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APPLICATION OF SATURN SYSTEMS TO ORBIT LAUNCH OPERATIONS

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ABSTRACT

The payload velocity spectrum for existing and future missions are compared with Saturn V capabilities. Maximum system uprating is considered and the increase in the mission spectrum coverage by use of orbital assembly and launch with Saturn V systems is presented. The system and operations requirements for an orbit launch vehicle are assessed and three orbital operations support modes are compared to these requirements. The permanent facility mode is selected and the necessary support elements and their functions described. Detailed orbit operations procedures are described for an orbit launch vehicle derived from the S-IVB and task-time networks of the procedures are presented. The required changes to the basic S-IVB are delineated and the Saturn V capabilities for the assembly orbit presented. An example OLO mission is examined to determine the total orbital operations and support procedures and requirements. The ground operations and support procedures and facilities requirements are assessed and compared to the presently planned ground launch complex. It is concluded that the S-IVB is adaptable as a pioneer orbit launch vehicle and that Saturn V/Apollo systems coupled with the presently envisioned orbit laboratory systems can form the basic components of an early orbital launch system for planetary reconnaissance missions in the next decade.

CREDIT

This paper presents a portion of the results from a Douglas funded study of Planetary Reconnaissance (SM-46912) conducted by the Advance Saturn and Large Launch Systems Directorate under the direction of M. W. Root.

APPLICATION OF SATURN SYSTEMS TO ORBIT LAUNCH OPERATIONS

INTRODUCTION

The objective of this paper is to explore the feasibility and problems of conducting orbital launch operations with the Saturn system and to determine the requirements for orbital launch operations and the corresponding adaptations of the Saturn V/Apollo systems. The Saturn V will launch the United States into manned space exploration. Its development and facilities represent not only a large monetary investment, but an expenditure of an important portion of the national technological capability as well. By the end of this decade, the nation will have invested over 17 billion dollars in the Saturn/Apollo systems, including approximately 9 billion dollars in the Saturn V launch vehicle and the supporting facilities. An additional 2 to 5 billion dollars may be invested in the development of Earth orbital laboratories. The scope of these programs demands the fullest exploitation of their systems and operational capabilities to perform future missions in order to amortize these investments over the next decade.

Although the Saturn V system is basically designed for lunar exploratory missions, numerous studies by NASA, Douglas, and other aerospace companies have evaluated the feasibility of using this booster for missions far beyond the manned lunar landing. If these applications are accepted into logical future programs, the cost of development may be amortized over a period of ten to fifteen years and permit exploration of the entire solar system.

Existing systems and those currently under development are, however, limited in payload capability and velocity required for many of the more attractive future missions. Burnout velocities on the order of fourteen kilometers per second (46,000 feet per second) and payloads of 70 metric tons (154,000 pounds) are required to accomplish even the minimum manned planetary missions, i.e., low energy Mars/Venus flybys. These requirements exceed the Saturn V launch vehicle direct ascent performance even with significant uprating. Even the nuclear third stage direct ascent performance is marginal or inadequate for these minimum manned interplanetary missions.

However, the orbital launch concept, utilizing Saturn V and the technologies and operational procedures that will be developed for the manned lunar landing program, form the basis of a system which will allow the Saturn V to adequately meet the future missions requirements. This is not to say that new development is not required, rather it defines the areas in which further and new development is necessary to fully exploit the systems and facilities being constructed.

Saturn V Mission Capability

The mission spectrum potential of the Saturn V with a combination of booster uprating and orbital assembly and launch operations is shown in figure 1. Uprating the Saturn V shows a considerable increase in mission capability but not enough for manned planetary reconnaissance. Orbital launch operations using two or three S-IVB's allow a significant support capability for a manned lunar base and performance of limited Mars and Venus manned flybys with a standard Saturn V. Orbital launch of uprated Saturn V-3 provides ample capability in two new classes of manned missions plus considerable increase in capability for unmanned capture and landing probes to Jupiter and Mercury. Further growth

SATURN V MISSION SPECTRUM MAP

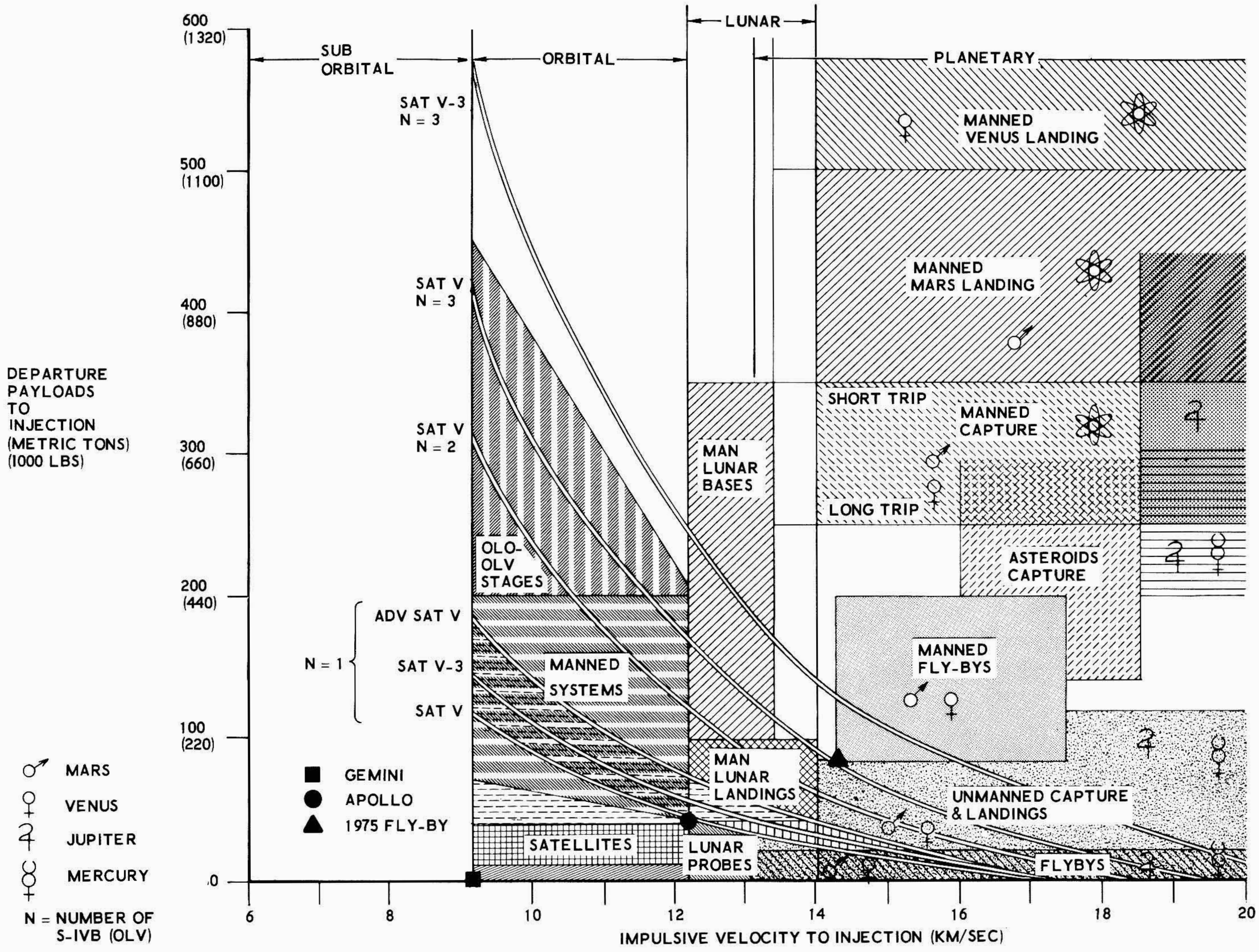


FIGURE 1

(four orbital launch S-IVB's and use of advanced Saturn V) will have the capability of manned capture missions to Mars and Venus, and manned exploration of the asteroids.

Orbit Launch vs Direct Ascent Comparison

The Saturn V capability achieved by uprating and orbital operations has significant advantages over the development of new vehicles with similar payload capability. For example, a new vehicle (based on current technology) capable of launching 70 metric tons directly to the Mars flyby trajectory from Earth would have to be two or three times as large as Saturn V. To send 180 metric tons to Mars, a single vehicle would have to be approximately 6 times as large as Saturn V. While more advanced approaches such as high pressure plug nozzle engines, more exotic propellants, etc., would reduce the growth factors, completely new stages and engine development programs would be required. The orbital launch/uprated Saturn V requires only evolutionary extensions of existing programs, and development of earth orbital assembly techniques. An orbital launch vehicle assembled from two or three modified S-IVB stages would have a payload capability of 90 to 180 metric tons, which is sufficient for manned Mars/Venus flyby missions. By trading payload for higher velocity, 30 metric tons can be delivered at 19 kilometers per second. This is sufficient for extensive exploration of the solar system (including satellites and the outer planets) with unmanned probes.

New Development and Facilities Requirements

The orbital launch concept will require new development in some areas to fully exploit the systems and facilities now being constructed. For example, rendezvous and docking must be perfected within the operational constraints imposed by meeting Earth, orbit, and planetary launch window schedules. Orbital assembly and checkout techniques must be developed and tested. New support equipment will be required in orbit. Both modified and additional support equipment and facilities will be required at the Kennedy Space Center and possibly in the world tracking network. The S-IVB stage must be modified to extend its orbit stay time and provide a rendezvous, docking, assembly and checkout capability. The orbital laboratory will have to be adapted for its dual role of orbital launch facility and manned planetary mission module.

Orbital operations developed for the Saturn V/Apollo systems not only would provide the Nation with an early capability to perform manned planetary reconnaissance but it will also provide the valuable operational experience and technological base for the development of more advanced systems in the 1980's for manned planetary landing programs.

Analysis indicates that the orbital launch concept is a feasible and logical extension of existing and planned programs, and that orbital operations are an essential ingredient for any manned planetary program.

ORBITAL LAUNCH OPERATIONS REQUIREMENTS

The basic requirements for orbital launch operations may be grouped into five broad categories as noted in figure 2. The components must be launched into

ORBIT LAUNCH OPERATIONS (OLO) REQUIREMENTS

S-IVB-1981

PERSONNEL

- CREWS ACCOMMODATIONS AND SAFETY
- CREW TRANSFER

BUILD UP

- LOGISTICS
- RENDEZVOUS
- DOCKING
- ASSEMBLY
- FABRICATION
- PROPELLANT TRANSFER

PREPARATIONS

- COMMAND AND CONTROL
- CHECKOUT
- FAULT DETECTION
- REPAIR AND REPLACE
- COMMUNICATIONS
- DATA EVALUATION

MAINTAIN

- PROPELLANT CONTROL
- ENVIRONMENT CONTROL
- ATTITUDE CONTROL
- MAINTENANCE AND SUPPORTING SUPPLIES

LAUNCH

- COUNTDOWN AND LAUNCH
- LAUNCH WINDOWS
- EMERGENCIES AND ABORT
- TRACKING AND NAVIGATION

FIGURE 2

orbit to *build-up* the orbit launch vehicle. These components must be *maintained* in orbit until the operations are completed and the orbit *personnel* (assembly crews, checkout crews, and the mission crew) must be accommodated. When the build-up is completed, *preparation* must be underway to perform the *launch* within the mission window constraints. Most of these task requirements are applicable to orbit launch of any vehicle. The particular manner in which the orbital operations tasks are performed will depend in part on the basic operational mode selected.

Orbital Launch Modes

Figure 3 shows the three basic modes considered for the orbital launch vehicle operations. Figure 4 is a general evaluation of these modes. The independent orbital launch vehicle concept imposes unacceptable penalties to the orbital launch vehicle stages. It is marginal in crew accommodations and excessive in workload per man. Preparation for launch, such as checkout, repair, etc., are marginal or severely limited. Rendezvous and assembly of the orbital launch vehicle and actual launch from orbit appears feasible, but limited. Although addition of temporary orbital support equipment may permit launch requirements to be met, crew accommodations and workloads will have a limited margin to deal with contingencies or with very sophisticated orbital launch systems and operations. The major factor against the temporary OSE mode may be its limited resources for achieving and meeting an orbital launch schedule. This is quite critical for such orbital launch missions as manned planetary reconnaissance. The permanent orbital launch facility concept represents maximum orbital support and resources. It provides added personnel for orbit operations and a considerable increase in the command and control functions, contingency response, repair capability, and resources in depth to ensure meeting the operational schedule. In selecting the permanent orbital launch facility mode for the orbital launch concept rather than the temporary orbital support equipment mode, two factors were paramount. The first was the added resources in depth which will lead to greater probability of mission success. The second is the assumption that a manned Earth orbit station similar to the orbital launch facility will be developed and deployed several years before orbital launch operations are conducted. The permanent orbital launch facility approach simply adds another operational role to a system previously developed. The

S-IVB-1979

OLO MODES

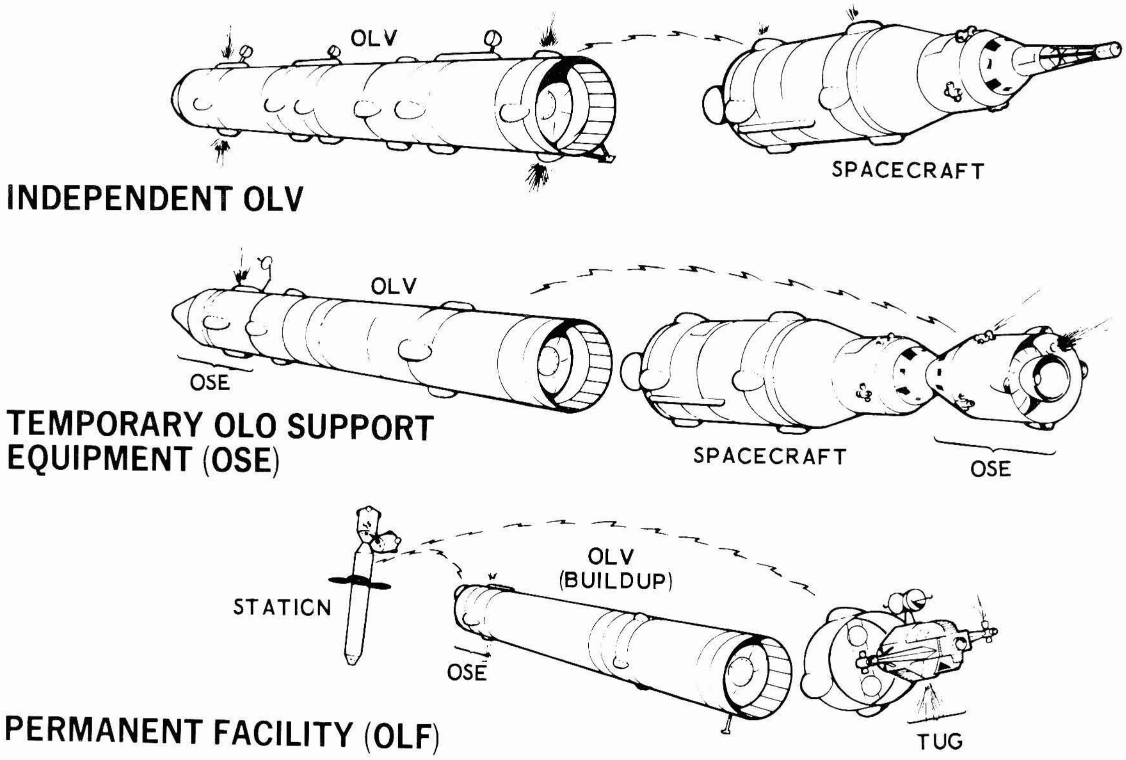


FIGURE 3

S-IVB-1980

OLO MODES EVALUATION

OLO REQUIREMENTS	INDEPENDENT OLV	TEMPORARY OSE	PERMANENT OLF
BUILDUP	ADEQUATE BUT LIMITED	ADEQUATE	ADEQUATE
MAINTAIN	INADEQUATE [UNLESS SUPPORT SYSTEMS ADDED TO OLV (DECREASED OLV PAYLOAD INCREASED COMPLEXITY)]	ADEQUATE	ADEQUATE
PERSONNEL PROVISIONS	MARGINAL TO INADEQUATE	LIMITED	ADEQUATE
PREPARATIONS	MARGINAL AND SEVERELY LIMITED	LIMITED	ADEQUATE
LAUNCH	ADEQUATE BUT LIMITED	ADEQUATE	ADEQUATE

FIGURE 4

peculiar orbital support equipment hardware must be developed in either of the two adequate modes. Orbital support equipment development and support will be easier in the presence of a manned station which can later be converted to serve as orbital launch facility during orbit operations. The assumption of prior manned station development is logical in that it is easier to accomplish than the orbit launch operation itself. In addition to providing (1) experience in orbital operations, (2) information on man's survival capability in orbit and long duration space missions, the orbital station hardware may serve as a prototype for manned interplanetary mission modules.

