TEST PROGRAM REVIEW

ABSTRACT

This paper provides a review of test program requirements and operations applicable to space instruments systems. The Apollo Lunar Surface Experiment Package (ALSEP) test program is summarized and then evaluated in terms of performance vs overall effectiveness in Section 2. Section 3 discusses the basic requirements for the definition of typical space instrument verification activities and indicates tradeoffs to be considered in the analysis and planning stages, and in the test operations phases of hardware development. In the final section, three classes of payloads are defined and verification tasks and documentation requirements are evaluated for these payloads in terms of cost effective program implementation. ALSEP is used in this case study as typical of the most critical payload for high reliability performance and life.

Prepared by:

D. Perkins

D. Fithian

Approved by:

B. Rusky
ALSEP Program Manager

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	ALSEP TEST PROGRAM	1
2.1	Test Requirements and Rationale	1
2,2	Documentation Requirements	8
2.3	Personnel and Facilities	18
2.4	Implementation of Test Program	21
2.5	Qualitative Evaluation of ALSEP Test Program	26
3.	TYPICAL PROGRAM REQUIREMENTS	28
3.1	Conceptual Planning	29
3.2	Detail Planning	37
3.3	Facility and Documentation Preparations	37
3.4	Program Implementation	39
3.5	Reporting	41
4.	RECOMMENDATIONS	42
5.	CONCLUSIONS	47

ILLUSTRATIONS

Figure	Title	Page
1	ALSEP Ground Operation Checkout Flow	4
2	Development of Hardware Verification Requirements	31
3	Phased Verification Requirements	33

TABLES

Table	Title	Page
1	ALSEP Development Model	9
2	Array E Test Model	10
3	Array E Breadboard Model Test Requirements	11
4	Array E Engineering Model Test Requirements	12
5	Array E DVM Test Requirements	13
6	Array E Qualification Model Test Requirements	14
7	Array E Flight Model Test Requirements	15
8	Cost Effectiveness Recommendations	44

TEST PROGRAM REVIEW

1. INTRODUCTION

The purpose of this review is to develop guidelines for typical space hardware development test programs. Test requirements vary with the type of equipment, reliability goals and phase of hardware development. The ALSEP program provides a wealth of experience in testing during all phases of development of a high reliability space system. The intent is to use this information together with other readily available data, to develop rational with economically effective guidelines for definition of test programs for space components or systems.

2. ALSEP TEST PROGRAM

2.1 Test Requirements and Rationale

The ALSEP development program ran for approximately 6 1/2 years during which time seven complete flight systems were built, including EASEP (Early Apollo Scientific Experiments Package). The flight systems were preceded by engineering, prototype, qualification, structural/ thermal,, crew training and demonstration models.

"The test program was formulated initially during the phase B study phase of the contract. Several technical memoranda outlined the philosophy and plans for the program. Typical examples of these are extracted and quoted below:

ATM 7. (9/17/65) - Engineering Development Testing

The Test Plan objective is to provide design development information to engineering, concerning parts, components, subsystems and systems designs selection for ALSEP. Tests conducted at all levels of flight hardware will provide design concepts and feasibility, establish detail hardware design and obtain reliability data. This plan will include supplier and subcontractor tests to show relationship with in-house effort. Tests will be conducted to investigate characteristics of operation, verify details of the design, investigate failure mode, and the effect of these failures. Major packages such as experiments and

central station will undergo structural, dynamic and thermal tests. Subsystem electrical/mechanical performance and interfaces will be demonstrated. System level tests are planned utilizing three models--a structural/dynamic model, electromagnetic compatibility model, and a thermal model. Static load tests and vibration surveys will be conducted on the structural/dynamic model. Thermal vacuum tests including solar simulation will demonstrate system performance utilizing the thermal model. The electromagnetic compatibility model has two prime uses: (1) demonstrate integrated system electrical performance, (2) demonstrate experiment-central station electromagnetic compatibility."

"The Test Program will be planned so that duplicate tests or tests producing similar information will not be performed at the various hardware levels. Maximum utilization of information will be obtained by eliminating test duplication between the various subsystems. Schedule is the constraint necessitating parallel testing."

"The Test Program will define all tests leading to the development of each major component and end item and will show the interrelationships between these tests. The end use of the data sought will be described; in other words, is the data useful to Engineering design, to Reliability, or as to background information for the Qualification Test Program. The Engineering Department will be responsible for detail planning of tests and their conduct, assisted by the Test Department with the Test Department serving a support function. The Engineering Department will document each test with procedures and reports.

ATM 8 (9/17/65) - Qualification Test Plan

"The system test objective is to demonstrate integrated system performance, interface compatibility, and the capability to withstand deleterious effects of environments, both natural and induced. Tests will demonstrate all operational modes at design limit conditions. The tests shall be planned to reveal any problem areas caused by inherent sensitivity to environments, to identify potential failures not revealed in design reviews and reliability analyses, and to verify design performance and life expectancy. A design verification program will precede the formal environmental qualifications and will measure the limits of equipment operating capabilities. Overstress tests will be conducted subsequent to qualification using qualification hardware. These tests will determine failure modes and design margins, and are for the purpose of providing additional confidence in the system."

A typical assembly and test/checkout flow plan was outlined in ATM 15 and is included here for review (Figure 1).

As a comparison with these plans, which were formulated during the proposal phase, the following quotations are from ATM 785 and relate to the ALSEP Qual SA Model, Qualification Test Plan, which was used during the hardware contract.

"The ALSEP Qualification Test Plan, which together with the ALSEP contract forms the basis for the ALSEP Qualification Test Program for Array A, includes requirements for three phases of testing on Qualification hardware:

a) Acceptance Testing
b) Design Limit Testing
c) Mission Simulation

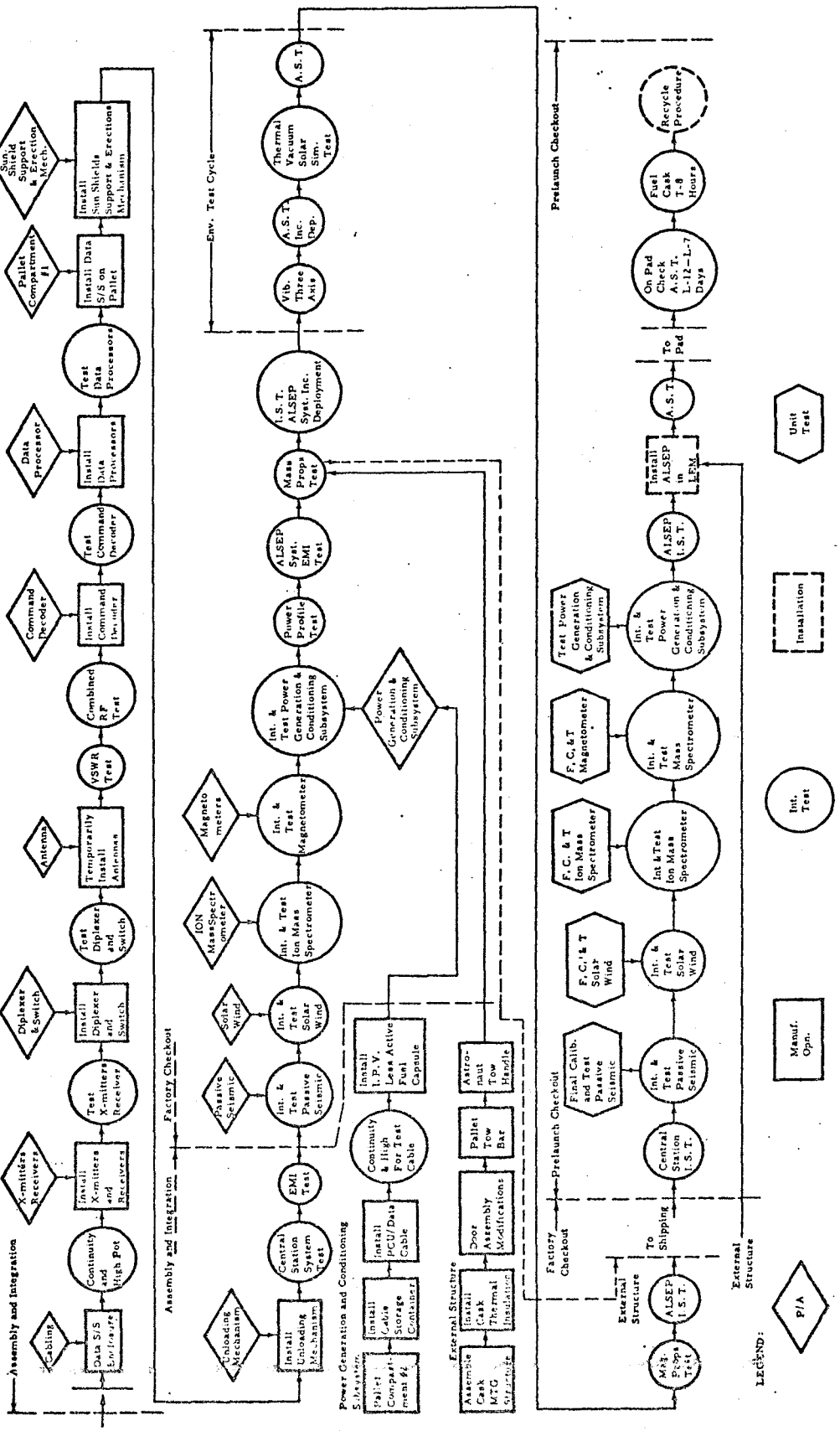
This document along with the test plans for Qualification of Array B and C follows the general requirements of ASPO-RQA-11, "Qualification Test Program Guidelines" for the Apollo Program.

