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SPACE STATION FACILITIES AND OPERATIONS AT THE KENNEDY SPACE CENTER

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ABSTRACT

The Space Station Program potentially will have a significant impact on the Kennedy Space Center (KSC). Current and past programs have had their major impact on KSC in the prelaunch and launch operations area with program support, subsequent to liftoff, generally performed at other locations. The Space Station Program also will impact prelaunch and launch operations at KSC but, due to its proposed 10-year operational lifetime, KSC also could have a significant role in support of the operational program. Support operations of the Space Station Program may be performed elsewhere; however, centralizing them at KSC has a number of attractive features which warrant study.

This paper, reporting work done for KSC under a contract with the NASA Marshall Space Flight Center, describes the Space Station prelaunch and launch operations and presents the results of a statistical analysis made to optimize prelaunch activities. The ground-based elements which are a part of the operational program during its 10-year lifetime are also described in terms of an integrated mission management concept. For purpose of the study it was assumed that these support elements are centrally located at KSC allowing a determination of the facilities, both new and modified, which would be required.

INTRODUCTION

A study of the impact that a program like Space Station will have on total ground operations must recognize the variety of operational requirements presented by its constituent parts.

The operations for the Space Station Program include not only the assembly, checkout, and launch of the 33-foot Space Station on an INT-21 launch vehicle (a one-time event), but the continued processing of Crew Cargo Modules, all Space Station cargo, flight crew members, and experiment modules/hardware for launch and return by the Shuttle throughout the 10-year life of the program. Also, considering the study ground rule of examining the impact of all operations which can potentially be performed at KSC, provision must be made for flight operations support, and mission integration support.

By taking advantage of Apollo and Skylab operations experience, the assembly, checkout, and launch of a Space Station presents no real challenge to experienced launch crews.

The remaining elements, the hardware to be processed, launched, and returned, and the function of overall mission management, present new challenges which must be addressed. Both of these areas differ from previous NASA manned space programs in that they are operational rather than R&D in nature.

Because of the Space Station Program's long-term nature, a new mission management concept comprised of Flight Operations Support, Experiment Operations Support, Mission Analysis and Planning Support, and Logistics Operations Support was developed along with accompanying interfaces and procedures. To identify the interfaces and define the facility impacts detailed operations concepts were developed for the Space Station/INT-21, including the Isotope Brayton Power System, Crew Cargo Module, experiment modules/hardware and cargo items.

As a result of the study, it was established that (1) the ground operations for above elements can be integrated and accommodated at KSC; (2) existing facilities can be adapted or modified to meet all the identified requirements; and (3) where the Space Station hardware interfaces with the Shuttle and the INT-21, the operations for the Space Station can be integrated on essentially a non-interference basis.

SPACE STATION PROGRAM DESCRIPTION

The primary elements of the Space Station Program are the Space Station, the Research and Applications Modules (RAM) which contain many of the experiments, the Crew Cargo Module (CCM) which acts as the logistics carrier and as an on-orbit storeroom since it remains attached to the Space Station for extended periods of time, and the ground support facilities for both launch and sustaining operations. These facilities, their requirements and associated operations, are the subject of this paper.

The other programs and elements which support the program, the Space Shuttle, the INT-21 Launch Vehicle, the Manned Space Flight Network, and a proposed Data Relay Satellite System are not discussed in this paper; however, where appropriate, interfaces with them are presented.

Space Station Description

The Space Station (Figure 1), scheduled to be operational in the late 1970's, is a large earth-orbiting laboratory having a crew of 12 and a nominal operational lifetime of a minimum of 10 years with a programmed 45-day resupply cycle. The station is launched unmanned by an INT-21 Launch Vehicle, a modified two-stage Saturn V (S-IC/S-II), and is activated upon completion of the initial Crew Cargo Module rendezvous and docking operations. Initially, it is configured and launched with a capability of performing an artificial-g experiment, using the S-II stage as a counterweight.

After completion of the artificial-g experiment, the associated hardware is disposed of and the station assumes the configuration as shown in Figure 2, providing positions for two CCM docking ports and five experiment module docking ports.

Crew Cargo Module Description

Logistics support of the Space Station is furnished via the Space Shuttle. This two-stage reusable system delivers replacement crews and cargo in a module that docks to and remains at the Space Station between Shuttle flights. During its stay, the CCM serves as a pantry or warehouse for delivered supplies and as a storage facility for spent material that is to be returned to earth.

The CCM shown in Figure 3 is designed to accommodate a variety of crew and cargo mixes. A single pressure shell houses the crew and solid cargo. The solid cargo is stowed in standardized containers any of which may be reached without removing adjacent items. Liquids and high-pressure gases are carried in the unpressurized section of the module and are transferred to the station through umbilical connections.

Research and Applications Modules Description

Experiments that cannot be performed inside the Space Station because of their size or their specialized needs will be accommodated externally in attached or free-flying modules. Attached modules are mounted at the docking ports for the duration of their experiments. Free-flying modules are self-propelled modules remotely controlled by the Space Station, and operate at ranges up to 1,000 nautical miles, returning to the station periodically for servicing. A typical free-flying module is illustrated in Figure 4.

Basically, all experiment modules consist of two sections, a system chamber and an experiment chamber. The system chamber houses equipment for propulsion, stabilization, power supply, thermal control, data acquisition, communications, etc., as necessary to meet the requirements of individual experiments. The experiment chamber houses the experiment sensors. When the modules are attached to the Space Station, both sections can be pressurized to permit access for servicing or repair.

Integrated Mission Management Description

There are three separate activities associated with management of the Space Station Program. The first is coordination with user agencies, the second is development of new program elements, and the third is mission management or the conduct and support of the active program. Organization of these activities is shown in Figure 5.

As shown in Figure 6, the tasks of mission management consist of ground operations support, and performance of the on-orbit activities.

The method for integration of all these tasks, together with assuring proper interface with supporting programs such as Shuttle, has resulted in the integrated mission management concept. This integrated mission management concept is somewhat independent of the various projects. As an example, in mission planning, Space Station activities are not planned independently of experiment activities nor are CCM activities planned independently. Rather, the Space Station activities, experiments, experiment modules, and CCM activities are planned together as a coordinated effort. This planning is coordinated on a functional basis with the other projects, such as the Shuttle and the communications networks. The integrated mission management approach that results is one in which mission management is not done for each project or major program element and then brought together and forced to fit; instead, activities are integrated on a function-by-function basis. The organization of integrated mission management is shown in Figure 7.

The major portions of mission management activities will be co-located in the mission operations support complex (MOSC) for maximum support coordination and cost considerations. Existing facilities with modification are available at Kennedy Space Center (e.g., the MSOB and CIF) which will meet the requirements of the MOSC, assuming that the Shuttle launch site is at KSC.

KSC PRELAUNCH AND LAUNCH OPERATIONS AND FACILITIES

This section presents the details of the analysis of Space Station prelaunch and launch operations along with the resultant facility requirements.

Prelaunch and launch operations include all KSC operations required to assemble, checkout, service, and launch the Space Station. These operations have been evaluated and optimized from the viewpoint that the Space Station launch is a one-time event. Hence, the concepts presented do not necessarily coincide with optimum operational concepts for a continuing program of many launches such as the Apollo Program or the Shuttle Program, although the Apollo Program in particular has exerted considerable influence on the concept. The goal has been to achieve a concept that will result in mission success, but will be of relatively low cost, and will require minimum modification to Saturn Apollo Launch Complex 39 (LC-39) and other facilities.

Six types of major elements comprising the Space Station (Table I) are shipped separately, and assembled at KSC to form the complete Space Station as shown in Figure 8. This approach was selected for several reasons: (1) to facilitate transportation and handling of the Space Station, (2) to allow flexibility in Space Station element manufacturing and assembly scheduling, and (3) to achieve a more predictable prelaunch and launch operations duration.

