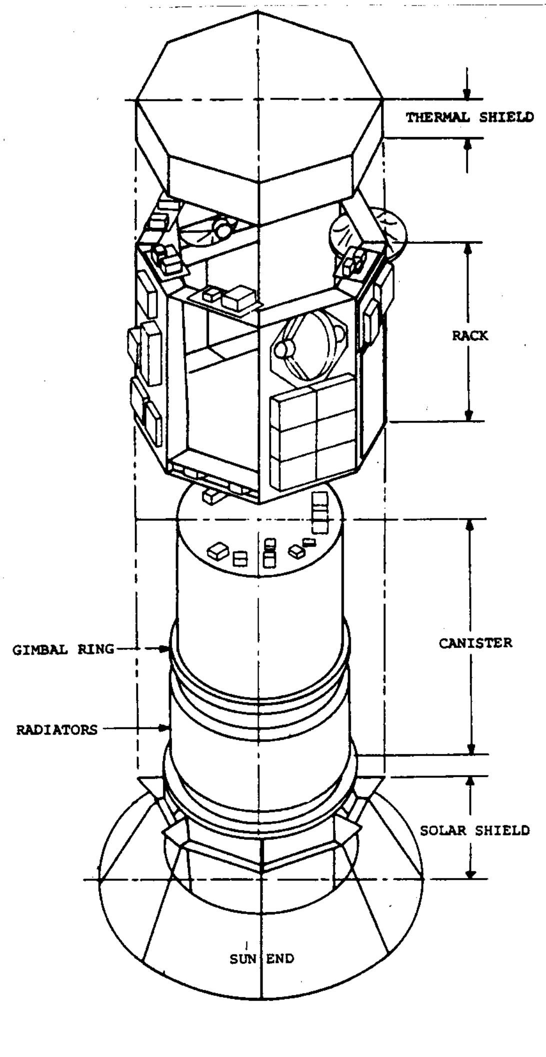
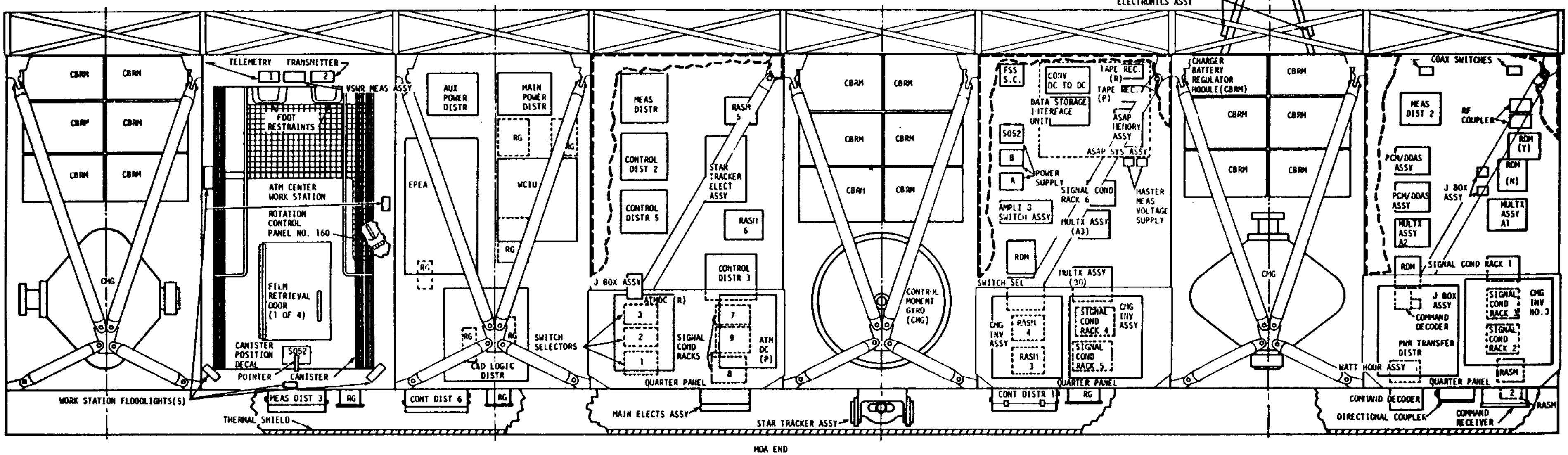



**Figure I-31 — ATM Major Structural Components**

## ATM RACK-MOUNTED EQUIPMENT




- CONT DISTR=CONTROL DISTRIBUTOR
- ATMDC=ATM DIGITAL COMPUTER
- RG=RATE GYRO
- ELECT=ELECTRONICS
- RASM=REMOTE ANALOG SUBMULTIPLEXER
- MEAS DISTR=MEASURING DISTRIBUTOR
- WCIU=WORKSHOP COMPUTER INTERFACE UNIT
- EPEA=EXPERIMENT POINTING ELECTRONICS ASSEMBLY
- C&D LOGIC DISTR=CONTROL & DISPLAY LOGIC DISTRIBUTOR
- CBRM=CHARGER/BATTERY/REGULATOR MODULE
- PCM/DDAS=PULSE CODE MODULATION/DIGITAL DATA ACQUISITION SYSTEM
- CMG=CONTROL MOMENT GYRO
- CMG INV ASSY=CMG INTERTER ASSEMBLY
- RDM=REMOTE DIGITAL MULTIPLEXER
- MULTX ASSY=MULTIPLEXER ASSEMBLY
- RCVR=RECEIVER
- DIR=DIRECTIONAL
- SEL=SELECTOR
- ASAP=AUXILIARY STORAGE & PLAYBACK ASSEMBLY
- FSS SC=FINE SUN SENSOR SIGNAL CONDITIONER

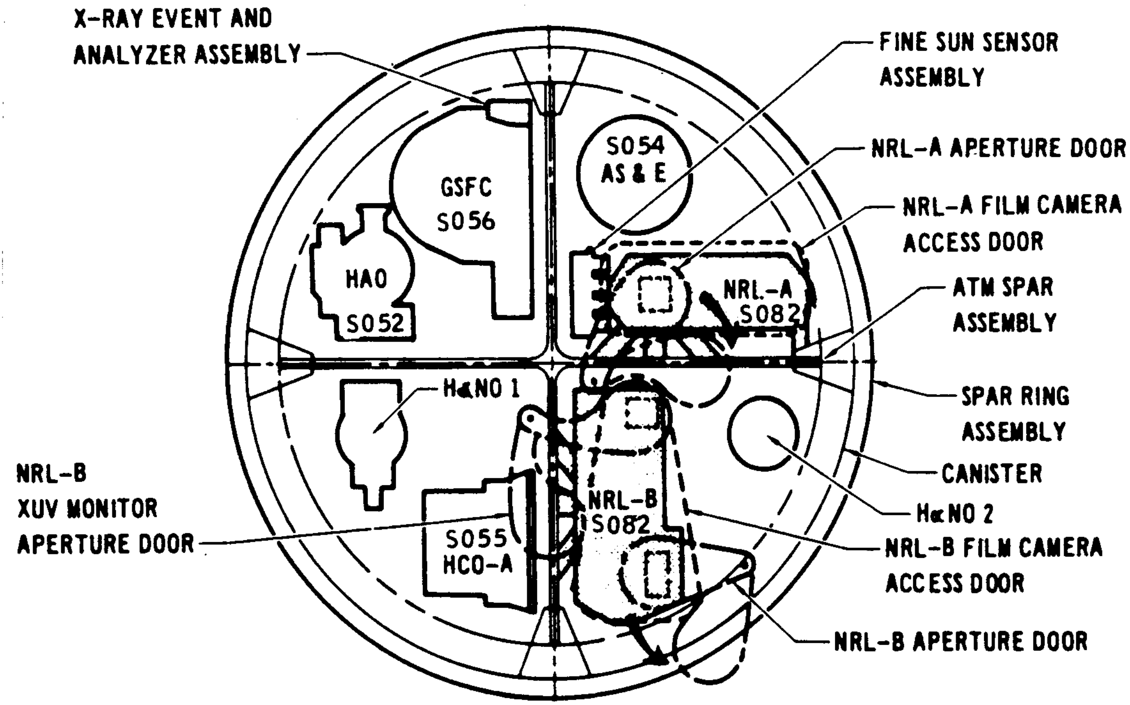



Figure I-35 – ATM Spar, Sun End View

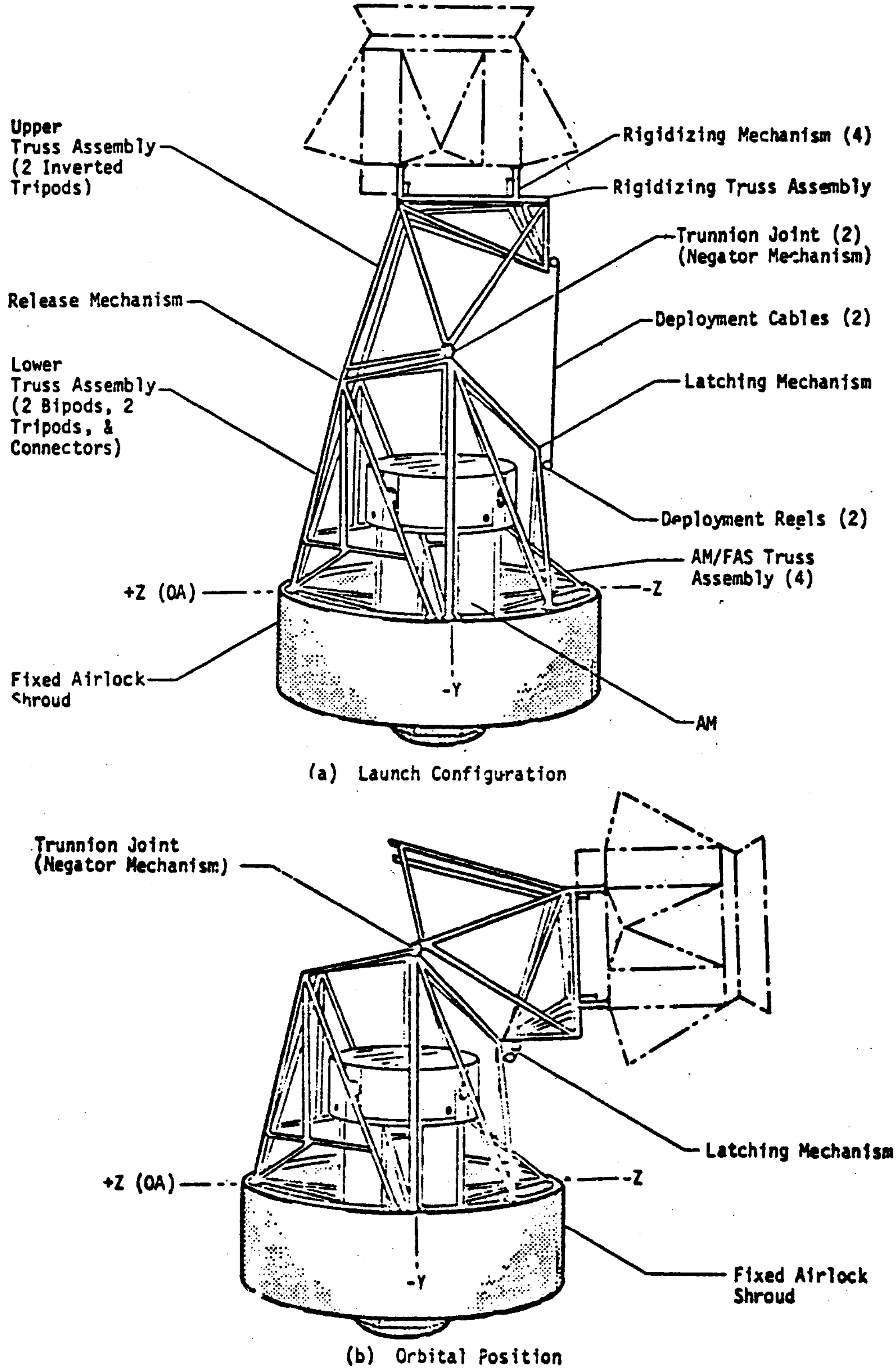



Figure I-36 — ATM Deployment Assembly

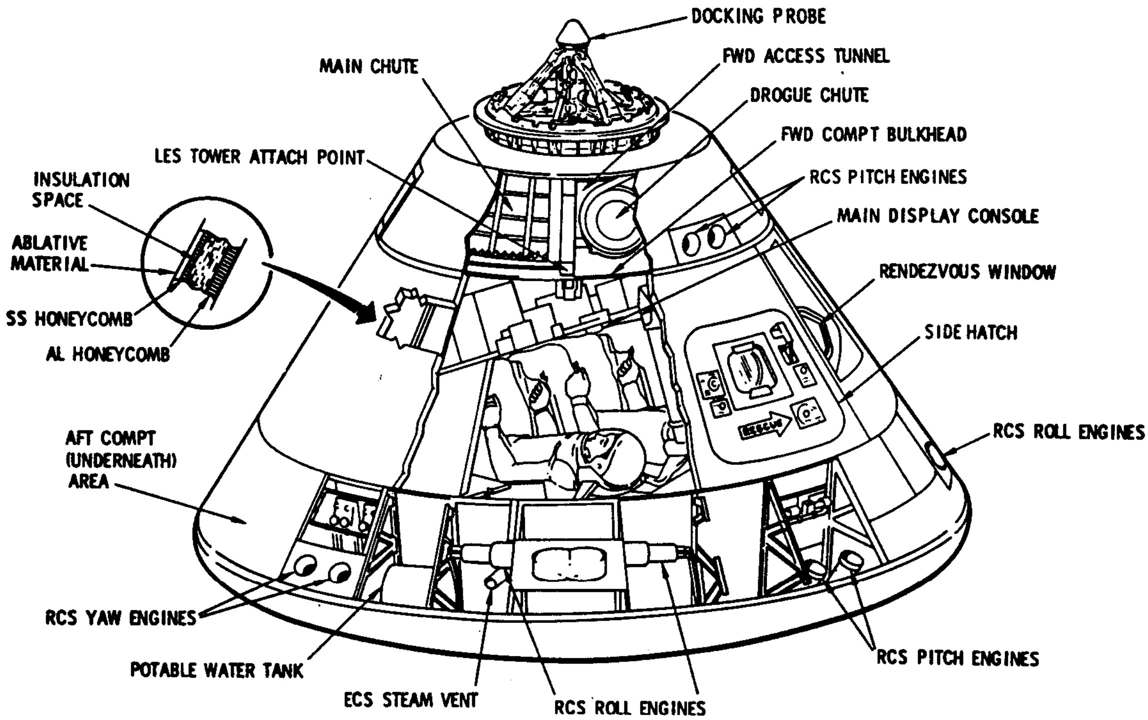
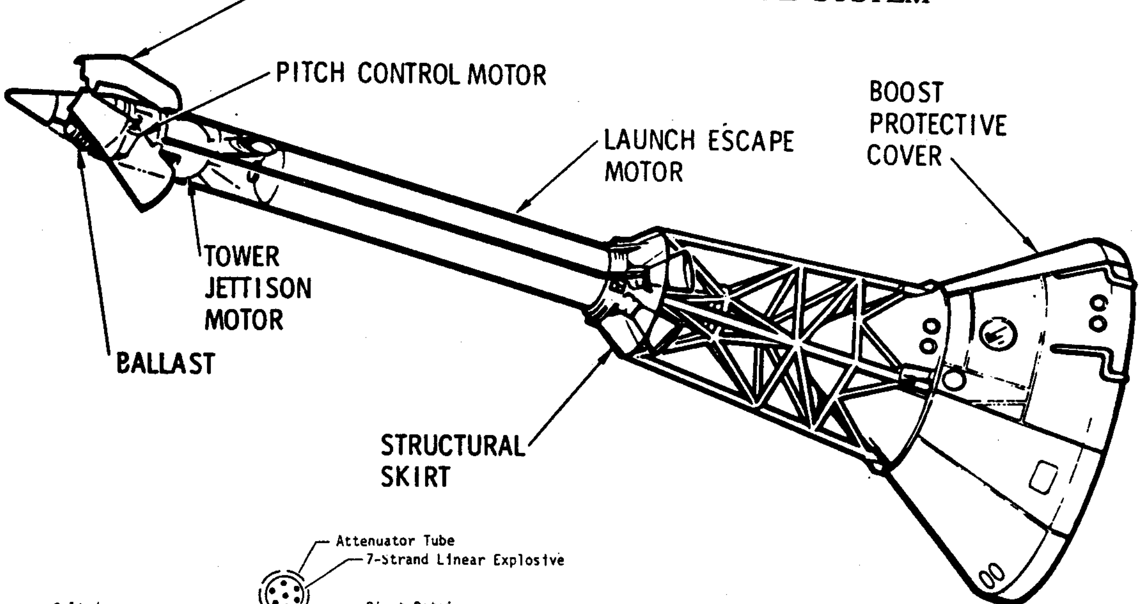



**Figure I-40 — Command Module**

## LAUNCH ESCAPE SYSTEM



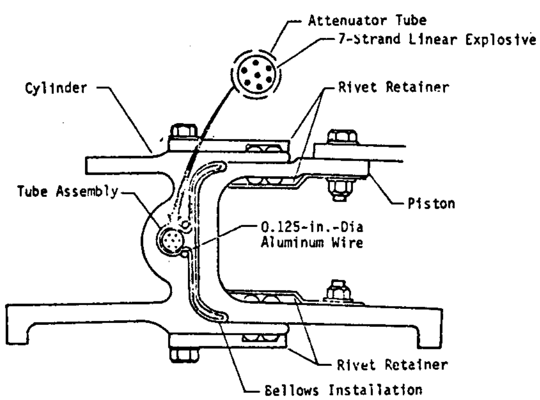




**Figure I-37 — PS Separation Bellows**

PS Payload Shroud
Diameter 6.6 meters (21.7 feet)
Length 16.8 meters (56 feet)
Weight 11,794 kilograms (26,000 pounds)

ATM Wi Apollo Telescope Mount
Width 3.3 meters (11 feet)
Height 4.4 meters (14.7 feet)
Weight 11,181 kilograms (24,650 pounds)

MDA Multiple Docking Adapter
Diameter 3 meters (10 feet)
Length 5.2 meters (17.3 feet)
Weight 6,260 kilograms (13,800 pounds)

AM Airlock Module
Diameter STS 3 meters (10 feet)
Diameter FAS 6.6 meters (21.7 feet)
Length 5.3 meters (17.5 feet)
Weight 22,226 kilograms (49,000 pounds)

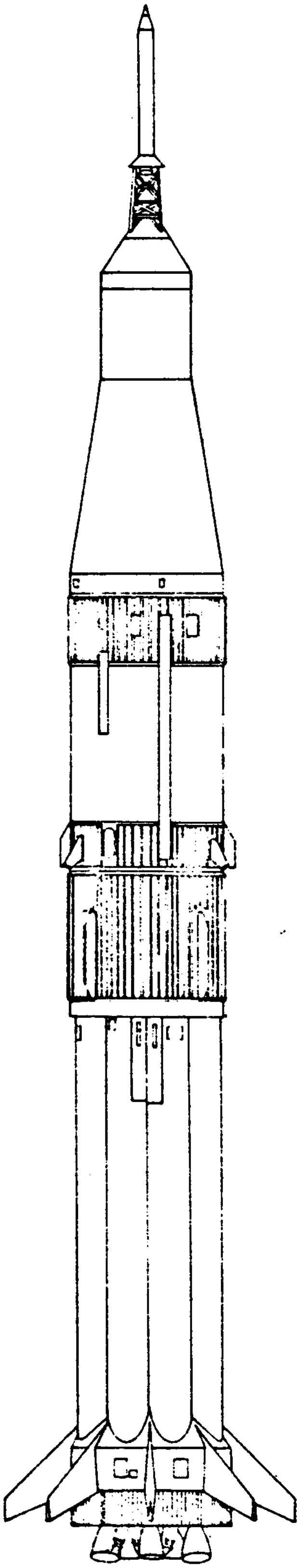
IU Instrument Unit
Diameter 6.6 meters (21.7 feet)
Length 0.9 meter (3 feet)
Weight 2,064 kilograms (4,550 pounds)

OWS Orbital Workshop
Diameter 6.6 meters (21.7 feet)
Length 14.6 meters (48.5 feet)
Weight 35,380 kilograms (78,000 pounds)

S-II Second Stage
Diameter 10 meters (33 feet)
Length 24.8 meters (81.5 feet)
Weight 488,074 kilograms (1,076,000 pounds) fueled
35,403 kilograms (78,050 pounds) dry
Engines J-2 (5)
Propellants: Liquid Oxygen 333,837 liters (88,200 gallons)
Liquid Hydrogen 1,030,655 liters (272,300 gallons)
Thrust 5,150,000 Newtons (1,150,000 pounds)
Interstage Approx. 5,171 kilograms (11,400 pounds)

S-IC First Stage
Diameter 10 meters (33 feet)
Length 42 meters (138 feet)
Weight 2,245,320 kilograms (4,950,000 pounds) fueled
130,410 kilograms (287,500 pounds) dry
Engines F-1 (5)
Propellants: Liquid Oxygen 1,318,315 liters (348,300 gallons)
RP-1 (Kerosene) 814,910 liters (215,300 gallons)
Thrust 31,356,856 Newtons (7,723,726 pounds)

**Figure I-42 — SL-1 Vehicle**



| | |
|---|---|
| LES | Launch Escape System<br>Length 10 meters (33 feet)<br>Weight 3,629 kilograms (8,000 pounds)<br>Thrust 653,856 Newtons (147,000 pounds) |
| CM | Command Module<br>Diameter 3.8 meters (12.8 feet)<br>Height 3.5 meters (11.5 feet)<br>Weight 6,033 kilograms (13,300 pounds) |
| SM | Service Module<br>Diameter 3.8 meters (12.8 feet)<br>Length 7.4 meters (24.8 feet)<br>Weight 7,938 kilograms (17,500 pounds) at Launch<br>Weight 7,462 kilograms (16,450 pounds) at Docking |
| SLA | Spacecraft/LM Adapter<br>Diameter forward end 3.8 meters (12.8 feet)<br>Diameter aft end 6.6 meters (21.7 feet)<br>Length 8.5 meters (28 feet)<br>Weight 1,952 kilograms (4,300 pounds) |
| IU | Instrument Unit<br>Diameter 6.6 meters (21.7 feet)<br>Height 0.9 meter (3 feet)<br>Weight 1,996 kilograms (4,400 pounds) |
| S-IVB | Second Stage<br>Diameter 6.6 meters (21.7 feet)<br>Length 17.8 meters (58.4 feet)<br>Weight 114,760 kilograms (253,000 pounds) fueled<br>10,433 kilograms (23,000 pounds) dry<br>Engine J-2 (1)<br>Propellants: Liquid Oxygen 75,700 liters (20,000 gallons)<br>Liquid Hydrogen 242,240 liters (64,000 gallons)<br>Thrust 1,000,800 Newtons (225,000 pounds)<br>Interstage Approx. 2,948 kilograms (6,500 pounds) |
| S-IB | First Stage*<br>Diameter 6.5 meters (21.4 feet)<br>Length 24.4 meters (80.2 feet)<br>Weight 452,240 kilograms (997,000 pounds) fueled<br>38,347 kilograms (84,540 pounds) dry<br>Engines H-1 (8)<br>Propellants: Liquid Oxygen 249,810 liters (66,000 gallons)<br>RP-1 (Kerosene) 157,077 liters (41,500 gallons)<br>Thrust 7,294,700 Newtons (1,640,000 pounds) |

* Approximations for AS-206 vehicle.