This test plan describes tests to be performed, facilities and test procedures required, ALSEP hardware requirements, the methods used to document changes, revisions, discrepancies, results and review of the test program."

"The Qualification test program objectives are to demonstrate the ALSEP System can withstand the environments (natural and induced), both acceptance (Flight) level and design limit, while functioning as an integrated system either during or after exposure to the environment. The functional portion of the test program will demonstrate integrated system performance and compatibility during all normal operational modes.

The tests listed above are planned to:

a) Verify design performance and compliance with specifications during and/or after exposure to both acceptance, design limit and simulated lunar conditions and accelerated temperature cycling.


Assembly and Integration
Factory Checkout
Env. Test Cycle
Prelaunch Checkout
Cabling
Data S/S Enclosure
Continuity and High Pot
Install X-mitters and Receivers
Test X-mitters Receiver
Install Diplexer and Switch
Test Diplexer and Switch
Temporarily Install Antennas
VSWR Test
Combined RF Test
Install Command Decoder
Test Command Decoder
Install Data Processors
Test Data Processors
Install Data S/S on Pallet
Install Sun Shields Support & Erections Mechanism
X-mitters Receivers
Diplexer & Switch
Antenna
Command Decoder
Data Processor
Pallet Compartment #1
Sun Shield Support & Erection Mech.
Unloading Mechanism
Install Unloading Mechanism
Central Station System Test
EMI Test
Int. & Test Passive Seismic
Int. & Test Solar Wind
Int. & Test Ion Mass Spectrometer
Int. & Test Magnetometer
Int. & Test Power Generation & Conditioning Subsystem
Power Profile Test
ALSEP Syst. EMI Test
Mass Props Test
I.S.T. ALSEP Syst. Inc. Deployment
Vib. Three Axis
A.S.T. Inc. Dep.
Thermal Vacuum Solar Sim. Test
A.S.T.
Passive Seismic
Solar Wind
ION Mass Spectrometer
Magnetometers
Power Generation & Conditioning Subsystem
Power Generation & Conditioning Subsystem
Test Power Generation & Conditioning Subsystem
Int. & Test Power Generation & Conditioning Subsystem
ALSEP I.S.T.
Install ALSEP in LEM
A.S.T.
To Pad
On Pad Check A.S.T. L-12—L-7 Days
Fuel Cask T-0 Hours
Recycle Procedure
Power Generation & Conditioning Subsystem
Power Generation & Conditioning Subsystem
Power Generation & Conditioning Subsystem

b) Reveal any problem areas caused by inherent sensitivity to environments.

c) Identify potential failure modes not revealed in design reviews and/or reliability analysis."

"The test program outlined in this document provides for the system level qualification tests. The major groups of tests are as follows:

a) Acceptance Tests (System Level)
b) Design Limit Tests (System Level)
c) Mission Simulation

Acceptance Tests

The purpose of the acceptance test program is to demonstrate system performance and compliance with specifications after exposure to nominal environments. The acceptance tests to be performed are as follows:

Baseline

IST*
Crosstalk
EMI
Central Station Power Dissipation
Mass Properties S/P #1 and #2
Vibration S/P #1
Magnetic Properties
Stray Field Magnetic Properties
Thermal/Vacuum

* To functionally test Subpackage 1 in the stowed condition after and before specified mechanical vibration environments, an abbreviated IST (T.P. 2338600) is performed. This test determines the operational integrity of the SWE, PSE, LSM and Central Station in a stowed condition by performing selected portions of the total IST test (T.P. 2333034)."

"Design Limit Tests

The purpose of the Design Limit test program is to demonstrate system performance and compliance with specifications during exposure to design level environments.

Test

Temperature Storage
Shock Subpackage No. 1 and 2
Acceleration Subpackage No. 1 and 2
Design Limit Vibration

The Design Limit Thermal/Vacuum test is an operational continuation of the Qual SA Mission Simulation Test. At the conclusion of the Mission Simulation Test, the average Lunar Surface Temperature will be increased to the Design Limit Lunar Noon condition of 280^{o} ($+20^{o}$) F for approximately five (5) days while performance on the ALSEP System is monitored at the STS."

"Mission Simulation

Objective - The purpose of the "ALSEP Deployed System Thermal Vacuum Mission Simulation Test" is to qualify system start-up and operation in a simulated pressure-temperature environment of the moon's surface during a typical lunar day.

Scope - ALSEP will be subjected to a simulated lunar environment for the duration of one lunar day in Bendix' 20' x 27' Space Simulation Chamber. This environment will be keyed to four parameters,

a) Pressure
b) Deep Space Cold Sink
c) Solar (Thermal) Radiation
d) Lunar Surface Temperature Extremes,

and throughout this test:

a) The internal chamber pressure will be maintained at or below 5×10^{-6} torr,

b) The chamber's cold shroud will be maintained at -280°F ±40°F,
c) The solar irradiation will be simulated with the normal portion only, of the total incident energy, and
d) The lunar surface temperatures will follow a nominal lunar surface time/temperature profile (±25°F).

Method - The Mission Simulation test cycles the ALSEP system from a lunar morning turn-on, to a lunar noon condition, and finally to the lunar night condition. This sequence is done over a time period of 28 days with integrated system tests performed during various times in the sequence.

Throughout the sequence from lunar noon to lunar night, the temperature conditions are stabilized and held for specified periods of time."

A comparison of these plans shows that the basic outline remained the same but that there were significant detail differences. For example, the original concept called for solar simulation at multiple sun angles and even an attempt to test for dust degradation using shadowing (ATM 99). A part of the qualification program included overstress testing and determining the point of failure. In addition, the original concept called for ALSEP acceptance testing at the Cape. The final program used infra-red radiation to simulate the solar input (ATM 505), at normal incidence only. The input level was determined by radiometers and was matched to the thermal coatings to account for spectral content differences between true solar radiation and the IR lamp spectrum. Design limit testing was performed to verify that adequate design margin existed but no overstress testing was implemented.

Final requirements for post delivery tests at the launch site were modified to eliminate all acceptance type tests. Each flight system was operated at the Cape, however, to verify compatibility with the Manned Space Flight network, these tests were known as Software Integration Tests (SIT Tests). Crew fit and function (CF^2) tests were also performed on each flight model to verify mechanical deployment performance and to familiarize each crew with the final flight hardware. On special occasions, where schedule prohibited final integrated system tests to be completed prior to delivery, selected instruments were integrated and checked for functional compatibility with the systems at the Cape.

The development and test program for ALSEP involved the use of many types of hardware models as noted in Table 1. Each of these models served a necessary purpose for verification of engineering design analysis, manufacturing processes and for qualification as well as for verification of crew functions, crew training and fit checks with other subsystems of the complex Apollo system.

Tables 2 through 7 provide examples of the extensive detailed testing performed on Array E (typical of all arrays) to verify the high performance, high reliability systems which was required of Apollo hardware.

2.2 Documentation Requirements

The documentation requirements for the ALSEP test program were also extensive, involving the following typical types of documents:

1) Test plans
2) Test procedures
3) Pre-test meeting minutes
4) Post-test meeting minutes
5) Test reports
6) Test Discrepancy Reports (TDR)
7) Discrepancy Reports (DR)
8) Log books
9) Handling procedures
10) Work order operation sheets (WOOS)

2.2.1 Test Plans

Test plans were required for each system model and each experiment model, sometimes with a requirement for an overall test plan which integrated the individual plans. These plans were usually Type I documents which required NASA approval.