Orbital Launch Vehicle System Requirements

In order to identify the OLV stage requirements, a specific Saturn V stage was selected for analysis. The S-IVB/Saturn V Stage because of its six hour orbit stay capability, restart capability, and mission profile for the Apollo LOR Program, is most similar to an OLV and was selected as a prototype stage for the requirements analysis.

An analysis of the S-IVB for the Orbit Launch Vehicle (OLV) booster stage indicates that neither fabrication or propellant transfer operations are required. The standard Saturn V booster can deliver a modified OLS-IVB to the assembly orbit with sufficient propellant on board to perform useful orbit launch missions using orbital assembly only. Moderate uprating of the Saturn V (250K J-2T) can deliver the OLS-IVB docked and unfired with 95% of propellant load (a rendezvous kick stage, CUSS, is required for the Gemini style rendezvous gross maneuvers in any case).

Figure 5 is a list of increased or new system requirements which must be provided to adapt or convert an earth launch stage to an orbit launch stage. Incorporation of all these requirements aboard the OLV stage would represent an unacceptable burden on the OLV performance and undue complexity in the stage systems. For these reasons, the concept of separate packages of orbit support equipment to meet or supplement these requirements is advocated. The particular requirements which can be off-loaded onto the Orbit Support Equipment (OSE) are noted on figure 5. Because of the multiple functions of some of the systems, they are categorized by design disciplines (propulsion, structures, mechanical, electrical/electronic) rather than functions (rendezvous, docking, environment control, checkout, etc.) noted under OLO requirements. Many of these system requirements are due to the time required for orbital build-up of the OLV and the desire to provide sufficient orbit hold time to mitigate launch window constraints on the operations schedule. A minimum orbit stay design time of 20 days was indicated and a desired time of 30 days selected for system criteria. Performance and control requirements for rendezvous and docking along with a desire to maintain the main stage propulsion system in a "buttoned-up" condition until orbit launch (improving orbit stay time, OLV performance, safety, and checkout capabilities) led to separate propulsion systems tailored to these functions. A rendezvous kick stage, designated as the cryogenic utility space stage (CUSS), can perform the major velocity injections (plane change, slow catch up injection, and near circularization) of a quasi-Gemini rendezvous technique. Added APS (Auxiliary Propulsion System) modules provide rendezvous attitude control, final circularization, and docking propulsion. Propellant control systems are needed to settle the main stage propellants for venting (thermal control, etc., are designed to allow at least

ORBIT LAUNCH VEHICLE (OLV) SYSTEM REQUIREMENTS

PROPULSION

- RENDEZVOUS SYSTEM
- DOCKING SYSTEM
- ▲ ATTITUDE CONTROL SYSTEMS
- ▲ PROPELLANT CONTROL SYSTEM (VENT & SETTLE)
- ABORT & DEBRIS RETRO MOTORS
- STEP T/W$\geq \sim$0. 7
- RESTART (S)
- HIGH ENERGY PROPELLANTS (MAIN STAGE)

STRUCTURES

- DOCKING STRUCTURES (MALE AND FEMALE)
- INSULATION AND HEAT BLOCKS
- MICROMETEROID SHIELDS
- ORBIT HANDLING AND ATTACH PTS.
- REPAIR & REPLACE ACCESS
- UMBILICAL TUNNEL
- ADDED SUPPORT STRUCTURES AND BRACKETRY

MECHANICAL

- DOCKING ACTUATORS
- ASSEMBLY LATCHES
- △ ORBIT UMBILICAL CONNECTORS AND ACTUATORS
- ▲ PNEUMATIC SUPPLY INCREASE
- △ SPACE RADIATORS
- △ THERMAL CONTROL PANELS (AND BLANKETS)

ELECTRICAL/ELECTRONIC

- ADDED COMMAND MODES
- TRACKING TRANSPONDERS
- ▲ POWER SUPPLY (DURATION INCREASE)
- △ HORIZON AND STAR SEEKERS
- INCREASED SEQUENCER PROVISIONS
- △ COMMUNICATION LINKS (COMMAND AND CONTROL)
- △ DIGITAL COMPUTER
- △ DOCKING SENSORS
- △ UMBILICAL CONNECTORS AND CARRY-THRU
- ADDED PROPELLANT MONITORING AND CONTROL ELECTRONICS
- RENDEZVOUS STAGE ELECTRONICS AND INTERFACE
- DOCKING ELECTRONICS (APS)
- ENVIRONMENTAL CONTROL SENSORS
- SAFETY MONITOR SENSORS
- △ CHECKOUT INTERFACES
- ORBIT F/D TEST POINTS
- ORBIT ABORT SENSING AND CONTROL

▲ REQUIREMENTS WHICH CAN BE MET OR SUPPLEMENTED (△) BY OSE

FIGURE 5

a 24-hour span between vent operations to minimize interference with orbit operations) and for launch. Abort motors are required to retro the OLV stages away from the manned spacecraft for a launch abort.

The debris problem has not been sufficiently analyzed, but possibly the abort motors can double as propulsion units to inject the spent OLV stages into "safe" junkpile orbits or destructive re-entry.

Step thrust to weight ratio of 0.7 or greater is desired to minimize gravity losses at orbit launch (first stage thrust to weight should exceed 0.25). Restart is desired to increase the orbital launch window even with a multistage OLV (a 40 second burn at apogee of the intermediate escape elliptical orbit allows about 6° to 8° plane change prior to final injection near perigee). High energy propellants are desirable for OLV stages to minimize OLV growth factor. This will not only decrease the cost of the OLV stage, but the cost of earth to orbit transportation (pounds required in orbit) as well.

The structure requirements listed in figure 5 are largely self explanatory... an exception might be the umbilical tunnel. The dynamics and structure problems of removing long umbilical lines (from the OSE to each OLV stage) with either flexible or rigid "arms" indicates the desirability of a built-in umbilical tunnel on each stage with automatic connections from stage to stage. Use of the standard ground umbilical plate for stage interface does not appear adaptable to a dual purpose (ground and orbit) interface. Proper minimization and selection of umbilical lines, and the use of staggered stacking connections minimized the penalty thus incurred. This added burden to the orbital launch vehicle (OLV) was considered acceptable in order to minimize the control dynamics and debris problem at launch, and simplify the orbital assembly operations.▸

Pneumatic supply must be increased to perform periodic valve "dither" to ensure valves do not become "frozen" during the several weeks in orbit. This can be accomplished by pneumatic supply lines from the OSE to the stage pneumatic vent valve downstream of the regulator. Thermal control requirements of the stage systems, subsystems, and components can best be met by a combination of coolant mounting plates (cold plates) and electrical heating elements (blankets). These will require space radiators on the stage. Power requirements for heating and pumping coolant can be supplied by OSE. Heat rejection from the coolant should employ a secondary closed loop space radiator rather than the present secondary open loop water sublimation.

Numerous control and sensor electronics are needed to perform the orbital operations. A major electrical requirement is the long duration power supply and possible load increases. This requirement would present an unacceptable weight penalty if incorporated on the OLV stage. Power supply for the OLV stage while docked in orbit can be supplied by the OSE. Stage power systems must be modified to meet the increased requirements during orbital rendezvous and possibly during orbital launch. Orbital umbilical interface must be incorporated in the power, command, and data systems. A checkout interface between the stage system and the checkout system (can be provided by OSE) must be incorporated.

These system requirements present a brief description of the necessary added weight and complexity of a stage to achieve a true orbit assembly and launch capability. If propellant transfer were employed, several additional systems and modifications would be required. It appears feasible to meet each of these requirements by modifying and adding systems to a suitable existing ground launch stage (e.g., the S-IVB). By developing separate orbit support equipment the requirements can be met within acceptable performance penalties to the orbit launch vehicle.

Orbital Launch S-IVB Description

The orbit launch version of the S-IVB stage is illustrated in figure 6 in the configuration as launched on the Saturn V Earth Launch Vehicle (ELV). The modified S-IVB, the CUSS stage, and nose cone comprise the payload to be injected to rendezvous orbit by a modified Saturn V.

The J-2 engine is replaced by the 250K/J-2T engine to increase performance and ensure adequate first stage thrust-to-weight ratio in multiple tandem assembled OLS-IVB's for the orbital launch vehicle. The propulsion system and thrust structure must be modified to accommodate the modified engine. The OLS-IVB can perform orbit launch missions with the 200K/J-2 engine but at marginal performance for a manned planetary reconnaissance mission. Three tandem OLS-IVB/250K/J-2T stages can boost an 86 metric tons (190,000 pounds) spacecraft into the heliocentric trajectory.

The LH_2 tank was lengthened 4.75 feet to increase LH_2 volume and allow the vent cycle (with the added external installation and heat blocks) to be increased from 10 hours to 24 hours. This decreased the settling and venting operations required during orbit build-up and preparation.

A separate (third) bulkhead was required to isolate the LO_2 tank from the LH_2 tank to reduce heat transfer and LH_2 boiloff. The LO_2 tank pressure was increased to meet J-2T engine requirements.

ELV S-IVB STAGE LAUNCH

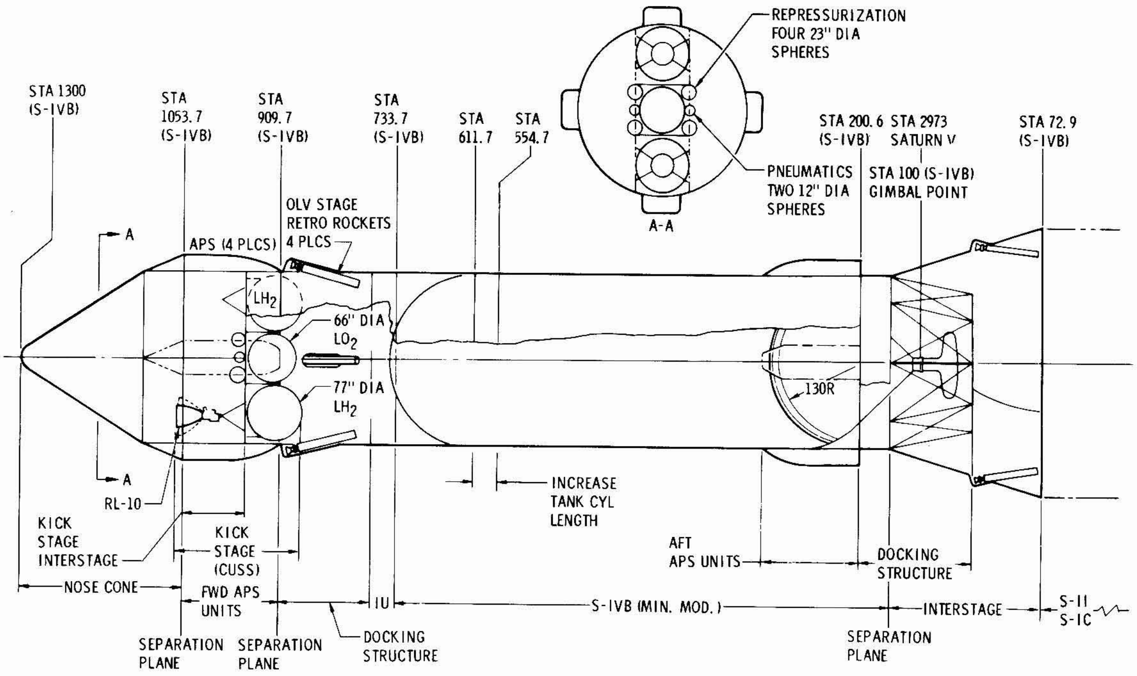


FIGURE 6

Docking structures are added with a male frustrum on the stern and a female frustrum on the bow. External installation is added to the LH_2 tank walls and additional structural heat blocks incorporated to reduce thermal input to the LH_2 tank.

A meteoroid shield is added to limit meteoroid penetration to a .99 probability of no more than one penetration of the shield itself during a 30 day stay in Earth orbit.

Eight auxiliary propulsion modules are added to each stage to provide attitude control during rendezvous, docking and launch, and to provide translational acceleration during final circularization, docking, and orbit launch ullage. All but the four aft modules on the orbital launch vehicle first and third stages are removed in the orbit assembly operations prior to orbital launch.

The Instrument Unit (IU) is retained with each S-IVB stage throughout the orbital operations and launch. It is an integral part of the S-IVB command and control, environmental control, and orbital checkout systems. During orbit launch, guidance and control commands are generated by the uppermost instrument unit with the other systems (first and second stages) slaved to it. This approach imposes a penalty of the S-IVB inert weight which might be eliminated if more extensive stage modifications were acceptable. However, it was deemed easier to provide slightly higher propulsion performance capability to compensate for retaining the instrument unit system intact at orbit launch.

The rendezvous kick stage (CUSS) consists of an LO_2/LH_2 propellant and pressurization system, two RL-10 engines, and interfaces with the S-IVB stage instrument unit and power supply (including emergency batteries). It is mounted on the bow of the S-IVB (the stage is docked stern first) and removed by the assembly crew using the orbit tug after the stage is docked.

The system descriptions presented in this paper are primarily intended to indicate the scope of the impact orbital launch operations imposed on the S-IVB stage. Further details on these systems modifications to the S-IVB stage are presented in Douglas Engineering Paper Number 3645, "Application of Saturn/S-IVB/Apollo Systems to Planetary Exploration," by M. W. Root presented to the Post-Apollo Space Exploration Symposium, AAS, May 4-6, 1965.

For clarity, the S-IVB modified to the orbital assembly and launch configuration is hereafter referred to as the OLS-IVB.

PERMANENT ORBITAL LAUNCH FACILITY - SUPPORT ELEMENTS

Orbital launch elements, based on the "permanent" orbital launch facility concept, are illustrated in figure 7. The supporting elements include the orbital station, the SORD, CUSS and the orbit tug. The orbit station provides housing and work areas for the station crew, assembly, checkout, and launch crew, and for a short time, the mission crew. The orbital station is the command and control center for the orbit operations.

A representative orbital launch vehicle is shown for a manned interplanetary flyby mission. The booster is comprised of three OLS-IVB stages docked in tandem. While in orbit the first stage stern will be docked to the supporting orbital dock (SORD). A cryogenic utility space stage (CUSS) is used for rendezvous of each OLV stage with the SORD buildup. This is removed by the assembly crew, using the tug, after each stage docks (and prior to ground launch of the next stage to rendezvous).

The supporting orbital dock (SORD) is used to build-up the orbital launch vehicle. It provides supporting functions (helium supply, auxiliary power, etc.) to the stages while in orbit and contains the checkout interface computers and RF links to the space station. It may be considered the orbital equivalent of pad equipment at the ground launch facility.