**Figure I-43 — SL-2 Vehicle**

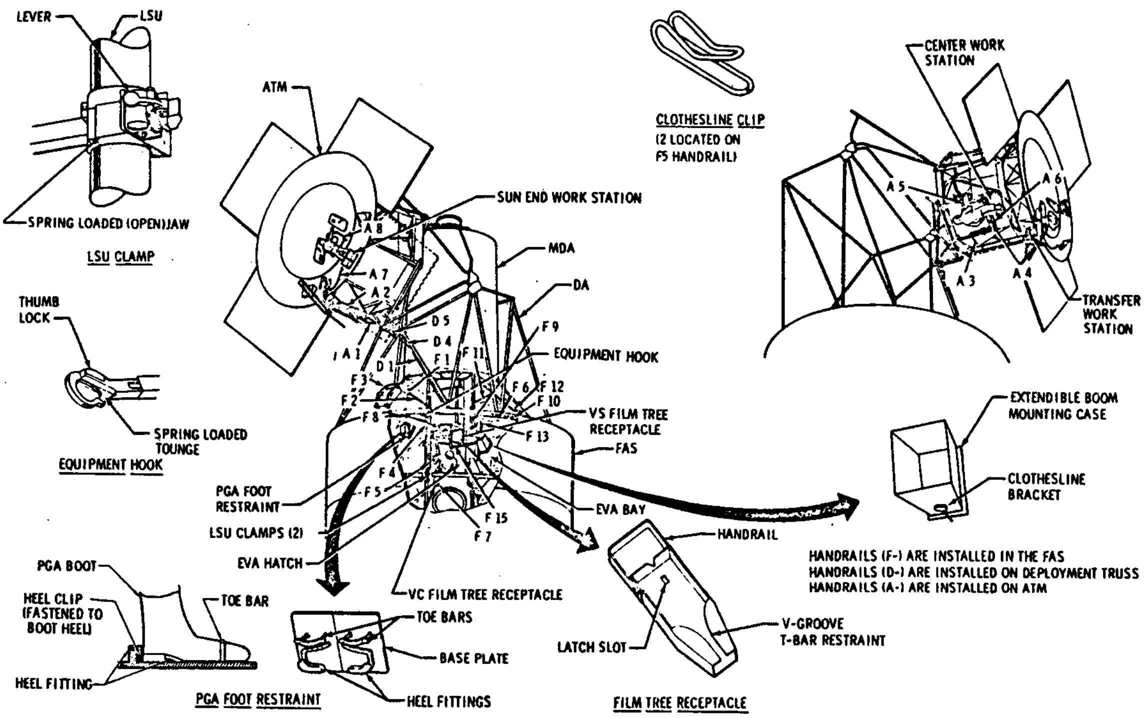



**Figure I-45 — External Restraints And Mobility Aids**

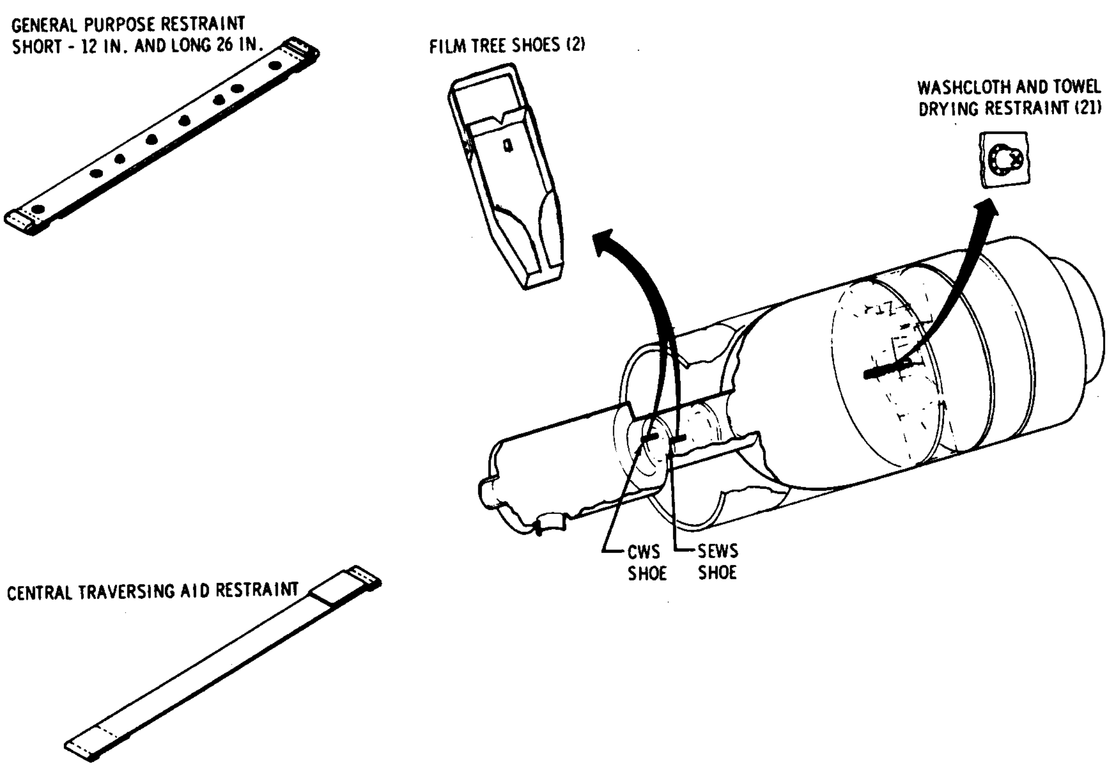



**Figure I-46 — Equipment Restraints**

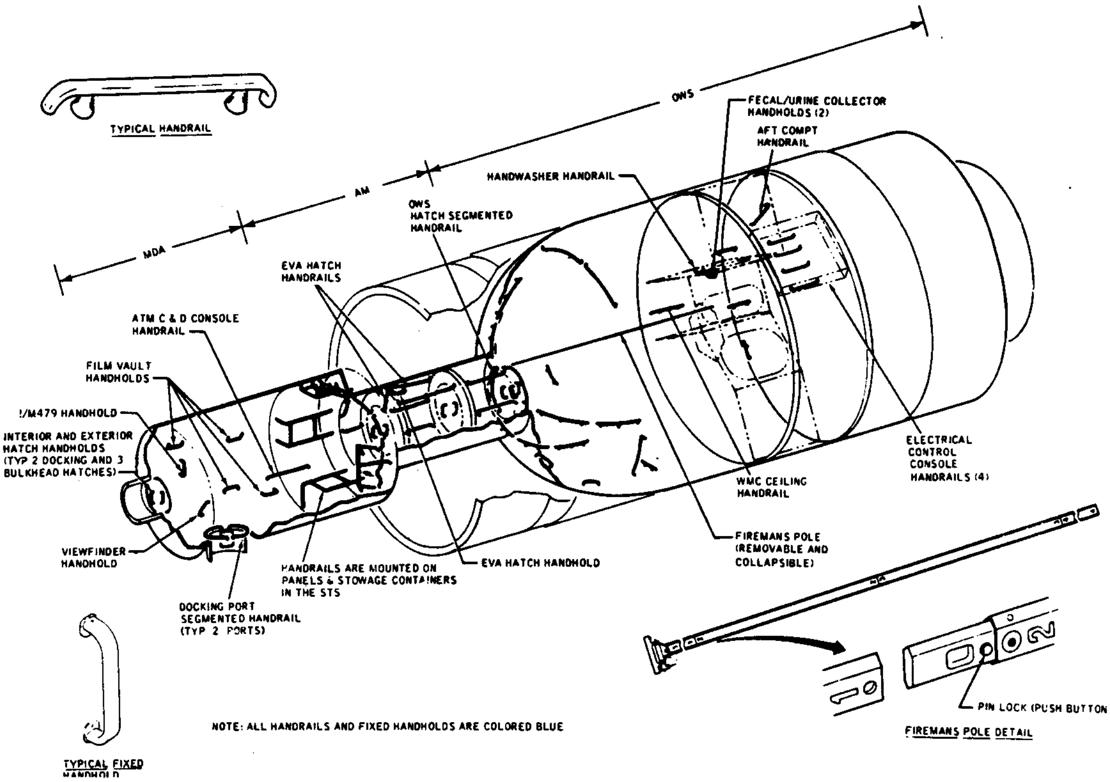



**Figure I-47 — Hand Restraints**

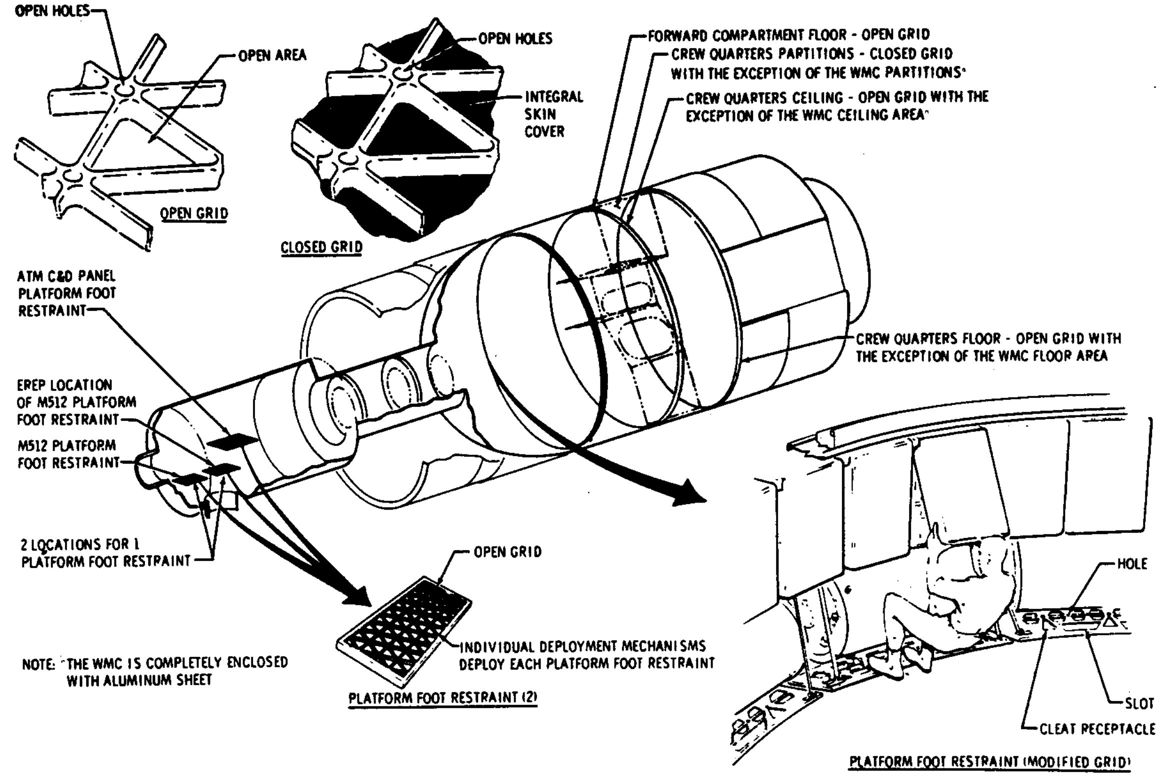



**Figure I-48 — Grid Type Restraints**

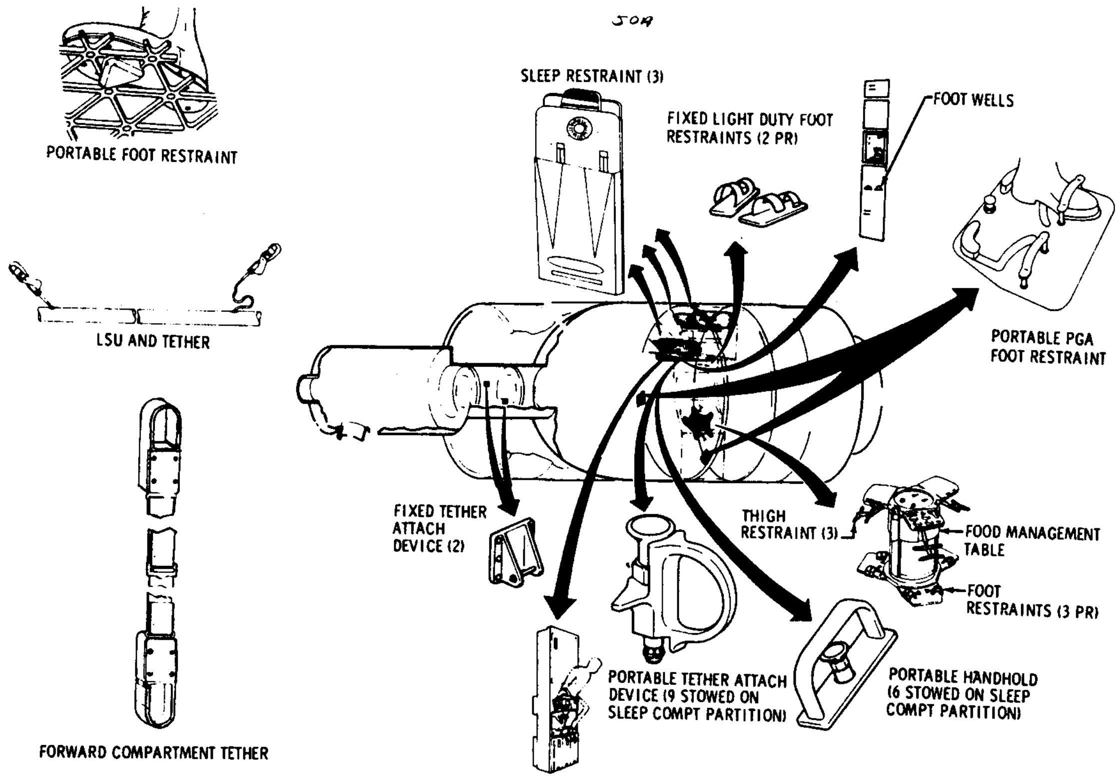



**Figure I-49 – Crewman Restraints**

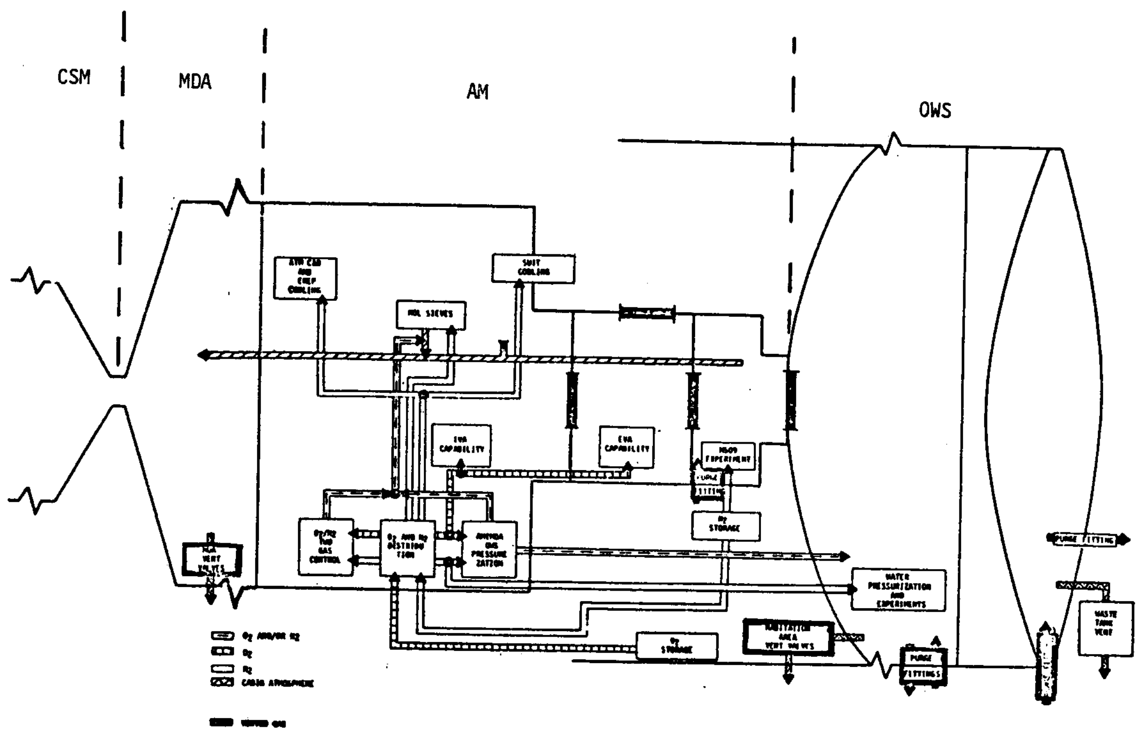



**Figure II-1 – Pressurization and Gas Distribution**

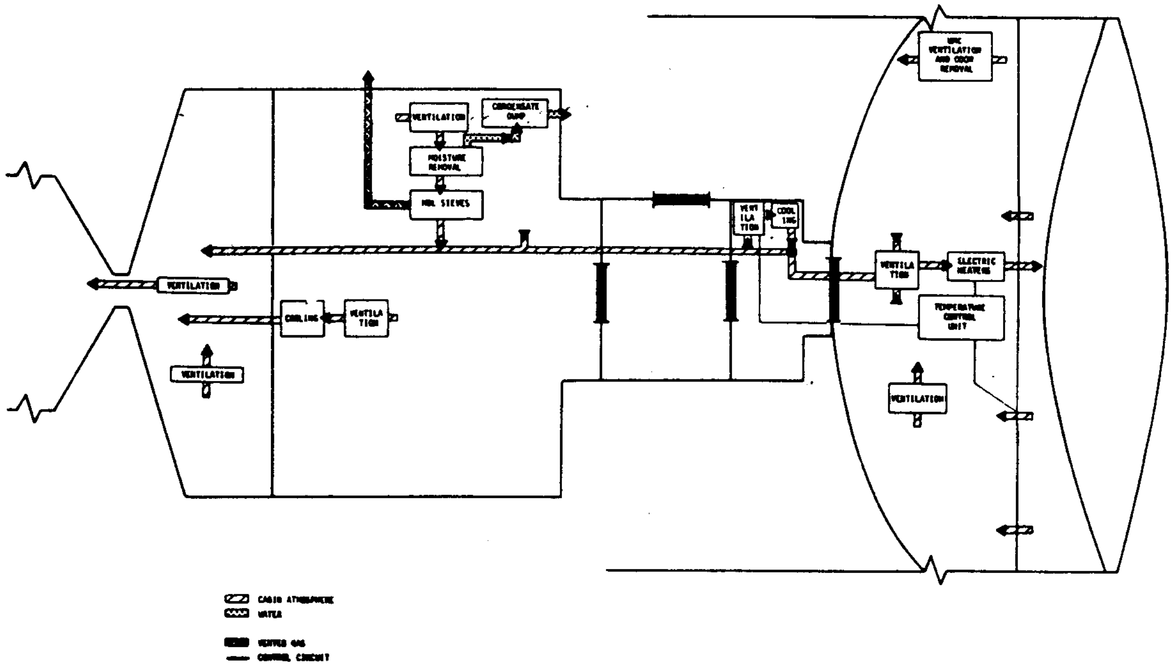


**Figure II-2 — Atmosphere Control Diagram**

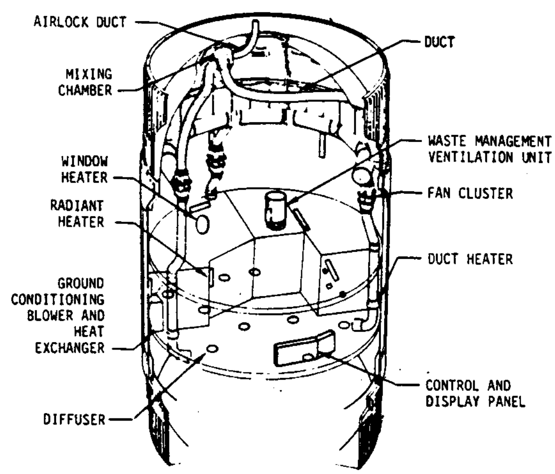



**Figure II-3 — OWS Atmosphere Control Equipment**

| Characteristic | Skylab | Earth |
|---|---|---|
| Oxygen | 72% | 21% |
| Nitrogen | 24 to 28% | 79% |
| Pressure | 3.45 $N/cm^2$ (5 psia) | 10.13 $N/cm^2$ (14.7 psia) |
| Temperature | 15.6°-32°C (60-90°F) | Variable |
| Dew Point | 8°-15.6°C (46°-60°F) | Variable |

Table II-2 — Water Tank Budget

| Function | Maximum 3 Crewmen Use Rate | Total Requirement, kg (lb) | Containers Required* | Remaining Usable, kg (lb) |
|---|---|---|---|---|
| CM return | 10.9 kg (24 lb)/mission | 32.7 (72) | [1, 10, 2, 3, 4, 5] | |
| Metabolic | 10.2 kg (22.5 lb)/day | 1373.9 (3,028.9) | 6 | (266.79) 121 |
| WR system bleed (end of mission) | 6.4 kg (14 lb)/mission | 20.4 (45.00) | (3,549.6 lb) 1610 kg | |
| WR system microbiological flush | 9.5 kg (21 lb) start 1st mission<br>26.3 kg (58 lb) start 2 and 3 missions | 62.1 (137.00) | | |
| WM system bleed (end of mission) | 4.5 kg (10 lb)/mission | | | |
| Housekeeping | 1.8 kg (4 lb)/day | 243.4 (536.52) | [7, 8, 9] 3 | |
| Personal Hygiene | 1.4 kg (3 lb)/day | 182.5 (402.39) | (1,774.8 lb) 805 kg | (453.39) 205.7 |
| OWS shower | 2.7 kg (6 lb)/shower (1 shower/man/week) | 163.3 (360.00) | | |
| Urine flush | 600 ml/day | 82.1 (180.99) | [6] 1 | |
| EVA & C&D panel | | 29.5 (65.06) | | |

*Based on actual usable quantity of 266.2 kg (591.6 pounds) per container.

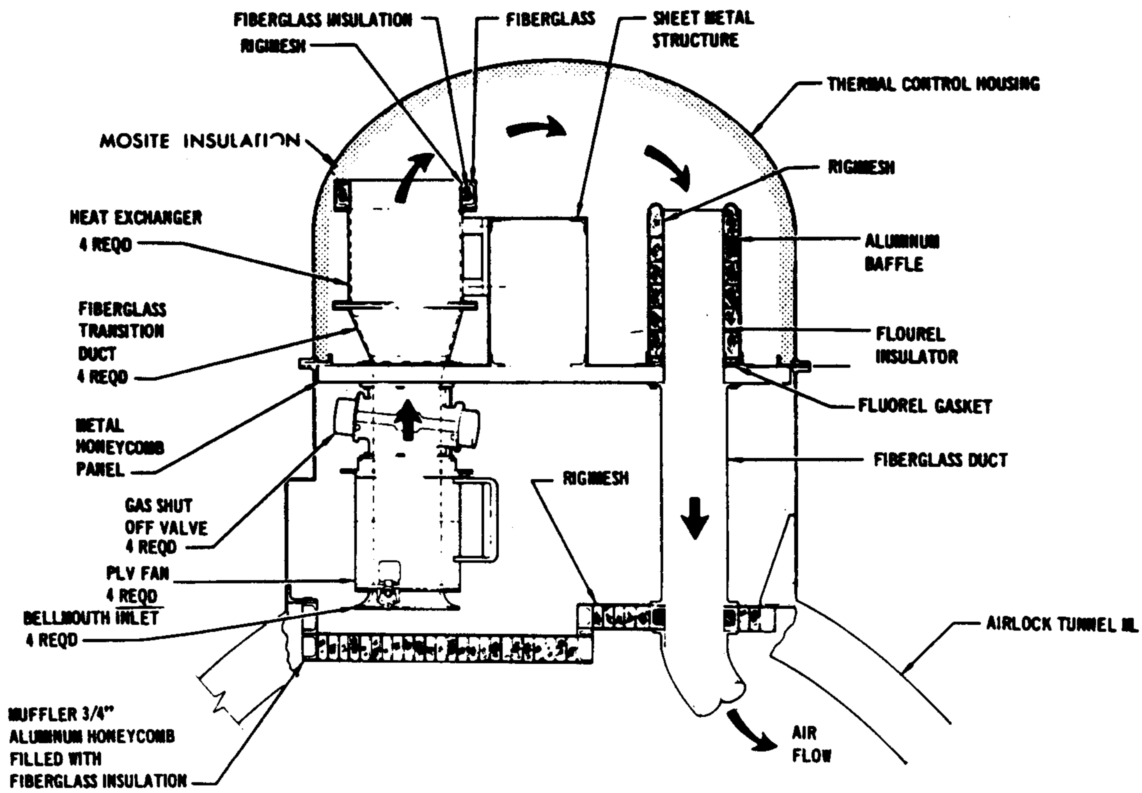



Figure II-4 – OWS Fan-Muffler

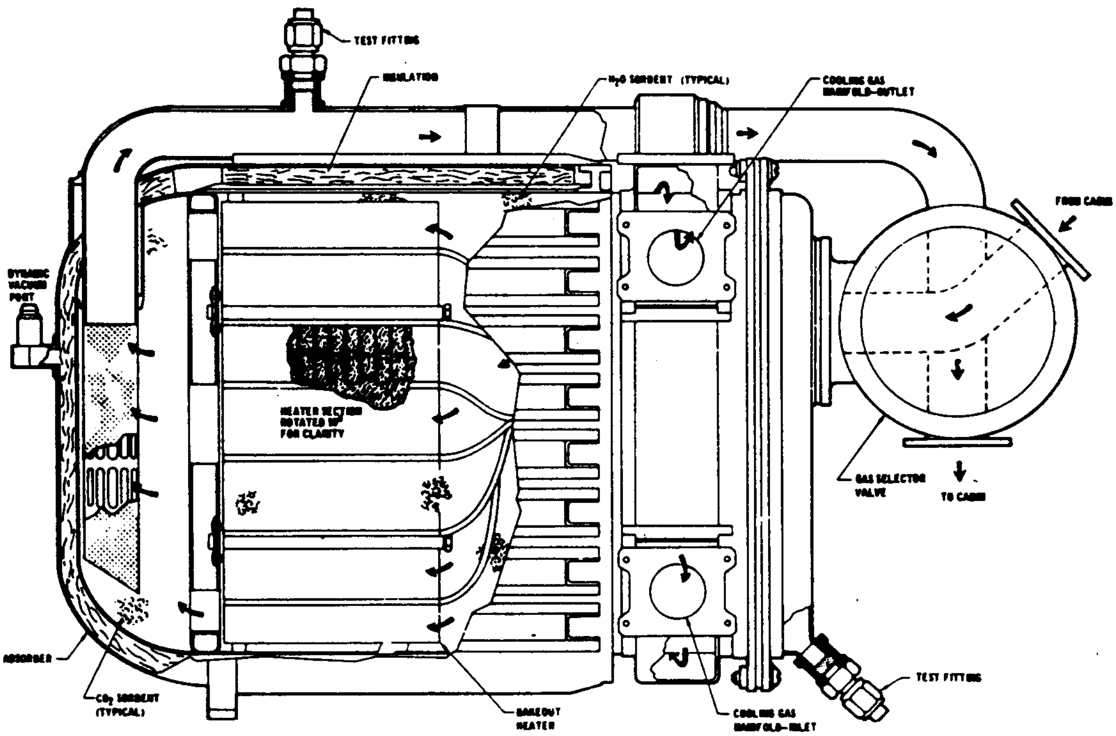



Figure II-5 – Molecular Sieve Bed, Adsorb Mode

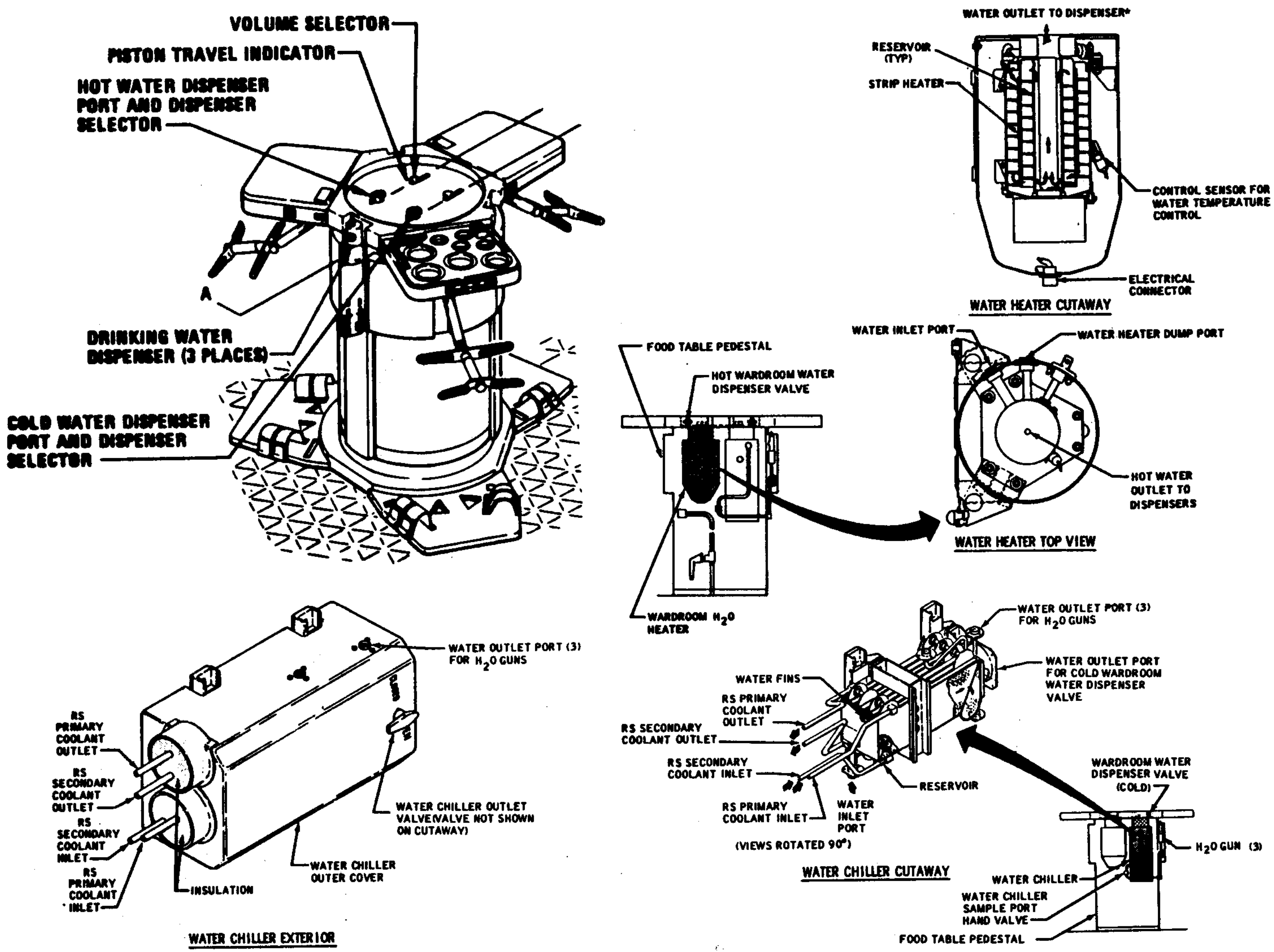



Figure II-9 — Food Table Pedestal

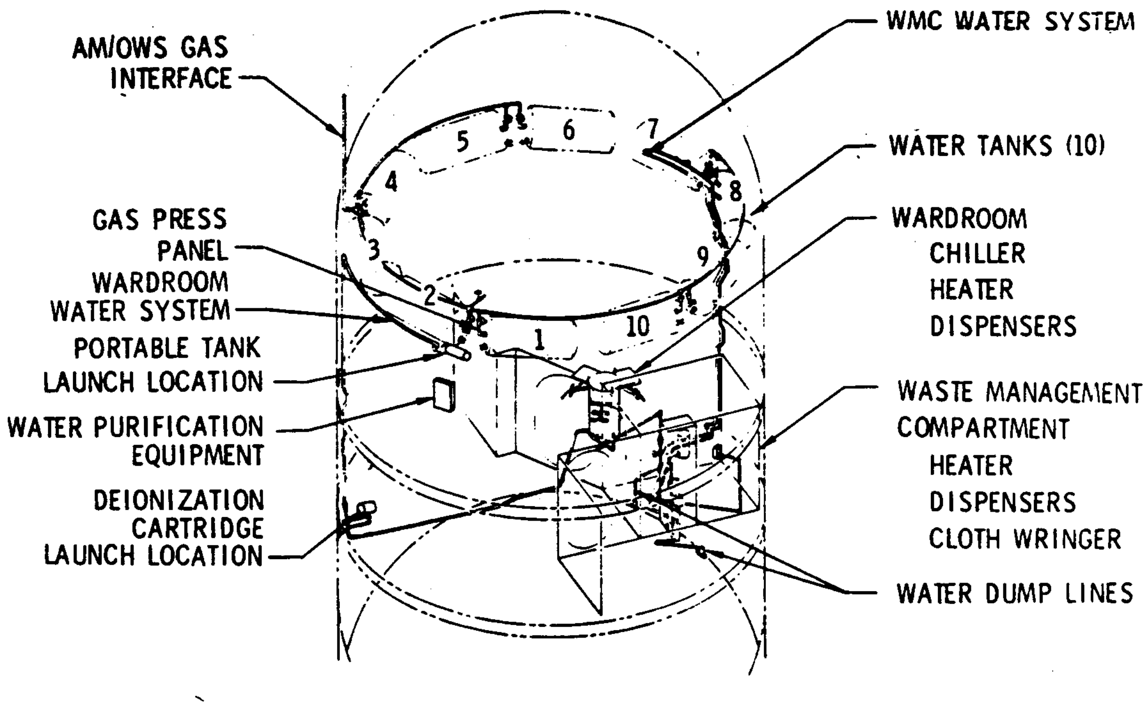



**Figure II-6 — OWS Water Systems**

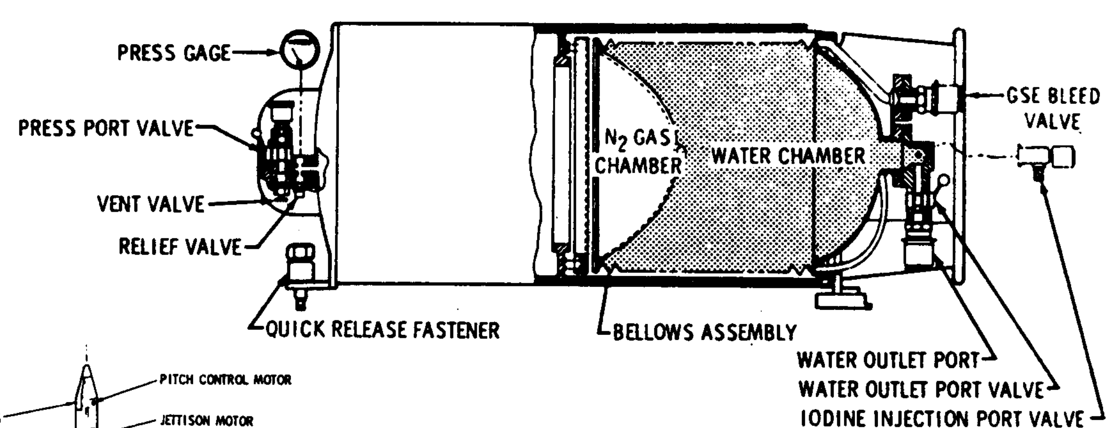



**Figure II-10 — Portable Water Tank Cutaway**

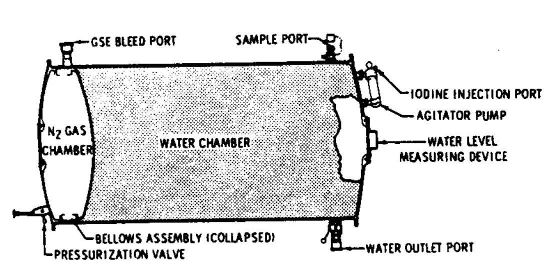



**Figure II-8 — Water Tank Cutaway**

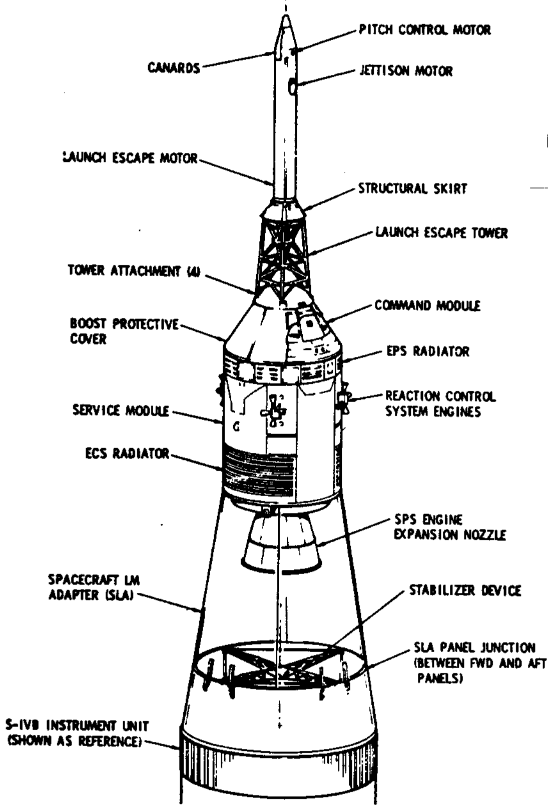



**Figure I-39 — CSM With LES**

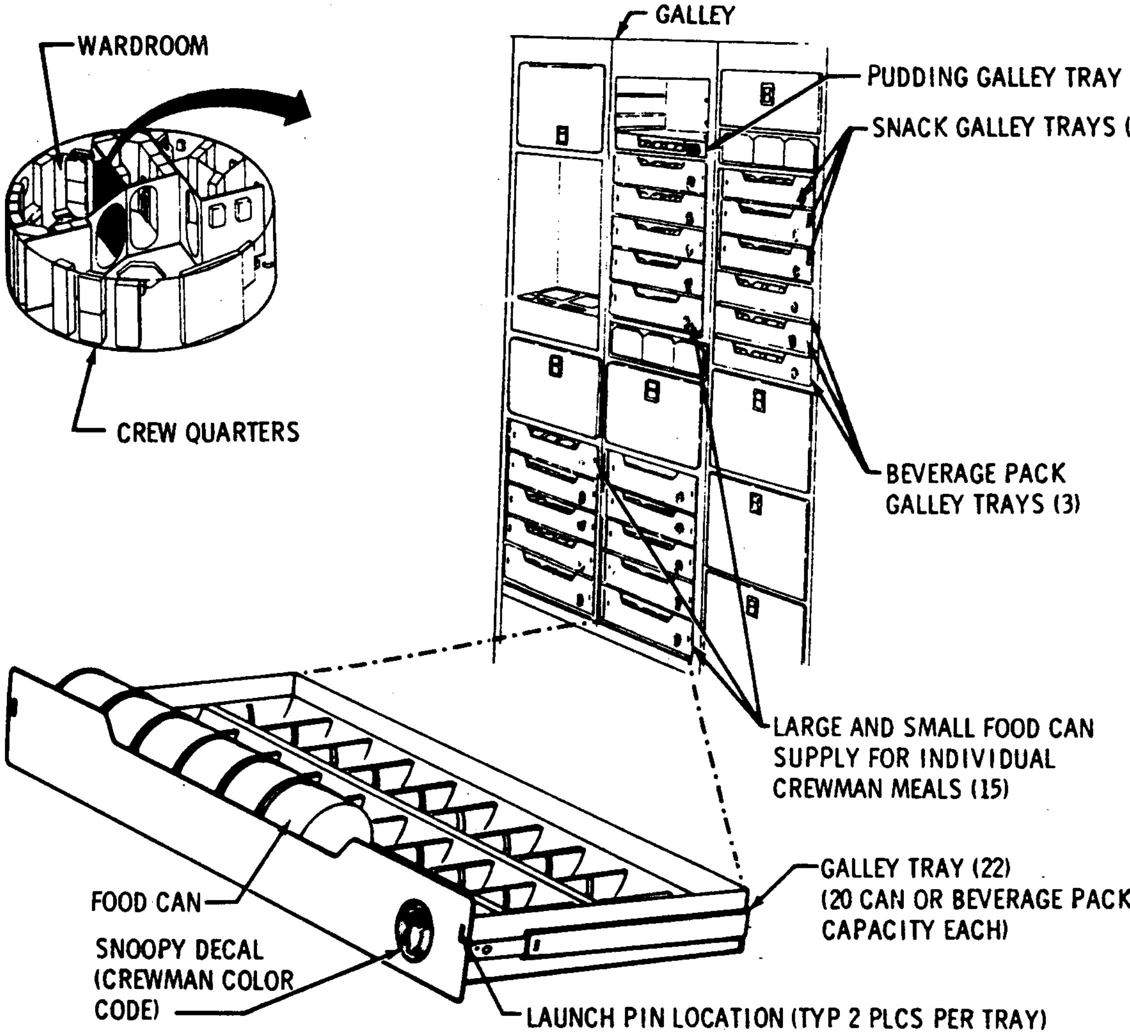



**Figure II-13 — Non-Refrigerated Food Storage — Daily**

**Figure II-17 — Food Table Restraints**

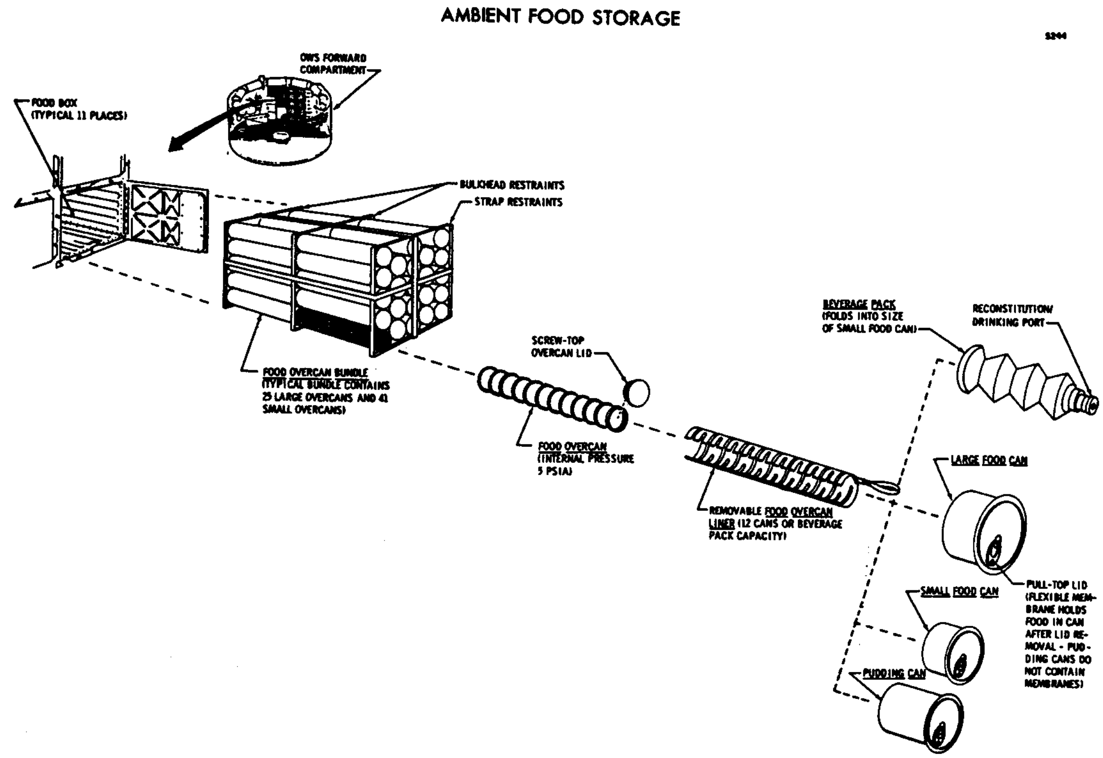



Figure II-14 – Non-Refrigerated Food Storage

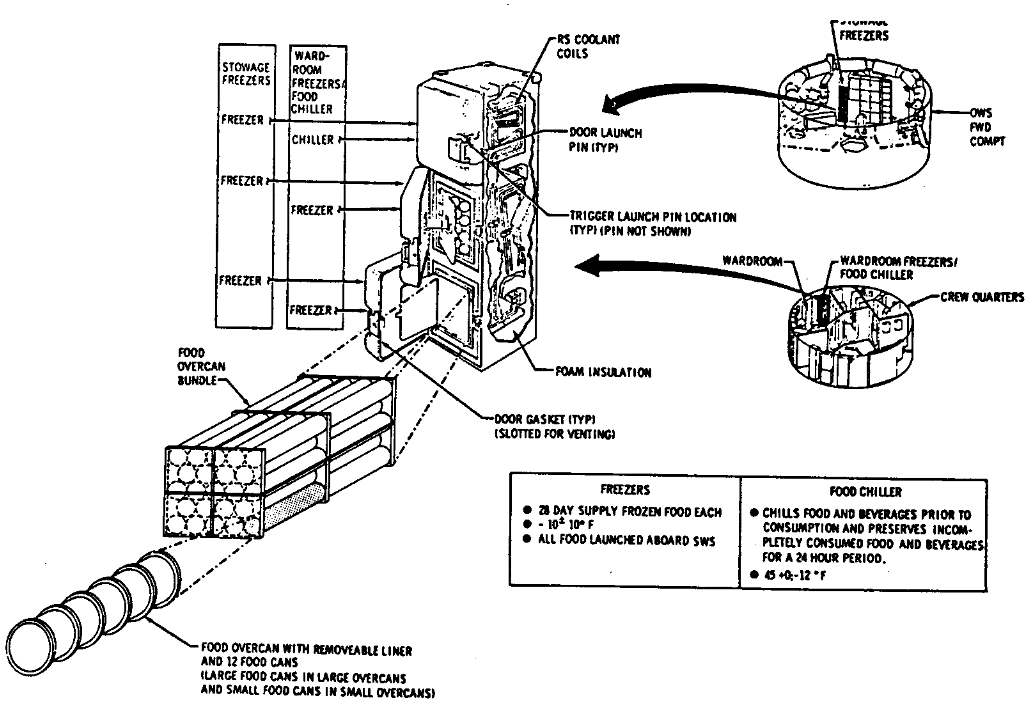
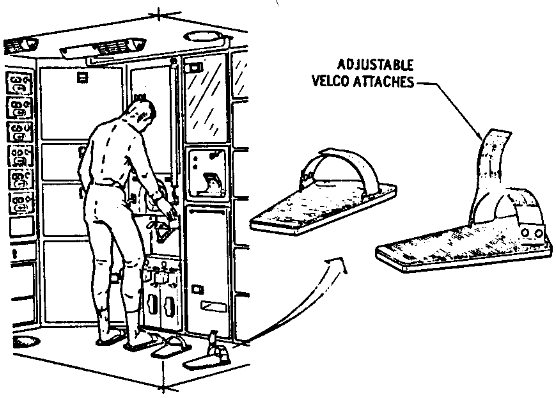



