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SPACE LAUNCH SYSTEM PROGRAM (SLSP) VERIFICATION & VALIDATION (V&V) PLAN

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REVISION AND HISTORY PAGE

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Release	1	-	Initial Release of SLS DRD 1406SE-023 for SLS PDR, MSFC Concurrence on file.	04/26/2013

NOTE: Updates to this document, as released by numbered changes (Change XXX), are identified by a black bar on the right margin.

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1.0 INTRODUCTION

The Space Launch System (SLS) Program Verification and Validation (V&V) Plan presents the plans, processes, and best practices for certification of the integrated SLS through V&V. The V&V Plan reflects the structure of the Program by delineating verification and validation activities performed with respect to the integrated vehicle and activities assigned to the Elements. Elements will be required to provide deliverables limited to those needed to support system-level verification closure as described in SLS-PLAN-186, SLS Program Agreements Document, and as identified in the SLS-RQMT-018, SLS Data Requirements List. The SLS Program Discipline Lead Engineers (DLEs) will coordinate with the Element Discipline Lead Engineers (EDLEs) to provide insight into verification activities at the Element level and below, and continuity between the element- and system-level verification tasks.

1.1 Purpose

The purpose of the SLS Program V&V Plan is to define the approach for requirements verification and validation. The verification process confirms that deliverable ground and flight hardware (HW) and software (SW) are in compliance with functional, performance, and design requirements. The validation process confirms realized end products, at any position within the vehicle system structure, conform to their set of stakeholder expectations captured in the SLS-PLAN-020, SLSP Concept of Operations (ConOps) document. The validation process also ensures that any anomalies discovered during validation are appropriately resolved prior to product delivery.

This plan identifies the organizational relationships within the SLS Program regarding V&V activities. This plan is intended to ensure the implementation of Program requirements driven by considerations of flight crew, ground personnel, public safety, integrity of flight HW and SW, and mission assurance.

1.2 Scope

Specific agreements between SLS SE&I, multi-element, and element disciplines necessary to implement verification and validation are documented in Section 5.0 of the SLSP Program Agreement Document (PAD), SLS-SPEC-186. SLS verification and validation will be implemented in two documents: this plan, and the SLSP Verification Compliance Report (VCR), SLS-RPT-195. This plan contains the processes and roles and responsibilities for verification and validation, and is managed at the Category 2 level; the VCR contains the details of verification, validation, and compliance, and is managed at the Category 1 level. Work content and organizational responsibilities described herein are provided to facilitate planning and convey the interrelationship of activities within the SLS baseline. In the event of an inconsistency of this document with SLS PAD documentation, the PAD document is authoritative. See section 2.0 for guidance on the primary authoritative sources for this Plan.

This plan is applicable to the SLS vehicle and system and provides guidance for Element-level verification. Element processes for implementation of verification activities are contained in Element-level documentation. The scope of this document includes all SLS configuration blocks. This version is focused on Block 1 verification and validation. Future revisions will address Block 1A and Block 2 V&V.

This plan adopts a tiered approach to verification planning. The plan focuses on detailed verification planning for the system-level requirements and delegates lower level verification planning to the disciplines and Elements responsible for lower level products. The verification activity defined in this document will be performed on applicable requirements to develop, qualify, accept, integrate, and launch the SLS. Validation activity will be defined as necessary at various levels of product development to ensure stakeholder expectations can be satisfied. The plan presents the program relationships, V&V methods, V&V approaches, organizational responsibilities, program documentation, and program controls that apply to all phases of the SLS V&V activities. The plan establishes the V&V data needed to demonstrate SLS requirements compliance to NASA Headquarters.

1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is Marshall Space Flight Center (MSFC) EV73. Changes to this document will be controlled at the OPR level, as a Category 2 document.

2.0 DOCUMENTS

The verification and validation agreements across organizations within the SLS Program are captured in section 5.0 of the SLS Program Agreement Document (PAD), SLS-PLAN-186, and are mapped into the sections shown in Table 2.0-1.

Agreement Area **Organization**	**Section**
SE&I	5.1
Multiple Elements	5.2
SPIO	5.3
Booster	5.4
Stages	5.5
Engines	5.6
Cross-Program	N/A

Table 2.0-1. Verification and Validation Agreements

2.1 Applicable Documents

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein. Unless otherwise stipulated, the most recently approved version of a listed document shall be used. In those situations where the most recently approved version is not to be used, the pertinent version is specified in this list.

ESD 10002	Exploration Systems Development (ESD) Requirements
ESD 10012	Exploration Systems Development (ESD) Concept of Operations (ConOps)
ESD 10016	Exploration Systems Development (ESD) Verification and Validation (V&V) Plan

MWI-8050.1G	Verification and Validation of Hardware, Software, and Ground Support Equipment for MSFC Projects
SLS-PLAN-003	Space Launch System Program (SLSP) Systems Engineering Management Plan (SEMP)
SLS-PLAN-004	Space Launch System Program (SLSP) Data Management Plan
SLS-PLAN-008	Space Launch System Program (SLSP) Configuration Management Plan
SLS-PLAN-013	Space Launch System Program (SLSP) Safety and Mission Assurance (S&MA) Plan
SLS-PLAN-020	Space Launch System Program (SLSP) Concept of Operations (ConOps)
SLS-PLAN-022	Space Launch System Program (SLSP) Insight/Oversight Plan
SLS-PLAN-023	Space Launch System Program (SLSP) Affordability Plan
SLS-PLAN-099	Space Launch System Program (SLSP) Integration Plan
SLS-PLAN-160	Space Launch System Program (SLSP) Product Data and Lifecycle Management (PDLM) Plan
SLS-PLAN-186	SLSP Program Agreement Document (PAD)
SLS-RQMT-018	Space Launch System Program (SLSP) Data Requirements List
SLS-SPEC-032	Space Launch System Program (SLSP) System Specification

2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document.

CEV-T-029800	Orion Multi-Purpose Crew Vehicle (MPCV) Program-to-Space Launch System (SLS) Program Hardware Interface Control Document (ICD)
CEV-T-029850	Orion Multi-Purpose Crew Vehicle (MPCV) Program-to-Space Launch System (SLS) Program Command and Data Handling

	(C&DH) Interface Control Document (ICD)
MPCV 70026	Orion Multi-Purpose Crew Vehicle (MPCV) Program-to-Space Launch System (SLS) Program Interface Requirements Document
MPR 7123.1	Marshall Space Flight Center (MSFC) Systems Engineering Processes and Requirements
MPR 8040.1 (Current Issue)	Configuration Management, MSFC Programs/Projects
MSFC-HDBK-2221	Verification Handbook
MSFC-HDBK-3173	Project Management and Systems Engineering Handbook
MWI 7123.1	Systems Engineering Stakeholder Expectations, Requirements Definition, and Management Processes
NASA/SP-2007-6105, Rev 1	NASA Systems Engineering Handbook
NPR 7123.1 (Current Issue)	NASA Systems Engineering Processes and Requirements
SLS-ICD-021	Core Stage to Booster Interface Control Document
SLS-ICD-029	Stages to Integrated Spacecraft and Payload Element (ISPE) Interface Control Document
SLS-ICD-031	Space Launch System (SLS) to Communications and Tracking Network (CTN) Interface Control Document
SLS-ICD-039	Stages to Engines Interface Control Document
SLS-ICD-052-01	Space Launch System (SLS) to Ground Systems Development and Operations Program (GSDOP) Interface Control Document
SLS-ICD-052-02	Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) Interface Control Document (ICD), Volume 2: Booster to GSDOP

SLS-ICD-052-03	Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) Interface Control Document (ICD), Volume 3: Core Stage to GSDOP
SLS-ICD-052-04	Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) Interface Control Document (ICD), Volume 4: ISPE to GSDOP
SLS-ICD-052-05	Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) Interface Control Document (ICD), Volume 5: SLSP Software to GSDOP
SLS-ICD-176	Space Launch System Program (SLSP) to Mission Systems Interface Control Document
SLS-MDL-068	Space Launch System Program (SLSP) Vehicle Functional Analysis Model (VFAM)
SLS-PLAN-024	Space Launch System Program (SLSP) Software Management Plan
SLS-PLAN-036	Space Launch System Program (SLSP) Certificate of Flight Readiness (CoFR) Implementation Plan
SLS-PLAN-075	Space Launch System Program (SLSP) Flight Software Verification and Validation Plan
SLS-PLAN-099	Space Launch System Program (SLSP) Integration Plan
SLS-PLAN-100	Space Launch System Program (SLSP) Flight Evaluation Plan
SLS-PLAN-116	Space Launch System Program (SLSP) Test Plan
SLS-PLAN-173	Space Launch System Program (SLSP) Modeling and Simulation Plan
SLS-RPT-105	Space Launch System Program (SLSP) Design Models Log
SLS-RQMT-015	Space Launch System Program (SLSP) Hazard Analysis Requirements
SLS-RQMT-019	Space Launch System Program (SLSP) Electrical, Electronics, and Electromechanical (EEE) Parts Management and Control Requirements Document
SLS-RQMT-040	Space Launch System Program (SLSP) Electromagnetic Environmental Effects (E3) Requirements
SLS-RQMT-044,	Space Launch System Program (SLSP) Vehicle Design

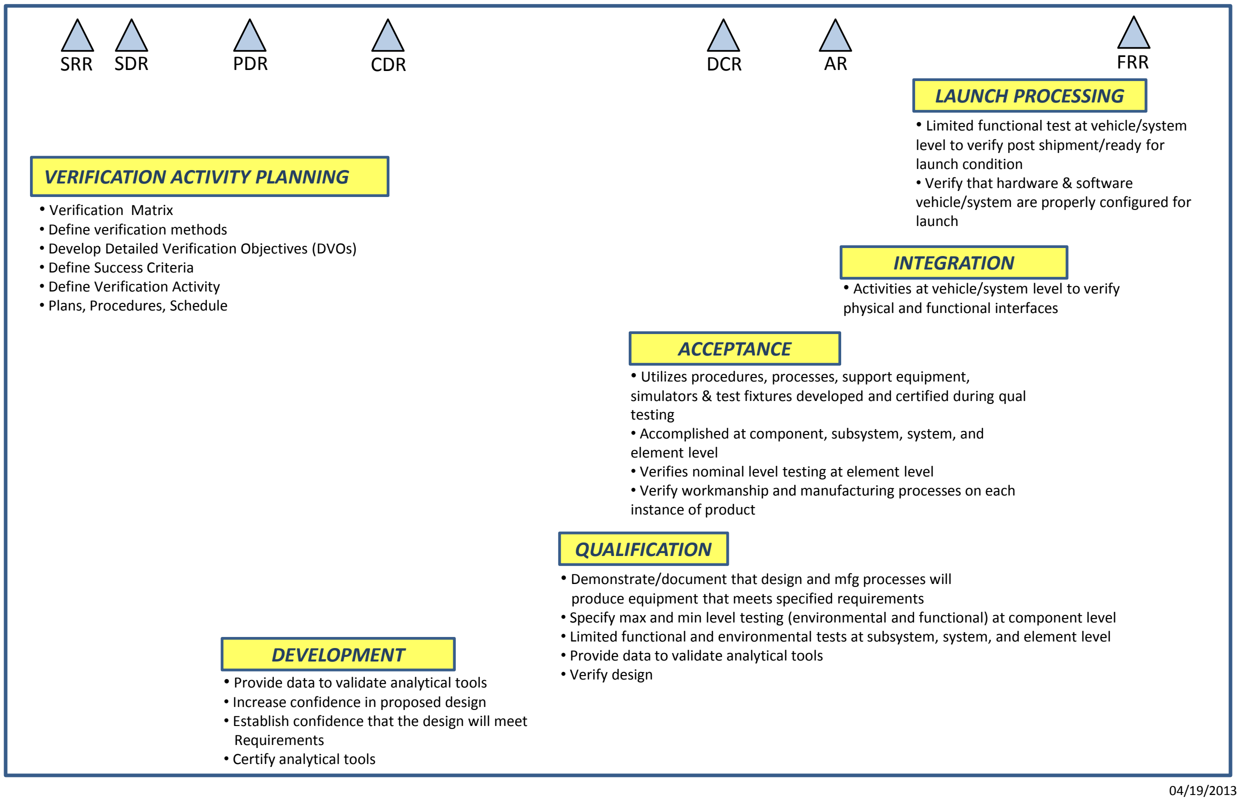
Volumes 1–9	Environments
SLS-RQMT-045	Space Launch System Program (SLSP) Integrated Vehicle Design Loads
SLS-RQMT-114	Space Launch System Program (SLSP) Tailored AFSPCMAN 91-710 Eastern Range Requirements
SLS-RQMT-161	Space Launch System Program (SLSP) Human System Integration Requirements (HSIR)
SLS-SPEC-028	Space Launch System Program (SLSP) Integrated Vehicle Structural Design
SLS-SPEC-030 Volumes 1–5	Space Launch System Program (SLSP) Support Equipment Specification
SLS-SPEC-048	Space Launch System Program (SLSP) Integrated Vehicle Coordinate System
SLS-SPEC-049	Space Launch System Program (SLSP) Integrated Vehicle Outer Mold Line (OML) Specification
SLS-SPEC-079	Space Launch System Program (SLSP) Vehicle Management Specification
SLS-SPEC-167	Space Launch System Program (SLSP) Imagery System Definition Document
SLS-RQMT-012	Payload Element (ISPE) to Payload Interface Control Document
STG-AV-ICD-0002	Space Launch System (SLS) Stages to Elements Communication and Data Handling (C&DH) Document

3.0 SLS VERIFICATION AND VALIDATION

The intent of the Space Launch System (SLS) is to provide an efficient and affordable means to meet multiple launch missions in support of human exploration beyond Earth orbit (BEO) and assembly of large and complex structures in space. The SLS is a single project Program managed at MSFC. The integrated SLS will interface with the Orion Multi-Purpose Crew Vehicle (MPCV) Program, Ground Systems Development and Operations Program (GSDOP), and Spacecraft Communication and Navigation (SCaN). The SLS system-level requirements are documented in SLS-SPEC-032, SLS Program System Specification, which also allocates the requirements to the Elements that comprise the integrated SLS. The SLS Elements include the Integrated Spacecraft and Payload Element (ISPE), Booster, Stages, and Liquid Engines.