In addition to the elements described in preceding paragraphs, at least one other major element is orbited prior to the mission itself. This is the propulsion stage or stages required prior to start of the OLV build-up to adjust the nodal regression rate of the space station so that the space station orbit node will drift into the proper orientation at the nominal orbit launch time.

S-IVB-1598

ORBIT LAUNCH VEHICLE AND SUPPORT ELEMENTS

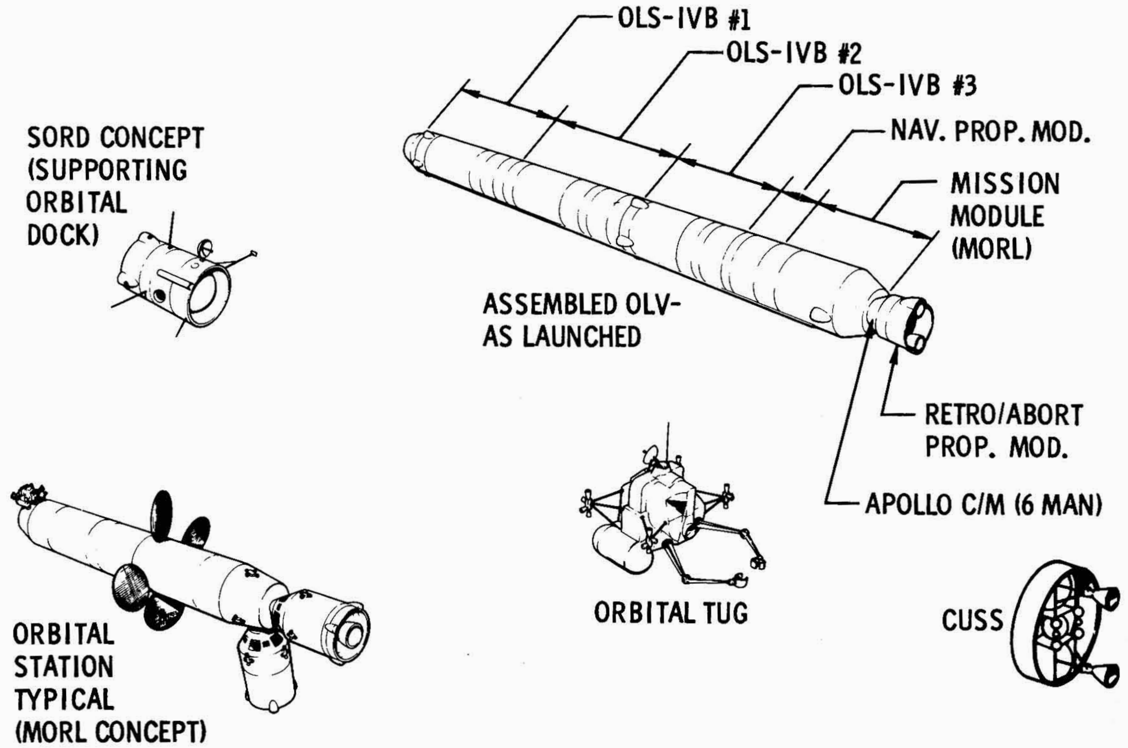


FIGURE 7

Supporting Orbital Dock (SORD)

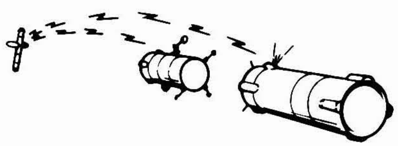
The basic functions of the Supporting Orbital Dock (SORD) are grouped into six categories illustrated in figure 8; docking, attitude control, OLS-IVB system support, checkout and monitor status, acceleration of the OLV, and launch countdown and positioning. The use of the SORD relaxes the OLV requirements and provides increased orbital support and stay time for the OLV. Without the SORD, most, or all, of these functions would have to be performed by each OLS-IVB and the OLV.

The SORD and OLV are not connected directly to the manned station, but are slaved to it some distance in-train in the same orbit. OLO crew access is via the orbit tugs. The SORD presents a "spacesuit environment" and does not have a life support system or module as presently conceived. Emergency space suit

SORD FUNCTIONS

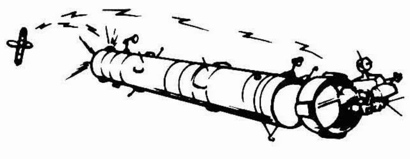
I DOCKING

- RIGID DOCK FOR OLS-IVB
- INTERFACE CONNECTIONS
- SEPARATES FUELED OLS-IVB FROM MANNED STATION
- STATION KEEPING



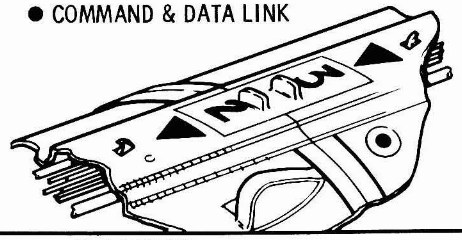
II ATTITUDE CONTROL

- OLV ATTITUDE FOR DOCKING, EQUIPMENT REMOVAL, ETC.
- OLV-SUN RELATION FOR THERMAL
- DURING VENTING
- LAUNCH ORIENTATION



III OLS-IVB SYSTEM SUPPORT

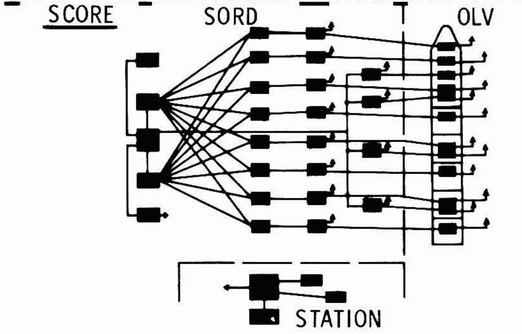
- ELECTRICAL POWER - 28V & 56V
- HELIUM GAS - 500 PSI
- 600KC VCO/DDAS LINES
- IU COMMAND REC LINES
- STAGGERED STACKED ROUTING TO ALL OL-SIVB's & S/C
- SYSTEMS STATUS & SAFETY MONITOR
- MAINTENANCE CYCLE & CONTROL
- COMMAND & DATA LINK



IV ORBITAL CHECKOUT

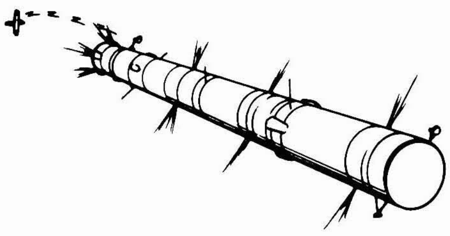
- STAGE FUNCTIONAL, OLV VERIFY
- AUTOMATIC - SORD SLAVE COMPUTERS
- MANNED STATION GP COMPUTER CONTROL AND DISPLAY
- PRE LAUNCH C/O AND C/D

SYSTEM FOR COMPUTERIZED ORBITAL EVALUATION



V ACCELERATE OLV

- VENTING ULLAGE
- LAUNCH ULLAGE
- POSITIONING
- PROPELLANT SETTLING (MEASURE)



VI LAUNCH

- ORIENTS
- SETTLES
- COUNTDOWN
- SEPARATES ~ 4 MIN PRIOR TO IGNITION - SORD CAN BE USED AGAIN FOR OTHER OLS-IVB MISSION
- IF OLV MISSES WINDOW AFTER SEPARATION (TWO TRIES), SORD CAN REDOCK & REFURBISH

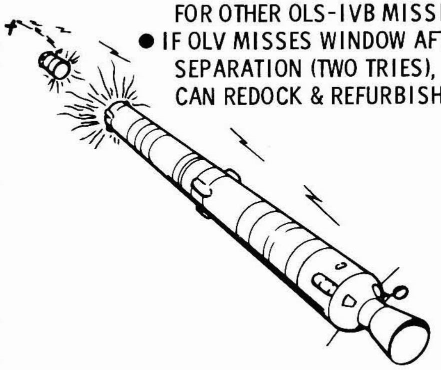


FIGURE 8

support packs and a means at donning such packs might be provided, but normally the SORD operates in an automatic unmanned mode or by remote control from the manned station. The SORD contains OLV pneumatic supply, electrical power supply, a stability and control system, reaction control and translation propulsion (possibly derived from the S-IVB APS modules), command, control, and data interfaces with the OLV systems, communication and control links with the station, part of the system for computerized orbital evaluation (SCORE) for OLV stages checkout, a female docking cone and OLV orbital umbilical interface, limited environment control for certain SORD systems, and rendezvous, docking, and station keeping systems. It also has a docking face for the orbit tug.

Orbit Tug

Two or more orbit tugs will be required to transport men and equipment from the orbit station to the SORD/OLV assembly. They will be used to remove all the expended equipment from the OLV (spent CUSS stages, expended auxiliary propulsion system units, etc.) and to aid in servicing the SORD and the OLV. Adaptation of the LEM ascent stage would appear to be a likely candidate for this function.

Orbital Crew Requirements

In addition to the major hardware elements, three crews are associated with the operations. This is over and above the mission crew itself. These crews are the orbital station crew, assembly crew, and the checkout and launch crew.

Station Crew

The station crew normally operates and maintains the station itself, independent of the orbit launch operations. They will normally be rotated into the station quite some time before the mission and their tour of duty may extend past the actual launch operation. This crew maintains the station and the equipment not directly associated with the launch operations. They also operate the communication links to the ground. Previous time-line analyses indicate four to six men are needed for the station crew.

Assembly Crew

The assembly crew will checkout, test, verify, and prepare the SORD to receive OLS-IVB's. This crew operates the orbit tugs and assists in inspection and assembly of the OLS-IVB's to the SORD (or to each other), moves equipment around, removes the CUSS stages, etc. The assembly crew is launched to the station several months prior to start of OLV assembly in order to prepare the SORD. Time-line analysis of the assembly operations indicate six men are needed. The assembly crew is comprised of two three-man work teams.

Checkout and Launch Crew

This crew prepares the orbital checkout system in the SORD and space station, performs the orbital checkout of the docked OLS-IVB's, and, together with the mission crew, the orbital checkout of the mission spacecraft. Members of the checkout crew can also double as alternates for the mission crew after the mission crew is orbited to the station. Teamed with the mission crew, they perform the final countdown and launch of the OLV. The checkout crew, like the assembly crew, is divisible into two work teams. The checkout crew is orbited to the station approximately one month prior to start of the OLV assembly. Time-line analyses of checkout and launch operations indicate six to nine men are needed for the checkout and launch crew; in the latter case, three men are supplied in a dual role from the assembly crew.

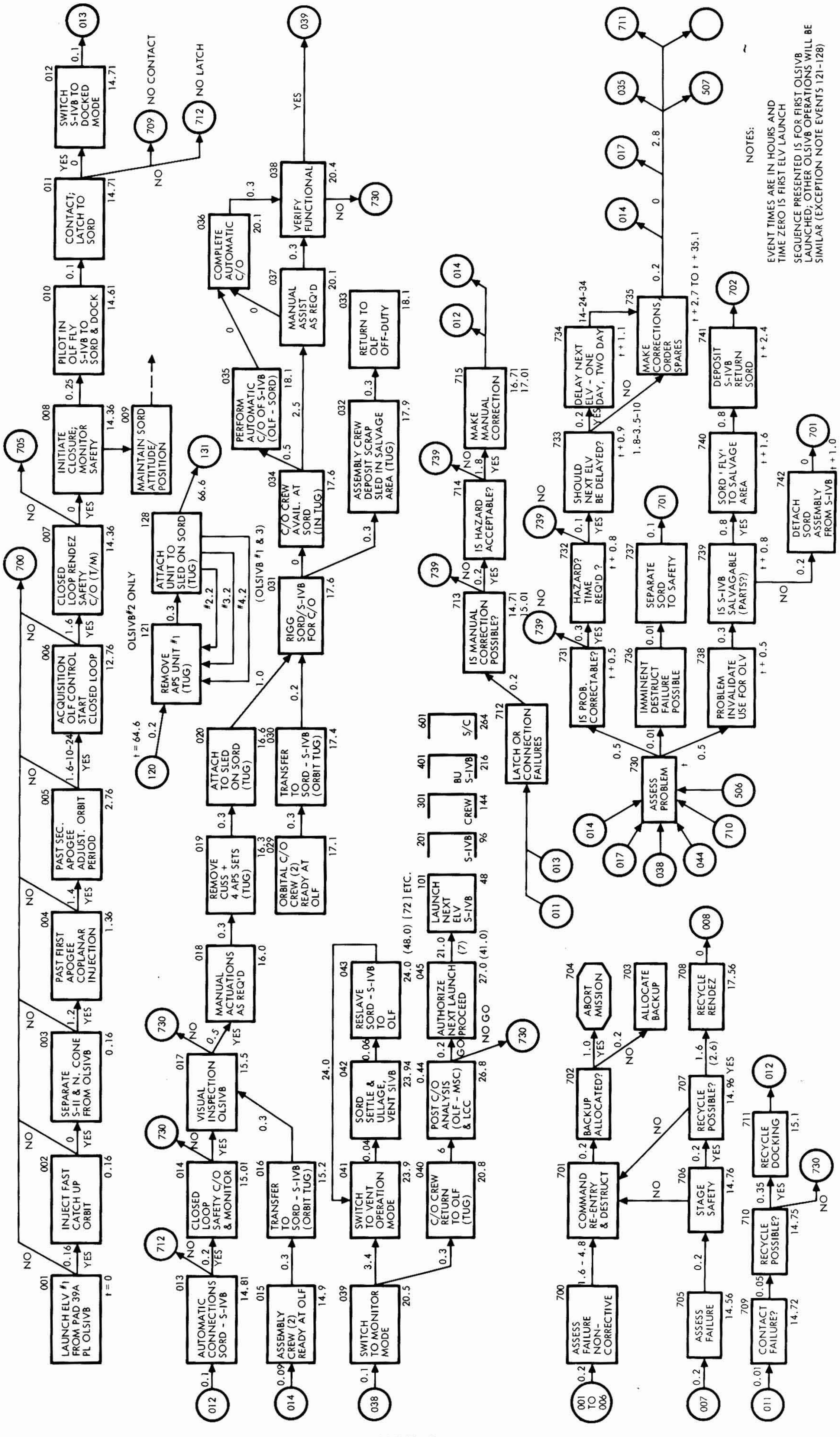
ORBITAL LAUNCH OPERATIONS TASKS

Orbital launch operations discussed in this section are applicable to any mission. Figure 9 presents a sample network of the sequence of operations for a single OLS-IVB from time of earth launch ($t = 0$) to acceptance of the stage for the OLV buildup and authorization ($t = 27$ hours) to proceed with earth launch of the next OLV stage. Details of each of these operations may be found in Douglas report SM-47371 -- "Applications of Saturn Systems to Orbital Launch Operations," September 1965.