Table I
MAJOR SPACE STATION COMPONENTS

Component	Quantity
Core Module	1
Artificial-g Module	1
High Gain Antenna Assembly	4
Artificial-g Telescopic Tunnel	1
Nose Fairing	1
Isotope Re-Entry Vehicle Components	2 Sets

Predictability of launch time is the major concern of Space Station operations since all planning and operations leading to launch, including those of the CCM, Shuttle, Apollo, and Saturn IB and V Programs, must be properly phased with the Space Station. This predictability depends on the expected uncertainty in duration of prelaunch and launch operations. Several alternative operational approaches were systematically evaluated during the initial Phase B effort aided by statistical computer simulation techniques (Reference 1). The alternatives, the resulting average durations, and the spread or uncertainty in duration of each alternative are shown in Figure 9. None of the alternatives represents the final flow resulting from this analyses exactly, as the selection of approach had to precede final development of the actual operational flow. The first alternative most nearly duplicates the final flow, however, differing from it only as a result of Space Station design changes occurring after approach selection, e.g., changing from solar array to isotope/Brayton power sources. Mating of the major elements at KSC results in a significantly narrower distribution of prelaunch and launch operations duration than the other alternatives.

A result of this overall approach is that a number of interfaces will have to be mated and verified at KSC. Figure 10 defines all possible interfaces which might exist between the major types of Space Station elements; each potential interface being represented by the intersection of a row and column in the matrix shown. An entry, or entries, in the matrix specifying the type of interface, e.g., mechanical, electrical radiofrequency (RF), or fluid, indicates a real interface will exist of the type noted.

Overall Space Station operational flow through launch site facilities is summarized schematically in Figure 11. Estimated duration of Space Station prelaunch and launch operations from arrival of the first element to liftoff is 99 working days (19.8 weeks). Descriptions of the major operations in the flow are included in the following paragraphs:

Space Station Assembly Operations - The artificial-g stage will be raised from its transporter and stacked on top of the launch vehicle in the Vertical Assembly Building (VAB). The core will be raised from its transporter, rotated to a vertical position, set on the transfer pad, hoisted by the high bay crane, and stacked on top of the artificial-g stage. The core will then be opened, access equipment set up, and internal lighting and ventilation established for internal inspection. The inspection team will not be allowed to enter the Space Station until all safety precautions have been implemented and escape routes established. Tunnel and antenna assembly mating operations will be accomplished after the core has been stacked on a non-interference basis but in parallel with other operations. The nose fairing will be moved to the high bay transfer pad, erected, and raised above the forward end of the Space Station, centered above the vehicle, and lowered around the tunnel, antennas, etc. Electrical connections will be mated and checked for continuity after the fairing has been bolted to the core.

Isotope Re-entry Vehicle (IRV) installation will be the last operation accomplished in the VAB before completing preparations to move to the Pad. Installation operations will consist of:

1. Clearing unnecessary personnel from the high bay area.
2. Moving each IRV, in its transporter, to the VAB high bay area.
3. Raising the IRV and transporter to the Space Station levels of the high bay.
4. Opening the transporter and removing IRV's using remote control handling equipment.
5. Moving the IRV into position for securing in the Space Station using remote control handling equipment.
6. Switching from direct GSE cooling to cooling via Space Station umbilicals. The redundant portable cooling unit will be connected to the launch umbilical tower (LUT) umbilicals prior to making the switch to reduce GSE requirements.
7. Securing the IRV in the Space Station.

Note that cooling must be maintained continuously except for a brief moment during the switchover. Emergency backup cooling for the IRV's must be provided. Such backup cooling systems would be used only in extreme emergency such as multiple cooling unit failures in prime and redundant units which would prevent normal cooling for several hours.

Checkout Operations - The Space Station integrated checkout will be accomplished in the VAB High Bay to verify overall operations of the Space Station module, and to verify major component integration. The Space Station integrated testing duplicates the last test performed at the factory, and to the extent possible, orbital testing. This is done to facilitate procedure generation, data correlation and comparison, and detection of degradation by standardizing all test operations. A relatively simple GSE concept is achived by using the onboard checkout system (OCS) as the basic test instrument for integrated testing. This concept results in a substantial reduction in stimuli generation and response detection requirements imposed on the GSE. Additional GSE simplification is obtained by using vehicle systems to support ground crew operations inside the Space Station, e.g., lighting, ventilation, and communication. Mechanical deployment of large assemblies, e.g., artificial-g equipment, is not verified at KSC due to size, although electrical motors, controls, or other devices used for deployment are verified to the extent possible without actual deployment.

Astronaut/flight crew participation is expected throughout Space Station testing. There will be a special crew compartment fit and functional test (C^2F^2) scheduled as a part of the Space Station integrated test phase. This will give the first flight crew and backup crew the chance to run through Space Station operation and become familiar with the actual flight configuration of the equipment they will activate on-orbit.

The Space Station represents a significant departure from past spacecraft in that it embodies a comprehensive and autonomous onboard checkout capability, necessitated by the requirement to perform on-orbit maintenance and repair. The Space Station OCS includes the equipment and software required to support in-flight checkout and fault isolation of Space Station subsystems and experiments. It provides a capability for evaluating the performance of the subsystems and experiments, including critical (Caution and Warning) functions; a basis for repair and reconfiguration actions; and verification of proper operation following failure correction. It is utilized as the primary checkout and fault isolation tool during post-manufacturing, prelaunch, and on-orbit phases of the Space Station Program to provide maximum consistency and continuity of testing from factory to orbit; to facilitate the building of a correlative data base for continuing spacecraft performance evaluation; and to allow a thorough on-line verification of orbital checkout hardware and procedures prior to launch. This approach also results in a substantial reduction in conventional ground checkout equipment and its associated software, thereby reducing program costs. Nevertheless, some GSE is required to verify external interfaces and process checkout data.

The most significant of the Space Station external interfaces which must be verified during prelaunch checkout and which cannot be checked by OCS are the RF communications links between the Space Station and the DRSS, MSFN, Free-Flying Modules, Shuttle, and EVA crewmen. These interfaces are illustrated in Figure 12. The capability of the Space Station to receive/transmit over each of the communications links and the quality of the links must be verified. Tests of other external interfaces including sensors such as star trackers and horizon sensors, and rendezvous/docking laser radars will require the provision of appropriate external targets and simulated sources. These test aids are attached to the vehicle or mounted on adjacent platforms during the VAB test operations, and are removed prior to transferring the vehicle to the pad.

The ground data processing requirements associated with Space Station prelaunch and launch operations include both on-line and off-line functions. On-line functions are those required in real-time or near real-time and include those associated with monitoring, control, test execution, and test results recording. Off-line data processing functions include computer software support and post-test data reduction. The software support activity involves computer program assembly, compilation, and similar operations associated with the generation of new programs and with changes to previously prepared programs. The data reduction task involves the post-processing and strip-out of recorded data and is not significantly different from similar functions performed for other spacecraft. Some modifications of existing capability may be required, however, to accommodate the increased bandwidths of Space Station data.

Space vehicle integrated test activities include verifying space vehicle/launch umbilical tower interfaces by simulating terminal countdown with retraction of umbilicals and operating the vehicle on internal power, and securing from test. Electromagnetic compatibility will be verified by monitoring for interference between all space vehicle elements during all space vehicle testing activities. Included also are off-nominal simulated flights from liftoff through crew rendezvous. A flight readiness test (FRT) will be performed immediately after the space vehicle integrated test to verify that flight systems, especially software, timing, and command capabilities after liftoff, are ready for unmanned flight. The FRT is in the form of a nominal simulated flight from liftoff through docking of the first flight crew.

Countdown Demonstration Test (CDDT) is a simulated countdown to verify flight vehicle and ground systems operation in the launch mode; it is a dress rehearsal for the actual countdown and is performed after the vehicle has been transported to the launch pad. The requirement for this test is apparent from the following considerations:

1. The Space Station launch is a unique occurrence; only the one Skylab launch will provide similar experience regarding Space Station countdown operations.
2. CDDT is the first operation in which all components of the total launch system (e.g.,

vehicle, launch site, LCC, tracking) are operated together in the manner they will be during the actual launch.
3. INT-21 launch vehicle countdown procedures may be sufficiently different from Saturn V procedures as a result of the new (or modified) IU and the Space Station/launch vehicle interface.

Countdown - Countdown includes the final vehicle and ground system preparations for launch, and launch itself. Space Station generalized countdown operations and procedures are as follows:

1. Space Station attitude control propellants (hydrazine) will be loaded on-pad.
2. Other Space Station fluid systems previously serviced in the VAB will be checked and topped-off.
3. All Space Station systems will be turned on, checked for functional status and placed in their proper launch state; i.e., turned off, switched to a dormant standby mode, or in the case of critical subsystems, left fully operational.
4. Space Station status will be monitored continuously on telemetry, and through umbilicals after final system checks have been completed. Monitoring (as a part of launch operations) will continue through liftoff.
5. Range interfaces with the Space Station will be given final open-loop verification.
6. Ordnance will be connected and armed during countdown.

