Mar 7th, 8:00 AM

Apollo Spacecraft Integrated Checkout Planning

H. C. Goff
Manned Spacecraft Center Support Operation, Apollo Support Department, General Electric Company

J. M. Schabacker
Manned Spacecraft Center Support Operation, Apollo Support Department, General Electric Company

APOLLO SPACECRAFT INTEGRATED CHECKOUT PLANNING

By H. C. Goff and J. M. Schabacker
Manned Spacecraft Center Support Operation
Apollo Support Department
General Electric Company
Houston, Texas

Summary

The Apollo payloads, Command Module, Service Module, and Lunar Excursion Module require long range integrated checkout planning to assure mutual checkout compatibility and launch vehicle/spacecraft checkout compatibility. This function, performed in support of NASA's Checkout and Test Division of the Manned Spacecraft Center, provides integrated checkout planning on an inter-center and inter-contractor level. The end product results in NASA approved checkout flows and activities, in conjunction with their related ground support equipment, which delineate optimized prelaunch checkout operations and requirements. This presentation describes some of the aspects of the integrated checkout planning activity and gives examples of benefits derived from this task.

Definition of Integrated Checkout

Spacecraft checkout as the word applies in the Apollo Program can be simply defined as the testing carried out on a space vehicle to assure that the equipment is built correctly and operates properly to meet the requirements of its planned space mission. Although some checkout is necessarily performed by the astronauts during the spacecraft flight mission to assure certain operations or experiments are ready for performance, the checkout discussed in this paper is the preflight testing performed on the spacecraft by engineers and technicians prior to the spacecraft's launch.

The prelaunch checkout starts when the spacecraft manufacture is completed at the contractor's factory and is not completed until the end of the launch vehicle countdown and the space vehicle's liftoff from the launch pad. This prelaunch checkout, which involves both contractor & NASA personnel has the objective of assuring the National Aeronautics and Space Administration (NASA) that the space vehicle is ready for launch and that it will meet mission and crew safety requirements.

Integrated checkout refers to that testing performed on many systems of a spacecraft taken together or that testing of more than one module joined at one time. For example the integrated checkout of the total Command Module/Service Module (when the Command Module is mated to the Service Module) is important because the two modules must not only fit mechanically but operate together electrically.

Need for Integrated Checkout Planning

Many Organizations Participate in the Checkout

The need for integrated checkout planning within the Apollo spacecraft program stems from the multiplicity of payload modules, participating prime contractors, and the NASA centers involved. The total spacecraft consists of five structures produced by two prime-contractors, as summarized below:

North American Aviation (NAA) Spacecraft Modules.

- o Command Module (CM)
- o Service Module (SM)
- o S-IVB/LEM Adapter (SLA)

Grumman Aircraft Engineering Corporation (GAEC) Spacecraft Modules.

- o Lunar Excursion Module Ascent Stage (LEM-A/S)
- o Lunar Excursion Module Descent Stage (LEM-D/S)

Figure 1 illustrates how the five above modules comprise the total spacecraft payload.

The NASA Centers. Two NASA Centers, Manned Spacecraft Center (MSC) Houston, Texas, and John F. Kennedy Space Center (KSC) Florida are involved in the spacecraft preflight planning required for the checkout. While both MSC and KSC jointly plan and coordinate the spacecraft checkout flow sequences, KSC concentrates its efforts on the checkout taking place at its own location - the field checkout and launch site.

The Checkout Locations. The three major checkout locations include the North American Aviation factory at Downey, California, the Grumman Aircraft Engineering Corporation factory at Bethpage, New York, and the field checkout launch site at Kennedy Space Center, Florida.

Coordination Required for Efficient Operations

Integrated checkout planning is necessary to assure a fully checked out, completely assembled space vehicle which is ready for launch. This requires not only integrated systems checkout at the KSC field site, but coordinated and efficiently scheduled checkout plans at the NAA and GAEC factories. Figure 2 shows the location of organizations associated with the checkout.

Utilization of Related Experience. A major objective of integrated checkout planning is the achievement of reductions in time consumed for checkout activities without compromising confidence, reliability or flight readiness. This can be achieved, in part, by applying techniques developed in one area to problems encountered in other activities. An example of the benefits derived from this approach can be seen when we contrast two checkout techniques. The first utilized individual LEM A/S and D/S module workstands (Figure 3) for performing factory checkout activities, with the resultant numerous moves, cable and de-cable operation, and validation of GSE reconnections. With this concept, the factory flow seemed unnecessarily complex. Studies conducted jointly by MSC/GAEC showed that improvement in checkout flow efficiency could be achieved by utilizing integrated workstands. These workstands which concentrate the LEM spacecraft testing at one location result in a reduction in the number of spacecraft factory moves, cable and de-cable operations, and GSE validations. Figure 4 depicts the simplified factory checkout flow resulting from this integrated checkout method.

Joint Usage of Facilities and GSE. Contractor joint usage of checkout facilities and sharing of common use ground support equipment (GSE) also requires an integrated approach to the planned activities. In a program of the magnitude of Apollo there are literally hundreds of models of GSE required. To achieve GSE economies, many models have been designated as common usage. This includes both shared GSE and that which is built by one contractor and provided to both. The commonality of CSM and LEM propellants makes this approach particularly attractive for GSE used to service the spacecraft. Also, the extensive usage of ACE (Acceptance Checkout Equipment) facilitates this common use GSE approach. The checkout plans for CSM and LEM are thus effected by the usage of identical GSE, in many cases, and futher substantiate the need for the integrated checkout planning being performed.

