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Verification Handbook

Volume I: Verification Process

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Verification Handbook

Volume I: Verification Process

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LIST OF ACRONYMS AND ABBREVIATIONS

ATP	Authority to Proceed
BER	Bit Error Rate
CDR	Critical Design Review
CEI	Contract End Item
CIR	Certification Inspection Review
CITE	Cargo Integration Test Equipment
DCR	Design Certification Review
DMS	Data Management Subsystem
DRD	Data Requirements Document
ECE	Electrical Checkout Equipment
EMC	Electromagnetic Compatibility
FRF	Flight Readiness Firing
FRR	Flight Readiness Review
GETG	General Environmental Test Guidelines
GIRD	Ground Integration Requirements Document
GOR	Ground Operations Review
GSE	Ground Support Equipment
I&C	Instrumentation and Communication
IIA	Instrument Interface Agreement
ICD	Interface Control Document
IPCL	Instrumentation Program and Components List
IPL	Integrated Payload
IPRD	Integrated Payload Requirements Document
IRD	Interface Requirements Document
IRR	Integration Readiness Review
KSC	Kennedy Space Center
MLI	Multi-Layer Insulation
MMI	Marshall Management Instruction
MPE	Mission Peculiar Equipment
MROFIE	Mission Requirements and Facilities/Instruments/Experiments for Space Transportation Systems Attached Payloads
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

NCR	Non-Conformance Report
OMRSD	Operations and Maintenance Requirements and Specifications Document
OPF	Orbiter Processing Facility
ORI	Operational Readiness Inspection
PCS	Pointing Control Subsystem
PDR	Preliminary Design Review
PN	Pseudo-random Noise
POCC	Payload Operations Control Center
PRR	Preliminary Requirements Review
RF	Radio Frequency
RFP	Request For Proposal
RID	Review Item Discrepancy
RR	Requirements Review
SPG	Single Point Ground
SRD	Systems Requirements Document
SRR	Systems Requirements Review
SSE	Space Support Equipment
STS	Space Transportation System
STE	Special Test Equipment
TCS	Thermal Control Subsystem
TCRSD	Test and Checkout Requirements Specifications Document
TDRSS	Tracking and Data Relay Satellite System
TRR	Test Readiness Review
TV/TB	Thermal Vacuum/Thermal Balance
VAB	Vertical Assembly Building
VRM	Verification Requirements Matrix
VRSD	Verification Requirements and Specifications Document
VSWR	Voltage Standing Wave Ratio
WBS	Work Breakdown Structure

LIST OF REFERENCE DOCUMENTS

MSFC DOCUMENTS

The following documents, latest revision unless otherwise specified, form a part of this handbook to the extent specified herein.

JA-447	Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads (MROFIE)
JA-061	Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Spacelab Payload
JA-062	Spacelab Integrated Payload System Verification Requirements
JA-081	Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE and ECE on STS Partial Payload Missions
JA-082	System Verification Requirements for Integrated Payloads on Partial Payload Missions
JA-276	Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Orbiter Middeck payload Missions.
MMI 8010.5	MSFC Baseline Design Review
MMI 8040.12	Standard Contractor Configuration Management Requirements MSFC Programs
MMI 1700.6D	MSFC Operational Readiness Program
MSFC-HDBK-670	General Environmental Test Guidelines (GETG) for Protoflight Instruments and Experiments
MSFC-HDBK-1912	Systems Engineering Handbook
MSFC-STD-126E	Inspection, Maintenance, Proof Testing, and Certification of Handling Equipment.

1.0 INTRODUCTION

Verification is the process of confirming that deliverable ground and flight hardware and software are in compliance with design and performance requirements. A verification program assures that all applicable program requirements have been met. The verification process begins early in project definition and continues throughout the life cycle of a project. The verification processes and associated documentation across Marshall Space Flight Center (MSFC) projects are not the same. Each project develops a verification program considering cost and schedule impacts and the risks associated with the impacts. All projects will strive to achieve the objectives of the verification process as described in this document.

1.1 PURPOSE

The purpose of this handbook is to describe typical verification activities utilized in MSFC Programs. It is meant to be a working reference and guide to performing the verification planning, requirements and compliance activities. This handbook is not intended to be a statement of policy, nor to recommend changes to any existing MSFC policies.

1.2 SCOPE

This handbook defines and documents the verification process preferred by the Systems Verification Branch for MSFC in-house programs. The handbook also defines additional activities and variations of the process that could be used with a launch vehicle program, a Spacelab Payload Program and a program developed by a contractor. No one process can be applied to every program, and each verification activity and product defined herein must be assessed as to the applicability it may have on any specific project. This handbook defines and describes each activity and product of a process beginning with a verification program concept and continuing through post-flight data analysis.

1.3 HANDBOOK ORGANIZATION

This handbook is divided into two volumes. Volume I, Verification Process, defines a verification process and variations to the process. Volume II, Verification Documentation Examples, provides examples of the documentation that are generally required as products of a verification program.

Volume I includes verification process flows for the verification process described and for the variation to the process that can be used for Spacelab payloads. The flows identify generally the period in the process that a particular activity occurs. The activity number identified in the flows corresponds to the number in the text that describes that particular activity. For example, activity number 2.1.1.2, Verification Program Planning, in the verification activity flow corresponds exactly to section 2.1.1.2, Verification Program Planning, of the handbook text.

1.4 PROGRAM AND ORGANIZATIONAL RELATIONSHIPS

Verification planning, requirements and compliance activities at MSFC are considered a part of the Systems Engineering process. However, all design and test organizations are heavily involved with verification planning and requirements definition activities. All the verification activities require considerable coordination by the verification organization.

Some verification planning generally begins in Phase A (preliminary analysis of a concept) of a program. Inputs to preliminary schedules and cost estimates are generally made during this phase. The activities increase substantially in Phase B (program definition and preliminary design) with the refinement of requirements, cost, and schedules. Systems requirements are assessed to determine preliminary methods of verification and to ensure that the requirements are verifiable. The outputs of Phase B are carried into Phase C/D activities. For

the purpose of this handbook, the verification process defines activities normally beginning in Phase C.

The verification activities and documentation required for a specific flight article generally depend upon the NASA payload classification of the flight article. There are four payload classifications, Class A through Class D. The verification program for a Class A payload which is developed with a minimum risk, is considerably more comprehensive than that for a verification program for a Class D payload, which is developed at a low cost, with greater risks and with minimum documentation.

Further definition, including program phases and payload classifications, of the systems engineering process and the relationship of verification to the systems engineering process is provided in MSFC-HDBK-1912, Systems Engineering Handbook, Volume I, Overview and Processes.

2.0 VERIFICATION PROCESSES

A verification process is tailored for every verification program. The distribution of verifications within the process is dependent upon the flight article (an experiment, a payload or a launch vehicle). Many factors are considered in developing the verification activities. Programmatic decisions and risk assessments are made that determine the methods of verification that are to be used and the phase within the verification process that the methods(s) of verifications will be performed. Program cost and schedule are big drivers of risk assessments and programmatic decisions generally have great impacts on the verification program. Program cost must be considered in the early development of the verification program and program schedule can adversely affect verification activities as a program progresses through the later phases. Trade studies, also, are performed to support development of verification methods, the selection of facility types and locations and the development of verification requirements.

A verification process developed in-house at MSFC and a process developed out-of-house by a MSFC contractor are generally similar because the process developed by the contractor is normally focused toward MSFC processes through the Statement of Work. Although the processes and their implementation may differ, they are developed to achieve the same end result.

2.1 PROCESS FOR MSFC DEVELOPED PROGRAMS

The verification process for MSFC developed programs should be tailored to meet the need of the individual program. Each process is designed to assure that the flight article and Ground Support Equipment (GSE) perform within their design and performance specifications, and that compliance to all the program requirements has been shown.

The handbook provides a verification process for an in-house program (e.g. AXAF-S) and also provides a variation to the process that can be used for Spacelab type payloads. Also, the handbook describes the variation in the process that can be used for a launch vehicle program.

2.1.1 VERIFICATION PROCESS

The verification process flow for most MSFC in-house programs is essentially the same. Figure 2.1.1-1, Verification Process Flow, shows a flow of the verification process. The flow provides a sequence of activities that occur during the verification process. The numbers of each block of the flow identify the corresponding paragraph within the text that describes the activity. More than one block may reference the same text paragraph as the activity may occur more than once during the flow.

Safety reviews as applied to verification activities are not shown as separate activities in the flow but are addressed as part of the text. The verification of the software after installation in the flight article is considered in the verification process, as is flight hardware.

2.1.1.1 Assess Level I/II/III Program Requirements

A thorough understanding of the program and mission requirements is necessary before the planning and development of a comprehensive verification program is initialized. The verification program must assure compliance to all the program requirements and is structured to do so. The requirements available are normally Level I program requirements generated by NASA Headquarters, and Level II and III program requirements generated by MSFC. The Level II and Level III Program Requirements are developed from the Level I requirements and requirements from the outputs of Program Phase A studies (preliminary analysis of a concept)

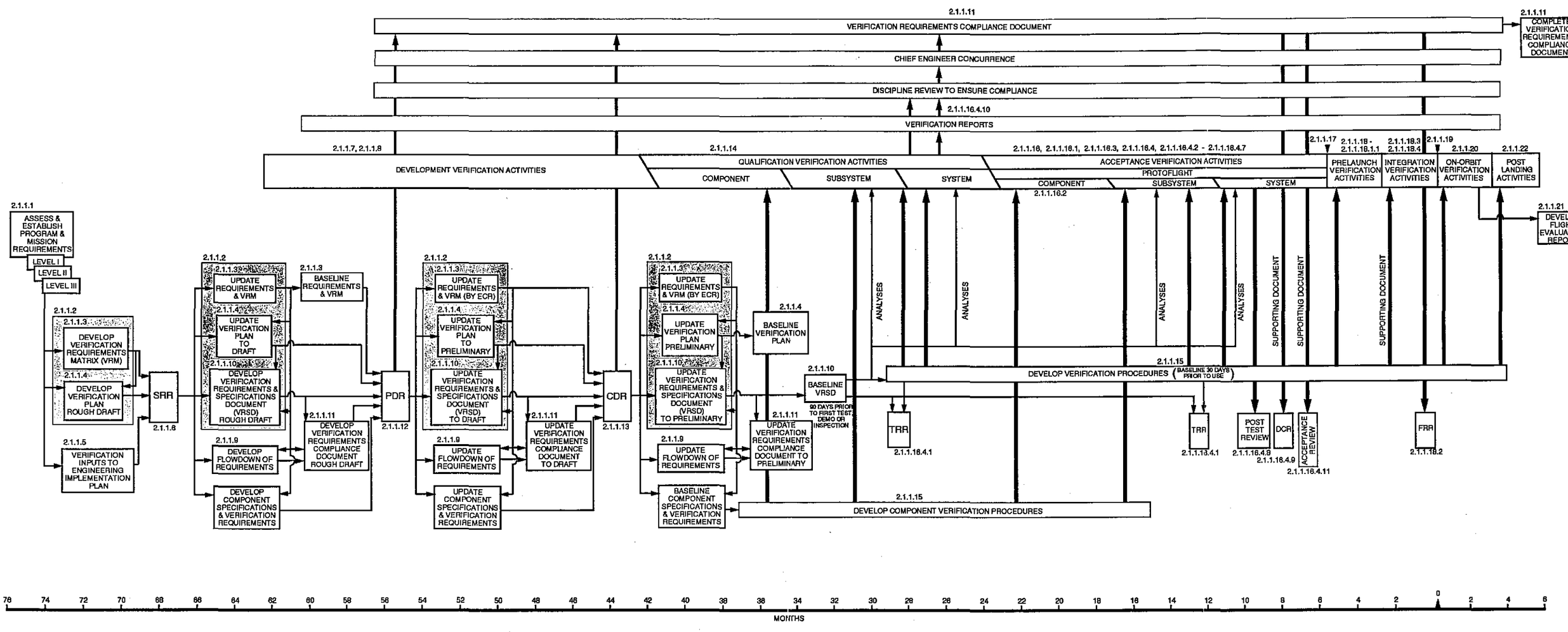

FIGURE 2.1.1-1 VERIFICATION PROCESS FLOW

and Phase B (Program definition and preliminary design). These requirements define the design and performance requirements for the flight article and are further defined in lower tier documents by the Level II and Level III Systems Requirements Documents (SRDs), the Contract End Item (CEI) Specification, the Interface Requirements Documents (IRDs) and Interface Control Document (ICD). Preliminary inputs to the Work Breakdown Structure (WBS) may also be available, as would be a program schedule and a technical schedule from Phase A/B studies.

2.1.1.2 Verification Program Planning

Verification program planning is an interactive and lengthy process occurring during all phases of a project, but more heavily during Phase C. An effort is made throughout the requirements definition of a program to phrase those requirements in absolute terms, to simplify verification of those requirements. A preliminary definition of verification requirements and activities is developed based on the program and mission requirements. The definition of verification requirements advances as the systems and interface requirements are established and refined. Design and performance requirements are assessed to determine the appropriate method of verification, usually, by either tests, analysis, inspection, similarity, demonstration, or a combination thereof. These design and performance requirements and the method(s) of verification are specified by the SRD or the CEI Specification. The methods of verifications to be performed are identified for each phase of verification. The level of development of the flight article at which the verification is to be performed is also identified. Environmental controls (e.g. contamination) that must be levied during verification activities are also considered.

Risk management must be considered in the development of the verification program. Risk assessments and risk analysis are performed to determine the most acceptable methods to ensure compliance with the design and performance requirements. The Program Office must determine what newly defined risks are acceptable in terms of cost and schedule. Considering all impacts and risks to the project, requirements for major verification activities are proposed and refined. An example of a trade-off would be to perform a modal test versus determining modal characteristics by analysis. Also, in planning for a verification program consideration must be given to the location in the flow of a payload where a particular test is to be performed. In general, all approaches to the verification of a requirement must be considered and assessed.

The Ground Support Equipment (GSE) necessary to perform testing and to handle the payload through all phases of integration is determined. This will include both electrical and mechanical GSE, including the data acquisition system to be used for testing. Facilities necessary for assembly, test, integration, and handling at all integration locations are identified. The verification of all GSE and facilities is planned. This planning activity may identify additional GSE and facilities. Preliminary ground test software necessary to accomplish the required verifications is identified.

During the planning activities, the documentation required to support the verification program is identified. Normally, a Verification Plan, a Verification Requirements and Specifications Document, a Verification Requirements Compliance Document, and a CEI or SRD Verification Requirements Matrix are necessary. Documentation for test implementation may also be defined.

A preliminary schedule of activities associated with development, qualification, and acceptance of the payload is outlined to be in accordance with program milestones and is updated as verification activities are refined.

2.1.1.3 Verification Requirements Matrix

The Verification Requirements Matrix (VRM) of a requirements document (generally a SRD or CEI Specification) defines how each design and performance requirement is to be verified and the particular phase of the program the verification is to occur. Verification levels,

such as component, system, etc., may also be defined. The VRM contents are tailored to each program's requirements, but the level of detail in the VRMs may vary. The VRM is developed through a close coordination with all technical discipline organizations. This matrix is baselined with the requirements early in Phase C and essentially establishes the base for the verification program. The VRM for a CEI Specification is developed in accordance with MSFC MMI 8040.12.

2.1.1.3.1 Methods

Verification methods are the method(s) by which the requirement is to be verified. The following methods are generally used:

(1) Test

Verification by *test* is the actual operation of equipment during ambient conditions or when subjected to specified environments to evaluate performance.

(1a) Functional Test

Functional testing is an individual test or series of electrical or mechanical performance tests conducted on flight or flight-configured hardware and/or software at conditions equal to or less than design specifications. Its purpose is to establish that the system performs satisfactorily in accordance with design and performance specifications. Functional testing generally is performed at ambient conditions. Functional testing is performed before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

(1b) Environmental Test

Environmental testing is an individual test or series of tests conducted on flight or flight configured hardware and/or software to assure the hardware will perform satisfactorily in its flight environment. Environmental tests include vibration, acoustic and thermal vacuum. Environmental testing may or may not be combined with functional testing depending on the objectives of the test.

(2) Analysis

Verification by *analysis* is a process used in lieu of or in addition to testing to verify compliance to specification requirements. The selected techniques may include systems engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and computer modeling. Analysis may be used when it can be determined that:

A. Rigorous and accurate analysis is possible.
B. Test is not feasible or cost-effective.
C. Similarity is not applicable.
D. Verification by inspection is not adequate.

(3) Demonstration

Verification by *demonstration* is the use of actual demonstration techniques in conjunction with requirements such as serviceability, accessibility, transportability and human engineering features.

(4) Similarity

Verification by *similarity* is the process of assessing by review of prior acceptance data or hardware configuration and applications that the article is similar or identical in design and manufacturing process to another article that has previously been qualified to equivalent or more stringent specifications.

(5) Inspection
Verification by *inspection* is the physical evaluation of equipment and/or documentation to verify design features. Inspection is used to verify construction features, workmanship, dimension and physical condition, such as cleanliness, surface finish, and locking hardware.

(6) Simulation
Verification by *simulation* is the process of verifying design features and performance using hardware or software other than flight items.

(7) Validation of Records
Verification by *validation of records* is the process of using manufacturing records at end-item acceptance to verify construction features and processes for flight hardware.

(8) Review of Design Documentation
Verification by *review of design documentation* is the process of verifying the design through a review of the design documentation during the Preliminary and Critical Design Reviews.

2.1.1.3.2 Phases

The verification phases are defined periods of major program activity when verification is to be accomplished. The following phases are generally used:

(1) Development
The Development Phase is the period during which a new program design or concept is initiated, refined and implemented up to manufacturing of qualification or flight hardware. Activities during this phase will provide confidence that the new design and concepts will accomplish mission objectives.

(2) Qualification
Qualification Phase is the period during which the flight (protoflight approach) or flight type hardware is verified to meet the performance and design requirements. Verifications during this phase are conducted on flight configured hardware at conditions more severe than acceptance conditions to establish that the hardware will perform satisfactorily in the flight environments with sufficient margin.

(3) Acceptance
Acceptance Phase is the period during which the deliverable flight end-item is shown to meet design and performance requirements under conditions specified by a particular flight or mission. The acceptance phase ends with shipment of the flight hardware to the launch site.

(4) Prelaunch
Prelaunch Phase is the period which begins with the arrival of the flight hardware and/or software at the launch site and terminates at launch. Requirements verified during this phase are those which demand the integrated vehicle and/or launch site facilities.

(5) Flight/Mission
Flight/Mission Phase is the period which begins at liftoff and continues through on-orbit verifications or through a mission and return to earth. During this phase, systems are verified to operate in space environment conditions and requirements requiring space environments are verified.

(6) Post-Flight
Post-Flight Phase is the period which begins at landing and continues through Post-flight verification activities. Requirements verified during this phase are those that prove accordance with post flight checkout, maintenance and resupply actions.

2.1.1.3.3 Levels

Verification levels are used to identify hardware levels at which discrete verification activities occur. The following are generally used if levels are defined:

(1) Component
The component verification level is the level at which verifications are performed on an individual end item. Verification at this level is the first activity applied prior to a component being integrated into a subsystem.

(2) Subsystem
The subsystem verification level is the level at which verifications are performed on two or more components, including interconnecting cabling, that have been integrated into a functional subsystem. The subsystem verification level follows the component verification level. Verification of a subsystem can be performed during the development, qualification, or acceptance phases, and may include flight or flight configured hardware separately or in combination. The subsystem level includes such as the electrical subsystem and thermal subsystem.

(3) System
The system verification level is the level at which verifications are performed on the integrated subsystems. The system verifications include subsystem and system interface checks, functional and mission sequence simulation tests.

Volume II of this handbook provides a sample VRM that identifies verification methods and phases which are generally used for a given requirement.

2.1.1.4 Verification Plan

The Verification Plan is the document that describes the overall verification program which has been planned. The plan defines assembly, qualification, analyses, and acceptance testing which is required to be performed to satisfy design, performance, safety and interface requirements. Each major activity is defined and described in detail. The plan also describes the development and acceptance test of flight and test software, the ground support equipment and the facilities necessary to support the verification activities. The methods and controls for these activities are also described. The plan provides a general schedule and sequence of events for major verification activities. Figure 2.1.1.4-1, Verification Schedule and Sequence of Events, provides a schedule and sequence of events for the process in this handbook.

The plan is developed through a thorough understanding of the design and performance requirements as defined by the Program Requirements Documents, the Systems Requirements Document (SRD) and/or the Contract End Item (CEI) Specification and the methods defined in the Verification Requirements Matrix (VRM) of the document. Again, development of the plan requires a close coordination with technical design, systems engineering and testing organizations.

The Verification Plan provides the content and depth of detail necessary to provide full visibility of all verification activities. The plan generally provides the following information:

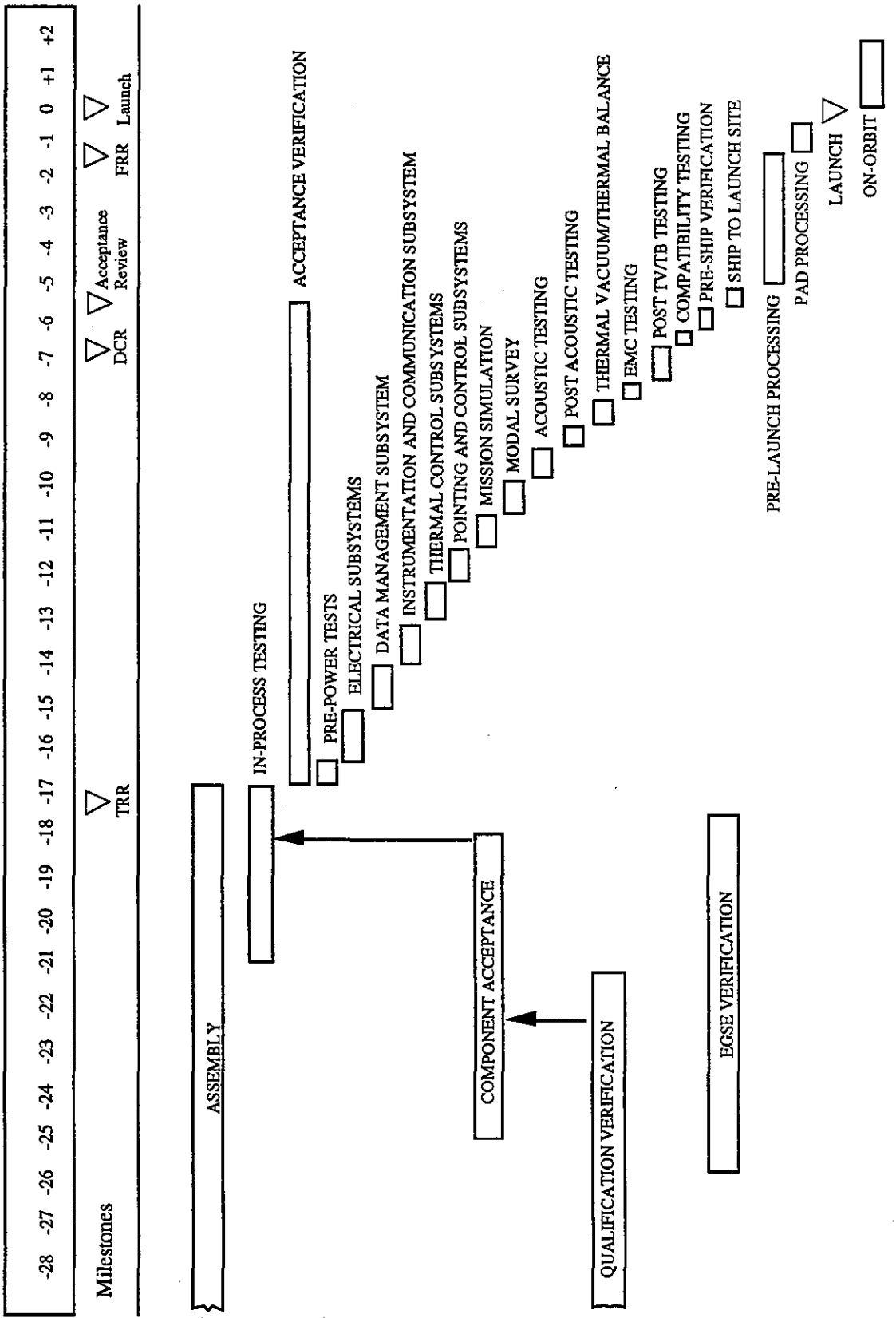

Figure 2.1.1.4-1 Verification Schedule and Sequence of Events

- Objectives and scope
- General description of flight systems
- Constraints to verification activities
- Detailed verification activities for each method during each activity phase
- Flight activities
- Post-flight activities
- Verification approach and methodology
- Verification organizations and responsibilities
- Management and organizational relationships
- Test operations control
- Verification related documentation
- Ground test software
- Support equipment
- Facilities descriptions.

