Skylab Facilities and Operations

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ABSTRACT

The purpose of this paper is to outline the essential objectives and elements of the Skylab Program and to describe the impact of the Program on the Kennedy Space Center. The operational test flows and the required facility modifications to support Skylab checkout and launch requirements will be highlighted.

INTRODUCTION

The Skylab Program, using basic hardware developed to support the Apollo manned lunar landing, supplemented by several new flight hardware modules, represents the next major step in the orderly progression of manned space flight. The Program has a number of basic objectives.

First is the conduct of long duration space flights of man and systems. These flights will demonstrate the unique capabilities of man to both function in a space environment for extended periods of up to 56 days and to contribute materially to mission success. Further, it will allow us to establish a habitable space workshop and verify our ability to conduct experiments within that structure. We plan to conduct a number of biomedical and behavioral experiments to determine the effects of long duration space flight on the crew so that a logical basis can be established for increasing crew orbital stay time.

Secondly, we will conduct scientific investigations in earth orbit using the Apollo Telescope Mount to observe the sun. Such observations can be much more accurately obtained outside the restrictive atmosphere of the earth.

Thirdly, a number of specific applications in earth orbit will be explored. Meteorlogical and earth resources experiments will be conducted and communications methods and equipment will be exercised and evaluated. The value of earth observation from space has already been partially demonstrated by previous manned missions and we expect to capitalize on this prior experience during the Skylab Program. Infra-red photographs taken by the Apollo 9 astronauts were used by scientists at the U. S. Geological Center at Menlo Park, California, to observe the St. Andreas Fault. These observations indicated a pressure buildup which forecast the imminence of a major earthquake in this area. This earthquake activity occured during the Apollo 14 mission in the California Imperial Valley.

Further, Skylab represents an effective and economical approach to the development of a basis for potential future space programs. These include a long duration earth orbital space station, with the capability of operation of up to two years or longer, and manned planetary exploration. The information we gather in Skylab will serve as a firm base upon which the future space systems can be developed.

The Kennedy Space Center is cast in its traditional role - being charged with the responsibility to conduct prelaunch checkout and launch operations for the Skylab missions. Accomplishment of this task also requires modification of KSC checkout and launch facilities previously utilized to support Apollo manned launches. The design, development and incorporation of the required modifications to meet the peculiar Skylab Program requirements is also a KSC responsibility.

The remainder of this paper will briefly outline the essential elements of the unique Skylab flight hardware and will highlight the KSC operational test flows, describing the processing of each module through the checkout areas of the Operations and Checkout Building and Launch Complex 39. Particular emphasis will be placed on the major modifications required which include the ATM clean room, the pedestal on the Launch Umbilical Tower to enable the Saturn IB/CSM vehicle to be launched from LC-39, and new access and service arms to meet peculiar program requirements. Of particular note is the fact that the inherent capabilities of Launch Complex 39 to absorb new program requirements are being fully exploited at minimum cost in support of Skylab Program needs. This theme will be stressed throughout this paper.

SKYLAB MISSION PROFILE

The Skylab Program consists of four launches, one unmanned and three manned, to conduct three interrelated missions. The first mission, SL-1/ SL-2 will consist of two launches approximately one day apart. The SL-1 vehicle configuration consists of a two stage Saturn V launch vehicle - the S-IC and S-II stages - and the Saturn Workshop (SWS) comprised of a modified S-IVB Orbital Workshop (OWS), Airlock Module (AM), Multiple Docking Adapter (MDA), Apollo Telescope Mount (ATM), and Instrument Unit (IU). After launch from LC-39 Pad A, the workshop will be placed in a nominal 235 nautical mile altitude by the two stage launch vehicle, the ATM deployed to its orbital configuration and the orbital assembly stabilized in the proper attitude.

The operation of the assembly will be verified by ground command and telemetry data prior to the launch of the manned CSM mission, SL-2, from LC-39 Pad B. The launch vehicle is a standard Saturn IB, consisting of the S-IB and S-IVB stage and Instrument Unit, similar to that used on Apollo 7 to place the first manned Apollo spacecraft in earth orbit. The SL-2 vehicle will be launched approximately one day after the SL-1 launch. The CSM will rendezvous and dock with the orbital assembly. Following docking, the crew will transfer into the OWS, activate the OWS life support systems and place the CSM in a quiescent, minimum energy demand mode, for the duration of this initial manned workshop operations period.