3.1 SLS Verification Phases

SLS Systems Engineering (SE) has developed a verification process that encompasses all verification activities including planning, detailed objective definition, and compliance activities necessary to support full-scale development of the SLS. The major phases of the initial SLS verification strategy are defined in Figure 3-1. Below each phase bar is a series of activities that make up the verification process which, when implemented, assure that the SLS hardware (HW) and software (SW) systems meet all design, performance, and safety requirements. The verification phases are defined periods of major program activity when verification is to be accomplished. The SLS verification phases include development (if pre-declared and approved), qualification, acceptance, integration, and launch processing.



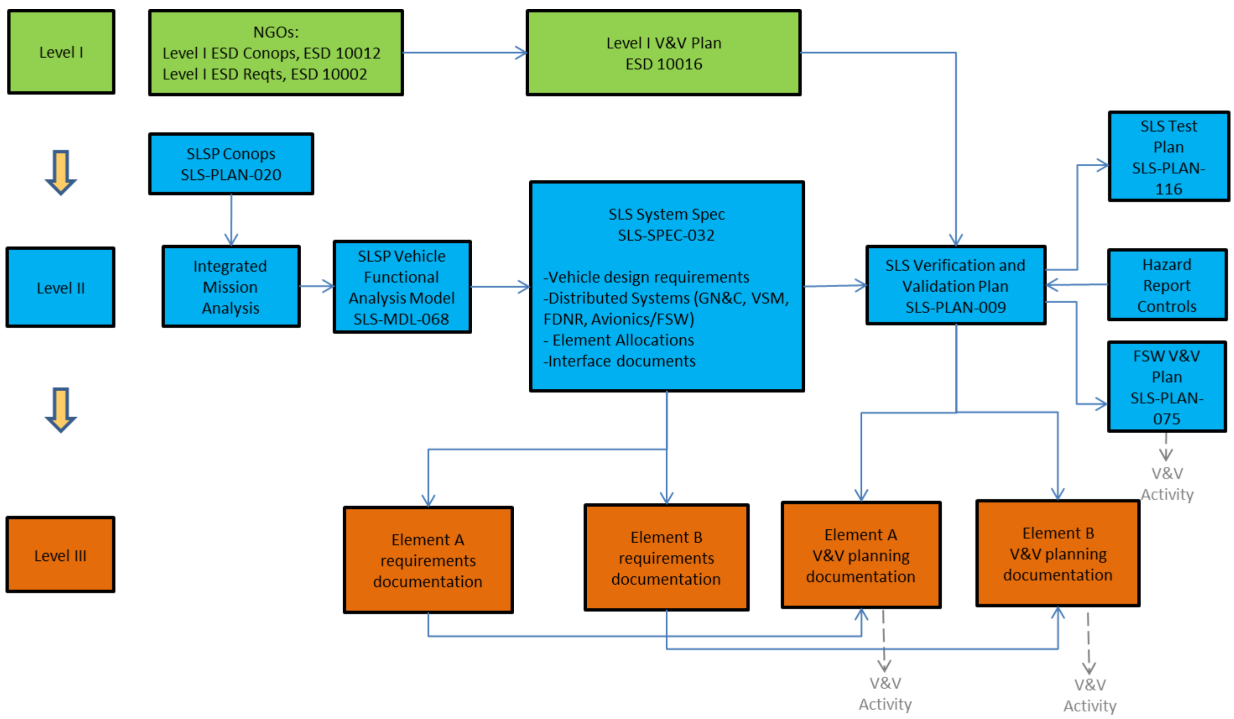
Key: AR – Acceptance Review; CDR – Critical Design Review; DCR – Design Certification Review; DVO – Detailed Verification Objective; FRR – Flight Readiness Review; mfg – Manufacturing; PDR – Preliminary Design Review; SDR – System Definition Review; SRR – System Requirements Review

Figure 3-1. SLS Verification Phases

3.2 SLS Verification Flow Down

The SLSP System Specification forms the foundation for the functional decomposition and top-down allocation of performance and design requirements to the Element level. The verification closure of all requirements is accomplished with a bottom-up approach using the appropriate requirements traceability.

A SLS requirement and verification flow down is depicted in Figure 3-2. The green areas represent the Level I Needs, Goals, and Objectives (NGOs) of the stakeholders. The blue areas represent the Level II SLS Program (i.e., vehicle system and subsystem) requirements and corresponding verification planning. The brown areas represent the Level III Element and component requirements and verification planning. This figure is not intended to be considered a specification or document tree, and its primary intent is to show the relationship between requirements and verification of those requirements.



Key: FDNR –Failure Detection, Notification, and Response; FSW – Flight Software; GN&C – Guidance, Navigation and Control; NGOs – Needs, Goals, and Objectives; VSM – Vehicle System Management.

Figure 3-2. SLS Requirements Flow Down

3.3 Relationship Between Integration, Verification, and Validation

The verification and validation process is performed to ensure the end-item design complies with the vehicle system requirements, meets the customer needs, and is capable of sustaining its operational role during the life cycle. Verification is the process for confirming that the technical requirements have been met, while validation is the process for confirming that the stakeholder expectations have been met. Verification proves (to an appropriate risk level) that an item satisfies its requirements.

The "V" diagram in Figure 3-3 illustrates the product development process and the relationship between the verification, integration, and validation processes. The product development process is initiated with an unfulfilled need expressed by a customer. The needs of the customer and other stakeholders are transformed into a definition of the top-level system that can accomplish the mission and satisfy the stakeholders' needs. The top-level system is the Exploration System Development (ESD) Capability Driven Framework (CDF).

System decomposition and definition descends down the left side of the "V". For example, the CDF is functionally and physically partitioned into hardware assemblies, software components, and operator activities that can be separately produced and managed. The systems that comprise the CDF are defined and decomposed into a set of elements that comprise each system. Once the definition of a system has been transformed into an end product (the HW and SW that performs the mission) the system can be verified. System integration and verification ascend the right side of the "V".

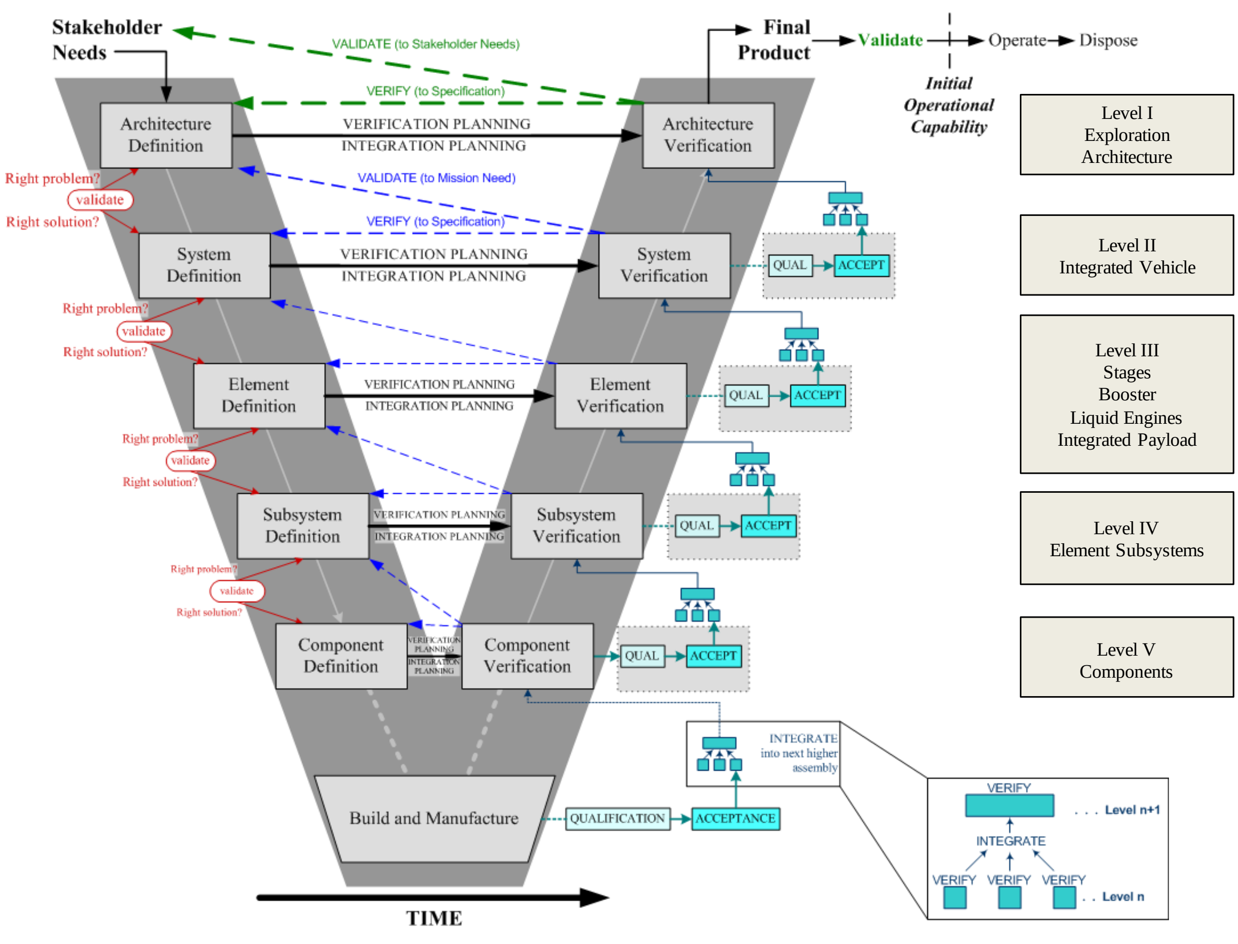


Figure 3-3. Integration, Verification, and Validation "V"

During integration, lower level assemblies and components are combined. Interfaces are verified and compatibility is assessed to ensure the lower level entities will successfully combine to produce the system required at the next higher level depicted on the "V".

Once a system has passed acceptance, it is integrated into the next higher level of assembly. The verification and integration cycle continues until the top-level system is produced and has been verified.

Validation of an end product demonstrates that the item can perform its mission and satisfy its stakeholders' needs, through the full range of operating conditions. When the top-level system has been validated, it is ready to be deployed and operated, and eventually disposed of at the end of its useful life.

Validation that the correct products have been created is also illustrated on the left side of the "V". Here, validation ensures that the interim products and systems engineering artifacts reflect the correct problem and that a valid solution has been identified.

As illustrated by the horizontal arrows from the left to right side of the "V", verification planning begins as soon as the system definition begins to take shape. The verification method and verification approach to be used at each level on the right side of the "V" must be determined as the specifications are developed at the corresponding level on the left side of the "V". Verification objectives are defined by the requirement owners at the same time they define the system performance requirements.

Integration planning begins when a system's definition begins to emerge, in order to ensure that the globally optimum set of entities has been found that will satisfy the stakeholders' needs. The available integration and verification approaches can impact the selection of the solution from a set of candidate alternatives. Understanding those impacts early helps to understand and manage the true systems cost and to ensure the availability of test and integration facilities when needed.

For the SLS Program, the primary database for system level verification and validation is the Cradle® SLS1 database **<TBR-002>**. See SLS-PLAN-160, SLSP Product Data and Lifecycle Management (PDLM) Plan, for software tools used for other Program activities.

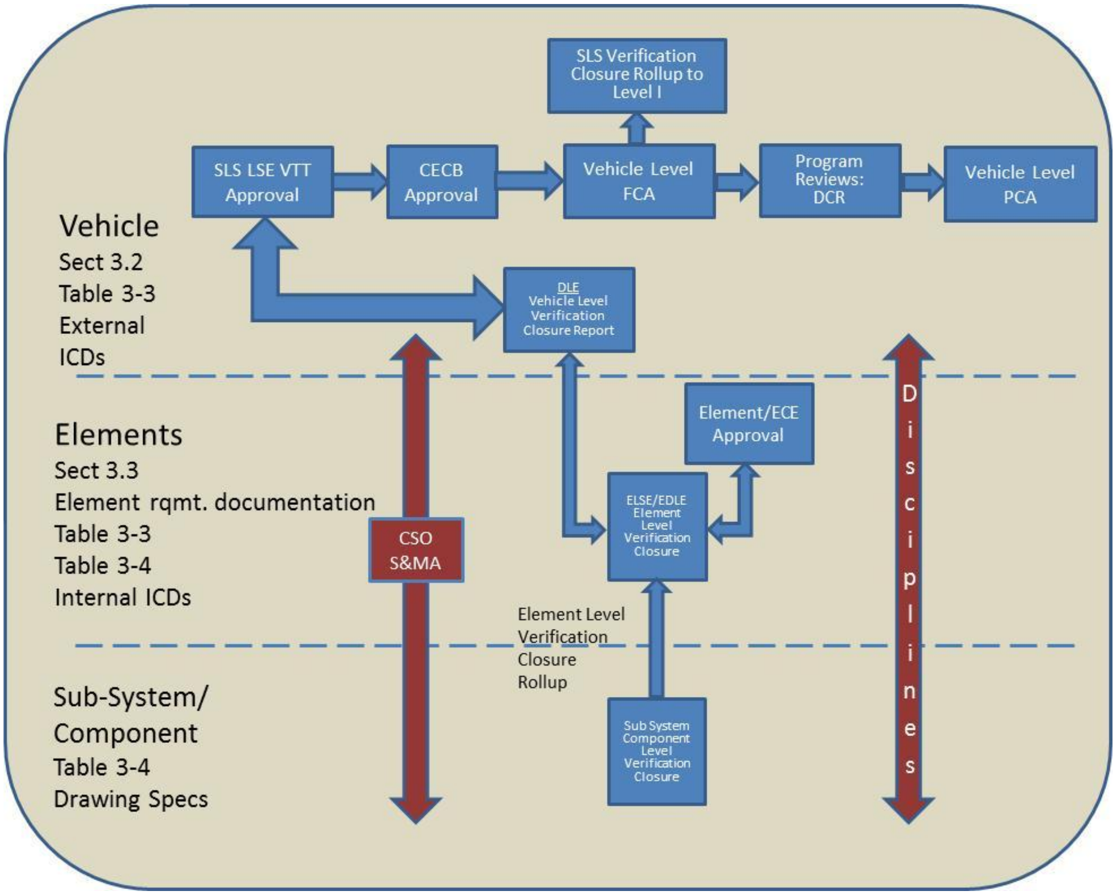
4.0 SLS VERIFICATION STRATEGY

This section describes a verification and validation (V&V) strategy that has been customized to the structure of the SLS organizations and the SLSP System Specification approach. Section 4.1 describes roles and responsibilities of the systems and discipline engineering organizations at both the vehicle and Element levels. Section 4.2 describes a verification approach tailored to the structure of the SLSP System Specification.