Docking

After the CUSS performs the rendezvous orbit coplaner adjustment (up to $\pm 0.42^\circ$) following the first apogee, the OLS-IVB is in a fast pursuit orbit with the SORD. When a 1.5° phase lag occurs, the CUSS injects the OLS-IVB into a slow catch up orbit, and radar from orbital launch facility station locks on the OLS-IVB and assumes command of rendezvous. While an accurate track is being computed, a preliminary checkout interrogation is telemetered to the OLS-IVB to determine its safety status. This is the first mode of the Systems of Computerized Orbital Evaluation (SCORE). It is designated as the pre-docking "safe check." Measurements are made using open loop transmission of the PCM/DDAS train to determine the vehicle is in a safe condition to be brought into

OLS-IVB ORBITAL ASSEMBLY AND CHECKOUT – SEQUENCE OF EVENTS



NOTES:

EVENT TIMES ARE IN HOURS AND TIME ZERO IS FIRST ELV LAUNCH

SEQUENCE PRESENTED IS FOR FIRST OLSIVB LAUNCHED; OTHER OLSIVB OPERATIONS WILL BE SIMILAR (EXCEPTION NOTE EVENTS 121-128)

FIGURE 9

the dock. The RF command link to the Instrument Unit is utilized to disarm and "safe" various piece of ordnance on board. The SORD computer evaluates the static stage condition via the PCM/DDAS to determine whether the stage is in a dangerous condition, i.e., burning or leaking hypergolic fuel, etc. If the OLS-IVB is accepted as "safe" the rendezvous and docking mode continues. However, if the vehicle is deemed unsafe, it will be jettisoned out of the "catch up" orbit and the ground will be notified that the "back up" OLS-IVB will be required.

Having been accepted as "safe-to-dock," the OLS-IVB is brought into the SORD stern first and is docked by remote sensor (TV and docking radar on the SORD) link from the manned station. The final docking operation includes the mating of docking cones on the OLS-IVB with conical apertures on the SORD. These docking cones contain a low pressure control helium line, auxiliary power lines, and closed loop coaxial links to the 600 kc VCO output of the OLS-IVB and IU DDAS's and the input to the IU command receiver. Then the SCORE program begins the second phase of checkout, the "Post-Docking Safety Check." This check is completed via closed loop coaxial cable and will be used to determine that the SORD/Vehicle combination can be safely approached.

Safety Check

A preliminary visual checkout of the vehicle is accomplished with the SORD TV cameras which can be swiveled to cover any section of the surface of the OLS-IVB or the SORD. The SORD will contain a TV transmitter which will present the multiplexed inputs from five SORD TV cameras to the OLF. Three of these cameras will be permanently emplaced on extended arms on the forward periphery of the SORD. They will be programmable from the OLF through a 360° lateral plane and a 180° angle of depression in conjunction with extendable focus transition optics (ZOOM lens) to allow complete visual monitoring from the station of every point on the OLV/SORD combination. This will also permit visual monitoring when the orbital assembly and launch crewmen are working around the vehicles outside the space station. Two more TV cameras designated "docking cameras" will be located at the docking plane, in juxtaposition to the docking cones. They will be in quick disconnect mounts and supplied by tension loaded, retracting and extending cables. After each element of the OLV is brought into the dock, the docking cameras will be manually removed from their present mounting, and "extended" to the equivalent positions on the newly docked stage to prepare for rendezvous with the next incoming element.

When the closed loop safety check is complete, the SORD/Vehicle combination will be visually inspected by the assembly crew looking for obvious mechanical defects, i.e., torn panels, etc. The assembly crew will remove and store such items as the rendezvous kick stage (CUSS) and any hardware not required after this point (e.g., excess APS modules) using the tug. They will remove the "docking cameras" from their positions and advance them to corresponding positions at the docking plane from which the kick stage was removed. The loading torque on the retracting camera cables will be a balance between that force which can be easily manipulated by the men in a zero "g" condition and the tension required to immobilize "whip" effects in the cable. Snap clamps will be provided on the OLV surface to pin the cables at each stage when the cameras are fully extended. The camera will lock into a dovetail mount which provides accurate alignment for judging precise docking maneuvers. After the safety check is complete the SORD will assume control of an automatic maintenance cycle of the OLS-IVB stage.

Orbital Checkout

NOTE: For orbital checkout purposes, each OLS-IVB/Instrument Unit is considered as an integral unit.

The SORD is used as a nucleus for orbital checkout. After docking and stage support connections are completed, a completely automatic programmed checkout of the stage will be accomplished as a "Stage OK Functional Test." This checkout will follow the philosophy of and be similar to the "Orbital Checkout of S-IVB" as described in the Douglas Report SM-46696, 27 May 1964, except that contact with earth stations will not be required. The equivalent of the ground station link will be in the SORD and station. The automatic test will be controlled and can be overridden by inputs from the OLF station which will command the SORD computer as a slave to its computer complex. All display and record functions will be a part of the general purpose computer capability of the OLF manned station.

The "Stage OK Functional Test" will be divided into four major categories; Propulsion System, Engine Gimbal System, Electrical System, and Guidance System. The prime objective of the functional test is to assure confidence in the operational readiness of the stage subsystems to perform the orbital start. Checkout of the OLV modules can be accomplished at varying levels; stage, systems, subsystems, and component and modules. Any attempt to define a checkout program must consider the value of the data obtained versus the penalties of weight, power requirement, and loss of reliability associated with exceeding life cycles. The major checkout modes are:

1. Fully automatic (computer program and comparative analysis - usually with manual monitor and override)
2. Semi-automatic (basically computer programmed but with manual operations involved in connect and disconnect, switching, etc.)
3. Manual (manual control, switching connect and disconnect, comparison, etc.)

Because of the shorter time involved (schedule), lower manpower requirements, costs, hazards, etc., a fully automatic programmed checkout of the stages and OLV is selected. The depth of the checkout will vary with the system, being on the component level for some and system level for others. Most checkout will be of a monitor and sample nature with only a few functional tests called. Some manual testing may be required in fault isolation. Figure 10 presents a schematic of the System for Computerized Orbital Evaluation (checkout system) and of interfaces with the OLV systems.

Checkouts will be performed as each stage of the OLV's is delivered to the OLF, when all three OLS-IVB's are assembled prior to spacecraft (S/C) mating, of the completed OLV after final assembly, and again just prior to initiation of the launch countdown. Partial or complete checkouts may be performed after repairs or when monitoring systems indicate problems.

Fault Detection and Isolation

When stage checkout data evaluation indicates malfunctions, isolation of the defective system and/or component is aided by the special purpose computers

SYSTEM FOR COMPUTERIZED ORBITAL EVALUATION SCORE

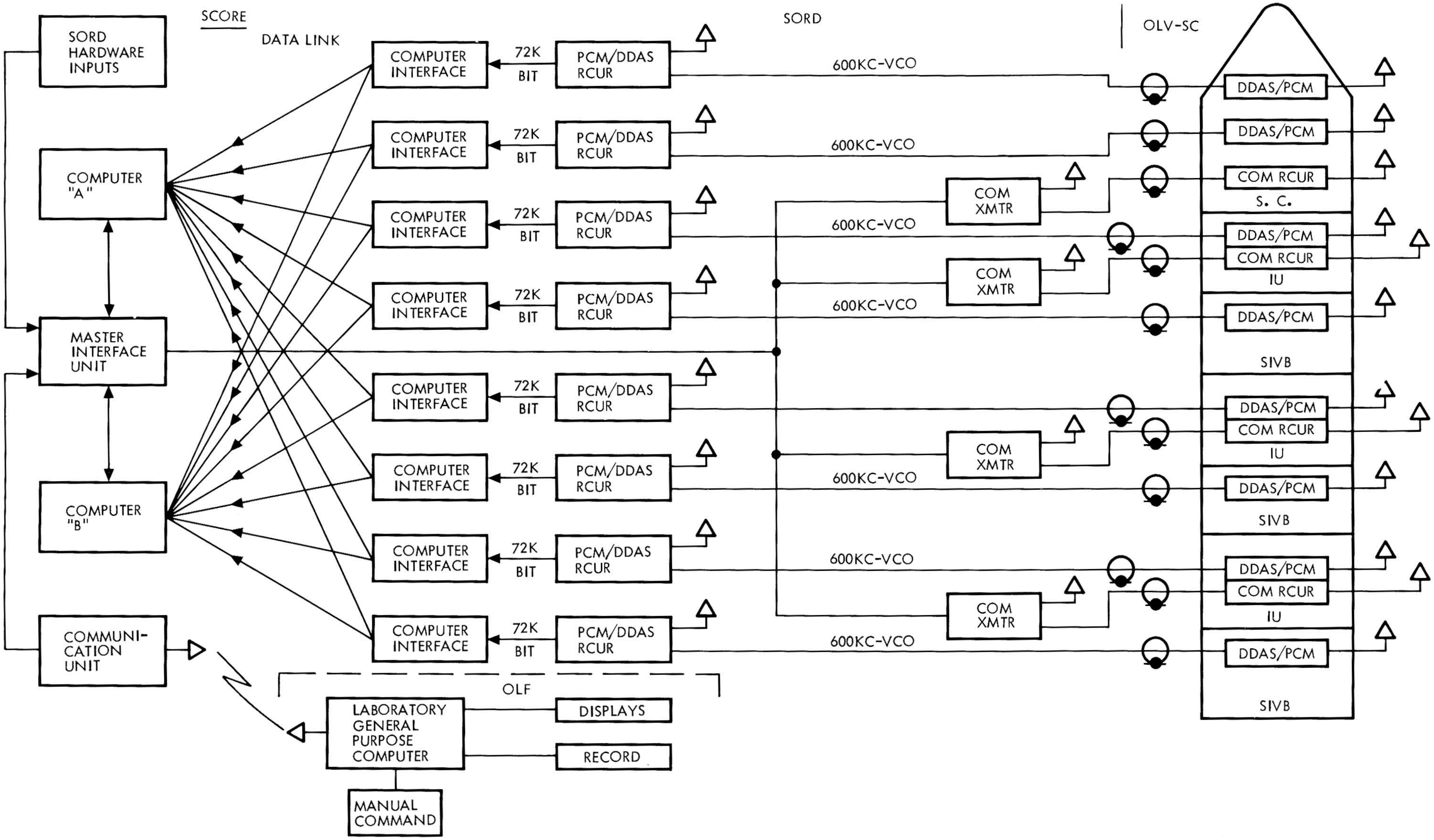


FIGURE 10

onboard the SORD. They are commanded by the test control operator in the station to perform specific test operations. A fault isolation computer program may operate down to the system level, but beyond this point is generally becomes impractical to perform the operation automatically due to increasing complexity and weight for subsystem bypass components on the stage. At the subsystem and component level, fault isolation must be performed by a manual test set at appropriate test points (usually the same as provided for ground tests). This will not be possible in all cases, obviously, and some balance must be achieved beyond the degree of fault isolation and the access to any given component. Unless a component can somehow be corrected, repaired, or replaced in orbit there is little point in providing fault detection for it. Thus, a combination of fault detection and isolation techniques are envisioned, tailored to each specific situation and component, ranging from a fully automatic computer monitored system (as in safety status), manually directed testing by the SORD computers through built-in detection and isolation networks, to manual testing on the spot with a portable (VTVM) test set and probe. Figure 9, OLS-IVB orbital operations sequence, indicates that up to eleven hours are available to isolate and correct faults on each stage before the next earth launch must be delayed. Launch delays would allow about a fifty hour extension to this time per stage.

Repair

The degree of repair in orbit is understandably limited in quantity and quality. Repair can take the form of removal and replacement of faulty components, minor component repair (which borders on a fabrication technique), and removal and replacement of an entire modular system or complete stage. The last technique, obviously, requires the availability of a back-up stage. Except for provisions for a back-up OLS-IVB, the repair techniques have not been determined. The removal and replacement capability is limited by what man can do wearing a spacesuit in free space or in the orbit tug (perhaps assisted by mechanical slave arms) and by the logistics for replacement parts. In the logistics, some minor replacement components can be ordered by the OLV crew after each stage C/O and included in the next stage launch. Larger (and heavier) replacement components (and systems) can be included in the logistic module orbited with the spacecraft (last OLV module). Further consideration of the time allowance, expected techniques, equipment and facility requirements, etc., is required to define the repair capability which might be employed for orbital operations.

Maintenance

Maintenance and Support is an important orbital operational requirement in view of the length of time the modules of the OLV are in orbit and the requirement for a high degree of confidence in system readiness during the short duration launch window. It will be confined to the following orbiting vehicles and equipment: the support orbital dock (SORD), OLS-IVB's, the assembled OLV, tug, spacecraft, and the launch facility station. The orbiting launch facility (OLF) station will be the command and control center for the performance and control of all orbital operations and maintenance functions. It will house operation and maintenance personnel (from the previously noted OLO crews) and the remote control equipment. Operation and maintenance procedures will be restricted to functional verification for SORD readiness, vehicular docking (assembly), functional verification of OLS-IVB's, minor corrective maintenance, venting, abbreviated OLV checkout and all up test, and abbreviated countdown and launch. A large share of procedures will be performed remotely from the OLF station, but extravehicular activity (EVA) will be required in readying the SORD, performing manual and checkout operations, and corrective maintenance.

Support of the OLV by the SORD will include electrical power supply, pneumatic supply, communication links, command links, and status and safety monitoring. In addition, the SORD provides several support functions, such as attitude control, propellant settling, checkout interface, station keeping, etc. Various functions such as venting, valve dither, and hydraulic cycling will be accomplished on a predetermined schedule which can be varied as DDAS inputs indicate a requirement to change, i.e., an unpredicted elevation or depression in tank pressure would modify the interval and period of the venting cycle. The maintenance program will be divided into the following major operations.

Tank Venting

Controlled tank venting of fuel (LH_2) and oxidizer (LO_2) tanks must be performed. (Venting of the LO_2 tank is not anticipated). Period and duration of this operation will be per a predetermined program in the SORD computer that is continually updated by tank pressure and temperature data. An audible and visual alarm system will announce prior to each venting cycle in order that local manned operations can be suspended and the crewmen retrieved before a vent is performed. Settling acceleration, attitude control, and positioning is provided by the SORD propulsion systems. The SORD/OLV assembly is temporarily unslaved from the OLF station and propelled at 0.0005 "g" for two minutes during which the propellant is settled and the tanks vented down to prescribed pressures. The SORD then nulls the accrued velocity and reslaves to the station. While more exotic venting schemes can be envisioned, this most conservative approach was employed to ensure compatibility with the operational sequence.

Flight Valve Dither Cycle

The valve "dither" cycle will entail utilizing a periodic burst of pneumatic control He to each valve in the OLV operational program. This would unseat the valve and then allow it to reseat immediately. The repeated "cracking" of all flight required valves would, for all practical purposes, eliminate the possibility of a catastrophic frozen valve during the final launch plan. The pneumatic control helium gas is supplied by the SORD through the S-IVB helium vent valve.