Space Station functional status checks, and configuring the systems to the launch mode complete the active launch operations. The Space Station is essentially ready for launch at this time.

Space Station Prelaunch and Launch Facilities Selection

Conclusions resulting from KSC facilities selection for the Space Station Program are that the basic operations functions can be incorporated in existing facilities at KSC.

Utilization of existing facilities was a prime objective throughout the study with special emphasis devoted to minimizing the facility impact on KSC. The study did not uncover a need for any major new facility; each major program function can be accommodated by modifying existing facilities.

Final selection was accomplished through an evaluation of the various hardware operations flows through possible facilities. As an example, all reasonable facility utilization options for processing the IRV's were listed even though a number of them were obviously not serious candidates. Comparison features used in evaluating the various candidates included cost, feasibility, impact relative to other programs, impact on planned operational concepts, general effect on KSC personnel and resources; safety of vehicular and ground equipment, and personnel; and schedule. The resulting candidates were then compared with others in a particular flow for compatibility and interface complexity to yield prime and alternate flows. From this, the facilities to be used were determined and their modifications established from the requirements developed during operation analysis. The facilities that will be used during prelaunch and launch operations are summarized below:

Complex 39 - Complex 39 facilities (Figure 13) required to support Space Station launch operations include one Launcher Umbilical Tower (LUT), one assembly high bay of the VAB, one launch pad, and ordnance storage/handling facilities. Other support normally provided for Saturn V launch operations is also required for the INT-21/Space Station vehicle, i.e., Launch Control Center, photo-camera tracking, range safety, general launch site safety provisions, closed-circuit television, intercom, emergency warning systems, etc.

Launcher Umbilical Tower - One LUT (Figure 14) is modified to support INT-21/Space Station operations. Existing S-IVB type service arms of the LUT will be modified to provide the means for access to the Space Station during launch pad operations. These arms will also be modified to support electrical and fluids umbilical interfaces. Certain items of integrated checkout equipment, electrical GSE, and mechanical GSE are installed on the LUT. Modifications will permit least-effort convertibility back to the Saturn V/Apollo configuration flight vehicle after launch of the Space Station.

Vertical Assembly Building - Assembly Bay 3 of the VAB (Figure 15) will be modified to provide the means for accommodating the Space Station. Extensible platforms A, B, and C (Figure 16) will be resized and reworked to provide access to the core module interior through docking ports and to the exterior as necessary to accomplish mating of the artificial-g module, core module, artificial-g tunnel, high-gain antennas, nose fairing, and the IRV's. Provisions will be made in the platforms for installation of access, handling, service, and checkout GSE and for establishing the Space Station/LUT interfaces.

Existing vertical locations of extensible platforms will be satisfactory for Space Station purposes. Extensive use will be made of moveable workstands to allow access to those areas that cannot be normally reached from extensible platforms and enclosure roofs. Vehicle cutouts in extensible platforms A, B, and C will require resizing to accommodate the 33-foot 10-inch diameter Space Station. Temporary platform cutouts with provisions for future fill-in are to be devised to enhance convertibility. Provisions will be made in extensible platform enclosure walls for different penetrations of service arms and protective enclosures required to provide access and services to the Space Station. Command module and service module arms are not used for Space Station support and are stowed out of the way during Space Station operations.

Provisions for installation of GSE will include bolting-down, floor cutouts, cable trays, piping runs, and electrical power receptacles. GSE to be installed or employed on the extensible platforms includes electrical test sets, servicing equipment, and mechanical handling equipment. Provisions may be made in ceilings of certain extensible platforms for attaching or hanging monorails, jib cranes, and GSE. Environmental enclosures may be employed on certain extensible platforms.

Existing provisions for the S-IC and S-II are satisfactory for the launch vehicle.

Launch Pad - Launch Pad A provides the structural/mechanical/electrical interfaces for physically supporting the LUT/flight vehicle. The pad has provisions for and supports propellant loading, high-pressure gas servicing, and environmental control of the S-IC, S-II, and Space Station module. Existing Pad A provisions for the S-IC and S-II are satisfactory without modification. LH_2 and LO_2 loading facilities for the S-IVB will be deactivated for Space Station operations.

Launch Control Center - The KSC Launch Control Center is used for INT-21 prelaunch checkout and launch control. The same provisions for Saturn-V launch operations are required for INT-21/Space Station operations, except for S-IVB functions. The LCC is not to be used for monitor and control of Space Station operations. Space Station launch control functions are to be conducted from the MSOB using the flight support capabilities.

KSC Support Facilities

In addition to Complex 39, other KSC facilities are required for Space Station launch support. These include waterways and docks; roads; the Manned Spacecraft Operations Building (MSOB); the Central Instrumentation Facility (CIF); supply, shipping, and receiving building; flight crew training building; and other general support activities. The Pyrotechnic Installation Building (PIB) will be required for assembly and storage of the IRV's.

Pyrotechnic Installation Building (PIB) - The PIB is to be used for Space Station power conversion system receipt and inspection, assembly, and checkout and storage. The PIB provides safe, secure, and efficient means for assembly of IRV's and storage after assembly in preparation for installation in the Space Station. The PIB has sufficient area and environment for two IRV's, associated GSE and operations, and personnel. The building is remotely located and provides safe separation from potentially dangerous environments. Security measures can be taken in accordance with AEC requirements for nuclear equipment and processes. Provisions can be made for protection of personnel from heat and radiation effects of the IRV heat sources.

Ordnance Storage - Existing ordnance storage facilities at KSC are used for storage of Space Station items of ordnance.

MISSION MANAGEMENT OPERATIONS AND FACILITIES

This section discusses operations during the lifetime of the program along with the support facilities at KSC. These are four prime support functions that will be performed on the ground during the 10-year operational lifetime of the Space Station.

Flight Operations Support - This function will be a real-time support activity quite similar to what is currently known as mission control. Flight operations support, in addition, will be responsible for crew training, simulation and other activities associated with preparation of flight operations.

Experiment Operations Support - This function provides the experiment operations support. Its prime function is to plan experiments, establish their procedures, and provide the capability for Principle Investigators to participate in real-time activities (on the ground) of their experiment while it is in orbit.

Mission Analysis and Planning Support - This function is important as part of the overall management of the Space Station in that the conduct of the on-orbit activities has to be coordinated with many agencies to assure mission success. The approach that will be followed in mission analysis and planning is to perform the function at two levels; first, there will be a 10-year plan which will generally structure the total Space Station mission. This 10-year plan will be broken down into 90-day segments, each one of which, for planning purposes, will be considered a separate mission. These 90-day segments coincide with the crew rotation cycle.

Logistics Operation Support - The procurement, accounting, and warehousing of all Space Station supplies to support resupply via scheduled carriers with a fixed cargo space necessitates development of new logistics concepts within NASA. The resulting logistics operation support function includes inventory management to insure that men, materials, and supplies are delivered to the Space Station at the proper time and in the proper quantity so that the mission can always be conducted to full capacity. The logistic support operation will provide configuration management so that there will always be knowledge on the ground of what the exact orbital configuration is. The logistics operations also will perform the more classical logistics functions of cargo handling, packaging, procurement, and transportation. Another function of logistics is testing, particularly testing of new equipment to make sure that it will fit and that it will function properly. The last major function of logistics is ground operations support of the Crew Cargo Module. The logistics function interfaces with the Crew Cargo Module in a staging (loading) area in the VAB. The CCM interfaces with the Shuttle orbiter after loading in the orbiter hangar.

An operational replica of the Space Station (Project Verification Model or PVM) assembled from program qualification test hardware will be utilized by the logistics segment of Mission Management as a configuration management tool. The PVM, in addition to being a configuration management tool, is available to meet these other requirements listed in order of priority:

1. Trouble-shooting orbital problems which cannot be solved by the flight crew.
2. Functional and physical integration of new or modified Space Station flight hardware, experiments and experiment modules and software.
3. Flight crew proficiency training.
4. Verification of Space Station/Flight Operations Support Center functional interfaces.
5. Development and revision of maintenance plans and procedures.
6. Principle Investigator (PI) orientation.
7. Software qualification testing.
8. Indoctrination of the scientific community.