4.1 SLS Verification Task Team (VTT) Roles and Responsibilities

The SLS verification program is managed by the SLS Verification Task Team at NASA MSFC with support from the Discipline Engineering organizations and the various Element Offices.

Figure 4-1 shows a notional mapping of the SLSP System Specification sections to the verification flow at the various Program levels. The figure highlights the roles of the vehicle- and Element-level Lead Systems Engineers (LSEs/ELSEs) and Discipline Lead Engineers (DLEs/EDLEs), and the flow of verification activity rolled up through the Program boards. Level I will participate in the Level II Functional Configuration Audit (FCA), Physical Configuration Audit (PCA), and Design Certification Review (DCR) reviews. The section and table numbers referenced on the left side of the figure refer to SLSP System Specification sections containing the requirements relevant to the integration level.



Key: DLE – Discipline Lead Engineer; ECE – Element Chief Engineer; ELSE – Element Lead Systems Engineer; EDLE – Element Discipline Lead Engineer; CSO – Chief S&MA Officer; ICD – Interface Control Document; CE – Chief Engineer; DCR – Design Certification Review; FCA – Functional Configuration Audit; LSE – Lead Systems Engineer; PCA – Physical Configuration Audit.

Figure 4-1. SLS Verification Flow

The SLS VTT, led by the LSE, is composed of ESD, SLS, MPCV, and GSDO representatives. SLS representatives include Systems Engineering (SE) personnel, along with DLEs, EDLEs, ELSEs, and CSO. The team defines the SLS verification approach and processes to accomplish the verification of the SLS and to ensure a fully functional launch vehicle. It will manage closure data for system-level requirements supplied by the DLEs, including entering and tracking closure in the Cradle® SLS1 database. The VTT is also responsible for providing direction and coordination with other Program participants to ensure that the verification processes are understood within the performing organizations, properly implemented, and properly reported to SLS management. The VTT will work with Safety and Mission Assurance (S&MA) to ensure thorough and complete verification in accordance with SLS-PLAN-013, SLS Program Safety and Mission Assurance Plan. Figure 4-2 shows the VTT members with respect to the SLS Engineering organization structure.

SLS Systems Engineering & Integration Organization	**Systems Engineering**	**Vehicle Mgmt.**	**Structures and Env.**	**Propulsion**	**Production**	**Integrated Avionics and Software**	**Operations**	**Test**	**Safety and Mission Assurance**
Program Chief Engineer (CE)	Lead Systems Engineer (LSE)	Discipline Lead Engineer (DLE)	DLE	DLE	DLE	DLE	DLE	DLE	Chief S&MA Officer
Stages Element Chief Engineer (ECE)	Element LSE (ELSE)	Element DLE (EDLE)	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	Element CSO (ECSO)
Booster ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Engines ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Integrated Spacecraft and Payload ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Advanced Development ECE									

Figure 4-2. SLS Engineering Organization Structure

4.1.1 Systems Engineering Responsibilities

SLS SE ensures that the V&V Plan is executed by coordinating verification efforts across disciplines, Elements, and other programs. SE will monitor changes in the SLS design and requirements source documents and assess impacts on the verification efforts being conducted by the discipline teams and other participants. The SE team supports the vehicle certification process by integrating and maintaining system-level verification closure data over the life of the Program.

The SE responsibilities are detailed below:

- Provide guidance to each DLE and Element verification team as they develop their verification strategy to ensure consistency across all Elements.
- Ensure coordination of verification efforts with other Programs.

- Obtain system-level verification closure data from the DLEs or CSO, maintain verification matrices, and enter/track closure in the Cradle® SLS1 database.
- Report to overall verification management progress via metrics of the implementation, as required.
- Develop the Verification Compliance Report documenting closure of system-level verifications.
- Participate in identifying joint verification activities for Program-level interface requirements.
- Provide guidance on modeling and simulation verification, validation, and certification.
- Coordinate with the SLS Chief Engineer's Control Board (CECB) on change requests (CRs) that impact hardware verification activities and verification closure.
- Support development of test plans, test reports, Test Readiness Review (TRR), and post-test activities to ensure accomplishment of requirement verification.
- Support validation and accreditation of the System Integration Laboratory (SIL) to ensure accomplishment of requirement verification.

4.1.2 Discipline Engineering Responsibilities

Per SLS-PLAN-003, SLSP Systems Engineering Management Plan (SEMP), the DLEs or their delegates plan and execute the development of deliverables with discipline-specific content and are accountable for the technical adequacy of all discipline-specific deliverables for the entire system. To accomplish this role with respect to verification, the DLE (including the CSO), or delegate, will be a member of the VTT and will be assigned one or more verifications by the VTT.

The DLE will be responsible for developing verification methods, verification requirements, Compliance Data Lists (CDLs) and Detailed Verification Objectives (DVOs). The DLE will coordinate with Element verification teams, other disciplines, and other programs to ensure that activities supporting DVO closure are being planned and accomplished. If necessary, the DLE may form a technical team to support development and review of verification products. The DLE will work with Element teams to identify appropriate data submittals needed to close system-level verifications. Per the SEMP, "The DLEs will negotiate with Elements to ensure that Elements provide data as input to the vehicle level deliverables. DLEs are responsible for insuring that Element level inputs to Element level deliverables produce adequate results at the vehicle level. EDLEs are technically accountable to the ECE that data provided by the Elements for use at the vehicle level meets the needs of the vehicle and is technically adequate with respect to their discipline scope. The DLE will review the results of verification activities as documented in verification reports and will provide closure data for DVOs to the VTT.

The DLE is responsible for:

- Developing verification methods, compliance data lists (CDLs), DVOs, verification activity details, and verification closure for each assigned verification event associated with system-level requirements.
- Insight into the verification process at the Element level through coordination with EDLEs.
- Reviewing each assigned SLSP System Specification verification closure, and the SLS side of Program-level interface requirements verification closures submitted for accuracy prior to putting it into the Verification Closure Report.
- Participates in development, review, and concurrence to the CECB for verification planning and closure of SLS external interfaces.
- Reviewing system-level integrated hazard reports to ensure that the vehicle requirement verification process is coordinated with safety verification.
- Establish Bilateral Exchange Agreements (BEAs) for shared interface verification activities between programs.
- Coordinate with multiple Element teams as necessary to establish closure of system-level DVOs with compliance assessment rationale.

The verification methods established by the DLE or CSO will drive those responsible for test activities to determine facilities and test setups to accommodate all items being verified by test, any analyses that require test data for validation, and any demonstrations that require facility equipment. The SLS-PLAN-116, SLSP Test Plan, and Element test plans provide descriptions of these tests.

4.1.3 Element Verification Responsibilities

Element verification teams will participate in the system-level verification planning as members of the VTT. Elements will be responsible for V&V planning at the Element level to ensure that Element verification planning and activities conducted at the Element level and below will support closure of the system-level requirements. Element requirements that do not support system-level verification will be closed at the Element level with discipline support from the EDLE. Element teams will work with the DLEs to plan the verification approaches for vehicle requirements through development of verification methods, DVOs, and detailed planning of verification events. The DLE will coordinate with multiple Element teams as necessary to establish closure of system-level DVOs with compliance assessment rationale.

Element teams are responsible for ensuring compliance of the element design with the vehicle's external and internal (element-to-element) interface control documents (ICDs). Element V&V plans will address management and implementation of the interface compliance approach. The

Elements will provide verification metadata for those design requirements of SLS-SPEC-032, SLSP System Specification, that are allocated to the elements.

4.1.3.1 Stages Verification Responsibilities

Section 3.3.1 of the SLSP System Specification provides requirements applicable to the Stages Element, with and without engines integrated. The Stages Element will develop and execute its own V&V planning, with the EDLEs performing an insight role to ensure compatibility with system-level verification closure.

4.1.3.2 Liquid Engines Verification Responsibilities

Section 3.3.2 of the SLSP System Specification provides requirements applicable to the Liquid Engines Element. The Liquid Engines Element will develop and execute its own V&V planning, with the EDLEs performing an insight role to ensure compatibility with system-level verification closure.

4.1.3.3 Booster Verification Responsibilities

Section 3.3.3 of the SLSP System Specification provides requirements applicable to the Booster Element. The Booster Element will develop and execute its own V&V planning, with the EDLEs performing an insight role to ensure compatibility with system-level verification closure.

4.1.3.4 Integrated Spacecraft and Payload Element Verification Responsibilities

Section 3.3.4 of the SLSP System Specification provides requirements applicable to the Integrated Spacecraft and Payload Element (ISPE). The ISPE is managed at MSFC by the Spacecraft and Payload Integration Office (SPIO). The ISPE will develop and execute its own V&V planning, with the EDLEs performing an insight role to ensure compatibility with system-level verification closure

4.2 Verification Approach

The SLSP System Specification was developed to reflect the Program's affordability model by only containing a few high-level vehicle functional requirements at Level II and allocating requirements to the vehicle disciplines and Elements to the extent possible. This approach departs from classical systems engineering which decomposed the high-level vehicle functional requirements into numerous detailed system-level requirements.

The verification implementation strategy is in accordance with the structure of the SLSP System Specification. Rather than using decomposed requirements as the basis for verification planning, the Level II verification implementation strategy is to use CDLs and DVOs as the decomposition tool to identify the data needed to demonstrate verification of integrated vehicle performance functions. The CDLs and DVOs will be discussed in greater detail in Section 5.0 Verification Process. The objective is to develop the same set of compliance data as would be developed using the classical approach. However, the compliance data and DVOs will be traced to a fewer number of high-level vehicle requirements.

The verification approach requires the accomplishment of the following objectives:

- Verify that the SLS meets all system-level requirements.
- Verify that the Elements fulfill their allocated requirements.

System-level verification closure will be established through system-level audits with Element support. The DLEs are responsible for providing compliance data and compliance assessments for requirement closure. The system-level compliance data will be stored and maintained in the Cradle database <**TBR-003**>.

The SLS verification implementation acknowledges SLS Program affordability concerns by requiring that Elements develop and execute their own V&V planning for requirements at the Element level and below. Elements will establish verification closure by holding Element-level audits. Elements will provide verification metadata as objective evidence of successful completion of the Element-level audit to the VTT for entry into the Cradle database. The verification metadata for the element design requirements of SLS-SPEC-032, SLSP System Specification, includes:

- Requirement
- Verification Methods
- Verification Activities/Success Criteria
- Compliance Assessment
- References to Associated Compliance Data

4.2.1 SLS System-Level Requirements

Verifications for each SLS-SPEC-032, Section 3.2 requirement will be assigned to a DLE or the CSO, who will be responsible for the development of CDLs and DVOs for the verification activities necessary to support closure of system-level requirements. The VTT will integrate with other programs (MPCV, GSDOP) in developing approaches to verification of interface requirements and ESD Level I requirements that require joint program-to-program interaction. SLS-RPT-195, SLSP Verification Compliance Report, contains the VCRM for the system-level requirements in Section 3.2 of the SLS-SPEC-032. The VCRM includes the requirement, verification methods, the assigned DLE or CSO, verification activity, and success criteria.

4.2.2 Element-Level Verification Supporting System-Level Verification Closure

System-level verification closure may be supported by the Elements in two ways: 1) Element-allocated vehicle requirements closed at the Element level will be delivered as Element verification metadata to SLS SE&I (LSE); 2) data products needed to support system-level verification activities delivered by Data Requirements Description (DRD).

SLS-SPEC-032, Table 3-5, contains Element-allocated vehicle requirements assigned to the various Elements. The assigned requirements will be closed at the Element level. If the requirement is closed at the Element level, it will be documented by Element verification metadata to SLS SE&I (LSE). The EDLE will ensure that the Element-allocated verification activities will produce the appropriate data needed to support closure of system-level verifications.

If data are required to support a system-level verification activity, the data will be provided through DRDs or controlled Element deliverables. The required Element verification data will be made available to the DLE through the definition of data requirements that will document Element-level data needed for system-level verification activities.

It is expected that some critical system-level verifications, such as those related to safety, high-risk items, interface functions, and distributed vehicle systems, will require an in-depth review by the VTT of closure data extending to the subsystem level or lower. The VTT will coordinate with the DLE or CSO and Elements to ensure that the verification activities are adequate to support closure of critical verifications.

4.2.3 Element-Only Verifications and Below

Verification of Sections 3.3.1 through 3.3.4 of SLS-SPEC-032 will be documented by verification metadata provided by the Elements. The EDLE teams will participate in the Element-level reviews to ensure that the Element verification process is complete.

The Elements will establish traceability, and maintain on-file and under configuration management (CM) control for the life of the Program, Element-level and lower verification closure data subject to review at the request of the VTT. The verification metadata will be delivered through a milestone review or the appropriate ECB for approval to support roll up of verification closure to the vehicle. If an element verification closure is tied to a hazard control verification, it needs the concurrence of the ECSO.

4.2.4 Verification of Technical Specifications and Standards <TBR-005>

Verification of SLS-SPEC-032 requirements called out by requirement SLS.27, and listed in SLS-SPEC-032 Table 3-3, “SLS Technical Documents and Standards Applicability,” may be closed at the System level or may be allocated to the Element level.

SE&I (LSE) will plan verification and generate system-level verification closure to address the contents of applicable documents in SLS-SPEC-032, requirement SLS.27 for SLS system-level verification activities. SE&I (LSE) will accept a Validation of Records report from the elements as objective evidence of element closure of SLS.27 in accordance with section 5.2, part 5 of this Plan.