Figure 11 presents a schematic of the external supply pneumatic helium control supply system. It is desirable to have only a single control helium on the SORD and to simplify its use as much as possible. The control helium on the stage is supplied from a 3000 psi sphere through a blocking regulator where it is reduced to 490 psi for use. The downstream side of the regulator is returned to the regulator as a blocking pressure set at 535 psi in parallel with an overboard control helium vent and electrically operated vent valve. By running a continuous helium line through each stage from stern docking cone to the forward docking aperature connected to the helium vent dump of the stage, a single SORD control helium pressure of 550 psi could be utilized to block the helium supply by overpressurizing the regulator and to supply control helium at 550 psi for operating stage valves. Since the stage

SORD-PNEUMATIC SYSTEM & HELIUM CONTROL

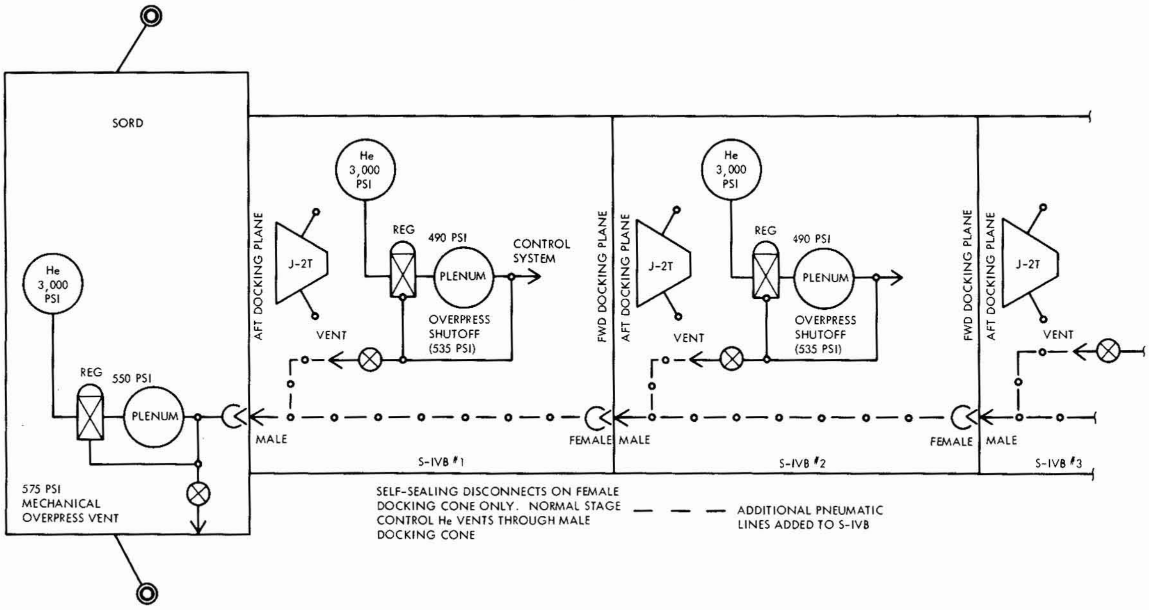


FIGURE 11

pneumatic control loop will operate satisfactorily with pressures up to 750 psi without damage, an auxiliary vent at 575 psi should be included on the continuous line through each stage. Then as each stage of the spacecraft is stacked to the next one, the SORD will automatically provide control helium for its pneumatic system. Sufficient helium will be carried to operate the control pneumatic system of the entire OLV during its stay in the dock. The helium supply will also be capable of recharging the OLS-IVB control helium bottles by auxiliary, manually handled, lines so that if the OLV must abort a launch after two unsuccessful tries to meet the Mars escape window, it will be redocked to the SORD and its control helium bottles can be repressurized for additional attempts.

Hydraulic Cycling

The viscosity of the hydraulic fluid will be maintained by utilizing electrically energized heater blankets around elements of the hydraulic system. However, periodic cycling of the hydraulic system is required to protect against freezing of the engine gimbal actuators and hardening of non-metallic portions of the hydraulic seal system. Electrical power (28 volt and 56 volt) is supplied by the SORD through the forward and aft battery bus on each stage.

Operational Power Replenishment

This is an internal problem of the SORD; however, it is a function of the power drain created by the OLV and must be part of a programmed maintenance cycle to allow updated power depletion information continually fed to the SORD computer to maintain adequate energy levels in the SORD power source.

The SORD will have a replenishable power source capable of operating its entire computer and checkout complex, the docking and monitoring television systems, the SORD/OLF voice, data, and control communication links, and supplying all required power for three OLS-IVB's and the spacecraft while these are in dock.

The electrical power required by each stage and the spacecraft for periodic maintenance operations such as venting, etc., must be continually available and power for stage checkout must be available on command. This is in addition to power requirements of the SORD itself. There are several possible solutions to this problem based on a study progression of battery design. The magnitude of the power required rules out the use of solar cells as we now conceive them.

A variety of pulsating force generators will be available in the near future such as atomic SNAP reactors or Sterling heat engines driving generators. The output of these units when filtered and stored by a highly efficient secondary battery system could conceivably supply all power required by the SORD/OLV combination. Each type of energy replenishing source has unique specific disadvantages. SNAP reactors, although small in size and maintenance free, will require exotic shielding to prevent radioactive contamination of the SORD. Sterling heat engines on the other hand operate on a sharp temperature differential and therefore require that the SORD be solar oriented and slaved so that the dark or shade side remains away from the sun and the absorption plane is always in the sun's rays. By the time actual implementation of an energy source system is required, research will have progressed sufficiently to allow a choice based on present design versus requirements. Considering projected state-of-the-art for the late 1960's, it is visualized that this power source will be upgraded secondary batteries in conjunction with a charging mechanism containing atomic SNAP reactors or Sterling heat engines which can utilize the temperature differential between the exposed and shaded side of a solar oriented SORD (this may not be feasible if SORD/OLV must rotate for thermal balance of the APS hypergolics). Small replaceable fuel cell batteries will be carried as emergency power for the SORD only, while the principal power system is being repaired or maintained.

Orbital Umbilicals

A problem exists in providing a minimum number of hardwire connections between stages and the SORD, to allow closed loop checkout and external power input without mating umbilicals, and to allow complete interchange of stages without altering test program. Figure 12 presents a proposed solution whereby the stages are coupled to each other and to the SORD with docking cones placed at the fore and aft mating surfaces and utilize a principal of "staggered-stacking" to continue wiring through stages. The following hardwire function would be required:

8 - 600 kc VCO/DDAS lines - 2 for each S-IVB/IU combination and 2 for spacecraft (RG62-Coaxial line)

4 - IU Command Receiver Inputs - 1 for each S-IVB/IU and 1 for spacecraft (RG214 - Coaxial line)

22 - External Power Lines - 6 each S-IVB and 4 for spacecraft

1 - 600 psi Control Line - Continuous through each vehicle.

With the "staggered-stacking" principal all lines appear in all stages but they are clocked one position between the male docking cone (aft) and the female docking cone (forward) with the number 1 line being used internal in the stage in each sequence.

It should be immediately obvious that all of the S-IVB/IU stages are wired identically and that the order of stacking makes no difference to the fact that Transmitter Number 1 will always be connected to the first stage and Transmitter Number 2 will always be connected to the second stage in the stack, etc. It is also logically apparent that this will remain true for any number of interconnecting wires that are off-set or "clocked" by one position in each group.

DOCKING S–IVB/SORD

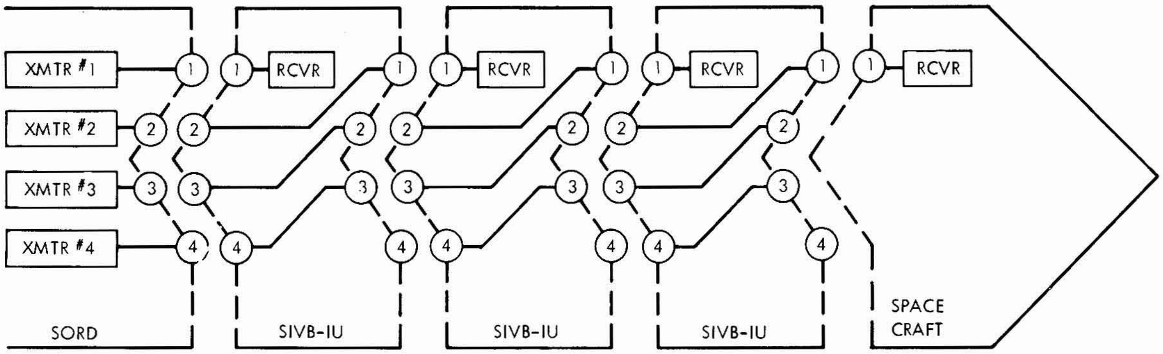


FIGURE 12

This will allow interchange of OLS-IVB stages in case one stage is deemed unacceptable for launch (e.g., if OLS-IVB #2 unacceptable, OLS-IVB #3 will replace it in the OLV configuration order becoming the second stage and the backup, OLS-IVB #4, will replace #3 as the third stage). Minor reprogramming of the command computer and stage sequencers may be required, these provisions can be incorporated in the stage with negligible penalty. The basic operational concept depends on this interchangeability and a single OLS-IVB backup stage ready on the pad at Complex 39 five days after OLS-IVB #3 is launched. Analysis of systems and operations indicates this approach is the most practical and imposes minor, acceptable penalties on the OLV performance.

Data Evaluation

The processing of the input data is accomplished by the use of three programs within the computers. These programs are the Data Compression and Queuing Program, the Operational Program, and the Communication and Control Program. The data received from the telemetry receiver or hardwire connection is assumed to be a 72 kilobit restored pulse train. This pulse train is fed into the telemetry interface unit where synchronization is established and the words of each frame are identified. When a data word is assembled in the interface unit it is transferred to the assigned computer along with the channel identification number and word address. The Data Compression Program will test the new value of the word against the last value and the predetermined limits. If the data is within the defined limits, the data replaces the last data received and the program is terminated. If the data received is out of limits, the value and its address are placed into an active queue. The second program, Operational Programs, is a set of data sensitive programs which are called for through the address of the data being received via the input queue from the Data Compression program. The operational programs will process the data to perform the monitoring and alarm function as well as for checkout of a vehicle and data display. The information which is input to the operational programs can be controlled by varying the limit for the desired word in the Data Compression program. By setting the limits to zero the word will enter the queue every time it is received.

The Communications Control program will receive all requests for action from the test control operator. This may be a request to perform specific test operations or requests for information to be monitored on the CRT display tube. This program will also control requests for information from the external bulk memory.

The computer will operate on the programs on a priority basis with the data compression program, control program, and operation program having descending priorities. When none of the other programs are active the self-test program will run.

Under typical operation with all eight input channels operating, the data compression program should require 20% of the computer time. Since all units of the system are to be interconnected, if any one unit fails the system will still operate with the loss of speed. Since one of the computers can be used to check out the other while still performing the monitor operation, fault isolation should be very fast and the down time minimized.

A prime question which must be asked if one of the data evaluation programs indicate trouble is: Are the evaluation programs working properly? Often there will be sufficient supporting information to indicate that the program is giving the correct answers, e.g., indication of a control system failure might be accompanied by erratic maneuvers during docking or propellant settling. However, an off-nominal performance such as low I_{sp} might not be immediately obvious except through the computer programs. In cases where there is a possibility that the programs are not working, a self-check will be necessary (this is part of the reason for dual computers on the SORD). This check can be accomplished quite simply by having a pre-cut tape to play through the programs. If this operation reveals that the program is working properly, there still exists the possibility that an instrumentation malfunction or telemetry printouts could reveal a dropout. However, an instrumentation malfunction, particularly one where the measuring device is working but is out of calibration, could not be caught visually. This should be resolved by redundant data sources and by data cross checks in the station computer.

Command and Control

Command and control of orbital operations is of primary importance in a complex and potentially hazardous operation. The limitation of data links, the resources available to the command and control facility, and the shortness and directness of communication links should be considered in selecting the command and control facility. The resources required in communications, data reduction and analysis, program control, etc., must be considered. A ground based facility, the OLF, or the Mission spacecraft can be considered for the command and control center during an orbital operation. For the system and concepts considered in this analysis, command and control for orbital closure, docking, assembly, checkout, maintenance, countdown and launch are centered in the OLF space station. During macro-rendezvous, the chaser stage is controlled by the ground based system. Although orbital countdown and launch is controlled from the OLF station, it is probable that, during the coasting ellipse between second and third stage, command and control would be switched to the ground based system (probably the MSC facility supported by the near earth and deep space tracking and communications networks).

Countdown and Launch

Countdown and launch techniques, like checkout, may proceed on an automatic, semi-automatic, or manual mode. Because of the severe time constraints of the launch window (less than five minutes in an orbit), the hazards, and the rapid sequence of events required as launch is approached, the countdown will be automatically programmed but will include hold events for crew assessment and decision points. Figure 13 presents the orbit countdown and launch operations sequence for an OLV comprised of a manned interplanetary spacecraft

OLV COUNTDOWN AND LAUNCH – SEQUENCE OF EVENTS

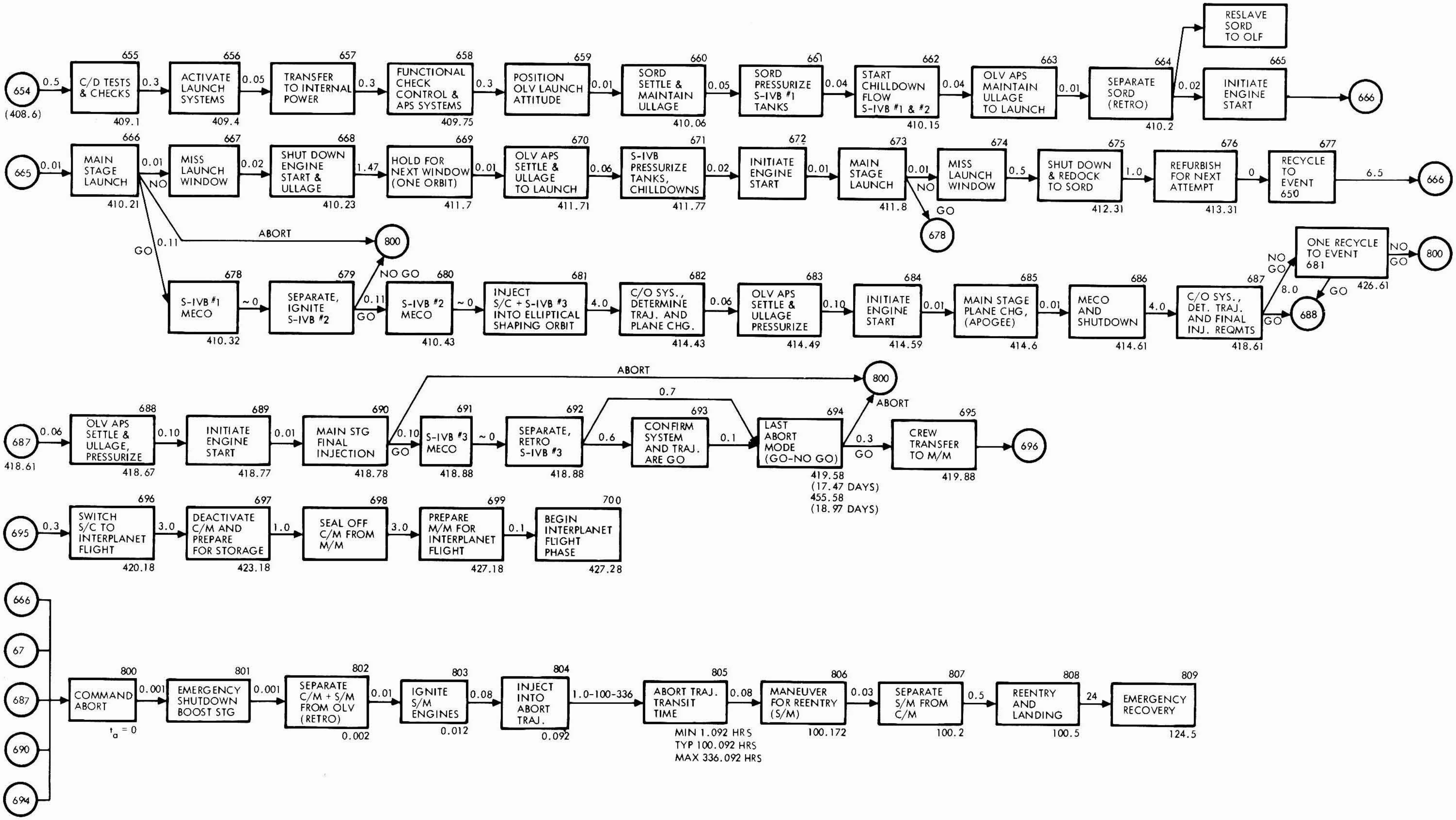


FIGURE 13

and three OLS-IVB stages. Event times are noted in hours. From proceeding assembly and checkout operations, countdown is initiated at t = 408.6 hours, ignition occurs at t = 410.21, and final (third) stage injection is at t = 418.88. Except for the mission crew in the C/M, no men will be in the vicinity of the SORD/OLV. A few minutes prior to ignition, the SORD will be retroed away from the OLV (event 664). The OLV will be able to hold independently for two orbital launch windows before it must be redocked to the SORD for replenishment (e.g., pressurization gases). After several orbits, the countdown and launch attempt can be repeated. In order to broaden the launch window (3 days estimated from nodal regression limitations), four days of operational schedule hold capability is provided between OLV readiness and start of countdown for the first launch opportunity to accommodate any schedule slippage.

Crew Accommodations

Crew accommodations are required for the orbit assembly and launch crews. Analysis of operations for the example mission indicate a six-man assembly crew and a nine-man checkout and launch crew are required. By combining some capabilities, this was restricted to twelve men total by having three assembly crewmen assist in the checkout. In general, the crews are divided into three man teams and rotate in shifts. This allows orbital operations to proceed on a 24-hour basis. At least one crewman serves as the support and communications link at the station while the other two are engaged in extravehicular operations. For the extravehicular functions, an orbital tug, based perhaps on an adaptation of the LEM ascent stage, is used for major transportation, life support at the SORD/OLV, and removal of heavy items (spent APS modules, the CUSS, etc.). "Permanent" housing for the OLO crews is provided in the OLF station. This must also accommodate the station crew (who run and maintain the station) and, for several days at least, the mission crew. Thus, crew accommodations indicate an 18-man (24 temporary) "permanent" capacity station.

Crew Transfer

The OLV crews are transferred between the station, SORD, OLV, etc., by the orbit tug. Generally, only two OLO crewmen are outside the station at any time. The operations generally lend themselves to two tugs with two-man capacity (four men for crew transfer) which can also serve as a temporary life support refuge at the SORD, as well as perform heavy equipment removal and transfer. The mission crew, which is orbited to the station prior to orbiting the spacecraft, transfers from the station to the mission module to assist in conducting the spacecraft checkout. If the spacecraft is first docked to the station prior to final assembly, the mission crew can have relatively direct access from the station to the mission module. If the spacecraft is immediately docked to the OLV assembly after rendezvous, the mission crew must be transferred by the orbit tug. This will require three trips from the station to the mission module. After completion of the OLV final checkout (spacecraft included), the mission crew transfers to the command module prior to initiation of the final countdown. For this, and other reasons, the mission module should have a direct access to the command module in the spacecraft launch configuration.

Communications

Communications links are required between the OLF station and the ground, between the SORD and stages, the stages and the station, the SORD and station, the orbit tug and station, and between extravehicular crewmen and the tug and station. During and after orbit launch, of course, communication links are required between the mission spacecraft and the ground based DSI network. The high density data links would be those employed in orbit checkout (station, ground, stages, and SORD). It appears quite feasible, however, to markedly reduce the normal station to ground link by preliminary reduction and condensation aboard the station prior to transmission to the ground stations. The communication telemetry links are a vital part of the orbital checkout of the OLV. There is no simple way to test the stage telemetry link unless additional equipment is included in the stage to provide test signals. This is impractical, and thus, a method is employed which will allow a bypass of portions of the stage telemetry through the orbital umbilical hardwire links between the OLV and the SORD. This can allow dual telemetry (stage and SORD) to the OLF station computer (or ground computers) as well as direct interface between the SORD computers and the stage DDAS. This allows sufficient data links and redundancy for the orbit checkout. During orbit launch, of course, this type of redundancy is not available after SORD separation. Another approach is employed based on cross check of data.

Launch Window

Launch Window for orbit launch missions are in three basic categories: ground to orbit, orbit to trajectory, and the actual interplanetary mission window; e.g., earth to Mars. In general, vehicle performance limitations restrict the launch windows in each case. The assembly orbit inclination must be compatible with ETR launch of the OLV modules. With a 28.72° assembly orbit, a 31-minute phasing orbit launch window is available once a day from ETR using the Gemini rendezvous profile. The orbital launch window is two-fold, one window is the orbit anomoly; i.e., the central angle between the launch point radii and the escape trajectory asymtote, the second is the launch orbit equatorial nodal orientation, i.e., the launch orbit line of nodes with respect to the equatorial plane, in which it precesses, should be coincident with the heliocentric escape trajectory plane equatorial line of nodes, in order to minimize any plane change requirements. The OLV performance is sized to allow a five-minute anomaly window each orbit plus a 3-day nodal window. To some extent these can be traded (i.e., decreased anomaly window for increased nodal window). The nodal window is achieved by modifying the OLF station orbit inclination slightly (up to ±4°) at least six months before the launch date. This modifies the orbit nodal regression rate so that, in time, the nodes may be programmed to coincide on the nominal launch date selected. This does not exclude farther inclination change, e.g., back to the original, of the OLF orbit prior to start of the OLV build-up in order to have a more rendezvous compatible or launch compatible inclination. Properly programmed, the nodes will still coincide on the nominal launch date. The orbital launch technique employs an intermediate parking elliptical orbit prior to the final injection to decrease flight path angle and thus velocity losses. It pays added dividends in allowing a greater plane change capability at apogee of the elliptical orbit and in meeting the injection anomaly. The intermediate eight-hour coast time can be used for final tracking and computation of the final injection. The interplanetary launch window is related to the synodic period between the launch planet (i.e., earth) and the target planet (e.g., Mars) and the type of trajectory selected (e.g., unpowered fly-by). In the example selected, this is approximately a ten to fifteen day window occurring every 26 months (exact span depends on the year selected). The infrequency of this window is a major factor in advocating the greatest amount of orbital support deemed practical to increase the confidence in a launch-on-time capability, since, if the window is missed, not only is the mission opportunity delayed for over two years, but also, the orbited components of the OLV and all the Saturn V boosters employed must be written-off (or the OLV employed immediately for an alternate mission).

Emergency and Abort

Emergency and Abort modes must be provided for all aspects of the mission operations, from earth launch through orbital operations and launch. Some emergency and abort techniques for orbital assembly operations are:

a. OLS-IVB failure in rendezvous: options; abandon in rendezvous orbit, rendezvous with tug and crew and correct, provide emergency orbit reject system -- probably the last option is most practical and desirable.

b. OLS-IVB non-safe in pre-docking safety check: options; tug and crew correct if possible (probably too hazardous), provide emergency orbit reject system (probable technique).

c. Docked OLS-IVB detected as progressing to unsafe condition: options; take emergency automatic corrective action if possible, tug and crew take corrective action to halt unsafe progression or remove and reject the stage (dependent on hazard level), retro SORD (and other OLS-IVB's) away from stage (possibly only if end stage).

During the final assembly and the launch phase-up to the last abort mode-systems are maintained for the abort and crew recovery. Events 800 through 809, in figure 13 present a possible sequence of events. If abort occurs during a boost phase, the OLS-IVB must be shutdown rapidly. The nature of abort during orbit launch is somewhat different than during earth launch. The spacecraft will already be traveling in some earth orbit, damage from overpressure will not occur, nor will retardation from drag, etc. In general, it appears that abort can proceed at a more leisurely pace than for earth launch. However, time does remain an important element, as in the case of the escape trajectory. The useful employment of the abort velocity injection to obtain a quick re-entry trajectory requires constant revision of the abort injection. Partly for these reasons, as well as others, it was selected as desirable to abort by retroing the OLV and Mission Module (M/M) away and aside from the Command Module (C/M) plus Service Module (S/M). This minimizes the velocity added to the C/M and places the S/M in approximately the correct orientation (retro) in the mission configuration for the earth return injection. Abort trajectory transit times for the mission and system considered appear to be on the order of two weeks for the maximum cases. Generally, longer transit times are beyond the abort capability anyway. Thus, the C/M plus S/M should have at least a two week life support capability for the six man mission crew.

Shortly after separation of the last OLS-IVB, the spacecraft and crew aboard the C/M will pass the last abort mode in which the service-retro module (which doubles during launch as the abort propulsion) can inject the C/M into a safe return to earth (re-entry) within a reasonable life support time (two weeks). For the 1973 mission with the earth departure velocity of

V_∞ = 0.22 EMOS, the last abort opportunity occurs about forty minutes after final injection. During this time the systems, crew, and trajectory must be confirmed as satisfactory and the mission verified GO (event 693).

Numerous other emergency cases and actions present themselves, but these will suffice to indicate the scope of the operations. In an operation as complex as required for this mission, with the primary requirement to minimize or negate the hazards, occurrence, schedule slippage, and damage that can result from any emergency situation, an exceedingly thorough emergency and abort analysis is required. A thorough procedures program must be readily available at all times to the command and control computer and crew. Such an analysis, with its design and operational procedures implications would be desired early in the development program; however, by its very nature it cannot be available in depth until well into the program definition and system design phase of the development.

Tracking and Navigation

Tracking and Navigation is required during the orbital rendezvous, during SORD/OLV station keeping and ullaging, at countdown and launch, during the intermediate elliptical parking orbit, and during the final injection (it continues to be required during the mission but this portion is considered beyond the scope of this paper). During orbital rendezvous, ground tracking by the near Earth stations are employed until the stage comes within radar lock-on from the OLF. Basic tracking is then performed by the OLF. Attitude control is established by the stage and navigation maneuvers commanded to the stage receivers by the respective tracking facility. In orbit, direct tracking of the SORD/OLV is done by the station for ullage maneuvers, etc. Station keeping and attitude control might be performed by the SORD with sensors slaved to the station. At launch, SORD/OLV orientation and ullaging is commanded and updated launch window navigation data transmitted to the spacecraft. Ground stations (NES) will track the launch with supplemental data from the OLF station and S/C on-board guidance and navigation systems. Launch control will be directed from the OLF station in this phase. During the elliptical shaping orbit and final injection, the DSI network will be required for tracking. Final injection navigation is commanded by the ground mission control center, similar to the Apollo mission.

EXAMPLE MISSION OPERATIONS

A manned Mars fly-by mission was selected for discussion to demonstrate the complexity and scope of orbital launch and support functions. It appears to be a logical early mission, which can utilize Saturn/Apollo systems and orbit launch operation capabilities. The manned Mars fly-by mission shown in figure 14 will require rendezvous, docking and assembly, checkout, and launch operations in orbit if Saturn/Apollo hardware is to be employed. Certain mission support elements will be needed to meet these requirements. The elements include added facilities and equipment at both the ground launch base, Kennedy Space Center (KSC), and in the launch orbit, as well as utilization of presently planned and projected facilities and equipment. A permanent orbital launch facility provides launch support for a multi-stage OLV comprised of three OLS-IVB stages boosting an Apollo spacecraft and a manned mission module derived from the earth orbital station systems. Figure 14 summarizes pre-mission support, mission support, and mission execution. The overall mission

ELEMENTS OF THE MANNED MARS FLYBY PROGRAM

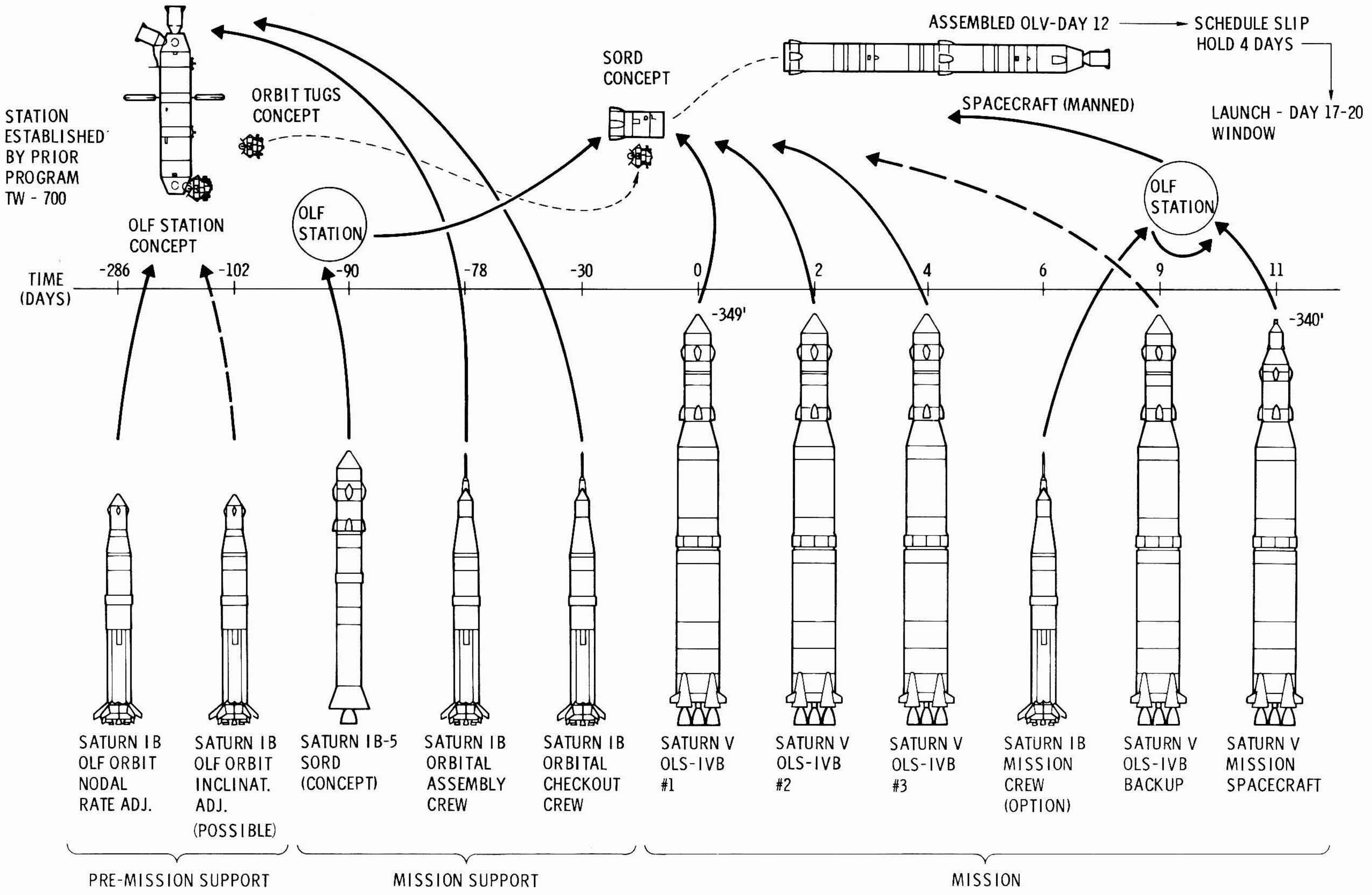


FIGURE 14

program is based on establishing a permanent manned orbital space station at least two years earlier to accrue experience and develop operations and equipment, and availability of orbital support equipment slaved to the space station several months before the mission launch date.

A new SORD, specifically assigned to the fly-by mission is placed in OLF orbit about three months prior to the OLV build-up. Orbital launch command and control equipment is incorporated or added to the space station for use with the SORD/OLV system.

The OLF manned station and orbital tugs are not explicitly considered as direct mission support since they can be employed for numerous other programs and missions as well. Nevertheless, functionally, they are required as an integral part of operations support for the mission.

The operational plan presented here has evolved from consideration of a baseline orbital launch vehicle (OLV) configuration: the operational plan and the baseline design have been mutually interacting in their evolution into the preliminary system baseline presented. Modification to the baseline configuration will generally lead to modification of the orbital operations.

The mission operations may be broadly categorized into four phases: ground launch operations, orbital operations, space (or mission pay-off) operations, and recovery operations. This paper is restricted to the ground and orbital launch operations. Considerations of the remaining mission phases are available in Douglas report SM-46912, "Planetary Reconnaissance," Douglas Aircraft Company, January 1965.