An example of a Verification Plan is provided in Volume II of this handbook.

2.1.1.5 Engineering Implementation Plan

The Engineering Implementation Plan (also called the Science and Engineering Development Plan) describes how Science and Engineering will accomplish the task for a given program. The plan generally defines the guidelines, approaches, activities, and responsibilities for all technical support. The plan, developed by the systems engineering organization, includes inputs of verification tasks as follows:

- Perform verification risk assessment.
- Develop the verification requirements matrix.
- Support systems engineering panels and working groups.
- Develop the Verification Requirements and Specifications Document.
- Develop the Verification Requirements Compliance Document.
- Develop the Verification Plan.
- Assess verification reports.
- Support testing activities to assure requirements acceptance and proper anomaly disposition.
- Support design certification reviews.
- Support acceptance reviews.

2.1.1.6 Systems Requirements Review

The Systems Requirements Review (SRR) is the first major review to occur during the design phase of a program and usually occurs when approximately ten percent of the design is complete. This normally is thirty to ninety days after the start of Phase C but may actually occur in Phase B. The purpose of the SRR is to ensure program requirements are adequately defined. The SRR will also ensure configuration concepts are in accordance with the program requirements and cover both hardware and software. The system requirements are baselined after the Preliminary Design Review (PDR). The scope of a SRR may vary, depending on the complexity of the program. Minimum requirements for the review are established by the Configuration Management Plan.

The SRR is conducted in accordance with MMI 8010.5, "MSFC Baseline Design Review". Review procedures such as Team/Board makeup and conduct and handling of Review Item Discrepancies (RIDs) are defined in documents developed in compliance with the MMI. The SRR is initiated and conducted by the Program Office, however, technical aspects of the review are provided by the Science and Engineering Directorate. The requirement review may be termed a Preliminary Requirements Review (PRR) or a Program Requirements Review (PRR) but the objectives of the reviews are the same.

The data required for assessment during the SRR consists of design concept documents, a verification plan, engineering plans, program requirements and specifications. The documentation related to verification activities is the Verification Plan, the Contract End Item (CEI) Specification Verification Requirements Matrix (VRM) or Systems Requirements Document (SRD) VRM, the Implementation Plan, and the Ground Support Equipment (GSE) Specification. The content of documents, related to verification activities and provided for the review, is specified in the respective sections of this handbook. The GSE Specification establishes the requirements for performance, design, verification, and configuration for all the electrical and mechanical support equipment, including Special Test Equipment (STE) and/or Government Furnished Equipment. The GSE Specification will be in preliminary issue but will identify the support equipment required and the equipment use.

2.1.1.7 Development Phase Verification

Development phase verification activities begin early in Phase C of a program, using some analyses developed in Phase B. The verification program to be accomplished during the development phase is planned early and is based upon the amount of new design and/or redesign of flight hardware required. The verifications performed during this phase include both test and assessment methods. Many of the analyses are performed, and later updated, to ensure that hardware and systems performance can meet project requirements. Some of the design and performance requirements defined by the Program Requirements Documents and the Contract End Item (CEI) Specification can be complied with during this phase. The flight and test software development also starts during this phase.

Some of the program requirements are verified or partially verified through the activities of the Preliminary Design Review (PDR) and the Critical Design Review (CDR) which both occur during this phase. Requirements that are verified through design review activities are those that relate to design features.

Development testing is performed to determine the applicability of the new designs and to fine tune the designs and may be performed over a long period of time. Testing during this phase is generally performed by the design organization or by the design and test organizations. Verification of some requirements, such as those associated with structural strengths and with pressure vessels is performed when testing of the hardware is to design limits. Test verifications whose results are used for compliance to program requirements must be performed with quality control surveillance.

2.1.1.8 Systems Analysis and Models

Systems analyses and models are used extensively throughout a program to verify and determine compliance to design and performance requirements. Most verification requirements that cannot be verified by a test activity are verified through analyses and modeling. The analysis and modeling process begins early in the requirements development phase of a program and continues through most of the acceptance phase. Many of the analyses and models are updated periodically throughout a program as actual data that is used as inputs become available. Many of the analyses and models are verified or supported by results of a test activity. The results of each analysis and modeling are presented in a report that documents the compliance data to a given requirement. Further definition of systems analyses and models is contained in Section 4.0 of MSFC-HDBK-1912, "Systems Engineering Handbook, Volume II", "Tools, Techniques, and Lessons Learned".

2.1.1.9 Flowdown Of Program Requirements

The Program Requirements are Headquarters (Level I) requirements and are defined in the Program Requirements Document. These requirements are the top-level program requirements and are normally defined in broad terms. The top-level requirements are allocated

to lower levels (Levels II through IV) as a more defined requirement and are normally defined in documents such as Systems Requirements Documents (SRDs), Interface Requirements Documents (IRDs), Interface Control Documents (ICDs), Contract End Item (CEI) Specifications, and component specifications.

To assure that all design and performance requirements have been properly allocated to all lower levels and that traceability is present in requirements that have been defined at all levels, a flowdown of the requirements from Level I through Level IV is performed. This flowdown will identify any disconnects in the requirements flow. This flowdown of requirements will also provide assurance that requirements have been properly allocated to the lower level tiers and that compliance to the lower level requirements will provide compliance to the Level I requirements.

Some requirements at Level II through Level IV may not be traceable to Level I. These types of requirements are usually derived design requirements or process requirements. Even though a requirement cannot be traced to Level I, the requirement is flowed down (or traced up) within Level II through IV.

The requirements defined in the Verifications Requirements and Specifications Document (VRSD) are traced up to Level I. The trace up of the VRSD requirements provides full traceability of Level I requirements through Level IV requirements and derived VRSD requirements. This flowdown (or trace-up) of requirements becomes the basis for the Verification Requirements Compliance Document.

2.1.1.10 Verification Requirements and Specifications Document

The Verification Requirements and Specifications Document (VRSD) defines the detailed requirements and specifications for the verification of a flight article, including systems, subsystems and the ground systems. The VRSD specifies requirements and specifications for activities during the qualification phase, the acceptance phase and on-orbit and post-flight activities. Requirements are also defined for flight software verification after the software has been installed in the flight article. The VRSD will define requirements verified by all verification methods necessary to ensure the flight article is in compliance with design, performance, safety and interface requirements. Some programs utilize a requirements document that defines only requirements to be satisfied by test. This document is the Test and Checkout Requirements and Specifications Document (TCRSD).

The VRSD includes the design, performance, safety and interface requirements defined by Level I, II and III requirements documents plus requirements derived to ensure proper performance of flight systems and subsystems. The document will also define the acceptance criteria and any constraints for each requirement. The VRSDs are designed to identify the activity location where requirements will be verified. However, on large programs, a VRSD is normally developed for each verification location, such as integration site functional testing, thermal-vacuum testing, pre-launch, and on-orbit, and each document is tailored to include requirements for that verification activity only. The VRSD is baselined ninety days prior to start of the verification activity. The VRSD, along with flight article drawings and schematics, is the base from which verification procedures are developed and is also used as one of the bases for development of the Verification Requirements Compliance Document.

The development of a VRSD requires a good understanding of the flight article, the program requirements, and the verification program. It also requires a close coordination with the design and test organizations. The Verification Requirements Matrix (VRM) of the Contract End Item (CEI) Specification or the Systems Requirements Document (SRD) has defined the major tests, analyses, and other assessments that must be implemented during the processing flow of the flight article. All requirements necessary to ensure systems and subsystems are in

compliance with design, performance, safety and interface requirements are defined in the VRSD, with the appropriate specifications.

The VRSD contains the following information:

- Purpose and scope
- Document maintenance and control
- General descriptions of the systems and subsystems
- Groundrules
- General requirements
- Detailed verification requirements and specifications.

The verification requirements, including both program and derived requirements specifications, to be verified are defined in a matrix format. A typical matrix format is shown in Figure 2.1.1.10-1, Typical Requirement Format. The matrix columns are defined as:

- (1) NUMBER - the numerical designation assigned to each requirement.
- (2) REQUIREMENT STATEMENT - the specific requirement to be verified.
- (3) MEASUREMENT/STIMULI - the command and/or measurement number used in the verification of the requirement.
- (4) CRITERIA/SPECIFICATIONS - the "Pass/Fail" criteria and tolerances for each requirement.
- (5) REMARKS AND CONSTRAINTS - remarks to aid in the understanding of the requirement. Constraints define limitations that must be observed.
- (6) EFFECTIVITY - the verification location or phase where the requirement will be verified.

An example VRSD is shown in Volume II of this handbook.

2.1.1.11 Verification Requirements Compliance Document

The Verification Requirements Compliance Document provides the evidence of compliance to each Level I through Level IV design, performance, safety and interface requirement and to each Verification Requirements and Specifications Document (VRSD) requirement. The Level I through Level IV requirements are the results of the flowdown of requirements as previously defined. The flowdown to VRSD requirements completes the full requirements traceability. Compliance with all the requirements ensures that Level I requirements have been met.

The Verification Requirements Compliance Document will define for each requirement, the method(s) of verification and corresponding compliance data for each method defined. The compliance data information will provide the actual data or will provide a reference to the location of the actual data that shows compliance with the requirement. The document will also specify non-compliances with the requirement, referencing the non-compliance report, and the re-verification of the requirement. The compliance data information may reference a

VERIFICATION REQUIREMENT AND SPECIFICATIONS DOCUMENT MATRIX

NUMBER	REQUIREMENT STATEMENT	MEASUREMENT/ STIMULI	CRITERIA/ SPECIFICATION	REMARKS & CONSTRAINTS	EFFECTIVITY
(1)	(2)	(3)	(4)	(5)	(6)

Figure 2.1.1.10-1 Typical Requirement Format

verification report, an automated test program, a verification procedure, an analysis report, or a test. The inputting of compliance data information into the compliance document occurs over a lengthy period of time and on large payloads, the effort may be continuous. The information in the compliance document must be up-to-date for the acceptance reviews and Flight Readiness Review (FRR) as it will be used as the reference for acceptance of requirements. Figure 2.1.1.11-1, Typical Compliance Matrix Format, provides a compliance document format. The compliance document is not baselined since data is input to the document through the life of the ground program and could require inputs from on-orbit activities.

The Verification Requirements Compliance Document contains the following information:

- Purpose
- Scope
- Requirements for which compliance is to be defined and the document from which the requirement is taken
- Verification method of requirement
- Compliance data
- Non-conformance data
- Remarks of explanation.

The compliance information is presented in matrix form as shown in Figure 2.1.1.11-1, Typical Compliance Matrix Format.

The following provides the information required for each column of the typical compliance matrix:

- (1) NUMBER - the numerical designation that is assigned to each requirement of the matrix.
- (2) REQUIREMENT DOCUMENT NUMBER - a number designation that defines the location where the requirement is defined.
- (3) REQUIREMENT STATEMENT - the requirement for which compliance is to be defined.
- (4) VERIFICATION METHOD - Verification Method identifies the method used to verify the requirement.
- (5) COMPLIANCE DATA - specifies the location of the data that shows compliance with the requirement statement. This information could be a test, report, procedure, analysis report or other information that fully defines where the compliance data could be found. Retest information is also shown.
- (6) NON-CONFORMANCE DATA - identifies any non-conformances that occur during the verification activities.

VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT MATRIX

MATRIX NUMBER	REQUIREMENT DOCUMENT NUMBER	REQUIREMENT STATEMENT	VERIFICATION METHOD	COMPLIANCE DATA	NON-CONFORMANCE DATA	DATA STATEMENT/ REMARKS
(1)	(2)	(3)	(4)	(5)	(6)	(7)

Figure 2.1.1.11-1 Typical Compliance Matrix Format

- (7) DATA STATEMENT/REMARKS - statements of compliance information as to any non-compliance or acceptance by means other than the method identified, such as a waiver.

An example of a Verification Requirements Compliance Document is provided in Volume II of this handbook.

2.1.1.12 Preliminary Design Review

The Preliminary Design Review (PDR) is the second of the three major reviews and is a technical review of the basic design approach to assure the approach will meet the program technical requirements and to ensure the integrity of the selected design. Verification planning, cost and schedule, and interface compatibility are also addressed during the review. The PDR is conducted when the design is a minimum of 50% complete and the drawings are approximately 10% complete.

The PDR is organized and conducted in the same manner as for the Systems Requirements Review (SRR) and in accordance with MSFC MMI 8010.5, MSFC Baseline Design Reviews. The deficiencies or discrepancies noted in the basic design approach or other technical areas under review are documented in Review Item Discrepancies (RIDs) and processed through the PDR structure. The RIDs generated during the SRR should be closed prior to the PDR.

The documentation required for the PDR is, in general, requirements and specifications, design drawings, analyses, development and verification plan, and schematics. The documentation required to assure that verification planning is adequate, with expected maturity as identified, is as follows:

- Verification Plan - draft copy
- Verification Requirements and Specifications Document - rough draft copy
- Verification Requirements Compliance Document - rough draft copy
- CEI Verification Requirements Matrix - baselined copy
- Ground Support Equipment Specification - preliminary
- Test Software Plan - preliminary
- Launch Site Operations Requirements - preliminary
- Launch Site Operations Plan - preliminary.

The content of the Verification Plan, the Verification Requirements and Specifications Document (VRSD), and the Verification Requirements Compliance Document is specified in the respective sections of this document. The Ground Support Equipment (GSE) Specification will define each item of electrical and mechanical support equipment and what the equipment is to be used for. The Test Software Plan will specify the ground test software, how the software is to be developed and validated, and what the software is to be used for. The Launch Site Operations Requirements Document will define the requirements for the ground processing flows, transportation at the launch site, description of GSE, identification of ground processing facilities, and identification of support requirements for personnel and test equipment. The Launch Site Operations Plan defines all processing activities at the launch site, including facilities and GSE use. The plan will provide a flow of all activities and an activity waterfall that will identify a time frame for each activity.

The verification related documentation is assessed to ensure that verification planning has been adequately reflected in the documentation. Verification and operational flows must be properly sequenced and must reflect adequate time frames for all activities. All verification related activities must be specified in the documentation even though details of the activity may not be firmed at the PDR. The approach to verification, including testing must be very evident in

the documentation and must be of an acceptable approach. A waterfall showing all test activities at all test locations is defined. Also, analyses required to show compliance to design and performance verification requirements are defined, including any models.

2.1.1.13 Critical Design Review

The Critical Design Review (CDR) is the third and last of the major design reviews and is generally held when the design and the drawings are approximately 90 to 95 percent complete. This technical review provides assurance that the design of the selected configuration is in accordance with design and performance specifications. The technical areas addressed during the review include the design configuration and integrity of the selected design; verification planning, requirements, and compliance; operations planning and requirements; Ground Support Equipment (GSE) requirements and specifications; and systems compatibility.

The CDR is organized and conducted in the same manner as the Systems Requirements Review (SRR) and the Preliminary Design Review (PDR) and in accordance with MSFC MMI 8010.5, "MSFC Baseline Design Reviews". The deficiencies noted in the selected design and/or other technical documentation are documented in a Review Item Discrepancies (RIDs) and processed through the CDR structure. The RIDs generated during the PDR should be closed prior to CDR. The RIDs generated during the CDR process should be closed as soon as possible after the CDR to baseline the design. The documentation required for the CDR is, in general, design drawings and schematics, requirements and specifications, plans, analyses and assessments, and Interface Control Documents (ICD). The documentation, with expected maturity as identified, that is required to assure verification planning and requirements are adequate is as follows:

- Verification Plan - preliminary
- Verification Requirements and Specifications Document - draft copy
- Verification Requirements Compliance Document - draft copy
- CEI Verification Requirements Matrix - baselined copy
- GSE Specification - baseline
- Orbital Verification Support Plan - Preliminary
- Launch Site Operations Plan - baseline
- Launch Site Operations Requirements Document - coordination copy
- Contamination Control Plan - baseline
- Systems Safety Analyses - preliminary
- Systems Hazard Analyses - preliminary
- Instrumentation Program and Components List - issue for baseline
- Interface Control Document - baseline
- Interface Requirements Document - baseline
- Test Software Plan - coordination copy.

The content of the Verification Plan, the Verification Requirements and Specifications Document (VRSD), the Verification Requirements Compliance Document, and the Contract End Item (CEI) Specification (or Systems Requirements Document) Verification Requirements Matrix is specified in the respective sections of this document. The CDR verification planning and requirements documentation is assessed to ensure that verification planning has been adequately defined and that verification requirements have been defined in general terms and firm in format. Verification and operational flows will show the proper sequencing and a waterfall time frame for all testing and test related activities. The details of all verification activities will be defined.

The GSE specifications will define all electrical and mechanical support equipment, indicate the equipment use, and provide a detailed description of the equipment. The Orbital Verification Support Plan will describe all the activities that are required to perform the orbital

verification activity. This plan will describe all ground systems that must be available to perform the verification activities. The plan will also describe all necessary ground test software. The Electromagnetic Compatibility (EMC) Control Plan will ensure that the requirements and specifications for Multi-Layer Insulation (MLI) bonding, component and structure bonding, and the grounding technique for the flight article (e.g. single point ground configuration) are properly implemented. The Launch Site Operations Plan will detail the processing activities at the launch site, a description of the electrical and mechanical GSE and facilities, and a flow of all activities with a waterfall that will identify a time frame for each activity. The Launch Site Operations Requirements Document defines the requirements for the ground processing flows, transportation at the launch site, description of GSE, identification of ground processing facilities, and identification of support requirements for test equipment and personnel.

The Contamination Control Plan outlines the methods and processes for controlling contaminants within and around the flight article within specification. This plan identifies impacts to testing activities due to contamination control that must be considered in planning activities. Systems safety and hazard analyses are assessed to assure that there is no impact to the verification process. The ICDs and Interface Requirement Documents (IRDs) are assessed to ensure that verifications can be performed to verify the flight hardware is in compliance with program requirements. The Test Software Plan provides the description of activities that will verify and validate the ground test software. The plan will define both general software programs required for systems data acquisition and monitoring and also the special programs required for system control and data processing. The Instrumentation Program and Components List (IPCL) specifies all commands and sensor response identifications, with assigned location within the telemetry data stream. This information is required to develop the VRSDs. All commands and sensor responses that can be verified prior to launch must be verified.

2.1.1.14 Qualification Phase Verification

Qualification phase verification activities begin after completion of development of the flight hardware designs and includes analyses and testing to assure that the flight or flight type hardware will perform its operational functions, including operational functions in known or anticipated environmental conditions. Qualification tests generally are designed to subject the hardware to worst case environments and stresses. Sometimes dedicated qualification hardware is not built for a project and the flight hardware itself is used for qualification purposes. When the flight hardware is used, qualification levels are the flight levels. This process of qualification is termed "protoflight". Additional information on protoflight testing is contained in MSFC-HDBK-670, "General Environmental Test Guidelines (GETG) for Protoflight Instruments and Experiments".

The hardware level for qualification is usually at the component level but a system could be qualified. Data resulting from qualification tests is used to update many of the earlier analyses. Many of the program performance requirements are satisfied during this phase. Some of the verifications performed to ensure hardware compliance to worst case environments or limits are vibration/acoustic, pressure limits, leak rates, thermal vacuum, thermal cycling, electromagnetic compatibility, high and low voltage limits, and life time/cycling. Safety requirements defined by hazard analysis reports may also be satisfied by qualification testing.

2.1.1.15 Verification Procedures

The verification procedures are documents that provide step by step instructions for performing a given verification activity on flight and non-flight hardware and software. The procedure is tailored to the verification activity that is to be performed to satisfy a requirement and could be a test, demonstration, or any other verification related activity. The procedure is generated to satisfy requirements defined by the Verification Requirements and Specifications Document (VRSD). Procedures are also used to verify the acceptance of facilities, electrical and

mechanical ground support equipment, and special test equipment. The information generally contained in a procedure is as follows but may vary according to the activity and test article:

- Nomenclature and identification of the test article or material
- Identification of test configuration and any differences from flight configuration
- Identification of objectives and criteria established for test by the applicable verification specification
- Characteristics and design criteria to be inspected or tested, including values, with tolerances, for acceptance or rejection
- Description, in sequence, of steps and operations to be taken
- Identification of computer software required
- Identification of measuring, test, and recording equipment to be used, specifying range, accuracy, and type
- Certification that required computer test programs/support equipment and software have been verified prior to use with flight hardware
- Any special instructions for operating data recording equipment or other automated test equipment as applicable
- Layouts, schematics, or diagrams showing identification, location, and interconnection of test equipment, test articles, and measuring points.
- Identification of hazardous situations or operations
- Precautions and safety instructions to ensure safety of personnel and prevent degradation of test articles and measuring equipment
- Environmental and/or other conditions to be maintained with tolerances
- Constraints on inspection or testing
- Special instructions for non-conformances and anomalous occurrences or results
- Specifications for facility, equipment maintenance, housekeeping, certification inspection, and safety and handling requirements before, during, and after the total verification activity.

The procedure may provide blank spaces for recording of results and narrative comments in order that the completed procedure can serve as part of the verification report. The as-run and certified copy of the procedure is maintained as part of the historical files. The submittal requirements for a procedure is normally thirty days prior to the start of the verification activity for which the procedure is to be used.