1. SE&I (LSE) will provide a verification closure statement based on Validation of Records that all SLS system-level verification products for Loads and Environments, as allocated in SLS-SPEC-032, Requirement SLS.27.1, meet SLS-RQMT-045 and SLS-SPEC-044.
2. System-level verification of SLS interfaces, as allocated by SLS-SPEC-032, Requirement SLS.27.2, is addressed in:
    a. External Interfaces: Section 4.2.5.1
    b. Internal Interfaces: Section 4.2.5.2
3. SE&I (LSE) will provide verification metadata based on Validation of Records that all SLS system-level requirements for specifications SLS-SPEC-028, -048, -079 and -167, as allocated in SLS-SPEC-032, Requirement SLS.27.3, have been successfully verified.
4. SE&I (LSE) will provide a verification closure statement based on Validation of Records that SLS system-level requirements for requirements documents SLS-RQMT-019, -040 and -161 and SLS-SPEC-049, -188, as allocated to SLS-SPEC-032, Requirement SLS.27.4, have been successfully verified.
5. SE&I (LSE) will verify Range Safety Requirements (SLS-RQMT-114, Vol 1, 2, 4, and 8), as allocated by SLS-SPEC-032, Requirement SLS.27.5, by providing the SLS system-level and element-level Range Safety DRDs and obtaining United States Air Force (45^{th} Space Wing) approval.

Table 3-3 in the SLS-SPEC-032 also includes a subset of ICDs that will be addressed in paragraph 4.2.5 herein.

1. The Elements will provide verification closure for SLS-SPEC-032, requirement SLS.27 by Validation of Records. The Validation or Records report will reference specific element requirements, verification activities, and associated compliance reports as conducted by the element to verify the contents of each applicable document.
    a. The Elements will provide a verification closure statement based on Validation of Records that all element-level verification products for Loads and Environments, as allocated to the Elements in SLS-SPEC-032, Requirement SLS.27.1, meet SLS-RQMT-045 and SLS-SPEC-044.
    b. Element-level verification of SLS interfaces, as allocated by SLS-SPEC-032, Requirement SLS.27.2, is addressed in Sections 4.2.5.1 and 4.2.5.2.
    c. The Elements will provide verification metadata by Validation of Records that provides objective evidence that specifications SLS-SPEC-028, -048, -079 and -167, as allocated to the Elements in SLS-SPEC-032, Requirement SLS.27.3, have been successfully verified.
    d. The Elements will provide a verification closure statement based on Validation of Records that element-level requirements of SLS-RQMT-019, -040 and -161 and SLS-SPEC-049, as allocated to the Elements in SLS-SPEC-032, Requirement SLS.27.4, have been successfully verified.
    e. The Elements will verify the requirements of Range Safety Requirements, SLS-RQMT-114 (Vol. 1, 2, 4, and 8), as allocated in SLS-SPEC-032, Requirements

27.5, by providing the element-level Range Safety DRDs to the SLS system.

Verification of SLS-SPEC-032 requirements called out by requirement SLS.28 and listed in SLS-SPEC-032 Table 3-4, "Other Technical Documents and Standards," represent design and construction standards and other technical specifications. The Elements will show that they meet the intent of the design and construction standards by providing a copy of the Element verification metadata through a milestone review or the appropriate ECB for approval.

4.2.5 Interface Verification

Verification of SLS internal and external interfaces is addressed in the following paragraphs. Internal and external interface responsibilities will be defined on a case-by-case basis as outlined by each ICD. Note that the Orion MPCV interfaces with the SLS vehicle via the ISPE. Orion and SLS will be responsible for leading verification activities required for the -to-SLS interface as allocated in MPCV 70026, Orion MPCV Program-SLSP IRD, Table 4.2-1, 'Verification Cross-Reference Matrix'. For each ICD, an interface compliance package will be developed, which will include the following interface verification metadata:

- Function Number
- Verification Methods
- Verification Activities/Success Criteria
- Reference to Compliance Data
- Compliance Assessment

4.2.5.1 Internal Interfaces

For internal interface control documents, the Stages element will coordinate and manage development of ICDs listed in Table 4-1 in accordance with SLS-PLAN-186, SLSP Program Agreement Document. Internal interface management activities delegated to the Stages element include:

- Coordinating and managing development of Verification Matrices
- Coordinating and managing development of Interface Hardware Responsibility Tables
- Collecting and integrating the compliance metadata into an Interface Compliance Package (ICP)
- Maintaining ICP metadata records under Stages configuration management
- Developing a single verification compliance statement for each ICD

SLS internal interfaces and associated interface documentation are listed in Table 4-1.

Table 4-1. Internal Interface Documentation

Internal Interface	Interface Documentation
Stages to Booster	SLS-ICD-021, Core Stage to Booster ICD
Stages to Engines	SLS-ICD-039, Stages to Engines ICD
Stages to ISPE	SLS-ICD-029, Stages to ISPE ICD
Stages to Elements Communication and Data Handling (C&DH)	STG-AV-0002, Space Launch System (SLS) Stages to Elements Communication and Data Handling (C&DH) Document

Note that the payload interface will be internal to ISPE. Therefore, any payload interfaces to Stages are included as part of the Stages to ISPE internal interface.

Interfacing elements will provide verification compliance metadata to the Stages element for interface functions assigned to the interfacing element (SPIO, Booster, Engines).

The interface compliance package will be approved by the Joint ECB with concurrence from the other affected Element.

4.2.5.2 External Interfaces <TBR-014>

Verification of external interface control documents listed in Table 4-2 will be conducted in accordance with SLS-PLAN-186, SLSP Program Agreement Document. For external interfaces other than the Eastern Range, SLS will lead verification planning and verification closure of interface functions allocated to the SLS system level.

Table 4-2. External Interface Documentation

External Interface	Interface Documentation
SLS to GSDOP	SLS-ICD-052-01, SLSP to Ground Systems Development and Operations Program ICD SLS-ICD-052-02, Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) ICD, Volume 2: Booster to GSDOP SLS-ICD-052-03, Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) ICD, Volume 3: Core Stage to GSDOP SLS-ICD-052-04, Space Launch System (SLSP)-to-Ground Systems Development and Operations Program

External Interface	Interface Documentation
	(GSDOP) ICD, Volume 4: ISPE to GSDOP SLS-ICD-052-05, Space Launch System (SLSP)-to-Ground Systems Development and Operations Program (GSDOP) ICD, Volume 5: SLSP Software to GSDOP
SLS to Communication and Tracking System (CTN)	SLS-ICD-031, SLSP to Communications and Tracking Network (CTN) ICD
SLS to Eastern Range	SLS-RQMT-114, SLSP Tailored AFSPCMAN 91-710 Eastern Range Requirements
SLS to MPCV	MPCV 70026, Orion MPCV Program-to-SLSP Interface Requirements Document
SLS to Mission Systems	SLS-ICD-176, SLSP to Mission Systems ICD

SLS SE&I document SLS-RPT-195, SLSP Verification Compliance Report (VCR), will encompass the following ICDs:

- SLS-ICD-052-01
- SLS-ICD-031
- SLS-ICD-176

The VCRs will be presented for approval at an SLS-hosted JICB. SLS will accept interface verification metadata from the SLS elements as objective evidence of verification closure of interface functions allocated to the elements per SLS-ICD-052-01, Section 3.3 and verification closure of detailed interface designs captured in SLS-ICD-052, Vol-2, Vol-3, Vol-4, and Vol-5.

For the MPCV interface specified in MPCV 70026, Orion MPCV to SLSP IRD:

- SLS will provide interface verification metadata for the SLS-allocated requirements as inputs to the overall interface compliance package
- MPCV will provide interface verification compliance data for MPCV-allocated requirements

This package will be presented for approval at a JICB.

For the interface with the Eastern Range, SLS will verify the requirements in SLS-RQMT-114, SLSP Tailored AFSPCMAN 91-710 Eastern Range Requirements, by providing the following products and obtaining Air Force approval:

- SLS system-level Range Safety DRDs identified in SLS-RQMT-018, SLSP Data Requirements List (DRL)
- SLS element-level Range Safety DRDs as negotiated with the Eastern Range

4.2.6 Safety Verification

A primary safety analysis for any launch system is the hazard analyses performed at both the integrated system level and at the detailed element-level. These hazard analysis processes include the identification of hazardous conditions, the analysis of these conditions to understand the hazard causes, the identification of controls to mitigate these causes, the derivation of safety requirements (if needed) as a means to implement these controls, the verification of that implementation, and the assessment of residual risk. Derived safety requirements typically fall into two categories: safety-related design requirements and safety-related process requirements. Both of these categories of requirements will necessitate verification activities to ensure proper hazard control is established across the system

Derived safety-related design requirements are to be captured in the applicable system or element specifications just like any other design requirements. The necessary and appropriate planning and compliance processes and products for design requirements verification are provided throughout this SLS V&V Plan. Changes to design requirements and associated verification activities that are identified as hazard controls must be coordinated between the Safety and Mission Assurance and Systems Engineering communities to ensure that proper hazard control is maintained. This coordination is accomplished, in part, by the explicit designation of this linkage within the associated DVO.

The hazard controls resulting from safety-related process requirements are typically mission constraints or operations procedures. These controls can take the form of fabrication or assembly inspections, hardware acceptance procedures, operations and maintenance requirements, or mission constraints. The processes and products for verification of these safety-related process requirements will be accomplished through the validation of records which contain the resulting controls. The development of detailed hazard reports at the element or system level includes the identification of the records necessary to provide verification that safety-related process requirements are being fulfilled. The formal approval of hazard reports through the joint authority of the Chief Engineer and the Chief Safety and Mission Assurance Officer thereby provides the compliance closure process for safety-related process requirements. However, it is understood and typical that at the time of design certification, the hazard reports contain a significant number of open actions. The final necessary verification activity prior to flight is the closure of these open actions that effectively represent the final completion of the hazard report content.

4.2.7 Flight Software Verification

Verification and validation of flight software is addressed in the Flight Software Verification and Validation Plan, SLS-PLAN-075. SLS-PLAN-075 is a Level II document developed and implemented by MSFC ES51 in support of the Integrated Avionics and Software (IAS) DLE. It is a child document to SLS-PLAN-024, SLSP Software Management Plan. The document provides the verification and validation planning approach for the requirements in SLS-PLAN-

095, Software Requirements Specification, which apply to MSFC-developed flight software. Certification that the MSFC-developed flight software has been verified will be provided by the Build Release Package approved by the Software Review Board (SRB). MSFC ES51 will be responsible for storage, tracking, and configuration management of supporting verification data. The MSFC flight software will be developed per SLS-PLAN-073, SLSP Flight Software Development Plan, and integrated with externally developed software for verification and validation. The certified software will be integrated in the SIL for use in SLS system level testing.

Although SLS-PLAN-075 provides a separate process for verification and validation of the flight software, the resulting certified software supports closure of the SLS system level requirements. The DLEs will establish traceability to the certified flight software where appropriate to support verification of the system level requirements. Traceability of system level verification closures to the certified flight software will be coordinated with the Integrated Avionics and Software DLE and will be documented in the DVOs and Compliance Data Lists for the system level requirements.

4.2.8 Ground Support Equipment (GSE) Verification

Organizations responsible for developing GSE will develop their own V&V plans for the GSE. Any GSE verification activities that support verification of SLS to GSDOP interfaces will be documented by the approach identified in Section 9.1.

Verification data generated from Element GSE verification activities needed to support closure of system-level verifications will be handled per Section 4.2.2. Element-level GSE verifications closed at the Element level or below will be handled per Section 4.2.3.

4.2.9 Verification of SLS Block Upgrades

Although the initial version of the V&V Plan is focused on Block 1, the Plan will evolve to account for verification of future block upgrades. As the block upgrades are identified in more detail, for example advanced booster, main engine upgrades, or upper stage evolution, the impacts of these changes on verification of the certified design will be evaluated and documented in this Plan. The overall approach will be to identify areas that require re-verification based on the block upgrades, in support of certification of the upgraded vehicle design and implement re-verification including evaluation of new or modified verification closure products. Because of affordability concerns, re-verification will not be conducted for vehicle elements or subsystems that are not impacted by the block upgrade.

Evaluation of the vehicle design for re-verification impacts will consider the extent to which Block 1 verification activities, such as analysis and test, account for vehicle evolution. The SLS-RPT-183, SLSP Evolvability Study Report, evaluates Block 1 structural margins for potential for future block upgrades and evolvability. SE&I (LSE) will verify the SLS evolvability requirements (as described in SLS-SPEC-032 requirements for Block 1A and Block 2 configurations) by analysis and provide as part of the SLS System level VCR. A compliance assessment of these requirements will be provided at each Life Cycle Review within SLS-RPT-183, *SLSP Evolvability Report*. Verification and validation of the specific SLS requirements that evolve for block upgrades will be coordinated with the evolvability analysis expectations identified in the ESD V&V Plan. The top-level approach by which Block 1 analysis will consider vehicle evolution is documented in SLS-PLAN-099.

The specific approach for re-verification of each block upgrade will be documented in the V&V Plan as the upgrades, associated missions, and new/modified requirements are identified. The approach will identify the means for obtaining new or modified verification data from the Elements and its applicability to updated requirements. Systems Engineering will work with the DLEs and EDLEs to identify specifically which elements and subsystems need to be re-verified based on block upgrade changes. The V&V Plan will identify the verification products that need to be updated including DVOs, Element data supporting design models and vehicle requirements, additional or modified test and analysis reports.

The new or modified verification closure data resulting from block upgrade re-verification will be submitted to the appropriate boards for approval and flowed up to ESD to support closure of Level I verifications.

5.0 VERIFICATION PROCESS

Verification planning is an interactive and lengthy process occurring during all phases of the Program (reference Figure 5-1). The Verification Task Team (VTT), in conjunction with the Discipline Lead Engineer (DLE), will develop a preliminary definition of verification activities based on Program and mission requirements. The VTT will use a five-step process to verify requirements closed at the system level, as shown in Figure 5-1. Elements will use the processes defined in the Element verification planning documentation. Elements will be required to provide Element-level metadata with traceability to compliance data per Step 5 of Figure 5-1.

The five steps are:

- Step 1: Identify all requirements.
- Step 2: Develop verification planning.
- Step 3: Implement verification activities.
- Step 4: Document DVO closures.
- Step 5: Document requirement closures.