The SL-1/SL-2 mission will be primarily directed toward the accomplishment of a series of medical experiments related to the extension of manned spaceflight. Secondary emphasis will be on solar astronomy, earth resources, and technical experiments. This mission is open ended but is planned to last 28 days beginning with the launch of the SL-2 CSM. At the end of this period, the workshop will be prepared for an unmanned phase during which it will be in a semiactive condition. The crew will transfer to the CSM, undock from the orbital assembly, deorbit and return to earth.

The SL-3 and SL-4 manned CSMs will perform revisit missions at three and six month intervals from the SL-2 launch. These missions are open ended and planned to last 56 days. These missions will reactive the workshop and reperform medical, technical, scientific, earth resources, and solar astronomy experiments. A mission profile of the entire sequence of Skylab missions is shown in Figure 1.

SKYLAB UNIQUE MISSION HARDWARE

To accomplish the Skylab Program objectives, a number of new hardware flight modules have been developed. The essential elements of each are briefly described below.

ORBITAL WORKSHOP (OWS)

The OWS is a modified S-IVB stage that is ground outfitted to provide a habitable environment for extended crew operations. The LH_2 tank is divided into two floors by open aluminum grid structures compartmented to provide space for crew habitation and operational activities. See Figure 2. The crew quarters are divided into four areas, as shown in Figure 3: sleep compartment, waste management compartment, wardroom, and experiment compartment. A side hatch into the wardroom is provided for access into the OWS during ground checkout.

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

A meteoroid shield is designed as a structurally-integrated part of the OWS and protects the cylindrical portion of the tank. After deployment, the shield does not extend more than 6 inches radially from the outer surface of the LH_2 tank. Deployment is accomplished during orbit by a signal from the IU.

A Solar Array System (SAS) is provided as a source of power during orbital operations. Routing of this power is accomplished via the Airlock Module power distribution system.

AIRLOCK MODULE (AM)

The AM provides the major work area and support equipment required to activate and operate the OWS. The AM includes a fixed airlock shroud (FAS) and an ATM Deployment Assembly. Integration of the AM structure within the cluster provides for: a pressurized interconnecting passageway between the MDA and the OWS; support for intervehicular activity (IVA) and extravehicular activity (EVA) via the AM airlock; structural support for the MDA; the supply, distribution and control of the cluster atmosphere, and thermal control of the SWS (excluding the ATM) before OWS SAS deployment and during dark-side operations.

The general arrangement of the AM and its component systems are shown in Figure 4.

MULTIPLE DOCKING ADAPTER (MDA)

The MDA is that part of the SWS which provides a permanent interface with the AM and a docking interface with the CSM. The MDA permits the transfer of personnel, equipment, power, and electrical signals between the docked module, the AM and the OWS.

Integration of the MDA structure within the cluster provides for: a pressurized passageway between the AM and the docked CSM; two docking interfaces (one axial; and one radial) for the CSM. The radial port has a physical docking capability only. Complete interfacing equipment and umbilicals at the axial port are provided to allow integration of the docked CSM with the SWS; internal storage of hardware and experiments launched and operated in the hardware and experiments launched and operated in the MDA; support for the conduct of experiments and crew operations; use of the ATM control and display console to control and monitor the attitude control system and the ATM. The general configuration of the MDA is shown in Figure 5.

APOLLO TELESCOPE MOUNT (ATM)

The ATM consists of various solar-observatory experiments and supporting equipment for observing, monitoring, and recording solar phenomena. Experimental data will be taken in the white-light, ultra-violet and x-ray regions of the spectrum. Observations will be conducted both within and near the solar disc. Figure 6 shows the ATM general arrangement.