Ground Launch Operations

The launch operations schedule is shown on figure 14. The ground operations mode is keyed to the orbital operations requirements except for the imposed limitation of two days between Saturn V launches (orbital operations could accept one launch each day under the most favorable conditions; however, increasing the delivery schedule to once every two days relaxes the constraints on rendezvous and orbital operations as well as on ground operations). The OLV modules are launched into orbit unmanned on Saturn V two-stage boosters (S-IC + S-II). The S-IVB propulsion system is not used prior to orbit launch; rendezvous propulsion is provided by a separate removable propulsion system (kick stage). The launch of each Earth Launch Vehicle (ELV) is constrained by a "ready to receive" acknowledgement from the orbital launch facility (OLF). This acknowledgement is normally scheduled to be transmitted a full day before the nominal next ELV launch time; and, under most circumstances, before ELV cryogenic loading.

In addition to the Saturn V launches, six Saturn IB launches are indicated (these might be reduced to four or five depending upon moderate revision in the operational plans). Two propulsion payloads are scheduled for the OLF station nodal regression maneuver, one launch is the unmanned supporting orbital dock (SORD) for the OLV, and three launches are six man Apollo systems for the two OLO crews and the mission crew.

The mission crew is launched aboard a Saturn IB/Apollo to the orbit station several days prior to launch of the spacecraft to the orbit. This allows them greater time for acclimation and physiological/psychological isolation in the space environment prior to the mission orbit launch. It also negates earth launch abort requirements for the mission crew from constraining the mission spacecraft configurations. The mission crew boards the spacecraft mission module while it is temporarily docked to the orbit station for removal of the CUSS and logistic module and orbital checkout of the spacecraft. This mode of mission crew operations schedule appears to be a good compromise among the various spacecraft-crew first, last, etc., modes considered.

As figure 14 indicates, the last launch (spacecraft payload) is scheduled to occur eleven days after the first Saturn V launch. The spacecraft weight is about 250,000 pounds, including additional systems for the rendezvous and orbital operations. This leaves about 30,000 pounds available for logistic supplies to the OLF (moderately uprated Saturn V's are employed).

For the operational plan considered, a spacecraft backup was not included. An additional Saturn V with a spacecraft backup may be considered as an option. A launch pad could be made available within acceptable schedule limits. However, additional Complex 39 and MILA support facilities might be necessary.

Note that pre-mission preparation launches of OLF nodal variation propulsion are made as early as eight months prior to the orbital assembly and launch of the OLV. This may be considered an extreme case since the nodal adjustment requirement may be much less, in which case this launch can be made later in the program. A factor not illustrated in figure 14 is the arrival at KSC of Saturn V mission elements as early as seven months prior to the mission orbit launch. This early arrival is necessary due to the assembly and checkout requirements of the back-up Saturn V (OLS-IVB payload) in a high bay which must be used later for another Saturn V (OLS-IVB #3). When checkout is complete, the backup is placed in a storage high bay. If the number of low bays are expanded and a fifth high bay instrumented for Saturn V assembly and checkout, delivery of the backup vehicle elements may be delayed a couple of months.

The tentative sequence requires the orbit launch operations (OLO) crew to be launched in (6-man) Apollo/Saturn IB some thirty days before starting the OLV modules launches. The three OLS-IVB/Saturn V launches follow in two day increments. The mission crew is then launched in an orbital Apollo/Saturn IB. Scheduling then provides for launch five days later of the backup OLS-IVB (all are interchangeable) if required. This is basically constrained by availability of VAB high bay #1 (t + -5), for a repeated checkout of the backup vehicle, and availability of launch pad 39A (t = +4).

The question as to whether KSC can launch five Saturn V's in less than two weeks cannot be adequately answered at this time. Certainly, the present and projected plans indicate that, given the additional facilities, equipment, and crew, such a launch program is feasible by the early part of the next decade. Experience with the Saturn I launch vehicles has demonstrated an excellent launch-on-time capability and also indicated many areas where launch operations times may be decreased. In the Mars Fly-by mission launch program, the major problem may well be simply the management and control of the manpower, equipment, supply, and associated logistics to insure that the right piece, or the right man, get to the right job at the right time.

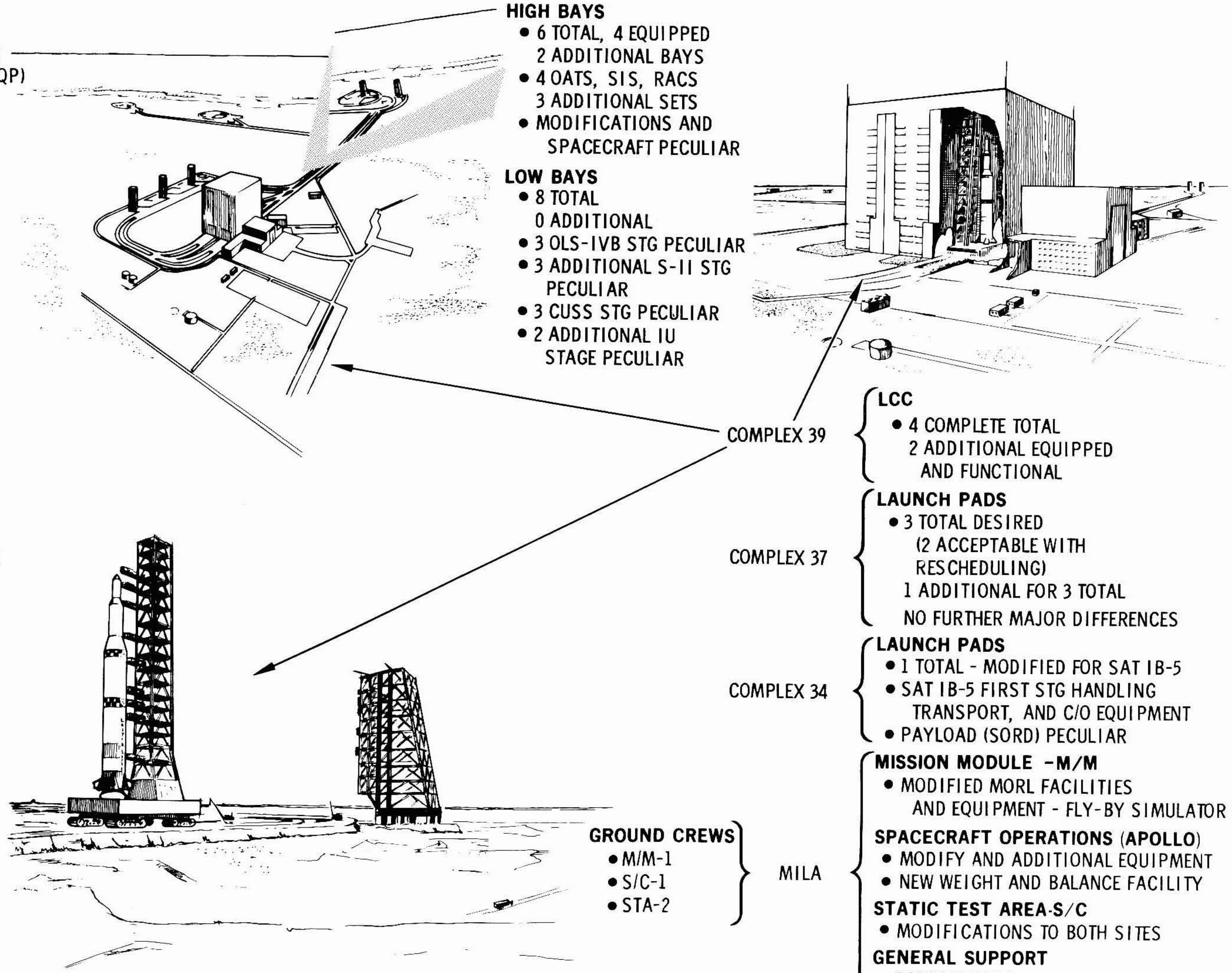
The ground launch operations for this mission will utilize the full capacity of the Saturn V launch complex presently planned plus some additional facilities and equipment for a period of over three months. Efforts have been made to compromise between operational desirability and facility requirements. Utilization efficiency is assumed to exceed that of the initial Saturn V/Apollo missions but to be somewhat less than a theoretical maximum efficiency program. Built into the ground operations and orbital operations are event times and dispensable hold times which can total two weeks or more in the operations schedule. The OLV design is based on these inherent schedule allowances and upon a significant variation in the mission orbit launch window. Douglas report SM-47371 presents the detail operational network for KSC ground launch operations. From this network analysis the necessary schedule and KSC supporting facilities and equipment for the Manned Mars Fly-by Program were determined. Figure 15 illustrates the program support required at the Kennedy Space Center (KSC) to support the orbital assembly of the Manned Mars Fly-by Vehicle.

Orbital Launch Operations - Sequence of Events

A composite summary network of the pre-mission and mission orbital operations is outlined in figure 16. In the pre-mission operations, five Saturn IB launches to the OLF are indicated (Events 001, 006, 020, 030). These include delivery of the propulsion necessary to modify the orbit inclination to vary the nodal regression rate of the OLF orbit. For planning purposes the node orientation of the OLF orbit should be considered incorrect for the launch dates selected and to require adjustment. Two launches are shown with the first launch occurring 286 days before elements of the OLV are launched into

KSC PROGRAM SUPPORT

COMPLEX 39



LAUNCH PADS
- 3 TOTAL - 39 A, B, C
  1 COMPLETE ADDITIONAL - 39C
  (INCLUDES SUPPORT FAC & EQP)

GENERAL SUPPORT
- 4 BARGE SETS (2 ADD.)
- ~ 10% MORE CRAWLERWAY
- INCREASED GAS STORAGE
- INCREASED SHOP AREA

CREWS
- LCC & HIGH BAYS - 4
- LOW BAYS & PAD - 3
- INCREASED MAINTENANCE AND REPAIR CREWS

HIGH BAYS
- 6 TOTAL, 4 EQUIPPED
  2 ADDITIONAL BAYS
- 4 OATS, SIS, RACS
  3 ADDITIONAL SETS
- MODIFICATIONS AND SPACECRAFT PECULIAR

LOW BAYS
- 8 TOTAL
  0 ADDITIONAL
- 3 OLS-IVB STG PECULIAR
- 3 ADDITIONAL S-II STG PECULIAR
- 3 CUSS STG PECULIAR
- 2 ADDITIONAL IU STAGE PECULIAR

LUTS
- 5 COMPLETE LUTS TOTAL
  2 ADDITIONAL LUTS, WITH GSE
- MODERATE MODIFICATIONS

ARMING TOWERS
- 3 TOTAL
  2 ADDITIONAL
- MINOR MODIFICATIONS

CRAWLER-TRANSPORTERS
- 3 TOTAL
  1 ADDITIONAL

COMPLEX 39

LCC
- 4 COMPLETE TOTAL
  2 ADDITIONAL EQUIPPED AND FUNCTIONAL

COMPLEX 37

LAUNCH PADS
- 3 TOTAL DESIRED
  (2 ACCEPTABLE WITH RESCHEDULING)
  1 ADDITIONAL FOR 3 TOTAL

NO FURTHER MAJOR DIFFERENCES

COMPLEX 34

LAUNCH PADS
- 1 TOTAL - MODIFIED FOR SAT IB-5
- SAT IB-5 FIRST STG HANDLING TRANSPORT, AND C/O EQUIPMENT
- PAYLOAD (SORD) PECULIAR

GROUND CREWS
- M/M-1
- S/C-1
- STA-2

MILA

MISSION MODULE -M/M
- MODIFIED MORL FACILITIES AND EQUIPMENT - FLY-BY SIMULATOR

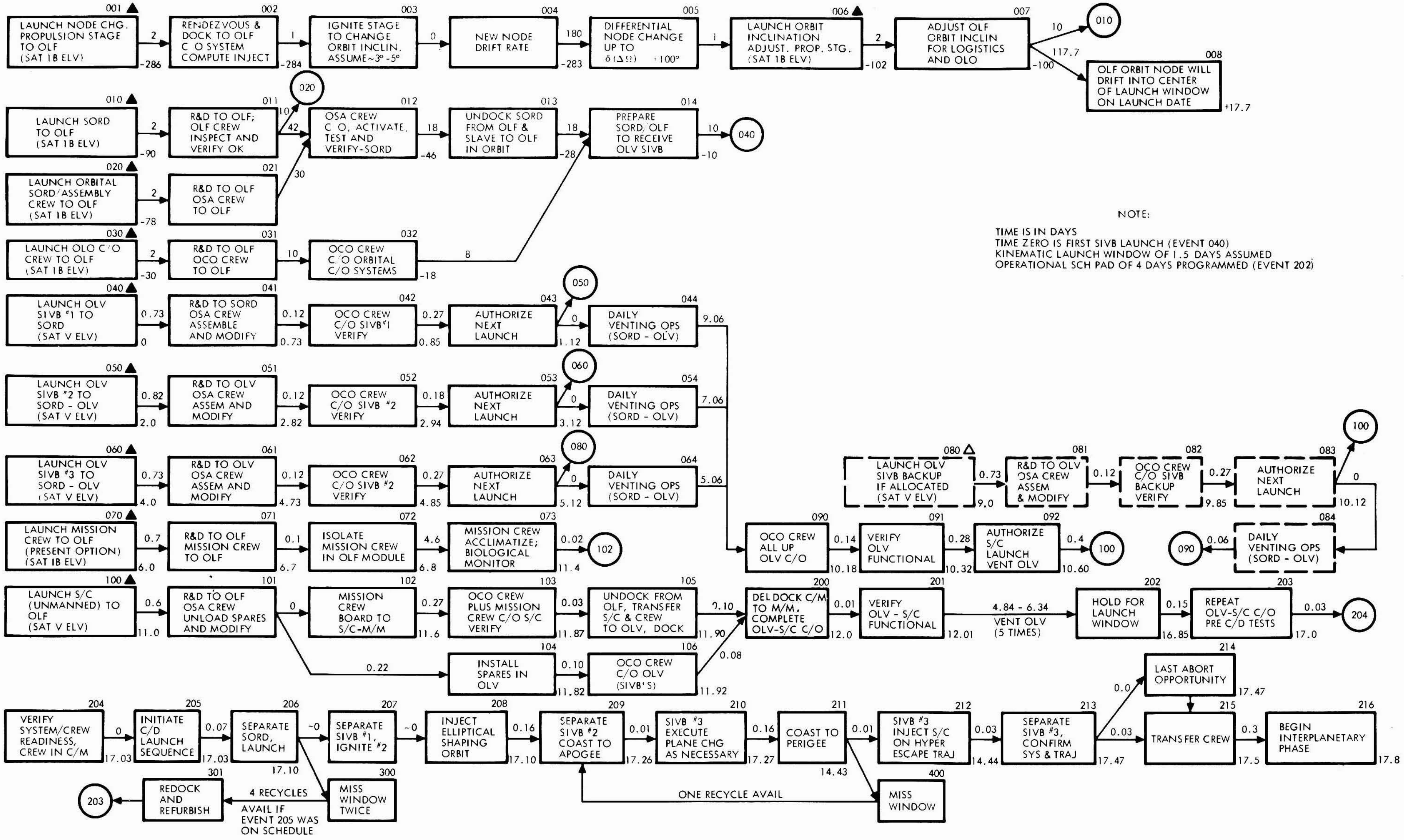
SPACECRAFT OPERATIONS (APOLLO)
- MODIFY AND ADDITIONAL EQUIPMENT
- NEW WEIGHT AND BALANCE FACILITY

STATIC TEST AREA-S/C
- MODIFICATIONS TO BOTH SITES

GENERAL SUPPORT
- POSSIBLE INCREASES

FIGURE 15

EXAMPLE MISSION ORBITAL LAUNCH OPERATIONS – SEQUENCE OF EVENTS



NOTE:

TIME IS IN DAYS
TIME ZERO IS FIRST SIVB LAUNCH (EVENT 040)
KINEMATIC LAUNCH WINDOW OF 1.5 DAYS ASSUMED
OPERATIONAL SCH PAD OF 4 DAYS PROGRAMMED (EVENT 202)

FIGURE 16

orbit (Events 040, 050, 060, etc.). The reason for a long lead time is to permit a small differential in nodal regression rate to cumulate into a large node change capability. This length of time may not be necessary, as node adjustment requirements may be much less. However, in examining the operational requirements, the more extreme case is considered. The second launch (Event 006) may or may not be necessary depending upon the nature of the propulsion system, the specific nodal angle/inclination change required, and the effects on orbital logistics. As shown, the OLF is considered to be re-established in a rendezvous and logistics compatible orbit about 100 days prior to starting the OLV build-up. The node will continue to drift, of course, and will now be drifting at the original rate. However, in selecting the magnitude of inclination changes and the time periods at different inclinations/nodal drift rates, some combination will occur that will allow the OLF orbit node to drift into the correct orientation within the interplanetary launch window (Event 008).