2.2.2 Test Procedures

Test procedures were generally in conformance with a standard Bendix format and gave step by step instructions for connecting the equipment and test article and for conducting the test. Changes were controlled by the normal drawing change method via Configuration Management. Variation sheets were provided to accommodate changes that were found necessary during test and which were approved by all observing parties

TA 1

ALSEP DEVELOPMENT MODELS

ARRAY MODEL	DEMO MOCKUP	TRAINER	BREADBOARD BRASSBOARD	ENG. MODEL	PROTO TYPE	QUAL	FLIGHT
EASEP	X	X		X		X	A-11
A	X	X	X	X	X	X	A-12
B	X	X	X	X	X	X	A-13
C	X	X	X	X	X	X	A-14
A-2	X	X		X		X	A-15
D	X	X		X		X	A-16
E	X	X	X	X	*	X	A-17

*FORMALIZED ENG. MODEL FOR ARRAY E USED ON SOME EXPERIMENTS

TABLE 2

ARRAY E T[illegible] MODELS

SYSTEM	DEMO/ MOCKUP	TRAINER	BREADBOARD	ENG. MODEL	PROTO* TYPE	QUAL	FLIGHT
SUBPACKAGE I	X	X		X (CREW)		X	X
STRUCTURE				X			X
CENTRAL STA				X			X
C/S COMPONENTS			X	X		X	X
ANTENNA						X	X
LSG	X	X	X	X		X	X
LMS	X	X	X		X	X	X
LSP CE			X		X	X	X
ANT.	X	X			X	X	X
GEO MOD	X	X			X	X	X
SUBPACKAGE II	X	X		X (CREW)		X	X
STRUCTURE				X		X	X
LEAM	X	X	X	X		X	X
HFE		X				X	X
AIM MECH		X		X		X	X
LSPE EXP. PKG.	X	X	X	X	X	X	X

*PROTO ON ARRAY E WAS BASICALLY AN ENG. MODEL WITH A FORMAL QA AND CONFIG. CONTROL SYSTEM

TABLE 3

ARRAY E BREADBOARD MODEL TEST REQUIREMENTS

Item / Test	Ambient Functional	Thermal Functional	Interface Compat.	
Cmd Decoder Data Processor PCU/PDU	#	#	#	
LSP CE & Geo.	#			
LSP Explosive Package	#			
LMS	#	#		
LSG	#			
LEAM	#			

TABLE 4

ARRAY E ENGINEERING MODEL TEST REQUIREMENTS

Item / Test	Ambient Functional	Thermal Functional	Design Limit Thermal Vac.	Hot, Cold, Ambient PIA	Acceptance Vib. Random Operating	Acceptance Vib. Sine Non-Op.	Design Limit Vib. Sine Non-Op.	Design Limit Vib. Random L&B Non-Op.	Design Limit Vib. Random LD Non-Op.	Design Limit Vib. Random Operating	Shock	Thermal Control Evaluation	
LSP CE & Geo	#	#		#									
LSP Explosive Package	#	#	#									#	
LMS	#	#											
LSG			#		#		#	#	#	#	#		
SP-1 ssy.							#	#	#				
P-2 Array D) E Subpallet							#	#	#				
nt. Aiming lechanism	#	#					#	#	#		#		

ARRAY E DVM T REQUIREMENTS

Item / Model	Ambient Functional	Interface Compatibility	Design Limit Thermal/Vac.	Hot, Cold, Ambient PIA	EMI	Ambient PIA	Electro-Explosive Device RFI	Experiment Integration	Integrated System Test	Field Tests	Accept. Vib. Random Op.	Accept. Vib. Sine Non-Op.	Design Limit Vib. Sine Non-Op.	Design Limit Vib. Random L&B Non-Op	Design Limit Vib. Random LD Non-Op.	Design Limit Vib. Random Operating	Shock	Thermal Control Evaluation	
C/S Components	X	X	X	X	X								X	X	X	X	X		
C/S Electronics Assembly	X	X	X		X			#	#										
LSP CE & Geo			X		X #	X		#	#	X			X	X	X				
LSP Explosive Package			X		X	X	X			X			X	X	X		X		
LSP Subsystem			X							X									
LMS			X	X	X	X		#	#		X	X	X	X	X	X	X		
LSG					X			#	#										
LEAM				X	X	X		#	#		X	X				X	X	X	
HFE								#	#										
PSE Optional								#	#										

System Level
X Component Level

TABLE 6

ARRAY E QUALIFICATION MODEL TEST REQUIREMENTS

X Component Level
System Level
SC Subcontractor Test

Item / Model	Accept. Level Thermal Vac.	Design Limit Thermal Vac.	Hot, Cold, Ambient PIA	EMI	Ambient PIA	IST	Mass Properties	Tumble	C/S Verification	Field Tests	RFI Immunity	Accept. Vib. Random Operat.	Accept. Vib. Sine Non-Op.	Design Limit Vib. Sine Non-Op.	Design Limit Vib. Random L&B Non-Op.	Design Limit Vib. Random LD Non-Op.	Design Limit Vib. Random Operating	Shock	Fastener Verification &
C/S Components	#	#	X	#			X						#	#	#	#		#	
C/S Electronics Assembly	#	#		#		#	#	#	X			X	#	#	#	#	X	#	
LSP CE & GEO	#	#		#	X	#	X #	#		X	#	X CE only	#	#	#	#	X	#	Geo onl
LSP Expl. Package		#			X		X			X	#		X	X	X	X		X	#
LSP Subsystem	#	#		#	X	#				X									#
LMS	#	#	X	#	X	#	X #	#				X	#	#	#	#	X	#	#
LSG	X #	X #	X	X #	X	#	X					X	X	X	X	X	X	X	#
LEAM	#	#	SC	#	X	#	X #	#				X	#	#	#	#	X	#	#
HFE	#	#		#	X		X												#
PSE Option					X		X												
SP-1 Assembly	#	#		#		#	#	#					#	#	#	#		#	#
SP-2(Array D) Subpallet	#	#					#	#					#	#	#	#		#	#
Ant. Aiming Mech.	#	#	X		X		X	#					#	#	#	#		#	#
RTG Short. Plug	#	#			X		X	#					#	#	#	#		#	#

TABLE 7

ARRAY E FLIGHT MODEL TEST REQUIREMENTS

Item / Model	Acceptance Thermal/Vac	Hot, Cold, Ambient PIA	EMI	Ambient PIA	IST	Mass Properties	Tumble	C/S Verification	Accept. Vib. Random Op.	Accept. Vib. Sine Non-Op.	Deployment & Fastener Verification
C/S Components	#	X	#			X				#	
C/S Electronics Assembly	#		#		#	#	#	X	X	#	
LSP CE & GEO	#	X	#	X	#	X #	#		X CE only	#	# not CE
LSP Explosive Package				X		X				X	X
LMS	#	X	#	X	#	X #	#		X	#	#
LSG	#	X	#	X	#	X #	#		X	X #	#
LEAM	#	SC	#	X	#	X #	#		X	#	#
HFE	#		#	X	#	X #	#			#	#
PSE Option	#		#	X	#	X #	#			#	#
SP-1 Assembly	#		#		#	#	#			#	#
SP-2 (Array D) +E Subpallet	#		#			#	#			#	#
Ant. Aiming Mechanism	#	X		X		X #	#			#	#
RTG Shorting Plug	#			X		X #	#			#	#
RTG	#			X	#	X #	#			#	#

SC Subcontractor Test

X Component Level

System Level

including, on some occasions, the LSPO representative. Handling procedures detailed methods of handling and deploying the experiments on hardware items.

2.2.3 Pretest and Post-Test Meeting Minutes

A meeting was held before the start of a test to verify that the procedure, necessary equipment and personnel were ready for the test and to verify that all prerequisites had been met. When the test was complete a meeting was again held to verify that all of the procedure was completed, including QC and DCAS stamps on every page, to verify that any discrepancy reports (DR's) had preliminary dispositions, Test Discrepancy Reports (TDR's) were closed and that there were no open items.

The activities at these meetings were reported in meeting minutes, signed by all cognizant parties.

2.2.4 Test Reports

There were various types of test reports. The Qual SA test plan identified reports as follows,

"Quick-Look Reports

Quick-look reports are generated daily for each ALSEP model stating the major activity for the following headings:

a) The Last 24 Hours
b) Present Model Status
c) Planned Activity for the Next 24 Hours
d) Problem Areas

These reports are posted on status boards at the Plant II facility and distributed to NASA/MSC and Bendix personnel.

Preliminary Reports

Preliminary reports are issued three working days after completion of the post-test meeting for all acceptance and design limit tests. The contents of the preliminary test reports are:

a) The "as run" procedure including all variation sheets.
b) All DR's generated during the test.
c) The minutes of the post-test meeting.

Final Test Reports

Final test reports are issued 20 working days after completion of the post-test meeting for all acceptance and design limit tests. The final test reports will consist of the following:

a) The minutes for the pre and post test meetings
b) All DR's generated during the test
c) Contents:

1) A brief description of the test, test objective and test scope.
2) A summary of results and conclusions; and recommendations
3) A detailed test description of the test item, test method, and test item performance.
4) A summary of the discrepancies and their disposition
5) Any back-up data required to support the conclusion; charts, photos, graphs, etc."

The final test reports for later models were reduced in scope to consist solely of copies of "as run" procedures, meeting minutes and DR's in an effort to reduce the substantial costs involved in this documentation area.

2.2.5 Test Discrepancy Reports (TDR) and Discrepancy Reports (DR)

When anomalies occurred during test in the early phases of the ALSEP program a DR resulted regardless of the severity of the problem; and MRB concurrence was required with the disposition before further action could be continued. At one point in the program the LSPO resident's concurrence was also required.