Mission Management Facilities Impact

The facility requirements for mission management are divided into three groups: (1) flight support facilities for the implementation of ground-based support of flight operations functions. Included in this group are the management and planning functions of flight operations support, mission analysis and planning support, logistics support, experiment support, crew accommodations, and crew training. (2) Logistics support facilities accommodate those logistics functions other than the management and planning part of flight support that are required to procure, control, warehouse and load logistics cargo for all elements of the Space Station including experiments. (3) Experiment support facilities accommodate those experiment functions other than those included in the flight support facilities that are required to process experiment flight hardware and house the experiment laboratories for the 10-year program. Requirements for establishing these facilities (Figure 17) become complex due to the interaction of the associated operations as noted in Figure 18.

Flight Support Facilities - Flight support facilities include those which support orbital flight operations, mission analysis and planning, direct real-time logistics advice and consultation for the Space Station and mission management activities, direct real-time support for experiment operations, flight crew training, and crew accommodations. This support continues throughout the Space Station's 10-year lifetime.

1. Mission Operations Support Center - The Mission Operations Support Center (MOSC) centrally coordinates and integrates all ground activities required for support of Space Station flight operations on a continuing basis for 10 years. A centralized control center is provided for integration of flight operations, mission analysis and planning, direct logistics advice and consultation for Space Station and mission management activities, and direct real-time experiment operations support. A design reference library consisting of microfilm and information stored in data banks, is located in the MOSC. The existing MSOB and CIF buildings provide the required capabilities for supporting the function of the MOSC.
2. Crew Accommodations Complex - The Crew Accommodations Complex (CAC) performs the following functions throughout the Space Station's 10-year orbital lifetime:
a. Live-in accommodations and separate isolation for two groups of 16 crew personnel each in final preparation for space flight and two supporting personnel assigned to each group.
b. Physical restriction of final preparation flight crew members in their interpersonal contacts with medically unscreened individuals.
c. Debriefing and observation of flight crew personnel just returned from space flight for a period of two weeks.
d. Continuation of flight crew training.
e. Continuation of flight crew physical fitness.
f. Dining and dietary management for flight crew and support personnel.
g. Recreational facilities for flight crew personnel in final preparation for space flight.
h. Medical and laboratory services for flight crew personnel.

The existing MSOB provides the space, electrical power, lighting, environment, and communications necessary for accomplishing the functions required of the CAC.
3. Crew Training Facilities - Crew training facilities provide floor space and the environment for conducting flight and ground crew training. Activities conducted in the facilities include classroom instruction, training on part-task trainers, establishing training programs and curriculum, student administration, and maintaining and controlling equipment necessary for training. Crew training facilities provide space and environment for the Space Station Command Simulator, Experiments Control Simulator Group, and the Flight Operations Support Room Simulation Group and will be located in the existing MSOB and Flight Crew Training Building.

Logistics Support Facilities - Logistics support facilities include those which support the planning of and providing of sustaining materials and services for the Space Station during its 10-year orbital lifetime. These facilities do not include those which support prelaunch and launch of the Shuttle and CCM.

1. Inventory Control Facilities - The inventory control facilities maintain centralized control over specialized activities dealing with Space Station inventory resupply. Functions include determining the logistics vehicle cargo constituents, procurement, control of inventory item quality, preparation of the resupply cargo for flight, and loading resupply cargo in the Crew Cargo Modules. Also included are unloading Crew Cargo Modules returned from flight and disposition

of that cargo. Resupplies are defined as consumables, expendable, experiments, and spares.

The Supply, Shipping, and Receiving Building is used as the bulk resupplies cargo storage and preparation-for-shipment capability. Included in these two functions are areas which support procurement; quality control; resupplies test and evaluation; shipping, receiving, and packaging; and storage for both Space Station and experiment cargo. Cold storage and certain environmentally-controlled areas are provided. Communications and data links are established with the logistics support area in the MSOB. Emergency power is provided for cold storage and environmentally-controlled areas and for other critical communications and data systems. The MSOB provides offices and support areas where procurement is coordinated and the cargo operations are monitored and controlled. A logistic-staging area is located in the VAB Low Bay behind the CCM maintenance, checkout, and loading area. In this area, the resupply cargo intended for next flight is collected, test loaded, and loaded on the CCM's.
2. PVM Installation Area - The PVM installation area contains and supports the operation of electronic equipment, maintenance shops, and offices. It provides space and environment for the PVM in the vertical or "heads-up" attitude modified for ground operations and necessary equipment to support total simulation of the Space Station configuration.

Adjacent areas are made available for offices, conference rooms, and maintenance shops. They have subfloor space with easy access for cable routing, cooling air distribution, and utilities installation. Proper grounding and radio frequency interference (RFI) protection is provided for instrumentation.

The PVM installation area should be located near the MOSC to minimize long-distance and interface problems between the PVM and the MOSC. Likewise, the PVM should be located near the training complex because it will be used in flight-/ground-crew familiarization and proficiency training.

Experiment Support Facilities -

1. Launch Site Biological Laboratory - The LSBL provides for physical and biological examinations of specimens as well as performance evaluations in order to establish baseline characteristics and determine flight readiness. In addition, transducers and other flight instrumentation are installed/implanted at this facility. The LSBL also serves as the 1-g ground control facility which supports the on-orbit experiment activity.

The MSOB provides space, electrical power, lighting, environment, and communications necessary for operation of the LSBL.
2. Experiment Module Operations and Checkout Facility - The MSOB supports the module/experiment operations and checkout functions at the launch site.

The MSOB high bay provides space and environment necessary for module and large experiment operations and checkout as they are received from the integration facilities. Personnel access to the high-bay area is isolated from the supporting shops and laboratories. A connecting facility provides office and administrative facilities for a maximum of 200 people, as well as shipping/receiving and material storage areas. The bulk of the shipping and receiving activities are conducted in the Supply, Shipping, and Receiving Building. Supporting shops and laboratories are an integral part of the operations and checkout facility.

CREW CARGO MODULE PRELAUNCH AND LAUNCH OPERATIONS AND FACILITIES

Crew Cargo Module (CCM) operations at KSC have several unique features which depart significantly from previous manned and unmanned spacecraft programs, although the CCM exhibits many of the characteristics of a conventional manned spacecraft. It differs from conventional spacecraft in that it carries a large quantity of cargo relative to its overall size (14 feet diameter by approximately 30 feet long) as well as the crew. It is placed in orbit by the Shuttle orbiter, and on return from orbit cannot re-enter the atmosphere unilaterally, but must be returned to earth by the Shuttle orbiter. It is returned to KSC after its mission. It is reusable - being returned to orbit many times during its lifetime.

As a result, CCM ground operations must consider post-orbiter landing activities; CCM refurbishment and maintenance, and cargo loading in addition to the more familiar prelaunch and launch operations associated with any launch. The operational flow typical of CCM processing at KSC, and illustrating these features, is summarized in Figure 19. Operations interfacing with CCM operations are shown for reference (connected with dashed flow lines). Note that CCM operations marked with an asterisk (*) are new to KSC and will have significant impact.

CCM ground operations must be accomplished efficiently to keep the overall 10-year program costs within reasonable limits. Unlike the Space Station launch, which was a one-time event, CCM launches occur every 45 days on the average for the duration of the program.

First flight operational flow is relatively simple, and is similar to that for a manned spacecraft, i.e., it is received and offloaded, inspected, verified for proper configuration, and checked out. No unique requirements are evident for this phase of CCM operations other than facilities necessary for accomplishment of the operations.

The CCM's will be maintained through an airline method of operation, i.e., preflight and post-flight checks, correction of malfunctions experienced during flight, and periodic maintenance. However, this ideal, as in the case of aircraft, cannot be realized initially. Early repeat flights of the CCM will require extensive post/preflight testing similar to that required for the first flight. These early flights are analogous to certification flights of aircraft before they are put in regular service. As experience and confidence in test procedures is gained, the amount and complexity of testing will be reduced

Crew Cargo Module Facilities Impact

KSC facilities required for support of CCM ground operations include those necessary for housing the CCM itself during checkout, maintenance, and loading/unloading operations; those required for storage and for performing lengthy modifications; those required for installation and storage of automatic checkout equipment, electrical equipment, servicing equipment, access and handling equipment, and transportation equipment; and those from which CCM checkout operations are conducted.