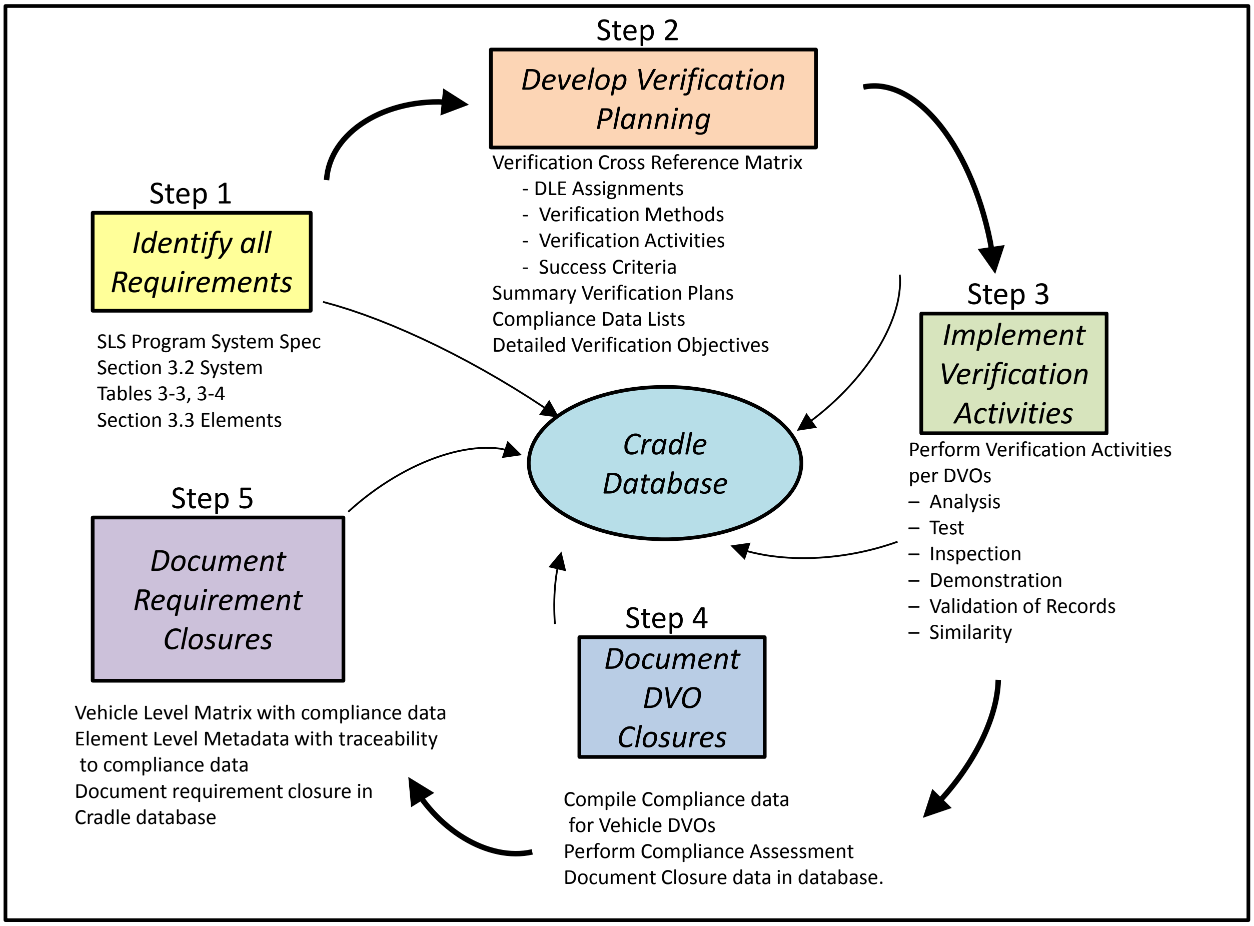


Figure 5-1. SLS Five-Step Verification Process

The process structures the requirement compliance activities from the lower levels to the higher levels of verification within the SLS Program.

The SLS Program Level II will utilize the Cradle® SLS1 database to capture and integrate the verification and validation work performed on SLS. This database will be used by VTT members involved in the SLS Program and will be the primary database for SLS system-level verification data.

5.1 Step 1: Identify All Requirements

Identification of all system and interface requirements is performed by the VTT. Once the requirements are defined, they will be validated to determine compliance with end product objectives, performance goals, and allocated in accordance with the SLSP System Specification.

SLS-SPEC-032 identifies the set of requirements that fall within the scope of the SLS V&V Plan. The SLS-SPEC-032 provides some specific requirements at the vehicle and Element levels as traditional, discrete "shall" statements, while other "shall" statements impose lists of documents as sources of additional design requirements.

5.2 Step 2: Develop Verification Planning

The next step is to identify the verification planning for the requirements identified in Step 1.

The SLS planning is comprised of the following components, which are intended to identify and implement an integrated verification solution for each of the system-level requirements:

1. Vehicle Cross Reference Matrix (VCRM) – A requirements matrix with DLE assignments, verification methods, verification activities, and success criteria. The VCRM is contained in SLS-RPT-195, SLSP Verification Compliance Report (VCR).

2. Compliance Data List (CDL) – A list that identifies verification activities and all data sets required to demonstrate compliance for each requirement.

3. DVOs – A detailed verification objective associated with verification activities that identify the specific activity of obtaining the compliance data. These are needed to support verification planning and development of test procedures, analysis models, demonstrations, inspections, and assembly planning. Examples include test data, output data from analysis, measurement data during assembly, validation data of vendor records, demonstration data, etc.

The system-level VCRM and CDL are used to form the PDR Draft of SLS-RPT-195, SLSP Verification Compliance Report (VCR). At CDR, VCRM and CDL are updated, and DVOs are added to the VCR. This serves as the baseline of the VCR for verification planning contents. At DCR, the VCR contents from CDR are updated and combined with the compliance data to finalize the report. Each of the verification planning steps is described in the following sections.

5.2.1 Verification Cross Reference Matrix

The highest level of the verification planning methodology for the system-level requirements is the VCRM. The intent of the VCRM is to identify the primary DLE responsible for verification of the requirement, and the top-level approach for verifying the requirement. The approach for verifying the requirement is provided by identification of the verification method, the associated verification activities, and the success criteria. Verification methods are defined in Section 5.2.5. The VCRM entry for each requirement is populated by the primary DLE for that requirement. Definitions of verification methods used in the SLS Program are provided below. For SLS.27 and SLS.28, which call out lists of technical documents and standards, the verification matrix will be expanded to contain line items for each document. The VCRM is located in SLS-RPT-195, SLSP Verification Compliance Report.

5.2.2 Compliance Data List

Once the verification matrix is developed, a CDL is developed for each requirement by the primary DLE assigned to that requirement. The CDL is a complete, detailed list of all the data needed to verify the requirement from all sources, including test data, output from analyses, element DRs, etc. It will be the basis for identifying the DVOs needed for each requirement. The primary DLE develops the CDL with input from the other disciplines. The CDL will be used to cross reference the DRL and Element DRDs to ensure that all compliance data needed for system verification is accounted for. Once compliance data is confirmed, the CDL will be entered in the Cradle database and will be linked to its associated system-level requirement. At least one DVO will be developed for each data item on the compliance data list.

5.2.3 Detailed Verification Objectives

Once the CDL has been developed for each system-level requirement, a DVO is written for each data item to define the details of how the data will be obtained. The DVO will address all aspects of the verification activity. Minimum DVO content is identified later in this section. These DVOs are used to prepare such items as test procedures, plans, demonstrations, inspections, and analysis models. The DVO verification activities will be planned as a logical sequence of events such that the roll up of lower level requirement closure data will facilitate the closure of upper level requirements.

The SLS-SPEC-032 Section 3.2 DVOs are developed by the DLE and maintained in the Cradle® SLS1 database by SE.

All Program-level DVOs will be baselined in the Cradle® SLS1 database after the SLS Critical Design Review (CDR), once all Review Item Discrepancies (RIDs) have been resolved and the changes incorporated into the DVOs contained in the database. However, individual DVO baselining can occur after Preliminary Design Review (PDR) to ensure the ability to support the DVO with test facility, support needs, etc. After baselining in the database, any changes to the system-level DVOs will be approved by the SLS Program via the SLS Chief Engineer’s Control Board (CECB). The CECB will have representation from each Element’s verification team, as well as engineering disciplines and Safety and Mission Assurance (S&MA). Representatives from Spacecraft and Payload Integration Office (SPIO), Ground Systems Development and Operations Program (GSDOP), Orion Multi-Purpose Crew Vehicle (MPCV), Range Safety, Mission Systems, and Communications and Tracking will also participate in the CECB regarding interface DVOs, as necessary.

The following list identifies mandatory DVO attributes**,** to be used for system-level requirements, captured in the Cradle® SLS1 database and a brief explanation of each. Identified as mandatory, these attributes form the minimum data set necessary for completing the verification activity. The Cradle® SLS1 database is configured to manage additional administrative DVO data beyond the minimum listed below; for example, status, schedule, version etc. For a complete listing of DVO attributes, refer to Appendix C.

- Identity –DVO number.
- Title – Identifies the DVO as it relates to the associated requirement.
- Compliance Data List Cross Reference – Identifies the associated Compliance Data List from the SLS V&V Plan.
- Verification Activity – Provides details of the verification activity that must be performed to verify the given requirement object for the given assembly level in the given program

phase. The attribute also describes how the input data items and conditions are going to be used in the verification activity, and how the output data items are going to be generated and captured. For an inspection, the specific item to be examined and the intent of the inspection is identified. For an analysis, identify the specific source of data to be analyzed and a description of the analysis to be performed. For a demonstration, the specific action to be demonstrated is identified. For a test, the article to be tested and high-level details of the testing to be performed are identified. For similarity, identify the items and configurations to be compared and the prior data needed to show similarity. For validation of records, identify the records and applicable standards needed to ensure that the requirement has been met.

- Verification Method – This is a multiple pick list consisting of test, demonstration, analysis, inspection, validation of records, and similarity.
- Success Criteria – The measure by which the test, analysis, demonstration, inspection, validation of records, or similarity will be considered complete to satisfy the objective of the DVO. Where the success criteria are specified as a numerical value or a range, explain the basis for selection of the success criteria. Identify safety factors and margins included in the value, identify applicable operating and environmental conditions, and define terms such as “nominal,” “operational,” etc.
- Compliance Data **–** Provides the results of the verification activity performed. Provides traceability to the verification report(s) needed to close the DVO.
- Compliance Assessment – Description of how the data compare to the success criteria and provides a recommendation for closure, deviation, waiver, etc.
- Constraint – Identifies other DVOs that need to be closed prior to closure.
- Point of Contact (POC) – Identifies who owns the DVO, who supports the DVO, who is affected by the DVO, who needs to be notified about activity with the DVO, who is required to implement the DVO, and who the parties are if the DVO is jointly owned.
- Hazard report number – If a verification is associated with a potential hazard, the control number of the hazard must be listed.
- Allocation **–** Identify whether the DVO is at the vehicle or Element level (DLE or EDLE).

Elements are not required to submit DVOs. Elements will demonstrate compliance via submittal of verification metadata. Contents of the Element verification metadata are defined in Section 4.2.

5.2.4 Verification Methods

The verification methods used to verify each SLS hardware/software requirement are analysis, inspection, demonstration, test, validation of records, similarity, or any combination of these methods. Each of these methods is described in the following paragraphs.

5.2.4.1 Analysis

Verification by analysis is a process used in lieu of or in addition to testing to verify compliance to requirements. Analysis is a method of verification utilizing techniques and tools such as systems engineering analysis, statistics and qualitative analysis, computer and hardware simulations, analog modeling, and tolerance analysis to confirm that design requirements to be verified have been satisfied. Analysis can be used to evaluate the results of multiple tests and analyses at a lower level, such as vendor-supplied manufacturing or processing records or commercial off-the-shelf (COTS) products, which are applied to a higher level of assembly. Analytical methods selected for verification will be supported by appropriate rationale and be detailed in the applicable documents.

Analysis may be used whenever any of the following apply:

a) The spectrum of flight conditions cannot be simulated adequately on the ground, and it is necessary to extrapolate test data beyond the performed test points.

b) Analysis provides an accurate representation of the conditions and behavior that affect the verification.

c) It is desired to determine closure status of verification activities being performed at lower levels of assembly to support closures at higher levels.

d) The range of parameters to be applied could lead to hardware damage, e.g., structural factors of safety.

5.2.4.2 Inspection

Verification by inspection is the assessment of a physical characteristic that determines compliance of the item with requirements without the use of special laboratory equipment, procedures, test support items, or services. Inspection uses standard methods such as visuals, gauges, etc., to verify compliance with requirements. Inspection is usually used to verify satisfaction of design and manufacturing requirements such as construction features, workmanship, dimension, and physical condition (e.g., cleanliness, surface finish, locking hardware identified on the engineering documentation), and specification and/or drawing compliance. Inspection also includes Review of Design (ROD), a review of drawings to confirm that a design feature has been incorporated into the design. Formal inspection may be used on software artifacts to fully or partially verify attributes such as adherence to standards, maintainability, modifiability, testability, portability, and reusability.

Inspection may also be used in cases where verification of a requirement consists only of confirming closure of lower level verifications, with no analysis necessary.

5.2.4.3 Demonstration

Demonstration method of verification is used to determine the properties of an end item or component by observation of its operation or characteristics. Demonstration is used with or without special test equipment or special instrumentation to verify characteristics such as operational performance, human engineering features, serviceability, accessibility, physical interface compatibility (fit check), maintainability (reach, accessibility, clearances, etc.), built-in test/built-in test equipment, transportability, and display data. When used as a formal verification activity, demonstrated performance will be observed and recorded. Interface verification by demonstration will use flight HW and SW, simulators, interface tooling, or flight-equivalent qualification hardware.

Where specific training requirements are to be verified by demonstration using mockups (non-flight materials, construction, or operation) they will require concurrence of the requirement owner and would be explicitly mentioned in the associated DVO. When use of a mockup is mentioned in the DVO, its required level of fidelity and “validation” or “certification” status should be described in the DVO.