This amount of control was determined extremely costly and time consuming and towards the end of the program the system of TDR's was instituted which allowed troubleshooting to be performed, without formal MRB action, to isolate the problem. There were however, definitive rules

imposed to safeguard the equipment and qualification or acceptance status of the hardware. The method meant that simple problems such as procedural errors on faulty test equipment could be disposed of rapidly. A DR was initiated only when the anomaly was identified in the hardware or a piece of test equipment. In the latter case the equipment would be exchanged for an equivalent validated item and the test continued. This method prevented the Alsep hardware documentation from being overly complicated with DR's which really belonged to test equipment, or operator errors as happened under the early scheme.

2.2.6 Logbooks

All major items of hardware or test equipment were required to have logbooks which contained historical data pertinent to the items they represented. This data included operating events log, open DR's, open item status, open Work Order Operation Sheets (W.O.O.S), etc.

These log books were maintained on a day by day basis and were reviewed for completeness prior to every test.

2.2.7 Work Order Operation Sheets (W.O.O.S)

The work order operation sheet was the "traveller" which followed a piece of hardware throughout the manufacturing and test cycle. The manufacturing steps were identified and detailed, and provisions were made for the recording of manufacturing process details (e.g., mix quantities for adhesives, cure times, and traceability information), all of which were verified by Q.C. In addition, the tests required during manufacture and assembly of an item were called out on the W.O.O.S at the relevant steps. This was the standard way of getting an item tested during the manufacturing process.

2.3 Personnel and Facilities

2.3.1 Personnel

The personnel utilized during a test consisted of a test conductor and one or more test technicians, depending upon the complexity of the test. These people performed the test in accordance with the procedure.

Quality assurance and DCASR personnel witnessed the test and verified its results and conformance to the procedure. Engineering support was constantly in effect to monitor test results and troubleshoot anomalies when required.

Towards the end of the program the test conductor was given Q.C. authority which reduced the number of people required and the program costs.

2.3.2 Facilities

The test facilities and test equipment required to support the ALSEP test program were controlled, maintained and calibrated to the same high standards applicable to the total program. Verification of the condition and calibration status of all test facility items was routinely required prior to every test, and was logged in the test procedure during test set up. The significance of the effort required to support the test program with facilities can be appreciated from the following descriptions of the major items:

a) Components Test Laboratory

The Components Test Laboratory (CTL) is an ambient clean room where data subsystem test sets are stored and the component PIA and Central Station Integration tests are performed. S/P#1 and S/P#2 buildup is performed in the CTL.

b) Experiments Test Laboratory

The Experiments Test Laboratory (ETL) is an ambient clean room, where the experiment test sets are stored and all experiment PIA tests are performed. It is also used to perform the RTG acceptance leak and performance test.

c) System Test Laboratory

The System Test Laboratory is an ambient clean room, and is used to perform the majority of the systems tests not requiring an environment, i.e., power dissipation, experiment integration, integrated

system test, etc. Depending on the sequence of tests to follow, the tests mentioned above may be performed in an adjacent shielded enclosure to decrease the number of test set ups required. The STL room houses a system test set which is used in conjunction with the shielded enclosure when performing EMI, stray field magnetic properties, or certain system tests.

d) Electromagnetic Facility

The electromagnetic facility includes a conventional RFI screen room and a shielded room providing both electrostatic and magnetic isolation. The small screen room's dimensions are 20' x 10' x 8'; the shielded enclosure 30' x 16' x 16'. The EMI, the Stowed Magnetic Properties and the Stray Field Magnetic Properties are performed in the shielded enclosure. In addition, depending on the sequence of tests to follow, certain system tests may be performed in the shielded enclosure to decrease the number of test set-ups required.

Included with the Electromagnetic Facility are:

a) Helmholtz coil - 6 ft diameter
b) Instrumentation - Empire Devices - 14 kHz to 10 GH_z
c) Automation Foster Magnetometer, 10 gamma full scale

e) Vibration Facility

The test cell containing the 30,000-lb force and the 1200-lb force exciters is specially constructed to provide acoustic isolation from the rest of the building. Each vibration exciter is equipped with a granite slip table to facilitate testing in three axes. The slip table used with the 30,000-lb force exciter is 8-ft square.

Tests may be programmed using the automatic/manual sinusoidal controls, magnetic tape recording, or the automatic random controls. All automatic tests are closed-loop, servo-controlled using a control transducer to measure the input to the test item.

f) Shock Facility

A 1500-lb free-fall shock machine is used for performing mechanical shock tests. The characteristics of the shock is a function of the medium on which the carriage impacts. A wide variety of half-sine and saw-tooth shock characteristics is available.

g) Acceleration Facility

The Bendix Mishawaka Division provides the facility for the acceleration tests. The Centrifuge is a Rucker Model USN 008128.

h) Thermal Vacuum/Solar Simulation Facility

The 20' x 27' space simulation chamber is capable of 5×10^{-8} torr vacuum (230-mile altitude). A full-end-opening door allows easy installation. The interior of the chamber is lined with black optically tight panels. Liquid nitrogen under pressure is passed through these panels to simulate the cold black of space.

Banks of infrated lamps are available for solar simulation. These lamps are powered by three high-output Power Controllers which may be operated individually or in unison. Heating inputs may be at a fixed level or programmed to a suitable time profile.

2.4 Implementation of Test Program

The test program was implemented in five broad phases

a) Planning

b) Procedure preparation

c) Readiness review

d) Test performance

e) Test review/acceptance.

The extent of these phases was dependent upon the magnitude of the test to be performed. The readiness and acceptance reviews were generally held at the system level for major activities such as the Qualification or Flight acceptance programs. They were occasionally held for single items which were being qualified outside the main stream effort; for instance on a replacement component design for an already qualified system.

The test plans were prepared by Engineering and Type I documents were approved by NASA. The plans were formally agreed to at the test readiness review and a flow chart was included which reflected the intended order of test. This flow chart was usually maintained and updated by a model manager, who documented changes and obtained the necessary customer approvals, via ALSEP Engineering Requirements (AER) or internal memo.

The procedures were prepared by a procedures group using inputs from engineering. Changes were controlled by the normal configuration management policy for drawings. Copies of procedures were reproduced for all meeting attendees at pre-test meetings and copies of "as-runs" were reproduced for engineering analysis, Q.A. audit and post-test meetings.

The major phases of the test program such as system qualification or Flight acceptance were considered sufficiently important that special test Readiness Reviews were held. These meetings consisted of a general session at the system level with satellite meetings for each experiment or discipline area. These meetings were attended by Bendix and NASA personnel and sometimes the Principal Investigator. The conclusion of the test program was followed by a Customer Acceptance Readiness Review (CARR) which followed similar lines to the Test Readiness review. Items needing further action or response were documented on "chits" which required formal processing for response, action and closeout.

An outline of the purpose and form of these reviews is taken from the Qual, SA Model, test plan, ATM 785, and copied below.

"TEST REVIEWS

To assure the customer that the hardware and software is ready to start acceptance testing a Qualification Test Readiness Review (QTRR) is held before the start of acceptance testing. To assure the customer that the

hardware is acceptable and has met the test requirement and test program defined in the QTRR, a Qualification Assessment Review is held upon completion of the total test program.

Qualification Test Readiness Review (QTRR)

Before the formal system qualification test program is initiated, there must be reasonable assurance that the system will complete qualification. This assurance will be obtained from sources such as development and design verification testing and failure analyses. A formal QTRR will be scheduled with NASA to determine the state of readiness for qualification. The test procedures, physical and technical descriptions of the test systems and setup will be reviewed. The analysis of the design verification test results will be correlated with the failure mode and effects analysis and the final design. Differences between the design verification test articles and the production hardware will be explained, including the logic for all changes. An analysis will evaluate whether the previous DVT results are affected by the changes. A list and an analysis of all failures and the corrective action taken during the development and design verification program will be available for review. The result of the QTRR will be a decision whether to proceed with qualification or what action must be taken prior to commencement of qualification.

A. Agenda for QTRR

The following items will be discussed in the QTRR:

1. Test objectives, purpose, sequence and schedule
2. Test set-ups and functional instrumentation
3. Test Environmental Instrumentation
4. General hardware description
   (Evolution of major items and differences between Qual and Flight)
5. Test procedures status and plans
6. Test report plans
7. Review of facilities

In addition, before the review, a data package will be supplied to MSC for review consisting of the following:

1) Comparison between prototype and qualification
2) Comparison between qualification and flight
3) Rationale for differences between qualification and flight
4) All failure reports
5) All discrepancy reports
6) Up-to-date OCS
7) Component serial number assignment
8) Inspection records - Op sheets for C/S integration and for the 399 assembly and higher
9) Status of all chits from the CDR plus all unresolved and rationale
10) All CRD's as result of DVT, prototype plus a description of hardware
11) All assembly drawings for 200 assembly and up, plus a description of hardware
12) Copies of any additional material presented as a part of the review agenda.

Qualification Assessment Review

Upon completion of the Qualification Model acceptance and design limit test program a customer review will be held to assure that all the test program objectives have been achieved. The agenda for the review is as follows:

a) Qualification Model Test Plan
b) Summary of tests (including test objectives, test configuration, test results, open items)

    1) Acceptance Tests
    2) Design Limit Tests
    3) Mission Simulation

c) Test Report Status
d) QTRR Chit Summary and Status
e) Qualification Status
f) Identification of open items and close-out plan
g) Acceptance Data Package"

The actual test followed a fairly consistent ritual. A pretest meeting was held to verify that everything, including the logbooks, test equipment and test facilities was reviewed and approved by QC and DCAS and was ready for test.

In addition, pre test/post test meetings were held between axes of vibration or changes of environment in thermal vacuum tests. These meetings verified that there were no open items or DR's which would prevent commencement or continuation of testing.

The test started with the equipment set up and interconnection, each step being identified in the procedure and verified by QC and DCAS. This phase was very important in the case of the thermal vacuum test where it was uneconomical to open the chamber door once vacuum was achieved. An "open door" test was performed to ensure that the system was operating correctly before pumping was initiated. The test itself was conducted in an identical fashion. Anomalies occurring during test were reported on TDR's, DR's or variation sheets as indicated elsewhere in this report.

The system tests were run sequentially experiment by experiment followed by tests on the complete system. The tests were performed either at each stable environment in thermal vacuum or before and after vibration, shock and acceleration.

The personnel supporting the tests included the test crew of test conductor and one or more technicians, system engineering, experiment engineering and in environmental tests, one or more technicians from the environmental laboratories.

In component tests or single unit tests the procedure was generally the same but the number of personnel was reduced to test conductor, one technician and/or experiment engineer, plus environmental engineers as required. Quality and DCAS personnel witnessed all testing.

Subsequent to the test a post-test meeting was held to verify that the procedure was completed, to decide on the applicability of variations to future tests, to verify that all TDR's were closed and that all DR's had a preliminary disposition and to verify that no other open items existed.

When the test program for a particular model was completed a customer review was held to evaluate and to gain agreement on acceptance of the results.

2.5 Qualitative Evaluation of ALSEP Test Program

The success of the ALSEP hardware in lunar operation, as well as the entire Apollo program is undoubtedly partially attributable to the control and thoroughness in which the total development program was enforced under Apollo standards. The ALSEP test program performance contributed its share to their success. In spite of this fact, it is recognized that additional cost effective measures might still be applied to a program of this nature, without compromise of hardware quality and reliability. It is the intent of the following discussion, to review the ALSEP test program and through hindsight, assess the areas that could be changed on future programs to reduce cost and yet achieve the same high quality of success.

2.5.1 Test Plans

Test planning is a vital part of all programs, and in particular, was significant in ALSEP due to the complex nature of the system. The ALSEP test program was fully documented in this respect requiring Integrated System, System Acceptance and Qualification Plans, and Subsystem Test Plans for each major experiment or subelement. In reviewing the content of each of these plans relative to its effectiveness on program performance, it is concluded that a fair amount of redundancy existed between each plan. As a result, it is recommended that the three system test plans could be combined into one document. Furthermore, additional reference to subsidiary test plan documents could reduce the redundant detail and still result in adequate documentation of the requirements. A "stand-alone" document is desirable for a single point reference, but expensive to prepare and maintain.

The maintenance of current test planning documentation can be a costly item in a program as dynamic as ALSEP. Test plan maintenance was achieved on the ALSEP program through the use of the basic approved plan and with supplemental flow charts which documented the interior changes. Major updates to the plan were initiated at the Test Readiness Reviews and the final "as run" sequence was incorporated at the final Acceptance Review. This procedure resulted in reduced costs as opposed to continually updating and re-releasing the complete test plan.

2.5.2 Procedures

The tests performed on the ALSEP hardware were basically manual in nature, assisted only in part by automated telemetry processing equipment. As a result, test procedure preparation required an extreme amount of detail and accuracy. The procedures used were very concise, step by step instructions consistent with test repeatability requirements as well as the program traceability philosophy. During test, any variations to the basic procedure were carefully documented and were then incorporated in the next revision of the released procedure. As a result, the ALSEP test procedures, although at times appearing to be cumbersome, did fulfill the intended purpose well. This fact is borne out by the ease with which the ALSEP Test Facility was set up and operated nine months after completing the final main stream program tests.

In general, test procedure preparation, control and maintenance was a relatively high cost task on the ALSEP program. The majority of procedures were Type I documents requiring customer approval of the basic release and all subsequent changes. A possible relaxation of this requirement might be considered if detailed test specifications for a given unit were prepared and approved one time leaving the detail of the actual procedure under Type II or III control only. The detail test specification would indicate the test requirement for various levels of test and would indicate methods and test equipment required. This type of document would be more significant to the customer and would be easier to review. The test procedure writers would then use this as the basic input for the detailed procedure.

An additional cost effective measure which could be applied to procedures involves the use of general purpose Standard Test Methods (STM's). The procedure preparation task would be substantially reduced by reference to STM's for operations involving standard test equipment or repetitive operations.

Another facet of cost savings could have been obtained by reducing the approval requirements for procedures. The sign off requirements for ALSEP procedures involved a standard list for all documents including all changes. A screening authority by the configuration control group could reduce the scope of this task and the bulk of reproduced copies by eliminating non-applicable approval requirements.

2.5.3 Reviews and Pretest Meetings

The test readiness reviews were conducted to insure that a system was ready for test prior to embarking on a test program. These reviews verified that the hardware was of anticipated and approved configuration, with no open items, open DR's or other unexpected problems that might jeopardize the test results. The merits of these reviews for large systems have been proven on more than one NASA program.

Pretest meetings served a similar purpose at lower test levels and were used prior to major phases of system tests. The necessity and utility of pretest meetings on lower tier items is questionable.

A high cost item in regard to reviews and pretest/post test meetings is the number of personnel involved and the formality of presentation required. The numbers should be restricted to the minimum required to achieve the intended purpose and to those who will actively contribute. Preparation for these reviews involved a considerable amount of engineering activity to generate formal presentation material. If conducted on a small working group basis this added cost could be substantially reduced.

2.5.4 Test Performance

Actual test conduction was generally performed in an effective and thorough manner. Because of the many disciplines and groups involved, and the extreme constraints on accuracy of test performance, some phases of the test program suffered minor ineffiencies. A relaxation in some of the detailed controls and formalities of test conduction could produce a more efficient operation on future programs. An additional trade off which could be considered in the relative skill of test conductor vs. the details of the procedure. For example, use of engineering personnel, fully knowledgable on the unit under test, performing the test could result in a more cost effective operation of the test program.

3. Typical Program Requirements

A logical approach can be outlined which will be applicable to any hardware item or system of hardware items. The differences will be in detail elements only.

A systems approach should be applied to the problem so that an overall view of the program can be obtained before embarking on detail definition. The major steps to be performed in any program are,

A. Conceptual planning
B. Detail planning
C. Facility and documentation preparation
D. Implementation of Program
E. Reporting.

The degree to which any of these steps is implemented is dependent upon the type of hardware, intended mission for the hardware, program defined requirements and procuring activity special requirements.

3.1 Conceptual Planning

The conceptual and detail planning steps are those where the systems approach is most important. The test program must be viewed as part of the hardware development and not as an entity on its own. The tasks to be performed at the conceptual phase are the identification of the following:

a) the item and its intended usage and environments
b) the development status and resulting test program needed to verify that the design and fabrication processes are adequate
c) data required from test program
d) test equipment and facility requirements
e) time scale imposed and outline schedule
f) allowable budget

Analysis

The basic planning for test and verification of the hardware in any development program is generally performed during the Phase B Definition Phase. The results of this activity are documented typically in part 4 of the system specification to establish the basis for the phase C/D hardware development program. Activities subsequent to the start of phase C/D should be based on firm requirements and should be limited to developing the details necessary for implementation of the basic plan.

In order to adequately define the hardware verification requirements, consistent with programmatic limitation, a systematic analysis must be performed. Figure 2 illustrates the parameters which must be considered and traded off to achieve the most cost effective verification program. The result of this analysis is the verification section of the hardware specification and the basic test plan. Iteration of this sequence may be required depending on complexities of the program and based on changes which may be dictated during negotiation of the hardware contract or as a result of redirection during the on going development phase.

The major parameters and trade offs which require analysis are as follows:

a. System Hardware Design Data: Performance requirements and electrical/mechanical interface parameters must be evaluated at each level of assembly to define test and integration requirements. This analysis includes consideration of the manufacturing plan to determine optimum inspection and test points in the assembly sequence. The qualification philosophy must also be established in conjunction with this analysis to identify the hardware levels which will require qualification.

b. Mission requirements analysis include definition of mission phases, associated operating modes, environmental requirements, crew operation interfaces and data management consideration.

c. Operability requirements include reliability, maintainability, safety and life considerations of the equipment.

d. Model requirements definition is dependent upon all of the above in addition to an assessment of the state of the art of the hardware, the technology mix, and its previous development status. Some simple projects could conceivably be completed with only qualification and flight hardware models being required, whereas more complex programs require a full range of development models.

e. Test methods, test equipment and test facilities must also be considered and input to the decision loop. For example, an instrument system may be sufficiently complex in its operational modes,

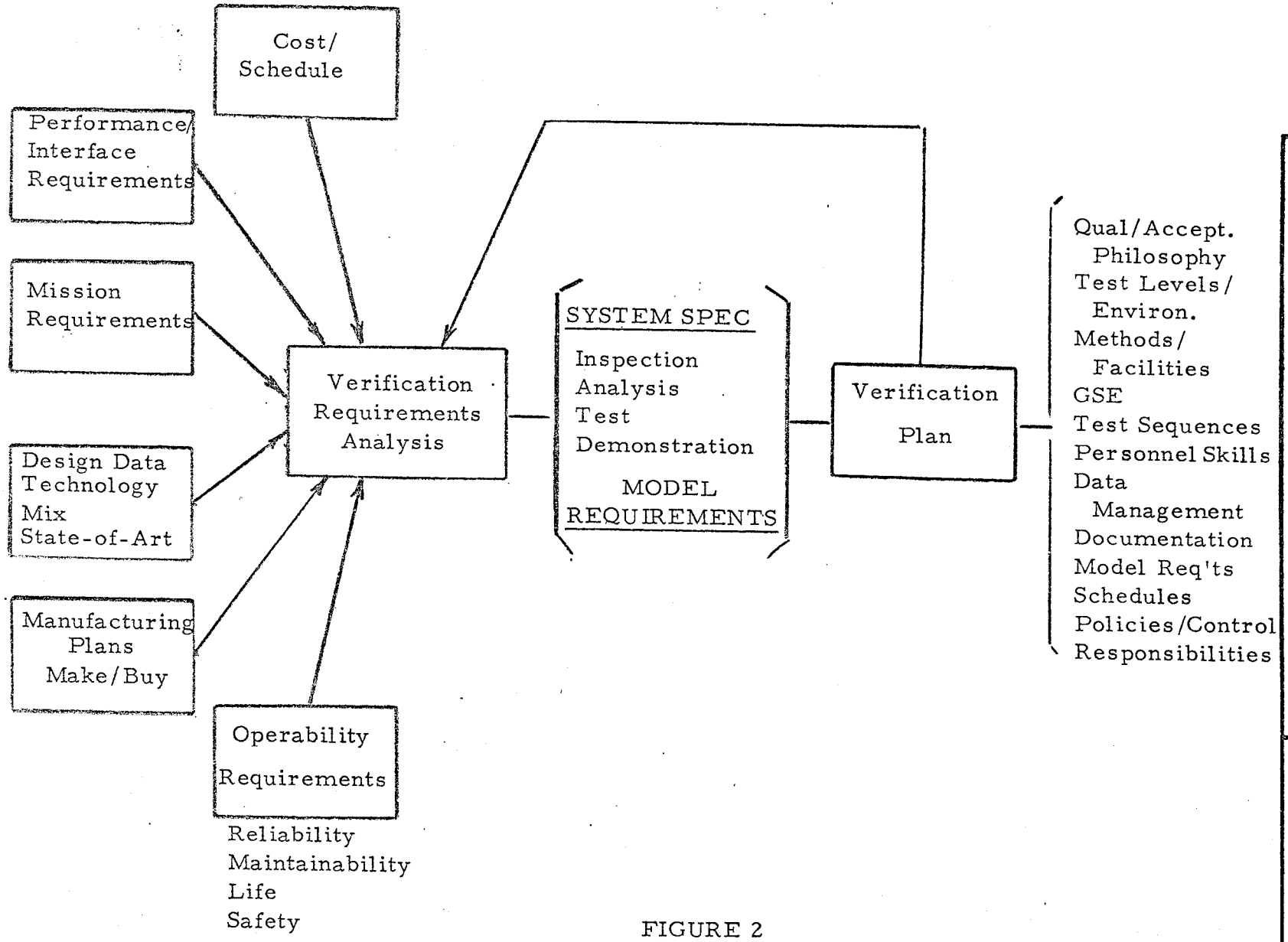


FIGURE 2

DEVELOPMENT OF HARDWARE VERIFICATION REQUIREMENTS

data format and input stimuli, that a complete model may be warranted to accommodate verification of test methods and test hardware and software prior to starting the flight acceptance and qualification test program. Conceptual design of the test equipment must also be performed at this stage to allow the full analysis to be completed for the verification program.

f. Finally, all of the above consideration must be traded off with the programmatic constraints of cost and schedule to produce the most economic approach consistent with the necessary development requirements. This final step must be carefully evaluated relative to the risks involved in reduction of the verification phases and details.

Verification Phases

The verification phases involved in a typical space instrument development program are shown in sequence in the flow chart of Figure 3. A total analysis includes consideration of the requirements for each phase as follows:

- Development Phase:- Verification requirements for this phase involve analysis and test sufficient for verifying the feasibility of the design approach and for providing confidence in the design such that passing the qualification tests is assured. In general, these tests and analyses are performed by the engineering groups and involve hardware models such as breadboards, simulators, mockups, engineering models and prototypes.

- Qualification Phase: - This phase is self explanatory including all verification activities required to verify that flight type and ground support equipments meet the performance requirement with adequate margins under the anticipated operational environments and conditions.

- Acceptance Phase: - The detailed acceptance requirements are the basis for verifying that the end item is equivalent to the previously qualified design.

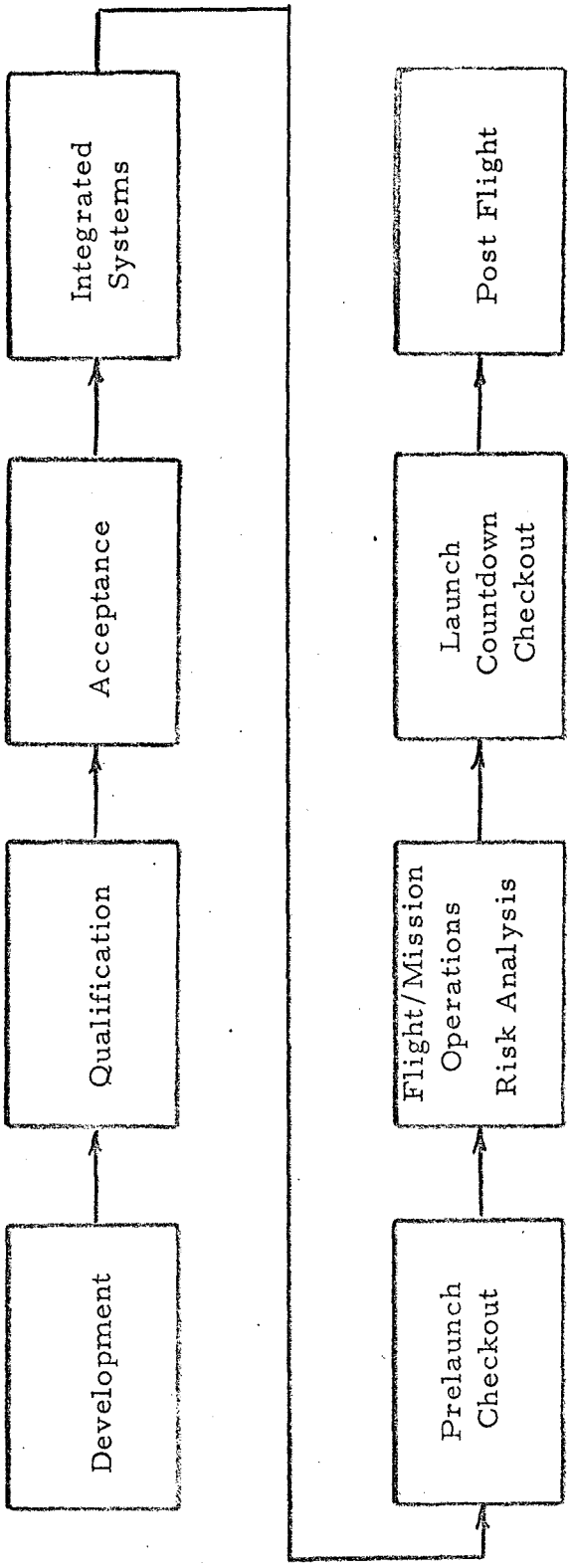


FIGURE 3

PHASED VERIFICATION REQUIREMENTS

- Integrated System: - The integrated system verification requirements establish the acceptability of the instrument or ground support equipment when operating in conjunction with other required interfacing equipments of the program. Results of this phase establish compatibility with interfacing system elements and indicate satisfactory physical and functional performance when operating in the final configuration.

- Pre-launch Checkout: - Prelaunch checkout verification establishes that the instrument as integrated into the space vehicle is ready for launch, or the ground equipment as integrated into the support system is ready to support the launch.

- Flight/Mission Operation: - A final analysis of the results of ground tests may be performed to access the probability of success of the end item to perform the intended mission. This could amount to a risk assessment in the worst case to determine whether or not to proceed with the launch.

- Launch Countdown: - Applicable requirements in this phase are the basis for making predetermined decisions for launch go, launch hold, or launch scrub.

- Post Flight: - The post flight verification requirements are the basis for determining the effects of mission operation on performance and construction of recovered equipment. These requirements will receive additional emphasis in the Shuttle era since recovery of some of the space instruments is planned.

Test Model Requirements

The total development program can be subdivided into two general phases from a test and verification standpoint. The first phase involves design, development, analysis and testing of various hardware models to result in a flight design with sufficient confidence to proceed into the final formal qualification and flight acceptance phase of manufacturing and test. Determination of the hardware models required for these two phases depends on the technological and programmatic considerations outlined above. Some or all of the test models listed below may be required with the lowest technical risk requiring sequential development.

MOCK UPS

Interface verification
Weight, c.g., volume demo.
Man/machine design features
Fit checks/form factor
Design review tool

TRAINERS

Functional/non functional/both
Classroom demo
System and/or GSE compatibility
Maintainability
Crew field training

- Installation
- Deployment
- Operation
- Maintenance
- Recovery

Simulation-Pre/post launch
Design tool for improvement demo
Variable configurations

- Light weight space simulation
- Deployable/non deployable

BREADBOARD/BRASSBOARDS

- Verifies analytical model
  - Empirical test model for performance demonstration under simulated environment
- Demonstrates interface compatibility
- Provides tool for design/checkout of GSE
- Establishes basis for packaging design
- Results with supplementary test data for analytical model
- Provides laboratory tool for verification of design changes

Brassboards serve similar purposes but are sophisticated versions of breadboard models - approaching the engineering model.

ENGINEERING MODELS

- Built to final packaging configuration
- Verifies final design
- Demonstrates structural, electrical, thermal, optical, etc., performance under environment - identification of design improvement requirements
- Demonstrates inter system compatibility - including GSE
- Allows checkout, alignment, assembly procedures to be developed
- Provides basis for design freeze
- Provides basis for completion of tooling design development of manufacturing methods, test procedure checkout, operational and maintenance procedure development
- Verifies complete theoretical design
- Provides engineering tool for change verification
- May be subsystem functional/mechanical models as well as integrated system

PROTOTYPE

- Built using manufacturing tools and methods
- Provides complete test model to verify production test procedures, verify environmental test set ups and GSE compatibility
- Verifies adequacy of manufacturing tools and processes
- Trains manufacturing and test personnel

QUALIFICATION MODEL

- Built using final parts, materials, processes
- Selected (ideally) from production run at random
- Subjected to design limit testing to demonstrate margin of design safety
- Final demonstration of specification compliance

3.2 Detail Planning

Performing the detail planning involves establishing the models to be used, tests to be performed on each model, the order of test, the test equipment and test procedures required to satisfy the program. In addition, the overall program must satisfy the defined schedule and conform to established budgets. The process is thus iterative; involving several attempts to satisfy all the requirements while remaining within budget.

When the models are defined the tests on each model can be detailed. The output of this phase should be a detailed test plan which will include the following:

a) Test models
b) Equipment required
c) Facilities
d) Tests to be run on each model, including test levels and test sequence
e) Test procedures to be used, by title and number
f) Data requirements

This test plan should be the governing document, under configuration management control, and should be the authority to run tests.

The data obtained during test should be part of a coordinated data plan which includes all testing and mission operational data. This is to ensure that all mission aspects are covered during test and that data collected during test is relevant to the mission and can be used in the future for correlation purposes. The requirements for the test equipment are a natural fall out of the data requirements definition.

3.3 Facility and Documentation Preparation

3.3.1 Facility Preparation

The facility requirements include test equipment, laboratories and environmental facilities.

The test equipment must be designed and built in accordance with the detail plans previously prepared. The data management capabilities shall be considered in the light of the overall data handling concept for the program. One of the pitfalls to be avoided is that of expecting meaningful manual evaluation of output from an experiment which outputs volumes of data. Analysis of such data in a reasonable time with any expectation of accuracy is difficult. Careful consideration should be given to the use of a minicomputer or computer compatible storage. Another very important aspect of test set design is to ensure that all interfaces are an identical representation of those to be experienced in the mission and that all functions can be exercised.

The laboratory factors to be considered include those of power, special facilities, cleanliness and limited access. The environmental facility requirements depend upon the type of tests to be performed, but would normally include handling fixtures, vibration fixtures, thermal vacuum equipment and special fixtures, cabling and special recording equipment.

3.3.2 Documentation

The major component of documentation is the test procedure. The depth and detail necessary in the test procedures is governed partially by the type of program. In a program where several models are to be tested in a production like manner, by semi-skilled technicians, the procedures should be well detailed and specific such that no interpretation is left to the operator. When the items to be tested are one or two of a kind, specialized pieces of hardware, necessitating the presence of engineering, either to assist or virtually conduct the tests, a less structured procedure can be used. The purpose of the procedure in this case is to ensure accountability and recording of results, to ensure repeatability and to allow for subsequent analysis of results and actions.

The control of procedures should be under configuration management but via a simpler and less formal method than that used for drawings.

The first task in facility and documentation preparation is to coordinate the activities with the detailed test plans and schedules formulated in the earlier activities. The scheduling of procedures often overlooks the time required for review, modification and approval by both the contractor's and customer's personnel. This time must be allowed for in the schedules and not under estimated.

3.4 Program Implementation

The following items are typical of the major consideration involved in implementation of the verification program and test operations.

a. Assignment of Responsibilities: A clear definition of responsibilities is most important for all verification programs regardless of the size or complexity. Engineering, manufacturing, quality assurance and reliability groups or disciplines may be involved in the various levels of test during a typical verification program. In addition, customer representatives may also be required to witness some or all to the testing. The contract end item specification and work statement should delineate the customer requirements. This definition, however, should be carefully weighed in terms of accomplishing the particular program in the most cost effective manner. For example, the development verification phase primarily involves engineering. Qualification and acceptance phases may require some or all of the other disciplines, depending on the program. In the case of a small rocket type experiment, engineering may be assigned responsibility for all verification requirements with a final sell off under customer witness. High reliability programs requiring traceability of all parts and materials or programs which are critical in saftey areas would probably require all disciplines at many levels of test.

b. Preparation for test: Efficient test performance and application of personnel requires thorough preparatory activities. These activities include test procedure and software preparation and verification, test equipment checkout and calibration, facility preparation and test personnel training. In programs of significant size or complexity, pre-test meetings which include representatives of all participating groups are useful to establish the final test preparation and assume the scheduling of personnel.

c. Test Conduct: Test conduction is an orderly, controlled activity involving man and machine. The factors involved are test personnel skill requirements vs. complexity of test article and sophistication of test equipment, adequacy of procedures, operation and control of environmental facilities, interpretation of test results, in process documentation requirement, safety consideration for both personnel and equipment, and quality and customer witness and control requirements.

Performance of test for space quality instruments is typically much more sophisticated than would be involved in routine testing of large quantities of items in a production process. The test of space systems requires a very high degree of skill and a complete understanding of the function of the unit under test. As a result, the selection and training of the test personnel is a critical factor. In some cases, use of the engineering design personnel for test performance provides the most cost effective approach. This is particularly true for a small one-of-a-kind instrument in which the testing can be performed in conjunction with other tasks such as analysis and data reduction. This provides the advantage of having engineering support always at hand for troubleshooting anomalies, etc. Additionally, test procedures can be somewhat abbreviated when the proper skill is available to perform specialized performance tests.

Thorough documentation of the test performance and results is always required although the formality of the documentation is again dependent on the type of program. In the case of the high reliability program, the tendancy is to formalize all steps and changes performed during test with QA witness and approval throughout. This extent of control tends to be somewhat inefficient in the apparent real-time conduct of test, but is necessitated in order to control the traceability aspects of the hardware.

d. Other Verification Requirements: In addition to test, verification of performance and design can include inspection, analysis, demonstration and verification of records. Inspection, for example could involve verification of mechanical interfaces either by measurement or a fit check with an interface tool. Analysis relates to requirements which are impractical to verify by test or demonstration, e.g., reliability, life, etc. Maintainability or deployment aspects of the hardware can be verified by demonstrations. Verification of parts and materials selection is accomplished through review of design documents and manufacturing records. Engineering reliability and Quality Assurance disciplines may be involved in all of these types of verification tasks.