Vertical Assembly Building Low Bay - The VAB Low Bay must be modified to accommodate the CCM. As shown in Figure 20, the two southeastern uncompleted S-II checkout areas are to be used for horizontal checkout, maintenance, and loading. The CCM's will move down the VAB transfer aisle on their transporters after being offloaded from the Shuttle orbiter. They will be positioned in the modified S-II areas where they will be turned around for the next flight. Uncompleted S-IVB checkout areas opposite the S-II areas are to be used for CCM storage or extensive maintenance/modification. CCM test control is to be maintained from the test control area in the support areas behind the low bay. A logistics staging area will be on the first floor adjacent to the CCM checkout area.

The two CCM checkout positions permit horizontal installation of the CCM's and have sufficient area for installation of servicing and electrical equipment, ground handling equipment, test umbilicals, access equipment, and loading equipment. Electrical and fluids support is to be provided with exception of propulsion system requirements. Two additional positions are to be provided on the opposite side of the low bay with essentially the same provisions except that they will not have an automatic checkout capability.

Automatic checkout equipment is installed in the existing test control area on the third floor behind the CCM checkout areas. Cables interconnect the two areas. The Logistics Staging Area is on the ground floor underneath the test control area and is adjacent to the CCM checkout area.

The existing low bay environment is adequate for CCM operations. If special particulate or oil/volatile control of the atmosphere is required, it will be provided through portable protective enclosures and other GSE.

CONCLUSIONS

Many new and diverse functions, particularly in the areas of mission management and logistics, may be accomplished at KSC in addition to the traditional prelaunch and launch functions. These activities can be accommodated within existing KSC facilities with only simple modifications. However, both the new and traditional activities will require techniques and procedures new to KSC, or new applications of existing techniques and procedures in order to effectively achieve the overall Space Station Program.

NOMENCLATURE

AEC - Atomic Energy Commission
Apollo, Apollo Program - The present program to put man on the moon
C^2F^2 - Crew Compartment Fit and Functional Test
CAC - Crew Accommodations Center
CCM - Crew Cargo Module
CDDT - Countdown Demonstration Test
CIF - Central Instrumentation Facility located at KSC
Command Module - The crew compartment/re-entry vehicle of the Apollo Program
Data Relay Satellite System - See DRSS
DRSS - A proposed world-wide satellite communications network for use with manned space flight programs
EVA - Extravehicular activity
FRT - Flight Readiness Test
GSE - Ground Support Equipment
INT-21 - A launch vehicle comprised of a S-IC first stage, S-II second stage, and a modified Instrumentation Unit
IRV - Isotope Re-entry Vehicle; a re-entry vehicle containing Pu-238
Isotope/Brayton Power Source - A gas turbine power system that converts heat generated by plutonium (Pu-238) to electrical energy
KSC - Kennedy Space Center
Launch Pad A - One of the two LC-39 launch pads
LC-39 - Launch Complex 39 located at KSC
LCC - Launch Control Center of LC-39
LUT - Launcher Umbilical Tower, also called the Mobile Launcher, used with LC-39
LH_2 - Liquid hydrogen
LO_2 - Liquid oxygen
LSBL - Launch Site Biological Laboratory
Manned Space Flight Network - See MSFN
MOSC - Mission Operation Support Complex
MSFN - Manned Space Flight Network, the existing world-wide communications network used with manned space flights
MSOB - Manned Spacecraft Operations Building located at KSC, also called the Operations and Checkout Building
NASA - National Aeronautics and Space Administration
OCS - Onboard Checkout System
PI - Principle Investigator
PIB - Pyrotechnic Installation Building located at KSC

PVM - Project Verification Model
RAM - Research and Application Module(s), also referred to as experiment modules
R&D - Research and Development
RF - Radio frequency
RFI - Radio Frequency interference
S-IC - The first stage of the Saturn V booster
S-II - The second stage of the Saturn V booster
S-IVB - The third stage of the Saturn V booster
Saturn-IB - An early booster used by the Apollo Program
Saturn-V - The booster used by the Apollo Program
Service Module - Supporting module for the Apollo command module
Shuttle - A proposed program comprised of a number of two-stage reusable vehicles
Space Shuttle - See Shuttle
Skylab, Skylab Program - A program using the third stage of the Saturn V booster as the basic structure of an orbiting 3-man laboratory
VAB - Vertical Assembly Building located at KSC and part of LC-39

ACKNOWLEDGEMENT

The authors wish to express their appreciation to J. C. McHaffie for his contributions in the facilities impact area, and to the other members of the McDonnell Douglas Astronautics Company's Space Station Study Team, all of whom contributed significantly to this paper.

REFERENCES

(1) Erickson, D. L., J. B. Newton, Space Station Operations and Logistics Scheduling Using Activity Networks, MDAC Paper WD 1082, November 1969, presented to Operations Research Society of America, Space Sciences Section Meeting, Miami, Florida, 12 November 1969.

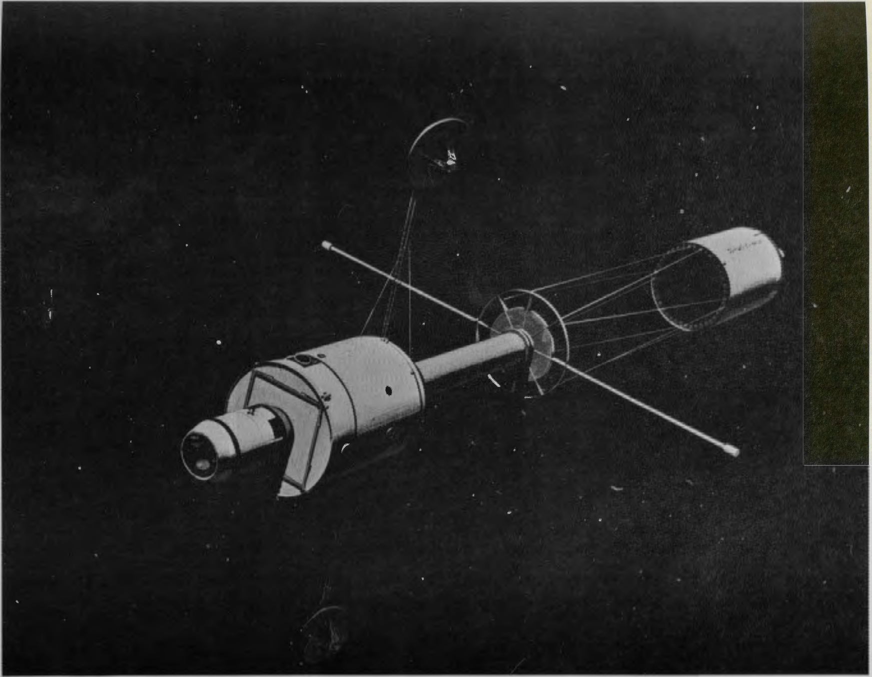
(2) Space Station Program Definition, prepared for the National Aeronautics and Space Administration's George C. Marshall Space Flight Center under Contract NAS8-25140

Volume I Experiment Support Requirements Analy Analysis, 13 January 1970
Volume II Mission Definition, 1 April 1970
Volume III Analysis of Operations, 24 April 1970

(3) Space Station Program MSFC-DRL-160 Line Item 22, Analysis of Space Station Impact on KSC, Volumes I and II, prepared for the National Aeronautics and Space Administration's George C. Marshall Space Flight Center under Contract NAS8-25140, December 1970