Implementation of Integrated Checkout Planning

The Apollo Spacecraft Program Office at MSC is the NASA customer for the CSM and LEM contractors. As such, this office, supported by its own and other NASA divisions provides technical direction and performs the role of integrating and coordinating activities of many agencies to achieve its responsibilities to NASA Headquarters of meeting spacecraft delivery and checkout schedules. This office must set the basic checkout philosophy and provide consistent technical direction to the contractors. Decisions involving shared facilities, ground support equipment, delivery schedules, site activation dates, and many other complex activities requires integrated planning approaches to permit optimum technical decisions.

MSC's Checkout and Test Division within the Apollo Spacecraft Program Office (ASPO), with the technical support of General Electric's Apollo Support Department, provides coordination and integration of these checkout requirements of the spacecraft modules, prime contractors, three major checkout locations, and the two NASA Centers involved.

Functional Categories of Checkout Planning

The required integrated checkout planning can be divided into four functional categories:

1. Correlation of contractors' checkout plans with the NASA checkout criteria.

2. Correlation of the CSM factory checkout plans versus the LEM factory checkout plans.

3. Integration and correlation of individual checkout activities of CSM and LEM at the field site.

4. Planning for combined CSM/LEM checkout operations at the field site.

Progression of Checkout

The four functional categories generally follow the checkout flow progression of the spacecraft leading up to launch. First, the contractors' overall concepts for the total checkout operation must be formulated and approved. As will be discussed later, the contractors utilize direction given them from various NASA documents as a basis for their checkout planning. Detailed checkout plans can then be formulated for the factory phase of checkout and for the field checkout at the launch site.

For the factory phase of checkout the contractor coordinates with its subcontractors and the MSC-ASPO Checkout and Test Division. Kennedy Space Center personnel enter the checkout planning for the field site. It is apparent that all organizations must work together on the overall approach to the spacecraft checkout flow because the checkout carried out at one location effects the extent of checkout required at the other. Hence, if it is decided to do additional spacecraft checkout at the factory location, for instance, then the depth of checkout at the KSC field location can be reduced.

As was mentioned earlier, the spacecraft checkout is initiated at the factory immediately after the module is turned over to the test team from the manufacturing personnel. The Command Module and Service Module are built and checked out at the North American Aviation, Downey, California, factory.

The S-IVB/LEM Adapter is built and checked out at the North American Aviation, Tulsa, Oklahoma factory. The Lunar Excursion Module is built and checked out at the Grumman Aircraft Engineering Corporation, Bethpage, New York factory.

The field site checkout follows a progression of spacecraft buildup, starting with the individual checkout of each module (CM, SM, LEM A/S, and LEM D/S), followed by mated checkout of the CSM and LEM and finally into the combined checkout of the mated CSM/LEM and launch vehicle. Figure 5 summarizes this progression of checkout.

First Apollo with Full Payload

The first few Apollo missions include only the flight of the CSM payload. However, the first Apollo with a full payload will contain the LEM as well as the CSM. For this mission the CM and SM will be first checked out individually, mated and then given an integrated spacecraft checkout at the NAA factory. The LEM Ascent Stage and Descent Stage will be checked out in like manner at the GAEC factory. After this checkout, the modules will be shipped to the KSC field site for the final checkout and launch.

Factory Operations

The checkout operations at the factory are intermixed with certain black box installation into the spaceraft. In applying the building block approach to checkout, the systems of components are individually tested after their installation into the spacecraft, the systems are tested along with other interfacing systems and finally all systems are tested together in the spacecraft's integrated systems checkout. For example, the CSM Stabilization and Control System (SCS) would go through the following progression of test:

1. SCS installed system test (test of system after installation in spacecraft).

2. Combined SCS/Guidance and Navigation (G&N) System/Reaction Control System (RCS)/Service Propulsion System (SPS) testing.

3. Integrated System Test using all systems.

In addition to the buildup of the electrical systems such as those above, three major mechanical tests phases are a part of the spacecraft factory checkout sequence. These are Propulsion System and Environmental Control System (ECS) pressure testing, Quality Verification Vibration Test (QVVT) and spacecraft module weight and center of gravity (CG) determination.

Pressure Cell Testing. Propulsion system and ECS pressure testing is performed on each module before certain of the electrical systems and black boxes are installed to facilitate accessibility to the fluids piping systems. This high pressure testing is done in a protective pressure cell for safety purposes. Pressure tests are performed to validate proof pressure capability, proper operation and regulation at normal operating pressures, and acceptable leakage rates. Typical pressures used are 5500 psia for the proof pressure tests, 4000 psia operating pressure, and 185 psia downstream of the regulators. Leakage rates can be determined by use of a halogen leak detector or by a bubble count versus time measurement. Nitrogen with freon added is commonly employed, although many tests are performed with helium.