2.1.1.16 Acceptance Phase Verification

The acceptance phase verification activities provide the assurance that the flight hardware and software are ready for shipment to the launch site. For the purpose of this handbook the acceptance phase begins with the acceptance of each individual component or piece part for assembly into the flight article and continues through the flight article acceptance review. Also, as stated earlier, the handbook provides an acceptance verification process for a flight article that is manufactured and assembled at the same location. Some flight articles could be assembled into major elements at different locations, verified to function properly, and then integrated into the flight article at an integration location. Verifications of the integrated flight article are the same at the system and flight article levels. All flight hardware systems are functionally and environmentally tested to ensure that they operate, within constraints, to all defined design, performance, and derived requirements. All functions of the flight software are verified. Analyses and models are verified and updated as test data is acquired.

The assurance that the flight hardware and software is performing as designed is determined by systems successful operation. To obtain this assurance, the flight hardware and software is verified through a building block process. Individual components are first verified and then verified as part of a system. This process continues with the verification of integrated systems, leading to a Compatibility Test or Simulated Mission Test during a thermal vacuum

environment, which provides systems operation as near as possible to flight conditions. The acceptance of these verifications at the different hardware/software levels provide a high probability for a successful on-orbit operation.

2.1.1.16.1 Facility and Ground Support Equipment Verification/Operational Readiness Inspection

Before a flight article is installed in a facility for testing or connected to an item of Ground Support Equipment (GSE) or special test equipment (STE), the facility or support equipment item must be verified to ensure no damage will occur to the flight hardware. The facilities and support equipment are verified under procedure control and to established verification requirements and specifications. The facilities and support equipment are generally verified under quality control, as would be flight hardware.

A facility is verified to assure that it meets the required support requirements and its intended use. Support services provided by the facility, as well as accessibility to the services, including entering and exiting the facility, are verified. Contamination, temperature, and humidity are controlled to be within program specifications and are usually connected to an alarm system that will provide a warning if the parameters fall out of a given range.

To assure that the facility is ready to support flight article activities, an Operational Readiness Inspection (ORI) is performed on the facility, the support equipment and the operations. The ORI is a review and inspection, including safety aspects, of all equipment to be used in the activity; the facility capabilities and support services; and the plans and procedures for facility/equipment activation, verification, and operation. The ORI is accomplished through an ORI Committee and a Safety Review Team with a Chairman and an Executive Secretary, and in accordance with MMI 1700.6D, "MSFC Operational Readiness Program". The committee is made up of persons that are experienced in the technical areas, but, to the extent possible, are from organizations without a vested interest in the activity for which the review is being conducted. The Safety Review Team is made up of persons from the Safety organization.

The ORI Committee reviews all the design data to assure interface compatibility with the test article and to identify hazards. A walkdown inspection of the facility/equipment is performed. The Committee will also review and approve all operations controls, plans and procedures, including the data for facility/equipment acceptance. Personnel qualification and training is also assessed. The Safety Review Team conducts a review and inspection of equipment, facilities, operations, and operating procedures that do not require an ORI. A report is prepared of ORI activities that includes a summary of the activities, actions, findings, conclusions, and recommendations and data to support the findings and conclusions.

The electrical and mechanical GSE required to support test and handling of the flight article must be verified and certified prior to its use. The GSE is verified in accordance with defined requirements and with few exceptions, through use of approved procedures. The data acquisition GSE is usually verified with use of a flight article simulator, using the ground test software. This activity also verifies the test software. Test equipment must be calibrated and certified such that re-calibration periods do not interfere with test operations. The mechanical GSE is tested and certified. Lifting equipment is certified through actual lifts of proof-load weights after hooks, clevises and lifting bars are verified by X-ray or dye-penetration techniques. Mechanical GSE is inspected and tested in accordance with Marshall Standard MSFC-STD-126E, "Inspection, Maintenance, Proof Testing, and Certification of Handling Equipment."

2.1.1.16.2 Component Acceptance

Each item of flight hardware is accepted for flight prior to being assembled into a flight article. The degree of acceptance activity is dependent upon the item of hardware. Cables may be accepted with continuity and leakage tests with electrical boxes subjected to functional

and qualification tests. The electrical boxes are considered components. Each electrical component is carried through an acceptance program that certifies the component. Each component is individually certified and for each item, a "Certificate of Qualification" is issued. The component acceptance program is developed by the applicable design organization which also ensures certification of the components. The flight software is validated and verified with a flight type hardware system prior to being integrated with the flight hardware.

2.1.1.16.3 Assembly/Integration

The assembly process begins after the piece parts for the flight article have been obtained, through manufacture or purchase, and have been certified and accepted for flight. Some of the piece parts may be large elements that have been assembled at other locations and shipped to the integration site for integration into a flight article. The elements will have been verified at their assembly locations in a similar process as described in this handbook. In some cases, especially for a launch vehicle, the final assembly and integration will occur at the launch site; however, engines for a launch vehicle are generally installed at the assembly site. Verification of the mechanical interfaces at the assembly sites is essential prior to transporting the flight hardware to the integration site. This enhances a proper mate of the flight hardware. Most of the mechanical interface verifications are performed through the use of a template of the interfaces. Assembly of all flight hardware is desirable prior to the start of verification activities in the testing facility, with the exception of the verifications required during the assembly process.

2.1.1.16.4 Acceptance Testing

Acceptance testing consists of a series of tests that ensures that the performance of the flight hardware, systems, and flight software is in compliance with design and performance requirements. Acceptance testing begins with in-process testing and continues through functional testing, environmental testing, and compatibility testing. Functional testing normally begins at the component level and continues at the systems level, ending with all systems operating simultaneously. All tests are performed in accordance with requirements defined in the VRSD. When flight hardware is unavailable or not appropriate for a specific test, simulators may be used to verify interfaces. Power to the flight article under test may be supplied by either flight type test batteries or by a ground power source. Acceptance testing is required at the launch site if payload elements are integrated to verify interfaces and system compatibility and functionality. All downlink test data is recorded on ground wide band recorders and maintained for any future need.

Anomalies occurring during a test are documented on a reporting system such as a Non-Conformance Report (NCR). The anomaly could be a hardware or system failure or an out-of-specification condition. Any failure during a test must be documented on a NCR (or equivalent) and a proposed resolution of the failure be defined before testing continues. Major anomalies or anomalies that are not easily dispositioned may require resolution by a Materials Review Board made up of representatives of design and other organizations.

The following paragraphs define test activities that are typically performed on a flight article but may vary according to the flight article configuration or due to program considerations.

2.1.1.16.4.1 Test Readiness Review

A Test Readiness Review (TRR) is held prior to each major test to ensure the readiness of all ground, flight, and operational systems to support the performance of the test. A review of the detailed status of the facilities, Ground Support Equipment (GSE), test design, software, procedures, and verification requirements is made. The test activities and schedule are outlined and personnel responsibilities are identified. Verification emphasis is directed to

assurance that all verification requirements that have been identified for the test have been included in test design and procedures.

2.1.1.16.4.2 In-Process Testing

Some verifications cannot be performed after a flight article, especially a large flight article, has been assembled and integrated due to inaccessibility. These verifications must, therefore, be performed during the assembly and integration process. This is termed in-process testing. Typically, the verifications performed during the assembly phase are structure to structure bonding, component and Multi-Layer Insulation (MLI) bonding to structure, cable interface checks for continuity, mechanical alignment, and heater continuity and resistance tests. Specifications for structure, component, and MLI bonding are specified on the installation drawings and in the Electromagnetic Compatibility (EMC) Control Plan. Pressure tests of fuel tanks or gas spheres and leak tests of propulsion or gas systems are performed during the assembly process. Pressure tests of fuel tanks occur early in the assembly phase. Other verifications may be required to be performed depending on the complexity of the flight article.

2.1.1.16.4.3 Pre-Power Tests

Before GSE is connected to the flight article and power is applied, some tests must be performed to ensure no damage will occur to the flight article. All Ground Support Equipment (GSE) interfaces to flight hardware are verified. The resistance between the structure single point ground (SPG) and the disconnected return to SPG is measured and must be large enough to prevent any noise on the data system due to current flow. This SPG resistance value is determined for each flight article. Power bus continuity and isolation of the power bus positive and return paths must be verified. After connection of the electrical GSE, including the ground power source, isolation of the power bus positive and return paths are again verified.

2.1.1.16.4.4 Functional Testing

Functional testing ensures the proper performance of the flight hardware and systems, including flight software, under ambient conditions. Testing normally begins at the component level and continues through systems level and then flight article level. Testing is structured such that systems required to support testing of other systems are verified first. Parallel testing is performed on systems to the extent possible. Functional testing establishes parameters of systems performance that is used as a baseline for future testing. The following paragraphs describe functional testing typically performed on a flight article at the systems and integrated level:

2.1.1.16.4.4.1 Electrical Power Subsystem

The electrical power subsystem provides the electrical power generation, storage conditioning, control, regulation, distribution, and circuit protection. The first electrical power system test after connection of GSE is the application of power to the main buses. The main bus voltage and current is measured by the Ground Support Equipment (GSE). Any necessary adjustment of the ground power source would be made at that time. Before connecting cables supplying main bus voltage to components, the bus voltage is verified to be on the proper pins of the supply cables at the interface to the components. The following tests are typically performed on the electric power subsystem:

- Primary and redundant systems
- All systems configuration (cross strapping)
- Battery system with flight type battery
- Standard operating configuration
- System protection circuitry
- Voltage controller circuitry
- Reference voltages
- Power loads

- Diode operation
- Battery temperatures
- System parameters
- Bus load currents
- External to internal battery power transfer
- High/low systems operating voltage.

If the flight article configuration has solar arrays for battery recharging, the following additional tests are performed:

- Solar array interface
- Battery charging
- Charge current controller subsystem
- Change current controller charge rates
- Solar Array current feedback circuit.

2.1.1.16.4.4.2 Solar Arrays

The solar arrays are verified off-line prior to integration with the flight article. The deployment/retraction of the solar arrays must be performed in a Ground Support Equipment (GSE) fixture to counteract the force of gravity. GSE to simulate sunlight is also necessary to test the solar cell current output. Tests of solar arrays include:

- Deployment and retraction rates
- Primary and redundant systems
- Motor operation
- Motor currents
- Solar cell current
- Diode circuitry
- Latch mechanisms
- Manual deployment and retraction
- Solar array removal and replacement
- Solar array electrical interface.

2.1.1.16.4.4.3 Data Management Subsystem

The Data Management Subsystem (DMS) provides the systems control capability, data processing and storage, and data acquisition and formatting. The DMS is activated and verified very early in the functional testing activity, as the data acquisition, processing and command capability of this subsystem is used for most all verifications in systems test. The DMS on very large and complicated payloads will be in comparison, large and complicated and require significant verifications. Large and small data management systems are controlled through one or more computer systems. The flight software is also a part of the DMS.

The main data management unit is verified to interface with and control other systems. The data and command transfer between the main data management unit and interface units is verified. Many requirements of the DMS are verified as interfacing systems and activated and tested. Typical DMS tests are:

- Telemetry formats and data rates
- Synchronization signals
- Decoders
- Analog to digital conversion
- Sensor responses
- Commands/systems control
- Discrete data levels

- Flight software loads/operation
- Primary and redundant systems
- Systems configurations (cross-strapping)
- Flight software program loading/change
- Systems timing/control
- Timing/synchronization signal frequency rates
- Reference voltages
- Data storage and playback.

The flight tape recorders are tested to ensure they respond to all commands, record and playback all data formats and data rates, provide automatic control and switching, operate in all modes, and provide a Bit-Error Rate (BER) within design specifications. To verify that the tape recorders can record and playback data within its design specification of error rate, a bit-to-bit comparison must be made of playback data to the original data recorded. Pressures of electronic components that are pressurized must be verified to be within acceptable limits and acceptable leak rates.

2.1.1.16.4.4.4 Instrumentation and Communication Subsystem

The Instrumentation and Communication (I&C) Subsystem transmits engineering and scientific data, receives and demodulates commands, and provides tracking via ground tracking systems. The I&C subsystem consists of transmitters, transponders and diplexers, multiplexers, radio frequency (RF) switch, and antennae.

The Voltage Standing Wave Ratio (VSWR) and insertion loss of all RF paths is checked. These tests are performed after the RF coax cables and wave guides are connected to multiplexers, diplexers, and switches, but prior to being connected to antennas, receivers, and transmitters.

The transmitters are typically tested to verify:

- Output power and reflected power
- Center frequency and upper and lower limit
- Control functions
- Transmit modes
- Transmit data rates
- Modulation modes
- Forward/return link RF power loss
- Signal strength
- Inhibits
- Forward/return frequencies
- Subsystems functions.

The receivers are typically tested to verify:

- Command rates
- Command threshold
- Carrier/Pseudo-random noise (PN) code tracking
- Carrier/PN code acquisition
- Threshold
- Signal strength
- Sync words
- Systems functions
- Center frequencies/range.

The I&C operation through all systems configuration is verified. Data is transmitted through all ground system configurations, including the Tracking and Data Relay Satellite System (TDRSS) if used. All coax and RF switch positions are verified. Data is transmitted through each antenna through the use of an antenna hat when open-loop RF radiation occurs inside a structure or facility. Both open-loop and closed-loop data transmission is verified as well as the signal level of each antenna output. The parameters for monitoring systems performance and for engineering data are all verified to the extent possible to be active and within specified limits.

2.1.1.16.4.4.5 Structures Subsystems

The structures subsystem provides the mounting structure for components and subsystems and the structural interface for all flight article elements, for payloads and with the launch vehicle and Ground Support Equipment (GSE). There is generally no testing of the subsystem during functional test.

2.1.1.16.4.4.6 Mechanisms Subsystems

The mechanisms subsystem provides the motors and mechanisms to operate appendages, umbilicals, doors, and latches. Typical tests of the mechanisms subsystem are:

- Telemetry responses
- Commands to mechanisms, motors, and electronics
- Motor and mechanism functional operation
- Appendage drive
- Latch open/close operation
- Appendage removal/replacement demonstration
- Manual latch/appendage operation
- Microswitch operation
- Mechanism pre-load
- Systems Configuration (cross-strapping)
- Primary and redundant systems
- Umbilical retraction.

2.1.1.16.4.4.7 Thermal Control Subsystem

The Thermal Control Subsystem (TCS) provides the thermal control for all structures, mechanisms, components, and interfaces of the flight article. Both active and/or passive control techniques are used. Verification of the TCS for many flight articles cannot be accomplished during functional testing at ambient conditions. The thermal systems, including thermal circuits, thermostats, thermistors, and controller are verified during a Thermal Vacuum/Thermal Balance (TV/TB) test or in a facility that has a wide range heating/cooling capability. The TCS tests during functional testing at ambient conditions are:

- Thermal control surface optical properties
- Heater and thermostats installed at designated locations
- Telemetry responses
- Systems commands
- Thermostat set point
- Heater operation
- Thermal circuit continuity
- Heat pipe, thermal louver, thermo-electric cooler operation
- Heater circuit power
- Fluid loop operation
- Avionics air coolant loop operation
- Thermal control instrumentation.

Heater operation and thermostat set point for those circuits that operate near ambient temperatures may be verified to be functional by an adequate change in facility temperature or through heating/cooling the thermostat directly.

2.1.1.16.4.4.8 Pointing Control Subsystem

The Pointing Control Subsystem (PCS) provides the flight control, maneuverability, pointing control, stability, and/or safing for a flight article. The PCS may control an orbiting payload or may provide the flight control for a launch vehicle. Simulators that simulate vehicle dynamics and signal inputs may be used during functional testing to verify some requirements. Orbiting payloads may have a very complicated PCS that include gyros, star trackers, reaction wheels, fine guidance systems, magnetic sensing, magnetic torque's, and safe mode electronics that have more than one redundant system. Testing is performed on all back up systems and components. Typical tests of the PCS are:

- Component pressure and leak rate
- Thrust vector control gimbal test
- Telemetry responses
- Safing of systems
- Safing configurations
- Electronic functions
- Systems operating modes
- Systems closed loop operation
- Command modes
- Systems configuration status
- Guide star acquisition
- Reaction wheel torque/speed
- Gyro torque
- Data interfaces
- Systems operating temperatures
- Systems self test
- Flight software programs
- Flight software loading/change
- Primary and redundant systems
- System/component cross-strapping.

2.1.1.16.4.4.9 Propulsion Systems Verification

The Propulsion System(s) provides the propulsion necessary to transport a payload to outer space and beyond and to provide maneuverability in outer space. The systems include fuel tanks, engines, actuators, instrumentation and control electronics. The instrumentation internal to the fuel tanks is tested as the tanks are assembled and proof tested. Typical propulsion system tests are:

- Tank pressurization
- Systems leak checks
- Control electronics
- Valve operation and control
- Actuator operation and control
- Engine control/gimballing
- Telemetry responses
- Hazard gas detection
- Engine operation
- Interface checks.

2.1.1.16.4.5 Environmental Testing

Environmental testing ensures that the flight hardware will perform as designed when exposed to a simulated flight environment. Environmental testing normally includes, depending on the flight article, a modal survey, vibration tests, acoustic tests, and a thermal vacuum/thermal balance test. Electromagnetic Compatibility (EMC) testing in some programs is considered a part of functional testing, however, for this handbook, EMC testing is addressed as a part of environmental testing. Environmental testing of a flight article, performed as a part of acceptance testing is normally performed at maximum expected flight levels, or slightly above. This testing, as previously stated, is termed "protoflight testing." Environmental testing during the acceptance phase may serve as a part of the qualification of the flight article if no article was built specifically for qualification. The acoustic test and vibration test are both performed to ensure hardware ability to withstand launch and ascent environments. Very large payloads may be exposed only to acoustic testing, where as small payloads that can be installed on vibration tables may be exposed only to vibration testing.

Before and after each exposure of an environmental test, all systems of the flight article are verified to be performing properly at ambient condition by performance of a functional test. This test is designed to ensure that any degradation of the systems due to the environmental exposure is detected. Also, the flight article is very closely inspected after each exposure to ensure no visible damage has occurred. Environmental testing of re-flight hardware depends on the amount of rework performed on the hardware.

2.1.1.16.4.5.1 Modal Survey

The Modal Survey provides information pertaining to the modal characteristics of the flight article which are the basis for the system dynamics analysis. The survey provides the means for experimental determination of various modal parameters. The modal survey also provides information to support jitter evaluation. Test instrumentation is installed at selected critical points for this testing and is monitored on ground support equipment. The flight article is configured as close as possible to flight configuration and is suspended in such a manner that any effects from equipment operation can be detected. The flight article is excited by shakers that are frequency and phase correlated. The data acquired from the test will determine resonant frequencies, damping behavior, node shapes, and jitter.

2.1.1.16.4.5.2 Acoustic Test

The Acoustic Test demonstrates the ability of the flight hardware to withstand the acoustic and vibration environments occurring during launch and ascent. The test is performed in an acoustic test chamber that will simulate the expected flight environment in both frequency and intensity. The flight article is in as near flight configuration as possible.

Power (if applicable at launch) is applied to the flight systems and telemetry is monitored during the test to detect failures and/or intermittent circuit dropouts or relay/switch contact changes. The test will also ensure that the excitation does not induce vibratory or acoustic responses beyond the qualification levels of any component or structure. The test will also detect latent material workmanship defects and/or deficiencies. A flight article may be subjected to vibration testing rather than acoustic testing, depending on the size of the flight article and availability of adequate testing facilities.

2.1.1.16.4.5.3 Vibration Testing

Vibration testing demonstrates the ability of the flight article to withstand the vibration loads imposed during launch and ascent. The tests also simulate landing loads. The flight article is mounted on a vibration test fixture that has a flight type mating interface. Test instrumentation is installed on the flight article for measurement of responses. Components that are pressurized and systems that are powered during flight should be in the flight configuration

during the tests. If possible, the flight item should be powered during the test to observe circuit dropouts or relay/switch contact changes.

Vibration consists of sinusoidal testing and random vibration testing. The sinusoidal and random vibration tests are performed in each of three orthogonal axes. Vibration levels are determined for each flight article. The data from the tests is used to verify loads analyses.

2.1.1.16.4.5.4 Thermal Vacuum/Thermal Balance Testing

The Thermal Vacuum/Thermal Balance (TV/TB) tests are performed to ensure the hardware and systems perform as designed when exposed to a thermal vacuum environment. The TV/TB tests provide the most realistic simulation of expected on-orbit environment extremes. The flight article is functionally tested while being exposed to a number of cycles of hot and cold conditions.

The flight article should be in as near a flight configuration as possible. Simulators are used if flight hardware is missing, especially at interfaces where a heat transfer is a significant factor in the thermal control system design. Test instrumentation is installed (and verified) at pre-determined locations to provide additional data of systems operation. This test instrumentation is monitored through TV/TB ground support equipment. Heat flux simulator lamps that can be used to simulate orbital heating are installed in the chamber and adjusted prior to installing the flight hardware. The cold cycles are produced by liquid nitrogen in the chamber walls. The flight systems are functionally operated and continuously monitored during the tests.

The temperature extremes and number of hot-cold cycles are pre-determined based on earlier analysis. The TV/TB tests are performed over a number of days, depending on the time required to achieve the desired near vacuum and thermal conditions. The size of the flight article under test and the rate of off-gassing is a factor in the time to achieve the desired vacuum level. The TV/TB tests can be used to verify or demonstrate:

- Hardware and software functions
- Flight to ground interfaces
- Commands and telemetry responses
- Primary and redundant systems
- Cross-strapping
- Hardware degradation
- Systems interaction
- Workmanship
- Heater operation
- Thermal control during operational excursions
- Thermal models
- Thermal system design
- Hardware interaction
- Thermal interfaces.

The data taken during the TV/TB tests are not only used to verify the thermal model and system design, but could produce data that could initiate thermal design changes. Contamination control must be considered in the re-pressurization of the chamber if contamination of the flight article is critical. The test instrumentation is removed, if not fly-away, after the tests.

A functional test which is performed after moving the flight article back to the integrated test facility may be in the form of a confidence test that ensures that all systems are functioning properly or could be a part of systems compatibility testing. Any rework that is required on the flight article must be completed before this systems level test.

2.1.1.16.4.5.5 Electromagnetic Compatibility

The Electromagnetic Compatibility (EMC) tests are performed to assure that electromagnetic emissions and susceptibility have been controlled at the component level and that integrated systems are electromagnetically compatible. Critical test points within the systems are selected to be monitored for interference from sources generated internally. For the purposes of this handbook, EMC testing is to be performed on the integrated systems with the flight article in as near as possible to the mission configuration. Some of the circuits monitored during EMC testing are the power buses, power interfaces, single point ground, and structure returns. EMC testing is performed using both a ground power source and the flight type power source. The monitoring of the transfer of external to internal power is critical to verify safety margins. Other EMC test are:

- Structure skin current measurements
- Radiated missions
- Radiated susceptibility (at payload and/or launch vehicle transmitted frequencies).