5.2.4.4 Test

Verification by test verifies that hardware and systems meet Program performance and functional requirements throughout a range of environmental conditions and operational modes anticipated throughout the product’s life cycle. Test is usually the preferred verification/validation method for quantitative operational performance requirements. Test measurements will require the use of calibrated laboratory equipment, recorded and subsequently archived data, approved and configuration managed procedures, test support items, or services. For all test activities, pass/fail test criteria or acceptance tolerance bands (based upon design and performance requirements) will be specified prior to conducting the test. Acceptance tolerance bands used at the manufacturer’s facility for component- or subsystem-level tests will be derived from the component or subsystem specifications and will consider and account for the manufacturing and operational tolerances the component(s) and subsystem(s) must meet in the operational environment. Interface verification by test will use flight hardware/software or flight-equivalent qualification hardware.

The environmental dimension of testing is conducted on flight-configured hardware to verify the hardware will perform satisfactorily throughout its entire flight environment and perform satisfactorily after exposure to worst-case nonoperational environments. Environmental tests include, but are not limited to, electromagnetic interference (EMI), vibration, shock, acoustic, outgassing, off-gassing, thermal, thermal shock, ascent pressure profiles, thermal vacuum, and configuration specific tests determined during the design process.

Embedded flight software will be tested with the flight hardware. Test requirements and procedures will explicitly include software tests. These software tests will include the following:

a) Nominal conditions with no failure, stress, dispersion, or error induced.

b) The ability to diagnose, detect, and recover from HW and SW faults.

c) Off-nominal dispersed conditions including both environmental and system conditions.

d) Invalid or erroneous signals or commands in format, content, or timing.

e) Stress conditions at, near, and exceeding (including very large and small values) both high and low units.

Items b–d may be invoked either singularly or in combination.

5.2.4.5 Validation of Records

Validation of records is the use of vendor-, element-, discipline-, or interfacing project-supplied verification metadata or furnished/supplied manufacturing or processing records to ensure the requirement(s) has been incorporated or met. Validation of records can be used as the method to satisfy incorporation of requirements for such items as commercial off-the-shelf products, products purchased to standards, or closure of allocated requirements.

5.2.4.6 Similarity

Similarity is the process of assessing prior data, configuration, processes, or applications and concluding that the item under assessment is similar or identical to another item that has previously been verified to equivalent or more stringent specifications or validated to an equivalent use or function.

The Elements will perform an applicability assessment for any verification data generated under a previous qualification/certification effort when that data is being used for the purposes of fulfilling verification requirements under the SLS Program. Such an assessment will inform verification planning, will be a constituent of verification compliance documentation, will only be valid if citing source data that is accessible upon demand, and will take into consideration:

- all changes to the configuration of the product being verified
- all changes to the fabrication or quality processes used to create the product
- all changes to imposed functional or performance requirements
- all differences to loads, environments, or interface conditions to which the product is exposed

This agreement serves as a tailoring approach to the provisions of MWI 8050.1 with regards to the use of “similarity” as a verification method, per SLS-PLAN-186, SLSP Program Agreements Document.

All hardware, whether heritage or not, needs to be qualified for its expected environment and operational usage. All heritage flight hardware shall be fully qualified and verified for use in its new application. In order to minimize cost, Elements are allowed to use previous qualification data to the extent possible when qualifying for the new operational uses.

Similarity analysis may be combined with other verification methods, such as delta qualification testing, to accomplish verification of an integrated system. This qualification will take into consideration necessary design modifications, changes to expected environments, and differences in operational use.

5.3 Step 3: Implement Verification Activities

Once the DVOs are completed, the verification implementation activities are performed. Each verification activity (inspection, analysis, test, demonstration, validation of records, similarity) is individually analyzed and its closure strategy defined and documented in the DVO. Implementation plans are developed. The number of plans and the level of detail in each plan are driven by the complexity and inter-team coordination required to accomplish the verification activity. Required procedures are developed and the verification activity is performed with the appropriate quality assurance, safety, and configuration control. When a verification activity is successfully completed, the details and results of the verification activity are reported in the Cradle® SLS1 database. If the results are not successful, the results will be analyzed to determine the root cause and a recommendation for a corrective action will be approved by the SLS Chief Engineer's Control Board (CECB). Options to re-test, or submit a deviation/waiver, will be performed after approval of the corrective action. If a re-verification activity requires design changes to the test hardware/configuration identified in the DVO, the change must be approved by the SLS Program via the CECB. If a deviation or waiver is required it will be in accordance with SLS-PLAN-008, SLSP Configuration Management Plan. The verification closure package will not be processed without appropriate paperwork when a deviation or waiver is required.

5.4 Step 4: Document DVO Closure

Once all of the verification activities for a specific system-level DVO have been completed, the DLE/CSO must present the DVO with closure rationale to the LSE/VTT.

System-level DVOs will be entered in the Cradle database by SE. The basis for closure of a DVO will be provided by the DLE for the "Compliance Assessment" field of the DVO, which explains how the results of the completed verification activity meet the success criteria. Supporting technical data and reports will be referenced in the "Compliance Data" field of the DVO. If compliance data contains information needed to close more than one DVO, the "Compliance Data" field of the DVO will reference the specific section(s) of the report that applies to the DVO.

The LSE/VTT will evaluate the completeness of the closure data and recommend closure of the DVO if the closure data is sufficient. Once the LSE/VTT determines that the closure data is sufficient, the DVO will be closed <**TBR-012**>.

Elements are not required to submit formal verification reports to the DLEs for Element verification closure. Element-level reports of verification closure activities will be developed per the Element verification planning documentation and will be reviewed and approved at the Element-level.

5.5 Step 5: Document Requirement Closure <TBR-013>

System-level requirements closure will be satisfied when the combined DVOs and compliance data list have been completed for a given requirement. The responsible DLE will provide a verification summary for each requirement describing how the integration of all verification methods and activities from each discipline prove the requirements are satisfied in order to support the Design Certification Review (DCR). The verification summary and the compliance data of a system-level requirement will be controlled in the Cradle® SLS1 database and will be used to produce a verification closure report (VCR).

Once the LSE/VTT determines that the closure data is sufficient, the DLE/CSO will present the VCR for approval at the CECB for final closure, as shown in Figure 5-2.

When all system-level verifications are complete, the LSE will generate a final version of SLS-RPT-195, SLSP Verification Compliance Report (VCR) as described in Section 5.2. Per SLS-PLAN-003, SLSP Systems Engineering Management Plan, this final VCR acts as the final verification compliance document that documents completion of the verification process for all vehicle requirements, as shown in Figure 5-2.

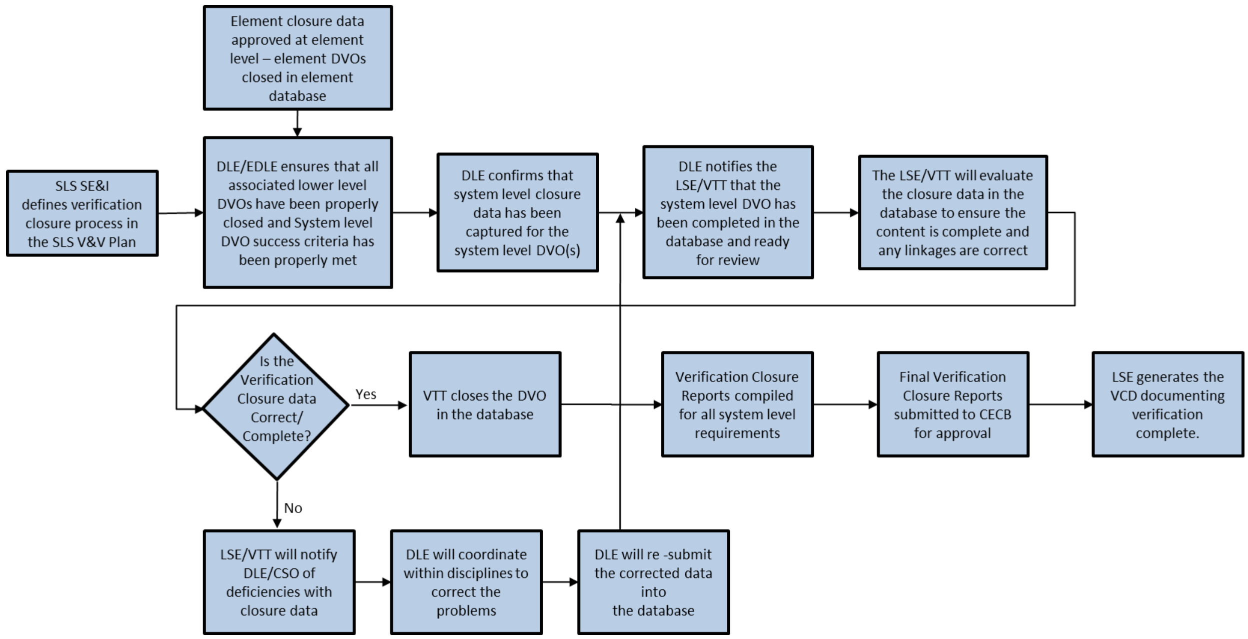


Figure 5-2. Program-Level Verification Closure Process

6.0 PRODUCT VALIDATION <TBR-014>

Verification and validation activities are very similar, but they address different issues. Verification addresses whether the system, its elements, its interfaces, and incremental work products satisfy their requirements. Validation confirms that the system, when placed in the envisioned environment, will perform its mission as intended. Validation confirms the design is based on the right requirement set and that the system implementation provides the right solution to the customer's problem.

Validation begins during vehicle system requirements development and decomposition and continues throughout the delivery of hardware at all levels of system hardware integration. Validation that occurs during design considers the end user's needs and expectations to ensure that the decomposed requirements are complete. Validation that is performed at the end of the design cycle ensures that the delivered products have met the intent of the end users as well as all other stakeholders.

A simplified system design validation asks the following questions:

- Will the system, as designed, provide the desired solution?
- Does the system work as intended (i.e., will it perform its intended mission)?
- Is the system as safe as required?

If the answer to any of these questions is no, then changes to the design or stakeholder expectations will be required, and the design process is started again. It is important to note that the goal of this process during design, development, test, and evaluation (DDT&E) is to validate the design which is distinct from validation of a particular flight system item. Validation that is performed post-DDT&E ensures that the delivered integrated system hardware (HW) and software (SW) have met the intent of the end users as well as all other stakeholders through the realistic operating conditions.

Validation activity planning and execution utilizes many of the same tools and similar processes used for verification. Both processes require prior planning, resource allocation, definition of objectives, definition of success criteria, reporting of discrepancies and anomalies, and documentation and assessment of results. Verification and validation activities should be planned in parallel to maximize efficiency when allocating resources. It is possible to mitigate overall evaluation costs by making certain that each end product in the system was correctly realized in accordance with its specified end-user requirements during verification. For example, a test may be performed which satisfies a test detailed verification objective (DVO) for verification while also providing data to validate a model/simulation. However, it is important to note that successful verification does not necessarily imply that the system under consideration can be considered valid.

6.1 Types of Validation

SLS Program validation covers the following types of validation:

1. Requirement validation.
2. Model and simulation validation.
3. Software Validation
4. Functional Performance Validation

6.1.1 Requirement Validation

Requirement validation involves two different sets of criteria to result in a "good" requirement. Requirements validation is an approach used to ensure that the performance requirements captured in system requirement and interface documents satisfactorily describe the system to be implemented. The criteria for a good requirement are identified in Table 6-1, and are explained in detail in NASA/SP-2007-6105, NASA Systems Engineering Handbook. The second set of criteria determines if the requirement is the "right" requirement. This criterion determines if the requirement supports the function from which it was derived, and that function is completely captured in the requirements set.

Several resources are available which provide further guidance on requirements development. These include NASA Procedural Requirements (NPR) 7123.1, NASA Systems Engineering Processes and Requirements, as well as the NASA/SP-2007-6105. Per NASA/SP-2007-6105, the checklist items listed in Table 6-1 should be considered on SLS when developing/refining requirements.

Table 6-1. Requirement Validation Criteria

Clarity	Consistency	Functionality	Maintainability
Completeness	Traceability	Performance	Reliability
Compliance	Correctness	Interfaces	Verifiability/Testability
Data Usage			

6.1.2 Model and Simulation Validation

For models and simulations, validation is the process of determining the degree to which a model (or simulation) provides an accurate representation of the real world from the perspective of the intended uses of the model or simulation. Data are derived from a real world test or series of tests to provide empirical data from which to "anchor" or validate the model and determine the models' ability to accurately predict and represent how the real systems respond to a variety of scenarios. Flight data used to anchor models, acquired from development test flights on previous programs, establish the requirements for developmental flight instrumentation (DFI). When the model has shown the ability to accurately represent the systems' performance, that model is then certified to perform an analysis for a specific range of input data. Validation of the model input data—that is, the environments applied to the model—is also performed.

Models and simulations also represent environments which include, but are not limited to, natural and induced environments. Validation of design environments can be performed through ground and/or flight tests. Comparisons are made between predicted and actual environments at specified conditions. Therefore, environment validation is frequently constrained to matching predicted and actual data for a specific design condition and extrapolating from that agreement whether the range of design environments is adequately conservative. If the predicted and actual environments agree within accepted engineering practice, then the design environment is considered validated.

Models will be incrementally developed for use in vehicle design and analysis activities in accordance with SLS-PLAN-173. The performing organization will maintain their models under configuration control and will verify, validate, and certify them for their intended use in generating data for SLS DVOs in accordance with the processes in SLS-PLAN-173. For the model and simulation validations which will occur after DDT&E, refer to Section 6.1.2.3.2, Validation by Flight Test Objectives.

Leading up to design certification at DCR, design models will be controlled as deliverables through SLS-RPT-105, SLSP Design Models Log. This includes models developed and submitted by Elements and vehicle-level disciplines. Changes to models that affect hardware performance following baseline into SLS-RPT-105 will require resubmission of changes to the SLSP vehicle for assessment.

At DCR, consistent with the delivery requirements of SLS-RQMT-018, the Elements and vehicle disciplines will provide confirmation of certification that models represent the final baseline designs. Model updates will be submitted at that time, as required to address any identified changes, as part of the design certification package.

6.1.3 Software Validation

SLS will verify and validate the flight software as defined in SLS-PLAN-075. Software validation is performed to confirm that developed software, modified software, and commercial off-the-shelf (COTS) software will meet the required functions. Validation that the system-level software meets the intended operational functions across all mission profiles for ground and flight operations including nominal, off-nominal, and contingency operations will be considered part of the functional performance validation process and will be documented per Section 6.2.