3.5 Reporting

The reporting aspects of the verification program also vary with the type of program and the intended utilization of the test results. As a minimum, the "as-run" test procedure including documented anomalies and resolution of the anomaly can be sufficient documentation for acceptance of the test article. In some cases data must be extracted from the basic test procedure and analyzed in detail. The results of this analysis can be required before acceptance in assured and thus these results must be reported. Another possible use of test data could be in characterizing or calibrating the instrument. This data would need to be documented in order to support mission flight data interpretation.

The formality and need for approval requirements of post-test documents should be considered carefully in all cases since this can be a costly activity.

4.0 RECOMMENDATIONS

The ALSEP test program is considered as fairly typical of the requirements for a high reliability type test program for a space instrument system. This program has consequently been used as a baseline for recommending the approaches to planning, defining the documentation and conducting verification tasks on similar programs.

In an attempt to quantify test requirements in terms of cost effectiveness for various types of scientific payload programs, a list of requirements has been compiled and evaluated against three basic types of payloads. Table 8, Cost Effectiveness Recommendation, summarizes this analysis and the following paragraphs define three basic payload classes and the associated assumption used to perform the evaluation.

Class I

A Class I payload involves equipment which is basically nonrecoverable and nonmaintainable. Further, the mission involves an important single scientific opportunity and requires a relatively high investment to deploy the payload (i.e., launch vehicle, support system, etc.). As a consequence, the highest achievable reliability in the payload is the primary driver. The program approach for this type of payload, then includes full hi-reliability program requirements with necessity criteria, full documentation and reporting, formal approvals for design, parts and materials, program plans and verification results, and formal design reviews, readiness reviews and acceptance reviews. Customer/contractor interfaces are detailed and continuous under this type of program and normally, the customer witnesses all inspection, test and acceptance activities. Additionally, configuration management tasks are required to the fullest extent with a FACI and Class I change approval requirements. Examples of this type of payload are ALSEP, VIKING, LST, and other interplanetary space payloads such as the Mariner series.

Class II

A Class II payload is defined as follows:

a. The scientific objective is a secondary mission objective (i.e., the return on mission investment would not be significantly compromised by loss or malfunction of the science.)

or, b. When the science is primary to the mission objective, multiple scientific opportunities exist, the payload can be maintained in flight or recovered and refurnished for subsequent mission, and a medium to low investment is involved in deploying the payload.

In both of these cases, cost effectiveness of the payload development program is the primary driver. The program costs can be reduced with the following guidelines:

- Minimal organization - Program Manager with Engineering, R&QA, Manufacturing Supervisors typical.
- Reduced customer/contractor interfacing requirements.
- Contractor QA only inspection, test, acceptance.
- Documentation minimized to absolute essential.
- Reduced formal meetings.
- Utilization of existing (acceptable) contractor plans/procedures.
- Reduced Configuration Management (no FACI).
- Test program performed under engineering cognizance, minimal QA.
- Manufacturing documentation and controls minimized to "good commercial practice".
- Reliability engineering performed as basic design discipline but formal reporting/documentation reduced to essential only.
- Typical program examples: ASTP, Shuttle Sortie Mission Experiments, Skylab Experiments.

Class III

A Class III payload is based on a development program and mission in which low cost is the primary driver. Multiple scientific opportunities exist for the mission and the deployment investment is minimal. Rocket and balloon borne instrument packages are examples of the type of payloads considered in this class. All activities of the development program for Class III payloads are performed on an engineering/model shop basis with project management, design, parts and materials selection, fabrication, assembly and test, and configuration management and quality assurance functions all under engineering cognizance. Documentation and reporting is informal and encompasses a basic minimum consistent with acceptable project completion at lowest possible cost.

TABLE 8

COST EFFECTIVENESS RECOMMENDATIONS

Program Requirement and Subelements	Payload Class I	II	III	Notes
Verification Requirements Analysis	X	X	X	1
End Item Specification (Section 4)	A	A	A	1
Test Plan Documents	A	A	I	2
Test Facility Review and Approval	A	-	-	
Test Equipment Design Documentation	A	I	X	3
Test Equipment Software Documentation	A	I	X	3
Test Equipment Acceptance	A	I	X	3
Test Equipment Maintenance Manuals	A	I	-	3
Development Models/Verification Results				4
Breadboard	A	I	X	
Engineering Models	A	I	X	
Simulators & Mockups	A	I	X	
Prototype	A	I	-	
Qualification	A	A	X	
Flight	A	A	A	
Test Program Reviews				
PDR	A	I	-	
CDR	A	I	X	
Qual Test Readiness Review	A	I	-	
Qual Assessment Review	A	A	-	
Flight Test Readiness Review	A	I	-	
Customer Acceptance Review	A	A	A	
Detail Test Procedures	A	X	X	5
Pre/Post Test Meeting	X	X	-	6
Test Witness, Contractor QA	A	X	-	7
Test Witness, Customer Representative	A	X	-	7
Material Review Board Control	A	A	X	8
Test Reports	A	A	-	9
Design Certification Reports	-	-	-	10

TABLE 8 (CONT.)

Legend:

X: Task performed but not necessarily on a formal customer control or documentation basis

A: Customer approval required

I: Information only documentation or informal task not requiring customer approval

-: Task or document not recommended.

TABLE 8 NOTES

1. Analysis of verification requirements and documentation of results in the end item specification is a necessary activity in all payload classes. This serves as the basis for contract work definition and negotiation.

2. For a low cost program, the task statement may serve as the test plan. A formal Test Plan Document should not be required.

3. Hardware design and software documentation for test equipment should be generated by the contractor for maintenance and calibration purposes. For deliverable GSE, documentation can also be minimized, particularly if maintained under contractor cognizance in field use. Interface data may require review and approval if the GSE is integrated into higher level systems in field use.

4. Requirements for various models depend on the particular program and state of development. For low cost Class III payloads multiple use of single hardware models should be considered. For example the first item built may be basically an engineering model updated and tested to qualification requirements and then flown as the flight article.

TABLE 8 NOTES (CONT.)

5. The level of detail in test procedures can be reduced for the different payload classes. Test operations in a Class III payload program, for example would probably be accomplished by engineering personnel, and would not afford a significant expense in preparation of detailed test procedures. A tradeoff is obviously required, however, in that the level of skill of the test personnel is probably inversely proportional to the completeness of the test procedure.

6. Pre and post test meetings are in some respects a function of program size and test complexity, and are additionally dependent on internal test program policies of individual contractors.

7. Test witness by contractor QA and customer representative is variable. Final acceptance of the end item would always involve customer approval. Actual witness of test, however, may not be absolutely necessary. A customer acceptance review of test results only would probably be acceptable in Class III payloads, for example. The level of test witness also varies; Class I programs would probably involve QA and customer witness at least in subsystem and system levels, whereas in Class II programs, end item acceptance testing witness would probably be sufficient.

8. Material review board (MRB) functions would probably be formal activities in Class I and II payload test programs. The functions could be informally performed under the engineering project, however, for a Class III payload to save costs.

9. Test reports are normally prepared and submitted for review and approval for Class I and II payload programs. The content should be minimized in both cases for cost effectiveness. Availability of as-run documentation for review only is necessary for the Class III program and no separate report is recommended.

10. The Design Certification Report is typically a summary of all tests and verifications conducted during the development, qualification and acceptance phases. While this document provides a convenience for the reviewers of test program results, it is felt that it is redundant with other program documentation and its requirement should be carefully considered in a cost effective atmosphere.

5.0 CONCLUSIONS

The foregoing sections of this report have described the ALSEP test program, provided some thoughts on areas of possible improvement, and, based on knowledge gained from the ALSEP program as well as other similar space instrument projects, developed the general guidelines which must be considered in any verification program. Probably the most significant aspect of the general information noted is in the formulation and planning phases. The thoroughness of the system analysis effort can have a major impact on the hardware development phase and the overall cost effectiveness of the verification program. Further, it has been noted that a certain amount of flexibility must be considered in the preliminary planning phases. As the development program proceeds, changes do occur and new insights into methods and alternate verification concepts develop as a result.

An additional factor of the total test program which should be carefully considered is the formality and quantity of documentation. This can be a significant cost item and should be limited to that which is absolutely necessary to fulfill the program requirements.

Finally, it is recognized that the observations and recommendations presented in the latter portion of this paper are general in nature. The intent was to compile the basic elements of a verification program which must be analyzed and traded off prior to committing to the actual program implementation. While these considerations are generally applicable, the specific requirements and constraints of the particular program must be analyzed in detail to produce the most cost effective approach consistent with the technical requirements of the test program.

REFERENCES

ALSEP Technical Memoranda (ATM)

ATM 7	ALSEP Test Plan 9-17-65
ATM 8	Qualification Test Plan 9-17-65
ATM 15	ALSEP Ground Operations Plan
ATM 785	ALSEP Qual SA Qualification Test Plan
ATM 99	Thermal Test Requirements and Plans
ATM 505	Development of Space Thermal Simulation Techniques for ALSEP

MSFC Data Procurement Document #395 for LST - CEI Specification Format