The cylindrical ATM experiment canister provides for the following:

a. Installation and removal of experiment film cassettes during orbital operations (by means of EVA);

b. Remote-controlled protective covers for the experiments and for the pointing optics at the sun end of the experiment canister. These covers can be controlled from the ATM control and display panel located in the MDA;

c. Contamination protection and thermal control for solar experiments and internally-mounted hardware;

d. Gimballed fine pointing and offset pointing for solar experimentation. This experiment package gimbal is locked in place during launch to provide a separate load path that prevents it from being damaged.

Control and display of the various ATM systems is furnished at the ATM control and display console located in the MDA.

COMMAND AND SERVICE MODULE (CSM)

For Skylab missions, modifications to the Apollo Block II modules are required because of the different operational and support requirements for Skylab which result from longer mission duration, new orbital rendezvous requirements, cluster support requirements, mission attitude constraints, and increased return payload. The Skylab CSM will operate essentially as does a Block II spacecraft during ascent, rendezvous and docking to the cluster. When docked, much of the equipment in the modules will be shut off to conserve power.

PRELAUNCH CHECKOUT OPERATIONS AND RELATED FACILITY MODIFICATIONS

A summary hardware checkout flow of the activity within the Operations and Checkout (O&C) Building and Launch Complex 39 is shown in Figure 7. This section will describe the major elements of the flow and the attendant facility modifications required to accommodate checkout operations.

O&C BUILDING

The AM/MDA, the ATM and the CSM undergo simultaneous checkout in the Operations and Checkout Building in the KSC Spacecraft

Industrial Area.

A layout of the O&C Building is shown in Figure 8. Early in this flow, a docking test between the CSM and AM/MDA will be performed to verify the docking interfaces. The CSM is placed in the West Integrated Test Stand. The AM/MDA is removed from its mobile transporter and lowered, MDA down, to mate with the CSM. The CSM has a probe identical to that used in Apollo and the MDA docking port has a drogue similar to that used in the Apollo LM for docking. A leak check is performed to verify the mechanical docking interface. Electrical/communications tests are accomplished to validate all electrical connections. These tests are the only interface tests involving the flight CSM and the AM/MDA prior to launch. The next time these modules interface is following rendezvous manuevers in earth orbit as earlier described.

After the docking test is complete, the CSM will be moved to the East Altitude Chamber where it will undergo a series of premate tests including manned altitude tests similar to those performed on the Apollo mission CSMs. No modifications are anticipated to the Altitude Chamber for Skylab. The West Integrated Test Stand will then be reconfigured to accept the AM/MDA (see Figure 9). Basic structural modifications will have been incorporated prior to the docking test. Minor modifications to the work platforms will be made to accommodate the AM/MDA vehicle profile. The Fixed Airlock Shroud (FAS) will be installed in the test stand, the AM/MDA mated and aligned with it and a leak check performed to verify the interfaces. This will be followed by installation of the ATM deployment assembly, verification of its operation and systems tests of the installed experiments.

The third of the Skylab unique models, the ATM, will be undergoing its prelaunch tests in a specially designed clean room as seen in an artist's concept in Figure 10. This facility is the only major modification required in the O&C Building. The environment around the ATM must be rigidly controlled in order to avoid contamination of the lenses and other critical components of the ATM experiments. The clean room has the following essential characteristics.

a. Cleanliness: class 10,000 as defined by Federal Standard 209A.

b. Temperature: $75^{o} \pm 3^{o}$ F

c. Moisture content: 54 grains/pound of dry air

d. Size: approximately 36' x 37' x 38'

e. Floor stability: less than 5 arc seconds in 24 hours.

The Clean Room will be constructed within the O&C Building adjacent to the Apollo LM Ascent and Decent Stage checkout stands. Because of on-going Apollo LM operations for Apollo 17, construction of the Clean Room will require extraordinary care and coordination between operational, design, and fabrication elements to preclude interference with LM checkout operations. The design of the Clean Room was planned to require only a minimum amount of welding and other contamination producing activities within the O&C Building that might contaminate the surrounding areas and disrupt operations.

A complete systems test of the ATM and its experiments will be conducted and the experiment optics aligned and verified. Following installation of inflight film and the solar panels, the ATM will be prepared for its move to the VAB.

LC-39/SL-1

In parallel with the activity in the O&C Building, the S-IC and S-II launch vehicle stages, and the Orbital Workshop (OWS) will be undergoing checkout in the Vehicle Assembly Building (VAB) at Launch Complex 39. The launch vehicle stage checkout is virtually identical to that for the Apollo Saturn V stages and no facility changes are required in these areas. The three upper extensible platforms in the VAB High Bay (Platforms A, B and C) will require modifications because the vehicle profile and protuberances on the SL-1 vehicle payload are different than the Apollo Saturn V configuration. The SL-1 space vehicle has a 22 foot diameter from the OWS to the nose cone covering the ATM. The Apollo vehicle has a conical section between the Instrument Unit and the CSM which reduces the diameter of the upper portion of the vehicle to 13 feet.

In order to maintain a clean environment around the ATM following mate with the other modules in the VAB, a clean room will be required on Platform A of the High Bay. This will allow for access to the optics during integrated checkout operations.

In addition to the above changes in the VAB, a number of modifications to the Launch Umbilical Tower (LUT) will also be required. While the space vehicle is on the pad, a membrane, installed between the AM/MDA and the ATM, will keep the clean environment around the ATM. In addition, there will be a number of work platforms within the payload enclosure surrounding the AM/MDA and ATM to provide access during checkout operations and for film loading prior to closeout of the payload prior to launch. These platforms and the membrane described earlier will be removed prior to launch through the ATM Access Arm (Service Arm #8) modified from the Apollo configuration. For Apollo, this Service Arm provided servicing to the Service Module. The basic Arm is being utilized for Skylab with changes to the extension and retract systems, addition of new payload services across the arm, and modifications to the accessway from the tower.

The Apollo missions required a white room for astronaut and spacecraft checkout crew access to the CSM. This was accomplished via Saturn V Service Arm #9 (Apollo Access Arm) with an environmental chamber attached to the end. Since the SL-1 vehicle has no requirement for this service at that location, the arm will be removed and relocated with a new environmental chamber to provide access to the OWS at the launch pad via the side hatch. The present arm is made of two basic truss sections. A spacer will be added between these sections to compensate for the difference in location between the OWS hatch and the CSM hatch.

Service Arm #7, formerly used to provide services to the Lunar Module and the Saturn V S-IVB third stage, will provide services instead to the AM/MDA and ATM and OWS. A new umbilical plate will provide the interface into these modules. The arm and umbilical will be requalified for operational use via testing at the Marshall Space Flight Center. These tests will include umbilical withdrawal, liftoff simulation, and vehicle motion simulation.

Since there are only two propulsive stages in the SL-1 launch vehicle, minor modifications will be required at the launch pad and in the firing room to remove S-IVB stage propellant control and sensing circuits. Control and monitoring consoles for the OWS will replace S-IVB consoles in the firing room.

LC-39/SL-2

The most significant single modification required to support the Skylab missions at LC-39 is the construction of a 127 foot high pedestal on the Launch Umbilical Tower to adapt the shorter Saturn IB vehicle to the tower. This pedestal allows the Saturn IB second stage, instrument unit, and spacecraft to interface with the LUT at the same vehicle stations as an Apollo Saturn V. This method of adapting the smaller Saturn IB vehicle to the Complex provided a much more economical approach to the problem than would have resulted if all S-IVB stage, IU and CSM interfaces had been relocated lower on the tower and the S-IB stage erected on the existing launcher deck.

Some of the essential characteristics of the pedestal include:

a. A four-legged round section steel structure

b. K-truss welded construction

c. Floating connections between the tower section and the pedestal (The pedestal will be stiffer than the LUT Tower. The floating connection feature eliminates the transfer of stresses between the two structures.)

d. A horizontal spring constant of 450 kips/inch

e. A launcher ring - 28' diameter inside - 44' diameter outside

f. A combined SL-2 vehicle, LUT, and pedestal weighs 13,130 kips compared to 12,740 kips for the Apollo Saturn Vehicle (Apollo 13) with its LUT.

Holddown arms, service masts and other selected items of ground support equipment which were used to launch Saturn IBs from LC-34 and LC-37 will be removed from those complexes and installed on the pedestal. Existing Apollo Saturn V Service Arms 1, 3, 4 and 5 (S-IC and S-II stage servicing) will not be required for the Saturn IBs and will be removed and stored. Service Arm #2 will be modified from its present S-IC configuration to provide for S-IB stage servicing. This arm will not require any modification but the umbilical plate will be changed to the S-IB configuration and the arm relocated to the old Service Arm #5 location on the tower.

Again, the launch pad and firing rooms will require changes in the propellant servicing, control and monitoring areas to be compatible with a two stage launch vehicle. Operations will be similar to a normal Apollo CSM checkout except that a launch vehicle tanking test will be run early in the test flow. This test is designed to validate the new propellant loading system. Minor modifications to the Mobile Service Structure will also be needed to provide access to the smaller diameter S-IB stage on the manned launches.

CONCLUSIONS

In summary, the essential elements of the facilities designed and developed to support the Apollo lunar missions are being employed with only minor modifications required to support the Skylab Program. This same inherent flexibility will make it possible to adapt Launch Complex 39 to future program requirements such as the Space Shuttle and Space Station. Operational modes for Skylab again are based on precedence and experience gained during the processing of Apollo CSMs and LMs through their phases of checkout. Thus the resources of the Kennedy Space Center have been effectively focused on the accomplishment of Skylab with minimum changes and maximum effectiveness. We all look forward to the successful completion of these missions as a prelude to more sophisticated and ambitious manned missions in the years to come.

NOMENCLATURE

AM - Airlock Module
ATM - Apollo Telescope Mount
CSM - Command and Service Module
EVA - Extravehicular activity
FAS - Fixed Airlock Shroud
IU - Instrument Unit
IVA - Intravehicular activity
KSC - Kennedy Space Center
LC-39 - Launch Complex 39
LH_2 - Liquid Hydrogen
LM - Lunar Module
LUT - Launch Umbilical Tower
MDA - Multiple Docking Adapter
O&C Building - Operations and Checkout Building
OWS - Orbital Workshop
S-IB - First stage of Saturn IB launch vehicle
S-IVB - Second stage of Saturn IB launch vehicle
S-IC - First stage of Saturn V launch vehicle
S-II - Second stage of Saturn V launch vehicle
SAS - Solar Array System
SL-1 - First Skylab launch
SL-2 - Second Skylab launch
SL-3 - Third Skylab launch
SL-4 - Fourth Skylab launch
SWS - Saturn Workshop