6.1.4 Functional Performance Validation

Functional performance validation is the process of showing that a given component, subsystem, element, or launch vehicle can perform its intended function in the envisioned environment. Limited, or partial, validation can be accomplished with performance tests to show that for simulated environmental conditions, the system performs the functions as designed. These functional performance tests will be conducted in all of the feasibly testable environments that a system will be subject to under operational conditions. Systems, and their applicable higher level functions, can be validated by the review and approval of lower level functions. However, functional validation is completed when the system and the elements of which it is made are shown to perform their functions as intended during actual operation.

6.2 Validation Process

The validation process, depicted in Figure 6-1, begins with identifying mission needs by evaluating the Design Reference Missions (DRMs), the Needs, Goals, and Objectives (NGOs) of the stakeholders, the ConOps document, and by discussions with the stakeholders. The Level I Stakeholder Expectations have been provided by NASA Headquarters, Exploration Systems Development (ESD) via the Level I ESD 10002, ESD Requirements, and ESD 10012, ESD Concept of Operations, with verification and validation (V&V) of ESD expectations captured in ESD 10016, ESD V&V Plan. The Level I Stakeholder Expectations are an input to the Level II SLS ConOps document.

Once the mission needs are understood, specific validation objectives will be developed that contain measurable success criteria. The validation objectives will determine specific tasks that will be undertaken to accomplish meeting objective goals. The identified tasks and associated validation activities will be detailed in plans and procedures. Upon completion of the verification activities covered in the plans and procedures, evaluations and assessments will be conducted to determine if validation objectives were satisfied. The data captured from the validation activities, along with the assessment of meeting validation objective success criteria, will be captured in closure reports. The validation approach discussed in this plan maps directly to the Cradle® SLS1 database non-project specific schema (NPSS), and the Cradle® SLS1 database will be used to capture all necessary validation activities and details to provide closure against validation objective success criteria.

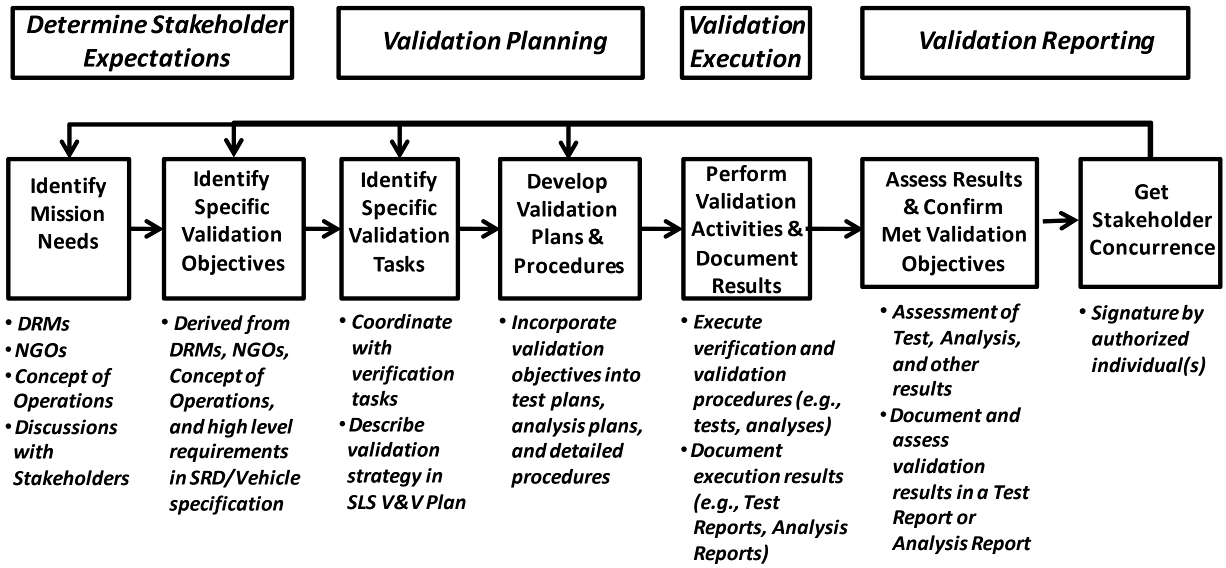


Figure 6-1. Program Validation Process

6.2.1 Validation Objectives

In general, a specific validation objective(s) will be defined for each validation activity prior to initiation and be traceable to the NGOs of the stakeholders. When the validation activity (generally a test) is completed, the data/information are provided to the individual or group that created the validation objective, which then makes an assessment that the validation objective has been met.

Identifying validation objectives essentially involves deciding what needs to be validated to satisfy stakeholders that the vehicle system, as designed and implemented, will perform as desired in the intended environment. A validation objective is generated with sufficient clarity to provide guidance for validation activity planning to provide the information needed to assess the confirmation of the validation objectives. When they exist, separate validation activities should be documented for preflight and post-flight activities.

The Cradle® SLS1 database will be developed and populated with required validation details. The database allows traceability of validation objectives through implementation to the closure reports documentation. It provides the automated capability needed to manage and control the validation program to ensure that all program validation objectives are satisfied.

The following list identifies mandatory validation attributes **<TBR-015>** captured in the Cradle® SLS1 database, and a brief explanation of each. Identified as mandatory, these attributes form the minimum data set necessary for completing the validation activity.

- Identity – Validation Objective number.

- Name – Provides Validation Objective descriptive name.
- Validation Activity – Provides details of the validation activity that must be performed to validate the given validation objective for the given assembly level in the given program phase. The attribute also describes how the input data products and conditions are going to be used in the validation activity, and how the output products are going to be generated and captured. For an analysis, the specific source of data to be analyzed and a description of the analysis to be performed will be identified. For a demonstration, the specific action to be demonstrated will be identified. For a test, the article to be tested and high-level details of the testing to be performed will be identified.
- Validation Method – This is a multiple pick list consisting of test, demonstration, and analysis.
- Validation Objective – Description of what is expected to be accomplished from the specific test, analysis, etc., that will be executed to satisfy the corresponding success criteria of the associated objective. This should provide details of the desired results when validating the objective.
- Success Criteria – The measure by which the test, analysis, or demonstration, will be considered complete to satisfy the success criteria of the validation objective.
- POC – Point of Contact. Identifies who owns the validation objective, supports the validation objective, needs to be notified about activity with the validation objective, is required to implement the validation objective, and the parties if the validation objective is jointly owned.
- Result – Captures the results of the validation activity performed. The Result attribute of the database will provide complete details of results including result type, validation report number, dates of planned and actual submittal and closure, and all other information to adequately process and track results for closure of the validation objective.
- SBU Markings – Sensitive But Unclassified (SBU)/International Traffic in Arms Regulations (ITAR) markings for an object.
- Maturity Status – Item status that identifies the step function stages of the item maturation up to and after baselining.
- Version – Used to identify the version of a data object/item as it is modified and baselined throughout its life cycle. A two-character string that is either empty for items that have not been baselined, or a version number in the sequence 01, 02,...99 that is used to distinguish instances of an item and reflects the number of versions of the item that exist in the project’s baseline(s).
- Notes – Any comments for performing the validation activity.
- Event – Milestone or activity that is tied to the execution of the validation task.

- Constraints – Planning information to assist in scheduling the data requests.
- Assets – The identification of the specific building, center, test stand, venue, equipment, etc., needed to perform the validation activity.

6.2.2 Validation Activities

The SLS DLEs will work in conjunction with the stakeholders to define validation activities that will provide data/information to support the validation objective assessment. It is essential that the validation of lower products in the SLS vehicle system be conducted so that any design failures or deficiencies may be caught as early as possible. Validation is typically carried out in the intended operational environment under simulated or actual operational conditions. Off-nominal testing as well as nominal testing should be included in the validation process.

Model and simulation (M&S) and functional performance validations are focused on proving both that the environments used as the basis for design are conservative (actual environments less than predicted design environments) and that the design operates (performs) as intended under actual operating conditions. Therefore, the majority of validations will be via the test method. But the methods of demonstration and analysis may also be used. Section 5.2.5 provides the basic definition of methods for the SLS Program, and this section provides additional clarification on their use for validation purposes. These validation methods are described below:

a. Test is used to obtain detailed data to validate performance or to provide sufficient information to validate performance through further analysis.

b. Demonstration is used to show that a set of stakeholder expectations can be achieved. It is generally used for a basic confirmation of performance capability and is differentiated from testing by the lack of detailed data gathering.

c. Analysis for validation purposes is performing a comparison to other validated models and simulations or other previous test results.

6.2.3 Vehicle System Validation

Components, subsystems, and elements are assembled into an SLS vehicle which is tested to determine if the system performed as intended. The validation of each SLS vehicle configuration is performed in part by means of validation test objectives in conjunction with each flight. Each integrated flight will be performed after the Design Certification Review (DCR) has been completed, and all elements have been accepted. The flight validation data will be evaluated against validation objectives derived from the NGOs, DRMs, and stakeholder expectations to determine whether the SLS architecture is capable of performing missions as expected. Validation objectives developed by SLS will be accomplished by both ground and flight tests.

6.2.3.1 Ground Operations Validations

The Operations DLE will be responsible for coordinating with SLS and GSDO programs to ensure that validation objectives have been satisfied. They will be performed to ensure satisfactory implementation to meet stakeholder expectations. The GSDOP is responsible for implementing validation objectives performed in on-line facilities at Kennedy Space Center (KSC) within the constraints defined by the SLS Program, as mutually agreed to by the SLS and GSDO Programs and as described in the GSDO Ground Operations And Maintenance Requirements and Specifications (OMRS) Plan. Validation activities will be conducted during the assembly and test/checkout, and de-servicing processing phases. These activities will include operations such as assembly, inspection, test/checkout, and maintenance, and will validate that flight and SLS provided ground systems will meet stated objectives.

6.2.3.2 Validation By Flight Test Objectives (FTO)

Validation objectives that must be accomplished in flight are documented as FTOs. One purpose of an FTO is to validate hardware/software functions in actual flight environments. Another aspect of FTOs is acquiring data via operational flight instrumentation (OFI) and developmental flight instrumentation (DFI) to validate models/simulations. SLS-PLAN-100, SLS Flight Evaluation Plan, addresses the overall approach for FTOs and will document all FTOs.

6.2.4 Validation Reports <TBR-016>

Results from validation activities will be assessed for completeness, necessity, correct value, and language. Once the results from the validation activities have been assessed, they will be documented in reports to support validation closure. Once the validation activities have been completed, the results will be analyzed to confirm that the end products provided will supply the SLS Program needed capabilities within the intended environments. It is very important to ensure that the validation procedures were followed and that the supporting resources functioned correctly.

It is crucial that the actual results from the validation activities are compared to the expected results. In the event that any deficiencies are discovered in the system, it will be necessary to conduct all required redesign activities needed to correct the problem. The deficiencies, along with the recommended corrective actions and resolution results, should be recorded and the validation should be repeated as required.

The validation reports will be reviewed by the stakeholders for concurrence. Once the stakeholders concur with the results of the validation activities, their signatures will complete the validation process.

7.0 DOCUMENTATION

7.1 Verification Plans

The overall objective of verification is to ensure that the SLS and all of its elements comply with all specified requirements. Verification planning is used to clearly delineate a strategy to satisfy each requirement, as well as the applicable interface control document (ICD) criteria. Planning will define how each requirement will be verified and which of the verification methods (test, demonstration, analysis, inspection, similarity, or validation of records), or any combination of these methods, will be used.

7.1.1 Test Plans

The SLS Program Test Plan, SLS-PLAN-116, documents the planned test activities that will be performed at the Vehicle Level and addresses Vehicle Level verification requirements for which a test method has been specified. It also provides a summary of major test activities that will be performed at the Element Level. Each SLS Discipline and Element will develop and execute their own detailed test plans documenting development, qualification, and acceptance testing in their respective areas.

8.0 REVIEWS

8.1 Qualification Review

Qualification of the vehicle design (hardware and software) is accomplished by reviewing verification and validation compliance data versus the vehicle's requirements set. This review is typically accomplished by performing a Functional Configuration Audit (FCA). The FCA examines the functional characteristics of the configured product and verifies that the product has met the requirements specified in its functional baseline documentation. Each Element will provide verification metadata to support the system-level FCA, certify their developed designs for flight, and provide a Certificate of Qualification (CoQ). Results from the Element certification processes and the vehicle FCA will form part of the basis for certification of the vehicle's flight configuration and will be presented at the SLS Design Certification Review (DCR). Any design changes to the certified configuration, whether from block upgrades or response to anomalies, must be addressed by performing a delta FCA to assure that the vehicle's flight configuration is qualified for its intended operation.

8.2 Acceptance Review

Acceptance of the vehicle hardware and software is accomplished by reviewing as-built verification and validation compliance data versus the certified vehicle design. This review is typically accomplished by performing a Physical Configuration Audit (PCA). The PCA examines the physical configuration of the as-built configured product and verifies that the product corresponds to the product baseline design previously approved at the FCA/DCR. Results from a PCA form the basis for acceptance of a specific set of hardware and/or software and will be presented at an Acceptance Review (AR).

Responsibility for the process to accept element hardware and software is delegated to the Elements. The output of this process is an Acceptance Data Package.

The acceptance review will result in delivery to the SLS Program of the Element ADP that will provide the documentation trail needed to establish the acceptability of the hardware/software for its intended use. The ADP will include the Element CoQ and verification metadata that the delivered end item has fulfilled the established acceptance criteria. Further, the ADP will provide a complete identification by part number and serial number of the as-built configuration down to the lowest level of hardware accountability. The ADP will include the forms necessary (DD250/1149) that will provide the authorization and instructions for shipping the product undergoing acceptance. Approved Element ADPs will be used to support vehicle assembly and integration activities. Once the vehicle assembly and integration is complete, an Integrated Vehicle Data Package **<TBR-017>** will be developed to document the vehicle configuration.

8.3 Certification of Flight Readiness (CoFR) Support

The successful completion of the vehicle DCR and Element acceptance reviews support the Flight Readiness Review (FRR) and, subsequently, the CoFR process. The CoFR and FRR process is documented in SLS-PLAN-036, SLSP Certificate of Flight Readiness (CoFR) Implementation Plan.