QVVT. The Quality Verification Vibration Test (QVVT) is accomplished after all electrical systems are installed but prior to the integrated systems testing. This low level vibration test is performed to discover any loose electrical connections so that they may be corrected prior to spacecraft shipment. For the QVVT, the Command Module and Service Module are individually vibrated by electromechanical thrusters at a level well below the flight vibration level. The two modules are electrically mated and operating during this test, although they are mechanically unmated, being mounted on adjacent workstands. Figure 6 depicts this test set up, showing the arrangement of the modules and the thrusters which provide the driving force.

Weight & CG Determination. The Service Module weight and center of gravity (CG) is determined after the integrated systems test and prior to the service module's preparation for shipment to KSC. This test need not be repeated at KSC. The Command Module, however, is given its one and only center of gravity determination at KSC. This is a necessary part of the CM/Launch Escape System (LES) alignment procedure which can be done only at KSC for safety reasons. The solid propellant launch escape system motors are shipped directly from the vendor to the KSC field site because of their high TNT explosive equivalent.

Summarized Factory Flow. While the Command/Service Module factory checkout is specifically covered in the explanation above, the LEM is given essentially the same type of factory test sequence at GAEC's Bethpage location. The general factory checkout sequence may be summarized by the following flow sequence:

1. Individual spacecraft module proof, leak and functional pressure tests.

2. Final systems installation, installed systems individual checkout and combined systems testing.

3. Quality Verification Vibration Test (QVVT). For this test the LEM Descent Stage and Ascent Stage are both mechanically and electrically mated while the CM and SM are electrically mated only. This is possible, in part, because of the LEM's lighter weight.

4. Spacecraft integrated systems checkout and mission profiles with modules mechanically and electrically mated.

5. Final mechanical system fit checks, weight and CG determination, and spacecraft preparation for delivery to KSC.

<u>KSC Field Site Operations</u>

When the individual modules comprising the CSM and LEM arrive at KSC, the progressive buildup previously mentioned takes place until the CSM/LEM are mated. Then, after a compatibility check the CSM/LEM spacecraft is transported to the launch complex for mating with the launch vehicle. The spacecraft and launch vehicle combined comprise the space vehicle (S/V).

<u>Initial Checkout at Industrial Area</u>. The first main activity at KSC after each module's receiving inspection are those unmated tests pertinent to each module's particular on-board systems. The following testing is carried on in parallel:

1. Command Module - Reaction control system (RCS) functional checkout.

2. Service Module - Service propulsion system (SPS) functional checkout (at Launch Complex 16) and fuel cell functional checkout (at Cryogenic Facility).

3. Service Module Reaction Control System Quadrangles (RCS Quads) - SM reaction control system functional checkout (The SM RCS Quads may be removed from the Service Module. This feature adds the capability of performing this additional checkout in parallel with all other systems.)

4. Launch Escape System (LES) - Buildup of solid propulsion motors.

5. S-IVB/LEM Adapter (SLA) - Installation and checkout of pyrotechnic initiators wiring and repair of any minor surface defects.

6. LEM Ascent Stage - Reaction control and main propulsion systems functional checkout.

7. LEM Descent Stage - Main propulsion system functional checkout.

<u>Integrated Checkout at Industrial Area</u>. After the individaul tests are accomplished the Command/Service modules are mated and the LEM Ascent/Descent stages are mated for their separate integrated systems testing in the KSC Industrial Area. Each contractor, NAA and GAEC, have separate facilities in the KSC Manned Spacecraft Operations Building for these specific integrated tests so operations may continue in parallel. The following two tests are the primary checkout activities of both the CSM and the LEM in this series:

1. The Spacecraft Combined Systems Test is performed to verify the spacecraft's systems end-to-end compatibility during a flight simulation and to verify normal spacecraft systems operation during testing of the various abort modes.

2. The Spacecraft Altitude Chamber Test is performed to verify normal spacecraft systems operation in a near flight environment and during the simulation of a descent profile.

The spacecraft modules are then ready for mating in preparation for transportation to the launch complex. The LEM is mated to the SLA which is followed by the mating of the CSM to the SLA. After a CSM/LEM interface check the combined payload is transported by flat-bed trailer to the launch complex for combination with the launch vehicle.

<u>Integrated Checkout at Launch Complex</u>. After the mechanical mating of the spacecraft (CSM/LEM) to the launch vehicle a final series of integrated tests are performed to insure that the total space vehicle is ready for launch. The following seven tests are the primary spacecraft oriented checkout activities carried out at the launch complex:

1. The Integrated Test with Launch Vehicle Simulator is performed to verify the functional compatibility of the spacecraft electrical and mechanical systems as well as to verify the launch complex compatibility of the spacecraft electrical systems.

2. The Spacecraft (S/C) - Launch Vehicle (L/V) Electrical Mate and Interface Test is performed to demonstrate the integrity of the S/C-L/V electrical interface.

3. The Space Vehicle (S/V) Plugs-In Integrated Test is performed to demonstrate the compatibility of the S/V electrical systems with the launch complex GSE and the range.

4. The Space Vehicle (S/V) Plugs-Out Integrated Test is performed to demonstrate the S/V - range compatibility in as near a flight configuration as possible. During this test the GSE monitoring equipment is not connected and the spacecraft umbilicals are disconnected in the normal time sequence of the countdown.