After the node adjustment is provided and the OLF returns to a more logistic compatible orbit, the supporting orbital dock (SORD) which will be used on the mission is launched to the OLF (Event 010). After the space station crew dock the SORD to the station they inspect it. If there is no apparent damage or problem, they verify the SORD is available for test and checkout. If damage has occurred it will be assessed and corrected. This may include ordering spare parts and other supplies from the ground base to be orbited prior to, or with the SORD crews. The SORD has not been sized pending further definition of its functions and requirements; however, a review of the functions and requirements presently identified indicate the Earth Launch Vehicle (ELV) may be a standard Saturn IB, or possibly an uprated Saturn IB in the 60,000 pound payload class.

After the SORD is verified acceptable, the first orbital operations crew (a six man/two team assembly crew) is launched (Event 020) to the OLF station in a six man orbital Apollo. This crew is also proficient and responsible for SORD activation, test, and checkout (Event 012). When the SORD is verified, it is undocked from the OLF space station, flown some distance from it in the same orbit and slaved to the station (Event 013).

In the meantime, the orbital checkout crew (a six man/two team crew) is orbited to the OLF (Event 030). This crew checks out the SORD/OLF checkout system, possibly using some simulator packages. Assisted by the assembly crew they prepare and verify the SORD ready to receive the OLS-IVB's for the OLV.

The launches and operations for the OLS-IVB's comprising the OLV are indicated by Events 040 through 064. The operational sequence for each OLS-IVB is similar (see figure 9). The orbited OLS-IVB stages are docked to the SORD/OLV assembly in tandem as they arrive. The CUSS and excess APS modules are removed and the stage rigged for checkout. Each is checked out and verified as it arrives so checkout is completed before the next ground launch. The first OLS-IVB launch, aboard a Saturn V ELV, is the Event (040) selected for time zero in all networks. If the backup OLS-IVB is needed, it is launched (080) and follows similar procedures as the other OLS-IVB's. Launch of the backup is constrained by availability of a launch pad and also a high bay checkout.

After the OLV is assembled, the mission crew is launched (Event 070) in a six man orbital Apollo to the OLF orbit station. The crew will then remain aboard the station for several days (Event 073) before transferring to the spacecraft (Event 102). During this time they may be isolated for physiological and possibly psychological purposes in one of the orbit station life support modules. The orbit station crew and mission crew doctors, supported by ground based personnel, can monitor and assess the crew.

Several days later, the unmanned mission spacecraft is launched (Event 100) aboard a Saturn V ELV. The spacecraft (S/C) first docks to the OLF station. It carries a logistic module with spares and supplies (Event 101) which have been ordered by the OLO crews. The logistic supply capability is required for spares and replacement modules ordered for the OLS-IVB's as a result of the orbital checkouts or unexpected failure and expenditure (e.g., APS systems), life support refurbishment for the orbit station, replacements and servicing for the SORD, LEM orbit tug, and the orbital Apollo's (to be used to return the orbit assembly and checkout crews), a retro-stage for cleaning up the debris from the orbital operations (spent CUSS stages, APS units, rejected OLS-IVB, etc.), and possibly some equipment for the service and checkout of the spacecraft itself while in orbit. After the mission crew board the S/C at the station (Event 102), the spacecraft is checked out and transferred to the OLV where it is docked to the third stage OLS-IVB (Event 105). For the S/C configuration shown, two of the mission crew then leave the mission module (M/M) and, activating the C/M, separate and dock the C/M nose access hatch to the M/M (Event 200). This allows direct access of the mission crew between M/M and C/M and also completes the mission configuration of the spacecraft. (Other spacecraft configurations may not require this operation). After the OLV and S/C are checked out and verified in this configuration, an operational hold time is programmed into the schedule (Event 202). Schedule slippage in ground launches, orbital operations, etc., may have utilized all or part of this time. Final orbital venting operation should be performed during this time. The orbit launch window is assumed to be 1.5 days, although recent analysis indicates three to four days is more representative. The orbit launch would then occur about 17 to 20 days after start of OLV assembly (first OLS-IVB).

Depending on the time available and the operational hold time, a repeated final OLV-S/C checkout is performed (Event 203). Pre-countdown tests are performed and system and crew readiness confirmed (Event 204). During this time the mission crew enter the C/M and prepare for the countdown, sealing off the C/M from the M/M and activating the separation and abort system. The OLV-S/C is then ready for launch and the countdown is initiated (Event 205). Just prior to ignition the SORD is retroed away (Event 206) and the first and second stage OLS-IVB's inject the third stage and spacecraft into the high elliptical 8.5 hour shaping orbit. Figure 17 illustrates the orbit launch profile. This operation not only minimizes gravity losses but increases the plane change (Event 210) capability by an apogee ignition prior to final third stage injection. In addition, it allows time for a more accurate tracking and assessment for the plane change operation and the final injection near perigee into the interplanetary trajectory (Event 212). The third stage is separated (Event 213) and the trajectory, systems, and crew confirmed within tolerances.

After the last abort opportunity (for two week earth re-entry - Event 214) the crew transfers to the mission module to begin the interplanetary phase (Event 216). The mission space operations comprise the navigational corrections, in-transit deep space experiments, Mars Fly-by and passage, Mars probe launches, data reduction and transmittal to Earth, aphelion observations, and initiation of the earth recovery phase.

TWO PHASE ORBIT LAUNCH PROFILE

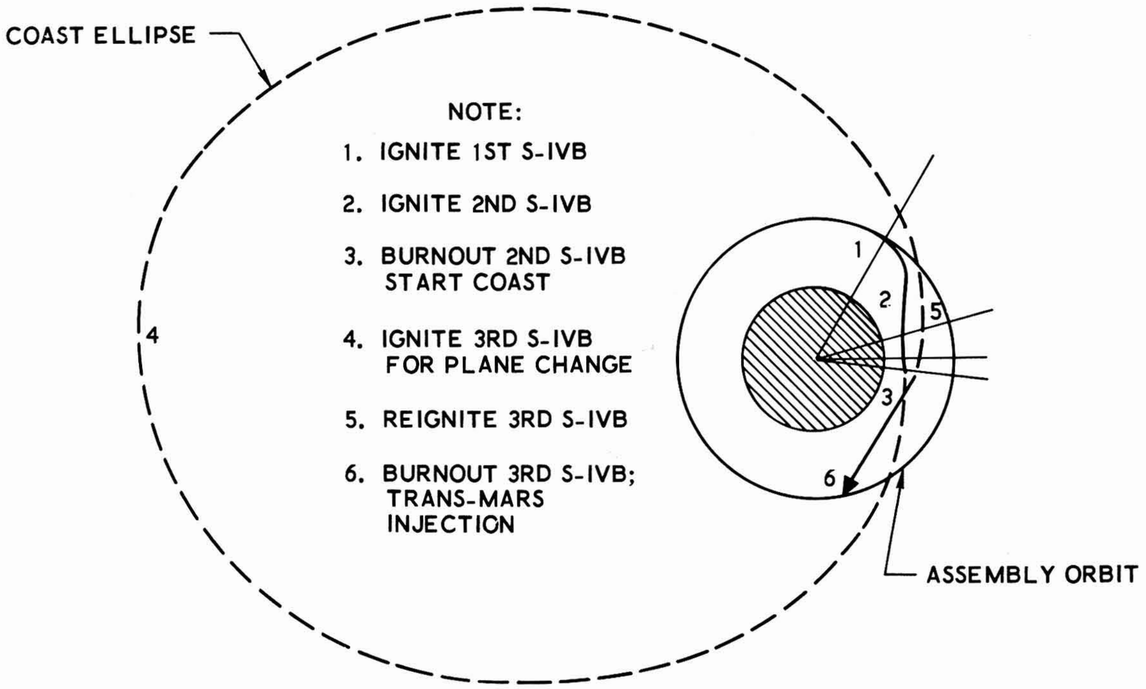


FIGURE 17

CONCLUSIONS

Orbital assembly and launch operations developed for Saturn V/Apollo systems can provide the Nation with an early (1975 to 1980) capability to perform several new classes of missions, particularly manned planetary fly-by reconnaissance, and can provide the available operational experience and technological base important in the development of more advanced systems (nuclear in post 1980 decade) for manned planetary landing missions.

The orbital operations requirements are considerable, despite the elimination of orbital refueling operations (assembly only modes). The program complexity will require considerable proficiency and confidence in the ground launch operations for the Saturn V system as well as in the performance of the various orbital operations of rendezvous, docking and assembly, checkout, etc.

Efforts were made to minimize the extravehicular manual operations in orbit, but it appears such activities will remain highly desirable (e.g., replacement of faulty modules, some manual latching and connections insertion, etc.) in providing an all systems GO signal at countdown. Orbital checkout is deemed necessary and desirable due to the long orbit "soak" times, etc., arising from multiple docking and assembly operations, extraneous equipment removal, rendezvous times, and a limited ground launch rate.

The known and anticipated requirements for supporting the OLS-IVB in orbit over a period of days and even weeks led early to a requirement for orbital supporting equipment as exemplified by the supporting orbital dock (SORD). The desire to minimize the jeopardy to the human habitat in orbit (the orbit station) led to a separation of the loaded OLS-IVB boosters assembled on the SORD from the orbit station. This also decreased the propellant required for the periodic venting ullage and maintained the station as an unperturbed navigation checkpoint in orbit with an accurately determined emphemeris from prior tracking.

The supporting elements are complex and costly and will take time to develop. However, it must be pointed out that the technologies, capabilities, and hardware developed and established are directly applicable to numerous missions which have escape payload requirements considerably in excess of the Saturn V systems. An orbit launch capability based upon multiple orbited payloads requires many of the supporting operations and elements of a ground launch facility, albeit to a lesser degree in most cases. An increased requirement is the severe intolerance to schedule slippages engendered by orbital launch.

Because of the detrimental environmental effect on the hardware systems and the restrictions of interplanetary launch windows, a proficiency is required of the orbit launch crews which exceeds that of ground launch crews. The first manned orbit launch, as a result, should not be performed in a vacuum (no pun intended). Rather, it should be preceded by several unmanned orbital launches (e.g., large probes to the planets, etc.) to develop the techniques, equipment, and experience required of orbital launch. Thus, the orbital launch system (space station, SORD, OLS-IVB orbital boosters, etc.) must be regarded not as an element of a manned Mars Fly-by mission alone, but rather as a prime system for the total family of programs for both unmanned and manned exploration of the planets and solar system.

Except for the SORD, the essential elements of the orbit launch system exist in varying degrees of development. Development of the earth orbiting laboratory is a logical step in the development of the orbit launch facility (OLF) station. A grouping of two expanded laboratory modules or three basic laboratory modules will provide the basic make-up of the OLF orbit station which can be launched with a single Saturn V system. The spacecraft mission module is also based upon a derivative of the laboratory hardware. Thus, the orbital laboratory, the orbit launch facility, and the mission module are all derived from the same basic family in a sequential development culminating in the interplanetary mission module itself. All these applications must perform the same function, i.e., provide a suitable and ample shirt sleeve environment for long periods for at least six men.

The experience and operation time accumulated with the laboratory systems will be largely transferable to the design and development modifications for the mission module. Evolution of the mission module, then, would follow the same basic pattern as the evolution of the spacecraft service module and command module from the Apollo systems. This approach should not only minimize development cost and schedule, but should also assist in achieving the long lifetime system reliabilities and man/machine integration required for the interplanetary mission.

It is obvious that the basic abilities and hardware employed for a manned Mars Fly-by mission are largely applicable to other missions; e.d., manned Venus fly-by, Mars and Venus orbit, lunar logistics shuttle (orbital launch operations), etc. Much of the experience and hardware systems gained through orbit assembly and launch of chemical stages lend themselves to adaptation to orbit launch of nuclear stages in the more distant future for Mars and Venus landing expeditions. The manned Mars Fly-by mission will require rendezvous, docking and assembly, checkout, and launch operations in orbit if Saturn/Apollo hardware is to be employed. Certain mission support elements will be needed to meet these requirements. These elements include added facilities and equipment. The operational plan is based upon availability of important supporting elements at both the ground launch base, KSC, and in the launching orbit to contribute significantly to the probability of meeting the mission schedule and insuring a high confidence of mission launch success. Provisions are incorporated, however, to provide for schedule slippage in both the ground and orbital operations. The infrequency of launch opportunities (about once every two years) dictates a high degree of mission support. Some compromise is made, however, in an effort to limit program costs. No backup is provided for the spacecraft launch, for instance; and the ground launch facilities are limited to the minimum which can be reasonably expected to provide an adequate ground launch frequency to support the orbit operations within the OLS-IVB orbit lifetime design constraints.

The operational plan presented in this paper is selected primarily as a baseline to uncover functional requirements and the interaction of the hardware design and operations. Although the present plan appears to be a logical and feasible approach based on evaluation of existing and planned systems and operations, further analysis may lead to moderate or major departures and revisions. In addition, as the operational plan is examined in detail, the constraints and requirements for the system hardware design may vary; e.g., the orbit lifetime capability of the OLS-IVB may be decreased from thirty days to twenty days, providing increased performance for the OLV. Similarly as system hardware requirements are defined in greater detail or modified, the operational plans may be revised to reflect these requirements. Nevertheless, it is concluded that orbital assembly and launch operations are feasible using the S-IVB modified as a pioneer OLV propulsion stage, provided separate orbit support equipment as exemplified by the SORD, is developed. It is also concluded that propellant transfer in orbit is not required if the S-IVB is employed for orbital launch operations in combination with a moderately up-graded Saturn V ELV.

Figure 18 summarizes the conclusions from this investigation of OLO with Saturn/Apollo systems.

OLO WITH SATURN/APOLLO SYSTEMS
CONCLUSIONS

- OLO OPS & SUPPORT REQUIREMENTS SIMILAR TO GROUND LAUNCH OPERATIONS
- HIGH PROFICIENCY & CONF. NEEDED IN SAT V GROUND LAUNCH OPERATIONS
- EVA DESIRABLE
- ORBITAL C/O NECESSARY
- SEPARATE OSE REQUIRED
  - GASES
  - POWER
  - CHECKOUT & FUNCTIONS
- SEVERE INTOLERANCE TO SCHEDULE SLIP
- PROGRAMMED HOLDS NECESSARY
- HIGH DEGREE OF MISSION SUPPORT
- HIGH PROFICIENCY FOR OLD CREWS
- ADDED FACILITIES & EQUIPMENT AT KSC
- 'PERMANENT' OLF MODE DESIRABLE,
  'TEMPORARY' OSE MODE ACCEPTABLE,
  INDEPENDENT OLV MODE INADEQUATE
- SAT V S-IVB + IU IS ADAPTABLE AS OLV STAGE
- PROPELLANT TRANSFER IN ORBIT NOT REQUIRED

FIGURE 18

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