ILLUSTRATIONS

Figure 11-11

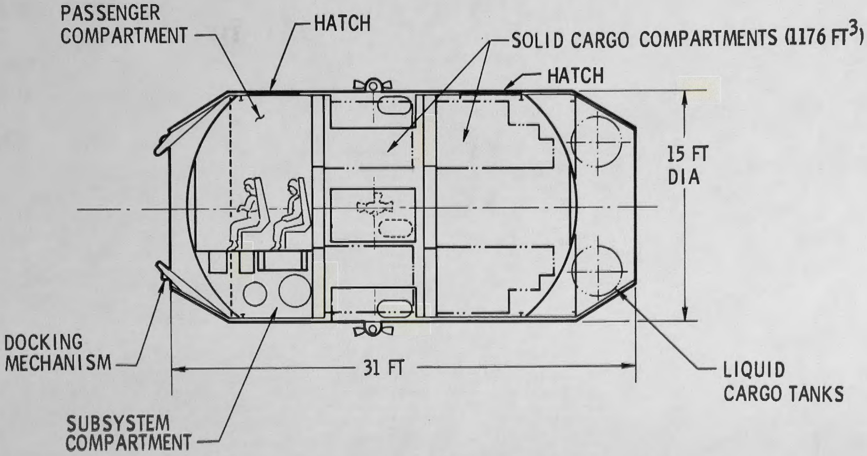


RENDERING OF BASELINE SPACE STATION IN ARTIFICIAL-G MODE

RENDERING OF CUTAWAY BASELINE SPACE STATION

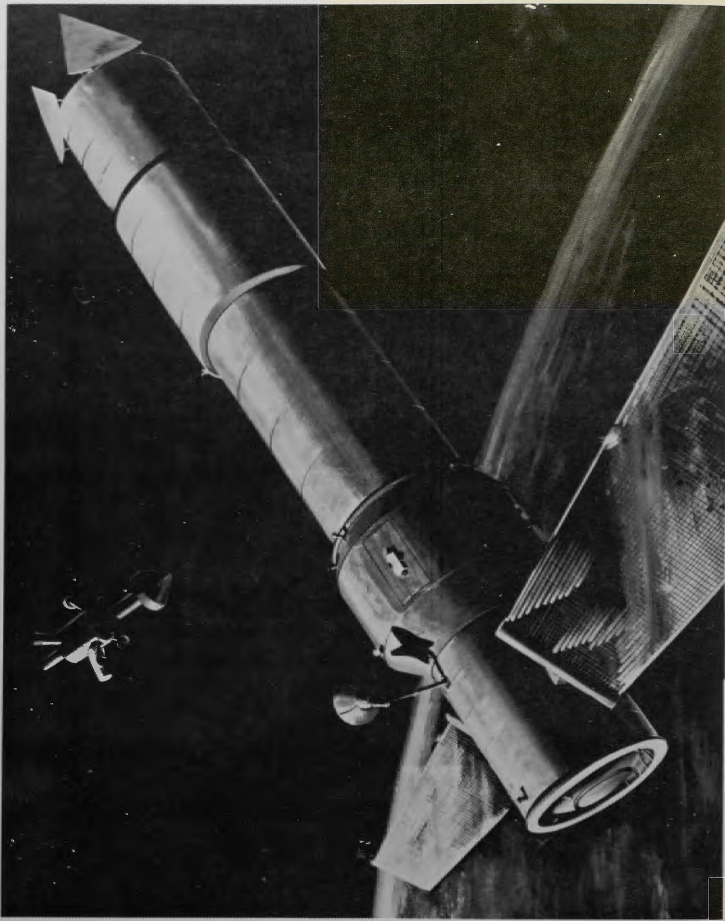
Figure 2

CREW CARGO MODULE



GROSS WEIGHT = 20,000 LB

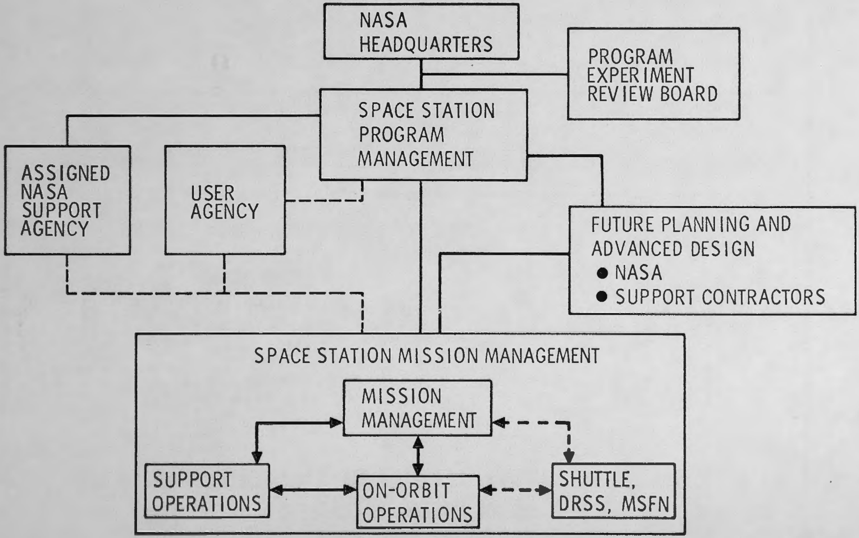
CREW/CARGO CAPACITY = 13,000 LB



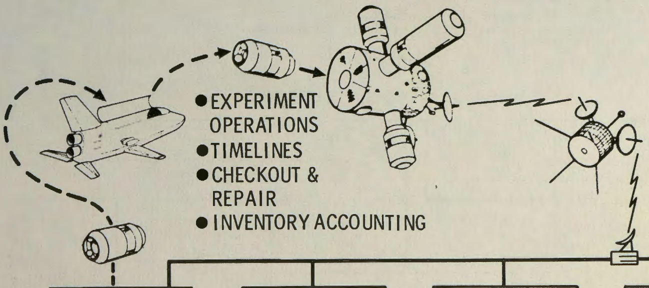
RENDERING OF FREE-FLYING MODULE

Figure 4

SPACE STATION PROGRAM AND MISSION MANAGEMENT



SPACE STATION MISSION MANAGEMENT OPERATIONAL FUNCTIONS



- EXPERIMENT OPERATIONS
- TIMELINES
- CHECKOUT & REPAIR
- INVENTORY ACCOUNTING

LOGISTICS OPERATIONS SUPPORT

- INVENTORY
- CONFIGURATION MANAGEMENT
- CARGO HANDLING
- PROCUREMENT
- TESTING
- CREW CARGO MODULE

MISSION ANALYSIS & PLANNING

- MISSION PLANS
  - -10 YEARS
  - -90 DAYS
- SCHEDULES
- CONFIGURATION AUTHORIZATION

FLIGHT OPERATIONS SUPPORT

- FLIGHT CONTROL
- SIMULATION
- CREW TRAINING
- NETWORK CONTROL
- HARDWARE
- DEFINITION

EXPERIMENT OPERATIONS SUPPORT

- EXPERIMENT COORDINATION
- DATA HANDLING
- EXPERIMENT
- OPERATIONS PLANNING

INTEGRATED MISSION MANAGEMENT

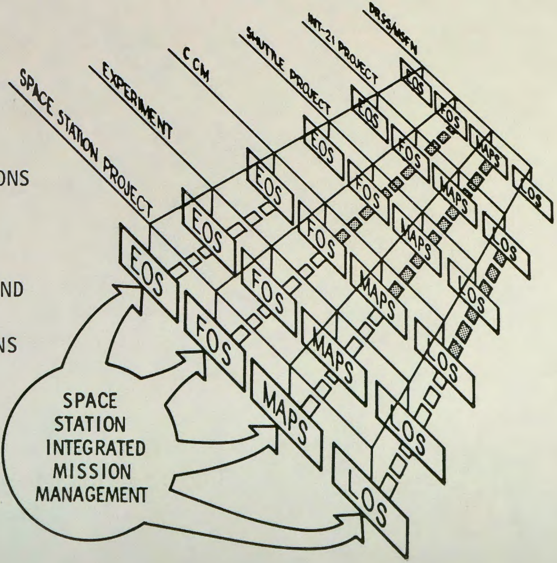
(OPERATIONAL)