5. The Countdown Demonstration Test is performed to demonstrate the time phasing of the normal sequences necessary to prepare the spacecraft for launch.

6. The Space Vehicle Flight Readiness Test is performed to show a final systems verification in all modes prior to the entering of the launch countdown.

7. The Launch Countdown is performed to carry out the final activities to launch the space vehicle.

MSC's Role in Checkout Planning

MSC's modus operandi is to supply NAA and GAEC with management information necessary to coordinate checkout plans between themselves at contractor working level meetings. For instance, MSC supplies the contractor with mission and schedule information, development philospphy, and general spacecraft checkout criteria.

Mission Information

Two examples of mission and schedule information are the Mission Directives and the Master Development Schedules. There is one mission directive for each flight spacecraft. These directives give the primary, secondary, and tertiary mission objectives, a brief description of the spacecraft systems, and the flight plans. The Master Development Schedule defines missions of each flight and the flight hardware that comprise the space vehicle. Both the Mission Directives and Master Development Schedules give launch dates and are therefore classified as Confidential.

Apollo Checkout Criteria

Developmental philosophy as well as general spacecraft checkout criteria was transmitted to the contractors in part by the"Apollo Checkout Criteria" document issued by MSC and created by the GE Apollo Support Department. The "Apollo Checkout Criteria" written in 1964 gave guidance to the contractors by establishing certain ground rules for checkout such as the following:

1. Checkout flow will follow a buildup from the component level to complete space vehicle.

2. Each succeeding checkout operation shall be based upon a progressive growth pattern which takes advantage of all proven acceptable checkout data previously accomplished.

3. The sum total of the test and checkout operational sequence performed on a vehicle shall exercise the vehicle through all operations of a mission profile.

4. All operational, redundant, and abort modes of the spacecraft systems shall be operated and tested for compatibility and flight readiness.

5. No tests shall be performed without a valid engineering requirement, and developmental tests shall not be performed on qualified man-rated flight vehicles.

6. During simulated flight-test phases of the checkout program, each subsystem will be subjected to conditions and operations simulating normal flight profiles and alternate modes of operation.

The contractors then individually formulated their checkout plans and pursued joint coordination through meetings such as the Apollo Mission Planning Task Force (AMPTF) and the Prelaunch Operations Working Group (POWG).

Apollo Mission Planning Task Force

The Apollo Mission Planning Task Force made up of NASA, NAA, GAEC, and Massachusetts Institute of Technology (MIT is developing the Guidance and Navigation for the spacecraft) has contributed to integrated checkout planning by creating the Design Reference Mission to describe a single mission which can be a basis for project reporting and continuing spacecraft design and operational studies. The report of the Design Reference Mission is presented in three volumes.

Volume I - "Mission Description" contains the mission - related spacecraft design and trajectory ground rules which were assumed, and a description of the mission by phases.

Volume II - "Preflight Sequence of Events" contains a detailed description of the preflight sequence of events. This description includes summary charts of the scheduled activities for a typical CSM and LEM from the time of Vertical Assembly Building (VAB) roll-out to liftoff and a list of pertinent assumptions and comments.

Volume III - "In-Flight and Recovery Sequence of Events" summarizes the sequence of events taking place for the typical mission from the SV liftoff through the post-flight recovery operations.

Preflight Sequence of Events. Volume II - "Preflight Sequence of Events" contributes to the integrated checkout planning because it details those checkout and countdown operations at the time the most integrated checkout planning is required - when the full space vehicle is assembled. The launch vehicle as used in the Design Reference Mission consists of the S-IC, S-II, and S-IVB stages and the instrument unit (IU), and the launch area is therefore Launch Complex 39. See figure 7 for the Launch Complex 39 configuration. The spacecraft consists, as mentioned before, of the Command Module, Service Module, Lunar Excursion Module, Launch Escape System, and the S-IVB/LEM Adapter (SLA).

Prelaunch Operations Working Group

The Prelaunch Operations Working Group (POWG) principally consists of NAA and GAEC members although NASA and MIT personnel attend the meetings as visitors for coordination purposes as required. The Prelaunch Operations Working Group reviews and discusses NAA/GAEC operational interface problems and prepares integrated checkout flow plans for all missions which consist of combined CM and LEM's. Test plans and facility/GSE requirements for common tests, such as the CM-LEM Ascent Stage docking test, are worked out at the POWG. The Prelaunch Operations Working Group and the Apollo Mission Planning Task Force work together on like tasks often because of the similar objectives of the two organizations. For instance the AMPTF Preflight Sequences Working Group prepared a set of constraints and ground rules for Launch Complex 39 which was discussed at the Prelaunch Operations Working Group meetings. As actual utilization of Complex 39 is approximately a year in the future these ground rules are subject to change as refinements are made in operational plans.

Launch Complex 39 Constraints. The following are some examples of Launch Complex 39 constraints taken from the document:

1. The CSM live launch escape system (LES) shall be installed at the Launch Pad after the mobile service structure (MSS) moves into place.

2. Radio frequency (RF) silence is required during installation and connection of pyrotechnics. S/C power other than RF (less than 150 KC) may be turned on during the operation.

3. After LES installation, atmospheric electrical activity within 5 miles of the space vehicle requires a clearance of the pad area.