2.1.1.16.4.6 Compatibility Testing

The Compatibility Test ensures that flight systems are compatible when operated through a mission sequence. The test is designed to operate systems as near as possible to on-orbit operations or through a launch sequence, depending on the flight article. Maximum flight conditions, to the extent possible, are demonstrated. Data transmission should be in the flight mode through antennas with the use of antenna hat couplers. As this test is performed with the hardware in its most flight like configuration, additional electromagnetic compatibility testing may be performed. Selected systems may be monitored for electromagnetic interference which is sometimes referred to as a noise test. The Compatibility Test for non-returnable to earth payloads may consist of a number of simulated flight orbits to test different configurations. This test is sometimes called an All Systems Test or a Simulated Flight Test. The following are verifications accomplished during this test:

- Mission sequencing
- External to internal power transfer
- Systems compatibility
- Systems operation at high and low voltage
- Maximum power load
- Battery charging
- Noise interference
- Flight software execution
- Real time commanding
- Systems timing
- On-board data recording and playback
- Telemetry formats and data rates
- System safing
- Engine gimballing (launch vehicle)
- Launch sequencing (launch vehicle)

2.1.1.16.4.7 Pre-Ship Verification

The pre-ship verifications are performed to assure the launch site procedures, test programs and, if applicable, the on-orbit procedures and activations are valid. If possible, pre-ship verifications are integrated with the final functional or compatibility tests. Ground systems also are verified. Any verifications required to close Non-conformance Reports must be completed and open items must be dispositioned. The flight article is configured for shipping before final power is removed. The flight article is weighed in flight configuration and the center-of-gravity is measured. A final inspection is made, observing very closely for visible

contamination, non-flight items that must be removed, sharp edges, fasteners installed, cables connected, and that all latches and panels are closed.

2.1.1.16.4.8 Post Test Review

The Post Test Review provides a detailed status of the performance of the test activities and the test results. The review also provides the operational status of both flight and ground systems. The systems operations and performance, changes to planned operations, and discrepancies occurring during the tests are also statused, with their disposition and their impact on test performance and compliance to requirements. Acceptance of the test is also determined. Assurance that compliance to all verification requirements that were identified for each test activity is determined and all open requirements are identified.

2.1.1.16.4.9 Design Certification Review

The Design Certification Review (DCR) provides a formal, comprehensive review that examines all hardware and software to certify that design and performance requirements are satisfied. The DCR addresses all flight systems, ground operations and ground systems, and supporting mechanical and electrical ground support equipment. Normally a DCR will assess:

- Problems encountered during fabrication, assembly, and verification
- As-built configuration versus designed configuration
- Compliance to design and performance requirements including verification requirements
- Safety and Reliability, including hazard analyses
- Waivers and deviations
- Material usage
- Contamination control
- Crew systems operability
- Flight and ground test software
- Qualification configurations versus as-built configuration.

The magnitude of the review is dependent on the complexity of the flight article. Some assessments listed above may not be required for all DCRs. The DCR is a formal review consisting of structured teams, pre-board, and board and could take three to six months to complete. A DCR Plan is prepared outlining the procedures to be used for the review and a schedule of review activities. A data package will be defined for the review and will become a part of the DCR record. The Certification Board will be chaired at a high management level, generally the Program Manager or higher. Discrepancies noted during the review are documented on a Review Item Discrepancy (RID) and are processed through the established DCR system.

The review will identify open items that must be resolved prior to flight. These open items could be against the hardware, software, testing, documentation, and/or schedules. A review of the verification documentation (analyses, test reports, procedures, etc.) must ensure that all design and performance requirements and the derived requirements of the Verification Requirements and Specifications Document (VRSD) have been complied with or have been waivered or shown as an open item that can be closed prior to flight. The Verification Requirements Compliance Document which contains the latest compliance information is used as a tool for ensuring requirements have been met. Verification reports are assessed to ensure acceptance of the verification activities and results. The DCR assessment of verification activities and requirements compliance is used as a major input to the flight article acceptance review, which is the acceptance of the flight article as ready for shipment to the launch site.

A Certification Inspection Review (CIR) may be performed on a flight article rather than the DCR. Both reviews accomplish the same objectives. The CIR is normally performed over a longer period of time and is accomplished through many smaller reviews, usually assessing only one system during each review. The CIR is conducted in accordance with MMI 8010.5, "MSFC Baseline Design Review".

2.1.1.16.4.10 Verification Reports

The verification reports provide the results of all verification activities including tests, inspections, analyses, and demonstrations on the flight hardware, software, and ground support equipment. A number of verification reports may be provided to adequately present the results of all verifications. A report is provided for each analysis and, as a minimum, for each major testing activity, such as functional testing, environmental testing, and compatibility testing. If testing occurs over long periods of time or is separated by other activities, verification reports may be provided for individual activities, such as functional testing, acoustic testing, vibration testing, and thermal vacuum/thermal balance testing.

Each verification report will provide and summarize the results of all verification activities, special tests, and ground support equipment and provide the accepted evidence of the verification. The reports are prepared in a manner that relates each reported item to a verification requirement. The verification report includes as appropriate:

- Verification objectives and degree to which they were met
- Description of verification activity
- Test configuration and differences from flight configuration
- Specific result of each test, each procedure including annotated tests
- Specific result of each analysis
- Test performance data, plots, pictures (as appropriate)
- Description of deviations from nominal results, failures, approved anomaly corrective actions, and re-test activity
- Summary of non-conformance/discrepancy reports including dispositions
- Conclusion and recommendations relative to success of verification activity
- Status of support equipment as affected by test
- Copy of as-run procedure.

The verification reports are required to be submitted within thirty days of completion of the associated verification activity.

2.1.1.16.4.11 Acceptance Review

The Acceptance Review is held to provide management assurance that the flight article is ready for shipment to the launch site for pre-launch activities. The review is a formal, comprehensive review that examines all elements of the flight article and ground support equipment to ensure their acceptance and to identify open items and issues and to document the actions necessary for their resolution. Results of other reviews such as the Configuration Inspection Review and/or the Design Certification Review (DCR), systems reviews and systems safety reviews and analyses may be used as a part of the review assessments. An Acceptance Review is held for all flight articles and/or launch vehicle elements.

The Acceptance Review may be conducted over a short period of one to two days, or conducted over a period of one to two weeks, depending on the complexity of the flight article and the quantity of data to be reviewed. The formal review of findings is presented to a management team at the end of the review period. The data to be assessed during the review is defined by the Acceptance Data package and usually includes:

- As built drawings/schematics
- Certification of flight worthiness
- Assessment of hardware, software, and Ground Support Equipment (GSE) compatibility with requirements
- Materials review records
- Verification reports
- As run procedures
- Inspection reports
- Compliance documentation
- Qualification data
- Specifications
- Test conductor's log
- Configuration list
- Log books
- Mass properties report
- Work planned but not completed
- Work planned for launch site
- Non-conformance reports
- Hardware shortage
- Waivers and deviations
- Limited life items list
- Non-flight hardware list
- Packaging/handling/transportation record
- Safety compliance data
- Manufacturing/assembly quality control buy-off.

The assessment of the acceptance data package will ensure proper verifications have been performed and requirements have been met. The compliance document assessment is the most critical verification activity of the review. The verification of the compliance data to satisfy the applicable requirement will ensure testing, analyses, and other verifications have been performed adequately. In general, the review must provide evidence that:

- Verification requirements have been complied with.
- Compliance data is valid and complete.
- Components were qualified and accepted.
- Verification reports reflect activities performed.
- Non-conformances are properly dispositioned.
- Test data is valid and acceptable.
- GSE is developed for launch site.
- Work planned was completed or identified as open.
- All open areas are identified.
- Waivers and deviations are valid.
- Hardware shortages and non-flight hardware are defined.
- Limited life items are defined with run time/shelf life/cycles specified.
- Safety requirements and hazards have been satisfied.

All items that are determined to be open or not in compliance with requirements are identified and become part of the initial DD250 that accompanies the flight article to the launch site.

2.1.1.17 Ship To Launch Site

Payloads are shipped to the launch site via truck, ship barge, or airplane, depending on the size of the payload. Verifications are not performed during the shipping process. However, monitoring of the environmental conditions during shipping may be performed.

2.1.1.18 Pre-Launch Verification

The pre-launch phase of activities for this handbook, begins with the arrival of the payload at the launch site and concludes at liftoff, even though some activities such as countdown may be associated directly with launch. The pre-launch phase end point varies for different payloads. This handbook considers the launch site to be Kennedy Space Center (KSC). The flight article could be processed through horizontal or vertical processing, depending on the flight article. The launch vehicle could be the Space Transportation System (STS) or some other launch vehicle or the flight article may be an element that makes up a part of the launch vehicle. This handbook will address both payload processing and launch vehicle processing, and considers the STS as the launch vehicle for payloads. Battery charging, cooling air, and/or purges may be required for some flight articles. All flight elements and payloads are subject of a Flight Readiness Review (FRR) before major moves are made and before launch. The FRR is discussed in Section 2.1.1.18.2. Contingency verifications and procedures are developed for any contingencies that may occur during pre-launch and countdown. These contingency verifications and procedures are critical in that some contingencies may require a move of the launch vehicle or payload from the launch pad back to the processing facility.

2.1.1.18.1 Payload Processing

The payload is processed in a vertical or horizontal processing facility depending on requirements of the payload. A payload containing hazardous materials is processed through a hazardous payload handling facility. The payload is generally installed in a facility test stand during the verification activities. The Ground Support Equipment (GSE) used for processing is installed, verified, and certified, prior to use, including all lifting devices. An Operational Readiness Review is performed on major facilities. Before verification activities begin, a very close inspection is made of the payload to ensure no visible damage occurred during transporting to the launch site.

2.1.1.18.1.1 Processing Facility Verification

The verifications that are performed on the payload are those that are necessary to ensure that the payload systems continue to function properly and that no damage has occurred during shipment. The testing performed at the launch site on large payloads will be considerably less than the testing performed at the integration site but could be essentially the same tests for smaller payloads. Requirements for all verifications are defined in the Operations and Maintenance Requirements and Specifications Document (OMRSD) or the Verification Requirements and Specifications Document (VRSD), depending on which document is used for the payload. The verifications at the processing facility normally are:

- Single Point Ground test
- Bus isolation
- Systems confidence test (primary and redundant systems)
- Flight battery test (if installed at processing facility)
- Cargo Integration Test Equipment (CITE) Test
- Payload/ground system test
- Compatibility systems test
- Orbiter control of payload.

In addition to the above tests, special tests may be required to close open items that were transferred to the launch site. Also, if component or payload elements are shipped separately and integrated at the launch site, testing of the interfaces and systems will be required. If the payload is integrated into a carrier at the processing facility, the interface to the carrier must be verified. The carrier interface could be only a mechanical attachment requiring installation, structure grounding and threaded fastener verification or could also include an electrical interface requiring power, signal, command, and grounding verifications. Flight

battery installation should occur at the latest opportunity in the processing flow. The flight batteries are fully charged off-line but could require trickle charging after installation into the payload. Other verification related activities must be performed prior to moving the payload for integration with the launch vehicle. Some of these activities are:

- Removal of non-flight items
- Door closures
- Sharp edge inspection
- Cable connections
- Mechanical fasteners
- Latch closures
- Final walk down and inspection.

2.1.1.18.2 Flight Readiness Review

The Flight Readiness Review (FRR) is a formal, comprehensive review that provides to management the assurance that the payload is ready for flight. The review process is defined in a FRR Plan and is generally accomplished over a number of weeks utilizing results of earlier reviews. The review is structured for team reviews, pre-board and board reviews, and the certification of flight readiness. The FRR provides an assessment of all aspects of the flight hardware and software, including requirements compliance, the ground data network systems, and associated Ground Support Equipment (GSE). Discrepancies and/or items of non-compliance are recorded on Review Item Discrepancy (RID) forms which are then processed through the review system. The Data Package, which includes documentation from earlier reviews, will contain the information necessary to show compliance to program requirements and the flight readiness of all flight hardware and software.

The review data package will include the necessary documentation to achieve the objectives of the FRR, which are an assessment of:

- Safety and reliability, and critical item, including failure modes and hazard analyses
- Compliance to design, performance, and derived requirements
- Life limited hardware
- Materials and processes
- Mass Properties
- Loads, fracture mechanics analyses, and fracture control
- Ground operations
- Mission operations
- Crew operations
- Interface compatibility
- Non-conformances
- Open items and plans for closure.

The verification emphasis is directed to the assurance that design, performance, and derived requirements have been complied with. These include all flow-down requirements from Level I and those defined by the Verification Requirements and Specifications Document (VRSD). The Verification Requirements Compliance Document is used to make this assessment. All open items and non-compliances are assessed to assure proper closures have been identified. All verification activities that are required to be performed are identified and completions are scheduled. The discrepancies noted in the review of the data package are documented as a RID and processed through the FRR system. A summary of the findings and open issues is presented to the FRR Board for final review and disposition.

2.1.1.18.3 Integration In Launch Vehicle

Integration of a payload into the launch vehicle can occur in a facility such as the Orbiter Processing Facility (OPF) prior to moving to the launch pad or the payload can be integrated at the launch pad if constraints such as contamination servicing or late access dictate. Verifications of the Orbiter/payload interface largely depend on the services provided by the Orbiter. Normally, these verifications include:

- Trunion closure
- Grounding
- Orbiter power to payload
- Data through Orbiter telemetry systems
- Payload commanding through Orbiter
- Payload commanding via Orbiter SSP
- Setting of systems to launch configuration.

2.1.1.18.4 Verification At Launch Pad

The Orbiter with the payload installed is moved from the Orbiter Processing Facility to the pad by way of the Vertical Assembly Building (VAB) where it is integrated with the External Tank and Solid Rocket Boosters. Verifications of the payload are not performed at the VAB. Verifications at the launch pad provide the final assurance that all systems are functioning properly and the payload is ready for launch. The launch pad testing is minimal and the test would be designed to monitor the payload at the systems level. The ability to activate systems, voltages, currents, pressures and temperature sensors is monitored. Ground systems test and range systems tests are performed. The payload systems must be placed in launch configuration before power is removed from the systems. If any systems of the payload are to remain powered, the critical parameters of the payload are monitored continuously through the Orbiter systems.

Payloads installed at the pad can complete their pre-launch close-outs prior to installation into the launch vehicle. The payload would be subjected to a systems level confidence test, flight battery installation, and final closure of systems that are not to be activated in the launch vehicle. After installation in the launch vehicle, the interfaces are verified as if integrated in the OPF (see section 2.11.18.3). After interface verifications the following are performed:

- Systems confidence test
- Critical parameter monitoring
- Ground systems test
- Range systems test
- Launch configuration.

External services may be required for the payload, such as battery charging, purge gases, and/or cooling. These services must be removed and interfaces closed out. A final inspection of the payload is made before access doors are closed.

A countdown demonstration test is performed prior to start of launch countdown. The payload will be in a launch configuration with any active parameters being monitored continuously. The payload is monitored during the countdown leading to launch in the same manner.

2.1.1.19 Launch/Ascent

Launch and Ascent may provide the first opportunity to insure that some design and performance requirements of a payload or a launch vehicle are within specification. Most of these requirements are related to structures and dynamics systems. Most payloads are in a non-powered configuration or limited power during the ascent phase, limiting verifications and

monitoring of systems. Systems monitored during the ascent phase are monitored through the launch vehicle data management system to determine systems performance.

2.1.1.20 On-Orbit Verification

On-orbit or flight verification provides the assurance that the systems function properly in a near zero gravity and vacuum environment. These verifications are performed through systems activation and operation, rather than through a verification activity. Some requirements that are verified on-orbit are those associated with appendage operation and with systems which operate only in a vacuum and/or require an on-orbit exitation source. Also, if applicable, charging of batteries through use of solar arrays must be verified.

Payloads that are assembled on-orbit must have each interface verified and must function properly as a system during end-to-end testing. Mechanical interfaces that provide fluid and gas flow must be verified to ensure no leakage occurs and that system pressures and flow rates are within specification. Environmental systems must be verified. Redundant systems are generally not verified unless a malfunction occurs that requires activation of the redundant system. The requirements for the on-orbit verification activity, whether for activation of a system or a verification activity, are defined in a Verification Requirements and Specifications Document (VRSD). The requirements of the VRSD are implemented through the flight timelines.

2.1.1.21 Flight Evaluation Report

The Flight Evaluation Report presents the results of payload performance during on-orbit operations or the results of the launch vehicle performance. The report provides a general description of the systems and how each system performed. The report will also identify anomalies and any corrective action taken. The objectives for a payload and the extent accomplishment of the orbital activity are identified. The Flight Evaluation Report may identify each verification requirement to be verified on-orbit through activation or a verifications activity. The report also provides the systems performance and a description explaining the degree of requirement satisfaction.

2.1.1.22 Post-Landing Activity

The post-landing activity is not a verification activity but rather an assessment of the payloads systems, generally performed by the Payload Developer. This assessment is used as an input to the flight evaluation report and establishes a status of the systems before refurbishment or reflight. This activity begins when the mission is completed and concludes when all information is acquired and activities necessary to satisfy post-landing requirements are finished.

2.1.2 PROCESS VARIATIONS FOR LAUNCH VEHICLE PROGRAM

A launch vehicle is processed somewhat differently from a payload in that the elements of the launch vehicle are generally manufactured and verified at separate locations and mated at the launch facility. The launch vehicle could be a Shuttle configuration or an Expendable Launch Vehicle type configuration. Verification of launch vehicle elements at the manufacturer's facility would in general be for a payload as discussed in Section 2.1.1 with the additional Verification of the Propulsion System. Only the differences in verification activities between a large payload and a launch vehicle will be discussed.

For the purpose of this handbook, the verifications discussed are for the first flight vehicle to be processed. Verifications may be reduced on later flights as the vehicle configuration remains firm and confidence in the vehicle is built. The first flight vehicle elements should be subjected to a static firing of the engines. This firing could be performed at a site prior to being shipped to the launch site or the main booster stage engines could be fired at the launch site after delivery. This handbook addresses engine firings at both locations.

The Ground Support Equipment (GSE) to be used in the processing must be installed and verified, including lifting and handling equipment. The lifting and handling equipment is verified in the configuration for which it is to be used. An Operational Readiness Inspection (ORI), as for a payload, will be performed on major facilities. The verification activities performed on the launch vehicle booster stage and the upper stages will, in general, be the same. This handbook addresses variations to the verifications process for the booster element only.

2.1.2.1 Process with Flight Readiness Firing

The verification process flow for a launch vehicle booster stage may include a Flight Readiness Firing (FRF). This verification process flow follows the large payload process until post-shipment verifications have been completed at the launch site.

2.1.2.1.1 Booster Stage Processing Facility Verifications

The verifications that are performed at the booster stage processing facility are those necessary to ensure that the vehicle systems continue to function properly and that no damage has occurred during shipment to the launch site. Once the booster stage has been installed into the processing facility, an inspection is performed to ensure no visible damage has occurred. A single point ground test is performed prior to connecting the Ground Support Equipment (GSE). The other verifications at the booster stage processing facility are:

- Bus isolation
- Systems confidence tests
- Flight battery test (if installed at the processing facility)
- Special tests
- Systems compatibility test.

The systems confidence test is structured to ensure the systems continue to function properly. This test does not operate systems through all modes and configurations. Redundant systems are tested to be active. The flight batteries are installed at the latest opportunity in the flow. When flight batteries must be installed early in the processing flow, the booster stage may be required to accommodate a ground power source. The flight batteries normally do not require trickle charging prior to launch. All open items transferred to the launch site with the booster stage requiring verification will be closed. A final inspection is made of the stage prior to movement to the vehicle integration facility.

The processing of upper stage elements may require integration in the stage processing facility prior to moving to the vehicle integration facility for final integration. This would occur when a shroud and payload are integrated with the upper propulsion stage. This integration would require the additional verification of:

- Latch mechanisms
- Interface signals
- Structure bonding
- Structure interface
- Interface power
- Shroud closure
- Door panel closure.

A final inspection is performed before movement of the upper stage element/payload to the vehicle integration facility.

2.1.2.1.2 Launch Vehicle/Transporter Integration

The elements of the launch vehicle (with or without a payload installed) are brought together at a launch vehicle integration facility for integration onto the launch vehicle/transporter. The mechanical and electrical interfaces including signals, power, mechanical, bonding and grounding are verified.

The first flight stage may also be used for tanking tests at the pad prior to a firing of the liquid fueled engines to determine their flight readiness. The flight readiness firing should be performed especially if no static firing of the engines occurred after their integration with the booster stage. This handbook will address the scenario of a flight readiness firing of a liquid engine launch vehicle booster stage.

2.1.2.1.3 Flight Readiness Firing

For a Flight Readiness Firing (FRF), the vehicle booster stage and transporter are positioned at the pad as if for launch. Pad facilities and electrical and mechanical interfaces are verified. The tanking/drain interfaces are connected and tanking and drain tests of the liquid oxygen and liquid hydrogen tanks and systems are performed. The tanking test presents an opportunity to perform a FRF with minimum schedule and cost impact. A successful firing will verify the manufacturing and assembly procedures, the operational integrity of most flight systems and ground support equipment, and the countdown procedures. Confidence tests of the launch vehicle booster stage systems are required after the tanking test if a FRF is conducted. Test instrumentation is installed on the booster stage and verified. The Ground Support Equipment (GSE) is verified prior to connecting to the booster stage. Vehicle power for the firing could be supplied by internal test batteries or an external power source. Verifications performed for the FRF are:

- Booster stage/GSE grounding
- Bus isolation
- Systems confidence test.

The FRF is a short firing of approximately 30 seconds or less using launch tanking and countdown procedures. Telemetry data transmission could be open or closed loop. Range safety procedures are also verified during the firing. Continuous monitoring of the vehicle booster stage is performed to provide a cut-off of the firing if red line parameters are exceeded. An assessment and acceptance of the firing data is completed before the booster stage is prepared for the move back to the launch vehicle integration facility for refurbishment and final integration.

The flight readiness firing will verify:

- Systems functional operation
- Systems Operating Pressures
- Propellant flow rates
- Vehicle trust
- Vehicle control
- Engine gimballing
- Propulsion System Valve Operation
- Tank pressures
- Thermal control
- Tanking/Detanking of propellants
- Vehicle dynamics.

2.1.2.2 Process With Static Firing

The verification process leading to the readiness of a vehicle booster stage prior to moving to the static firing facility is essentially the same as for a payload. Upon completion of all systems verifications, the vehicle booster stage is transferred to the static firing facility which could be at the manufacturing site or at a remote location. The major difference between the verification process for a payload and a vehicle booster stage, except for the static firing activities, is that the vehicle booster stage is returned to the post-manufacturing test facility for a post-firing verification.

2.1.2.2.1 Static Firing

The verifications leading to a booster stage static firing is as for a Flight Readiness Firing (FRF). Test instrumentation installed at the static firing facility and flight systems are verified to be functioning properly and are ready to support a static firing. The static firing process could consist of a short firing of approximately 30 seconds and when successful, it is followed by a full flight duration firing. Another option could be to perform only a full flight duration firing. Some system flight pressures are not achieved during a short duration firing. Systems are functioned as during an actual flight with few exceptions. Flight software is installed and engine gimballing is performed. The static firing will verify systems as defined for a FRF in section 2.1.2.1.3. Before the stage is prepared for the move back to the post-manufacturing testing site for refurbishment and re-verification, an assessment of the static firing data is performed to assure that all systems have functioned properly. An inspection is performed to assure that no visible damage has occurred during the firing(s). Test instrumentation is removed prior to removal of the stage from the static test facility. A report of the static firing results is prepared.