Figure II-15 – Chilled and Frozen Food Storage



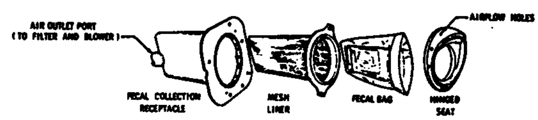




Figure II-20 — Fecal Collection Assembly

Figure II-19 — Foot Restraints at Urine Collector

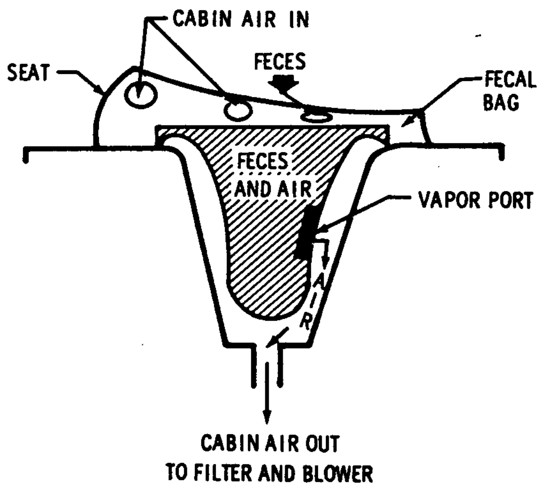



Figure II-21 — Fecal Collection

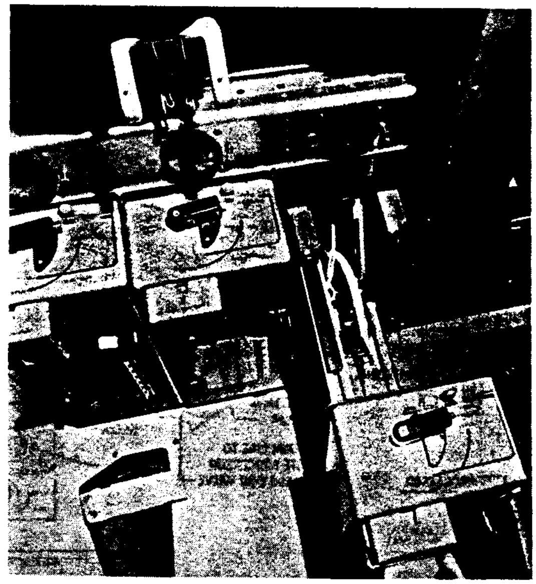


Figure II-22 — Urine Drawer

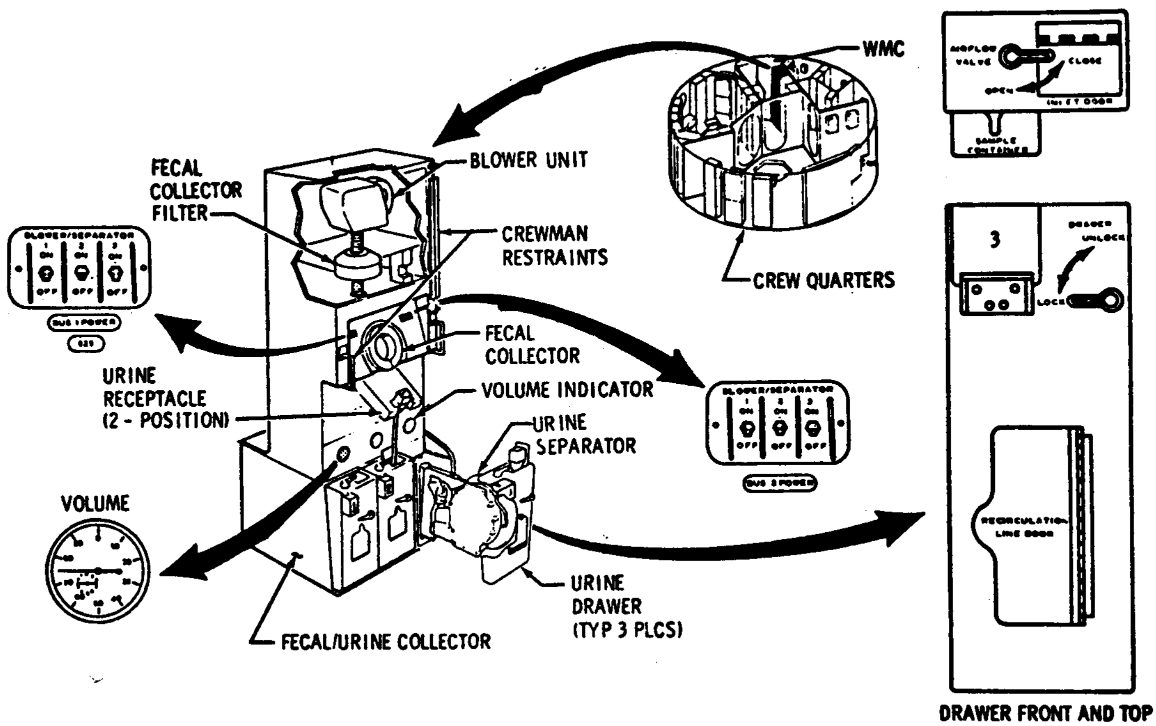
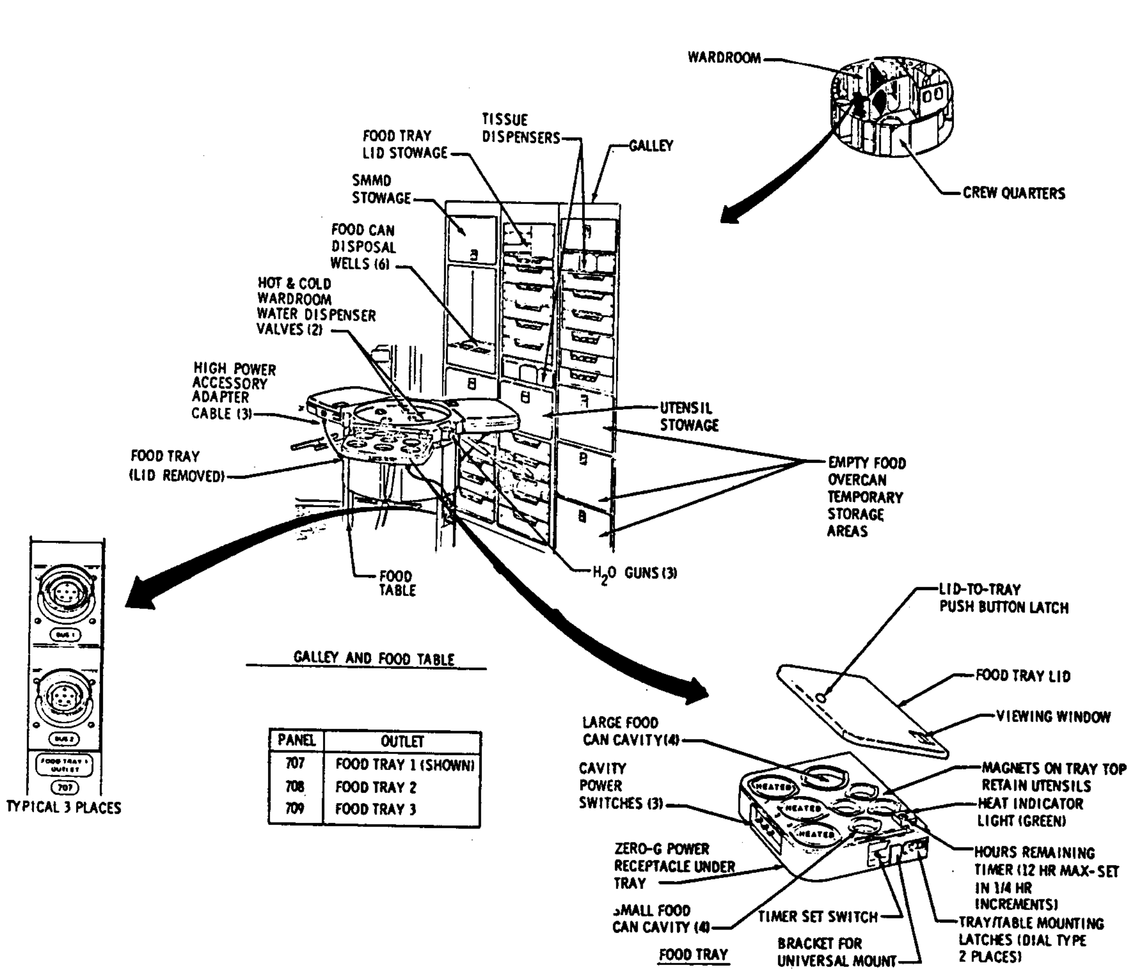



Figure II-18 — Fecal/Urine Collector




| PANEL | OUTLET |
|---|---|
| 707 | FOOD TRAY 1 (SHOWN) |
| 708 | FOOD TRAY 2 |
| 709 | FOOD TRAY 3 |

**Figure II-16 — Food Preparation Equipment**

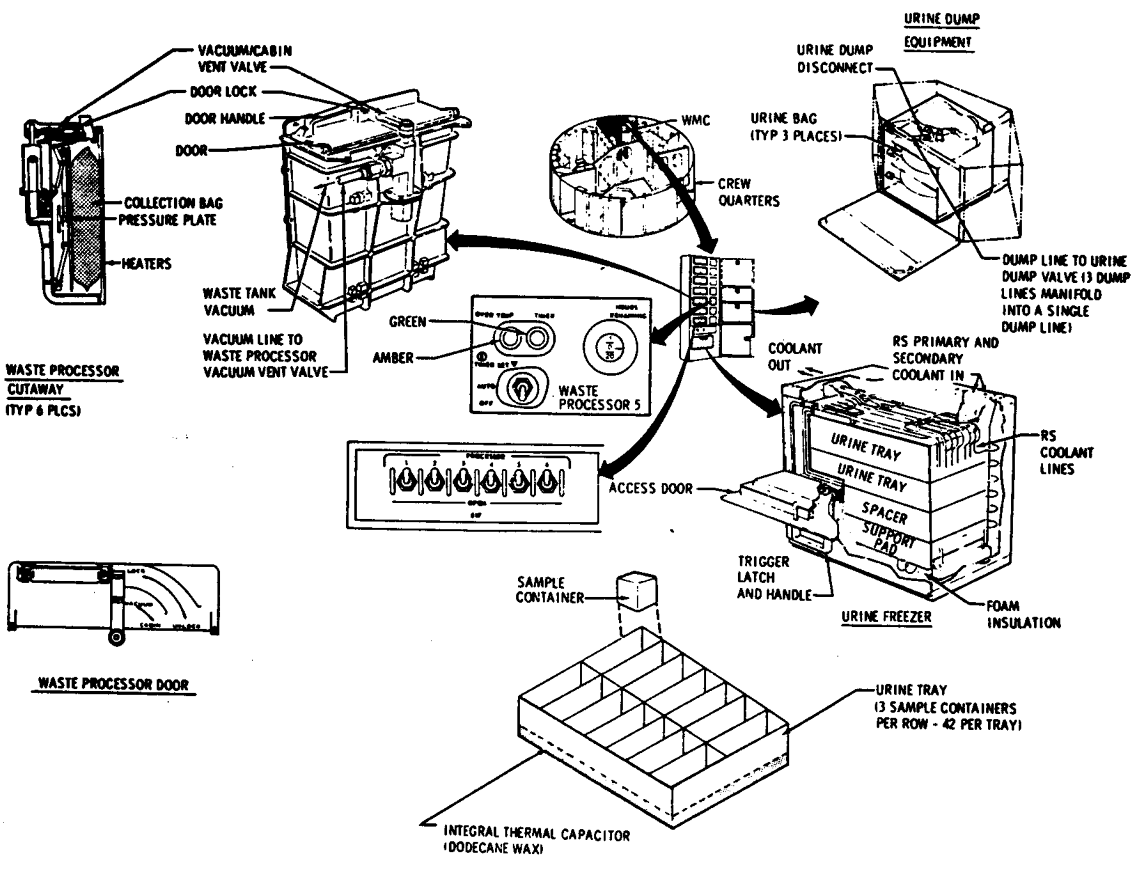



**Figure II-24 — Waste Processing**

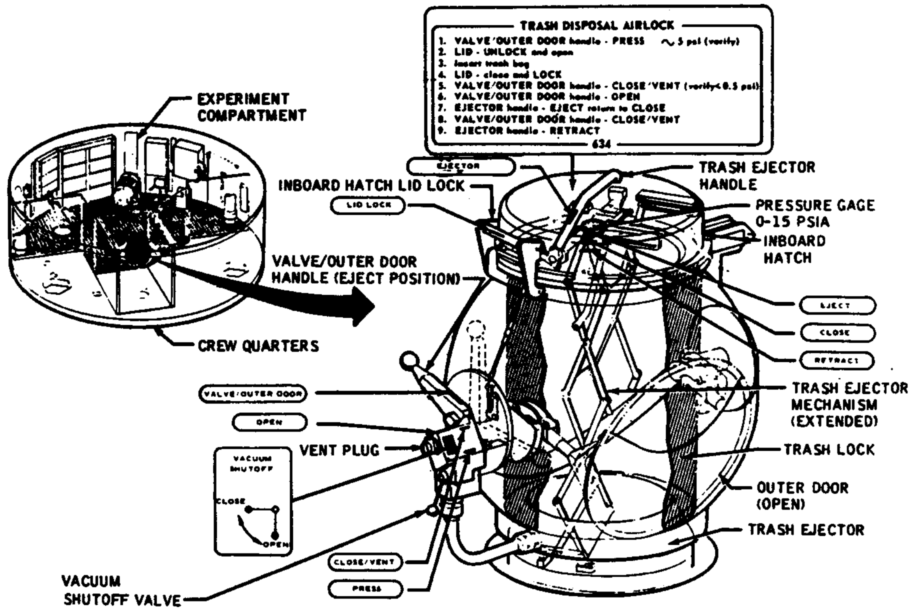



**Figure II-26 – Trash Disposal Airlock**

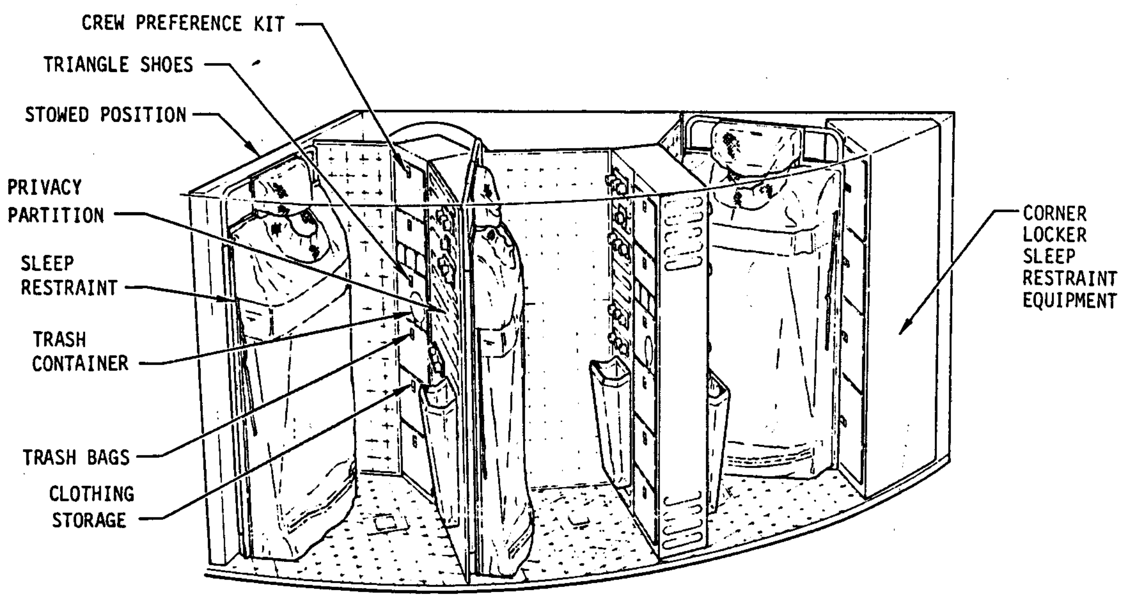



**Figure II-27 – Sleep Compartment**

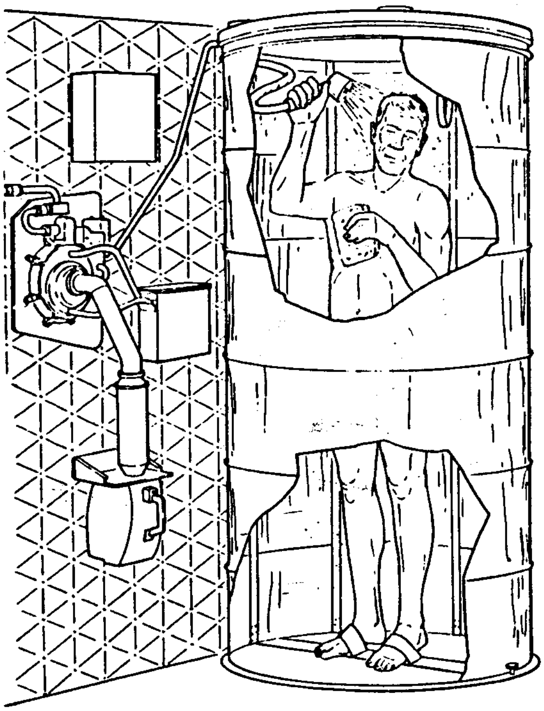


Figure II-31 – Shower

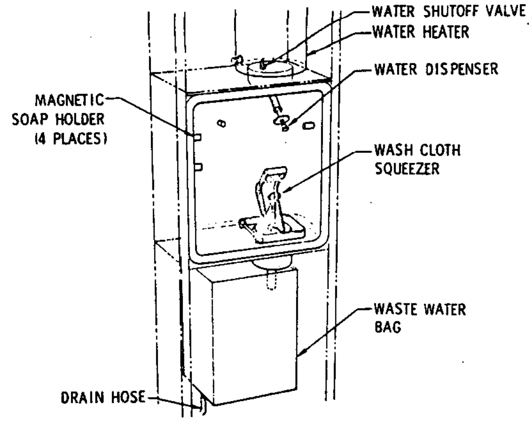



Figure II-29 – Handwasher

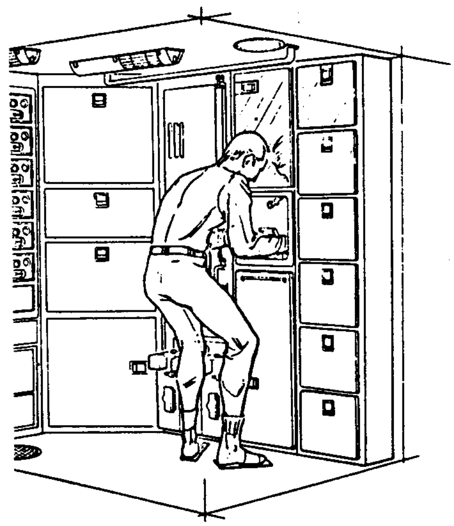


Figure II-30 – Handwasher Foot Restraints

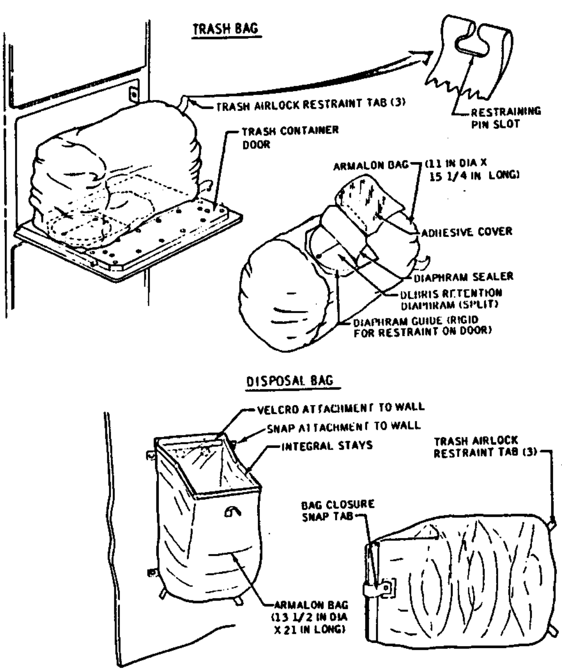
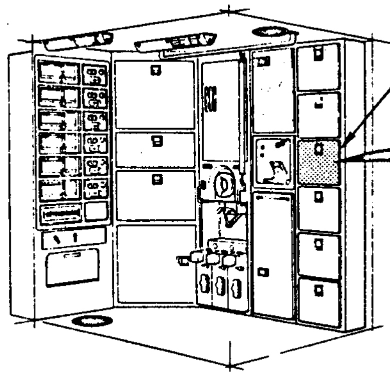
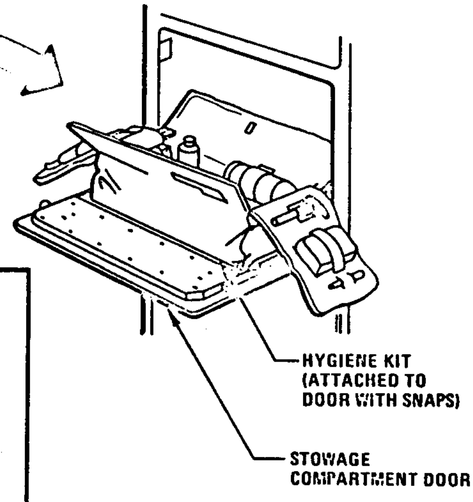



Figure II-25 – Trash and Disposal Bags

Table II-4 – Microbial Control Replacements

| Component | Replacement Schedule |
|---|---|
| Absorption Cartridge, Metabolic Analyzer | After Each Use of Analyzer |
| Protective Assembly, Ear Plug | After Each Use |
| Urine Collection and Sample Bags | Daily |
| Wash Cloth Squeezer Bag Assembly | During Activation of SL-3 and SL-4 |
| Top Blanket of Sleep Restraint | As Necessary |
| Stabilizer Assembly, $CO_2$ Stabilizer | Every 28 Days |
| Urine Inlet Hose Assembly | Daily |
| Trousers | Weekly |
| Socks, Shirts, Underwear | Every 2 Days |




**TYPICAL HYGIENE KIT CONTENTS**

| | |
|---|---|
| SHAVING CREAM | 6 OZ |
| RAZOR | 1 |
| STYPIC PENCIL | 1 |
| TOOTHPASTE | 3 OZ |
| TOOTHBRUSH | 1 |
| DENTAL FLOSS | 80 IN. |
| SOAP | 4 OZ |
| EMOLIENT | 6 OZ |
| SAFETY SWABS | 30 |
| HAIR BRUSH | 1 |
| HAIR CREAM | 3 OZ |
| NAIL CLIPPERS | 1 |
| DEODORANT | 1 1/2 OZ |
| EXPECTORANT COLLECTOR | 15 |

Figure II-32 — Personal Hygiene Kits

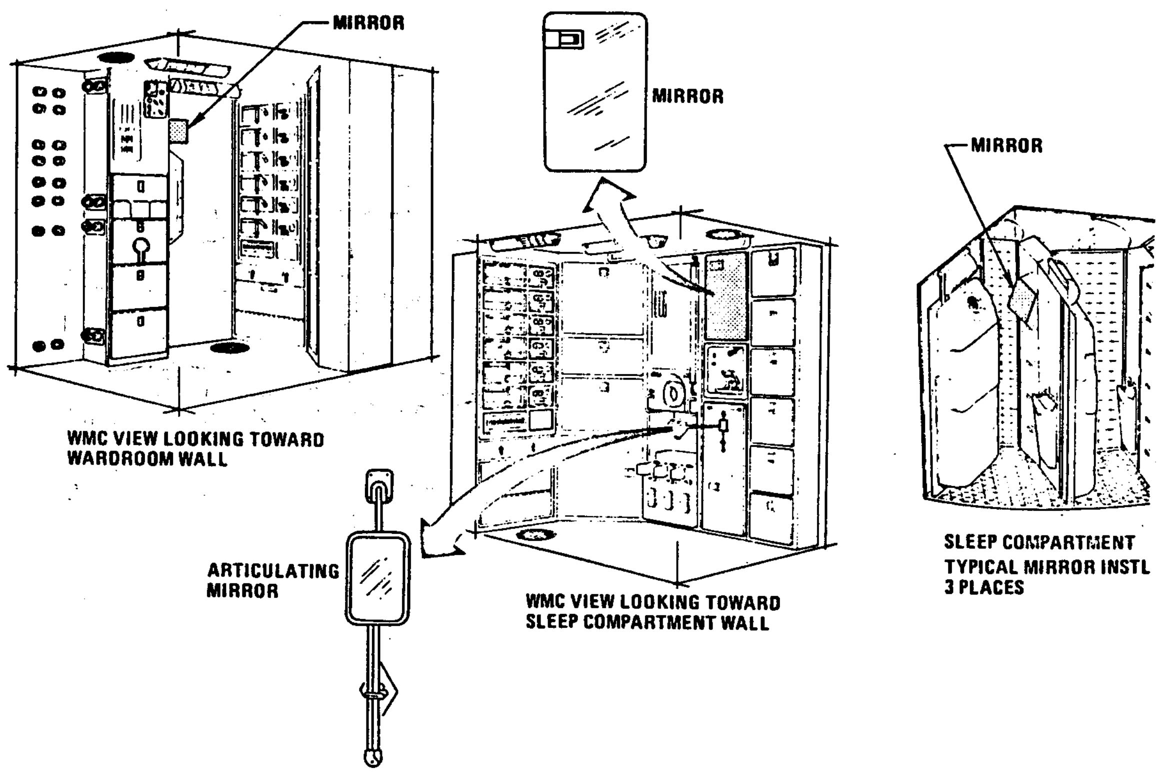



Figure II-33 — Personal Grooming Mirrors

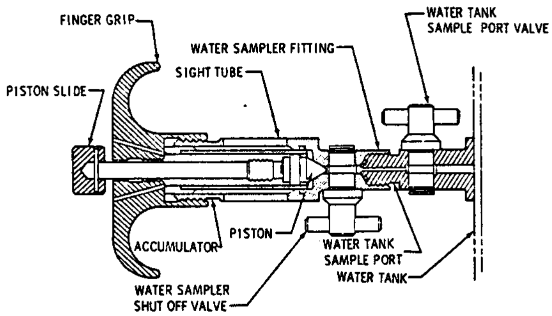



**Figure II-34 – Water Sampler**

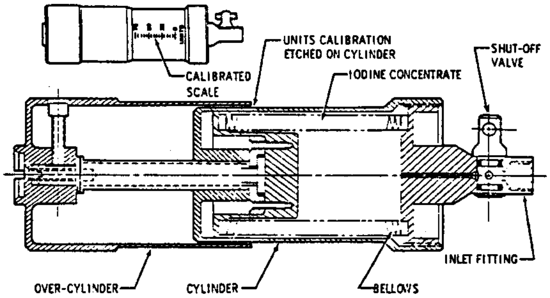



**Figure II-35 – Iodine Injector**

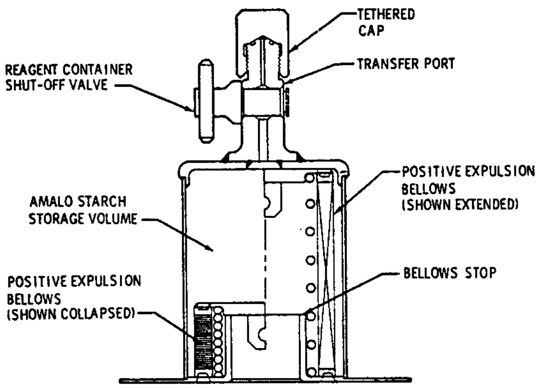



**Figure II-36 – Reagent Container**

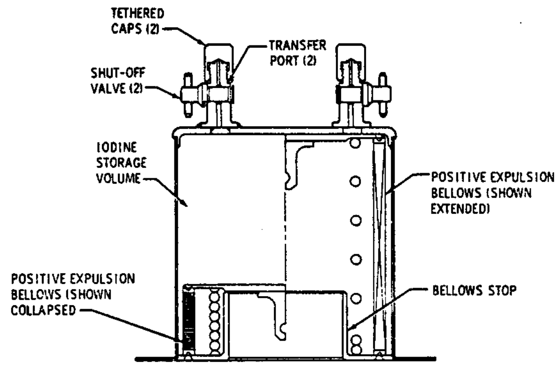



**Figure II-37 – Iodine Container**

Table II-5 – Disinfectant Wipe Schedule

| Component/Area | Disinfectant | Schedule |
|---|---|---|
| Vectorcardiogram Electrodes | Zepherin | Prior to Each Use |
| Eating Utensils | Zepherin | After Each Use |
| Food Trays | Zepherin | After Each Use |
| Urine Receiver Support | Betadine | Once Each Week |
| Fecal Collector Support Hardware | Betadine | Once Each Week |
| Trash Airlock | Betadine | Once Each Week |
| Urine Drawer | Betadine | Once Each Week |
| Urine Receiver Storage Area | Betadine | Once Each Week |
| Fecal Collector Seat | Betadine | Once Each Week |
| Food Chiller | Betadine | Every Two Weeks |
| Trash Locker Diaphragms | Betadine | Every Two Weeks |
| Urine Dump & Holding Area | Betadine | As Required |
| Vacuum Cleaner Accessories | Betadine | As Required |
| LBNPD Back Rest, Waist Seal, Inner Walls, Saddle, & Foot Restraints | Betadine | Every Two Weeks |
| Tool Kit | Betadine | Contingency |

Table II-5 (Continued)

| Component/Area | Disinfectant | Schedule |
|---|---|---|
| Food Management Area | Betadine | Contingency |
| Fecal Bags | Betadine | Contingency |
| SMMD | Betadine | Contingency |
| Blood Pressure Cuff | Betadine | Contingency |
| Metabolic Analyzer Chest Board, Exhalation Hose, & Seat | Betadine | Once Every Two Weeks |
| Biomedical Harness Electrodes | Zepherin | Prior to Each Use |
| Urine Chiller | Betadine | Once Every Two Weeks |
| Urine Inlet Support and Track Assembly | Betadine | Once Every Two Weeks |
| Urine Centrifugal Separator to Urine Storage Bag & Chiller | Betadine | Contingency |
| Fecal Collector | Betadine | In Event of Bag Rupture |
| Waste Processor | Betadine | In Event of Bag Rupture |
| Waste Process | Betadine | Contingency |
| Urine Collector or Other Areas | Betadine | In Event of Bag Rupture |
| Towel & Washcloth Drying Holder Assembly | Betadine | Once Each Week |