4. During L/V LO_2 and LH_2 loading the pad area is cleared of non-essentail personnel. Pad in condition "RED."

5. S/C hypergolics servicing will be scheduled to serially load fuel (MMH & Aerozine 50) then oxidizer (N_2O_4).

6. CSM and LEM have individual fluid distribution systems but share the transfer, storage and command transfer equipment.

7. S/C will load LO_2 and LH_2 serially; however, GO_2 and GH_2 will be transferred simultaneously for fuel cell operations.

8. Helium servicing will be scheduled as a serial operation between the CSM and LEM using concurrent equipment on a time shared basis.

9. Prior to MSS removal, the LEM cabin is closed out, the SLA internal platforms completely removed, and the LES pyros connected.

10. The CSM and LEM umbilical will remain connected across the swing arm during transport to the pad.

11. MCC (Houston) will have the capability of monitoring pad operations. Mission simulation will include S/V control switchover.

12. All umbilical and service lines are disconnected during plugs-out and mission simulation tests.

Launch Complex 39 Ground Rules. The following are some examples of Launch Complex 39 ground rules taken from the document:

1. A simulated flight at the pad will be conducted after the Countdown Demonstration Test (CDDT) with the MSS inplace, and the connections to the S/V may be broken.

2. A spacecraft system verification test will be required late in the countdown.

3. Mission simulation will consist of a segmented mission encompassing all automatic sequential functions from liftoff to reentry and recovery.

4. Interface testing between the spacecraft and L/V are completed in the VAB.

5. T-0 occurs at hold down release (first motion).

6. Final swing arm umbilical disconnect tests will be performed in the VAB.

7. Countdown demonstration will be performed on a real time basis simulating actual countdown operations as far as practicable.

Apollo Checkout Management Board

In addition to the contractor meetings, the MSC-ASPO Checkout and Test Division convenes formal NASA/contractor coordination meetings such as the Apollo Checkout Management Board meetings. The Apollo Checkout Management Board has the task of carrying out integrated checkout planning and then of implementing these plans. The Checkout and Test Division, realizing the need for close coordination with each contractor as well as the integration of all Command/Service Module and LEM activities formated the meetings of the Board to include NASA/NAA meetings (to discuss Command/Service Module Checkout) and NASA/GAEC meetings (to discuss LEM checkout) as well as NASA/inter-contractor meetings (to discuss integration of CSM and LEM checkout). The Board including checkout management representatives from NASA-MSC, NASA-KSC, NAA, GAEC, MIT, AC Electronics and General Electric's Apollo Support Department discuss such varied topics as checkout flow schedules, facility utilization to meet checkout requirements, and the status of hardware and software to meet schedules.

In individual NASA/NAA meetings CSM checkout is specifically discussed. As checkout experience is gained changes to the CSM flow are proposed and discussed. In like manner, individual NASA/GAEC meetings are held to specifically discuss LEM checkout. Those changes in one contractor's checkout flow applicable to the other contractor's checkout are passed on since the same NASA Board members attend both the CSM meetings and the LEM meetings. When inter-contractor problems arise causing the requirement for additional operations coordination, the complete Checkout Management Board meets to jointly solve problems under the leadership of NASA/MSC as the chairman of the Board.

Ground Operations Requirements Plan

The information thus obtained by these various meetings is used by the contractors for checkout planning purposes. One resulting contractor document is the Apollo Spacecraft Ground Operations Requirements Plan.

The Ground Operations Requirements Plan is the contractor top document defining the engineering requirements for checkout of the spacecraft. The preflight spacecraft operations and checkout is broken down into numerous test data sheets giving the test objectives, spacecraft configuration, GSE/facility requirements, and the test description. The test data sheets in the Ground Operations Requirements Plans are sufficiently detailed such that process specifications and operational checkout procedures (OCP's) may be prepared from the document. Operational checkout procedures are the documents used by the test engineers in the actual implementation of the checkout. North American Aviation prepares the Ground Operations Requirements Plan for the CSM while GAEC prepares the Plan for the LEM. See Figures 8 and 9 for typical test data sheets from these documents.

The contractors pursue initial coordination of their documents through the Prelaunch Operations Working Group (POWG) as part of their integrated checkout planning. In addition, MSC Checkout and Test Division sponsors review meetings for each Ground Operations Requirements Plan published to completely coordinate the information in the document as well as make the necessary changes when required. MSC, KSC, NAA, GAEC, and MIT representatives take part in these meetings to insure that the interdependent features of the spacecraft checkout are satisfactory to all participants.

Common and Concurrent Use GSE

Interdependent aspects include sharing of facilities and ground support equipment as well as the combined checkout of the CSM/LEM spacecraft. The integrated checkout planning allows the utilization of common and concurrent use GSE in which NAA and GAEC share certain types of GSE for the checkout of the CSM and LEM respectively. Through the utilization of regularly scheduled contractor GSE requirements reviews, when each contractor had like requirements for an item of GSE only one model was developed and that model was designated as common use. The design of the model of GSE would then be coordinated between the contractors by Interface Control Documents (ICD's) and the producing vendor would make enough units for use at KSC, NAA/Downey, California, GAEC/Bethpage, New York, or wherever they were needed.