2.1.2.2.2 Post Firing Verification

When the stage has been returned to the integration site and placed in the testing facility, another inspection is made to note any visible damage. Again, the electrical ground support equipment is functionally tested prior to connection to the stage to ensure no damage to the flight systems could occur from the Ground Support Equipment (GSE). A single point ground test is made both prior to and after connecting GSE. A bus isolation test is performed prior to power being applied to the main busses. Systems and subsystems level verifications, as performed during post assembly, are performed to assure proper operations after refurbishment. As part of the systems verifications, a compatibility test is performed to ensure the stage is ready for shipment to the launch site. Analyses and models are updated using data from the static firing(s).

2.1.2.3 Launch Vehicle Integration Verification

A Vehicle booster stage that has undergone a Flight Readiness Firing (FRF) and refurbishment must be re-verified prior to integration with other launch vehicle elements and the payload. A confidence test is performed that will verify that systems are functional. Any

component replacement or rework that invalidates a system previously verified must be re-verified to initial acceptance requirements.

The integration of the launch vehicle elements require verification of the interfaces and of the systems that cross interfaces. The mechanical and electrical interfaces are verified to ensure that mechanisms have been latched and that each signal path of each electrical cable is active. The verifications performed on the integrated vehicle are:

- Structure bonding
- Vehicle grounding
- Latch/mechanism closure
- Interface checks (power, signal paths, commands)
- Systems compatibility (RF open loop with antenna hat coupler)
- Launch configuration.

If flight batteries are installed at the integration facility, the batteries and battery system are verified. A load is applied to the batteries to ensure proper battery operation. Non-flight item removal and system close-out are performed to the extent possible. All systems of the integrated vehicle must be operating properly and the launch vehicle must be assured to be ready to support a launch before the vehicle is moved to the launch pad.

2.1.2.4 Launch Vehicle Pad Verification

Verifications at the launch pad are limited and consist of tests that ensure the systems continue to operate properly and to support any necessary payload activity. Flight batteries, if at the pad, are verified under load. A verification of the ground system data network with the flight vehicle must be made, as well as range safety checks. Critical parameters of the launch vehicle are monitored during the countdown to ensure red line parameters are not exceeded. The verifications required at the pad, generally, are:

- Vehicle/Ground Support Equipment (GSE) grounding
- Bus isolation
- Systems confidence test
- Ground data network
- Range safety check
- Battery test (it batteries are installed at Pad)
- Critical parameter monitoring
- Mechanism closures
- Door/panel closures
- Launch configuration
- Non-flight item removal.

A final inspection is performed on the launch vehicle as close-outs are performed. Special attention is given to door/panel closures and the removal of non-flight items.

2.1.3 PROCESS VARIATIONS FOR SPACELAB PAYLOAD PROGRAM

The verification process for Spacelab Payload programs is divided into two separate verification programs. One of the programs is developed for verification of the individual experiment and is directed by the experiment Project Manager. The other program is developed for verification of the integrated Spacelab payload and is directed by the Payload Mission Manager. This handbook is applicable to experiments developed in-house at Marshall Space Flight Center (MSFC) and will define variations in the verification process as the process is applied to Spacelab payloads. Figure 2.1.3-1, Verification Process Flow, presents the Verification Process Flow for a Spacelab experiment that incorporates the defined verification process with Spacelab mission requirements defined by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE). The flow also presents the integrated Spacelab Payload verification process. The numbers of each block of the flow identify the corresponding paragraphs within the text that describe the activity. Since only variations to the verification process are being addressed in the text of this section, many activity and product blocks of the flow will reference paragraph numbers of section 2.1.1.

2.1.3.1 Experiment Verification

The verification of the individual experiments must be performed before shipment of the experiments to the launch site for integration with Spacelab hardware. The verification process applied to individual experiments developed by MSFC is the process defined in section 2.1.1 with few differences. These differences are addressed in the paragraphs that follow.

2.1.3.1.1 Experiment Verification Plan

In addition to developing a verification program that will ensure compliance to all program requirements, the Experiment Developer must ensure compliance to all applicable requirements of JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE). These are safety and interface requirements defined in the Experiment Verification Plan, which is tailored for a given experiment and mission. The Experiment Verification Plan is developed by the Payload Mission Manager and is based on one of the following documents, depending on the type of Space lab mission:

- JA-061, "Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, Mission Peculiar Equipment (MPE), and Electrical Checkout Equipment (ECE) on Space Transportation System (STS) Spacelab Payload Missions"
- JA-081, "Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Partial Payload Missions"
- JA-276, "Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Orbiter Middeck payload Missions."

The requirements of the Experiment Verification Plan must be incorporated into the experiment requirements documentation if they were not included during experiment verification requirements definition. Compliance to requirements of the Experiment Verification Plan is ensured through the experiment verification process and is used as an input to the acceptance of the experiment. The compliance to these requirements as required by the Payload Mission Manager for experiment integration is also ensured by the Payload Mission Integration Contractor. The Experiment Verification Plan is also referred to as a Safety and Interface Verification Plan on some programs.

2.1.3.1.2 Payload Element Integration Readiness Review

The Payload Element Integration Readiness Review is held at the completion of the acceptance testing of the experiment to provide assurance to management that the experiment is ready for shipment to the launch site for integration into the Spacelab Payload. The review is conducted by the Payload Mission Manager in conjunction with the experiment developer. The requirements for the review are defined by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE). The review ensures the experiment developer has complied with all safety and interface requirements. The review leads to the signing of a certification that the experiment meets mission requirements, with exceptions if any.

The data required for the review for assessment is defined by MROFIE and includes:

- As built drawings/schematics
- Cleanliness Certification
- Operating time and cycle log
- Weight and balance data
- Shipping document
- Proof-loading certification
- Open items list
- Design Certification Review (DCR) status
- Assessment of hardware, software, and GSE compatibility with requirements
- Materials review records
- Verification reports
- Compliance to requirements
- Waivers and Deviations
- Work planned but not completed
- Non-conformances
- Hardware shortages
- Non-flight hardware list.

The assessment of the acceptance data package will ensure proper verifications have been performed and requirements have been met. The compliance document assessment is a critical verification activity of the review. The verification of the compliance data to satisfy the applicable requirement will ensure testing, analyses, and other verifications have been performed adequately. In general, the review must provide evidence that:

- Verification requirements have been complied with.
- Compliance data is valid and complete.
- Components were qualified and accepted.
- Verification reports reflect activities performed.
- Non-conformances are properly dispositioned.
- Test data is valid and acceptable.
- GSE is developed for launch site.
- Work planned was completed or identified as open.
- All open areas are identified.
- Waivers and deviations are valid.
- Hardware shortages and non-flight hardware are defined.
- Limited life items are defined with run time/shelf life/cycles specified.
- Safety requirements and hazards have been satisfied.

All items that are determined to be open or not in compliance with requirements are identified and become part of the data package that accompanies the experiment to the launch site.

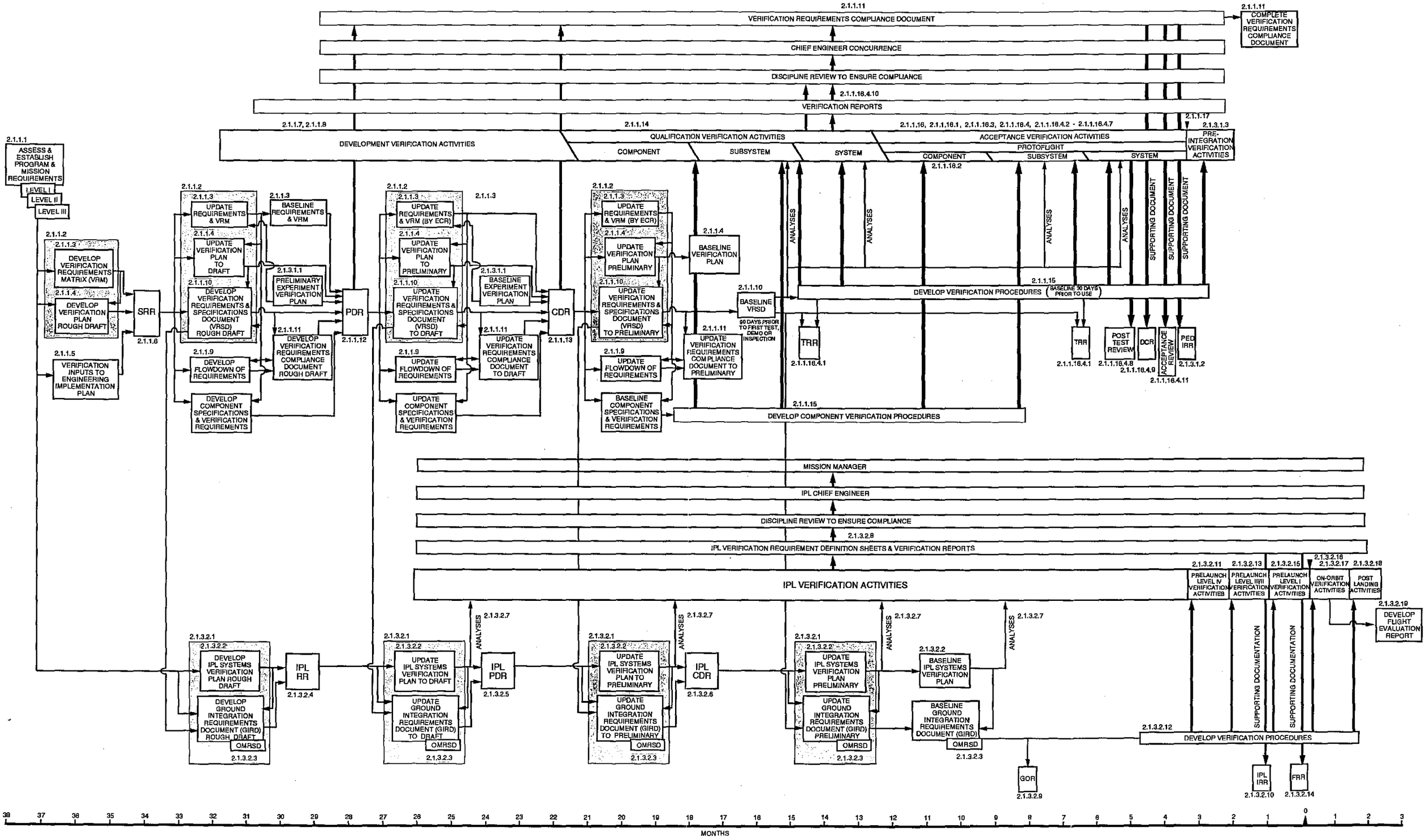

FIGURE 2.1.3-1 SPACELAB VERIFICATION PROCESS FLOW

2.1.3.1.3 Experiment Pre-Integration Verification

An experiment shipped to the launch site must be verified to be continuing to operate properly prior to its integration into the mission payload. This verification is performed off-line from the integration activities. A functional test of the experiment is generally performed to ensure proper performance. The test will operate and function all systems that can be operated in an ambient and 1-G atmosphere. The verifications are performed by the Experiment Developer using the Developer's documentation and ground support equipment. The verifications generally performed are:

- Grounding
- Power load
- Command/response
- Systems activation
- Launch Configuration
- Flight Battery Test (if applicable).

Open items that are transferred to the launch site may also be verified and closed. The flight battery test will occur at the location of flight battery installation. The flight batteries are fully charged off-line. Servicing may occur during the off-line activities. Also, a final inspection is made of the experiment prior to integration to ensure that no sharp edges exist, that non-flight items scheduled to be removed, are removed, and that all mechanical fasteners are closed.

2.1.3.2 Payload Integration Verification

The verification activities associated with integration of the individual experiments into a payload for a Spacelab Mission closely follow the verification activities associated with experiment development and acceptance. The verification activities begin as soon as the payload configuration for the mission is defined. Some payloads are flown in lockers or on specially designed equipment and do not require a Spacelab module nor a Spacelab igloo. This payload configuration is termed a "Partial Payload" by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE)

2.1.3.2.1 Verification Program Planning

The Integrated Payload (IPL) verification program planning begins with the defining of the experiment complement for a given mission. The planning activities concentrate on assurance of systems compatibility of the flight hardware and the verification and compliance to safety and interface requirements. The IPL activities to be performed are defined by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE), and the systems level verification requirements are defined by JA-062, "Spacelab Integrated Payload System Verification Requirements" or by JA-082, "System Verification Requirements for Integrated Payloads on Partial Payload Missions". The type of mission determines the documentation used to define the safety and interface requirements. Each requirement of either JA-062 or JA-082 must be assessed to determine applicability to the mission and for inclusion into the Integrated Payload Verification Plan.

2.1.3.2.2 Integrated Payload Verification Plan

The Integrated Payload Verification Plan defines all the verification requirements tailored to a specific mission that are to be satisfied during the verification process of the integrated payload. The requirements are selected from either JA-062, or JA-082. Each requirement is defined on an accompanying Verification Requirements Definition Sheet, as shown in Figure 2.1.3.2.2-1. The plan will identify all requirements to be verified by all methods, a narrative of each requirement, the data required to show compliance, and the organizations(s) responsible to provide the compliance data.

An example Integrated Payload Verification Plan is provided in Volume II of this handbook.

2.1.3.2.3 Operations and Maintenance Requirements and Specifications Document

The Operations and Maintenance Requirements and Specifications Document (OMRSD) defines the requirements and specifications for processing experiments or an integrated payload along with its associated hardware at the launch site. This document includes integration, launch, and post landing (including abort) operations and any experiment requirements transferred from the Verification Requirements and Specifications Document (VRSD) that must be verified after turnover. The OMRSD identifies each requirement, measurement/stimuli, specification, and constraint applicable to the processing activity. Specifications include allowable tolerance for standards of judgment to be used in determining acceptance performance. The OMRSD also provides servicing requirements, hazardous operations, crew participation and post landing requirements, if applicable, for de-integration.

An example page of an OMRSD is provided in Figure 2.1.3.2.3-1, Operations and Maintenance Requirements and Specifications Document Sample. The OMRSD is completed according to the following format information:

1) NUMBER - Requirement Number X XXX XXX X XXX XX
   1 2 3 4 5 6
   PART 1 - Project Element
   PART 2 - PIP Identifier
   PART 3 - Group Designator
   PART 4 - Requirement Category
   PART 5 - Sequence Number
   PART 6 - OMRSD Subset

2) REV - Line Number

3) DESCRIPTION - Title and definitive statement of the requirement

4) MEAS/STIMULI - Measurement number or command number

5) SPECIFICATION - Criteria/Specification necessary to satisfy the requirement

6) INTERVALS/CONSTRAINTS/REMARKS - Intervals, constraints, and remarks provided in the following format:

   A:
   B:
   C:
   D:
   REF:

WHERE:

A: Payload Effectivity
B: English language expression for the interval and effectivity
C: Remarks, constraints, cautions, and warnings
D: Documentation source or requirements
REF: Internal number coding for traceability back to other documentation.

An example OMRSD is provided in Volume II of this handbook.

EXPERIMENT AADSF	VERIFICATION REQUIRMENT DEFINITION SHEET	ELEMENT MUFFLE TUBE ASSEMBLY
REQUIREMENT NO.	REQUIREMENT TITLE	METHOD
3.2.1.1	Temperature	A and T

VERIFICATION REQUIREMENT:

Verify that the Muffle Tube Assembly withstands and sustains the sample ampoule throughout the entire operating temperature range given in Flight Specific ICD-3-60033/#. This shall be accomplished without interfering with the capacity of the furnace to provide the desired temperature environment.

DATA REQUIRED:

1. Stress analysis report.
2. Certified GCEL test report.

APPLICABLE DOCUMENTS AND NOTES:

MSFC-SPEC-2053, par. 3.2.1.1
ICD-3-60033/#

RESPONSIBLE ORG: (1) ED25 (2) EL63

DATA SUBMITTAL DATE: Feb., 1993

Figure 2.1.3.2.2-1 Verification Requirements Definition Sheet

Table 4. - PAYLOAD INTERFACES OMRSD - FILE II, VOL. II

Number	Rev	Description	Meas/Stimu	Specification	Intervals/Constraints/Remarks
		REQUIREMENT			
P009EB.300		HST CONTINUOUS POWER		ORB	A: PST
	0-000				B:
	0-001	MONITOR HST ESSENTIAL POWER			C: REMARK - NOTIFY P/L TEST
	0-002	DURING LAUNCH COUNTDOWN FROM			CONDUCTOR OF ANY POWER
	0-003	HST POWER UP UNTIL T-20 MIN			INTERRUPTIONS
	0-004				
	0-005	SSP EXT ESS PWR	P34X2101V	ON	
	0-006	SSP EXT ESS PWR	P34X2102V	OFF	
	0-007	MN BUS PWR	P34X2103V	OFF	
	0-008				
	0-009				D: PIP 14009 PARA 4.1.1
P009ED.200					
	0-000	RESISTIVE COUPLING MEASUREMENT		ORB	A: PST
	0-001				B:
	0-002	VERIFY RESISTANCE BETWEEN HST		5 K OHMS	C: REMARK - RESISTANCE BETWEEN HST
	0-003	SINGLE POINT GROUND AND		+/- 500 OHMS	MAIN BUS RETURN AND ORB STRUCT.
	0-004	ORBITER STRUCTURAL GROUND			GROUND SHALL BE VERIFIED BY
	0-005				RESISTANCE MEASUREMENT PRIOR TO
	0-006				UMB MATE
	0-007				
	0-008				
	0-009				REMARK - MEASUREMENT TO BE
	0-010				PREFORMED AT HST SINGLE PT
	0-011				GROUND X0995, V083, Z0424 (ORB
	0-012				COORD) AND ORB STRUCT POINT Z0388
	0-013				
	0-014				
	0-015				REMARK - P/L GSE WILL PROVIDE
	0-016				5 +/- 0.5 KOHM RESISTANCE
	0-017				
P009ED.300					D: ICD A-14009 PARA 10.7.4.3.2, FIG
	0-000				E10.7.4.2.2.1-1
	0-001				
	0-002	HST TO ORB BONDING		ORB	A: PST
	0-003				B:
	0-004	VERIFY BONDING EXISTS BETWEEN		</= 16 MILLIOHMS	C: CONSTRAINT - HST TO ORBITER
	0-005	HST STRUCTURE AND ORBITER			BOND SHALL BE VERIFIED BY
	0-006	STRUCTURE			RESISTANCE MEASUREMENT WITH
	0-007				HST UMB MATED
	0-008				
	0-009				
	0-010				REMARK - MEASUREMENT TO BE
	0-011				PREFORMED AT HST SINGLE POINT
					GROUND X0995, V083, Z0424 (ORB
					COORD) AND ORB STRUCT POINT Z0388

Figure 2.1.3.2.3-1 Operations and Maintenance Requirements and Specifications Document Sample

2.1.3.2.4 Integrated Payload Requirements Review

The Integrated Payload (IPL) Requirements Review (RR) is performed to establish and define the mission requirements allocated to each experiment. The requirements will define the interfaces between the payload elements and the allocation of the launch vehicle resources. The requirements are defined in the Integrated Payload Requirements Document (IPRD). The documentation of the IPL RR as required by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE), is as follows:

- Baseline Issue Integrated Payload requirements Document
- Preliminary Configuration Layouts
- Preliminary Generation Breakdown
- Preliminary Cable Interconnect Diagram
- Preliminary Mechanical Interconnect Schematic
- IPL Safety Compliance Data
- Compatibility Assessment Timeline
- Payload Compatibility Analysis.

The verification activities of the IPL RR are:

- To ensure interface requirements are defined in the IPRD
- To ensure verification of safety requirements can be accomplished
- To ensure compatibility of integrated payload hardware and systems.

2.1.3.2.5 Integrated Payload Preliminary Design Review

The Integrated Payload (IPL) Preliminary Design Review (PDR) is performed to finalize mission requirements, finalize payload experiment interfaces, finalize verification methods for safety requirements, and provide the preliminary design for physical integration. The documentation for the PDR data package includes experiment PDR results and mission documentation. The documents required for the IPL PDR by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE) are:

- Updated Configuration Layouts
- Baseline Issue Generation Breakdown, Cable Interconnect Diagram, and Mechanical Interconnect Schematics
- Baseline Issue Instrument Interface Agreements (IIAs)
- Preliminary Operations and Integration Agreements
- Baseline Issue Mission Peculiar Equipment (MPE) Design and Performance Specifications
- Preliminary Payload Data Package, Annex 1 Inputs
- Preliminary Electrical Systems Schematics
- Integrated Payload Mass Properties Status Report
- Preliminary Flight Supplement Payload Operations Guidelines
- Preliminary Software Requirements Document
- Preliminary Integrated Payload System Verification Plan
- Preliminary Ground Integration Requirements Document (GIRD)
- Preliminary Flight Definition Document
- Preliminary Stowage List
- IPL Safety Compliance Data
- Preliminary Spacelab Data Flow and Data System Configuration
- Payload Compatibility Analyses
- Preliminary Issue TV and Photographic Integration Requirements Document.

The verification activities of the IPL PDR are to:

- Assure proper closure of safety and interface requirements (as applicable).
- Assure definition of verification requirements in the Operations and Maintenance Requirements and Specifications Document (OMRSD) section of the GIRD.
- Ensure compatibility of integrated hardware and systems.
  Issues resulting from review activities are documented on Review Item Discrepancy (RID) forms and are worked through the RID system.

2.1.3.2.6 Integrated Payload Critical Design Review

The Integrated Payload (IPL) Critical Design Review (CDR) is performed to ensure payload compatibility with the Space Transportation System, ensure compatibility of payload experiments, and to verify system safety. The review will also ensure the physical integration of the payload can be accomplished as well as the compatibility of the flight definition and implementation documentation to the final design. The documentation resulting from the experiment CDRs are included in the IPL CDR documentation. The documents required for the CDR by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE), are:

- Baseline Issue/Update Operations and Integration Agreement
- Baseline Issue Assembly and Installation Drawings
- Baseline Issue Electrical Systems Schematics
- Update Payload Data Package, Annex 1 Inputs
- Baseline Issue Software Requirements Document
- Preliminary Crew Compartment, Annex 6 Inputs
- Baseline Issue Stowage List
- Payload Compatibility Analyses
- Baseline Issue IPL Safety Compliance Data
- Baseline Issue Integrated Payload System Verification Plan
- Baseline Issue Ground Integration Requirements Document (GIRD)
- Baseline Issue Mission-Peculiar Orbiter Interface Control Document
- Baseline Issue Mission-Peculiar Spacelab Interface Control Document
- Preliminary Payload Data Processing Requirements
- Baseline Issue Experiment Simulator Requirements Document
- Preliminary Integrated Training Plan
- Baseline Issue TV and Photographic Integration Requirements Document.

The verification activities of the CDR are:

- Assure proper closure of safety and interface requirements (as applicable)
- Assure definition of verification requirement in the OMRSD section of the GIRD
- Ensure compatibility of integrated hardware and systems
- Ensure all safety and interface verification requirements are defined in the IPL System Verification Plan

Issues resulting from review activities are documented on a RID form and are worked through the RID system.