ACKNOWLEDGEMENT

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ILLUSTRATIONS

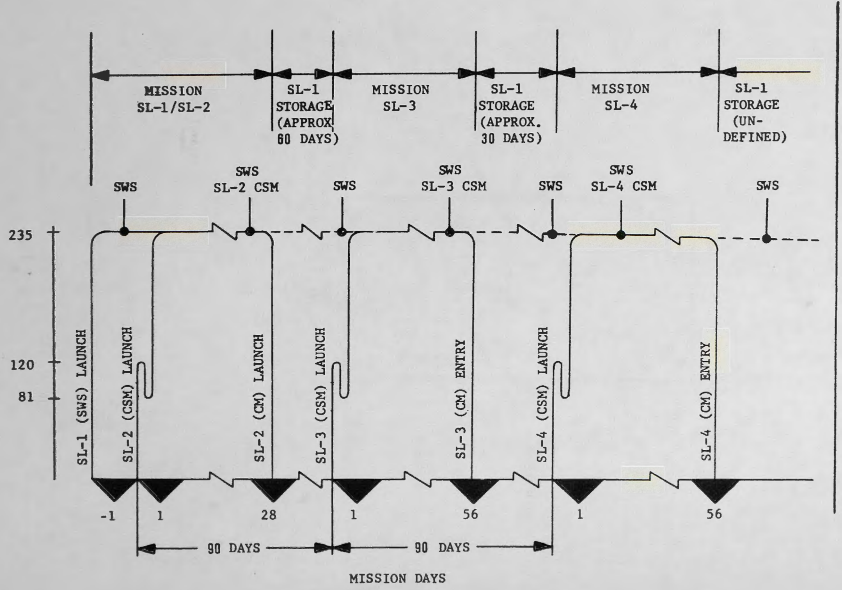


Figure 1 Skylab Mission Profile

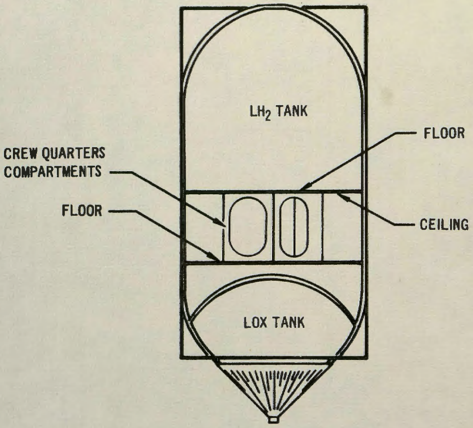


Figure 2   Orbital Workshop Crew Quarters Location

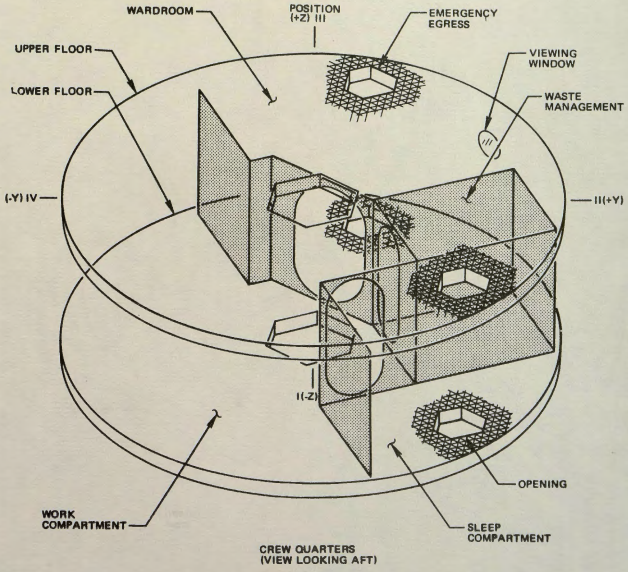


Figure 3 Orbital Workshop Crew Quarters Configuration

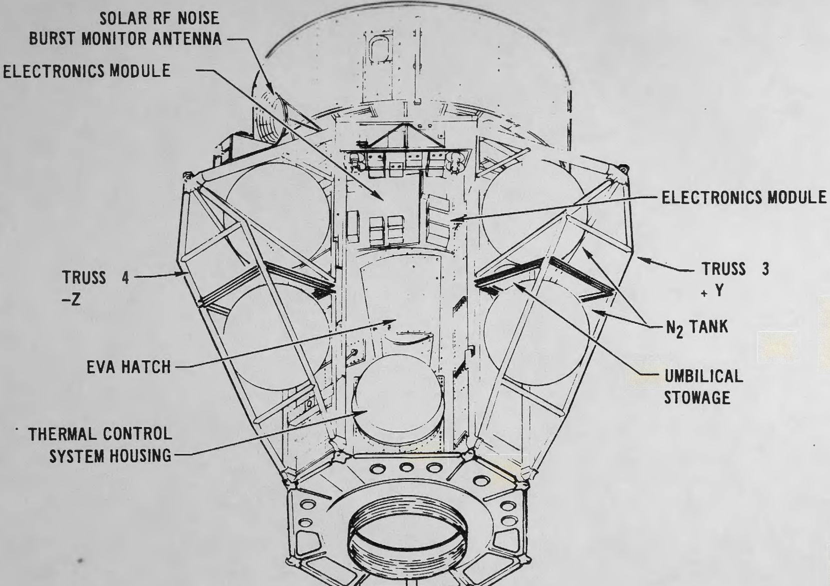


Figure 4 Airlock Module General Arrangement

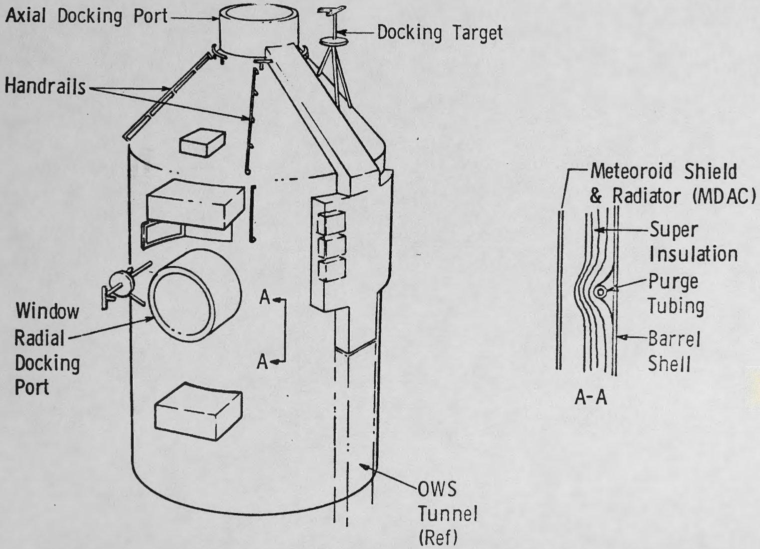


Figure 5 MDA General Arrangement

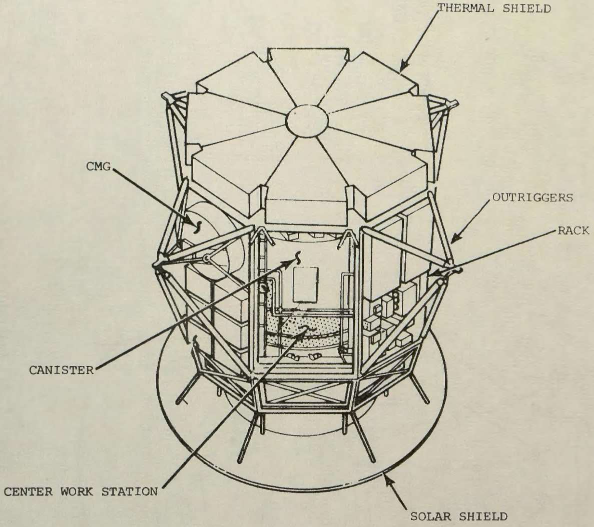


Figure 8 ATM General Arrangement

Figure 7 SL-1/2 Hardware Checkout Flow

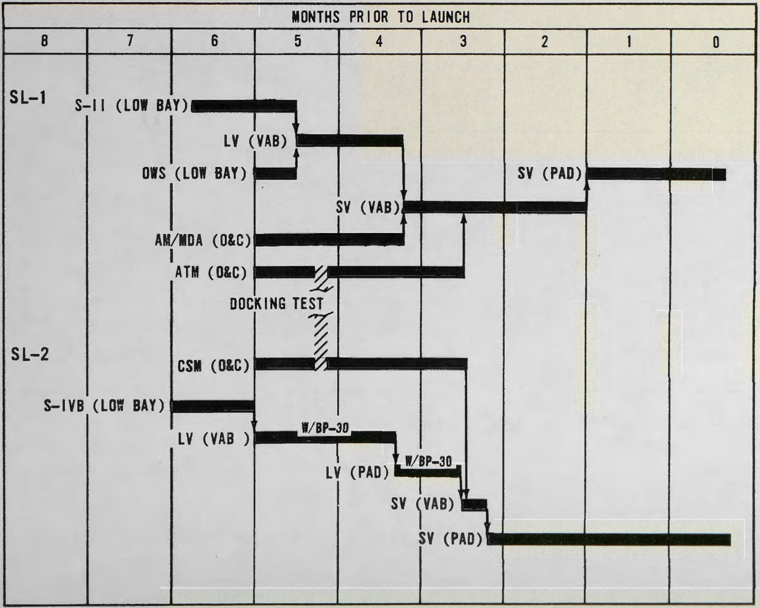
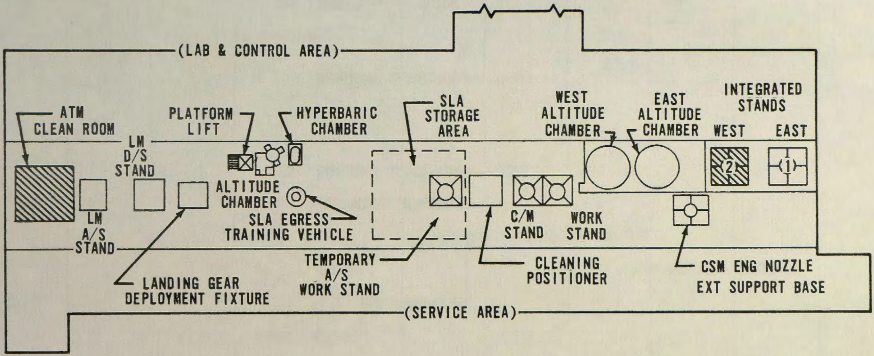


Figure 8 Assembly & Test Area, O&C Building

Support Equipment Layout



AM/MDA, DA ACCESS (ITS 1)

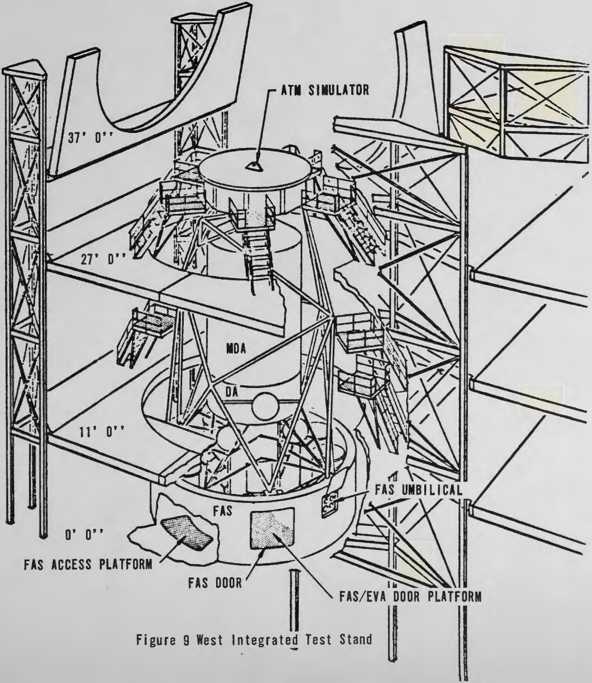


Figure 9 West Integrated Test Stand

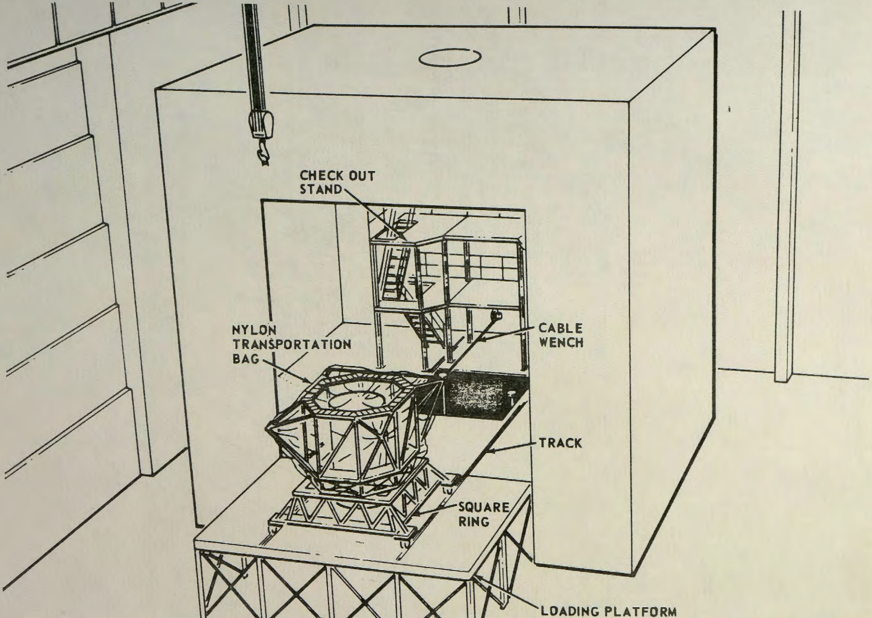


Figure 10 Artist Concept Of Clean Room