Concurrent Use. When actual units of common use GSE could be shared by NAA and GAEC at the KSC field site these units were called concurrent use GSE. By the two contractors using these units either in parallel or in serial a savings in total units required was affected which reduced costs appreciably in the program. As an example of concurrent use GSE, the following is a listing of typical concurrent use servicing GSE used by both NAA and GAEC at the KSC field site:

S14-002	Oxidizer Transfer and Conditioning Unit
S14-008	Fuel Transfer and Conditioning Unit
S14-052	Water Glycol Cooling Unit
S14-060	Fuel Toxic Vapor Disposal Unit
S14-061	Oxidizer Toxic Vapor Disposal Unit
S14-108	Fluid Distribution System, Launch Complex 39, Pad 39A
S14-111	Battery Charger

Required Coordination. The required inter-contractor common use/concurrent use GSE coordination and utilization scheduling is performed by NAA and GAEC in the Prelaunch Operation Working Group. In addition, MSC-ASPO issues a monthly summary document giving the identification and utilization of all common use and concurrent use GSE.

Common Facilities

Joint usage of KSC facilities by both the LEM and CSM also requires an integrated approach. For example, the spacecraft's checkout flow in the Manned Spacecraft Operations Building is inter-dependent even though separate work areas are provided for LEM and CSM. Maximum operational interdependence for each is a NASA goal but the achievement of the goal requires an overall knowledge and integrated planning approach. The checkout activities of both vehicles must be planned and performed to permit the CSM/LEM mated tests to occur at the optimum point in time to support the prelaunch operation.

Conclusion

The complexity of the checkout activities required to produce the completely checked out space vehicle demonstrates the need for the Apollo spacecraft integrated checkout planning. The planning techniques, successfully implemented can contribute to a well managed Apollo program and aid in achieving the lunar mission in a timely manner.

As the Apollo program progresses and accelerates to meet our goals, the benefits of this planning will become evident.