2.1.3.2.7 Integrated Payload Analyses

Analyses are performed to ensure the compatibility of the integrated payload, and to assure that the payload can be physically integrated. The analyses are documented in an Integrated Payload Verification Analysis Report that is used for closure of verification requirements. The analyses, in general, required by JA-062 or JA-082 for a Spacelab integrated payload are:

- Electromagnetic properties
- Systems compatibility
- Hardware integration/de-integration capability
- Mass properties
- Structural design capability
- Hardware deployment
- Electrical power
- Thermal capability/compatibility
- Interface compatibility
- Venting
- Software compatibility.

2.1.3.2.8 Integrated Payload Reports

Two different type reports are used to document information used to satisfy verification requirements. One report is the Verification Analysis Report which documents the results of the payload analysis and the second report is the Verification Test Report which documents the results of the test. Both reports are prepared in accordance with Data Requirements of JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE).

The information contained in the Verification Analysis Report is :

- Objectives of the analysis
- Verification requirements satisfied by the analysis
- Description of analytical technique
- Hardware and/or software configuration analyses
- Analysis input data (summary)
- Compliance to requirements
- Conclusions.

The information contained in the Verification Test Report is:

- Test objectives
- Description of test setup(s)
- Identification of the item(s) tested
- Identification of "as-run" test procedures
- Correlation of tests with the verification requirements
- Summary of the results including compliance to requirements
- Explanation of all failures and corrective actions taken.

2.1.3.2.9 Integrated Payload Ground Operations Review

The Integrated Payload (IPL) Ground Operations Review (GOR) is performed to ensure that the physical integration requirements have been defined and that the necessary support to ground operations has been allocated. The documentation for the review as defined by JA-447, "Mission Requirements on Facilities/Instruments/Experiments for Space Transportation System (STS) Attached Payloads" (MROFIE), is :

- Baselined Ground Integration Requirements Document (GIRD)
- Baselined/Updated Operations and Integration Agreements for each payload element
- Baselined Integrated Payload System Verification Plan
- Baselined Assembly and Installation Drawings
- Baselined Interface Schematics
- Preliminary Destowage Plan
- Baseline Issue of Payload Operations Control Center (POCC) Data Base
- Launch Site Support Plan
- Baselined IPL Safety Compliance Data.

The verification activities of the IPL GOR are:

- Ensure verification requirements defined by the Operations and Maintenance Requirements and Specifications Document (OMRSD) are complete.
- Ensure requirements of the System Verification Plan are complete and required compliance data are identified.
- Ensure verification support activities are identified.
- Assure proper closure of safety requirements.

2.1.3.2.10 Integrated Payload Integration Readiness Review

The Integrated Payload (IPL) Integration Readiness Review (IRR) is conducted to ensure that safety and interface requirements have been satisfied and that the Experiments are ready for integration. The IPL IRR is conducted in two phases. Phase I is conducted prior to the start of Level IV experiment integration and Phase II is conducted prior to the start of Level III/II integration. The verification activities of the IPL IRR are to ensure valid compliance to the safety and interface requirements and that all verification requirements to be satisfied are included in the Operations and Maintenance Requirements and Specifications Document (OMRSD).

2.1.3.2.11 Prelaunch Level IV Verification

The integration of the experiments into the flight racks and/or pallet occurs during the Level IV activity. This integration occurs after the experiments have been verified off-line and have been formally turned over for launch site control. The verifications performed at Level IV include interface checks and functional tests of each experiment. All interfaces that have been connected are verified through tests, including structure bonding. The functional tests of each experiment ensures the experiment continues to function properly. The degree of testing is dependent upon individual systems activation in an ambient and 1-G environment.

2.1.3.2.12 Integrated Payload Procedures

The Integrated Payload procedures are documents that provide step by step instructions for performing a given activity on hardware and/or software. The procedure is tailored to the activity that is to be performed to satisfy a requirement and could be for a test, a demonstration, or any other verification related activity. The procedures are generated to satisfy those requirements defined by the Operations and Maintenance Requirements and Specifications Document (OMRSD) and are used to verify the acceptance of facilities, ground support equipment, and special test equipment, as well as the Integrated Payload. The procedures contain detailed information of hardware and software configurations and of steps, in sequence, and operations to be taken.

The procedure will, also, provide blank spaces for recording of results and narrative comments in order that the completed procedure can serve as part of the verification report. The as-run and certified copy of the procedure is maintained as part of the historical files and is used for closure of safety and interface requirements. The submittal requirement for a procedure is normally thirty days prior to the start of the activity for which the procedure is to be used.

2.1.3.2.13 Prelaunch Level III/II Verification

The integration of the racks into the Spacelab module or the attachment of the Spacelab Igloo to the pallet occurs during the Level III/II activity. The new interfaces are verified. The verifications performed at Level III/II ensure that the experiment systems function together properly. This verification is accomplished through performing Integrated Performance Tests and Mission Sequence Tests. The interfaces with the Orbiter are verified through Cargo Integration Test Equipment (CITE) testing. The integrated performance testing will verify:

- Interfaces
- Experiment compatibility
- Ground systems
- Experiment functions
- Proper payload integration

The Mission Sequence Test is a time-slice of the mission timeline. This test verifies:

- Systems compatibility in a simulated mission
- Payload and ground systems compatibility
- Systems operation.

2.1.3.2.14 Flight Readiness Review

The Flight Readiness Review (FRR) is conducted to ensure that the flight payload, launch vehicle, and ground systems are ready to support the launch and mission. The FRR is conducted in two phases. The first phase is held prior to the start of Level I activities to ensure:

- Safety and interface requirements have been complied with.
- The Integrated Payload is ready for integration in the Orbiter.
- Payload requirements defined in the Ground Integration Requirements Document, including the Operations and Maintenance Requirements and Specifications Document (OMRSD), have been satisfied.

The second phase of the FRR is conducted after Level I activities are completed to ensure the payload, launch vehicle, ground systems, and support teams are ready to support the launch and mission.

2.1.3.2.15 Prelaunch Level I Verification

The level I activities include integration of the integrated Spacelab module, pallet or partial payload into the Orbiter and the verification of those interfaces. The Level I verifications include the verifications performed at the Orbiter Processing Facility, the Vertical Assembly Building, and at the launch pad. Compliance to all safety and interface requirements is certified. Verifications performed are:

- Orbiter support of payload requirements
- Payload/Orbiter interface
- Payload/Orbiter/ground system compatibility
- Range safety tests
- Final close-out and servicing
- Cleanliness certification.

2.1.3.2.16 Launch/Ascent

Launch and ascent provide the first opportunity to assure that some design and performance requirements of a payload are within specification. Most of these requirements are related to structures and dynamics systems. Most payloads are in a non-powered configuration or limited power of systems during the ascent phase, limiting verifications and the monitoring of systems. Systems that are monitored during the ascent phase are normally monitored through the launch vehicle data management system and are monitored only to determine systems performance. The requirements will have been verified by analysis and simulated environments prior to launch.

2.1.3.2.17 On-Orbit Verification

On-orbit verification is generally not performed on Spacelab Payloads or Partial Payloads. Compliance to all requirements is established prior to launch. Experiments and systems are activated and verified to be operating properly prior to any science operations. This

activity is generally the activation of the experiment systems and not the verification of the systems.

2.1.3.2.18 Post-Landing Verification

The post-landing activity is not a verification activity but rather an assessment of the payload systems, generally performed by the Payload Developer. This assessment is used as an input to the flight evaluation report and to establish a status of the systems before refurbishment or reflight. This post-landing activity begins when the payload compliment is returned to earth and concludes when information necessary to satisfy post-landing requirements is acquired.

2.1.3.2.19 Flight Evaluation Report

The Flight Evaluation Report for the payload presents the results of payload performance during on-orbit operations. The report provides a general description of the experiments and how each experiment performed. The report will also identify anomalies and the corrective action taken, if applicable. All the objectives of the mission and the accomplishments to the objectives are identified in the report.

2.2 PROCESS VARIATIONS FOR CONTRACTOR DEVELOPED PROGRAM

The verification process for a contractor developed program is the same as a payload developed at Marshall Space Flight Center (MSFC) as defined in Section 2.1 with some exceptions. A major exception to the activities is that the contractor prepares the documentation in accordance with a contract and MSFC provides an assessment of the documentation. The Science and Engineering Directorate provides technical inputs and recommendations to the Project Office. The verification organization participates in the contractor selection process by providing verification inputs to the Request for Proposal (RFP) and by accessing the contractor proposals in reply to the RFP. This handbook addresses only the variation of the verification processes that is applicable to a MSFC contractor developed program.

2.2.1 INPUT TO REQUEST FOR PROPOSALS

The Request for Proposals (RFP) is the document submitted to industry to obtain proposals to contract for the work requirements of Phase C/D. The RFP defines the baseline requirements and design approaches that were determined from Phase B as well as the tasks to be performed and the items to be delivered. The verification activities defined by the RFP are those necessary to accomplish a successful verification program as established during Phase A/B studies and pre-planning activities. A Request for Proposal is initiated only for out-of-house projects.

Listed below are verification related tasks and Data Requirements Descriptions (DRDs) that are normally required to be accomplished for a successful verification program. Some variations in the tasks may occur depending on the particular flight article. The DRDs specifying the submittal and content of documentation associated with the verification tasks are shown in Figures 2.2.1-1 through 2.2.1.-5. Verification related tasks are:

- Support primary reviews, working groups, technical interchange meetings, engineering panels, and design audits.
- Prepare and maintain the Verification Requirements and Specifications Document (VRSD) (DRD VR02).
- Prepare and maintain the Contract End Item (CEI) Specifications Verification Requirements Matrix.
- Ensure the definition of the Special Test Equipment (STE), Ground Support Equipment (GSE), and facility requirements at all assembly and verification sites and at the launch site and the landing site.
- Provide inputs to the Launch Site Contingency Plan.
- Provide inputs to the Launch Site Operations Requirements.
- Provide inputs to the Systems Engineering Plan.
- Provide inputs to the Orbital Verification Evaluation Plan.
- Provide Launch Site Support Plan Inputs.
- Provide verification support to NASA at MSFC and Kennedy Space Center (KSC).
- Perform special verification analysis and trade studies as directed.
- Ensure a compatibility assessment of all systems and systems elements.
- Ensure systems requirements flowdown analysis from Level I through Level IV.
- Prepare and maintain Verification Requirements Compliance Document (DRD VR05).
- Review and approve verification procedures for all verification sites for compliance to requirements and approved verification methods.
- Perform in-process verifications.
- Prepare all verification planning.
- Prepare and maintain the Verification Plan (DRD VR01).
- Ensure development of verification procedures (DRD VR03).

- Ensure qualification and acceptance verifications, including functional, thermal vacuum, acoustic, modal, interface verifications, Electromagnetic Compatibility (EMC), end-to-end test, systems compatibility, and other tests as needed.
- Ensure development of Verification Reports (DRD VR04).
- Audit the verification process at each verification site and at each level of integrated test.
- Participate in and support launch site working groups.
- Provide inputs to the Payload Integration Plan and the annexes.
- Provide planning for all Space Support Equipment (SSE) assembly and verification activities.
- Prepare and maintain orbital servicing SSE Verification Plan.
- Prepare and maintain orbital servicing SSE Verification Requirements.
- Approve orbital servicing SSE Verification Procedures.
- Ensure SSE in-process testing.
- Ensure SSE acceptance testing, including thermal vacuum, acoustic, modal, systems compatibility tests, and EMC tests.
- Ensure deployment test of all deployable items.
- Ensure development of SSE Verification Reports.
- Ensure hardware and software interface verification.
- Ensure a mission simulation, including conduct of an end-to-end verification of all communications paths to and from SSE payload.
- Prepare and maintain Orbital SSE Payload Levels I-IV Requirements Matrix.
- Prepare and maintain SSE VRSD Requirements Compliance Document.

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD)	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR01 / 3. Doc. TYPE 2
4. TITLE VERIFICATION PLAN		5. DATE REVISED 6. PAGE 1 OF 2
7. DESCRIPTION/USE TO DOCUMENT THE PLANNING POLICIES, VERIFICATION ACTIVITIES, AND ORGANIZATION NECESSARY TO DEFINE AND EXECUTE THE VERIFICATION OPERATIONS FOR BOTH FLIGHT AND GROUND SUPPORT EQUIPMENT AT ALL VERIFICATION SITES, LAUNCH SITE, ON-ORBIT, AND THE COMMUNICATION GROUND SYSTEM.		8. CDRM APPROVAL BASIC: _____ REV.: _____ REV.: _____
9. DISTRIBUTION PER CONTRACTING OFFICER'S LETTER.	10. INITIAL SUBMISSION SRR	

11. SUBMISSION FREQUENCY

DRAFT ISSUE:	PDR
PRELIMINARY ISSUE:	CDR
BASELINE ISSUE:	AFTER CDR
UPDATES:	AS REQUIRED

12. REMARKS

13. SOW INTERRELATIONSHIP

14. REFERENCE DOCUMENTS

15. DATA PREPARATION INFORMATION

15.1 SCOPE

THIS DRD ESTABLISHES THE CONTENT, MAINTENANCE, AND SUBMITTAL REQUIREMENTS FOR THE VERIFICATION PLAN. IT SHALL DESCRIBE ACTIVITIES FOR SYSTEMS QUALIFICATION AND ACCEPTANCE, SUPPORT EQUIPMENT, AND FACILITIES REQUIRED TO VERIFY THE PAYLOAD, SYSTEMS, AND SUBSYSTEMS AT ALL VERIFICATION SITES, LAUNCH SITE, ON-ORBIT, AND THE COMMUNICATION GROUND SYSTEM.

15.2 APPLICABLE DOCUMENTS

Figure 2.2.1-1 Verification Plan DRD VR01

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD) CONTINUATION SHEET	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR01 / 3. Doc. TYPE 2 5. DATE REVISED 6. PAGE 2 OF 2
4. TITLE VERIFICATION PLAN		

15.3 CONTENTS

THE PLAN SHALL CONTAIN THE FOLLOWING:

A. A DESCRIPTION OF THE ORGANIZATION, METHODS, AND CONTROL TO IMPLEMENT VERIFICATION.

B. AN OVERVIEW OF THE VERIFICATION PROCESS.

C. DETAILED DESCRIPTIONS OF ALL VERIFICATIONS TO BE PERFORMED, INCLUDING PREREQUISITES, CONSTRAINTS, AND TEST OBJECTIVES. THE VERIFICATIONS SHALL INCLUDE TESTS, ANALYSES, DEMONSTRATIONS, INSPECTIONS, AND/OR OTHER METHODS OF VERIFICATION.

D. A DETAILED TIME CORRELATED SEQUENCE OF VERIFICATION OPERATIONS FROM FLIGHT SYSTEM QUALIFICATION THROUGH SUBSYSTEM, SYSTEMS FINAL ACCEPTANCE, PRELAUNCH, AND ON-ORBIT.

E. DEFINITION OF THE METHOD OF VERIFICATION FOR EACH ITEM AT THE FLIGHT SYSTEM QUALIFICATION, ASSEMBLY, SUBSYSTEM, SYSTEM, AND PAYLOAD LEVEL.

F. DESCRIPTION, PLANNED USAGE, AND SCHEDULING OF THE SUPPORT EQUIPMENT, VERIFICATION SOFTWARE, FACILITIES, AND TOOLING NECESSARY TO EXECUTE THE VERIFICATION ACTIVITY.

15.4 FORMAT

CONTRACTOR FORMAT IS ACCEPTABLE.

15.5 MAINTENANCE

CHANGES SHALL BE INCORPORATED BY CHANGE PAGE OR COMPLETE REISSUE.

Figure 2.2.1-1 Verification Plan DRD VR01

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD)	1. DATA PROCUREMENT DOCUMENT No. ISSUE 2. DRD No. VR02 | 3. Doc. TYPE 2
4. TITLE VERIFICATION REQUIREMENTS AND SPECIFICATIONS DOCUMENT (VRSD)		5. DATE REVISED 6. PAGE 1 OF 3
7. DESCRIPTION/USE TO DOCUMENT ALL REQUIREMENTS AND SPECIFICATIONS FOR VERIFICATION OF THE FLIGHT ARTICLE, ITS SUBSYSTEMS, AND THE GROUND SYSTEM, WHETHER BY ASSESSMENT, INSPECTION, OR TEST. THESE REQUIREMENTS ARE NECESSARY FOR THE PREPARATION OF VERIFICATION PROCEDURES AND/OR OTHER VERIFICATION ACTIVITIES.		8. CDRM APPROVAL BASIC: _____ REV.: _____ REV.: _____
9. DISTRIBUTION PER CONTRACTING OFFICER'S LETTER	10. INITIAL SUBMISSION PDR	

11. SUBMISSION FREQUENCY

DRAFT:	CDR
PRELIMINARY ISSUE:	AFTER CDR
BASELINE ISSUE:	90 DAYS TO START OF RELATED VERIFICATION ACTIVITY
UPDATES:	AS REQUIRED

12. REMARKS

13.SOW INTERRELATIONSHIP

14. REFERENCE DOCUMENTS

15. DATA PREPARATION INFORMATION

15.1 SCOPE

THIS DOCUMENT SHALL INCLUDE THE REQUIREMENTS FOR SYSTEMS AND SUBSYSTEM VERIFICATIONS FOR THE FLIGHT ARTICLE, INCLUDING FLIGHT SOFTWARE, AND THE GROUND SYSTEM AND SHALL INCLUDE REQUIREMENTS FOR ASSESSMENTS, INSPECTIONS, AND TEST OPERATIONS. THE DOCUMENT WILL SPECIFY SYSTEM QUALIFICATION AND ACCEPTANCE VERIFICATION REQUIREMENTS AND SPECIFICATIONS TO BE SATISFIED AT ALL VERIFICATION SITES, AT THE LAUNCH SITE, AND ON-ORBIT.

Figure 2.2.1-2 Verification Requirements and Specifications Document DRD VR02

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD) CONTINUATION SHEET	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR02 / 3. Doc. TYPE 2
4. TITLE VERIFICATION REQUIREMENTS AND SPECIFICATIONS DOCUMENT (VRSD)		5. DATE REVISED 6. PAGE 2 OF 3

15.2 APPLICABLE DOCUMENTS

NONE

15.3 CONTENTS

THE VERIFICATION REQUIREMENTS AND SPECIFICATIONS DOCUMENT (VRSD) SHALL INCLUDE REQUIREMENTS FOR ALL VERIFICATIONS, INCLUDING TEST, ANALYSIS, DEMONSTRATION, AND INSPECTION. THE VRSD WILL IDENTIFY EACH REQUIREMENT, SPECIFICATION, AND CONSTRAINT APPLICABLE TO THE VARIOUS FUNCTIONAL AND ENVIRONMENTAL TESTS AND OTHER VERIFICATIONS REQUIRED FOR QUALIFICATION AND/OR ACCEPTANCE DURING THE SUBSYSTEM, SYSTEM, AND INTEGRATED SYSTEMS VERIFICATION ACTIVITIES. SPECIFICATIONS SHALL INCLUDE ALLOWABLE TOLERANCE FOR STANDARDS OF JUDGMENT TO BE USED IN DETERMINING ACCEPTABLE PERFORMANCE. TEST TYPES, LEVELS, AND DURATIONS WILL BE INCLUDED. QUALIFICATION TEST REQUIREMENTS SHALL INCLUDE TEST LEVEL MARGINS AND FACTORS OF SAFETY. REQUIREMENTS APPLICABLE TO ON-ORBIT VERIFICATION ARE INCLUDED.

15.4 FORMAT

A. NUMBER - UNIQUE DECIMAL NUMBERING SYSTEM FOR IDENTIFYING VRSD REQUIREMENTS.

B. STATEMENT - DETAILED STATEMENT OF REQUIREMENT TO BE SATISFIED.

C. MEASUREMENT/STIMULI - MEASUREMENT OR COMMAND NUMBER ASSOCIATED WITH THE REQUIREMENT OR SPECIFICATION.

D. CRITERIA AND SPECIFICATION - STANDARDS/LIMITS TO BE USED IN DETERMINING ACCEPTABLE PERFORMANCE.

E. REMARKS AND CONSTRAINTS - ANY REMARKS OR SPECIAL INSTRUCTIONS (e.g., SAFETY WARNINGS OR CAUTIONS, TEST METHODS OR SEQUENCES) THAT APPLY TO A PARTICULAR REQUIREMENT.

F. EFFECTIVITY - PROVIDE COLUMNS APPROPRIATE FOR LOCATION/TIME PHASE AND INDICATE WITH AN "X" AS APPROPRIATE. EFFECTIVITY COLUMNS ARE USED ONLY WHEN ONE VRSD IS DEVELOPED TO DEFINE REQUIREMENTS FOR ALL LOCATIONS.

15.5 MAINTENANCE

CHANGES SHALL BE INCORPORATED BY CHANGE PAGE OR COMPLETE REISSUE.

Figure 2.2.1-2 Verification Requirements and Specifications Document DRD VR02

ATTACHMENT A
DRD
PAGE 3 OF 3

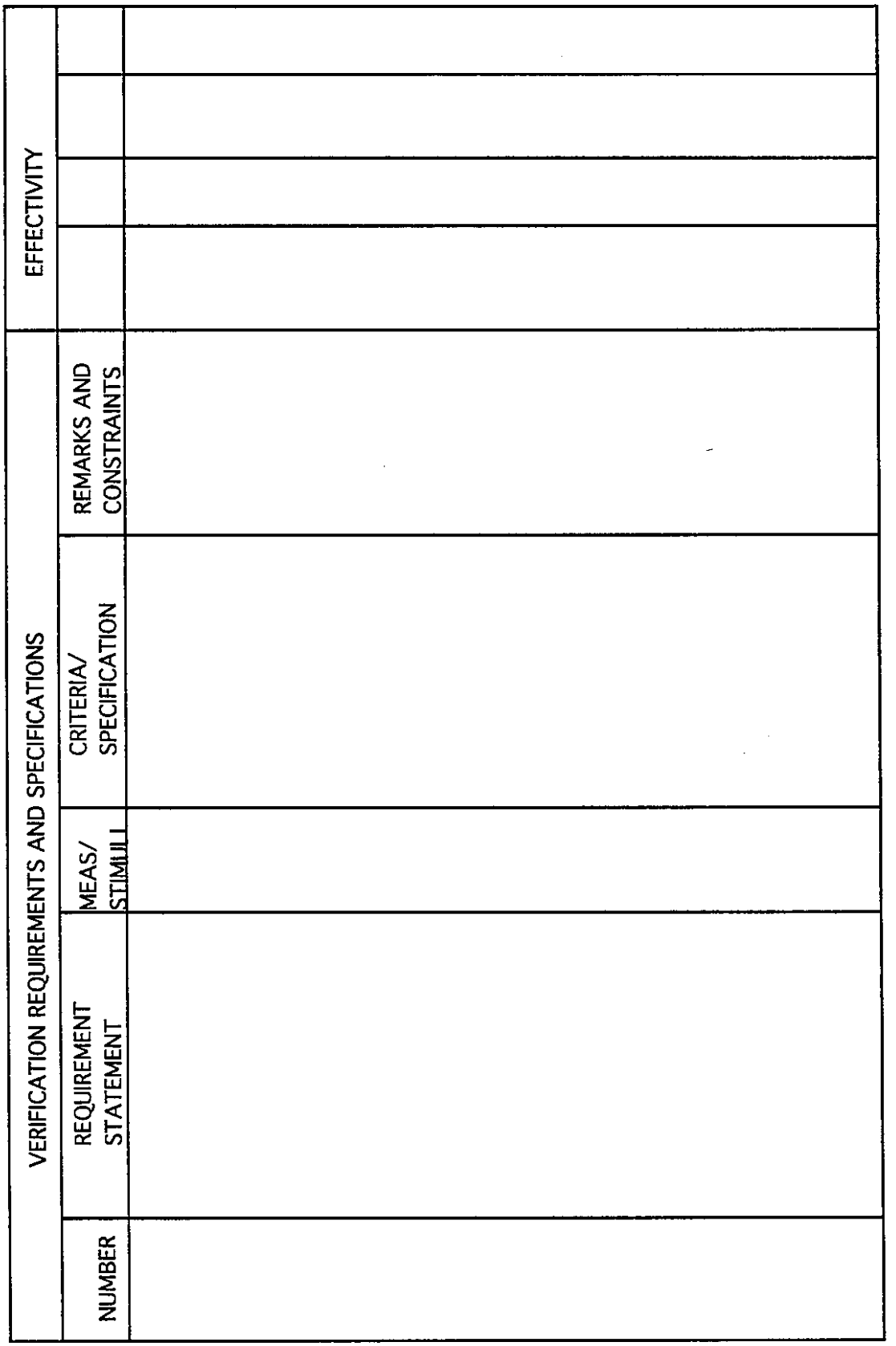

Figure 2.2.1-2 Verification Requirements and Specifications Document DRD VR02

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National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD)	1. DATA PROCUREMENT DOCUMENT No. ISSUE 2. DRD No. VR03 | 3. Doc. TYPE 3

4. TITLE

VERIFICATION PROCEDURE

5. DATE REVISED

6. PAGE 1 OF 3

7. DESCRIPTION/USE

TO DOCUMENT AND CONTROL VERIFICATION PROCEDURES FOR ALL HARDWARE, INCLUDING FLIGHT, SPECIAL TEST, AND GROUND SUPPORT EQUIPMENT.