EOS – EXPERIMENT OPERATIONS SUPPORT

FOS – FLIGHT OPERATIONS SUPPORT

MAPS – MISSION ANALYSIS AND PLANNING SUPPORT

LOS – LOGISTICS OPERATIONS SUPPORT



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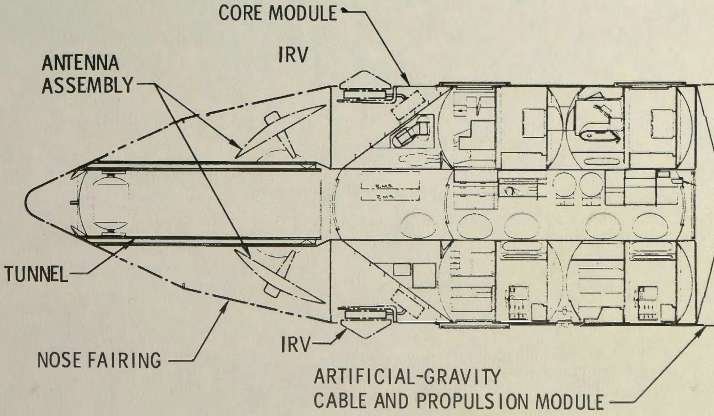
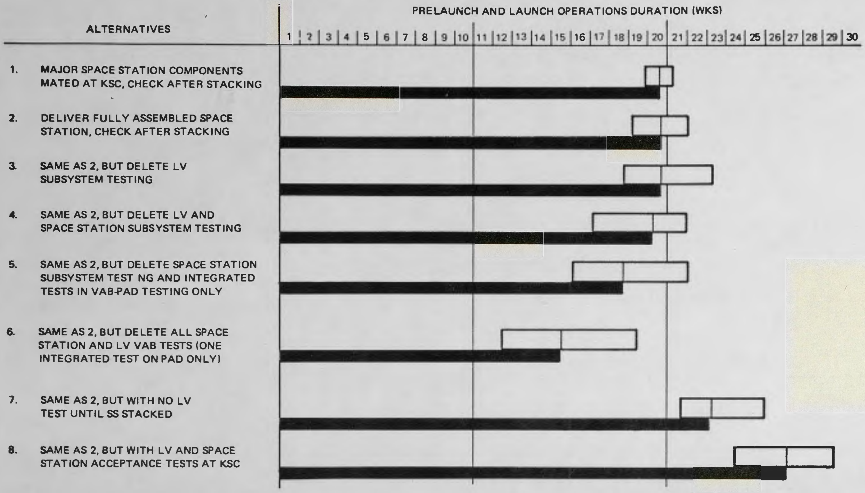
SPACE STATION CONFIGURATION
INBOARD PROFILE



COMPARISON OF PRELAUNCH AND LAUNCH OPERATIONS PHILOSOPHIES



NOMINAL DURATION

UNCERTAINTY IN LAUNCH DATE

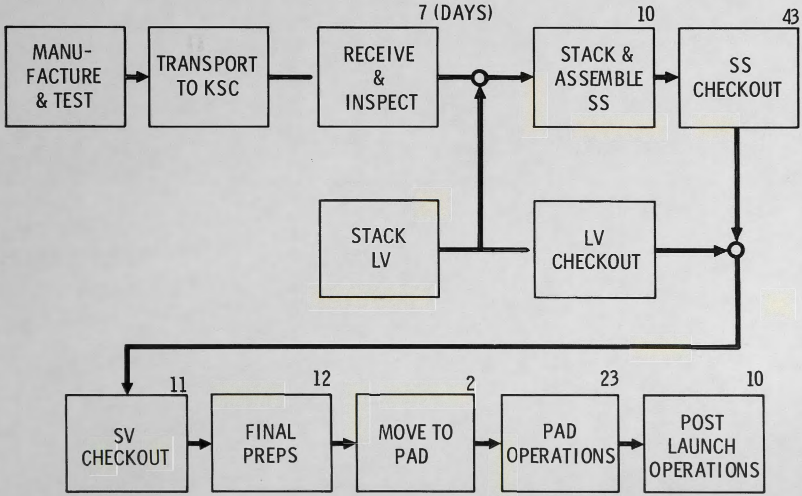
NOTES:
(1) THE PROGRAM REQUIRES THE MOST PREDICTABLE LAUNCH DATE (LEAST UNCERTAINTY) TO AVOID SIGNIFICANT PROGRAM COST IMPACT.
(2) ALTERNATIVES PERFORM SAME FUNCTIONS IN SAME ORDER EXCEPT FOR DELETIONS AND REARRANGEMENTS NOTED

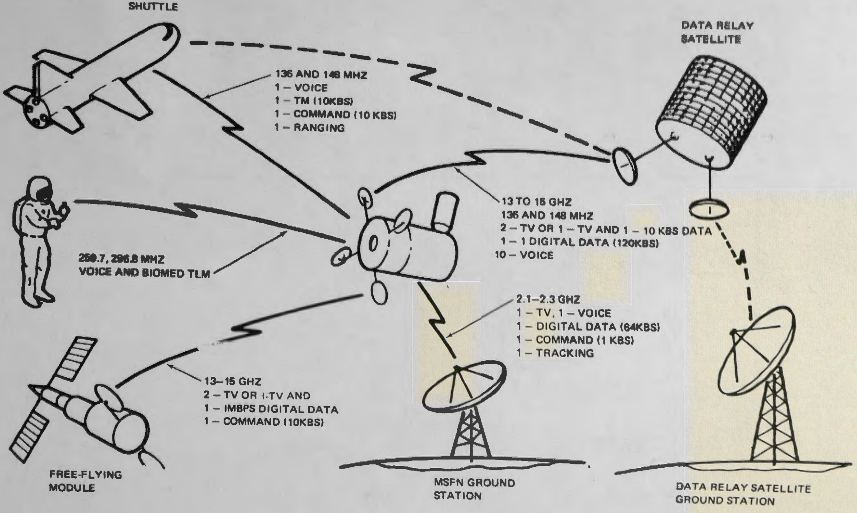
INTERFACE DEFINITION

	NOSE FAIRING	TELESCOPIC TUNNEL	ANTENNA ASSEMBLY	ISOTOPE REENTRY VEHICLE	CORE MODULE	ARTIFICIAL G MODULE	LAUNCH VEHICLE
NOSE FAIRING							
TELESCOPIC TUNNEL	• MECHANICAL						
ANTENNA ASSEMBLY							
ISOTOPE REENTRY VEHICLE							
CORE MODULE	• MECHANICAL • ELECTRICAL	• MECHANICAL • ELECTRICAL • FLUID	• MECHANICAL • ELECTRICAL • RF	• MECHANICAL • ELECTRICAL			
ARTIFICIAL-G MODULE					• MECHANICAL • ELECTRICAL		
LAUNCH VEHICLE						• MECHANICAL • ELECTRICAL	