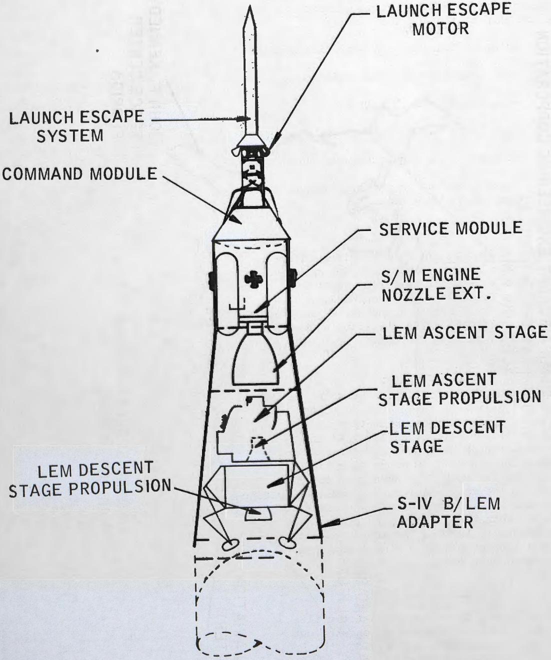

Figure 1 - Apollo Spacecraft Configuration

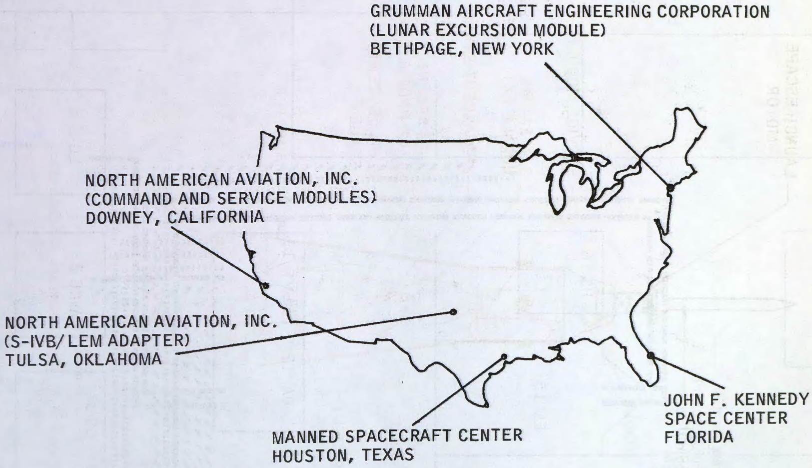

Figure 2 - Locations of Organizations Associated with Apollo Spacecraft Checkout

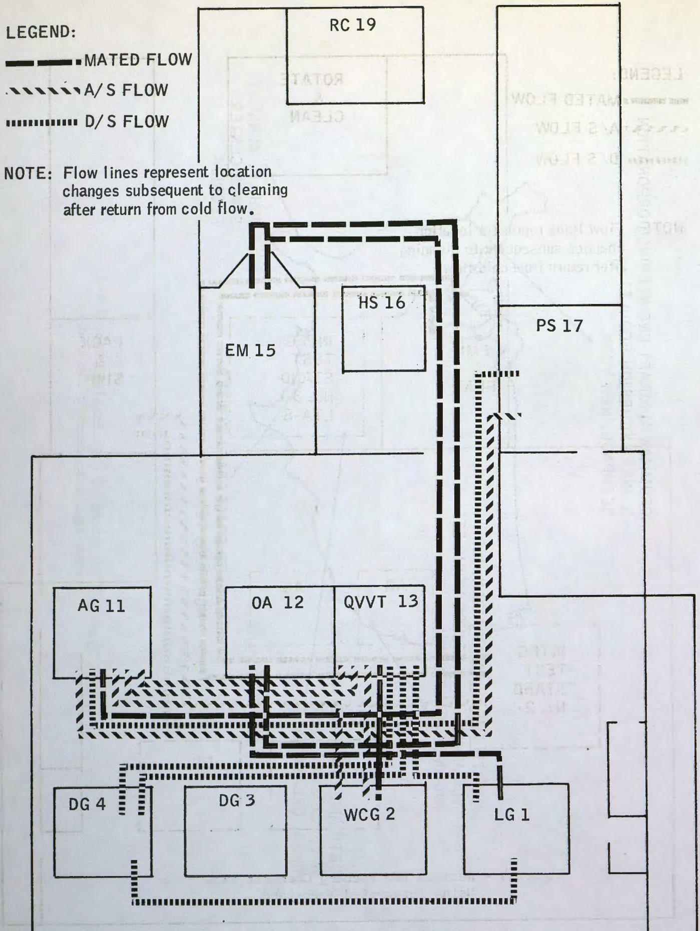

Figure 3 - Original LEM Factory Checkout Flow

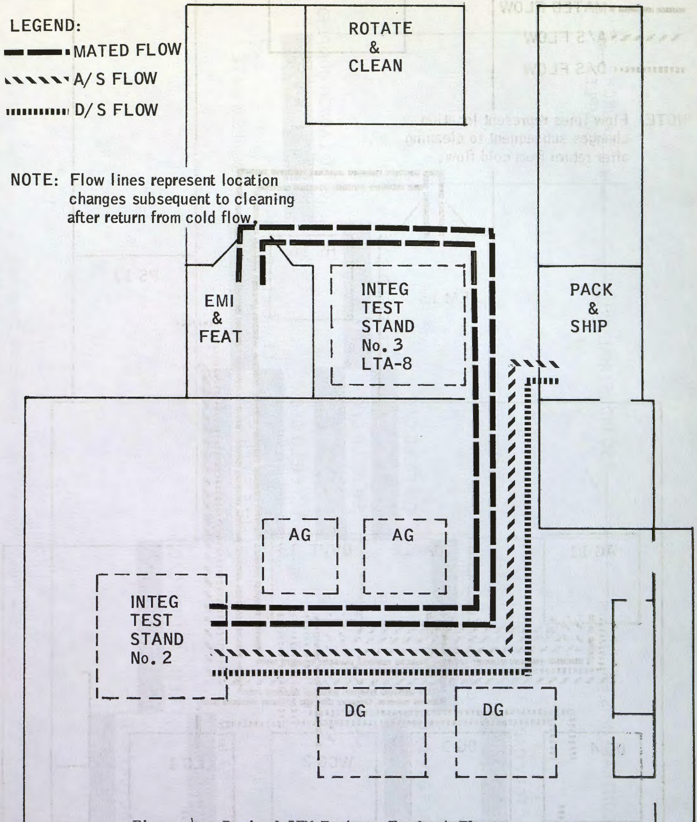

Figure 4 - Revised LEM Factory Checkout Flow
Using Integrated Workstand

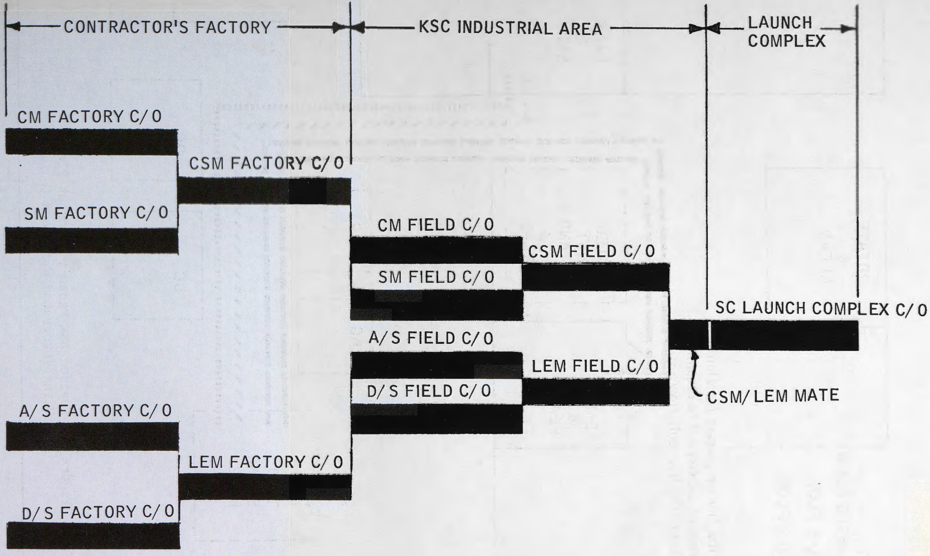

Figure 5 - Total Progression of Spacecraft Checkout

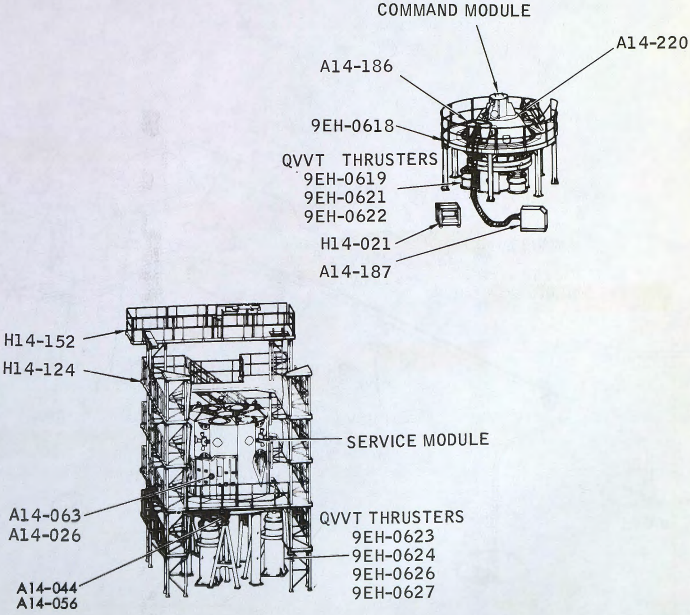

Figure 6 - Test Setup for CSM Quality Verification Vibration Test

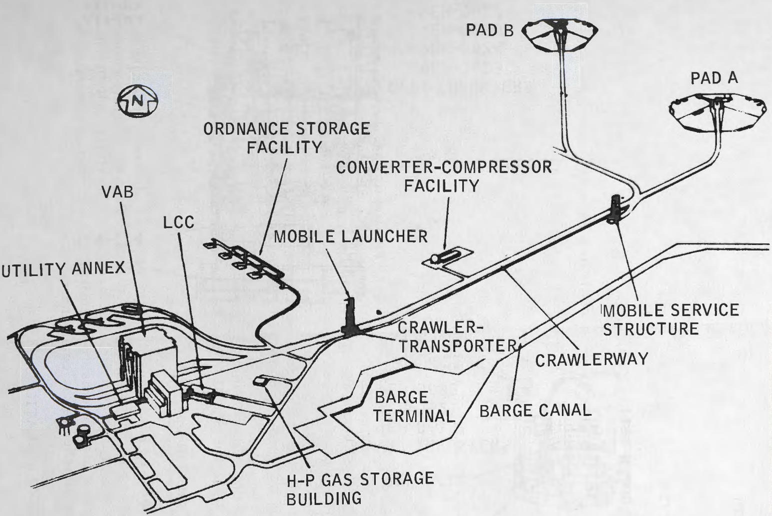

Figure 7 - Launch Complex 39 Configuration

SC-384, SPACECRAFT MATE AND FORWARD DECK BUILDUP

LOCATION

MSOB

OBJECTIVES

1. Install LEM in SLA.

2. Build up forward deck and install ordnance devices and forward heat shield.

TEST SETUP

CSM, SLA and LEM

TEST IDENTIFICATION AND SEQUENCE

LEM/SLA/CSM Mate

The lower section of the SLA is in position in the SLA/SC integrated test stand. The mated LEM is lowered into the SLA lower section and secured, followed by the installation of the upper section of the SLA and the internal access platform set. The LEM ACE carry-on equipment is moved from the ACE support platform to the internal access platform. The LEM carry-on cabling is not disconnected during this operation. The LEM/SLA umbilical is connected and verified and the LEM/SLA GSE tunnel is installed.

The CSM is then installed on the SLA and aligned using the optical alignment set. The SM/SLA electrical connectors are mated.

Forward Deck Buildup