8. CDRM APPROVAL

BASIC: _____

REV.: _____

REV.: _____

9. DISTRIBUTION

10. INITIAL SUBMISSION

INDIVIDUALLY 90 DAYS PRIOR TO START OF RELATED VERIFICATION ACTIVITY.

11. SUBMISSION FREQUENCY

BASELINE: 30 DAYS PRIOR TO START OF RELATED VERIFICATION ACTIVITY.

SINGLE SUBMITTAL FOR EACH VERIFICATION ACTIVITY.

REVISE OR UPDATE AS REQUIRED.

12. REMARKS

EACH PROCEDURE WILL BE TAILORED TO THE VERIFICATION PHASE AND HARDWARE LEVEL AT WHICH THE ACTIVITY IS TO TAKE PLACE.

13. SOW INTERRELATIONSHIP

14. REFERENCE DOCUMENTS

15. DATA PREPARATION INFORMATION

15.1 SCOPE

THIS DRD ESTABLISHED THE CONTENT, FORMAT, MAINTENANCE, AND SUBMITTAL REQUIREMENTS FOR ALL INDIVIDUAL HARDWARE VERIFICATION PROCEDURES.

Figure 2.2.1-3 Verification Procedure DRD VR03

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD) CONTINUATION SHEET	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR03 / 3. Doc. TYPE 3
4. TITLE VERIFICATION PROCEDURES		5. DATE REVISED 6. PAGE 2 OF 3

15.2 APPLICABLE DOCUMENTS

15.3 CONTENTS

EACH PROCEDURE SHALL IDENTIFY THE VERIFICATION REQUIREMENTS FOR THE ITEM FROM THE RELATED VERIFICATION SPECIFICATION. INDIVIDUAL REQUIREMENTS TO BE VERIFIED SHALL BE REFERENCED IN A MANNER THAT EXPEDITES PROCEDURE REVIEWING. AS A MINIMUM, THE FOLLOWING INFORMATION WILL BE INCLUDED:

A. NOMENCLATURE AND IDENTIFICATION OF THE TEST ARTICLE OR MATERIAL. IDENTIFICATION OF TEST CONFIGURATION AND ANY DIFFERENCES FROM FLIGHT CONFIGURATION.

B. IDENTIFICATION OF OBJECTIVES AND CRITERIA ESTABLISHED FOR TEST BY THE APPLICABLE VERIFICATION SPECIFICATION.

C. CHARACTERISTICS AND DESIGN CRITERIA TO BE INSPECTED OR TESTED, INCLUDING VALUES, WITH TOLERANCES, FOR ACCEPTANCE OR REJECTION.

D. DESCRIPTION, IN SEQUENCE, OF STEPS AND OPERATIONS TO BE TAKEN.

E. IDENTIFICATION OF COMPUTER SOFTWARE REQUIRED.

F. IDENTIFICATION OF MEASURING, TEST, AND RECORDING EQUIPMENT TO BE USED, SPECIFYING RANGE, ACCURACY, AND TYPE.

G. CERTIFICATION THAT REQUIRED COMPUTER TEST PROGRAM/SUPPORT EQUIPMENT AND SOFTWARE HAVE BEEN VERIFIED PRIOR TO USE WITH FLIGHT HARDWARE.

H. ANY SPECIAL INSTRUCTIONS FOR OPERATING DATA RECORDING EQUIPMENT OR OTHER AUTOMATED TEST EQUIPMENT AS APPLICABLE.

I. LAYOUTS, SCHEMATICS, OR DIAGRAMS SHOWING IDENTIFICATION, LOCATION, AND INTERCONNECTION OF TEST EQUIPMENT, TEST ARTICLES, AND MEASURING POINTS.

J. IDENTIFICATION OF HAZARDOUS SITUATIONS OR OPERATIONS.

K. PRECAUTIONS AND SAFETY INSTRUCTIONS TO ENSURE SAFETY OF PERSONNEL AND PREVENT DEGRADATION OF TEST ARTICLES AND MEASURING EQUIPMENT.

L. ENVIRONMENTAL AND/OR OTHER CONDITIONS TO BE MAINTAINED WITH TOLERANCES.

M. CONSTRAINTS ON INSPECTION OR TESTING.

N. SPECIAL INSTRUCTIONS FOR NONCONFORMANCES AND ANOMALOUS OCCURRENCES OR RESULTS.

O. SPECIFICATION FOR FACILITY, EQUIPMENT MAINTENANCE, HOUSEKEEPING, CERTIFICATION INSPECTION, AND SAFETY AND HANDLING REQUIREMENTS BEFORE, DURING AND AFTER THE TOTAL VERIFICATION ACTIVITY.

Figure 2.2.1-3 Verification Procedure DRD VR03

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD) CONTINUATION SHEET	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR03 / 3. Doc. TYPE 3
4. TITLE VERIFICATION PROCEDURES		5. DATE REVISED 6. PAGE 3 OF 3

15.4 FORMAT

PROCEDURES SHALL BE PREPARED IN LOGICAL FORMAT AND SHOULD CORRELATE AS APPLICABLE TO THE CORRESPONDING SPECIFICATION. THE FORMAT MAY PROVIDE BLANK SPACES FOR RECORDING TEST RESULTS AND NARRATIVE COMMENTS IN ORDER THAT THE COMPLETED PROCEDURE CAN SERVE AS PART OF THE VERIFICATION REPORT.

15.5 MAINTENANCE

WHENEVER, THE PROCEDURE IS AFFECTED BY APPROVED SPECIFICATION OR PROCEDURE CHANGES, IT SHALL BE UPDATED BY CHANGE PAGE AND/OR COMPLETE REISSUE.

Figure 2.2.1-3 Verification Procedure DRD VR03

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National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD)	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR04 / 3. Doc. TYPE 3

4. TITLE

VERIFICATION REPORTS

5. DATE REVISED

6. PAGE 1 OF 2

7. DESCRIPTION/USE

TO REPORT THE RESULTS OF ALL VERIFICATIONS INCLUDING TESTS, INSPECTIONS, ANALYSES, AND DEMONSTRATION ON FLIGHT HARDWARE, FLIGHT SOFTWARE AND GROUND SUPPORT EQUIPMENT.

8. CDRM APPROVAL

BASIC: _____

REV.: _____

REV.: _____

9. DISTRIBUTION

PER CONTRACTING OFFICER'S LETTER

10. INITIAL SUBMISSION

INDIVIDUALLY, 20 DAYS AFTER COMPLETION OF EACH VERIFICATION ACTIVITY.

11. SUBMISSION FREQUENCY

SINGLE SUBMITTAL FOR EACH VERIFICATION ACTIVITY.

CORRECT AS REQUIRED.

12. REMARKS

13.SOW INTERRELATIONSHIP

14. REFERENCE DOCUMENTS

15. DATA PREPARATION INFORMATION

15.1 SCOPE

THIS DRD DOCUMENTS THE RESULTS OF VERIFICATION ACTIVITIES PERFORMED AT EACH VERIFICATION SITE AND ON-ORBIT (AS APPROPRIATE).

Figure 2.2.1-4 Verification Reports DRD VR04

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD) CONTINUATION SHEET	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR04 / 3. Doc. TYPE 3 5. DATE REVISED 6. PAGE 2 OF 2
4. TITLE VERIFICATION REPORTS		

15.2 APPLICABLE DOCUMENTS

NONE

15.3 CONTENTS

EACH REPORT SHALL SUMMARIZE THE RESULTS FROM EACH VERIFICATION ACTIVITY AND SHALL BE PREPARED IN A MANNER THAT RELATES EACH RESULT TO THE APPROPRIATE VRSD REQUIREMENT. AS A MINIMUM THE FOLLOWING SHALL BE INCLUDED:

A. A STATEMENT OF VERIFICATION OBJECTIVES(S) AND DEGREE TO WHICH THEY WERE MET.

B. DESCRIPTION OF VERIFICATION.

C. NAME, PART NUMBER, DESCRIPTION, VENDOR, IDENTIFICATION OF NEXT HIGHER HARDWARE LEVEL, AND APPLICABLE VERIFICATION PHASE.

D. IDENTIFICATION OF TEST CONFIGURATION AND ANY DIFFERENCES FROM THE FLIGHT CONFIGURATION.

E. SPECIFIC RESULTS OF EACH PROCEDURE INCLUDING AUTOMATED TEST SEGMENTS, EACH ANALYSIS, OR OTHER VERIFICATION.

F. DESCRIPTION OF DEVIATIONS FROM NOMINAL RESULTS, FAILURES, APPROVED CORRECTIVE ACTIONS AND PROCEDURES, AND RETEST.

G. SUMMARY OF NONCONFORMANCE/DISCREPANCY REPORTS INCLUDING DISPOSITIONS.

H. CONCLUSIONS AND RECOMMENDATIONS RELATIVE TO SUCCESS OF VERIFICATION.

I. COPY OF AS RUN PROCEDURE.

15.4 FORMAT

CONTRACTOR FORMAT IS ACCEPTABLE.

15.5 MAINTENANCE

REPORTS SHALL BE CORRECTED, IF REQUIRED, BY CHANGE PAGE.

Figure 2.2.1-4 Verification Reports DRD VR04

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD)	1. DATA PROCUREMENT DOCUMENT No. / ISSUE 2. DRD No. VR05 / 3. Doc. TYPE 2

4. TITLE VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT	5. DATE REVISED 6. PAGE 1 OF 3
7. DESCRIPTION/USE TO PRODUCE EVIDENCE OF COMPLIANCE TO EACH VERIFICATION REQUIREMENT AND TO SHOW TRACEABILITY TO COMPLIANCE DOCUMENTATION.	8. CDRM APPROVAL BASIC: _____ REV.: _____ REV.: _____

9. DISTRIBUTION	10. INITIAL SUBMISSION
PER CONTRACTING OFFICER'S LETTER	PDR

11. SUBMISSION FREQUENCY

DRAFT:	CDR
PRELIMINARY ISSUE:	30 DAYS AFTER CDR
UPDATE:	(1) DURING INTEGRATED TEST (2) 3 WEEKS PRIOR TO CIR/DCR (3) ACCEPTANCE REVIEW (4) FLIGHT READINESS REVIEW (5) AFTER ON-ORBIT (AS APPROPRIATE)

12. REMARKS

13.SOW INTERRELATIONSHIP

14. REFERENCE DOCUMENTS

VRSD, LEVEL I TO LEVEL IV FLOWDOWN DOCUMENT, VERIFICATION REPORTS, ASSESSMENT REPORTS

15. DATA PREPARATION INFORMATION

15.1 SCOPE

THIS DRD ESTABLISHES THE CONTENT, FORMAT, MAINTENANCE, AND SUBMITTAL REQUIREMENTS FOR THE VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT. THE COMPLIANCE DOCUMENT SHALL INCLUDE ALL LEVEL I THROUGH LEVEL IV (OR LOWER LEVEL IF REQUIRED) REQUIREMENTS AND ALL VRSD REQUIREMENTS, INCLUDING APPROPRIATE ON-ORBIT REQUIREMENTS. THE DOCUMENT SHALL INCLUDE COMPLIANCE DATA FOR ALL REQUIREMENTS.

15.2 APPLICABLE DOCUMENTS

Figure 2.2.1-5 Verification Requirements Compliance Document DRD VR05

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	DATA REQUIREMENTS DESCRIPTION (DRD) CONTINUATION SHEET	1. DATA PROCUREMENT DOCUMENT No. / ISSUE	
		2. DRD No. VR05	3. Doc. TYPE 2
4. TITLE VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT		5. DATE REVISED	
		6. PAGE 2 OF 3	

15.3 CONTENTS

THE VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT SHALL INCLUDE THE FOLLOWING:

A. THE REQUIREMENT STATEMENTS OF THE VERIFICATION REQUIREMENTS AND SPECIFICATIONS DOCUMENT (VRSD) AND THE LEVEL I TO IV (OR LOWER LEVEL IF REQUIRED) REQUIREMENTS FLOWDOWN, VERIFICATION METHODS, COMPLIANCE DATA (TEST, VERIFICATION PROCEDURE, AUTOMATED TEST OR SEQUENCE, VERIFICATION REPORT, ANALYSIS, OR OTHER REPORTS), NONCONFORMANCES, REVERIFICATIONS, AND A DATA STATEMENT.

B. IDENTIFICATION OF THE DOCUMENTATION AND/OR ACTIVITY THAT IDENTIFIES COMPLIANCE TO THE REQUIREMENT (VERIFICATION REPORT, TEST, ANALYSIS, PROCEDURE, DESIGN REVIEW, ETC.). INCLUDES ALL SUPPORTING INFORMATION TO IDENTIFY DOCUMENTATION AND/OR ACTIVITY.

C. VERIFICATION METHODS IDENTIFIED AS TEST, ANALYSIS, INSPECTION, OR OTHER METHODS USED IN THE VERIFICATION PROCESS.

D. TRACEABILITY OF VRSD REQUIREMENTS TO LEVEL I THROUGH LEVEL IV FLOWDOWN REQUIREMENTS (PROJECT REQUIREMENTS DOCUMENT, INTERFACE CONTROL DOCUMENT, CONTRACT END ITEM REQUIREMENTS, ETC.).

15.4 FORMAT

THE FORMAT SHALL INCLUDE THE FOLLOWING:

A. NUMBER : REQUIREMENT NUMBER AS DEFINED BY THE VRSD OR LEVEL I TO LEVEL IV (OR LOWER LEVEL) REQUIREMENTS FLOWDOWN DOCUMENT.

B. STATEMENT: THE REQUIREMENT AS STATED IN THE VRSD AND LEVEL I TO LEVEL IV (OR LOWER LEVEL) REQUIREMENTS DOCUMENTS FOR WHICH COMPLIANCE IS TO BE IDENTIFIED.

C. VERIFICATION METHOD: METHOD OF VERIFICATION TO SATISFY REQUIREMENT.

D. COMPLIANCE DATA: COMPLETE IDENTIFICATION OF COMPLIANCE DOCUMENTATION.

E. NON-CONFORMANCE DATA: IDENTIFICATION OF NON-CONFORMANCE DOCUMENTATION.

F. DATA STATEMENT/REMARKS: STATEMENT OF WHETHER COMPLIANT, NON-COMPLIANT, OR WAIVER; WHETHER OPEN OR CLOSED; SUMMARY OF VERIFICATION RESULT; REMARKS AS NEEDED TO CLARIFY STATEMENT.

15.5 MAINTENANCE

CHANGES SHALL BE INCORPORATED BY CHANGE PAGE OR COMPLETE REISSUE.

Figure 2.2.1-5 Verification Requirements Compliance Document DRD VR05

ATTACHMENT A
DRD
PAGE 3 OF 3

VRSD AND LEVEL I TO LEVEL IV FLOWDOWN REQUIREMENTS COMPLIANCE/TRACEABILITY

REQUIREMENT		VERIFICATION	COMPLIANCE	NON-CONFORMANCE	DATA	
NUMBER	STATEMENT	METHOD	DATA	DATA	STATEMENT	REMARKS

Figure 2.2.1-5 Verification Requirements Compliance Document DRD VR05

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2.2.2 REVIEW OF PROPOSALS

The review of proposals in response to the Request for Proposals (RFPs) is performed as part of the overall source selection activity. The review is performed by technical review teams, each headed by a team chairman under the leadership of a review chairman. Guidelines are established for the review process that provide for consistency in assessment of the proposals. Usually there are more than one proposal to be assessed by the technical teams, with somewhat different approaches and methodologies. New approaches to and different methods for achieving verifications must be assessed objectively.

The proposal specifies how the tasks defined in the RFP are to be accomplished. The proposal must exhibit an understanding of the tasks to be accomplished and the approach to accomplishing the tasks must be well defined. All verification tasks must be adequately addressed.

In addition to assessing the proposal responses addressing the verification and verification activity related tasks, the proposal should adequately address the verification related areas specified in sections 2.2.2.1 - 2.2.2.7.

2.2.2.1 Contract End Item Specification Verification Requirements Matrix

The Verification Requirements Matrix (VRM) of the Contract End Item (CEI) Specification will specify the method(s) of verification and the verification phase(s) of each requirement of the CEI Specification. The VRM will not be adequately completed at proposal submittal and usually requires updating as the program progresses. The VRM should be assessed to assure proper verification methods are defined for design and performance CEI requirements.

2.2.2.2 Activity Schedule

A schedule will be included that will identify milestones and activities, including verification phases. The verification phases are defined and adequate time is allocated for each phase. The schedule must show proper sequencing of the verification phases and interfacing activities. The schedule must also show milestones and activities from Authorization to Proceed (ATP) through on-orbit verifications and post-flight servicing. All milestones are in accordance with program milestones. A generic schedule is shown in Figure 2.1.1.4-1, Verification Schedule and Sequence of Events.

2.2.2.3 System Engineering Response

The Systems Engineering response will provide descriptions and methods for performing systems engineering and integration activities for all elements of the payload. Verification related activities which the response shall address are:

- Technical description of planned engineering activities and control of requirements
- Plan for performance analysis
- Approach to development of analytical methods
- Relationship of system engineering activities to other verification related activities
- Approach to verifying internal and external interfaces and ensuring compatibility of interfaces
- Technical description of how the payload will be integrated
- Methodology for a systematic evaluation of compliance to program and derived requirements
- Approach to preparing and maintaining requirements flow down
- Definition of how verification tasks are to be accomplished
- Integration of the ground systems and the payload
- Rationale for any trade-off of testing and analysis

- Rationale for any testing that may be delayed to a late test phase
- Definition of verification documentation and products to be developed.

The Systems Engineering response may include a Systems Engineering Plan which provides a description of all systems engineering tasks to be accomplished. The plan will define the Systems Engineering organizations and their responsibilities as well as the interfaces between organizational elements. The verification tasks to be performed by the systems engineering organization include verification requirements development, requirements compliance, audits, analyses and models necessary for requirements compliance, and the support to test activities, including anomaly resolution and data acceptance. The plan will identify development of detailed logic diagrams for each system engineering task. Figure 2.2.2.3-1, Verification Requirements and Specifications Document Development Flow, shows a typical systems engineering logic network for development of a VRSD. The logic diagram will define all the activities and milestones required to achieve the task. More specifically, the plan should identify the following verification tasks:

- Perform risk analysis of verification activities
- Develop the Verification Requirements Matrix for design and performance requirements
- Support Systems Engineering panels and working groups
- Develop the Verification Requirements and Specifications Document
- Develop the Verification Requirements Compliance Document
- Ensure compliance to all program requirements
- Support development of the Verification Plan
- Support development of Verification Reports
- Approve Verification Procedures
- Support testing activities to assure requirements acceptance and proper anomaly disposition
- Support Design Certification Reviews
- Support Acceptance Reviews and Flight Readiness Reviews.

2.2.2.4 Design and Development

The proposal should present in detail the plans for the design, development, manufacturing, assembly, integration, and verification of the payload. Each subsystem should be described in detail, identifying each component of the subsystem and showing all interrelationships.

The Ground Support Equipment (GSE), electrical and mechanical, of a major item must be identified. This would include GSE such as the data acquisition and commanding system (testing system), equipment to perform environment testing, handling, and transportation. The ground software for equipment operation and test activities should be described.

The facilities necessary to manufacture, assemble, and test the payload should be identified, including those which are presently available. Facilities for each phase of testing should be described, including the handling capability of each facility. The verification of all GSE and facilities will be described, identifying specifications that the verifications will comply with.