SPACE STATION GROUND OPERATIONS FLOW

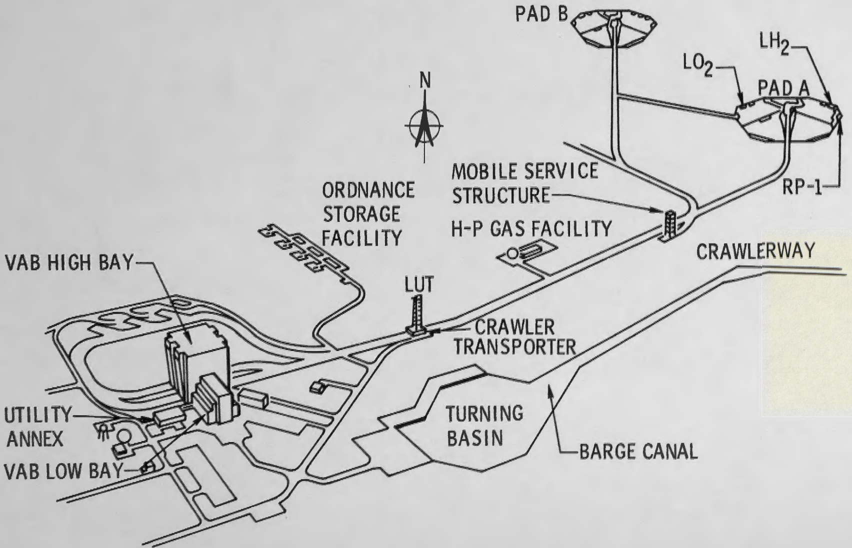
20720

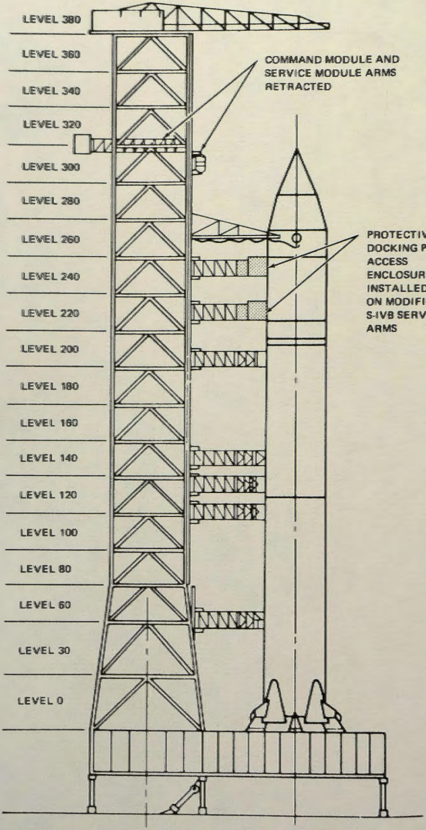




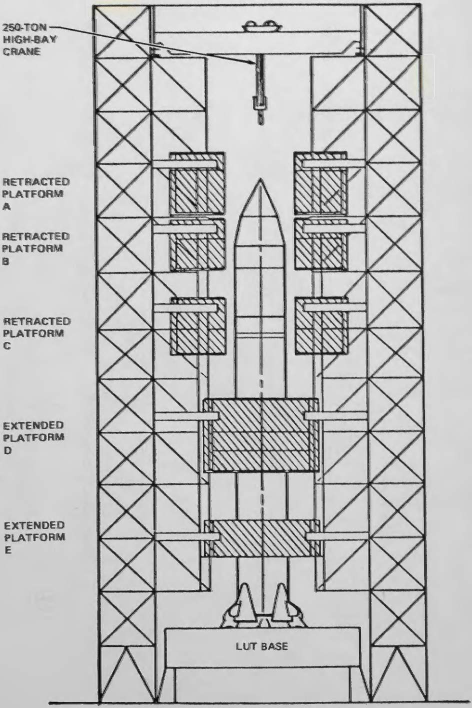
Communications Channel Requirements and Frequency Allocations

COMPLEX 39

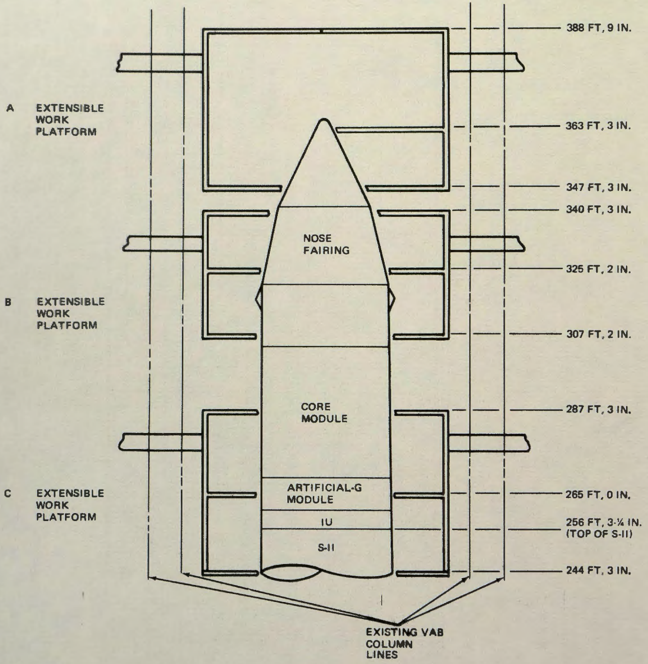

PAD B
LH_2
LO_2
PAD A
N
MOBILE SERVICE
STRUCTURE
RP-1
ORDNANCE
STORAGE
FACILITY
H-P GAS FACILITY
CRAWLERWAY
VAB HIGH BAY
LUT
CRAWLER
TRANSPORTER
UTILITY
ANNEX
TURNING
BASIN
BARGE CANAL
VAB LOW BAY



Space Station/INT-21 Shown on Saturn V Launcher Umbilical Tower

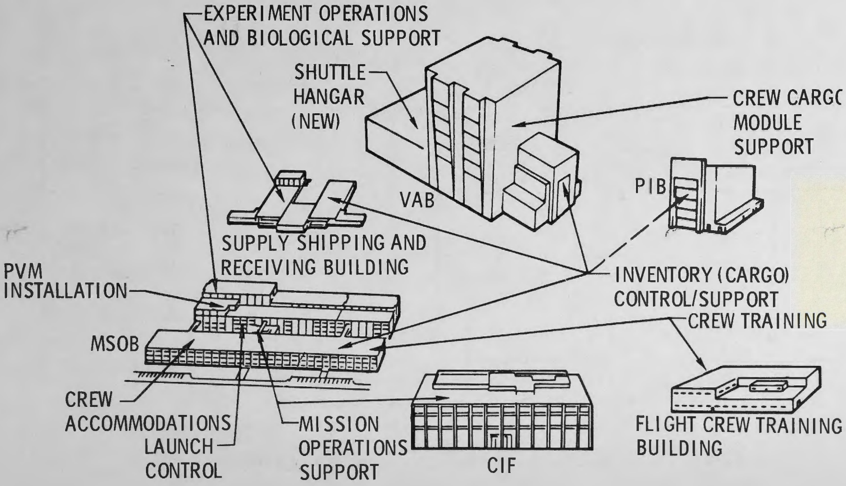


Space Station Shown in Existing Saturn V VAB Assembly Bay

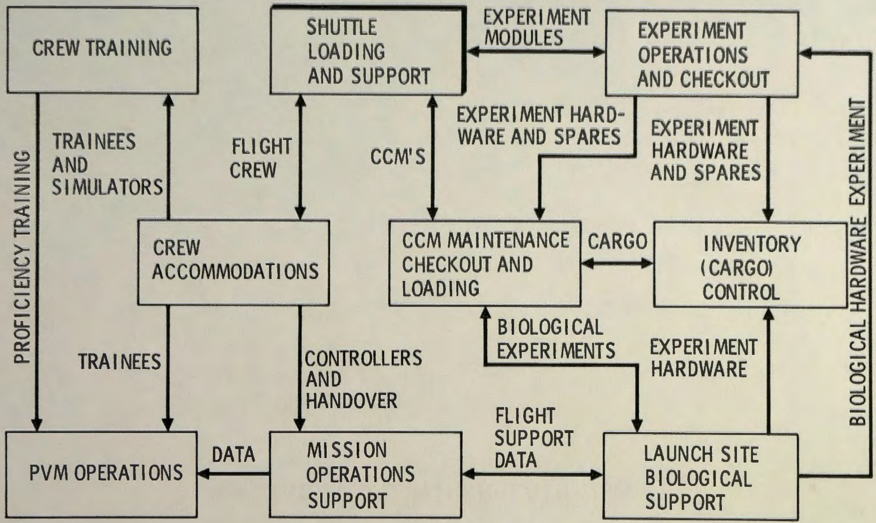


Space Station and VAB Extensible Platform Relationships

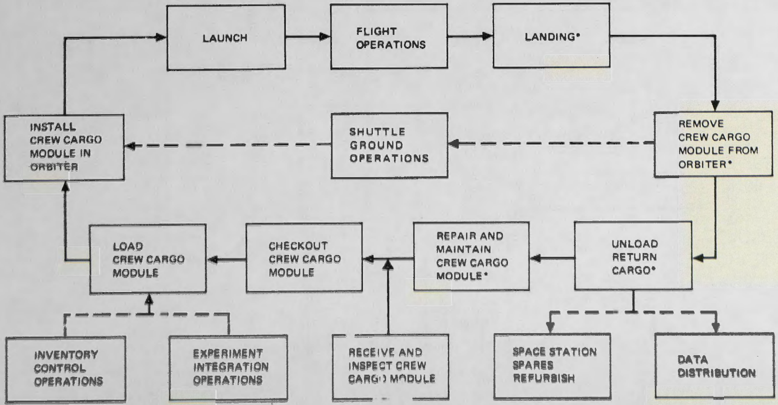
KSC FACILITIES INTERRELATIONSHIPS



KSC OPERATIONS FUNCTIONAL INTERDEPENDENCY



CREW CARGO OPERATIONS SUMMARY



*NEW TO KSC

CCM MAINTENANCE, CHECKOUT, AND LOADING