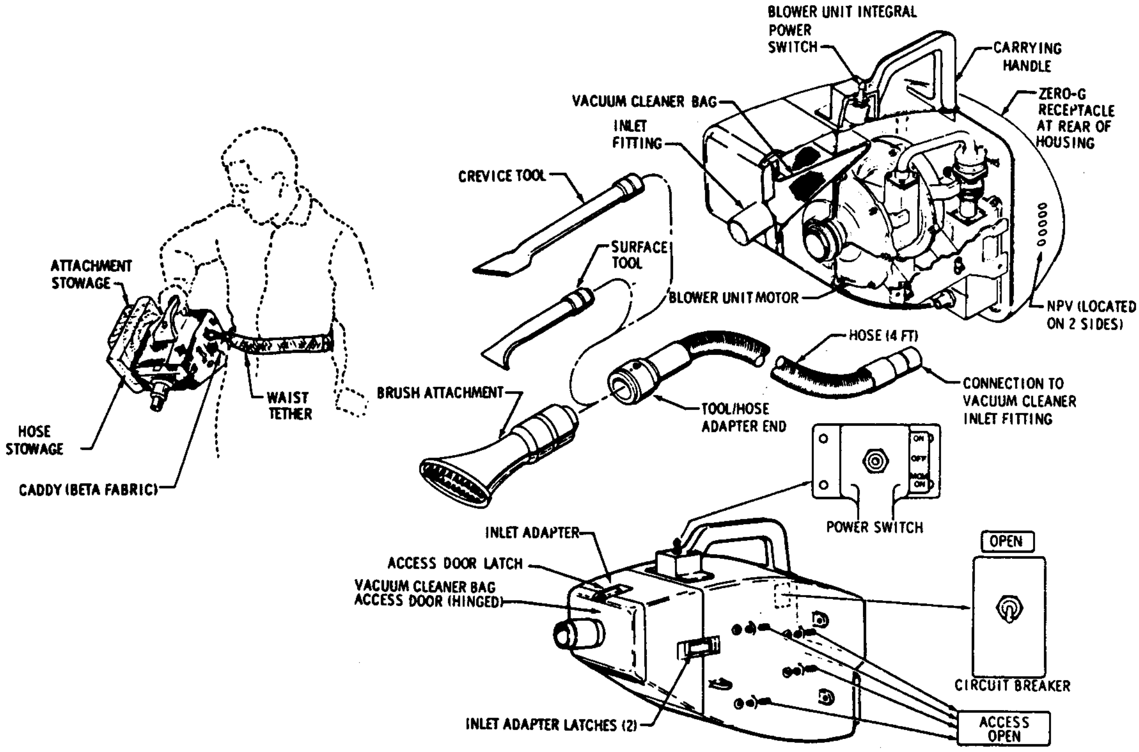



**Figure II-38 — Vacuum Cleaner and Accessories**

Table II-6 – Dry Wipe Schedule

| Equipment | Method of Cleaning | Frequency of Cleaning |
|---|---|---|
| LBNPD Waist Seal, Inner Walls, & Saddle | Utility Wipes | After Each Use |
| Vestibular Function Otolith Test Goggles & Bite Board | Utility Wipe or Tissue | After Each Use |
| Metabolic Analyzer Mouthpiece | Utility Wipe | After Each Use |
| Metabolic Analyzer BTMS Probe | Utility Wipe or Tissue | Weekly |
| Food Reconstitution $H_2O$ Dispenser | Utility Wipe or Tissue | After Each Use |
| Drinking $H_2O$ Dispenser | Utility Wipe or Tissue | After Each Use |
| Galley | Utility Wipes | After Each Use |
| Toothbrush | Utility Wipe or Tissue | After Each Use |
| Fecal Collector Seat | Utility Wipes | After Each Use |
| WMC Hand Washer | Utility Wipes | After Each Use |
| Urine Drawer | Cleaner Wipe & Utility Wipe | Daily |
| Food Chiller | Utility Wipe | Twice Each Week |
| Window Frames & Girth Ring | Utility Wipe | Weekly |

Table II-6 (Continued)

| Equipment | Method of Cleaning | Frequency of Cleaning |
|---|---|---|
| Fecal Bags | Utility Wipe or Tissue | As Required |
| Washcloth Squeezer | Utility Wipe | Contingency |
| OWS, MDA, AM Walls | Utility Wipe | Contingency |
| Personal Hygiene Equipment | Utility Wipe or Tissue | Contingency |
| Urine Chiller Cold Plate | Cleaner Wipe & Utility Wipe | Daily |
| Waste Processor Chamber | Utility Wipe | Daily |
| Urine Dump Compartment | Cleaner Wipe & Utility Wipe | Contingency |
| Urine Flush Dispenser | Utility Wipe | After Each Use |
| Urine Centrifugal Separator Compartment | Cleaner Wipe & Utility Wipe | Daily |
| Waste Processor Exterior | Utility Wipes | Weekly |
| WMC $H_2O$ Dispenser Valve | Utility Wipes | After Each Use |
| Food Management Area | Vacuum Cleaner | Contingency |
| WMC Charcoal Filter Screen | Vacuum Cleaner | Once a Week |

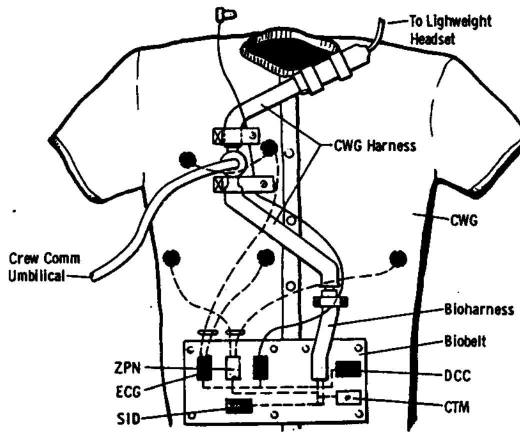



Figure II-49 — OBS Unsuited Mode

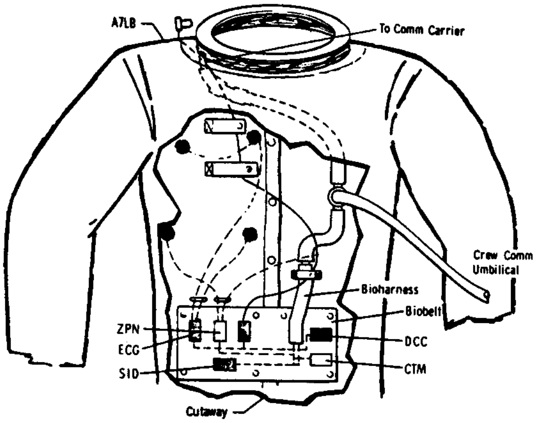



Figure II-50 — OBS Suited Mode

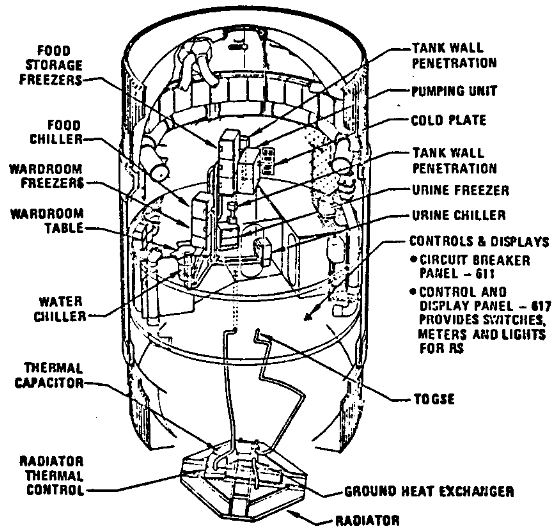



Figure II-51 — OWS Refrigeration

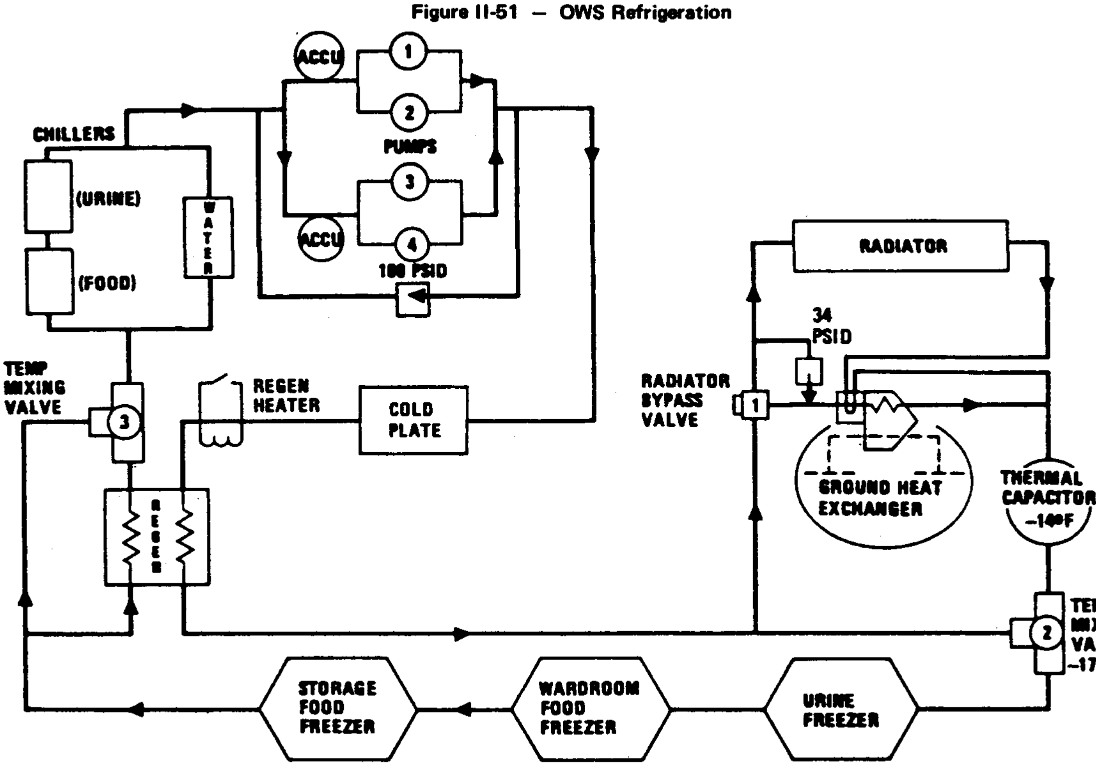



Figure II-52 — Refrigeration System

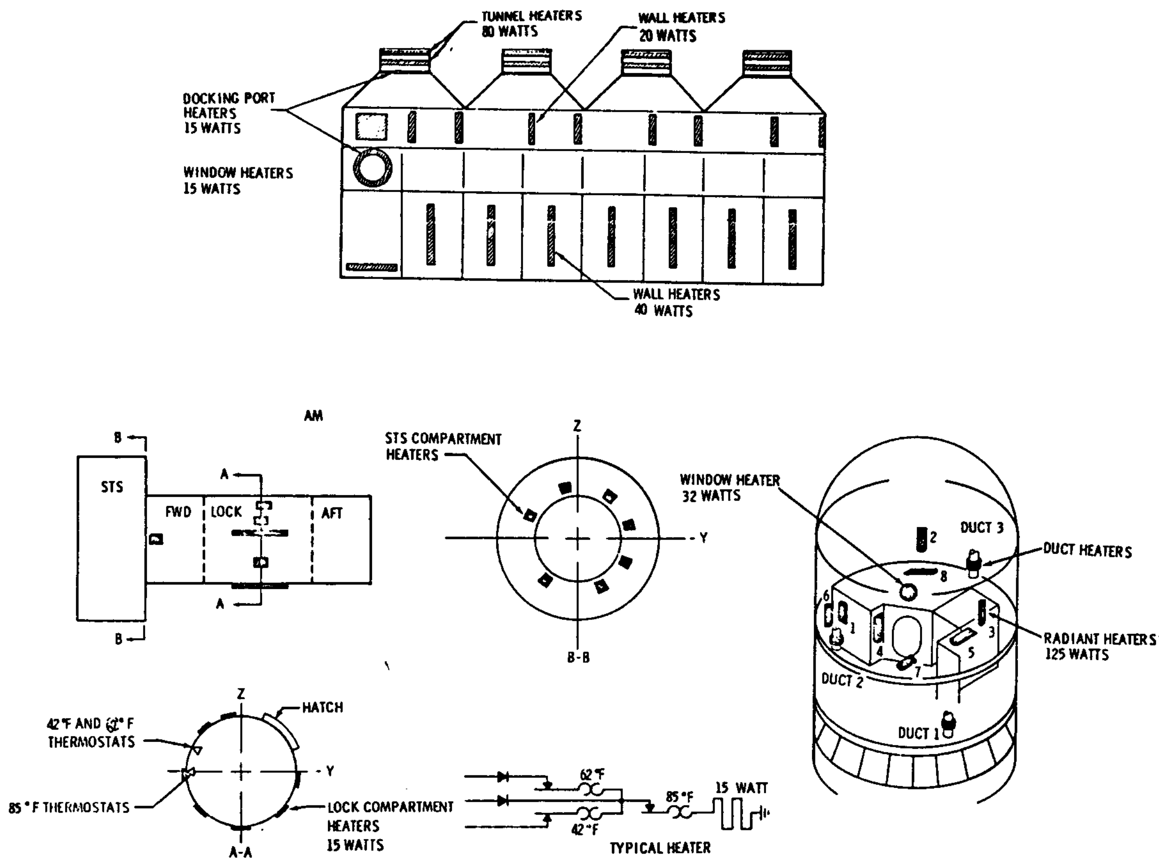



**Figure II-53 — Heater Locations**

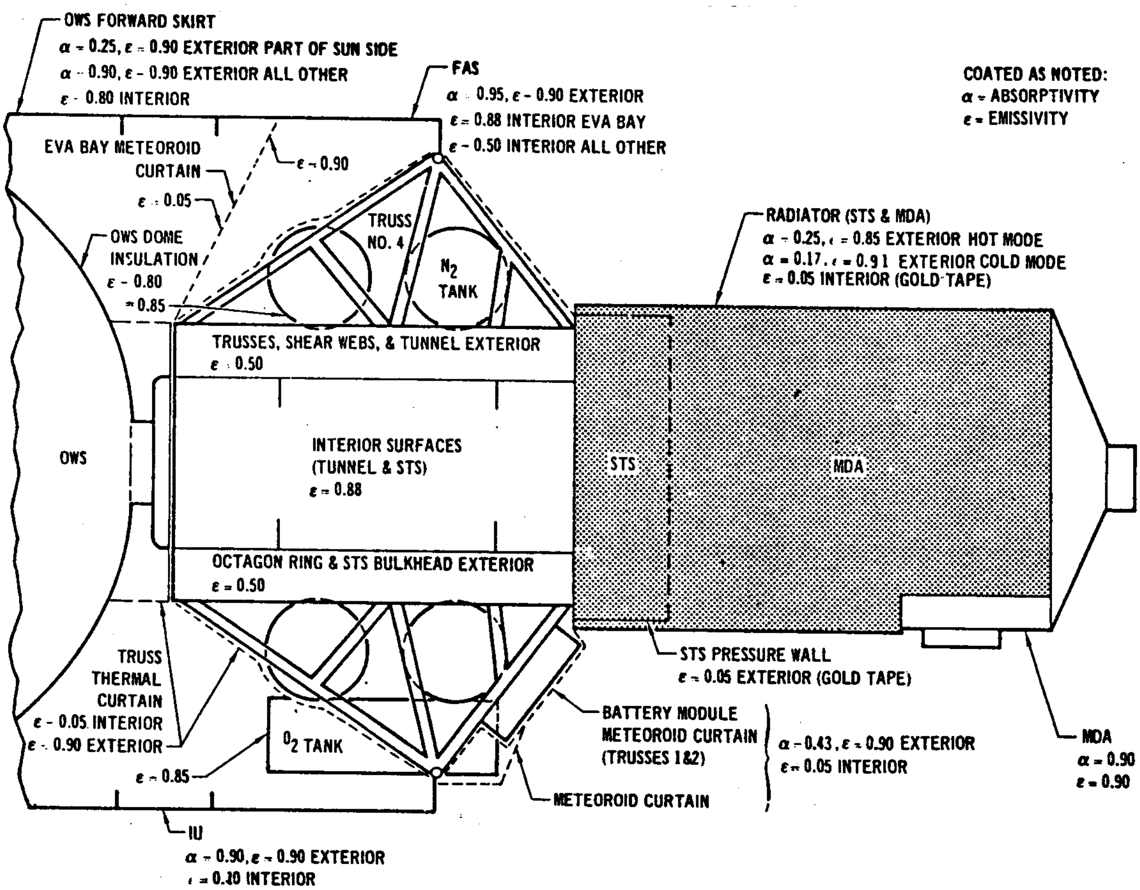



**Figure II-54 — Passive Thermal Control**

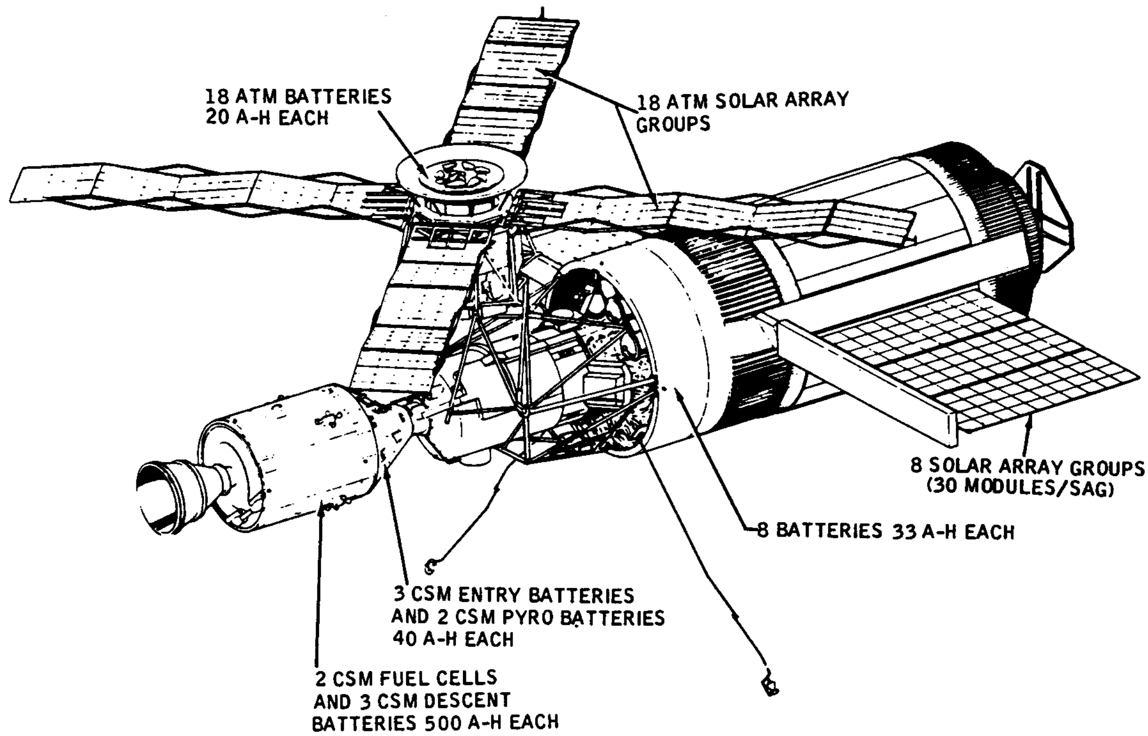



**Figure II-55 — Skylab Power Sources**

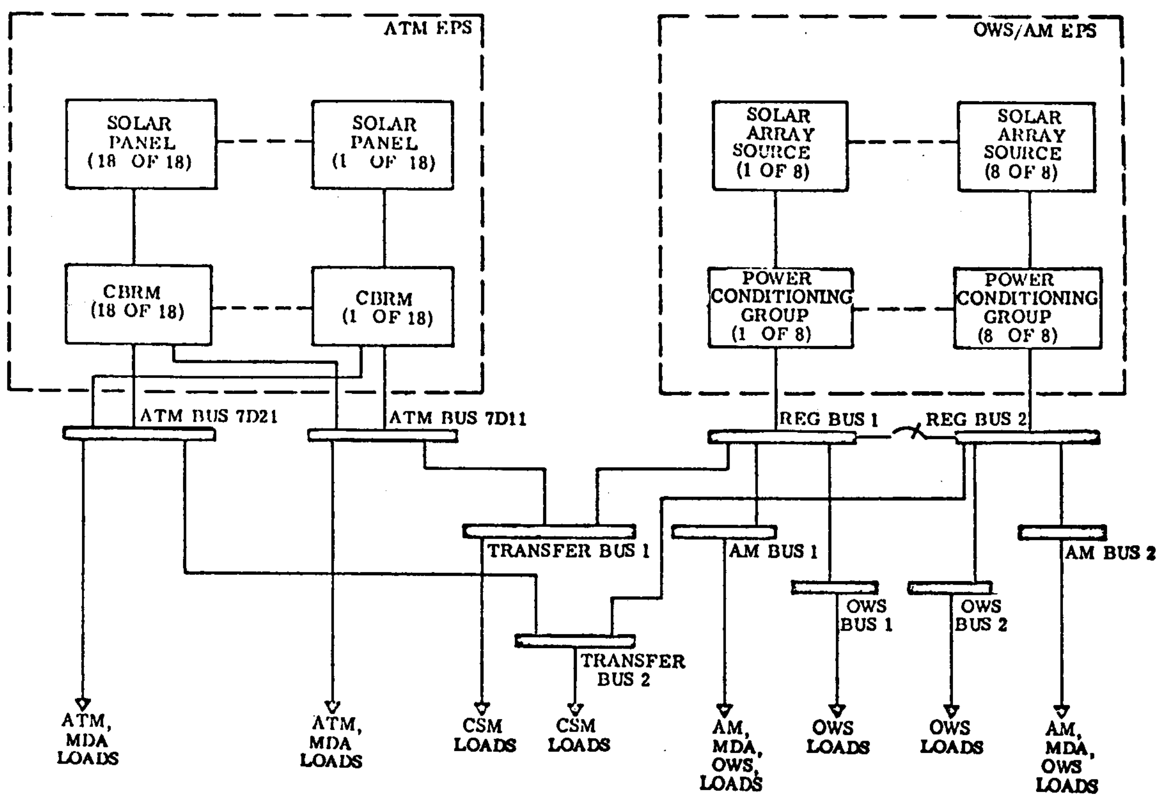



**Figure II-56 — Power Distribution**

Table II-9 – Physical Characteristics of OWS SAS

| | |
|---|---|
| **Array** | |
| Size | 9.5 by 8.3 m (372 by 328 inches) (per wing) |
| Weight | 1840 kg (4,056 pounds) (including deployment and stowage structures) |
| Panels Per Wing | 30 |
| Panels Per SAS | 60 |
| Total Solar Cells Per SAS | 147,840 |
| Modules Per SAS | 240 |
| **Solar Panel** | |
| Size | 0.7 m (27.13 inches wide), 3 m (120.7 inches long) |
| Weight | 12.7 kg (28 pounds) |
| Modules Per Panel | 4 |
| Series Cells Per Module | 154 |
| Parallel Series Strings Per Module | 4 |
| Total Cells Per Panel | 2,464 |
| Substrate | Aluminum Facesheet/Aluminum Honeycomb |
| Dielectric Insulation | Perforated 0.002-inch Kapton |
| **Solar Cell Group** | |
| Type | Overlapped |
| Cells Per Group | 11 series |
| Cell Interconnector | 0.025 mm (0.001 inch Kovar) (Solder Plated) |
| Group Interconnector | 0.075 mm (0.003 inch Kovar) (Solder Plated) |
| Cell to Substrate Adhesive | RTV 3145 |
| **Solar Cell** | |
| Type | N/P |
| Size | 2 x 4 cm (0.014 inch thick) |
| Efficiency | AMO, 28°C–11.1 percent minimum, Average Bare, New |
| Base Resistivity | 2 ohm-cm |
| Cell Contact | AgTi Machine-Pressed Fully Solder Covered Contacts |

## Table II-7 – Load Distribution Summary (Percent)

| | Maximum SI Orbit | Maximum 120° Z-LV Orbit | Maximum 60° Z-LV Orbit |
|---|---|---|---|
| Life Support | 36 | 34 | 35 |
| Housekeeping | 56 | 53 | 55 |
| Experiments | 8 | 13 | 10 |

The CSM EPS consists of the following major components:
- 2 fuel cell power plants (Bacon type)
- 3 solid state inverters
- 3 entry/post-landing batteries (40 amp-hr)
- 2 pyrotechnic batteries (40 amp-hr)
- 3 descent batteries (500 amp-hr)

Table II-8 – Physical Characteristics of ATM SAS

| | |
|---|---|
| **Array** | |
| Size | 13.2 m (521 inches long), 2.7 m (104.5 inches wide) (per wing) |
| Weight | 1723 kg (3,800 pounds) (including deployment structure) |
| Panels Per Wing | 5 (inboard panels are half covered with modules) |
| Total Panels | 20 |
| Total Solar Cells | 2 x 2 cm – 123,120 and<br>2 x 6 cm – 41,040 Total = 164,160 |
| Total Modules | 360 |
| **Solar Panel** | |
| Size | 2.7 m (104.3 inches long), 2.7 m (104.5 inches wide) |
| Weight | 66.2 kg (146 pounds) (including panel frame) |
| Modules Per Panel | 20 (inboard panels contain 10 modules each) |
| Total Cells Per Full Panel | 2 x 2 cm – 13,680 or<br>2 x 6 cm – 4,560 |
| **Solar Cell Module (Both Types)** | |
| Size | .5 m (20.0 inches long), .63 m (24.625 inches wide) |
| Weight | 2.2 kg (4.93 pounds) |
| Series Cells | 114 |
| Parallel Cells | 2 x 2 cm – 6 or<br>2 x 6 cm – 2 |
| Total Cells | 2 x 2 cm – 684 or<br>2 x 6 cm – 228 |
| Cell Interconnector | 2 x 2 cm – Expanded Silver Mesh<br>2 x 6 cm – Solder Plated Copper |
| Cell to Substrate Adhesive | 0.127 mm (0.005 inch) Silastic 140 |
| Substrate | Aluminum Facesheet/Aluminum Honeycomb |
| Dielectric Insulation | 0.127 mm (0.005 inch) Micaply |
| **Solar Cell** | |
| Type | N/P |
| Size | 2 x 2 cm and<br>2 x 6 cm (both 0.014 inch thick) |
| Base Resistivity | 7 to 14 ohm-cm |
| Cell Contact | AgTi, fully solder covered contacts |

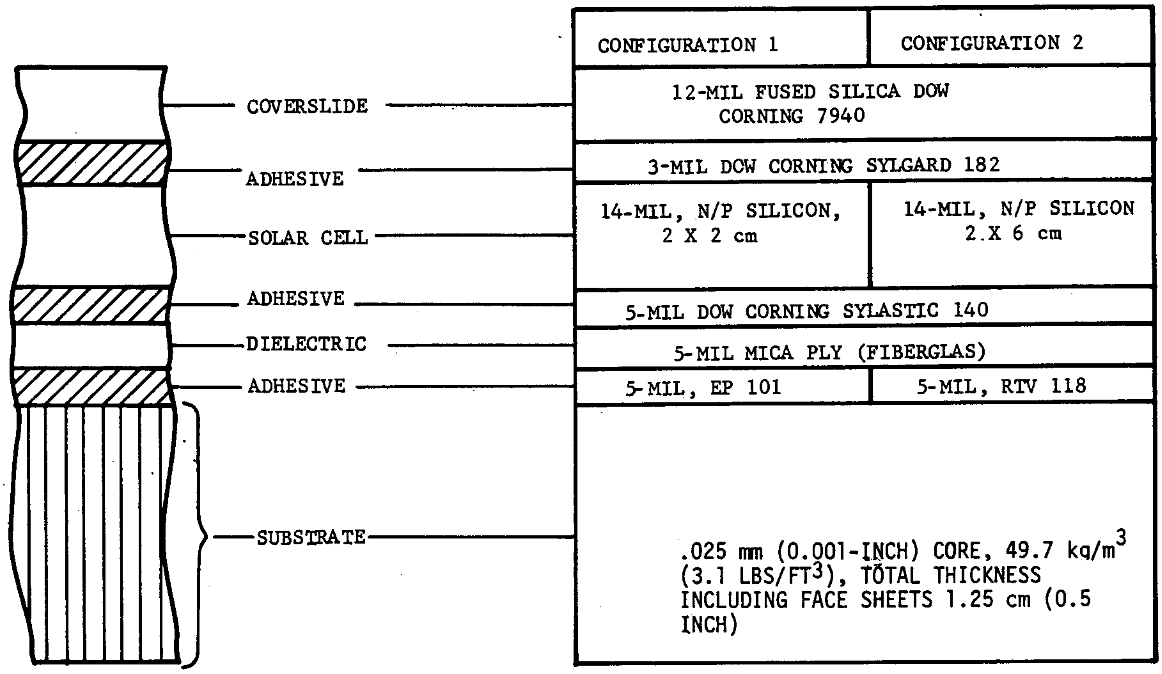



**Figure II-57 — Cross Section of ATM Solar Cell Module**

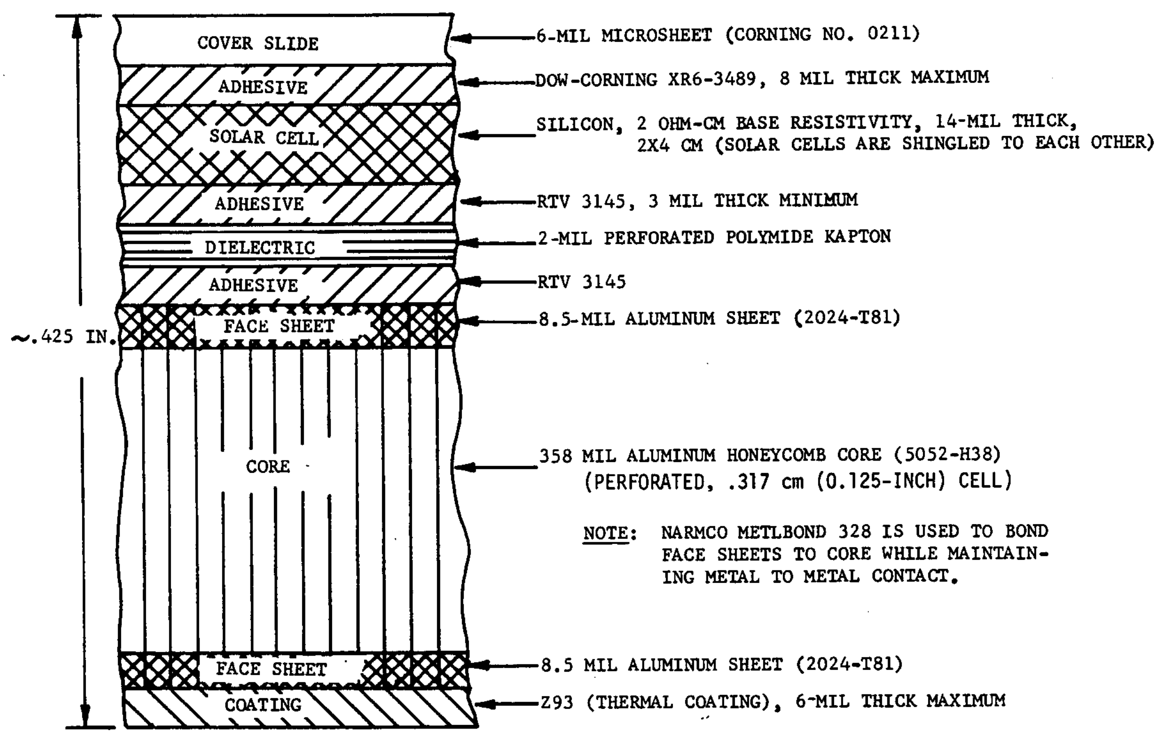



**Figure II-58 — Cross Section of OWS Solar Cell Module**

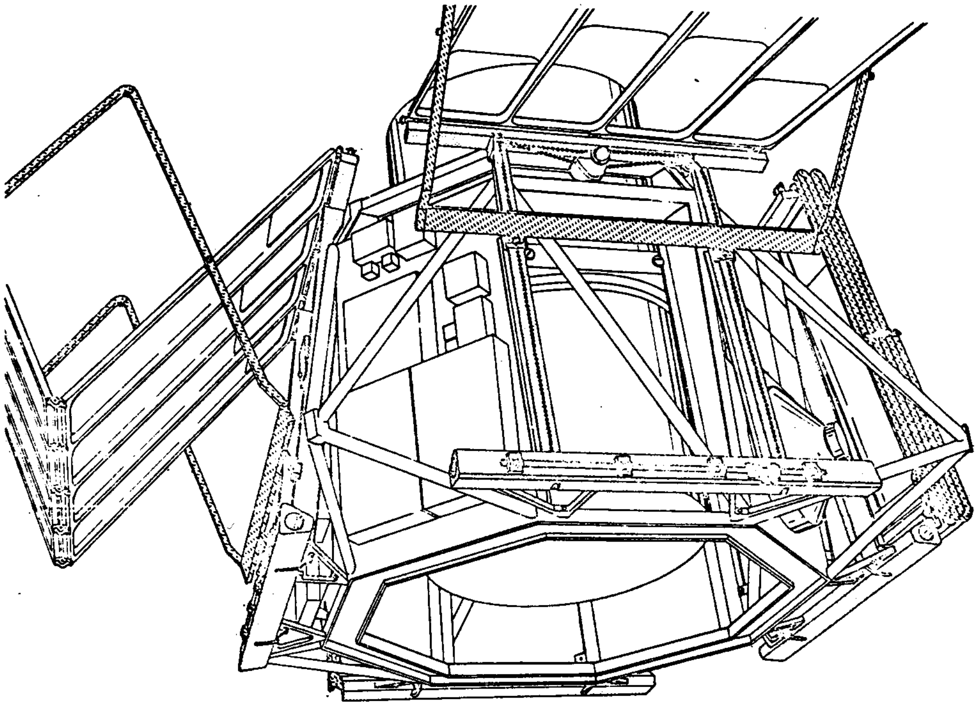


Figure II-59 — ATM Solar Wings in Stowed and Partially Deployed Positions

NOTES:

- 684 2X2 cm - or 228 2X6 cm SOLAR CELLS MAKE UP A MODULE
- 20 MODULES MAKE UP A PANEL (POWER SOURCE)
- 5 PANELS MAKE UP A WING
- 4 WINGS MAKE UP THE ARRAY
- THE NUMBER ON EACH PANEL INDICATES THE CBRM TO WHICH IT IS WIRED
- VIEWED FACING ACTIVE CELL SIDE

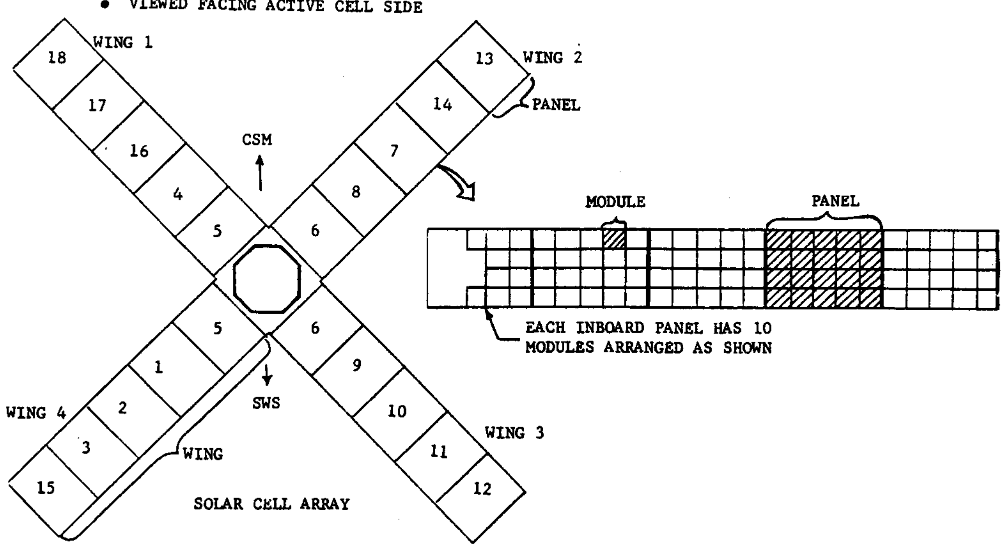



Figure II-60 — ATM Solar Array Configuration

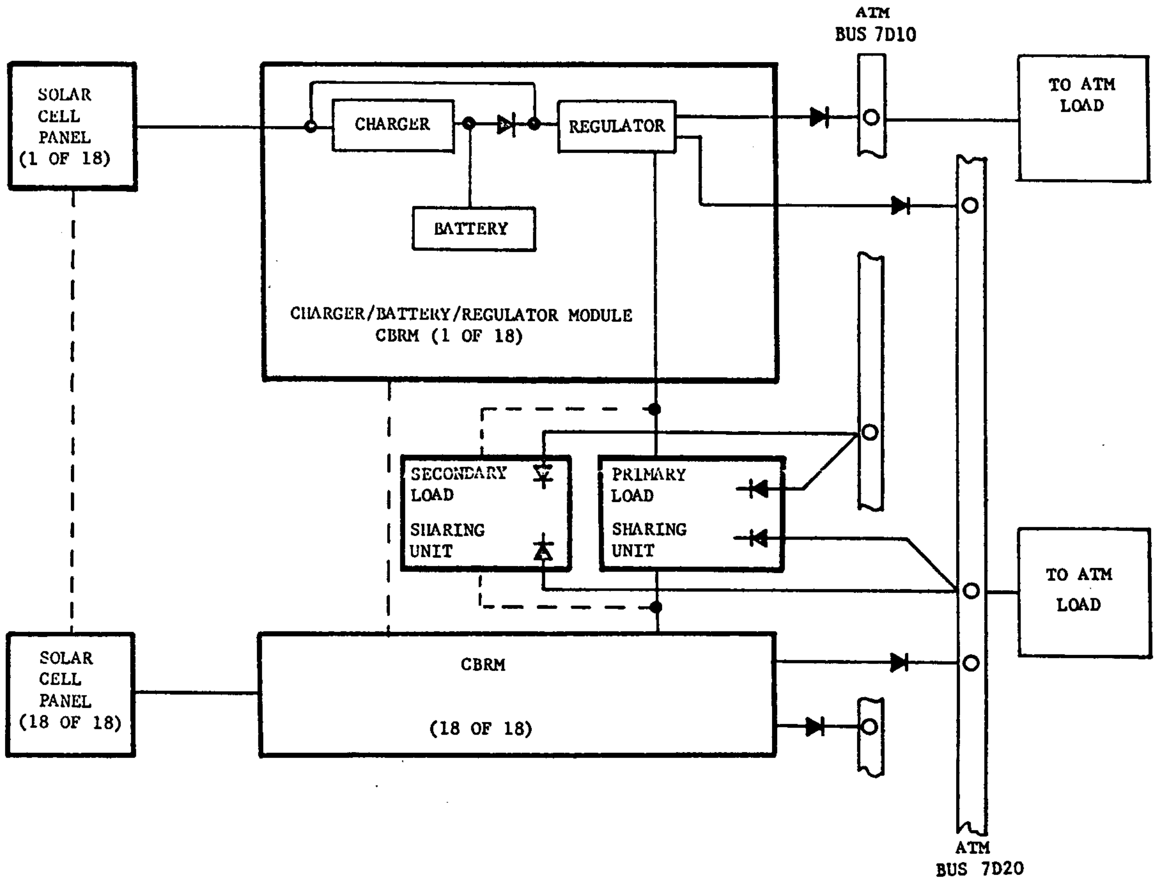



**Figure II-61 — ATM Electrical Power System**

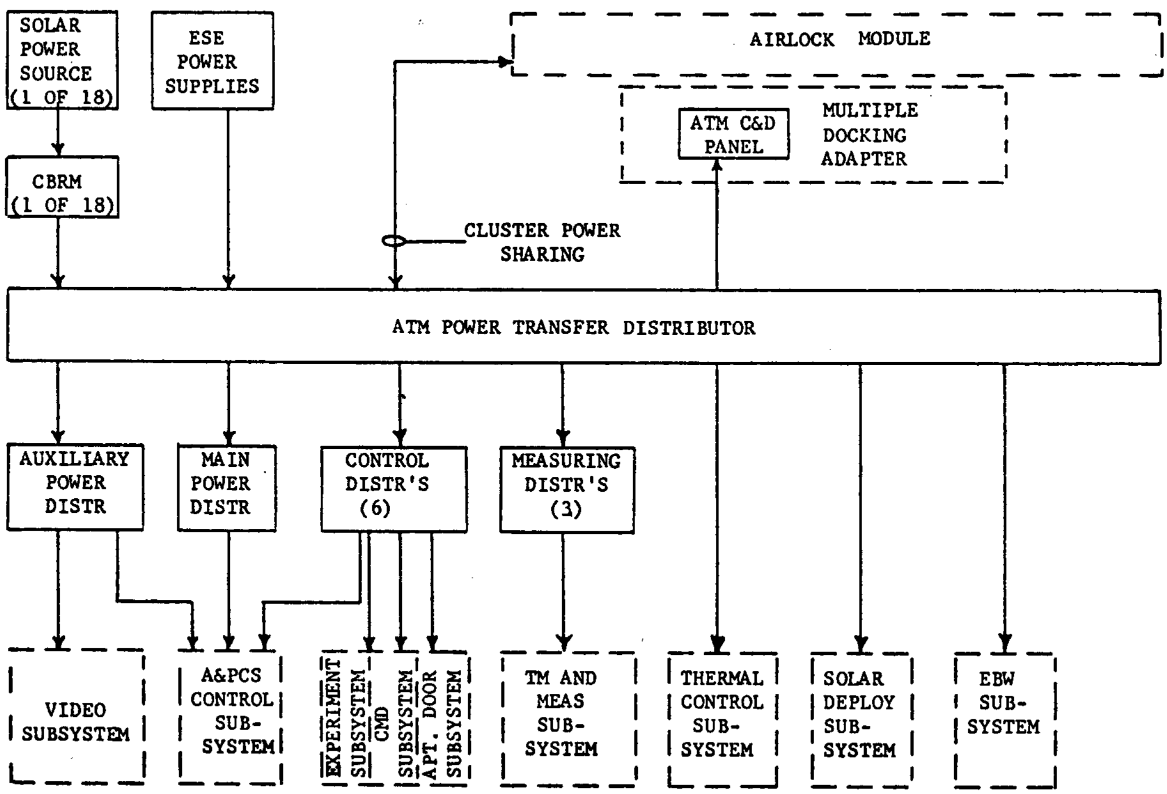



**Figure II-62 — ATM Power Distribution**

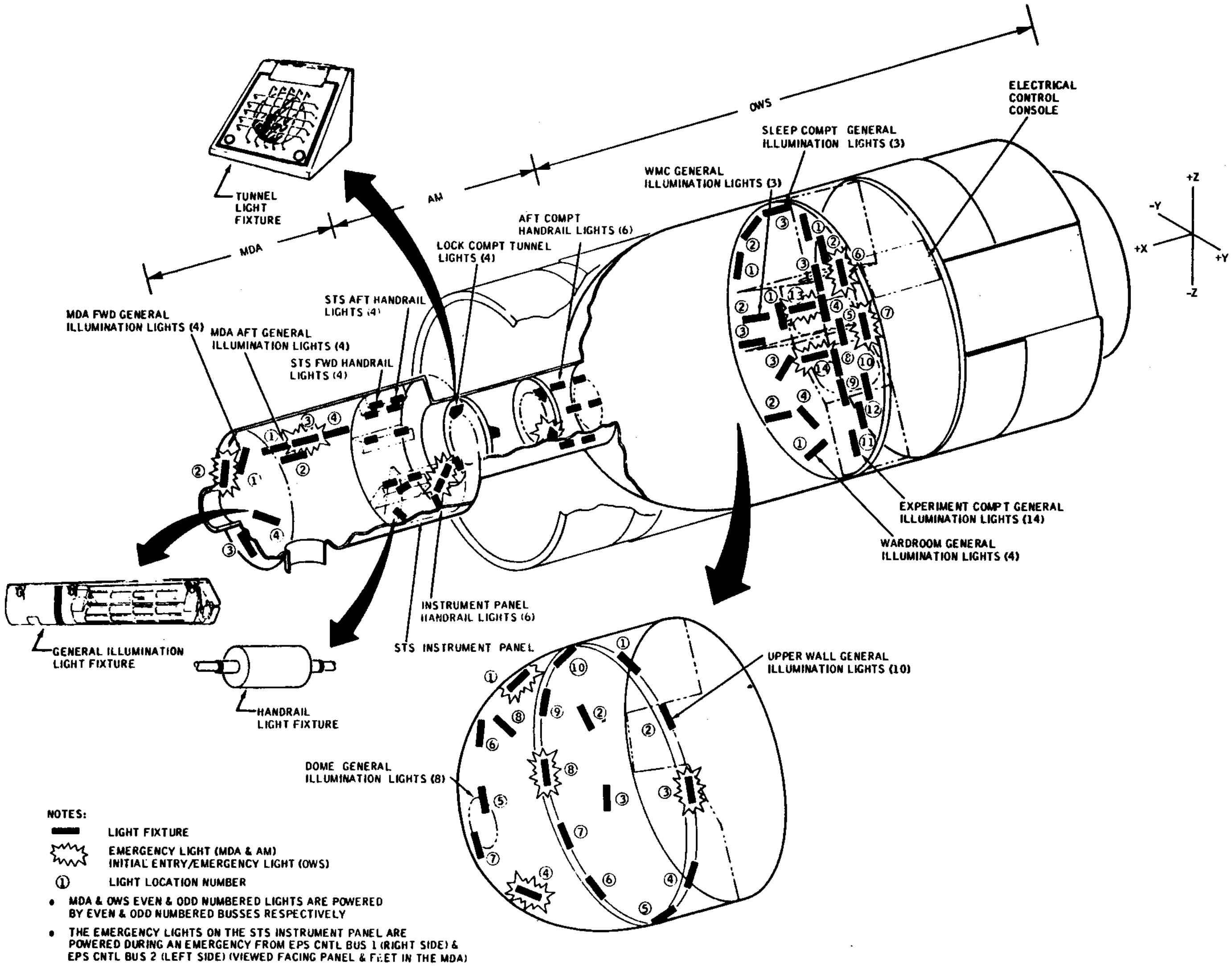



**Figure II-63 — Skylab Lighting Overview**

## OWS LIGHTS

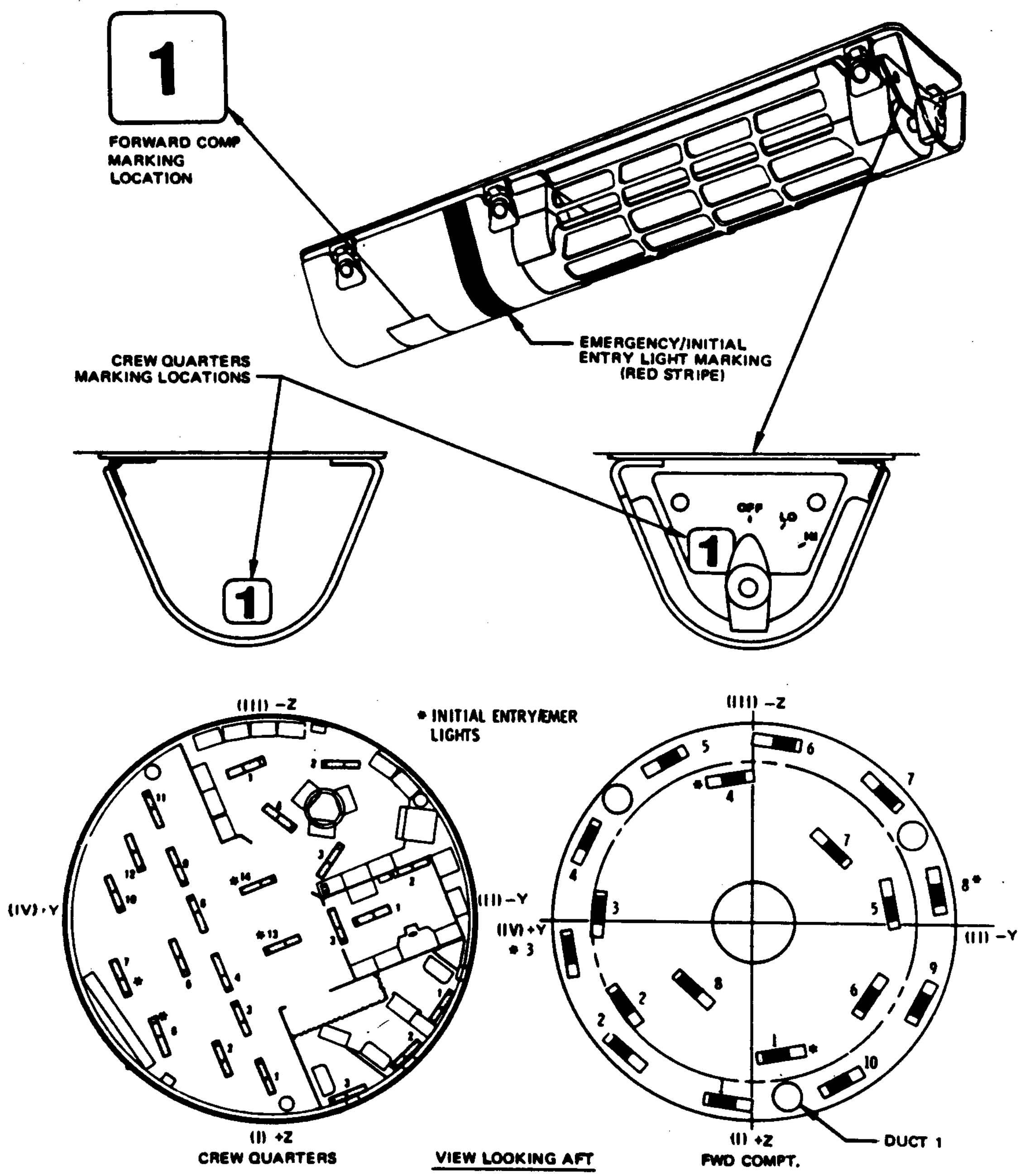



Figure II-64 — OWS Lights

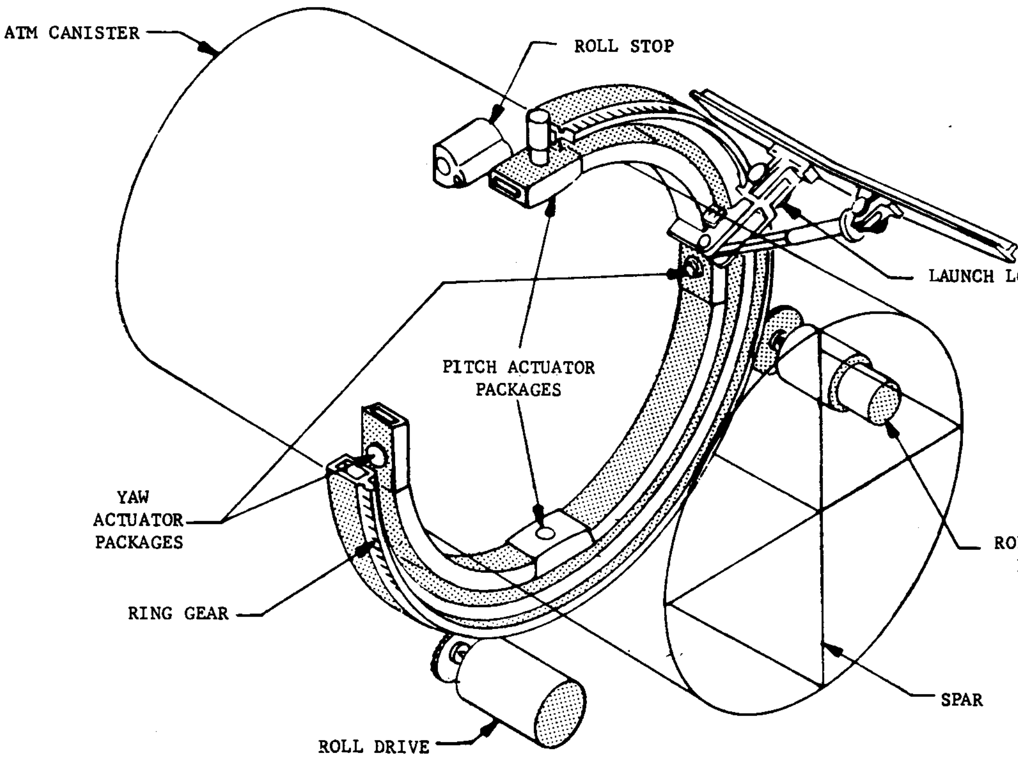



**Figure II-66 — Experiment Pointing Control Subsystem**

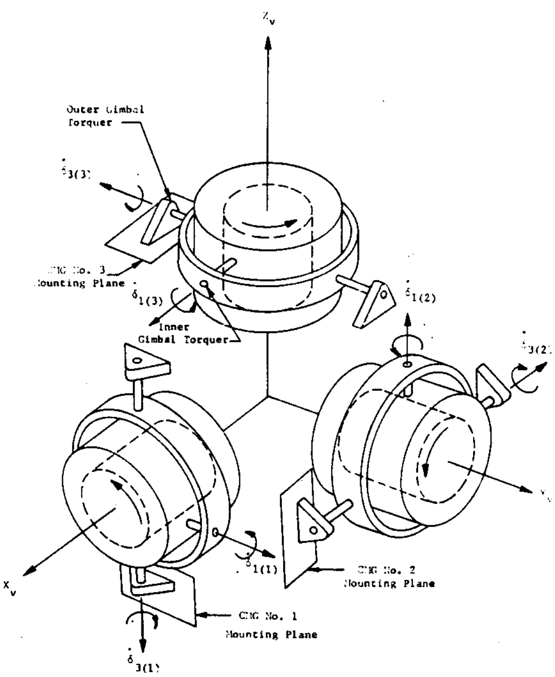



**Figure II-65 — CMG Mounting Arrangement**

Table II-10 – APCS Components

| |
|---|
| IU/TACS |
| IU (ST-124 Stabilized platform, ST-124 Servo Amplifier Box, Flight Control Computer, etc.) |
| Thruster Attitude Control System (TACS) Thruster Assemblies – 2 |
| TACS Power and Control Switching Assembly (PCSA) – 2 |
| CMGS/TACS |
| Rate Gyro Packages (RGPs) – 9 |
| Acquisition Sun Sensors (Acq SSs) – 2 |
| Control Moment Gyro Inverter Assemblies (CMGIAs) – 3 |
| Control Moment Gyros and Electronic Assemblies (CMGs and CMGEAs) – 3/3 |
| Apollo Telescope Mount Digital Computers/Workshop Computer Interface Unit (ATMDCs/WCIU) – 2/1 |
| EPCS |
| Rate Gyro Packages (RGPs) – 4 |
| Fine Sun Sensor (FSS) – 1 |
| Manual Pointing Controller (MPC) – 2 |
| Experiment Pointing Electronics Assembly (EPEA) – 1 |
| Experiment Package Caging and Gimbal Assembly – 1 |
| Star Tracker (ST) – 1 |

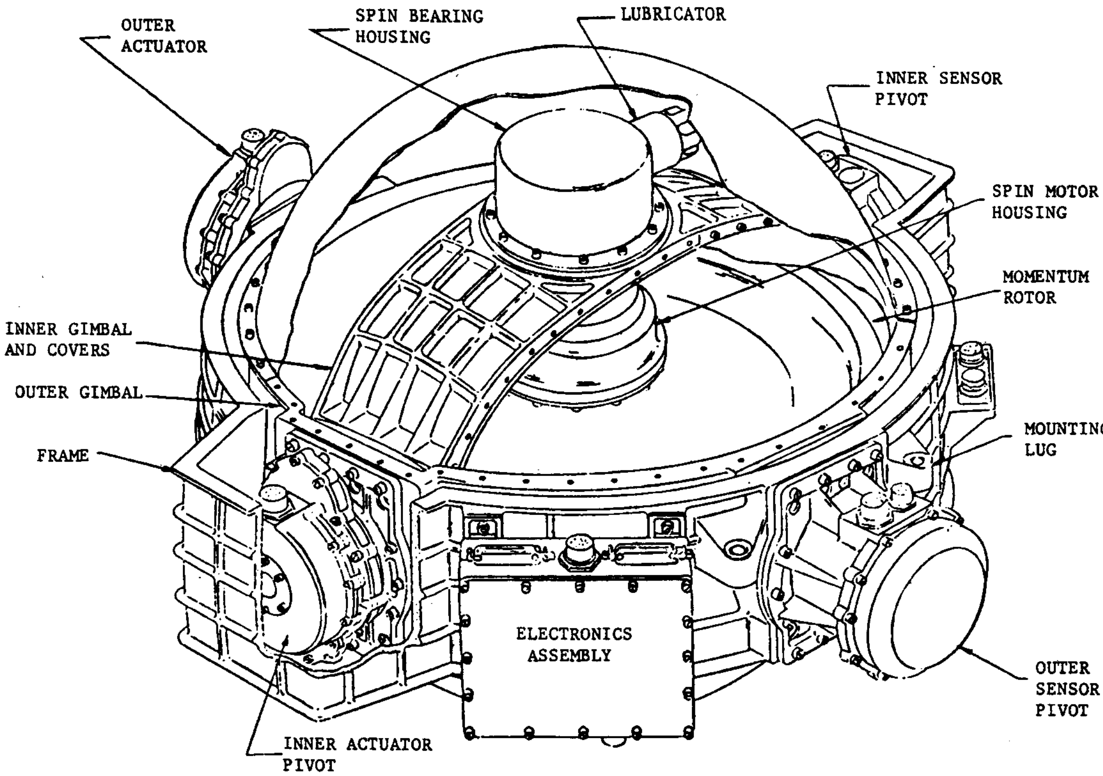



**Figure II-67 — Control Moment Gyro (CMG)**

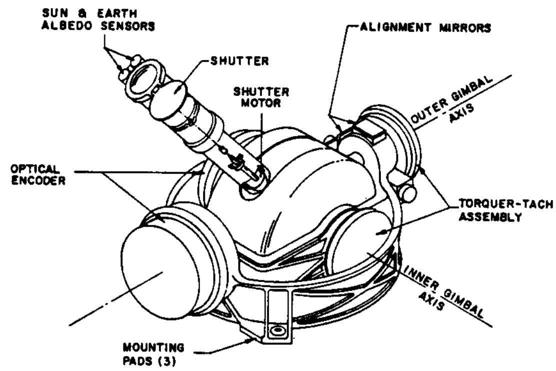



**Figure II-68 — Star Tracker**

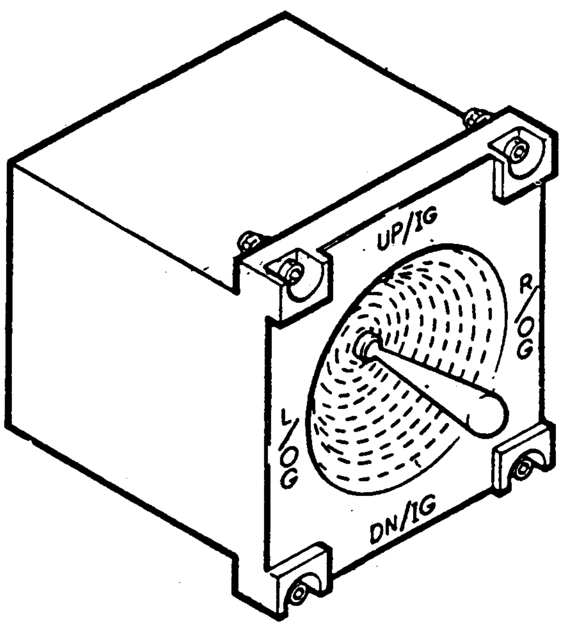



**Figure II-69 — Manual Pointing Controller**

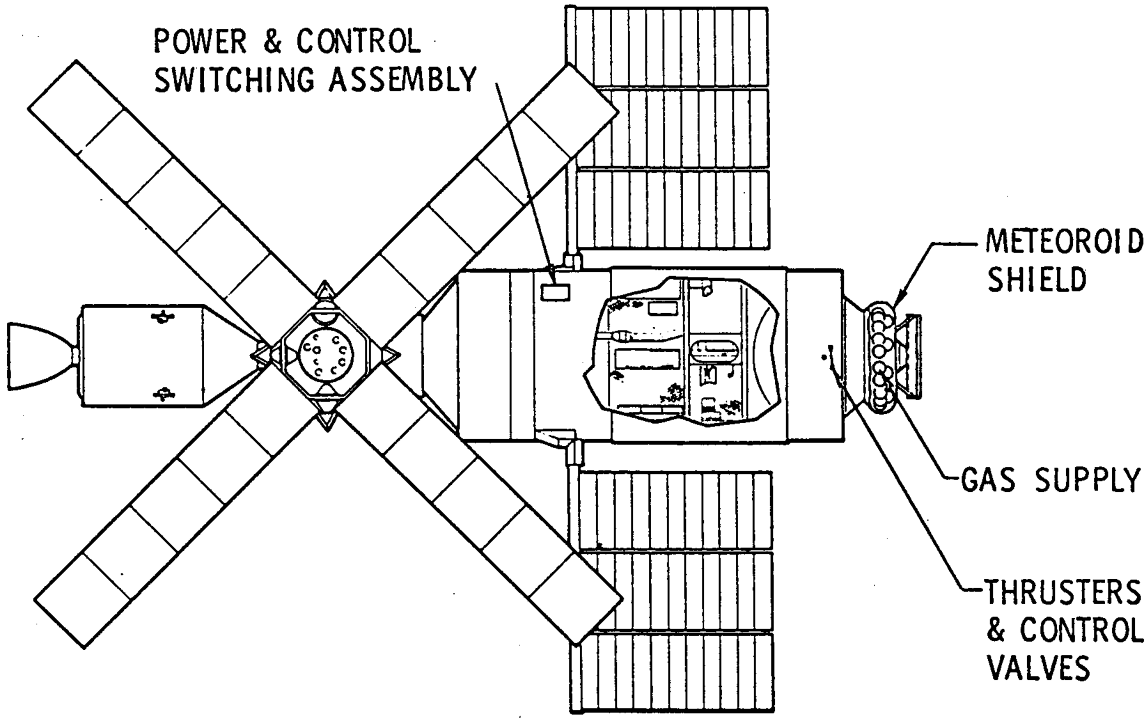



**Figure II-70 — TACS Components Locations**

Table II-11 – Skylab Communications Links

| Data System | Downlink | Uplink | Frequency (MHz) |
|---|---|---|---|
| CSM (USB) | R/T TM<br>R/T VX | | 2287.5<br>(All cluster R/T VX via CSM) |
| | D/T TM<br>D/T VX<br>R/T TV<br>D/T TV | | 2272.5<br>(Primary D/T VX via AM) |
| | | CMD<br>VX | 2106.4<br>(All cluster R/T VX via CSM) |
| CSM (VHF) | Voice | VX | 296.8/259.7 |
| AM (UHF) | | CMD<br>(Including Teleprinter) | 450 |
| AM (VHF) | R/T TM | | 230.4 and<br>235.0 and<br>246.3<br>(All cluster D/T VX normally via AM) |
| ATM (UHF) | | CMD | 450 |
| ATM (VHF) | Real Time<br>R/T TM<br>D/T TM | | 231.9 and<br>237.0 |

Notes: R/T = Real Time; D/T = Delayed Time; TM = Telemetry; TV = Television; VX = Voice; CMD = Command

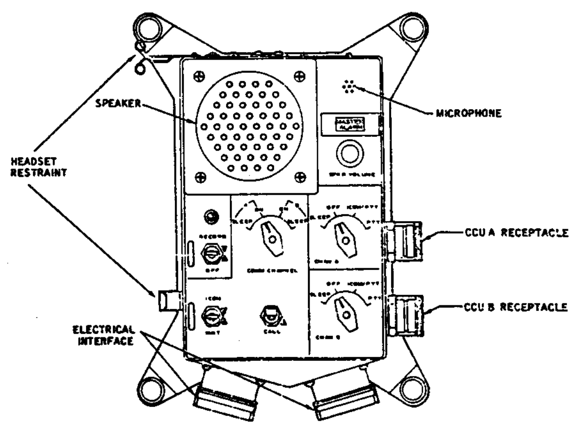



**Figure II-72 — Speaker Intercom Assembly**

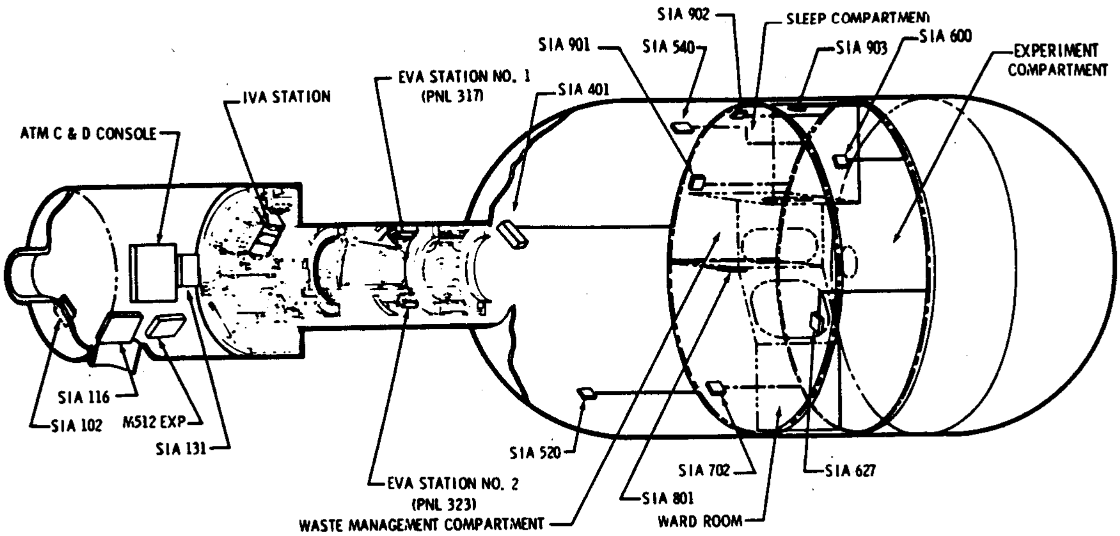



**Figure II-71 – Intercom Locations**

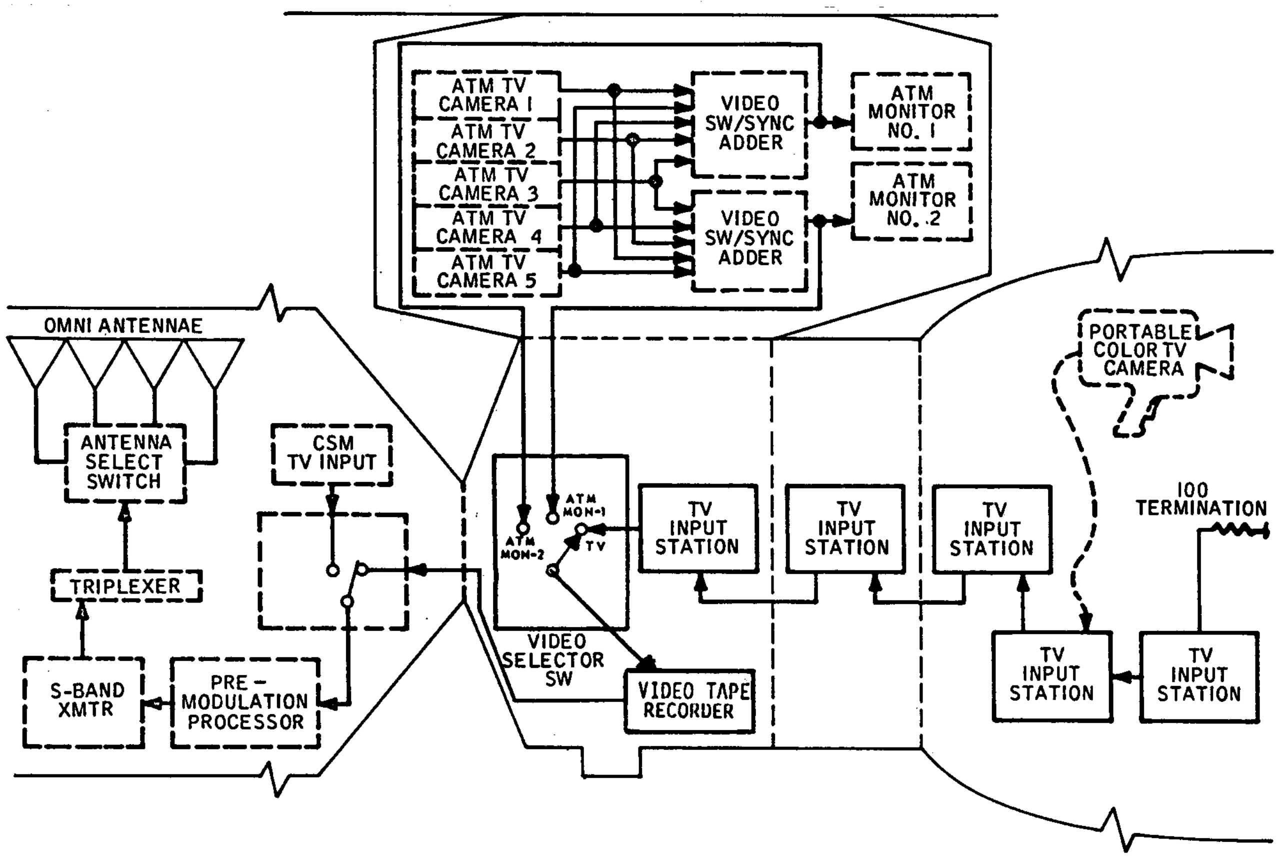



**Figure II-73 – TV Subsystem**

Table II-12 – ATM TV Cameras

| Experiment | Type | Manufacturer | Purpose |
|---|---|---|---|
| H-Alpha One | Vidicon | MSFC | Pointing control of the ATM toward specific points of the Sun. |
| H-Alpha Two | Vidicon | MSFC | View Sun through interference filter at H-Alpha frequency |
| NRL XUV | Low Light Level Vidicon | MSFC | View the Sun's image in the 150 to 600 Angstrom spectral region via conversion layer |
| NRL XUV Slit | Low Light Level Vidicon | MSFC | View the Sun's image directly through 2 x 60 arc-second slit |
| White Light Coronagraph | Low Light Level Vidicon | MSFC | View the Sun's corona in white light |

Table II-13 – TV Subsystem Elements

| TV Subsystem Element | Manufacturer |
|---|---|
| Television Input Station | Martin Marietta Aerospace |
| Video Selector Switch | Bendix |
| Portable Color TV Camera | Westinghouse Electric Corporation |
| Video Tape Recorder | RCA |
| FM S-Band Transmitter | Motorola |

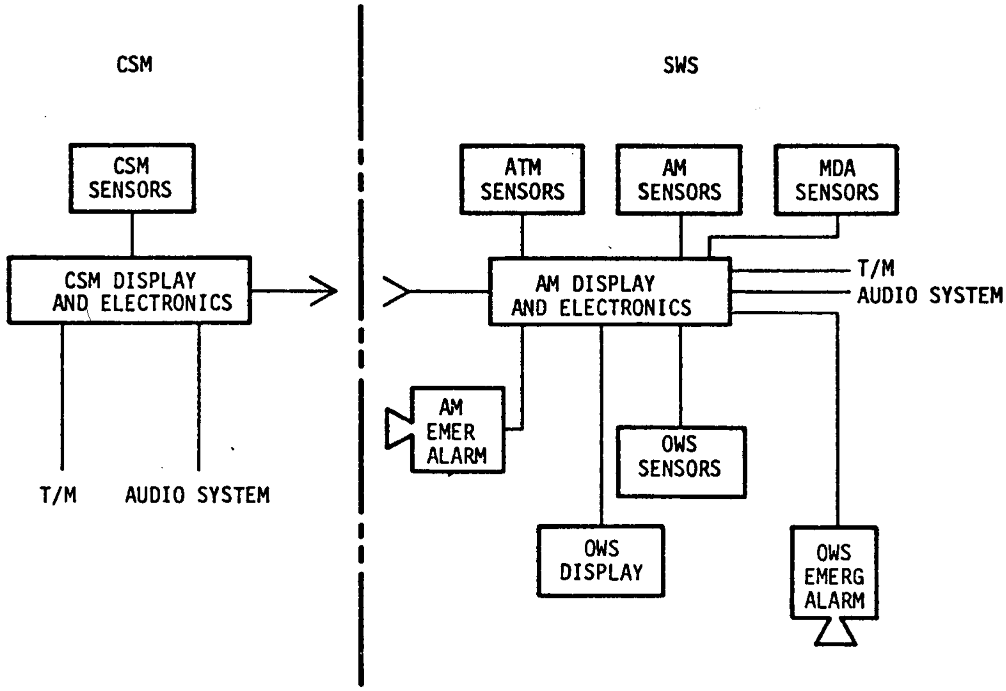



**Figure II-74 — Caution and Warning System**

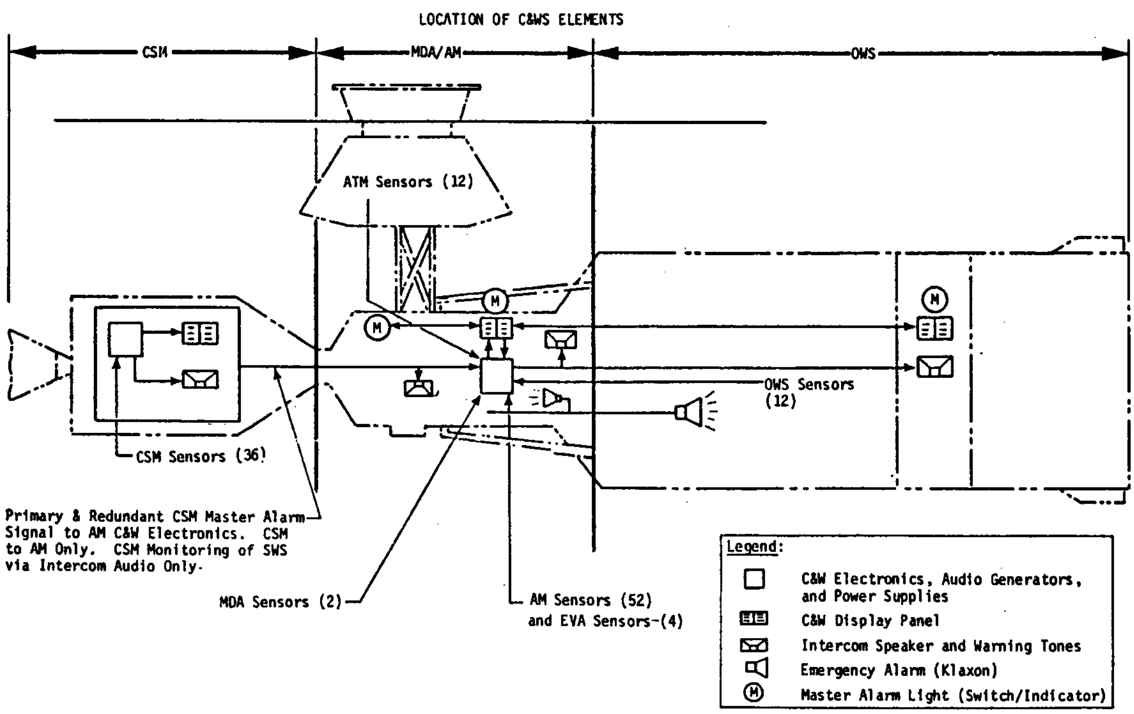



**Figure II-75 — C&W System Elements**

Table II-14 – C&W Parameters

| Item/Parameter | Monitored Module | Criticality (See Note 2) | No. of C&W System Channels (See Note 3) | Light Labeling |
|---|---|---|---|---|
| AM–ECS | | | | |
| 1. Sieve A Bed 1/2 | AM | C | 1 | SIEVE TEMP HIGH |
| 2. Sieve B Bed 1/2 | AM | C | | |
| 3. $PPO_2$ 1 | AM | W | 1 | $PPO_2$ LOW |
| 4. $PPO_2$ 2 | AM | W | | |
| 5. Pri Cool Pump 1 | AM | W | | |
| 6. Pri Cool Pump 2 | AM | W | 1 | PRI COOL FLOW |
| 7. Pri Cool Pump 3 | AM | W | | |
| 8. Sec Cool Pump 1 | AM | W | | |
| 9. Sec Cool Pump 2 | AM | W | 1 | SEC COOL FLOW |
| 10. Sec Cool Pump 3 | AM | W | | |
| 11. Cluster Pressure | AM | W | 1 (R) | CLUSTER PRESS LOW |
| 12. Sieve A $PCO_2$ | AM | C | 1 | SIEVE OUT $PPCO_2$ |
| 13. Sieve B $PCO_2$ | AM | C | | HIGH |
| 14. Sieve A Gas Flow | AM | C | 1 | SIEVE FLOW |
| 15. Sieve B Gas Flow | AM | C | | |
| 16. Sieve A Timer | AM | C | 1 | SIEVE TIMER |
| 17. Sieve B Timer | AM | C | | |
| 18. OWS Gas Flow | AM | C | 1 | OWS GAS INTER CHG |
| 19. Condensate Tank $\Delta P$ | AM | C | 1 | CNDST TANK $\Delta P$ |
| 20. Pri Cool 47° Valve | AM | C | 1 | PRI COOL TEMP LOW |
| 21. Sec Cool 47° Valve | AM | C | 1 | SEC COOL TEMP LOW |
| 22. Pri Cool Loop Temp | AM | C | 1 | PRI COOL TEMP HIGH |
| 23. Sec Cool Loop Temp | AM | C | 1 | SEC COOL TEMP HIGH |
| (Subtotal: 23 Inhibit SW's) | | | | |
| Integrated EPS | | | | |
| 24. Reg Bus 1 Low | AM | W | 1 | REG BUS 1 LOW |
| 25. Reg Bus 1 High | AM | W | 1 | REG BUS 1 HIGH |
| 26. Reg Bus 2 Low | AM | W | 1 | REG BUS 2 LOW |
| 27. Reg Bus 2 High | AM | W | 1 | REG BUS 2 HIGH |
| 28. ATM Bus 1 Low | ATM | W | 1 | ATM BUS 1 LOW |
| 29. ATM Bus 2 Low | ATM | W | 1 | ATM BUS 2 LOW |
| 30. C&W Power Control 1 (See Note 1) | AM | C | | |
| 31. C&W Power Logic 1 (See Note 1) | AM | C | | |
| 32. C&W Power Control 2 (See Note 1) | AM | C | 1 | C&W POWER |
| 33. C&W Power Logic 2 (See Note 1) | AM | C | | |
| 34. C&W Sig Cond Power | AM | C | | |

Table II-14 (Continued)

| Item/Parameter | Monitored Module | Criticality (See Note 2) | No. of C&W System Channels (See Note 3) | Light Labeling |
|---|---|---|---|---|
| 35. Emerg Power Control 1 (See Note 1) | AM | C | | |
| 36. Emerg Power Logic 1 (See Note 1) | AM | C | 1 | EMERG POWER |
| 37. Emerg Power Control 2 (See Note 1) | AM | C | | |
| 38. Emerg Power Logic 2 (See Note 1) | AM | C | | |
| 39. Emerg Sensor 1 | AM | C | 1 | EMERG SENSOR POWER |
| 40. Emerg Sensor 2 | AM | C | | |
| 41. OWS Bus 1 Low | OWS | C | 1 (R) | OWS BUS 1 LOW |
| 42. OWS Bus 2 Low | OWS | C | 1 (R) | OWS BUS 2 LOW |
| 43. Battery 1 70% D.O.D. | AM | C | | |
| 44. Battery 2 70% D.O.D. | AM | C | | |
| 45. Battery 3 70% D.O.D. | AM | C | | |
| 46. Battery 4 70% D.O.D. | AM | C | 1 | BAT CHARGE LOW |
| 47. Battery 5 70% D.O.D. | AM | C | | |
| 48. Battery 6 70% D.O.D. | AM | C | | |
| 49. Battery 7 70% D.O.D. | AM | C | | |
| 50. Battery 8 70% D.O.D. | AM | C | | |
| (Subtotal: 23 Inhibit Switches) (See Note 1) | | | | |
| ATM–ACS | | | | |
| 51. ACS–Overate | ATM | W | 1 | CLUSTER ATT |
| 52. ACS–Thruster Stuck | ATM | W | | |
| 53. ACS–CMG Saturate | ATM | C | | |
| 54. ACS–Auto TACS Only Option | ATM | C | 1 | ACS MALF |
| 55. ACS–2nd/3rd Rate Gyro Failure | ATM | C | | |
| 56. ACS–Computer Self Test Failure | ATM | C | 1 | COMPUTER MALF |
| 57. Computer X–Over | ATM | C | | |
| 58. ATM Collant Fluid Temp | ATM | C | | |
| 59. ATM Coolant Htr Temp | ATM | C | 1 | ATM CNST THERM |
| 60. ATM Coolant Pump $\Delta P$ | ATM | C | | |
| (Subtotal: 10 Inhibit Switches) | | | | |

Table II-14 (Concluded)

| Item/Parameter | Monitored Module | Criticality (See Note 2) | No. of C&W System Channels (See Note 3) | Light Labeling |
|---|---|---|---|---|
| Extravehicular Activity | | | | |
| 61. EVA LCG–1 Pump ΔP | AM | W | 1 | EVA 1 |
| 62. EVA LCG–1 $H_2O$ in Temp | AM | W | | |
| 63. EVA LCG–2 Pump ΔP | AM | W | 1 | EVA 2 |
| 64. EVA LCG–2 $H_2O$ in Temp | AM | W | | |
| (Subtotal: 4 Inhibit Switches) | | | | |
| Miscellaneous | | | | |
| 65. CSM 1 | CSM | W | 1 | CSM |
| 66. CSM 2 | CSM | W | | |
| 67. Crew Alert 1 | AM | W | 1 (R) | CREW ALERT |
| 68. Crew Alert 2 | AM | W | | |
| (Subtotal: 4 Inhibit Switches) | | | | |
| Emergency | | | | |
| 69. MDA/STS Fire 1 | MDA/STS | E | 1(R) | MDA STS FIRE |
| 70. MDA/STS Fire 2 | MDA/STS | E | | |
| 71. AM AFT Fire 1 | AM | E | 1 (R) | AM AFT FIRE |
| 72. AM AFT Fire 2 | AM | E | | |
| 73. OWS Fwd Fire 1 | OWS | E | 1 (R) | OWS FWD FIRE |
| 74. OWS Fwd Fire 2 | OWS | E | | |
| 75. OWS Exp Fire 1 | OWS | E | 1 (R) | OWS EXP FIRE |
| 76. OWS Exp Fire 2 | OWS | E | | |
| 77. OWS Crew Qtrs Fire 1 | OWS | E | 1 (R) | OWS CREW QTRS FIRE |
| 78. OWS Crew Qtrs Fire 2 | OWS | E | | |
| 79. Rapid ΔP 1 | AM | E | 1 (R) | RAPID ΔP |
| 80. Rapid ΔP 2 | AM | E | | |
| (Max Subtotal: 12 Inhibit Switches for Parameters) | | | | |

Note 1 – 'or' gates utilized to minimize switching complexity.
Note 2 – E = Emergency, W = Warning, C = C = Caution
Note 3 – Brackets denote use of 'or' gates to minimize channel complexity.
(R) – Denotes items repeated in OWS.

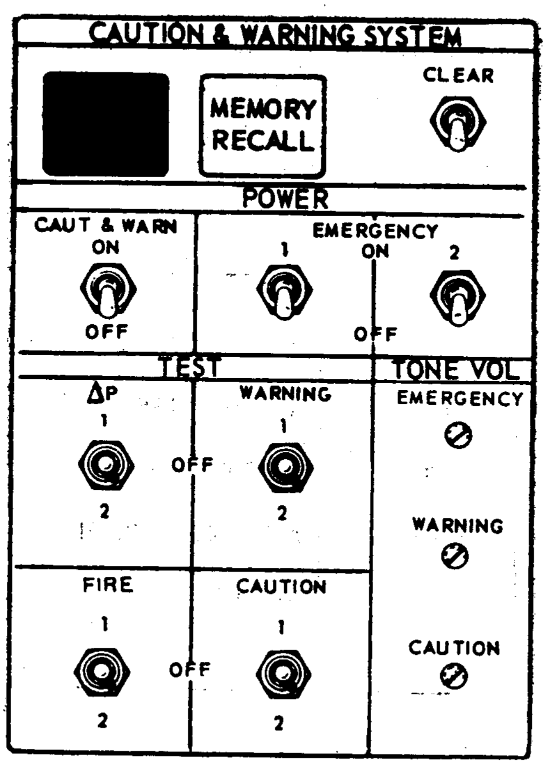



Figure II-76 – C&W Panel 206

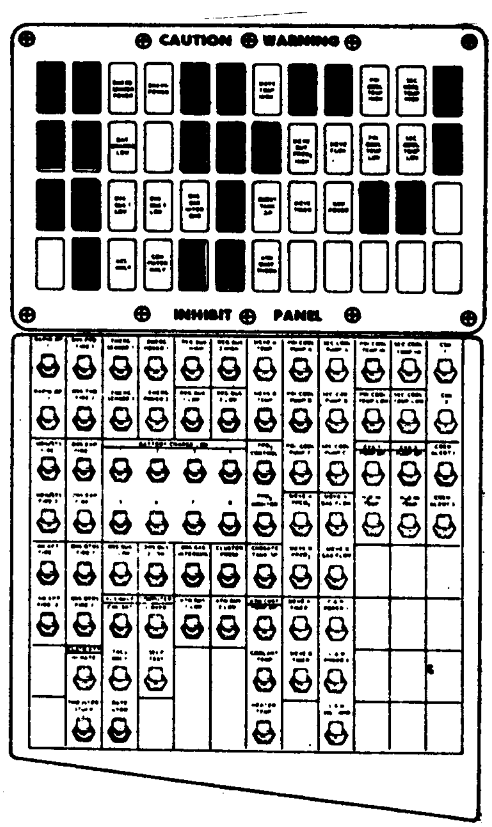



Figure II-77 – C&W Panel 207

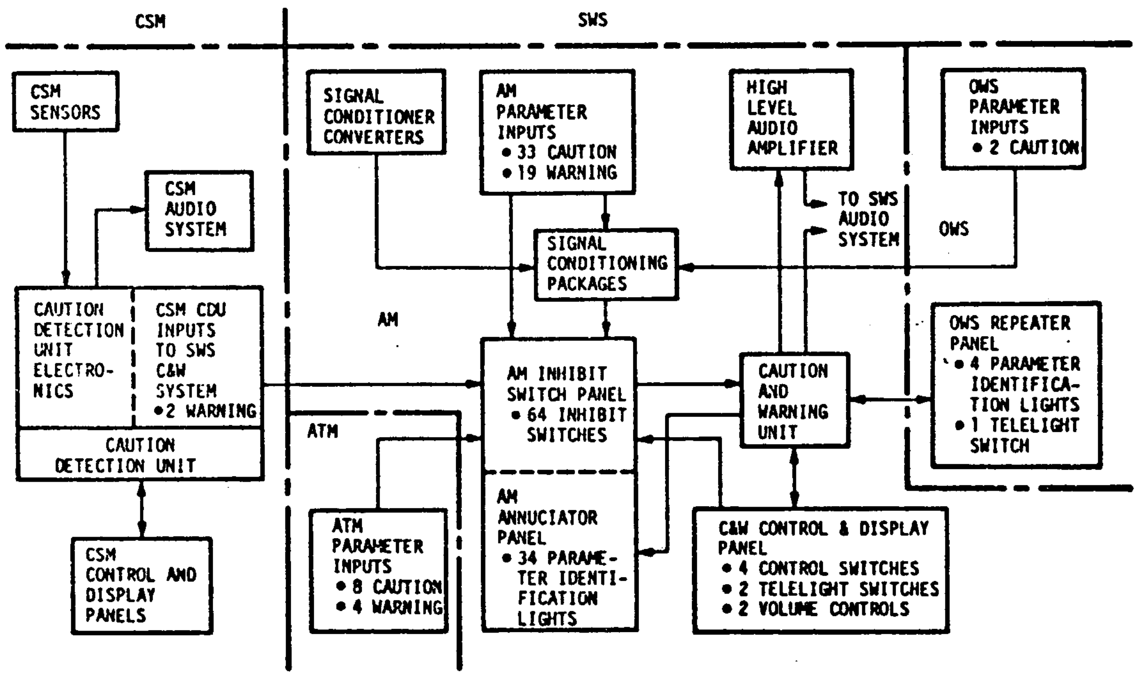



Figure II-80 — C&W Subsystem

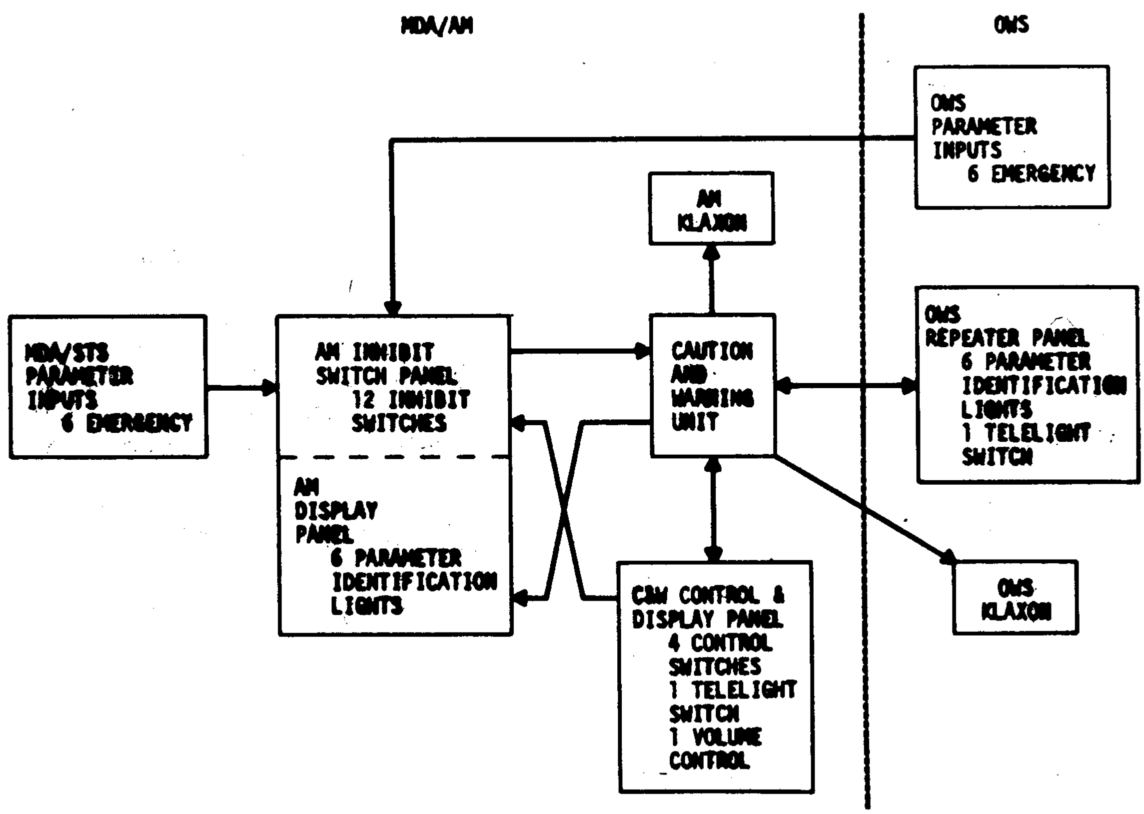



Figure II-81 — Emergency Subsystem

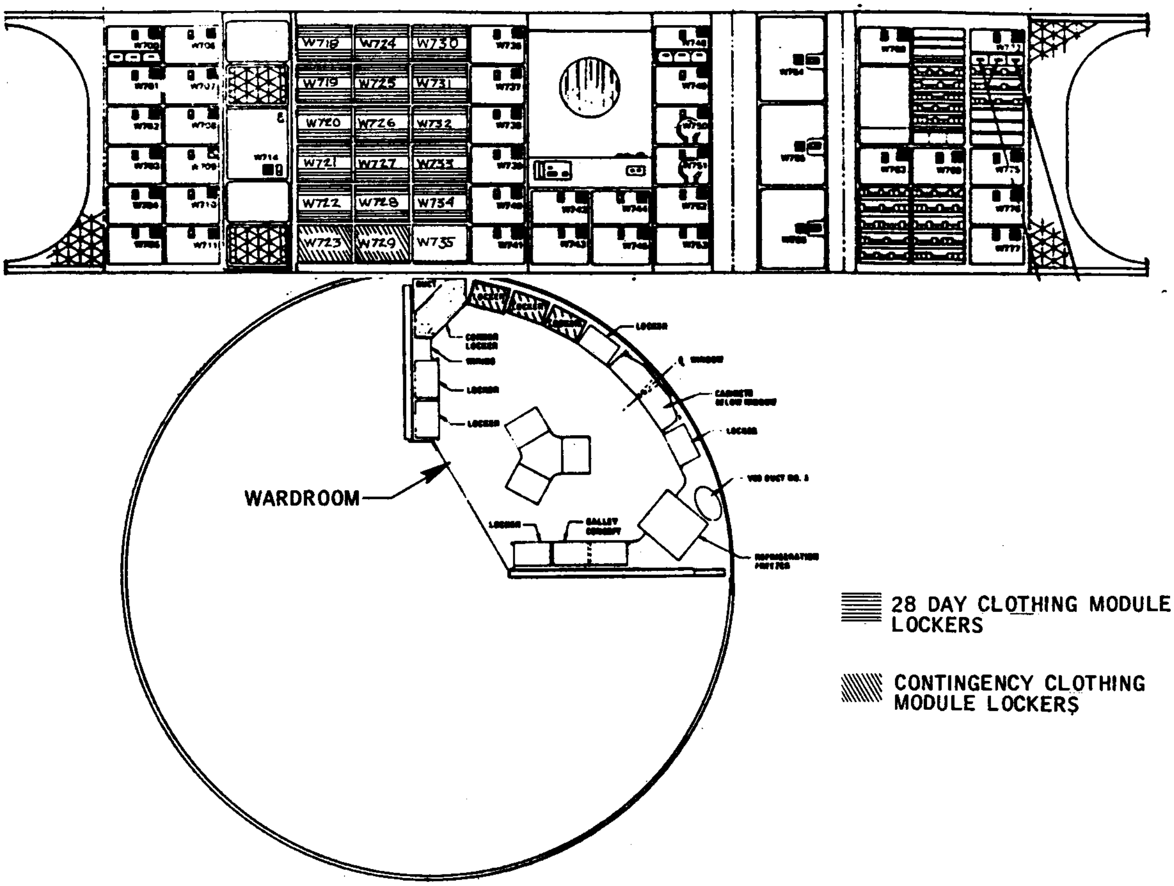



Figure II-82 — Clothing Module Stowage

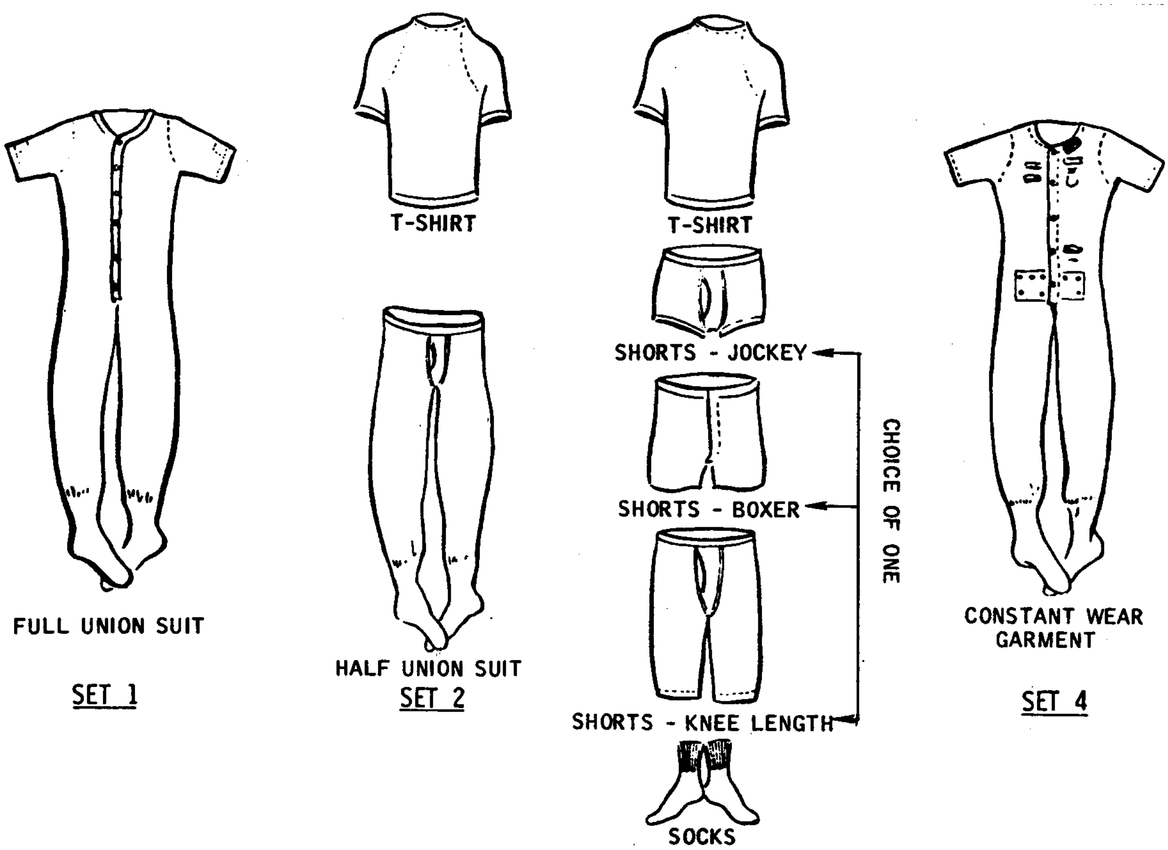
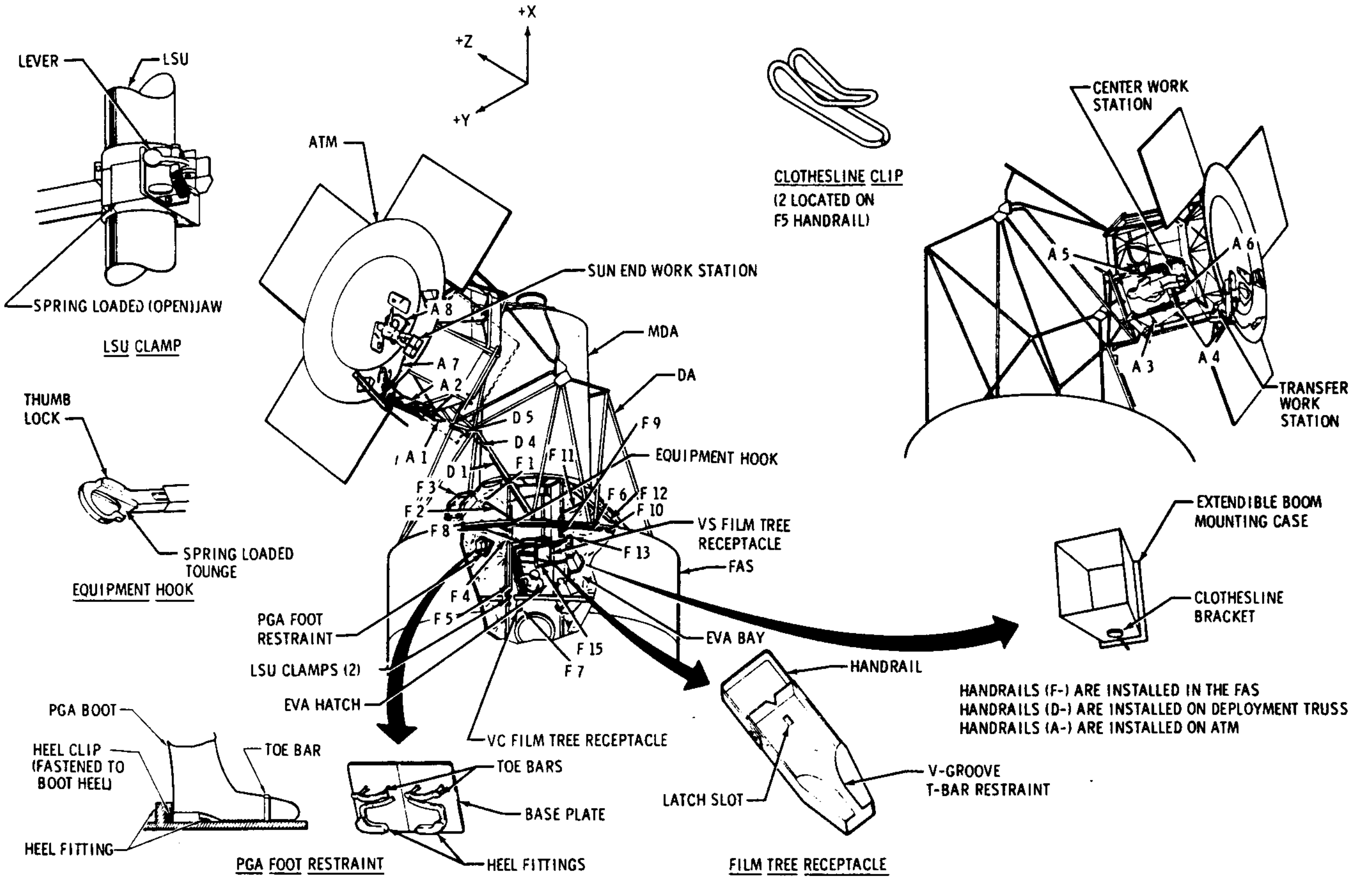
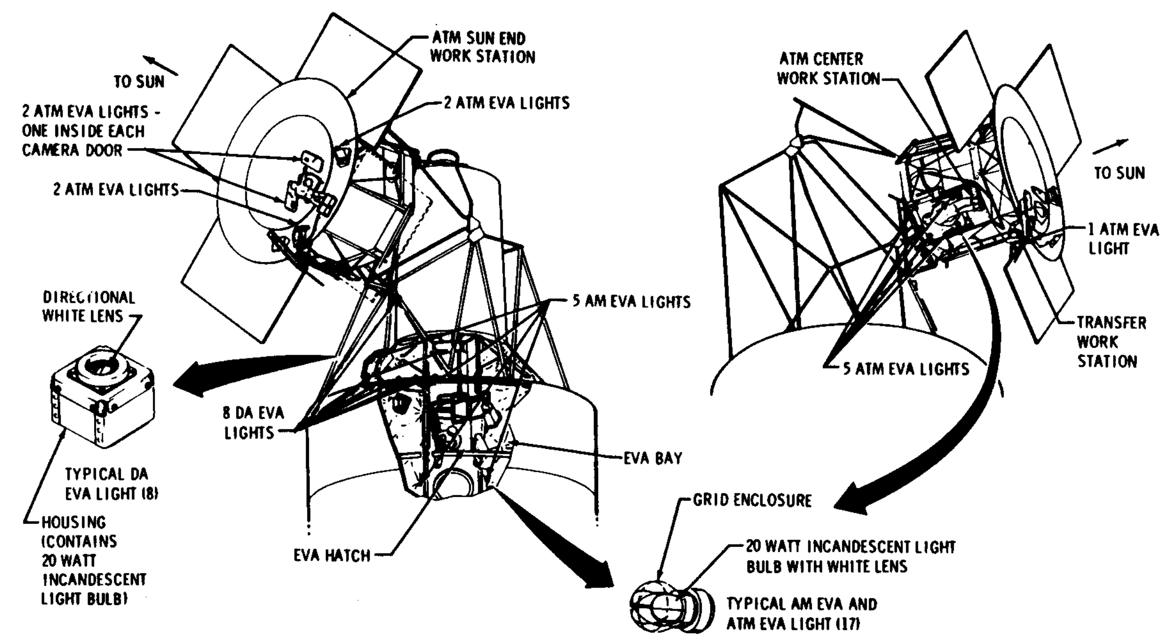



Figure II-84 — Crew Underwear




**External Restraints and Mobility Aids**




**EVA Workstations and Lighting**

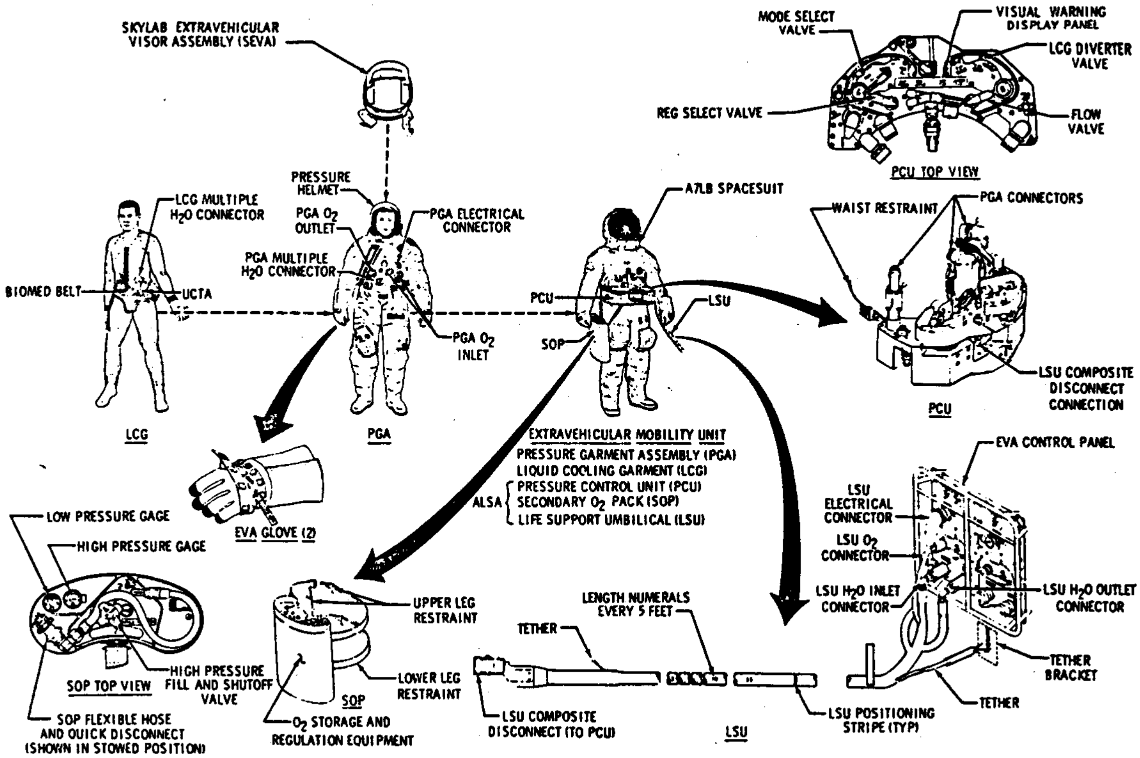



**Figure II-86 — Extravehicular Mobility Unit**

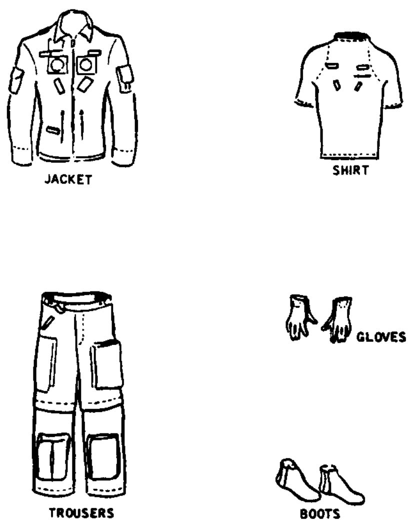



**Figure II-83 — Crew Clothing**

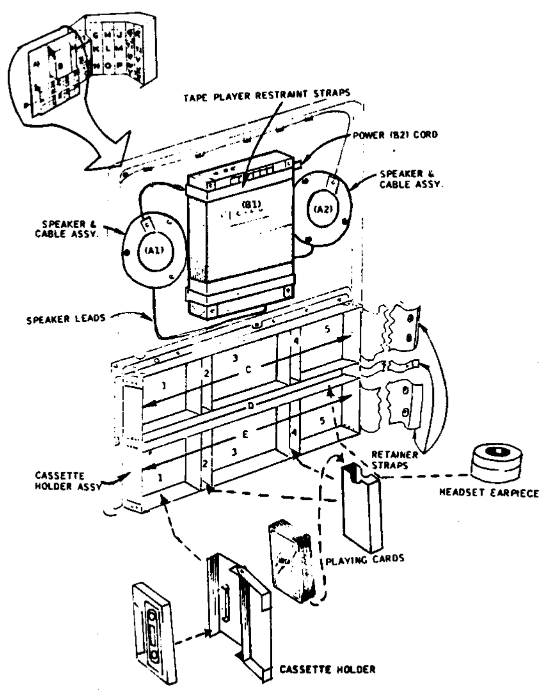



**Figure II-88 — ODAE Locker**

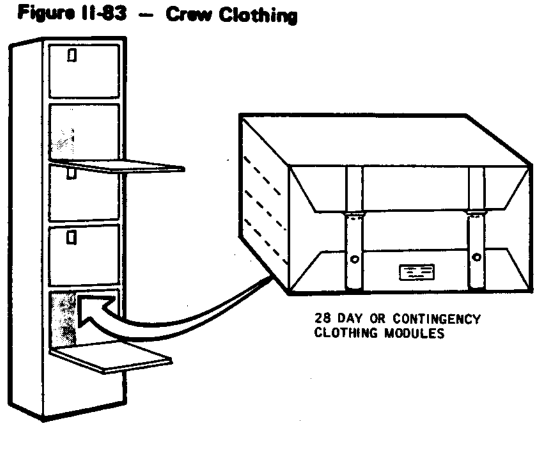



**Figure II-85 — Standard Stowage Locker**

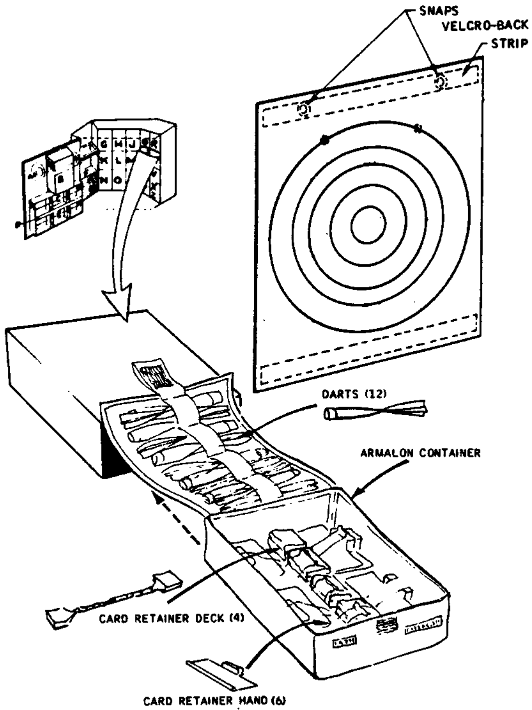



**Figure II-89 — Darts and Board**

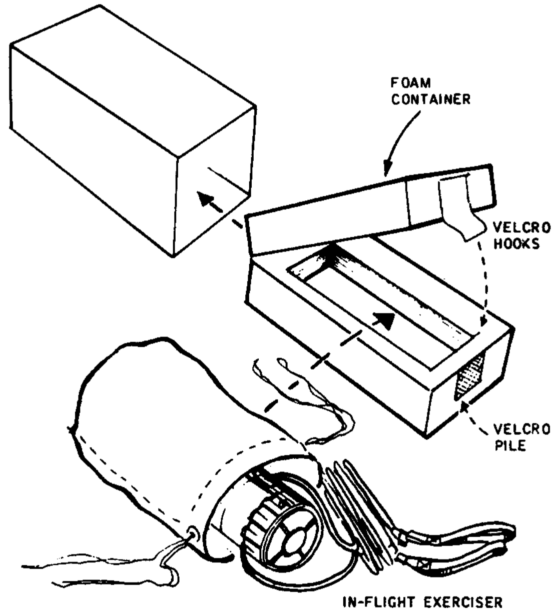



**Figure II-90 — Exer-Gym**

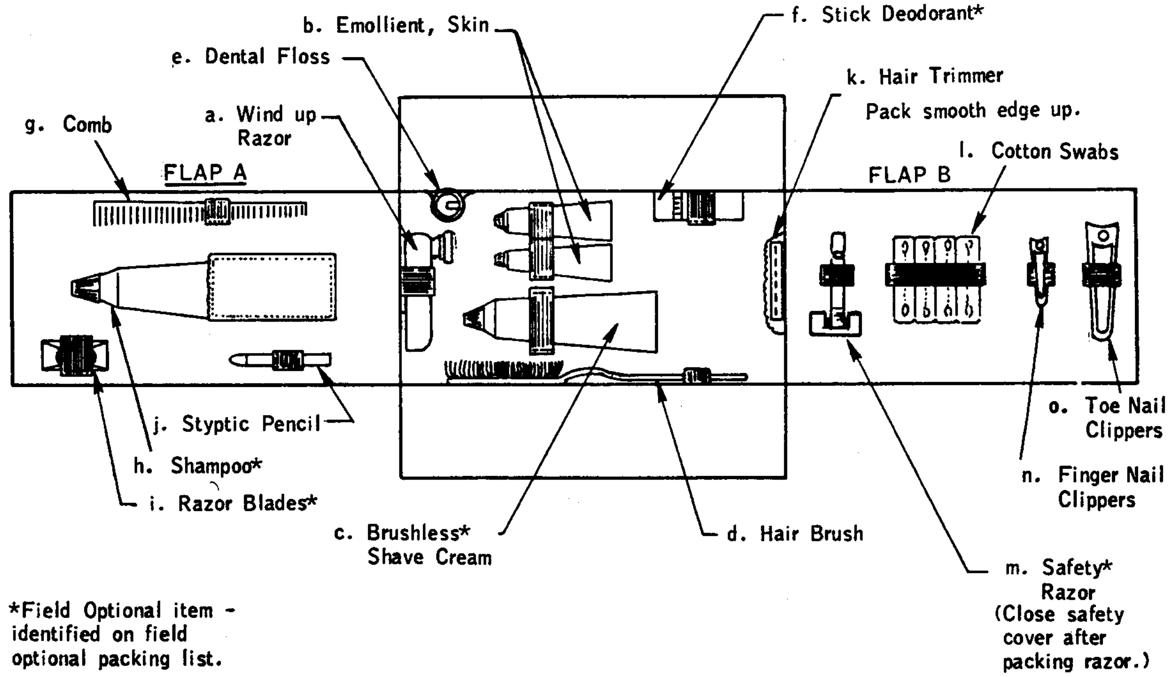



**Figure II-91 — Personal Hygiene Kit**

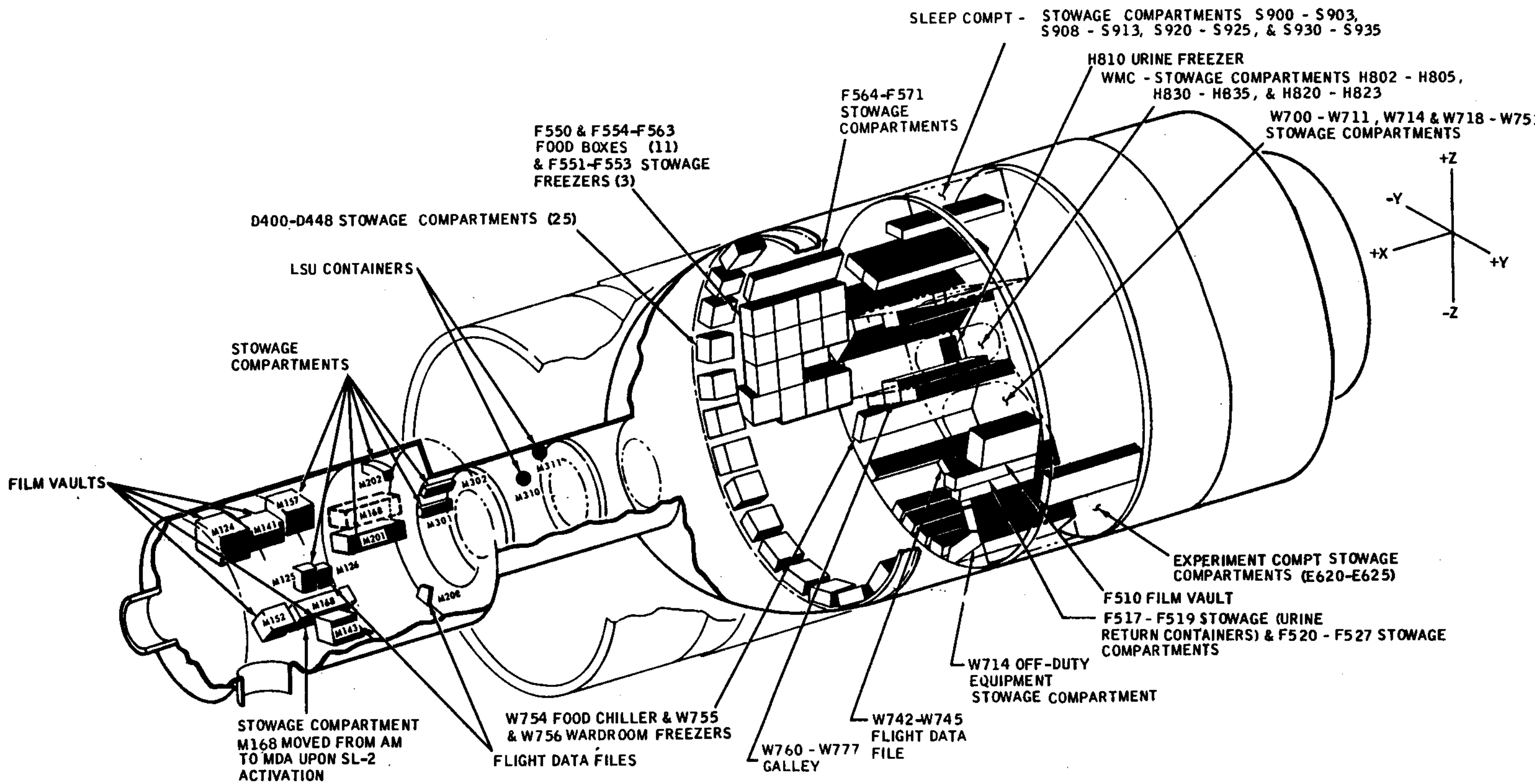



Figure II-93 — Skylab Stowage

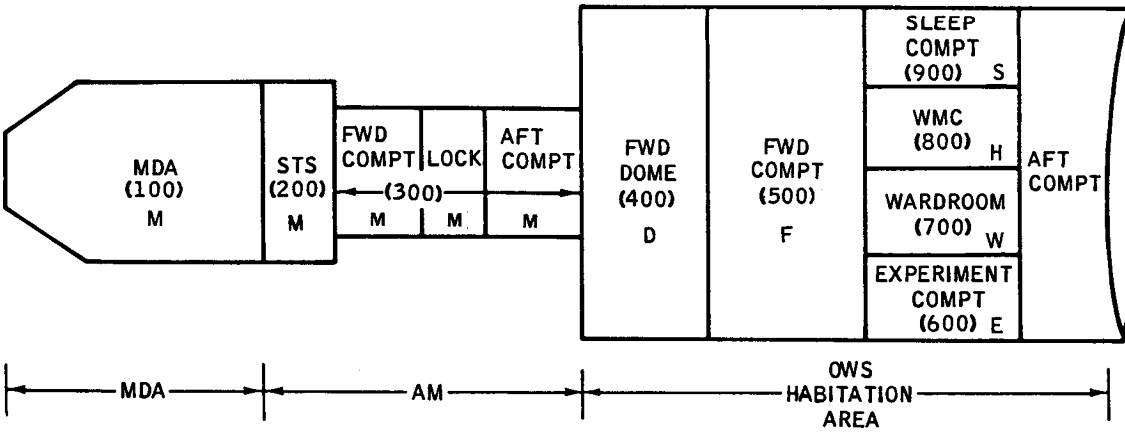
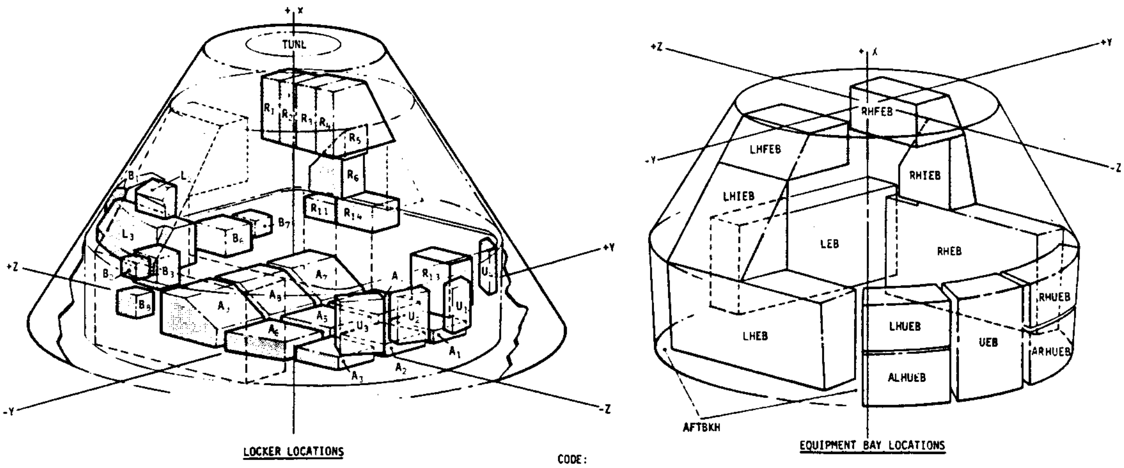



**Figure II-94 – Stowage Numbering**




CODE:

AFTBKH - AFTBULKHEAD
ALHUEB - AFT LEFT HAND UPPER EQUIP. BAY
ARHUEB - AFT RIGHT HAND UPPER EQUIP. BAY
LEB - LOWER EQUIP. BAY
LHEB - LEFT HAND EQUIP. BAY
LHFEB - LEFT HAND FORWARD EQUIP. BAY
LHIEB - LEFT HAND INTERMEDIATE EQUIP. BAY
LHUEB - LEFT HAND UPPER BAY
RHEB - RIGHT HAND EQUIP. BAY
RHFEB - RIGHT HAND FORWARD EQUIP. BAY
RHIEB - RIGHT HAND INTERMEDIATE EQUIP. BAY
RHUEB - RIGHT HAND UPPER EQUIP. BAY
TUNL - TUNNEL
UEB - UPPER EQUIP. BAY

NOTE: AXES SHOWN ARE FOR DYNAMIC REFERENCE; THEY ARE NOT MASS PROPERTY AXES.

**Figure II-95 – Command Module Stowage**

Table II-15 – Cameras and Film

| Camera | Experiment | Mission Number | Film Type |
|---|---|---|---|
| 16 mm DAC | M131 | SL2 and SL3 | S0168 |
| | M151 | SL2, SL3, and SL4 | S0168 |
| | M479 | SL3 | S0180 |
| | M487 | SL2, SL3, and SL4 | S0168 |
| | M512 | SL2 | 7242 |
| | Operational | SL2, SL3, and SL4 | S0168<br>S0368 |
| | S073/T027 | SL2, SL3, and SL4 | 2485 |
| | S183 | SL3 and SL4 | 103a-0 |
| | T013 | SL3 | S0168 |
| | T020 | SL3 | S0168 |
| | S191 | SL2, SL3 and SL4 | EK 3401 |
| 35 mm Nikon | S063 | SL2, SL3, and SL4 | 2485<br>S0368 |
| 70 mm Hasselblad | Operational | SL2, SL3, and SL4 | S0168 |
| | Operational | SL2, SL3, and SL4 | S0368 |
| | T020 | SL3 | S0168 |
| 70 mm Itek (6) | S190A | SL2, SL3, and SL4 | SO 022<br>EK 2424<br>SO 127<br>SO 356 |
| Earth Terrain Camera, Actron | S190B | SL2, SL3, and SL4 | SO 242<br>EK 3414<br>EK 3443 |

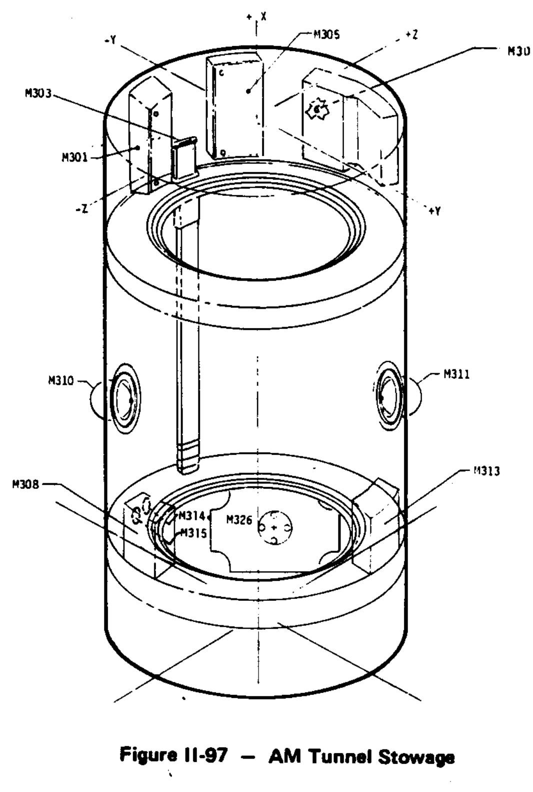



**Figure II-97 – AM Tunnel Stowage**

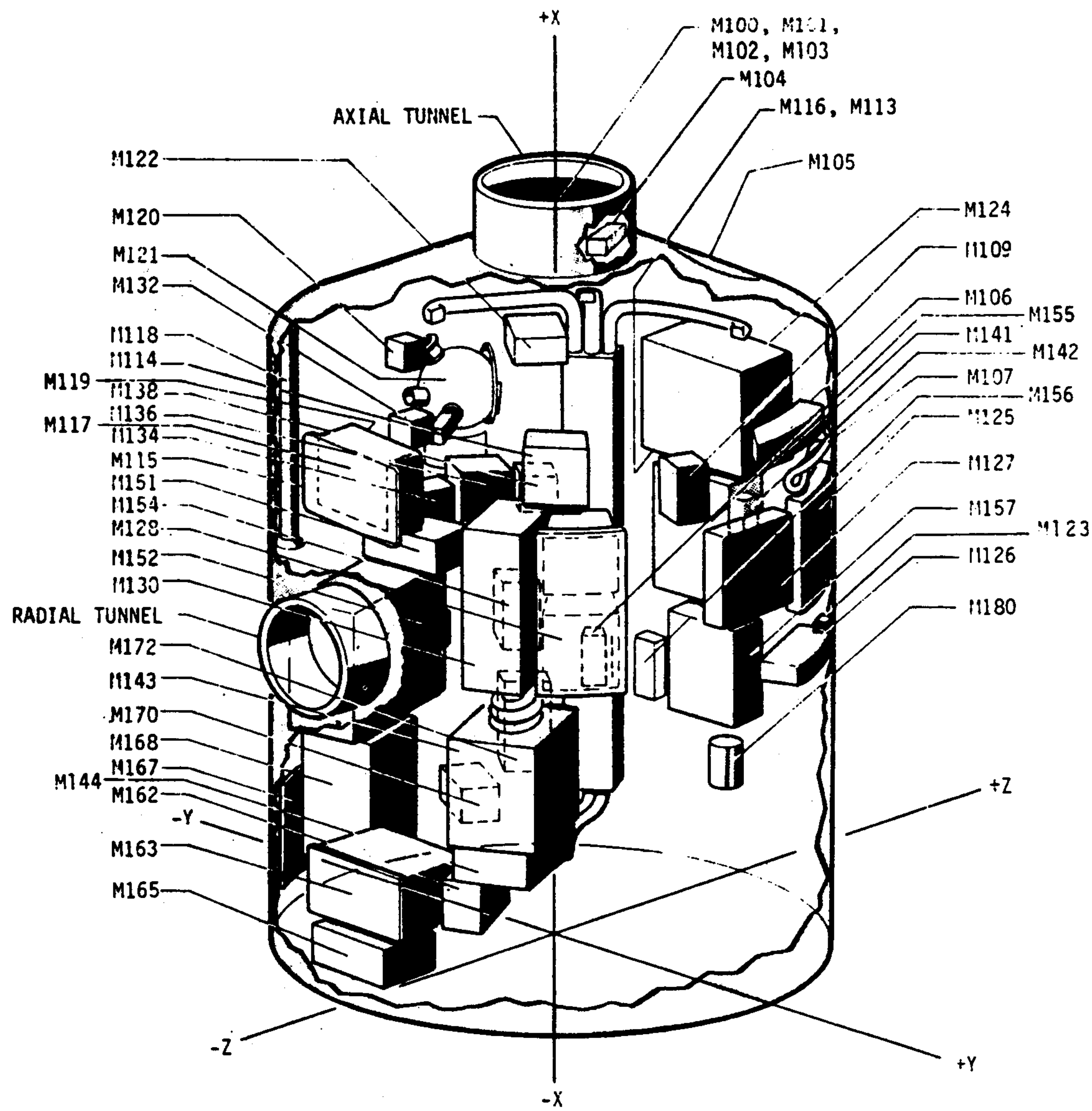



**Figure II-96 — MDA Stowage**

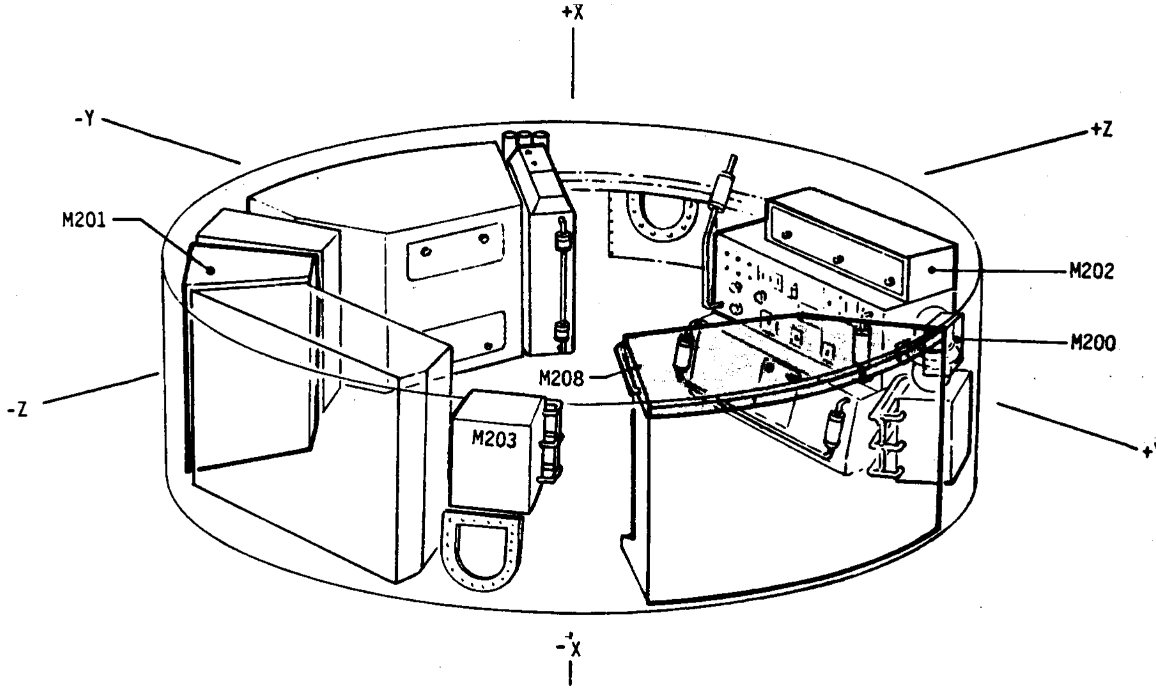



**Figure II-98 — AM STS Stowage**

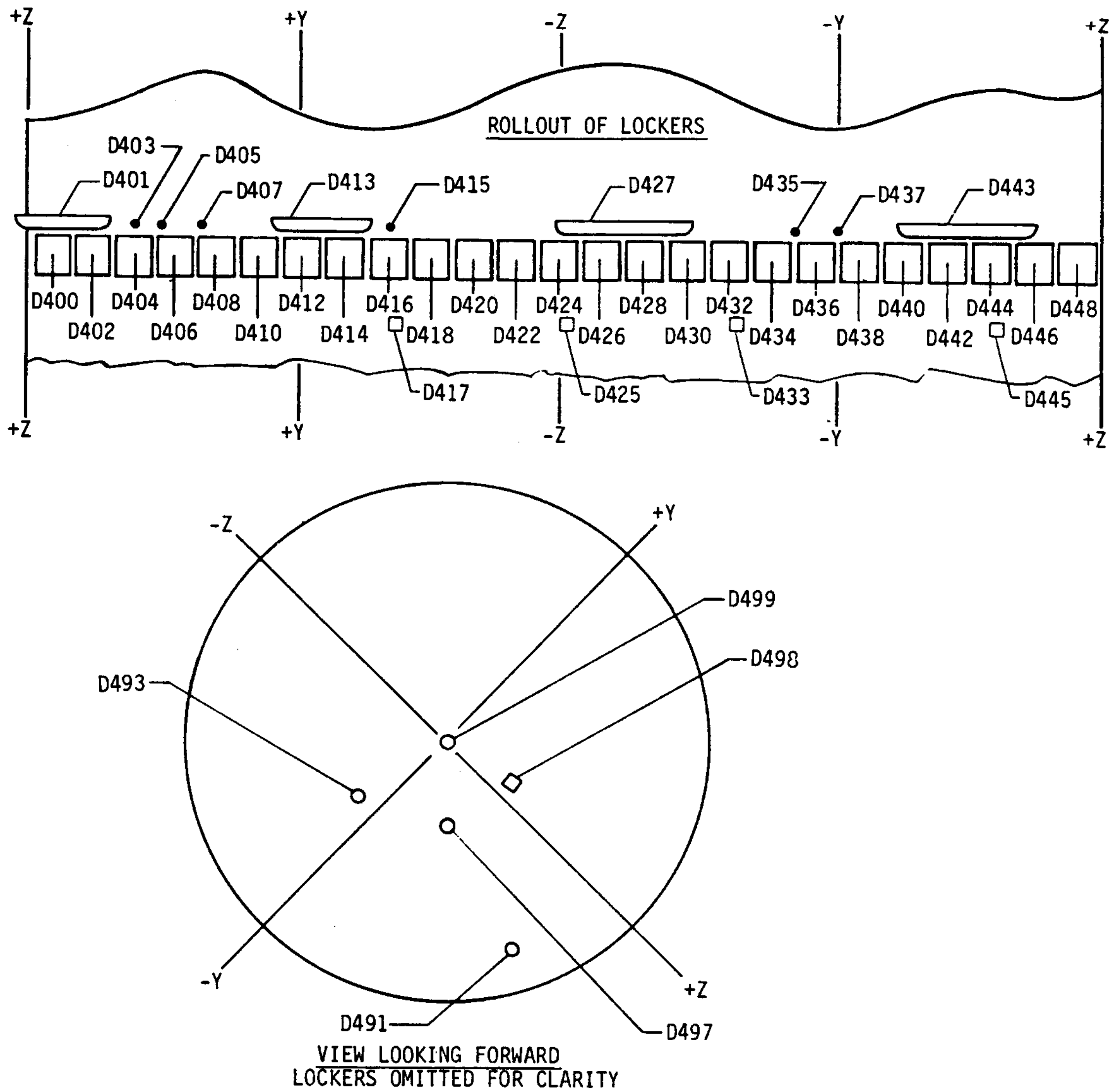



**Figure II-99 — OWS Stowage Ring**

Table II-16 – Film Description

| | |
|---|---|
| S0368 | Ektachrome MS; color reversal; ASA 64; daylight application |
| S0180 | Ektachrome Infrared; color reversal; aerial type |
| S0168 | Ektachrome EF; high speed color reversal; ASA 160; daylight, low light, level applications |
| S0212 | Panatomic X; black and white, very high resolution |
| S0101 | Panchromatic with extended red sensitivity; maximum sensitivity at 6560 Angstroms |
| SC-5 | Short Wave Radiation; Kodak-Pathe (French) manufactured |
| 7242 | Ektachrome EFB; color reversal; tungsten balanced; ASA 160; low light level applications |
| EK 3414 | Tri-X Aerographic, black and white |
| SO 022 | Panatomic-X; black and white; ASA 40; high resolution terrain photography applications |
| 2485 | Panchromatic with extended red sensitivity; very high speed black and white; ASA 6000; low light level applications |
| 2403 | Tri-X Aerographic; black and white with extended red sensitivity; low light level applications |
| 026-02 | Same as 3400 but with spectral sensitization and enhanced reciprocity response to long exposure times |
| 104-06 | Schumann type emulsion for ultraviolet applications in wavelengths shorter than 2200 Angstroms |
| 101-06 | Schumann type emulsion for ultraviolet applications in the 50-4000 Angstrom band |
| 103a-0 | UV emulsion, 2500 to 5000 Angstrom sensitivity; medium contrast, low resolution |
| SO 356 | Aerial color (High resolution) |
| EK 2424 | Infrared aerographic, sensitized to blue, red and infrared |
| 3401 | Black and white, high resolution aerial type, ASA 125 |
| 7241 | Experimental, in place of SO 168 for Experiment M512 |
| 2443 | Aerochrome IR, color (4 mil base) |
| 3443 | Aerochrome IR, color (2½ mil base) |

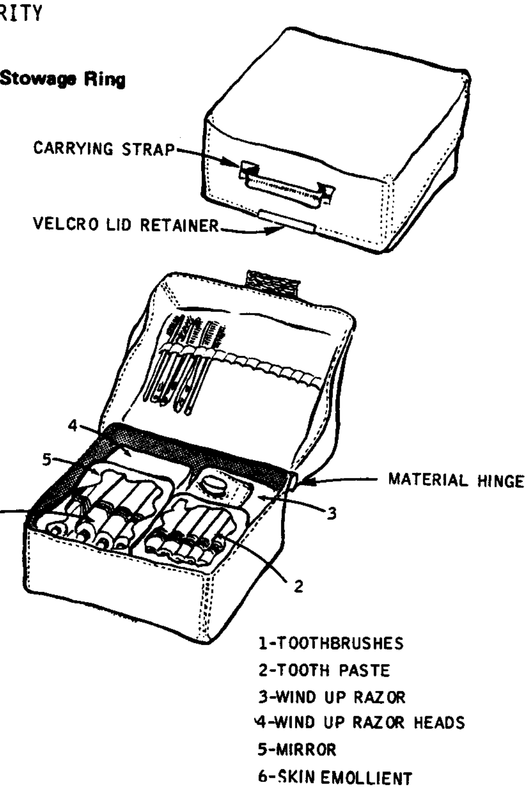



**Figure II-92 — Personal Hygiene Resupply Kit**

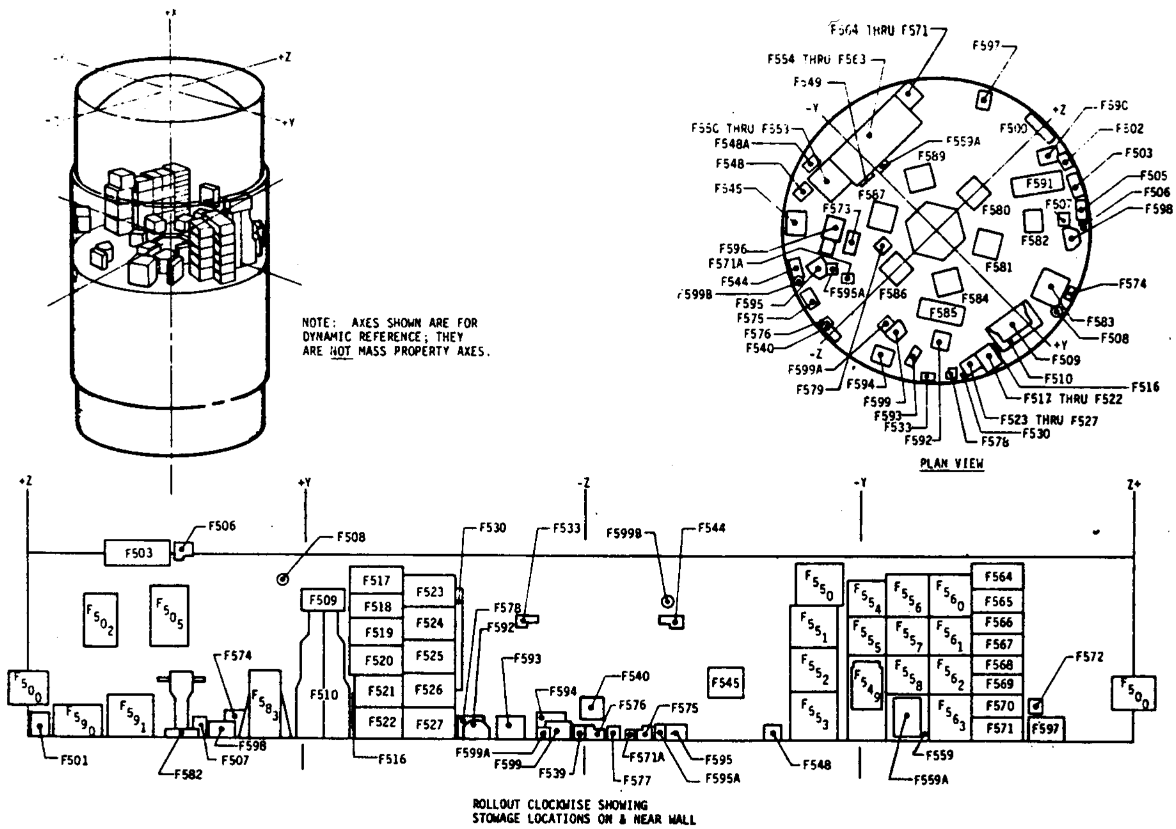



**Figure II-100 – OWS Forward Compartment Stowage**

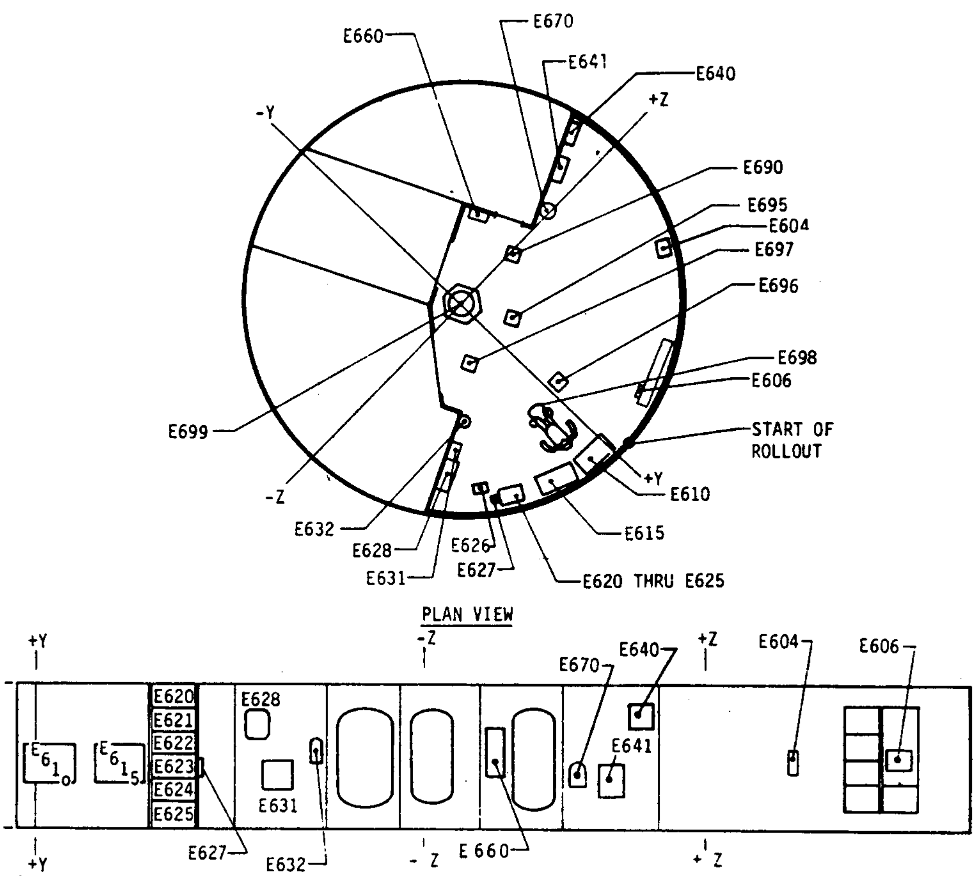



**Figure II-101 – OWS Experiment Compartment Stowage**

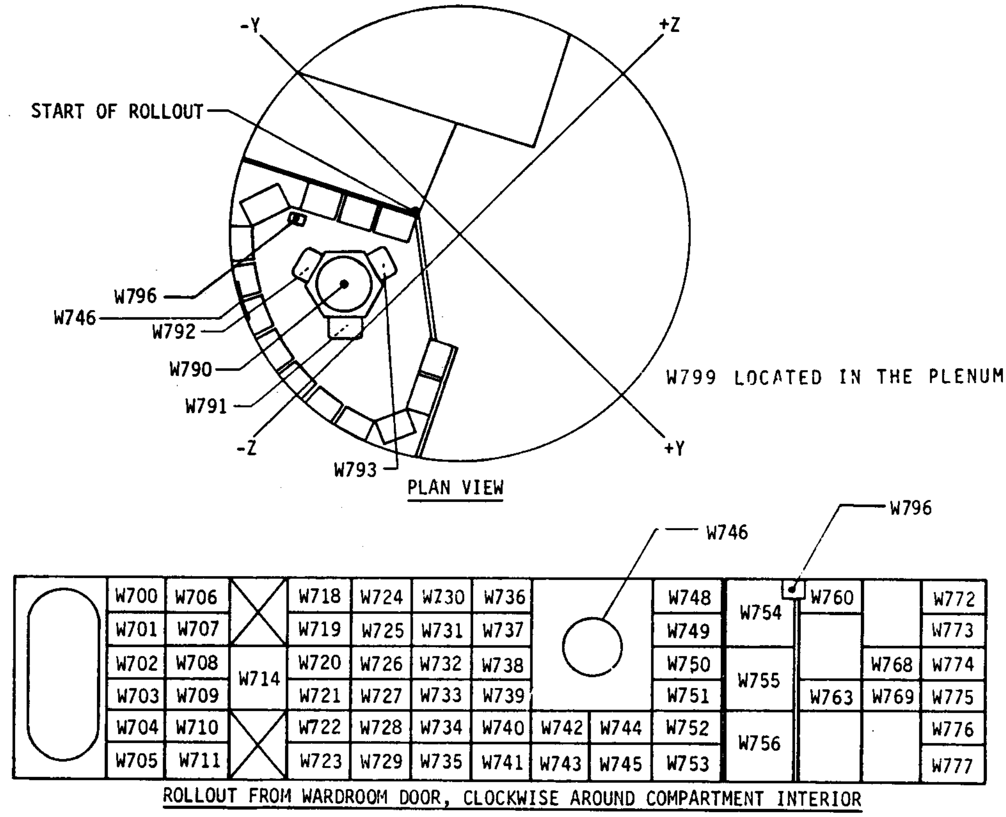



**Figure II-102 – OWS Wardroom Stowage**

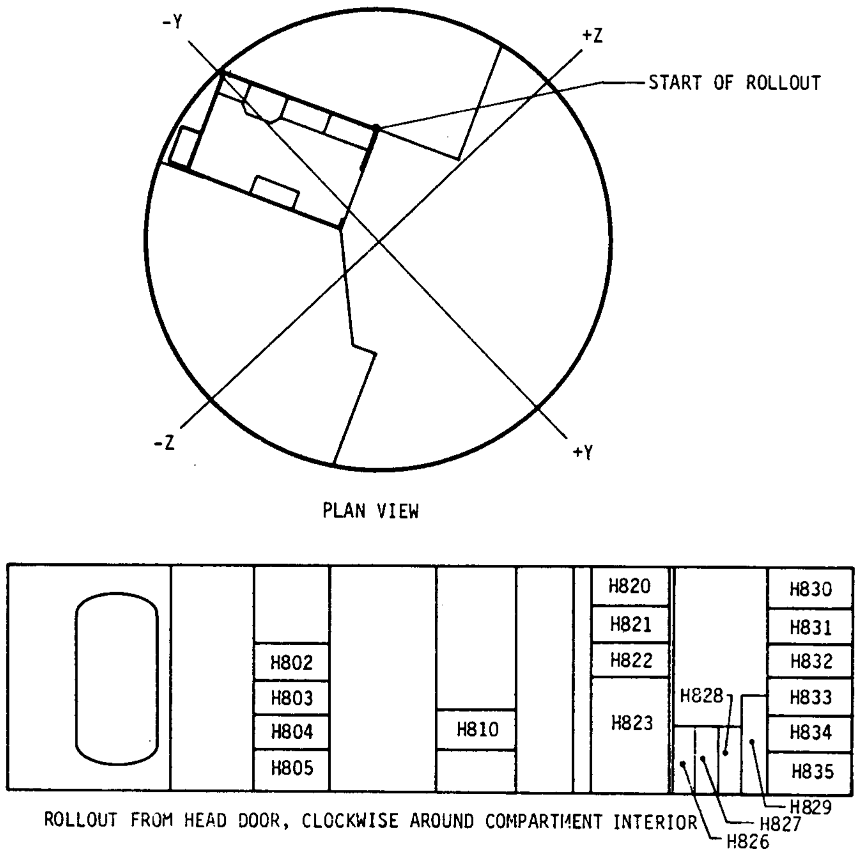



**Figure II-103 – OWS WMC Stowage**

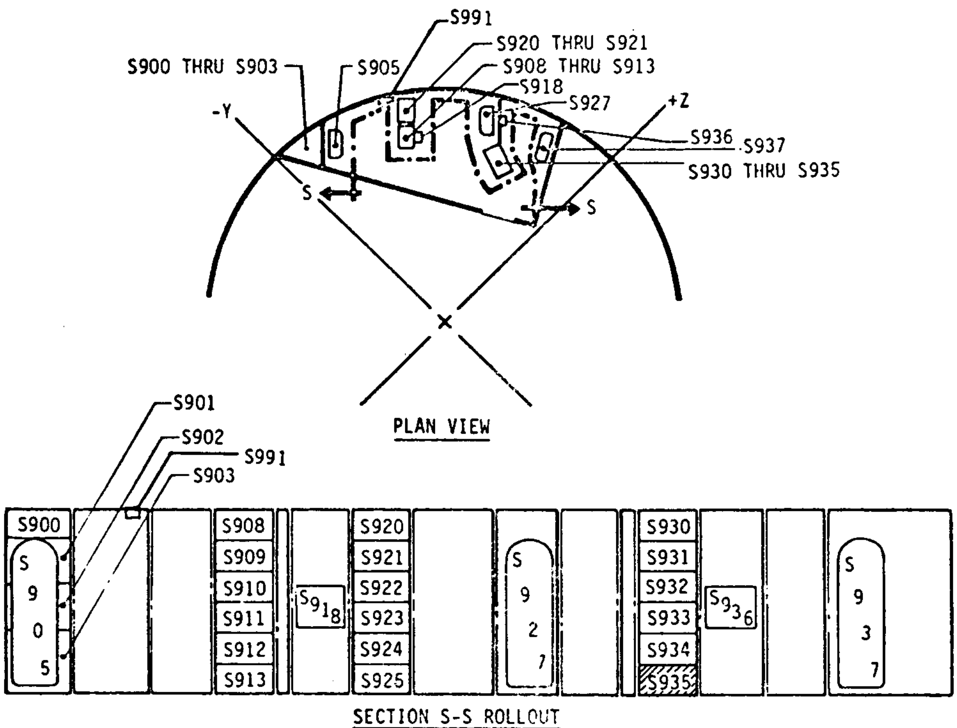



Figure II-104 – OWS Sleep Compartment Stowage

## KEY FOR FOLDOUT SKYLAB DRAWING ON NEXT PAGE:

### COMMAND & SERVICE MODULE

1. SPS Engine
2. Running Lights (8 places)
3. Scimitar Antenna
4. Docking Light
5. Pitch Control Engines
6. Crew Hatch
7. Pitch Control Engines
8. Rendezvous Window
9. EVA Handholds
10. EVA Light
11. Side Window
12. Roll Engines (2 places)
13. EPS Radiator Panels
14. SM RCS Module (4 places)
15. ECS Radiator

### MULTIPLE DOCKING ADAPTER

1. Axial Docking Port Access Hatch
2. Docking Target
3. Exothermic Experiment
4. Infrared Spectrometer Viewfinder
5. Atmosphere Interchange Duct
6. Area Fan
7. Window Cover
8. Cable Trays
9. Inverter Lighting Control Assembly
10. L-Band Antenna
11. Proton Spectrometer
12. Running Lights (4 places)
13. Infrared Spectrometer
14. Film Vault 4
15. Film Vault 1
16. SO82 (A&B) Canisters
17. M512/M479 Experiment
18. Area Fan
19. Composite Casting
20. Film Vault 2
21. TV Camera Input Station
22. Utility Outlet
23. M168 STS Miscellaneous Stowage Container
24. Redundant Tape Recorder
25. Radial Docking Port
26. 10-Band Multispectral Scanner
27. TV Camera Input Station
28. Temperature Thermostat
29. Radio Noise Burst Monitor
30. ATM C&D Console

### AIRLOCK MODULE

1. Deployment Assembly Reels and Cables
2. Solar Radio Noise Burst Monitor Antenna
3. Handrails
4. DO21/DO24 Sample Panels
5. (Removed)
6. Clothesline (EVA use)
7. Permanent Stowage Container
8. STA IVA Station
9. Nitrogen Tanks (6 places)
10. Oxygen Tanks (6 places)
11. Molecular Sieve
12. Condensate Module
13. Electrical Feedthru Cover
14. Electronics Module 1
15. EVA Hatch
16. Airlock Instrumentation Panel
17. Molecular Sieve
18. STS C&D Console
19. ATM Deployment Assembly
20. Battery Module (2 places)
21. EVA Panel
22. Airlock Internal Hatches (2 places)
23. S193 Microwave Scatterometer Antenna
24. Running Lights (4 places)
25. Handrails
26. Stub Antennas (2 places)
27. Thermal Blanket
28. Discone Antenna (2 places)

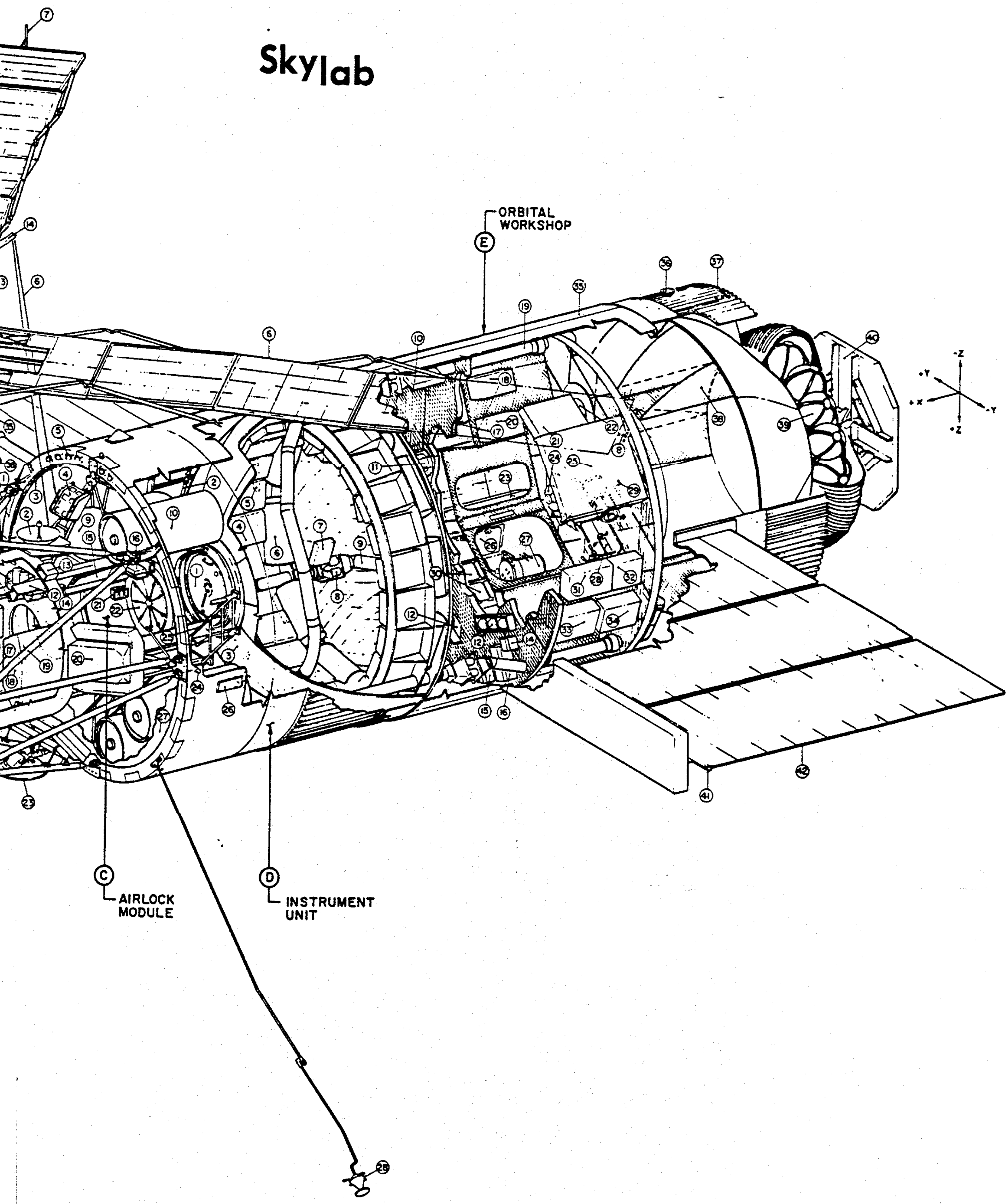
### ORBITAL WORKSHOP

1. OWS Hatch
2. Nonpropulsive Vent Line
3. VCS Mining Chamber and Filter
4. Stowage Ring Containers (24 places)
5. Light Assembly
6. Water Storage Tanks (10 places)
7. TO13 Force Measuring Unit
8. VCS Fan Cluster (3 places)
9. VCS Duct (3 places)
10. Scientific Airlock (2 places)
11. WMC Ventiation Unit
12. Emergency Egress Opening (2 places)
13. M509 Nitrogen Bottle Stowage
14. SO19 Optics Stowage Container
15. S149 Particle Collection Container
16. SO19 Optics Stowage Container
17. Sleep Compartment Privacy Curtains (3 places)
18. M131 Stowage Container
19. VCS Duct Heater (2 places)
20. M131 Rotating Chair Control Console
21. Power and Display Console
22. M131 Rotating Chair
23. WMC Drying Area
24. Trash Disposal Airlock
25. OWS C&D Console
26. Food Freezers (2 places)
27. Food Preparation Table
28. M171 Ergometer
29. MO92 Lower-Body Negative Pressure
30. Stowage Lockers
31. Experiment Support System Panel
32. Biomedical Stowage Cabinet
33. M171 Gas Analyzer
34. Biomedical Stowage Cabinet
35. Meteoroid Shield
36. Nonpropulsive Vent (2 places)
37. TACS Module (2 places)
38. Waste Tank Separation Screens
39. TACS Spheres (22), Pneumatic Sphere
40. Refrigeration System Radiator
41. Acquisition Light (2 places)
42. Solar Array Wing (2 places)

### APOLLO TELESCOPE MOUNT

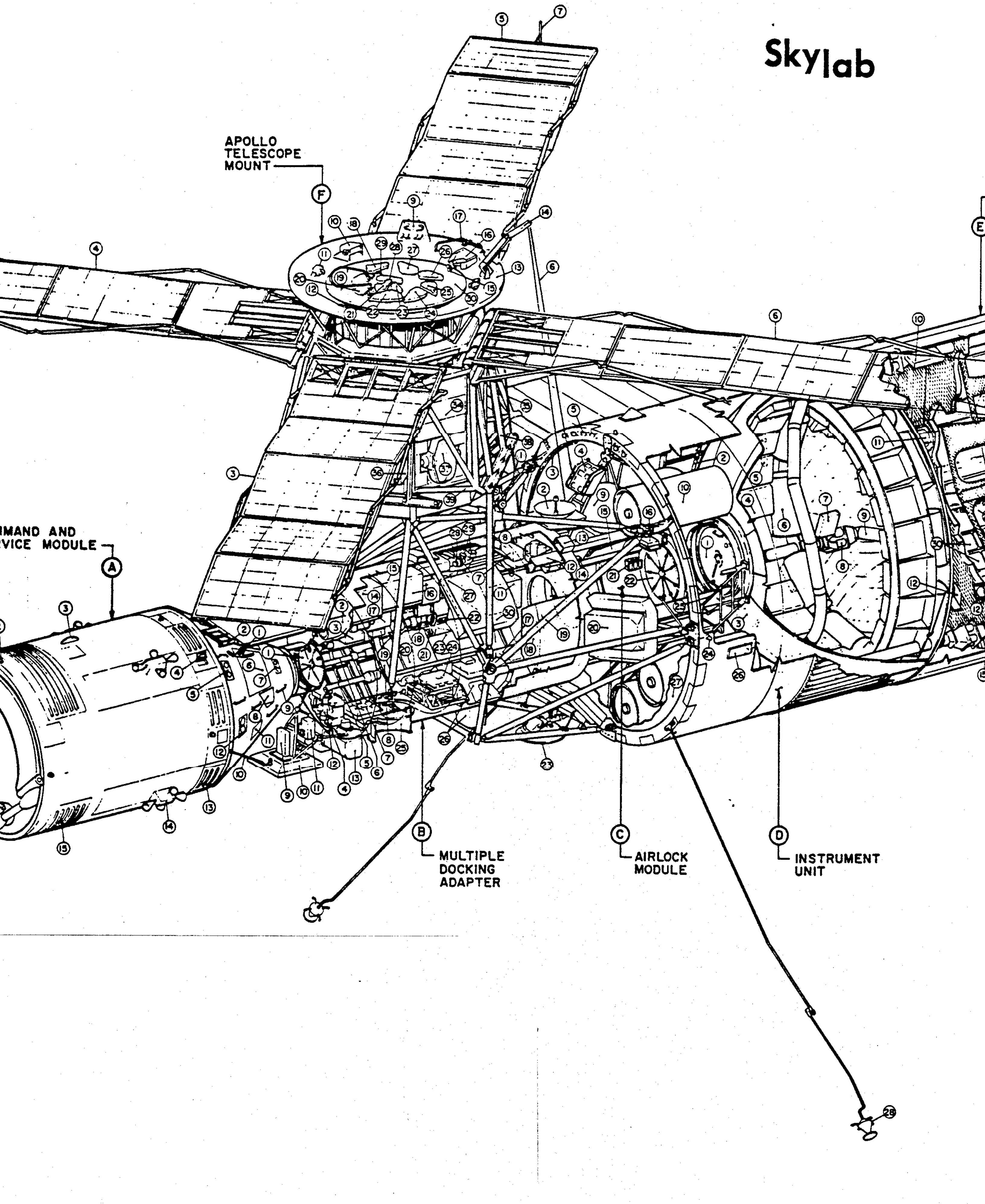
1. Command Antenna
2. Telemetry Antenna
3. Solar Array Wing 1
4. Solar Array Wing 2
5. Solar Array Wing 3
6. Solar Array Wing 4
7. Command Antenna
8. Telemetry Antenna
9. Sun-End Work Station Foot Restraint
10. Temporary Camera Storage
11. Quartz Crystal Microbalance (2 places)
12. Acquisition Sun Sensor Assembly
13. ATM Solar Shield
14. Clothesline Attach Boom
15. EVA Lights (8 places)
16. Sun-End Film Tree Stowage
17. Handrail
18. SO82-B Experiment Aperture Door
19. Ha-2 Experiment Aperture Door
20. SO82-A Film Retrieval Door
21. SO82-A Experiment Aperture Door
22. SO54 Experiment Aperture Door
23. Fine Sun Sensor Aperture Door
24. SO56 Experiment Aperture Door
25. SO52 Experiment Aperture Door
26. Ha-1 Experiment Aperture Door
27. SO55A Experiment Aperture Door
28. SO82-B2 Experiment Aperture Door
29. SO82-B Film Retrieval Door
30. Canister Solar Shield
31. Canister
32. Canister Radiator
33. Rack
34. Charger-Battery-Regulator Modules (18 places)
35. Handrail
36. CMG Inverter Assembly (3 places)
37. Control Moment Gyro (3 places)
38. Solar Wing Support Structure (3 places)
39. ATM Outriggers (3 places)

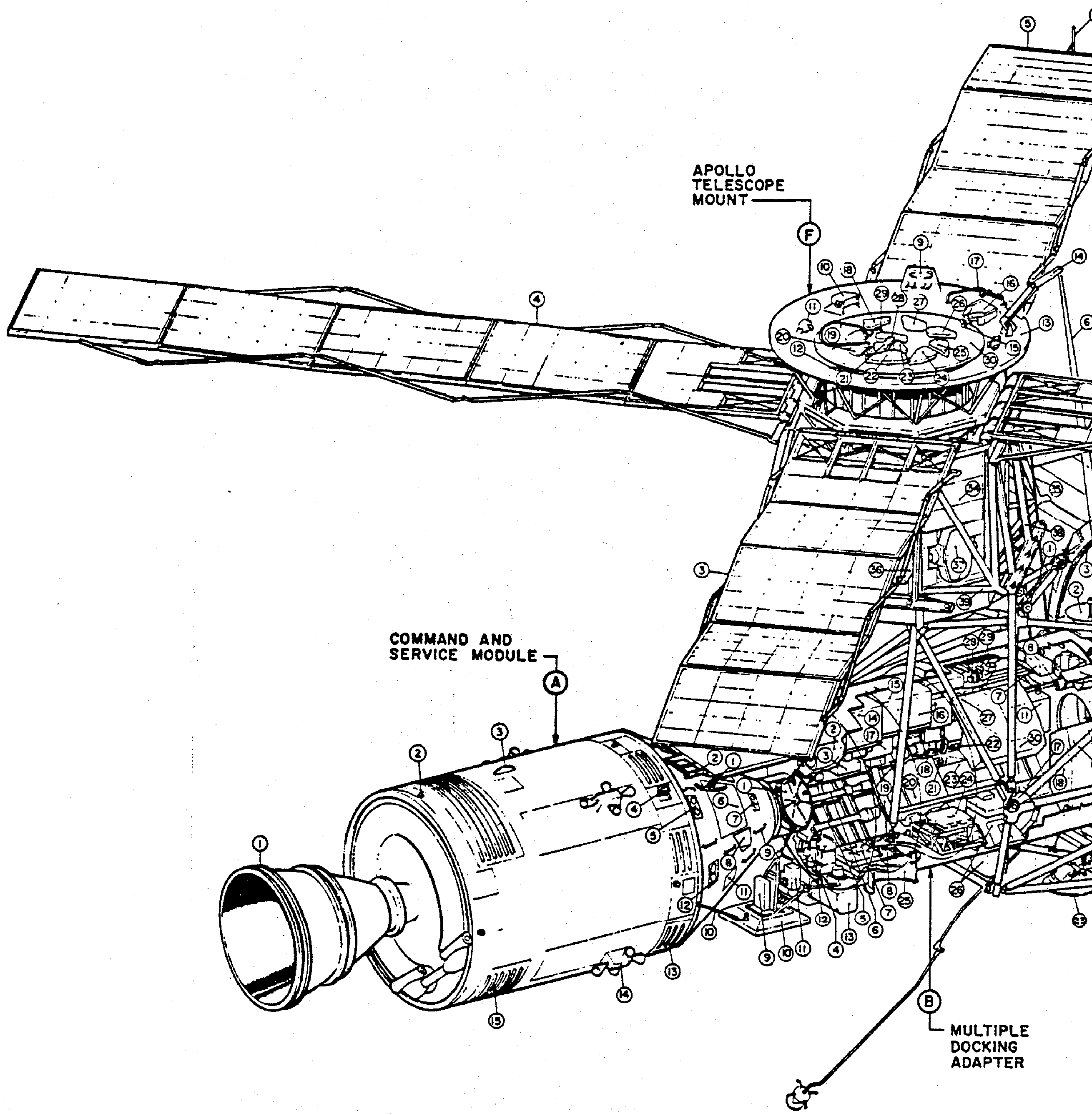
# Skylab



ORBITAL WORKSHOP
E
AIRLOCK MODULE
C
INSTRUMENT UNIT
D
-Z
+Y
+X
-Y
+Z

# Skylab


APOLLO TELESCOPE MOUNT
F
E
MMAND AND
VICE MODULE
A
B
MULTIPLE DOCKING ADAPTER
C
AIRLOCK MODULE
D
INSTRUMENT UNIT


APOLLO
TELESCOPE
MOUNT
F
COMMAND AND
SERVICE MODULE
A
B
MULTIPLE
DOCKING
ADAPTER