9.0 SUPPORT EQUIPMENT CERTIFICATION

Ground systems is that part of the architecture which includes facilities, facility systems, and support equipment hardware and software required to perform ground operations for the purpose of receiving, processing, integrating, testing, servicing, launching, and recovering tri-program assets (Space Launch System (SLS), Orion Multi-Purpose Crew Vehicle (MPCV), Ground Systems Development and Operations Program (GSDOP)). Certification of support equipment is described in SLS-SPEC-030, SLSP Support Equipment Specification. Facilities that support the integration and verification program must be certified and/or calibrated prior to use. However, the facilities certification processes are outside the scope of this V&V Plan.

SLS-SPEC-030 subdivides support equipment into ground support equipment (GSE), and non-GSE, which is equipment that supports the GSE but does not interface with the flight hardware. Further discussion of GSE verification, including commercial off-the-shelf (COTS) items, is provided in the following paragraphs. Certification of non-GSE items will be as discussed in SLS-SPEC-030.

9.1 SLS Ground Support Equipment Verification

GSE is non-flight equipment, systems, or devices specifically designed and developed for a physical or direct functional interface with flight hardware during post-manufacturing vehicle processing and launch operations. Organizations responsible for developing GSE will develop their own V&V plans for the GSE. The objective of GSE verification is to assure that the GSE has been designed, fabricated, assembled, and verified in a manner that will support the development, qualification, test, and acceptance activities of deliverables.

GSE design and verification has a compressed schedule relative to the development and verification of the associated flight hardware. The flight hardware design and handling constraints drive the design of the GSE, but the GSE must have completed its certification process prior to the initiation of the flight hardware's ground operations. Additional description of the GSE certification timeline can be found in SLS-SPEC-030.

SLS-SPEC-030-01, Volume I: Support Equipment Planning, addresses the planning, integration, and certification of the GSE which is designed, maintained, and provided by the SLS Program. GSE will be designed and developed in accordance with SLS-SPEC-030-02 Volume II: Design and Construction Requirements, and SLS-SPEC-030-03 Volume III: Derived Requirements. SLS GSE that is developed by the government will have interface requirement verifications as specified in SLS-SPEC-030-04 Volume IV: Interface Definition Document (IDD) for the Multi-Purpose Carrier. Evaluation, approval, and certification for any piece of heritage GSE will be in accordance with SLS-SPEC-30-05 Volume V: Heritage GSE Certification Process Plan.

9.2 Commercial Off-The-Shelf

All COTS hardware and/or software will be analyzed in detail, against the conditions for the planned use of that item. COTS hardware will meet the same design and data requirements as developed hardware as required by the criticality of application. The COTS software products are characterized as “certified by use” and hardware products are certified using standard commercial practices (e.g., Calibration/Certification Laboratory). Validation of records will be used as the verification method for COTS hardware requirements, where applicable. The COTS software will be verified and validated to the same level of confidence as would be required of the developed software. This verification and validation will ensure COTS software can be assigned the same level of confidence that would be needed for an equivalent class of software if obtained through a “development” process. The integration of COTS products with other products, including other COTS products, requires certification testing such as the performance of diagnostics to certify readiness to support testing. This may be accomplished individually or as a composite set of HW and SW using standard commercial practices.

APPENDIX A
ACRONYMS AND ABBREVIATIONS
AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

ADP	Acceptance Data Package
AFSPCMAN	Air Force Space Manual
AR	Acceptance Review
ATP	Authority to Proceed
AV	Avionics
BEA	Bilateral Exchange Agreement
BEO	Beyond Earth Orbit
C of C	Certification of Compliance
C&DH	Communications and Data Handling
CAD	Computer-Aided Design
CDF	Capability Driven Framework
CDL	Compliance Data List
CDR	Critical Design Review
CE	Chief Engineer
CECB	Chief Engineer's Control Board
CEI	Contract End Item
CIL	Critical Items List
CM	Configuration Management
CoFR	Certification of Flight Readiness
ConOps	Concept of Operations
CoQ	Certification of Qualification
COTS	Commercial Off-the-Shelf
CR	Change Request
CSO	Chief S&MA Officer
CTN	Communication and Tracking Network
DCR	Design Certification Review
DDT&E	Design, Development, Test, and Evaluation
DES	Discrete Event Simulation
DFI	Developmental Flight Instrumentation
DLE	Discipline Lead Engineer
DR	Discrepancy Report

DRD	Data Requirements Description
DRM	Design Reference Mission
DVO	Detailed Verification Objective
E3	Electromagnetic Environmental Effects
EAR	Export Administration Regulations
ECB	Element Control Board
EDLE	Element Discipline Lead Engineer
EEE	Electrical, Electronics, and Electromechanical
ELSE	Element Lead Systems Engineer
EMI	Electromagnetic Interference
ERB	Element Review Board
ERD	Element Requirements Document
ESD	Exploration Systems Development
FCA	Functional Configuration Audit
FDNR	Failure Detection, Notification, and Response
FEIT	Flight Element Integration Test
FMEA	Failure Modes and Effects Analysis
FRR	Flight Readiness Review
FSW	Flight Software
ft	Feet
ft^3	Cubic Feet
FTO	Flight Test Objective
GN&C	Guidance, Navigation, and Control
GOPDb	Ground Operations Planning Database
GSDO	Ground Systems Development and Operations
GSDOP	Ground Systems Development and Operations Program
GSE	Ground Support Equipment
HDBK	Handbook
HR	Hazard Report
HSIR	Human System Integration Requirements
HW	Hardware
ICD	Interface Control Document
IDD	Interface Definition Document
ISPE	Integrated Spacecraft and Payload Element
ISS	International Space Station
IT	Information Technology

ITAR	International Traffic in Arms Regulations
IVT	Integrated Vehicle Test
km	Kilometer(s)
KSC	Kennedy Space Center
lbf	Pounds Force
LCC	Launch Commit Criteria
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LOC	Loss of Crew
LOX	Liquid Oxygen
LRU	Line Replaceable Unit
LSE	Lead Systems Engineer
m	Meters
M&S	Modeling and Simulation
m^3	Cubic Meters
MDL	Model
MEA	Maintenance Engineering Analysis
MEIT	Multi-Element Integration Test
Mfg.	Manufacturing
MPCV	Multi-Purpose Crew Vehicle
MPR	Marshall Procedural Requirements
MSFC	Marshall Space Flight Center
MSI	Maintenance Significant Item
mT	Metric Tonnes
MWI	Marshall Work Instruction
NASA	National Aeronautics and Space Administration
NGOs	Needs, Goals, and Objectives
nm	Nautical Mile(s)
nmi	Nautical Mile(s)
NPR	NASA Procedural Requirements
NPSS	Non-Project Specific Schema
O&M	Operations and Maintenance
O&MR	Operational and Maintenance Requirements
OFI	Operational Flight Instrumentation
OML	Outer Mold Line
OPR	Office of Primary Responsibility

OWI	Organizational Work Instruction
P/N	Part Number
PCA	Physical Configuration Audit
PCB	Program Control Board
PDLM	Product Data and Lifecycle Management
PDR	Preliminary Design Review
POC	Point of Contact
PSET	Project Specific Engineering Test
R&M	Reliability and Maintainability
RCC	Range Commanders Council
RID	Review Item Discrepancy
ROD	Review of Design
RPT	Report
RQMT	Requirement
S&MA	Safety and Mission Assurance
S/N	Serial Number
SBU	Sensitive But Unclassified
SCaN	Spacecraft Communications and Navigation
SDR	System Definition Review
SE	Systems Engineering
SE&I	Systems Engineering and Integration
SEMP	Systems Engineering Management Plan
SIL	System Integration Laboratory
SLS	Space Launch System
SLSP	Space Launch System Program
SPEC	Specification
SPIO	Spacecraft and Payload Integration Office
SRD	System Requirements Document
SRR	System Requirements Review
STA	Structural Test Article
STE	Structure and Environments
STG	Stage
SW	Software
TA	Technical Authority
TBD	To Be Determined
TBR	To Be Resolved

TBX	To Be Determined or To Be Resolved
TRR	Test Readiness Review
UDS	Universal Documentation System
V&V	Verification and Validation
VCD	Verification Compliance Document
VCR	Verification Closure Report
VCRM	Verification Cross Reference Matrix
VET	Vehicle End-to-End Test Bed
VFAM	Vehicle Functional Analysis Model
VM	Vehicle Management
VSM	Vehicle Systems Management
VTT	Verification Task Team
WBS	Work Breakdown Structure

A2.0 GLOSSARY OF TERMS

Term	Description
Acceptance	A process performed to ensure all articles and materials meet the specified program/project quality requirements as documented and released through the approved program configuration management plan. This includes the closure of all applicable nonconformance reports and approval of all deviations and waivers.
Certification	The formal written act whereby a responsible official attests to the satisfactory accomplishment of specified activities and authorizes the specified hardware/software, procedures, facilities, and/or personnel for program usage.
Deviation	A specific written authorization, granted prior to the manufacture of an end item, to depart from a baseline requirement for a specific application, mission, or period of time.
Flight-equivalent Hardware/Software	Non-flight component built, inspected, and tested to flight component specifications used in flight operating conditions and built with manufacturing processes which are identical to those used for flight equipment
Qualification	Analysis and testing to assure that the flight-equivalent hardware will perform its operational functions, including in known or anticipated environmental conditions. Qualification tests generally are designed to subject the hardware to worst-case environments and stresses.
Validation	A process used to confirm that the system meets its intended purpose.
Verification	Proof, by examination of objective evidence that the product complies with specifications. Verification is performed to ensure the product complies with requirements and may be determined by test, analysis, demonstration, inspection, validation of records, similarity, or a combination of these.
Waiver	A waiver is a specific written authorization to accept an end item which, during or after manufacturing, was found to be noncompliant with a baseline requirement, but is acceptable either as is or after being repaired by an approved method.

APPENDIX B
OPEN WORK

All resolved TBDs, TBRs, and forward work items should be listed on the Change Request (CR) the next time the document is updated and submitted for formal review, and that will serve as the formal change record through the configuration management system.

B1.0 TO BE DETERMINED

Table B1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., **<TBD-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

Table B1-1. To Be Determined Items

TBD	Section	Description
		Previous TBDs (2) have been closed, and two were transferred to SLS-RPT-195, SLSP Verification Compliance Report (VCR)

B2.0 TO BE RESOLVED

Table B2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is sequentially numbered as applicable (i.e., **<TBR-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

Table B2-1. To Be Resolved Issues

TBR	Section	Description
TBR-002	3.3	Clarify the extent of Cradle usage for verification and validation. Flight software V&V will use DOORS rather than Cradle.
TBR-003	4.2	Add a section on Data Integration to the document or include a reference to the Data Management Plan if it contains the appropriate data integration information. Address configuration management of data stored in Cradle.
TBR-005	4.2.4	Develop the details of the verification approach for requirements SLS.27 and SLS.28.
TBR-010	4.2.7	Identify how flight software V&V integrates with the overall SLS V&V

TBR	Section	Description
		approach.
TBR-012	5.4	Clarify the process for closure of DVOs in the Cradle database.
TBR-013	5.5	Clarify the approach for development of closure reports for system level requirements.
TBR-014	4.2.5.2 and 6.0	Develop the details of the SLS cross-program verification and validation approach including roles and responsibilities.
TBR-015	6.2.1	The Verification Task Team will review and establish the list of mandatory validation attributes.
TBR-016	6.2.4	The VTT will work with the elements and DLEs to identify the content, submittal responsibilities, and data management approach for validation reporting.
TBR-017	8.2	Determine whether there will be an Integrated Data Package for vehicle acceptance.

B3.0 FORWARD WORK

Table B3-1 lists the specific forward work items identified during this document's Change Request (CR) review and evaluation. Each item is given a sequential number using a similar format to that for the TBDs and TBRs. For each item, include the section number(s) of this document that the open work will impact, and in the Description include the specific number of the comment from the Change Evaluation (CE), i.e., CE-10, CE-27. Do not include a placeholder for forward work items in the body of the document; list them only in Table B3-1.

Note: If there are no forward work items, do not include this subsection in your document.

Table B3-1. Forward Work

FWD	Section	Description
FWD-001		

APPENDIX C
DATABASE VERIFICATION DATA OBJECT CHART

The following are the Detailed Verification Objective (DVO) attributes captured in the Cradle® SLS1 database, and a brief explanation of each.

- Identity –DVO number.
- Title – Identifies the DVO as it relates to the associated requirement.
- Compliance Data List Cross Reference – Identifies the associated Compliance Data List from the SLS V&V Plan.
- Verification Activity – Provides details of the verification activity that must be performed to verify the given requirement object for the given assembly level in the given program phase. The attribute also describes how the input data items and conditions are going to be used in the verification activity, and how the output data items are going to be generated and captured. For an inspection, the specific item to be examined and the intent of the inspection is identified. For an analysis, identify the specific source of data to be analyzed and a description of the analysis to be performed. For a demonstration, the specific action to be demonstrated is identified. For a test, the article to be tested and high-level details of the testing to be performed are identified. For similarity, identify the items and configurations to be compared and the prior data needed to show similarity. For validation of records, identify the records and applicable standards needed to ensure that the requirement has been met.
- Verification Method – This is a multiple pick list consisting of test, demonstration, analysis, inspection, validation of records, and similarity.
- Success Criteria – The measure by which the test, analysis, demonstration, inspection, validation of records, or similarity will be considered complete to satisfy the objective of the DVO. Where the success criteria are specified as a numerical value or a range, explain the basis for selection of the success criteria. Identify safety factors and margins included in the value, identify applicable operating and environmental conditions, and define terms such as “nominal,” “operational,” etc.
- Compliance Data – Provides the results of the verification activity performed. Provides traceability to the verification report(s) needed to close the DVO.
- Compliance Assessment – Description of how the data compare to the success criteria and provides a recommendation for closure, deviation, waiver, etc.
- Constraint – Identifies other DVOs that need to be closed prior to closure.
- Point of Contact (POC) – Identifies who owns the DVO, who supports the DVO, who is affected by the DVO, who needs to be notified about activity with the DVO, who is required to implement the DVO, and who the parties are if the DVO is jointly owned.

- Hazard report number – If a verification is associated with a potential hazard, the control number of the hazard must be listed.
- Allocation **–** Identify whether the DVO is at the vehicle or Element level (DLE or EDLE).