The forward heat shield thruster rods are checked for length by placing a gaseous nitrogen pressure source at the gas generator source. The pyrotechnic gas generators are installed. The flotation bags, drogue, and pilot parachute systems are installed. The forward heat shield is lowered and attached to the command module.

SPECIAL CONSIDERATIONS

Only qualified parachute riggers are to perform parachute handling and packing procedures. Only personnel experienced with ordnance handling and special safety procedures are allowed to handle and install pyrotechnic devices.

Figure 8 - Typical Test Data Sheet from CSM Ground Operations Requirements Plan

Test No.	32202
Test Time	4 Hrs.
Revision	C

Location

GAEC

Subsystems

Structural & Mechanical

Title

Demate - Ascent From Descent Stage

Objective

To physically disconnect the ascent from descent stage.

Prerequisites

Test No.	
60051	Manufacturing Vibration Test
42506	Location Change

Test Description

The mated LEM is moved by the facility crane from the vibration area to the D/S support stand at DG-4. When the vehicle is secured in the stand all interstage connections (bolts, nuts, umbilicals, hardlines, etc.) are disconnected. The auxiliary crane then hoists the A/S clear and moves it to the ascent general install. area. The descent stage remains on the D/S support stand where engine installation will be initiated.

GSE Required

Part No.	Nomenclature
420-13650	D/S Workstand
420-13700	D/S Support Stand
420-13060	Aux. Crane Control
420-13100	A/S Sling
420-13400	A/S Support Stand

Vehicle Test Configuration

Mated LEM

Figure 9 - Typical Test Data Sheet from LEM Ground Operations Requirements Plan