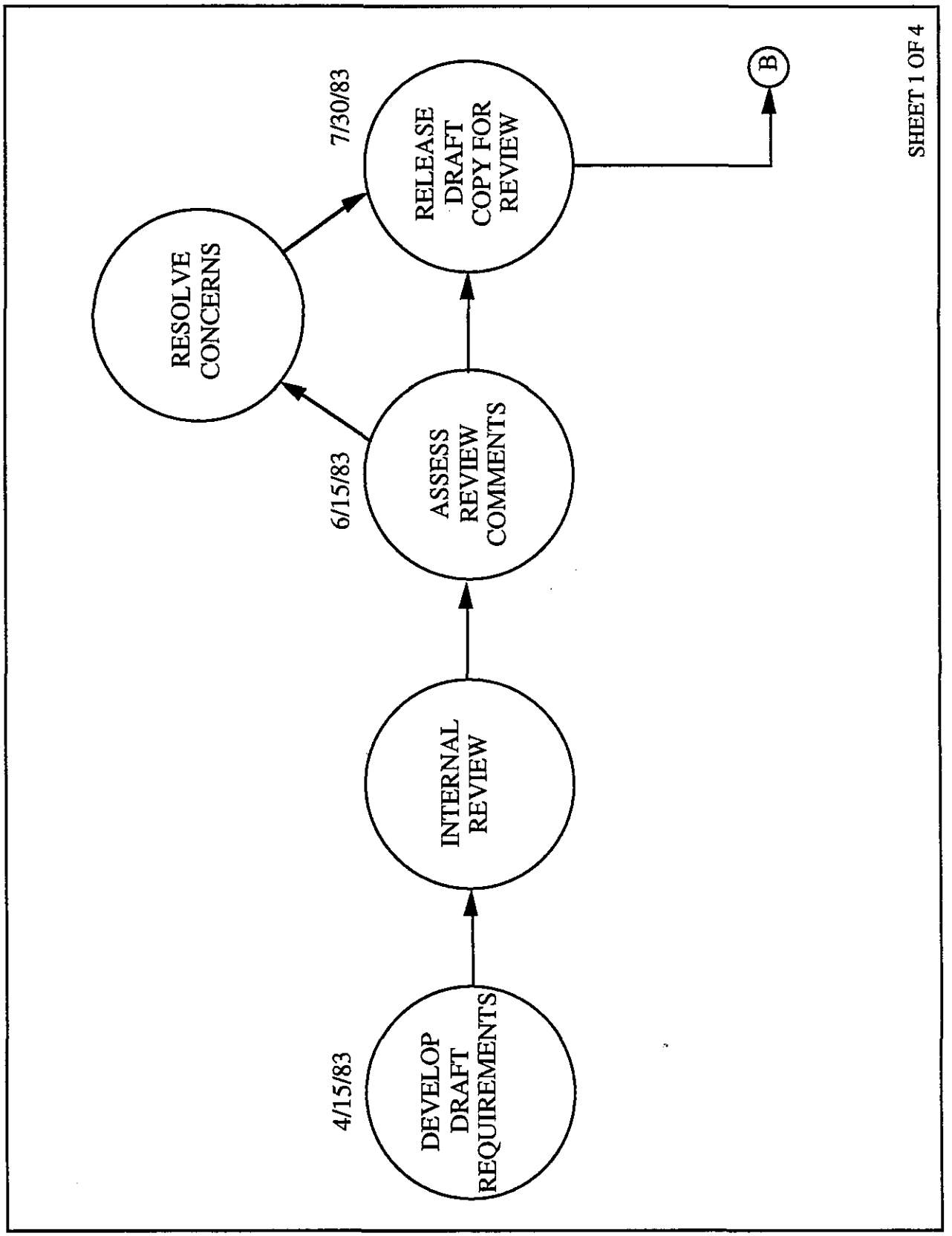

Figure 2.2.2.3-1 Verification Requirements and Specifications Document Development Flow

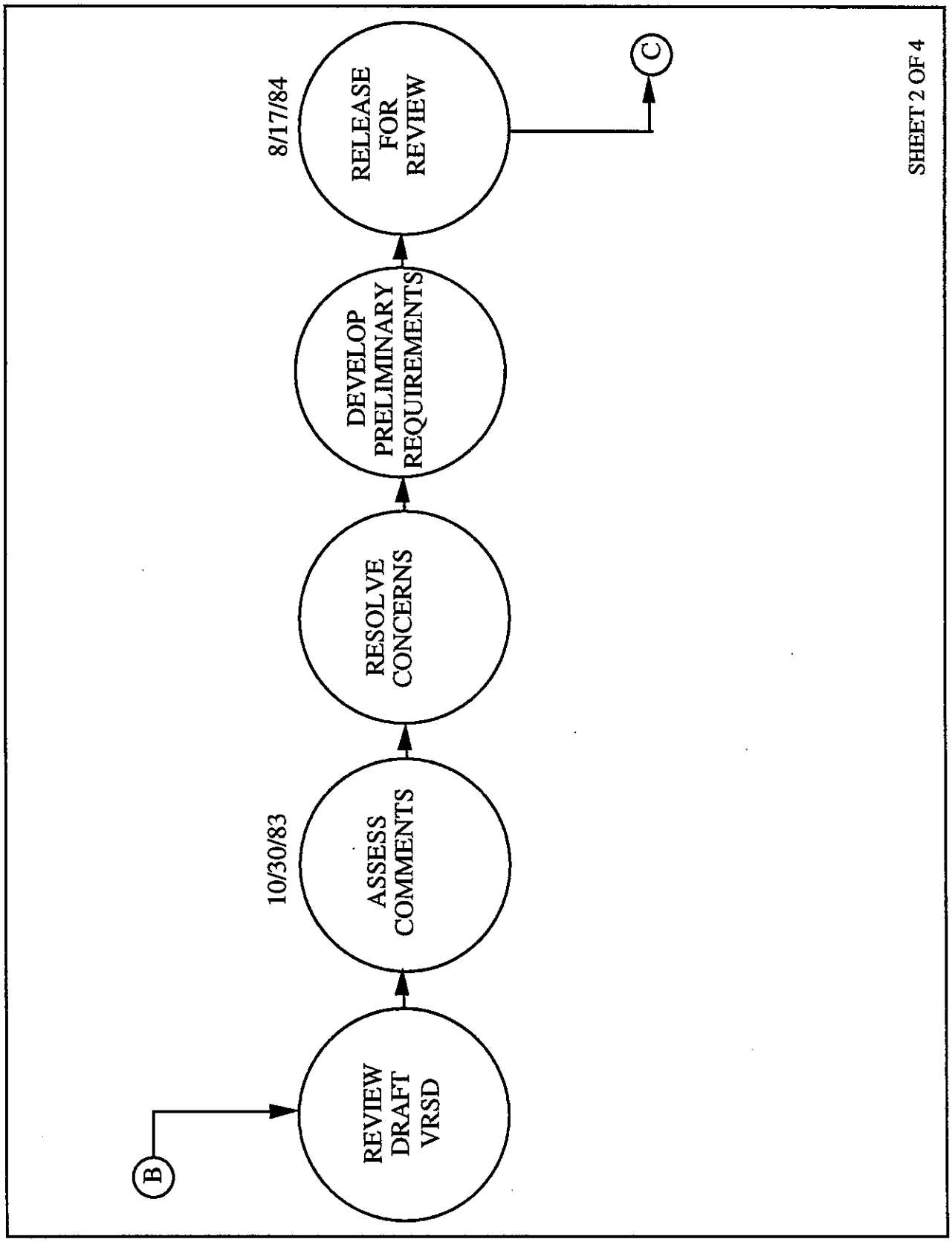

Figure 2.2.2.3-1 Verification Requirements and Specifications Document Development Flow (Cont.)

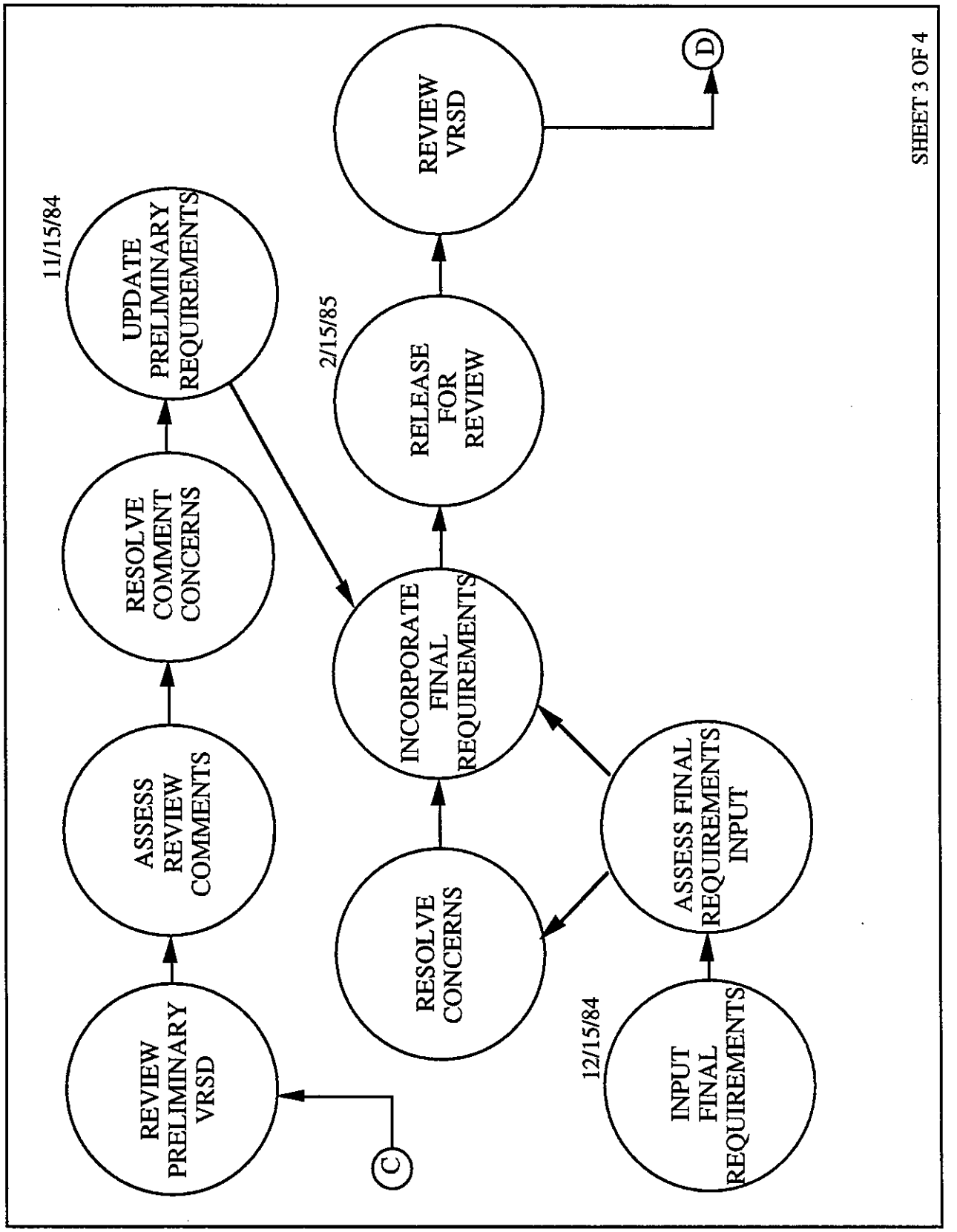

Figure 2.2.2.3-1 Verification Requirements and Specifications Document Development Flow (Cont.)

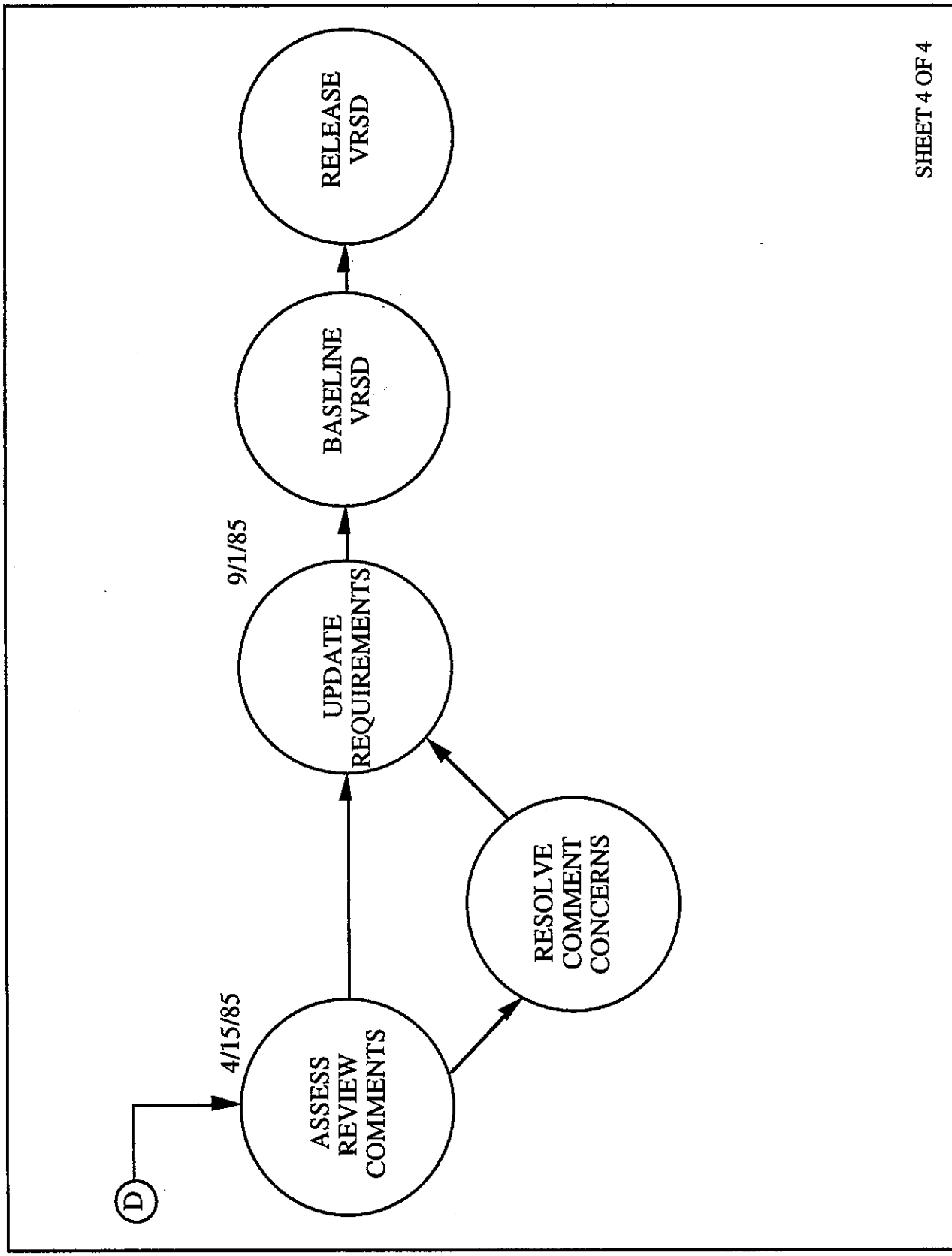

Figure 2.2.2.3-1 Verification Requirements and Specifications Document Development Flow (Cont.)

2.2.2.5 Verification

The proposal will provide the payload verification process in detail. Flows and schedule accompany each major activity description. Systems verification will determine, on the ground, that all payload elements will perform within specified bounds when the flight system is operational on orbit. The verification process is defined by the Verification Plan. The plan also defines the planning policies, methods of controls, and organizational responsibilities. The requirements that must be complied with during the verification process are defined by the Verification Requirements and Specifications Document (VRSD). The method of verification and the specifications for each requirement are also identified in the VRSD. From the VRSD, the verification procedures are developed. The procedures provide the instruction, including configurations, constraints, and prerequisites, for obtaining data that show compliance with the requirements. Verification results are identified in a Verification Report and the compliance data is compiled in the Verification Requirements Compliance Document.

The proposal will describe the general approach to systems verification. Verification for all phases are described, complete with the objectives, schedules and rationale for the sequencing proposed. The major verification activities required for development, qualification, and payload assembly (in-process testing) and integration are also described.

The start of integrated systems testing begins with the assembly process after all components have been qualified and accepted. Acceptance testing of a typical payload includes:

- Integration (Assembly) in-process testing
  - Component bonding
  - Multi-layer insulation bonding
  - Heater continuity/resistance checks
  - Mechanical alignment
- Pre-power checks
  - Power bus continuity (interfaces)
  - Power bus positive/return isolation
  - Power bus/Ground Support Equipment (GSE) isolation
  - Single point ground
- Functional testing
  - Subsystems/systems operation
  - Interface verification
  - Command and telemetry responses
  - Cross strapping/redundant system
  - Negative mode testing
  - Equipment calibration
  - Compatibility of subsystems
  - Workmanship
  - Radio Frequency (RF) Voltage Standing Wave Ratio (VSWR)
  - Insertion loss
  - Power-on/power-off sequencing
  - Systems safing
- Systems end-to-end- testing
  - Hardware/software functions and compatibility
  - Interfaces
  - Ground data network
  - Payload/ground systems compatibility
- Modal Survey
  - Information pertaining to modal characteristics (resonant frequencies, damping, behavior, mode shapes)
  - Data to support jitter evaluation

- Electromagnetic compatibility testing
  - Demonstration of electromagnetic compatibility of systems
  - Measurement of conducted emissions; radiated emissions; skin currents; transients; radiated susceptibility
- Mechanism test
  - Fit and alignment
  - Latch operations
  - Motor drives
- Acoustic test or vibration test when excited with expected flight levels
  - No intermittent circuit dropouts or relay/switch contact changes occur
  - Systems ability to withstand acoustic and vibration environments imposed during launch/ascent/decent/landing
  - Induced vibratory or acoustic responses are of acceptable levels
  - No latent material or workmanship defects
- Confidence (or functional) test performed before and after environmental test to ensure
  - No degradation of systems occurs during test
  - Hardware/software compatibility
  - Subsystem/systems performance
- Thermal vacuum test
  - Systems operate properly under thermal vacuum conditions
  - Ability of thermal control system to maintain thermal excursions within defined mission thermal limits
  - Validation of thermal model
  - Payload meets Interface Control Document (ICD) limits
  - Proper operation of heaters
  - Proper operation of safing system
  - Proper operation functions in mission mode
  - No degradation of latent material/workmanship when exposed to thermal vacuum stresses and simulated hot/cold conditions
- Solar array tests
  - Proper deployment/retraction
  - Continuity of cells and current output when exposed to light flash
  - Proper alignment
  - Proper latch operation
- Systems Compatibility test
  - Systems compatibility when operated in a mission sequence
  - Systems operate at high and low voltage extremes
- Launch site dress rehearsal
  - Launch site procedures/software
  - Payload to ground systems interfaces
  - Proper execution of mission sequences
  - Antenna RF end-to-end operation
- Orbital verification dress rehearsal
  - Validates orbital verification procedures
  - Verifies flight to ground interfaces
- Shipping preparations
  - Perform weight and center of gravity measurements
- Launch site tests for horizontal or vertical processing
  a. Systems functional test
     - Verifies systems continue to operate as determined by integrated functional testing
  b. Ground support equipment verification

c. Payload/Cargo Integration Test Equipment (CITE) interface test
   - Verified payload/launch vehicle interfaces through simulator
d. Battery interface (after installation into payload)
e. Payload/data network (Tracking and Data Relay Satellite System (TDRSS)) compatibility
f. Payload/launch vehicle interface

- On-orbit verification
  - Systems activation
  - Systems are functioning properly
  - Systems calibration
  - Systems data gathering capability
  - Flight systems/ground systems compatibility
- Post-flight verification
  - The payload systems function properly after space flight and return.

2.2.2.6 Launch Site

The proposal addresses all aspects of processing at the launch site. The proposal also provides the processing flow for both on-line and off-line activities, describing the integration and verifications for horizontal and/or vertical processing. The proposal will also address:

- Launch Site Verifications
- Launch Site Support Plan
- Launch Site Contingency Plan
- Launch Site Operations Requirements
- Ground Support Equipment GSE (including handling equipment) and facility requirements and verifications
- Battery use, installation charging, and cooling requirements
- Training.

The proposal will provide a generic flow of launch site activities. Facilities and GSE which the launch site will be requested to provide will be identified.

2.2.2.7 On-Orbit and Post Flight Servicing

The planning activity for on-orbit verifications and post-flight servicing will be addressed. A scenario of payload activation and calibration will be included as well as a description of payload health and safety monitoring. A description of the operations center functions will be provided, showing the data flow from the payload. The support equipment required for on-orbit servicing will be defined and its use discussed.

The proposal will address verification activities associated with removal and servicing of a payload that has been returned from on-orbit. This will include any GSE and/or facilities that should be used in the verifications.

PACKAGE NO. 10443R

DOCUMENTATION RELEASE LIST
GEORGE C. MARSHALL SPACE FLIGHT CENTER

MSFC CODE IDENT 14981/339B2
ISSUE DATE FEB 22 2007

C H	DOCUMENT NUMBER	DRL DSH	DRL REV	TITLE	CCBD NO.	PCN	PC	EFFECTIVITY
*	MSFC-HDBK-2221	203	-	VERIFICATION HANDBOOK VOLUMES I AND II	000-00-0000	0000000	ZA	NONE

CHG NO.	CHG REV	CHG NOTICE	RESPONSIBLE ENGINEER	RESPONSIBLE ORGANIZATION	ACTION DATE	DESCRIPTION
			T. ROWELL	EL45	04/05/94	BASELINE RELEASE
1		DCN001	S. FREEMAN	EL45	09/21/94	ADDITION OF VOLUME II TO THE VERIFICATION HANDBOOK.
* 2		DCN000	EUGENA GOGGANS	EO03	02/22/07	DOCUMENT RELEASED THRU PDS. NO LONGER TRACKED IN ICMS.

CHECKER

N/A
02/15/07

(FINAL)

PACKAGE NO: 10443R

PROGRAM/PROJECT: MULTI LAST UPDATED: 02/22/07

NOMENCLATURE: MSFC-STD- GOING TO NONE EFFECTIVITY

ECR NO:	PCN:	CCBD NO:	DATE PREPARED:
E003-0000	0000000	000-00-0000	02/22/07
		SB3-00-0000	

DWG SIZE	DRAWING NUMBER	DWG REV	EPL/DRL/DDS NUMBER	DWG REV	EPL DSH	EPL REV	EO DASH NUMBER	EO REV	PART NUMBER
			MSFC-HDBK-1453		202	-			
			MSFC-HDBK-1674		202	-			
			MSFC-HDBK-2221		203	-			
			MSFC-HDBK-505		202	-			
			MSFC-HDBK-670		202	-			
			MSFC-MNL-1951		209	-			
			MSFC-PROC-1301		202	-			
			MSFC-PROC-1721		202	-			
			MSFC-PROC-1831		202	-			
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			MSFC-SPEC-1238		202	-			
			MSFC-SPEC-1443		202	-			
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			MSFC-SPEC-2492		203	-			
			MSFC-SPEC-2497		211	-			
			MSFC-SPEC-250		202	-			
			MSFC-SPEC-445		202	-			
			MSFC-SPEC-504		202	-			
			MSFC-SPEC-521		202	-			
			MSFC-SPEC-548		202	-			
			MSFC-SPEC-560		202	-			
			MSFC-SPEC-626		202	-			
			MSFC-SPEC-684		202	-			
			MSFC-SPEC-708		202	-			
			MSFC-SPEC-766		202	-			
			MSFC-STD-1249		202	-			
			MSFC-STD-1800		202	-			
			MSFC-STD-246		202	-			
			MSFC-STD-2594		203	-			

PACKAGE NO: 10443R

DWG SIZE	DRAWING NUMBER	DWG REV	EPL/DRL/DDS NUMBER	DWG REV	EPL DSH	EPL REV	EO DASH NUMBER	EO REV	PART NUMBER
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			MSFC-STD-2906		202	-			
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			MSFC-STD-557		202	-			
			MSFC-STD-561		203	-			
			MSFC-STD-781		202	-			

SUBMITTED BY ENGINEERING AREA:	BASIC CHANGE	PARTIAL	COMPLETE	CLOSES ACTION
EO03	X		X	EO03

PREPARED BY:
EUGENA GOGGANS
12/19/06

SUBMITTED BY:

CONCURRENCE:

TRANSMITTAL DATES
TO RELEASE DESK 02/22/07 10:00
TO MSFC DOC REP 02/22/07 00:00

REMARKS: