



National Aeronautics and
Space Administration

SLS-PLAN-075

VERSION: DRAFT FOR PDR

DRAFT DATE: 3/14/13

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

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 3 of 31
Title: SLSP Flight Software Verification & Validation Plan	

TABLE OF CONTENTS

PARAGRAPH	PAGE
1.0 INTRODUCTION	5
1.1 Purpose.....	5
1.2 Scope.....	5
1.2.1 Flight Software Concept.....	6
1.3 Relationship to Other SLS Documentation.....	7
1.3.1 SLS FSW Documentation Relationship	7
1.4 SLS FSW Process Model.....	9
1.5 Change Authority/Responsibility.....	9
2.0 DOCUMENTS.....	10
2.1 Applicable Documents.....	10
2.2 Reference Documents	11
3.0 PROJECT ORGANIZATION	11
3.1 External Organizations and Interfaces	11
3.1.1 External Stakeholders Roles and Responsibilities	12
3.2 Internal Organizations and Interfaces	13
3.2.1 Internal Stakeholders Roles and Responsibilities	13
4.0 SLS FLIGHT SOFTWARE VERIFICATION AND VALIDATION APPROACH.....	13
4.1 Verification and Validation Processes during Software Lifecycle Phases	14
4.1.1 Verification Process	14
4.1.2 Verification Methods.....	16
4.1.3 Validation Process	18
4.1.4 Validation Methods	20
4.2 SLS Flight Software Team T&V Approach	21
4.2.1 Unit Test Process.....	22
4.2.2 Integration and Test Process.....	23
4.2.3 SRS Verification Process	24
4.2.4 SLS FSW Validation Testing Support	27

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 4 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4.2.5	Regression Test Approach.....	27
5.0	SLS FLIGHT SOFTWARE TEST ENVIRONMENTS.....	27
5.1.1	Software Development Facility	27
5.1.2	Software Integration Lab (SIL)	28
6.0	SLS FLIGHT SOFTWARE VERIFICATION AND VALIDATION SCHEDULE OF ACTIVITIES	28
7.0	REQUIREMENTS TRACEABILITY.....	28

APPENDICES

A1.0	ACRONYMS AND ABBREVIATIONS	29
------	----------------------------------	----

FIGURES

Figure 1-1	FCSW Modes of Operation.....	6
Figure 1-2	SLS FSW Relationship to Other Integration and Test Documentation	7
Figure 1-3	SLS FSW Documentation Tree.....	8
Figure 3-1	SLS FSW External Organizations and Interfaces	12
Figure 3-2	SLS FSW Internal Organizations and Interfaces	13
Figure 4-1	Verification Process	14
Figure 4-2	Validation Process.....	18
Figure 4-3	FSW Team Test Process Flow	22
Figure 4-4	Software Verification Process.....	25

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 5 of 31
Title: SLSP Flight Software Verification & Validation Plan	

1.0 INTRODUCTION

The Space Launch System (SLS) Program (SLSP) Flight Software (FSW) Verification and Validation Plan (SVVP) addresses the plans and processes used for the verification and validation (V&V) of the in-house developed FSW at Marshall Space Flight Center (MSFC). Throughout this document, every attempt has been made to avoid duplicating information that is more appropriately contained in other supportive documentation referenced in Section 2.

1.1 Purpose

The purpose of the FSW SVVP is to define the planned activities associated with the V&V of the FSW and associated documentation developed by the ES51 and ES52 Branches of the Flight and Ground Software Division (ES50) for SLS.

1.2 Scope

This SVVP applies to the MSFC-developed safety-critical and non-safety critical SLS flight software and associated products described in the SLS-PLAN-073, the SLS Flight Software Development Plan (SDP).

The software V&V activities associated with the RTOS/Wind River Vx Works 653, Drivers and Board Support Package (BSP) CSCI acquisition through the Stages avionics provider are excluded from the scope of this plan.

Program-provided model validation is the responsibility of the organization providing the model. ES50 FSW will ensure model verification in accordance with the defined requirements in the SLS-RQMT-095, SLS FSW Requirement Specification (SRS).

For each SLS FSW Release, defined by SLS-VDD-177, FSW Build Content Definition, details for the verification and validation activities will be addressed in SLS FSW test plans, procedures and reports for the SLS-RQMT-095, SLSP FSW Requirements Specification (SRS) requirements implemented (or changed) in each FSW release. Release specific SLS FSW test plans, procedures and reports will be treated as subordinate documents to this SLS FSW SVVP.

This document is a data managed (Category 2) document used to describe Program Scope defined with SLS Baseline (Category 1) documentation. Work content and organizational responsibilities described within this documentation are provided to facilitate planning and to familiarize the reader with the interrelationship of activities within the SLS baseline. Specific flight software Verification and Validation agreements in the execution of this document's Program Scope description are defined in the SLS baseline documentation. In the event of an inconsistency of this document with SLS baseline documentation, the Baseline documentation is authoritative.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 6 of 31
Title: SLSP Flight Software Verification & Validation Plan	

SLS FSW releases will be delivered to support subsequent SLS avionics and software integration and testing activities with agreements defined in SLS-PLAN-186, SLS Program Agreements Document. Additional guidance is described in the SLSP Avionics Integration and Test Plan, SLS-PLAN-130.

1.2.1 Flight Software Concept

The Flight Computer Operational Group (FCOG) is composed of three Flight Computers executing identical versions of software. Figure 1-1, below, depicts the FCSW modes of operation currently defined. It is provided here for reference only, the controlled FCSW modes are defined in SLS-RQMT-095, SLSP FSW Requirements Specification (SRS).

The Flight Computer Application Software (FCAS) can execute in one of five major modes including:

- Standby Mode
- Special Test (Command Pass-through) Mode
- Ascent Simulation Mode
- Countdown Demonstration Test
- Flight Operations Mode

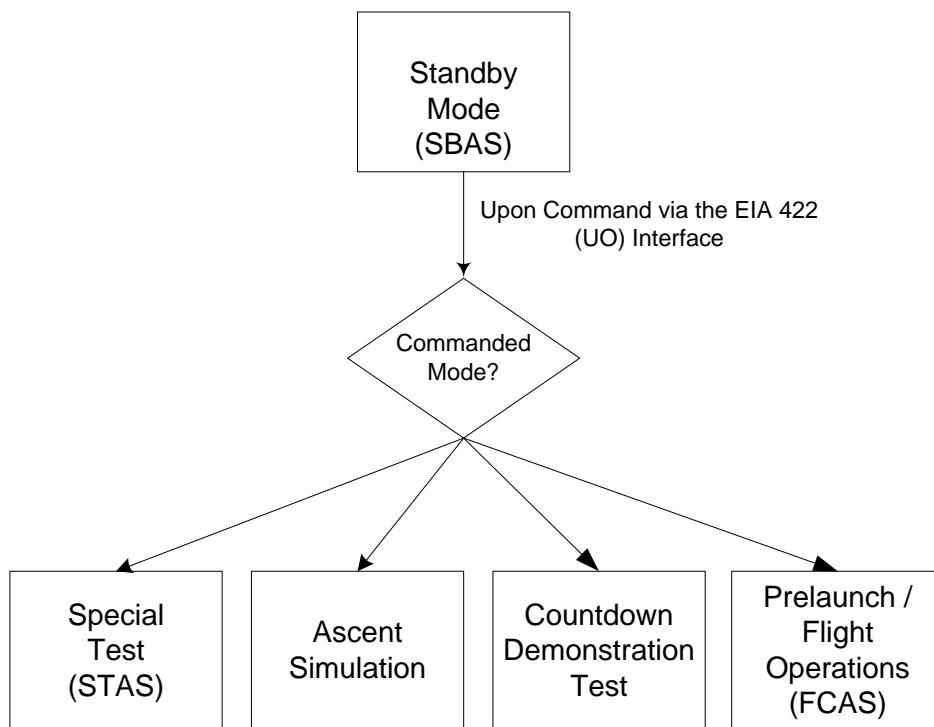


Figure 1-1 FCSW Modes of Operation (for reference only)

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 7 of 31
Title: SLSP Flight Software Verification & Validation Plan	

1.3 Relationship to Other SLS Documentation

Figure 1-2, below, illustrates a top level relationship to the relevant SLS Program Documents.

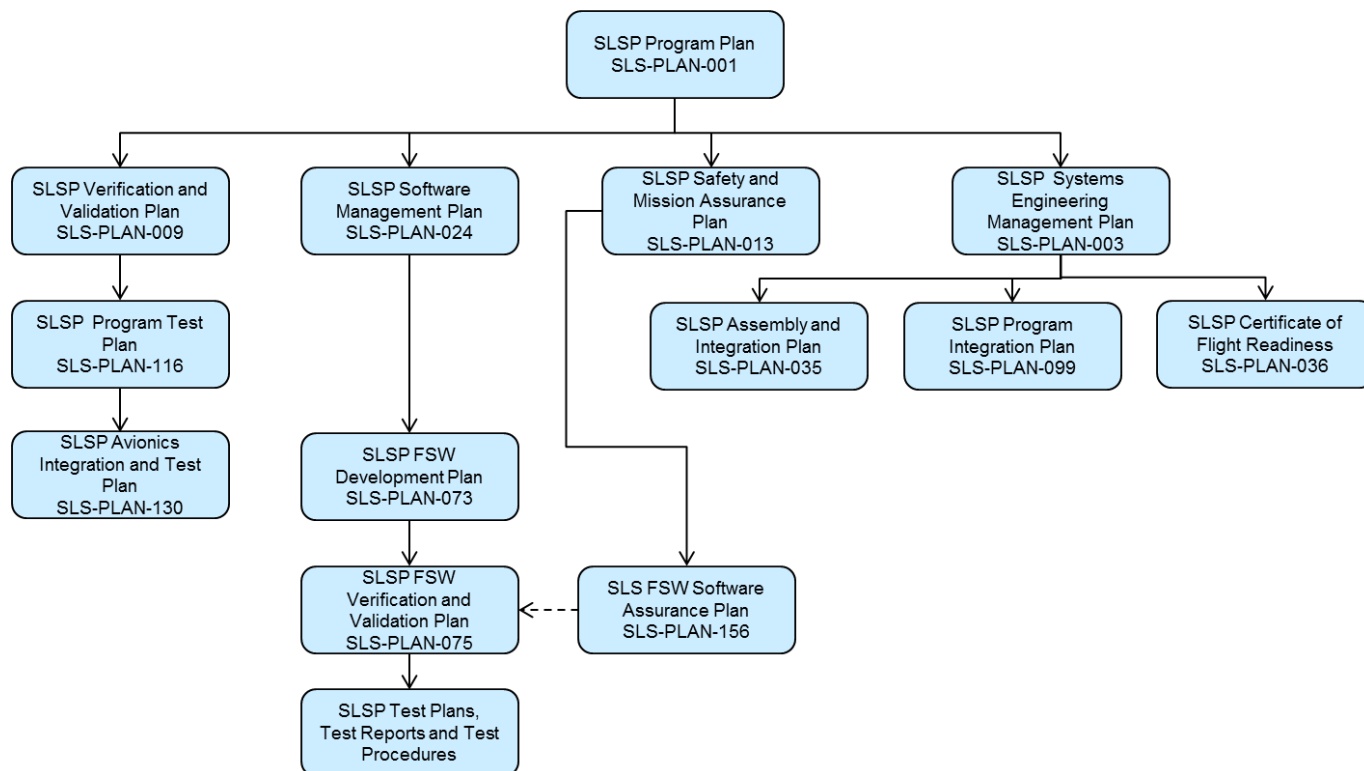


Figure 1-2 SLS FSW Relationship to Other Integration and Test Documentation (for reference only)

1.3.1 SLS FSW Documentation Relationship

SLS FSW project deliverables associated with V&V activities are developed in accordance with EI32-OI-001, SDPDD and NPR 7150.2, NASA Software Engineering Requirements. Additional guidance is described in SLS-PLAN-073, SLSP FSW SDP.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 8 of 31
Title: SLSP Flight Software Verification & Validation Plan	

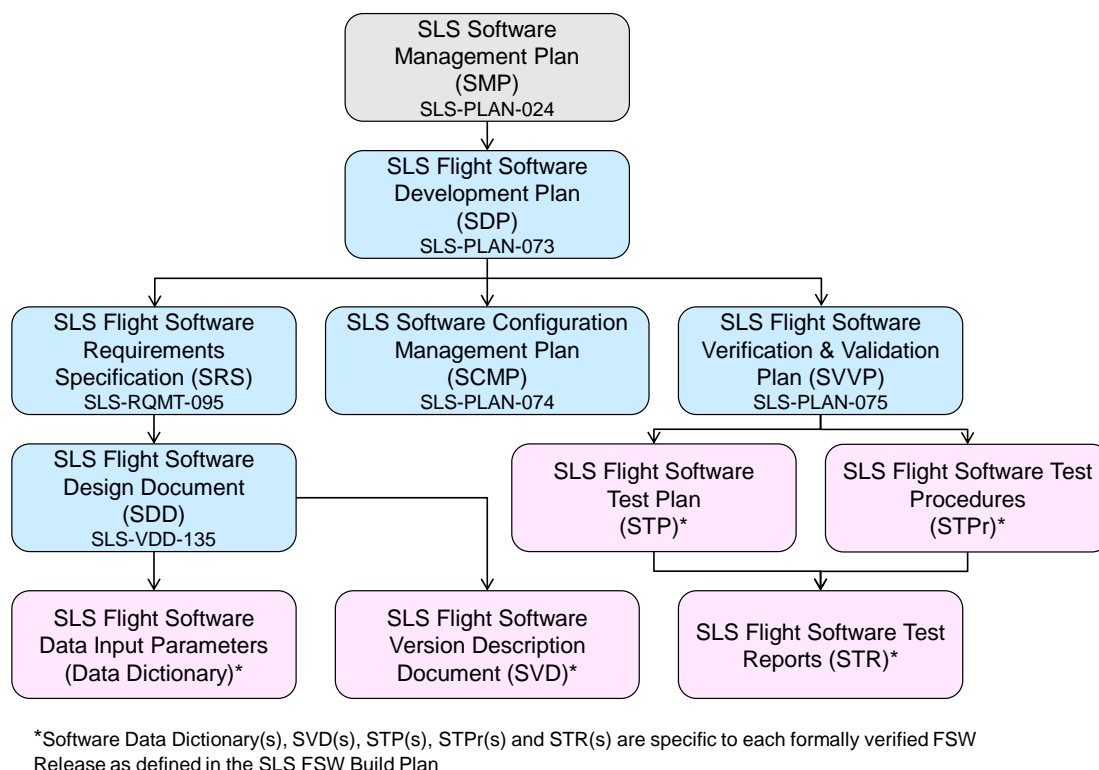


Figure 1-3 SLS FSW Documentation Tree (for reference only)

T&V deliverables associated with Flight Software Releases will follow MSFC Data Requirements Documents (DRD) defined content as described in SLS-PLAN-073, SLS FSW Development Plan.

Non-deliverable products are informal work products that include, but are not limited to, Software Change Requests (SCRs), software test metrics, and product peer review data.

For further information in regards to SLS FSW internal processes and how they relate to verification and validation, refer to the Work Instructions (WIs) in the Reference Documents list and specific references throughout this document.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 9 of 31
Title: SLSP Flight Software Verification & Validation Plan	

1.4 SLS FSW Process Model

In order to support SLSP integration activities and milestones, the Flight and Ground Software Division utilizes a tailored agile approach for software development. The incremental development lifecycle begins after the development of SLS FSW requirements and is managed thru the product backlog and time-boxed software engineering iterations called sprints.

Further information may be found in the SLS-PLAN-073, SLS FSW SDP, and detailed WIs.

1.5 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is ES50, Flight & Ground Systems.

This SVVP is a Category 2 document. Therefore proposed changes to this document will be submitted by an SLS ES50 Change Request (CR) to the Software Review Board (SRB) for disposition.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 10 of 31
Title: SLSP Flight Software Verification & Validation Plan	

2.0 DOCUMENTS

2.1 Applicable Documents

The following documents include specifications, standards, guidelines, plans and other special publications. 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.

NPR 7150.2A	NASA Software Engineering Requirements
EI32-OI-001	ES50 Software Development Process Description Document (SDPDD)
DO-178B	Software Considerations in Airborne System and Equipment Certification
SLS-VDD-177	SLSP FSW Build Content Definition
SLS-PLAN-013	SLS Safety & Mission Assurance Plan
SLS-RQMT-095	SLSP FSW Requirements Specification (SRS)
SLS-PLAN-186	SLS Program Agreements Document (PAD)

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 11 of 31
Title: SLSP Flight Software Verification & Validation Plan	

2.2 Reference Documents

The following documents contain supplemental information to provide guidance in use of this document. Detailed procedures needed to perform the Flight and Ground Software Division (ES50) processes documented here are captured in internally controlled work instructions.

SLS-PLAN-003	SLSP Systems Engineering Management Plan (SEMP)
SLS-PLAN-024	SLSP Software Management Plan (SMP)
SLS-PLAN-065	SLSP IATF Development Plan
SLS-PLAN-073	SLSP Flight Software Development Plan
SLS-FSW-WI-002	Flight Software Requirements Methodology
SLS-FSW-WI-009	SLS Flight Software Unit Test Methodology
SLS-FSW-WI-011	SLS Flight Software Integration Methodology
SLS-SCHE-064	SLS Integrated Master Schedule
SLS-VDD-135	SLS FSW Design Document (SDD)
NPD 7120.4	NASA Engineering and Program/Project Management Policy

3.0 PROJECT ORGANIZATION

The external and internal organizational relationships shown in Sections 3.1 and 3.2 illustrate direct reporting chains and are not meant to be an all inclusive list of technical and programmatic communication and/or coordination interfaces. Additional information regarding SLS FSW external/internal interfaces is found in SLS-PLAN-024, SLSP SMP, and SLS-PLAN-003, SLSP Systems Engineering Management Plan (SEMP).

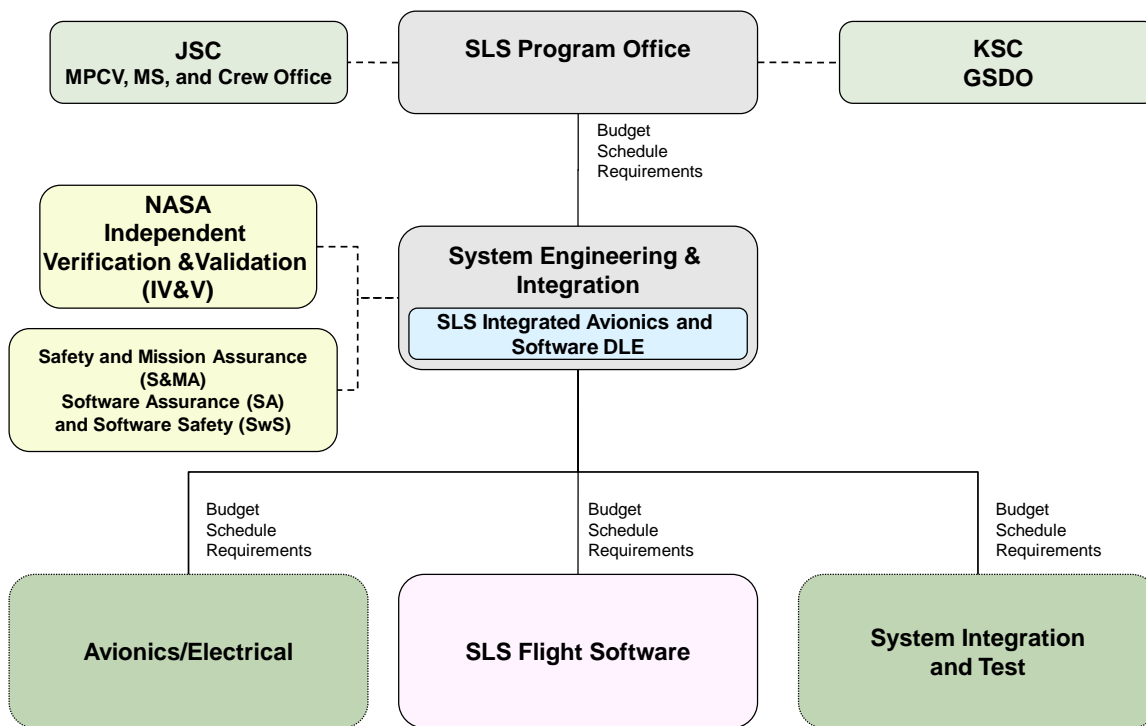
3.1 External Organizations and Interfaces

The SLS FSW external organizations and interfaces are shown below in Figure 3-1. The FSW identified by this plan is developed under the authority of the SLS Program.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 12 of 31
Title: SLSP Flight Software Verification & Validation Plan	



GSDO – Ground Systems Development & Operations; IV&V – Integrated Verification and Validation; JSC – Johnson Space Center; KSC – Kennedy Space Center; MPCV – Multi-Purpose Crew Vehicle; MS – Mission Systems; P/L – Payload; SA – Software Assurance; SE&I – Systems Engineering and Integration; SwS – Software Safety

Figure 3-1 SLS FSW External Organizations and Interfaces (for reference only)

3.1.1 External Stakeholders Roles and Responsibilities

Relevant External Stakeholders, depicted in the above Figure 3-1, roles and responsibilities are described within the SLS FSW SDP, SLS-PLAN-073. Technical inputs and engineering support, though not formal in nature, are also addressed.

SLS FSW 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.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 13 of 31
Title: SLSP Flight Software Verification & Validation Plan	

3.2 Internal Organizations and Interfaces

The SLS FSW internal organizations and interfaces are shown below in Figure 3-2. The groups identified are responsible for planning, monitoring, controlling, defining, implementing, verifying, validating, and deploying the software products.

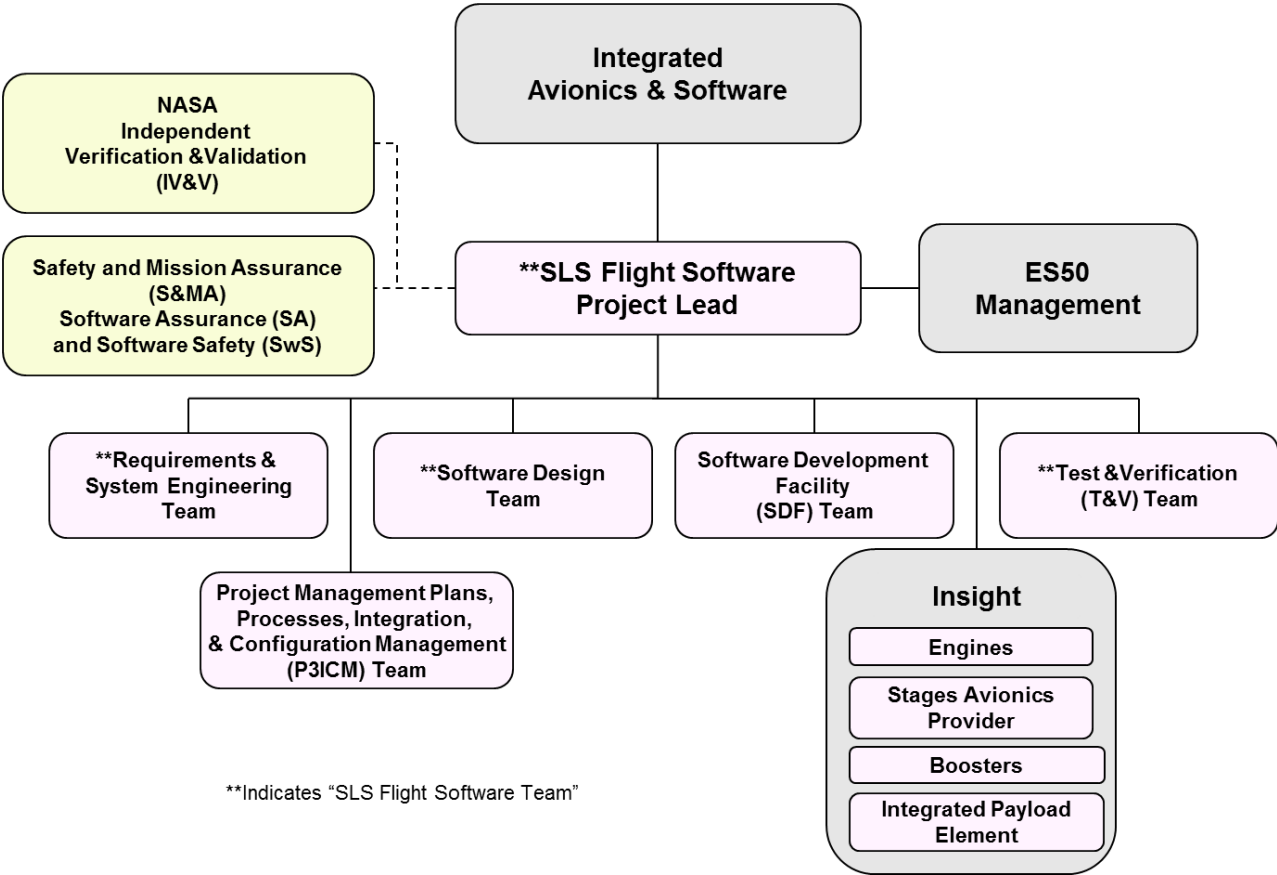


Figure 3-2 SLS FSW Internal Organizations and Interfaces (for reference only)

3.2.1 Internal Stakeholders Roles and Responsibilities

Relevant Internal Stakeholders Roles and Responsibilities, depicted in the above Figure 3-2, are described within the SLS FSW SDP, SLS-PLAN-073. Specific details are also captured in the team staffing spreadsheet under control of the Software Project Lead (SPL).

4.0 SLS FLIGHT SOFTWARE VERIFICATION AND VALIDATION APPROACH

This section discusses the SLS Flight Software Team processes used to perform V&V of the software and products identified in the SLS-PLAN-073, SLS Flight Software Development Plan.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 14 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4.1 Verification and Validation Processes during Software Lifecycle Phases

Verification and validation activities are performed throughout the software lifecycle to ensure that work products and/or services properly reflect the specified requirements and standards (verification) and fulfill their intended use when placed in the target environment (validation). Verification and validation activities include preparation, implementation, documentation, and taking the appropriate corrective action when issues are identified.

While this document provides a top level overview of verification and validation activities, release-specific Software Test Plans (STP), Software Test Procedures (STPr) and Software Test Reports (STR) are developed that relate to specific test activities for each build release of FSW. Each of these document products are V&V'd through Peer Reviews and Program Milestone Reviews.

4.1.1 Verification Process

The Verification process involves verification of the transitional and final work products against requirements and standards (customer/user and product). Verification activities occur throughout each phase of FSW development (requirements, design, implementation and test).

For all verification tests, pass/fail test criteria or acceptance tolerance bands (based upon design and performance requirements) are specified in each STPr prior to conducting the test.

Figure 4-1 – Verification Process shows the process of verifying selected work products.

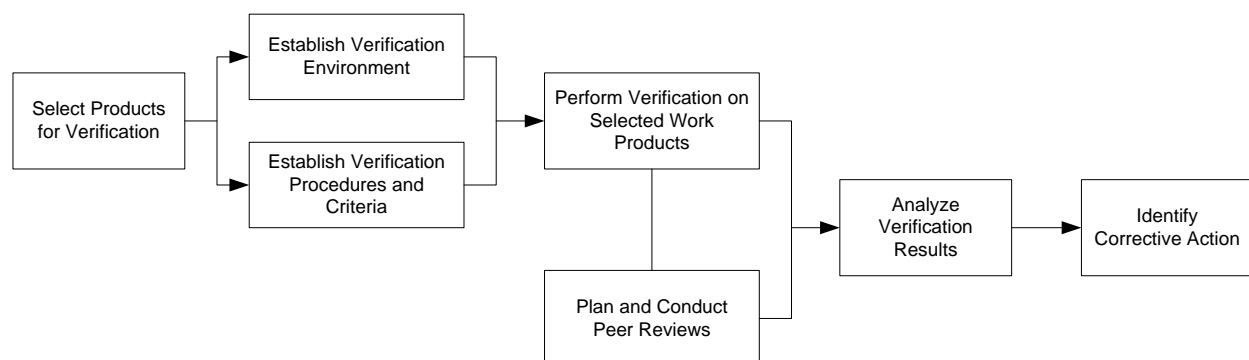


Figure 4-1 Verification Process (for reference only)

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 15 of 31
Title: SLSP Flight Software Verification & Validation Plan	

The following sections provide more detail on how the various verification activities are planned in each life cycle phase.

4.1.1.1 Requirements Phase Verification

Verification is critical in the requirements phase. The sooner inadequate and unacceptable requirements can be resolved into sufficiently rigorous, verifiable and achievable requirements, the less their impact will be to the project schedule. Early in the requirements definition phase, verification strategy is developed to describe how each requirement can be verified. Areas that the FSW Team addresses when reviewing requirements are:

- **Verifiability** – Requirements shall state a behavior or property of the product that can be verified (often interpreted more narrowly as ensuring that each requirement is testable). Requirements expressed as vague generalities or containing unbounded and/or undefined terms are not verifiable. Requirements must be succinct and not compounded.
- **Achievability** – A requirement may be stated correctly but may be unachievable in practice. A requirement that is impossible to achieve can cause a great waste of time and money if not identified and renegotiated early in the project.
- **Resources Needed** – Some requirements can lead to extensive/expensive testing. These requirements will be identified as resource drivers because they may not be compatible with project schedule and budget constraints. When recognized early, the project has the opportunity to negotiate other options such as additional test time/facilities (or other resources), or changing the verification method.
- **Verification Method** – The expected method of verification will be addressed during this phase, whether it is Test, Analysis, Demonstration, Inspection, or a combination of these methods. These Verification Methods are discussed further in section 4.1.2 Verification Methods.
- **Requirement Traceability** – During this phase, each requirement must also be traced to a verifiable requirement. Issues with requirements documentation will also be addressed during this phase.

Verification brings a unique perspective to the requirements review process that helps ensure consistency and completeness throughout the requirements phase. Representative members of all teams (designers, testers, process personnel, project leads, etc.) of the FSW Team participate in the requirements verification process.

Activities used to verify requirements include:

- TIMs
- Peer Reviews
- Software Requirements Reviews

4.1.1.2 Design Phase Verification

The software design is verified to ensure that it satisfies the system performance and functional objectives stated in the software requirements and interface documentation. To accomplish this,

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 16 of 31
Title: SLSP Flight Software Verification & Validation Plan	

reviews, TIMs, analysis, models (note: the SLS design is model based), simulations, and prototypes will be used to verify designs prior to implementation.

The Software Design Team will perform requirements traceability from SRS requirements to software module design. This information is described in the SLS-VDD-135, Software Detail Design (SDD) Documents for the FC (or more correctly, the model as the SLS design is model based and the documents are outputs of the model). The FSW Team will review the design implementation and traceability during the Software Test Planning and Preparation process activities described in section 4.2.3.1.1 Test Planning and Preparation.

Verification activities used to review software design are:

- TIMs
- Peer Reviews
- Preliminary Design Reviews (PDRs)
- Critical Design Reviews (CDRs)

4.1.1.3 Implementation Phase Verification

The primary and preferred method of verification in the implementation phase is software testing, but there are three other verification methods: Analysis, Inspection, and Demonstration, that are often required when requirements cannot be fully verified by the test method.

Verification Methods are further discussed in section 4.1.2 Verification Methods.

Implementation Phase Verification ‘Test’ process activities are further defined in Section 4.2 FSW Team Test Approach of this document.

4.1.2 Verification Methods

This section describes the accepted Software Engineering Verification methods used to verify Software Engineering components or documentation. Many requirements are verified using a combination of these methods.

4.1.2.1 Test Verification Method

The test verification method is generally the preferred and most often used test method in verification activities. For SLS FSW requirements that use the test method to verify the requirement (and its associated software implementation), the requirement is verified by measurement, or functional test, during or after the controlled application of functional and/or environmental stimuli (real or simulated).

Rationale justifying the correctness of pass/fail test criteria and/or acceptance tolerance bands are included as part of the test procedure. Wherever the correctness of pass/fail test criteria and/or acceptance bands is critical for system safety, the justification for those pass/fail test criteria and/or acceptance bands are sufficiently rigorous.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 17 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4.1.2.2 Analysis Verification Method

A general definition of analysis with respect to software verification is a method to confirm that requirements to be verified have been satisfied utilizing techniques such as:

- Path analysis (most likely to occur during unit testing)
- External Input analysis
- Fault trees
- Load analysis
- Output analysis
- Data analysis
- Performance analysis

Analysis may also include the evaluation of the results of multiple tests and analyses at a lower level as it would apply to a higher level of verification. For example, the Test & Verification Team may use the documented results of unit testing and analysis performed by the Software Designers as closure for SRS requirements. Analytical methods selected for verification are supported by appropriate rationale and detailed in the applicable STPr. Additionally, any analysis results performed by a Subject Matter Expert (SME), are documented, signed and attached to the STPr.

Verification by the Analysis method is used whenever (but is not necessarily limited to) any of the following apply:

- 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
- It is not cost effective to test, and/or
- It is desired to determine closure status of verification and validation activities being performed at lower levels of assembly to support closures at higher level

4.1.2.3 Demonstration Verification Method

Verification by demonstration is a qualitative exhibition of functional performance (i.e., serviceability, accessibility, transportability and human engineering features) usually accomplished with no or minimal instrumentation. The demonstration (and test) method, for example is used to confirm that the upload of a new version of the software via the GSE port pre-flight or perhaps to show that when an 'open valve x' command is sent, the 'demo' is a valve physically opens. All demonstration tests techniques are documented in the applicable STPr.

4.1.2.4 Inspection Verification Method

Inspection is a method of verification of physical characteristics that determines compliance of the item with requirements without the use of special laboratory equipment and test support items. Inspection verifications will include these standard methods:

- Technical reviews

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 18 of 31
Title: SLSP Flight Software Verification & Validation Plan	

- Code inspections
- Code walkthroughs

Code inspections are used primarily when it is not possible to verify requirements completely via the demonstration, test or analysis methods. Software requirements verified via the Inspection method are documented with a procedure and contain copies of all the relevant code and design (as necessary) reviewed to satisfy the requirement with cross references showing the exact lines of code that satisfy the requirement. Additionally, any inspection results performed by a Subject Matter Expert (SME), are documented, signed and attached to the procedure.

4.1.3 Validation Process

Validation activities are applied to all aspects of a product in any intended environment (i.e., operation, training, maintenance). Work products (requirements, designs, and prototypes) are selected based on which ones best forecast how well the product/product components satisfy user needs. The Validation approach is similar to verification (e.g., test, analysis, inspection and demonstration) and may run concurrently using parts of the same environment. The distinction being that the user/customer is involved in milestone reviews of plans, requirements and design documents and the operational environment (actual or simulated) is used for actual software implementation validation. Operational concept documents will be referenced and taken into consideration for validation procedures. The primary goal of validation testing is to confirm that the FSW team has built the right product.

Figure 4-2 – Validation Process shows the process of validation.

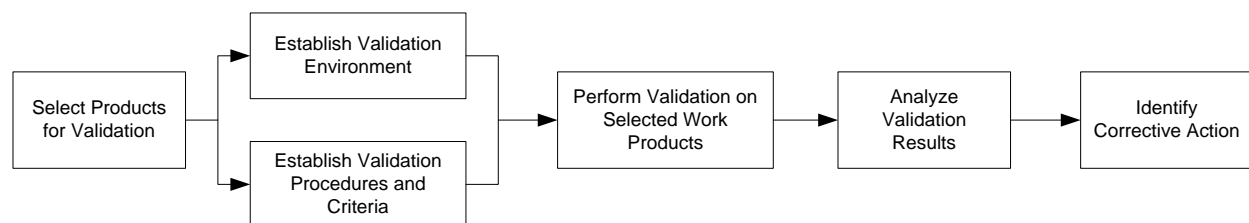


Figure 4-2 Validation Process (for reference only)

4.1.3.1 Requirements Phase Validation

The purpose of the requirements phase validation process is to get external stakeholder and end user 'buy-in' to the actual requirements that are being written to ensure that the Requirements Engineers have correctly interpreted and written the requirement to meet the end-users original intent. Validation with the end-user community is critical to the overall success of the project in

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 19 of 31
Title: SLSP Flight Software Verification & Validation Plan	

the requirements phase. Invalid requirements caught in the requirements phase are the least expensive to correct. They get more expensive to correct (both from a cost and schedule perspective) in each subsequent phase of the validation process. The sooner that the original operational intent of requirements can be validated with the end users to ensure they have been captured correctly, the less their impact will be to the project schedule. If the FSW Team waits until the product is delivered to the customer to validate its operational intent, the impact could have significant schedule and cost impacts.

Planned validation activities that will include external stakeholders' participation when reviewing requirements include:

- Software Requirements Reviews
- SLS program PDRs
- SLS program CDRs
- SRS Peer Reviews with External Stakeholders

4.1.3.2 Design Phase Validation

The purpose of the design phase validation process is to get external stakeholder and end user 'buy-in' to the actual implementation of the requirements into design. This ensures that the design engineers have correctly interpreted the requirements and produced a valid design that meets the end-users original intent.

Planned validation activities that will include external stakeholders' participation in design reviews or simulated end-user environments with preliminary design are:

- PDRs
- CDRs
- SDD External Peer Reviews
- Design prototyping efforts

4.1.3.3 Implementation Phase Validation

The primary and preferred method of validation in the implementation phase is software testing, but analysis, inspection and demonstration validation methods are also applicable and necessary when requirements cannot be fully validated by the test method. Validation in the implementation phase consists of exercising the software in various operational scenarios in its intended operational environment (real or simulated). These types of tests include end-to-end tests, performance tests, and pre-launch, countdown and flight tests. Validation methods are further discussed in section 4.1.4 Validation Methods.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 20 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4.1.4 Validation Methods

This section describes the accepted Software Engineering Validation methods used to validate Software Engineering components or documentation. Many requirements are validated using a combination of these methods.

4.1.4.1 Test Validation Method

The Test Method processes for generating procedures previously described in section 4.1.2.1 Test Verification Method is applicable to the Test Method to be discussed here for Validation of Software Requirements. Please reference section 4.1.2.1 for a general description of the Test Method. Differences between the test method used for verification activities in contrast to the test method used for validation activities include:

- The validation test method means that the software is tested in its intended operational environment, real or simulated. The real operational environment is preferred, but the Software Development Facility (SDF) is limited to a simulated environment.
- The types of tests that are run are operational scenario tests that would be expected during SLS operational and mission activities.
- It is preferred to use flight or flight-like equipment.

The SDF does not have flight or flight-like avionics, but is limited to the use of Engineering Development Units (EDUs) for Formal Qualification Testing (FQT).

The Test & Verification (T&V) Team validates software requirements in the SDF using a simulated environment and non-flight hardware. The T&V Team provides inputs to the System Integration and Test Facility (SITF)/System Integration Lab (SIL) V&V procedures to improve validation confidence. The T&V team also receives test results from these organizations, as necessary, in the form of as-run procedures, test data, data logs, etc., to help enhance validations efforts.

4.1.4.2 Analysis Validation Method

The Analysis Method process for generating procedures previously described in section 4.1.2.2 Analysis Verification Method is applicable to the Analysis Method to be discussed here for Validation activities. Please reference section 4.1.2.2 for a general description of the Analysis Method. The key differences between the analysis method for verification and the analysis method for validation are similar to those described in section 4.1.4.1 on Test Validation Method. Specifically, using the Analysis Validation Method, data from tests performed in the operational environment are analyzed. This data might be produced by the T&V Team testing in the SDF or from tests run at Integration Avionics Test Facilities (IATF), in an operational environment with increasing levels of fidelity of the ‘flight-likeness’ of the hardware environment. The ultimate validation analysis is from the analysis of actual flight test data.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 21 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4.1.4.3 Demonstration Validation Method

The Demonstration Method process for generating procedures previously described in section 4.1.2.2 Demonstration Verification Method is applicable to the Demonstration Method discussed here for Validation activities. Please reference section 4.1.2.2 for a general description of the Demonstration Method. The key differences between the demonstration method for verification activities and the demonstration method for validation activities are similar to those described in the previous paragraph on Test Validation Method. Specifically, for the FSW Team, the Demonstration Validation Method involves demonstrations performed in the simulated operational environment in the SDF. Execution of demonstrations in the SITF and SIL are the responsibility of other organizations, however, if the T&V team is allowed to witness these demonstrations, this method could be utilized for some degree of validation testing, in a more ‘flight-like’ hardware environment. The ultimate validation demonstration is the nominal performance of the SLS flight software during a mission.

4.1.4.4 Inspection Validation Method

The inspection validation method is different from the inspection verification method described previously, in that for validation inspections, it means that the external stakeholders or end-users are reviewing documentation such as SRSs and SDDs during milestone and Peer Reviews. FSW Team inspections are in reality more of a verification effort. The FSW Team relies on external stakeholders for the inspection validation of FSW Team products during the following types of reviews:

- SRS/SDD Peer Reviews
- SRRs
- PDRs
- CDRs
- External Peer Reviews of Software Test Procedures

4.2 SLS Flight Software Team T&V Approach

This section addresses all of the Flight Software Team’s primary test processes of the software lifecycle, to include the Development Phase Test Processes of Unit Test and Integration Test, as well as the Test Phase processes of Informal Test, Formal Qualification Test, and Avionics integration and System Integration Test Support. Further information on the processes are defined in the following paragraphs and a pictorial representation of the Test Flow Hierarchy is shown in Figure 4-3. - FSW Team Test Process Flow.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 22 of 31
Title: SLSP Flight Software Verification & Validation Plan	

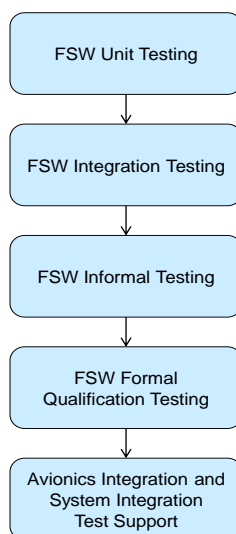


Figure 4-3 FSW Team Test Process Flow

4.2.1 Unit Test Process

The goal of unit testing is to ensure that all functions and features of a single unit of code perform as specified in the Design Specification. A unit test covers the testing of a [computer] software unit (CSU), or a group of closely related units, as a single entity. Unit testing is performed in isolation, using test drivers to simulate higher level units, and/or stubs to simulate lower level units. Unit test is a design based test as opposed to requirements based test. Generally, unit testing is performed by the team member(s) responsible for implementation of the CSU.

4.2.1.1 Unit Test Design Guidelines

The guidelines followed during the creation of Unit Test Procedures are:

1. All executable statements should be exercised at least once by at least one test case.
2. Tests should exercise the full range of operational conditions (exercise the boundary cases).
3. Invalid, erroneous, or out of range inputs should be tested to show appropriate error handling (exercise the boundary cases).

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 23 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4. If any design assumptions are made, the tests should verify the assumptions are valid over the operational range and inputs outside the operational range are handled appropriately.
5. Branch and/or decision coverage is tested by Modified Condition/Decision Coverage (MC/DC) as defined by DO-178, Software Considerations in Airborne System and Equipment Certification, “Every point of entry and exit in the program has been invoked at least once, every condition in a decision has taken all possible outcomes at least once, every decision in the program has taken all possible outcomes at least once, and each condition in a decision has been shown to independently affect that decisions outcome. A condition is shown to independently affect a decisions outcome by varying just that condition while holding fixed all other possible conditions.”

4.2.1.2 Conduct Unit Test

Unit tests are run according to the Unit Test Procedures created by the developer. This is generally automated using a unit test tool, such as TBRUN. If any of the actual results do not agree with the expected results, the developer determines the cause of the unexpected result, implements the corrective action into the code or the Unit Test harness as necessary. After all changes to code and/or documentation have been completed, the test is re-executed.

SLS-FSW-WI-009, FSW Unit Test Methodology contains more detailed information on Unit Testing.

4.2.2 Integration and Test Process

The SLS Flight Software uses an Aeronautical Radio, Inc. (ARINC) 653 Partitioned Operation System (POS). The POS enforces time and space partitioning. This time and space partitioning affords each developer a virtual machine or “sandbox”. This “sandbox” is enforced by the POS and code in one partition (“sandbox”) can not affect code in another partition. Exceptions arise when code in one partition depends on data provided by another. As a result, partitions usually integrate with very little effort. In fact, all the SLS source code is checked into the source tree and built together with one makefile. Because of this the code actually stays in an “integrated state” (otherwise it will not build). Therefore, this section will concentrate on the testing aspect.

The purpose of integration testing is to make sure the assembled CSUs function correctly as one unit (CSCI). Because those performing the integration will have access to the source code, it is anticipated that problems found will be fixed “on-the-fly.” Integration testing, a natural part of the creating the final CSCI, provides verification during product development by ensuring that each individual partition satisfies its respective data publication responsibility.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 24 of 31
Title: SLSP Flight Software Verification & Validation Plan	

Additional activities related to integration can be found in the FSW-SLS-011, FSW Integration Methodology WI. The integration and test can be broken down into two distinctive steps; Partition and Complete CSCI level testing. They are described in the following two sections.

4.2.2.1 Partition Level Testing

Partition level testing for FSW running under an ARINC 653 OS is similar to unit testing. A partition test harness (PTH) is used to supply input data to the partition under test. The PTH is executed for each test case and results analyzed for correct operation.

Partition Level Testing is a shared responsibility between the FSW T&V Team and the FSW Design Team. Specific procedures for Partition level testing are covered in the FSW Integration Methodology WI (SLS-FSW-WI-011).

4.2.2.2 Complete CSCI Integration Testing

This level of integration testing occurs when the Flight Computer application code is being readied for a release. This integration not only includes the FC FSW code (all its modules and partitions) but also the hardware in the loop simulation environment. This testing is normally carried out by the S/W Design and Development team to ensure proper operation of the software prior to releasing it to the S/W Test Team. Once the Design and Development team is satisfied and formalized release including SVD is made for the Test Team. Specific procedures for complete CSCI integration level testing are covered in the FSW Integration Methodology WI (SLS-FSW-WI-011).

4.2.3 SRS Verification Process

Software testing will be conducted in two primary phases: Informal and FQT. The informal test phase contains all test planning and test execution activities in the period of time in the software life-cycle up to and including the SLS FSW Test Readiness Reviews (TRR). The formal test phase includes the test execution activities that occur after TRR that are officially witnessed (or monitored) and signed off by Software Assurance personnel. Figure 4-4 (below) illustrates the process used for both Formal and Informal testing.

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 25 of 31
Title: SLSP Flight Software Verification & Validation Plan	

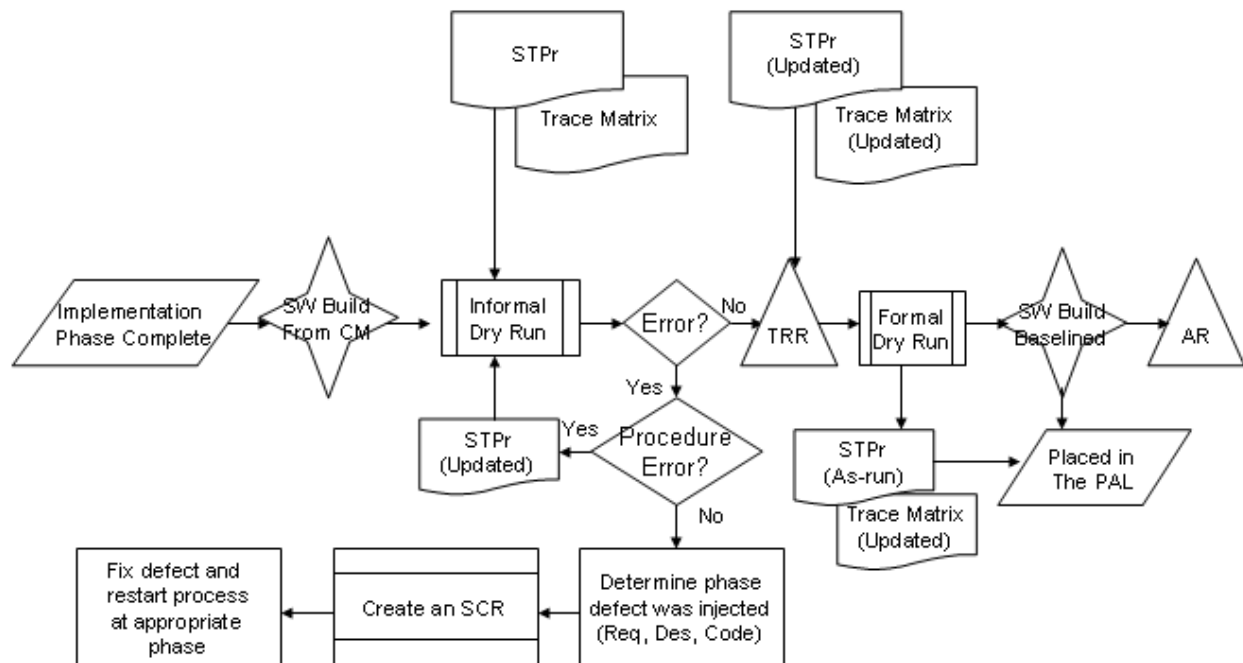


Figure 4-4 Software Verification Process (for reference only)

4.2.3.1 Informal Testing

Informal testing is part of the process of developing and evaluating STPrs. Validation of the test approach and verification of individual steps in the procedures is the objective. Updates, as necessary, to the test documentation are incorporated during Informal testing prior to Peer Review and TRR. While performing Informal Test, logical groups or “Test Classes” can also be identified and incorporated as a part of the STP and subsequent Formal test operations.

The Informal testing process is detailed in the SDPDD section 12.1. Informal testing is often used to develop and refine test procedures and scripts for use during subsequent FQT activities.

4.2.3.1.1 Test Planning and Preparation

The purpose of the test planning process is to document all information pertinent to performing the software testing tasks, including defining the activities, resources (personnel, test environments, etc.), responsibilities, risks, limitations, and scheduling.

Additional test planning and preparation activities include evaluating requirements documentation (SRSs, SDDs, Interface Control Documents (ICDs), etc.), via informal reviews or

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 26 of 31
Title: SLSP Flight Software Verification & Validation Plan	

formal Peer Reviews. T&V personnel will also assist in the verification of traceability between SRS requirements and their parent requirements and SRS requirements and their associated module in the design. Ensuring adequate coverage of the applicable SRS requirements associated with each FSW release is addressed during test planning.

4.2.3.1.2 Test Procedure Development and Execution

Test procedure development and execution includes running each procedure to eliminate any procedural problems and to identify software defects as early as possible.

Informal test procedure development activities begin in parallel with software development activities. All of the software, interface, hardware, and simulation pieces of the test system are assembled to determine the readiness to perform their functionality for the particular FSW release.

After all the procedures have been developed and executed, the T&V team evaluates informal test exit criteria and formal test entrance criteria to determine software readiness for the Formal test operations.

4.2.3.2 Formal Qualification Testing (FQT)

After the Test Readiness Review meeting, Formal testing will begin. The FSW T&V Team has the responsibility for conducting the FQT. During this activity, each procedure will be run with SA personnel either witnessing or monitoring the activity. The test conductor for the test activity will be responsible for ensuring that the test setup/systems configuration is accurate, with software assurance confirmation/signature. All procedures executed are completed and signed by SA and the test conductor, and all data collected during testing is preserved as part of the test record. Any real-time changes to test procedures will be initialed by SA.

Any significant procedure deviation will cause the test to be stopped and an investigation will be performed to determine if it is the test procedure, test configuration, test article or something else has caused the deviation. If the changes that caused the deviation are determined to be required updates to the procedure, the procedure is updated and the changes approved by ES50 management prior to rerunning the procedure. Any discrepancies noted during the formal test process execution, whether they are believed to be hardware or software in nature, are recorded on a Type I SCR.

At the end of the formal testing phase, the test status is reviewed, along with any problems found. Once all problems are corrected, as deemed necessary, and any regression testing is complete, the test report is developed and delivered, in accordance with the SDP.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 27 of 31
Title: SLSP Flight Software Verification & Validation Plan	

4.2.4 SLS FSW Validation Testing Support

The FSW T&V Team (ES51) works collaboratively with System Test personnel (ES61) to ensure common objectives are satisfied. ES61 has the primary responsibility to perform validation testing in the SIL. To the maximum extent possible, ES51 and ES61 share resources and experiences that support common objectives. As necessary, both groups share data, facilities, scripts, procedures and data to ensure the verification and validation activities assigned to each respective group are successful.

4.2.5 Regression Test Approach

When limited FSW changes are made to code residing in a single partition, subsampled regression test operations on the unaffected partitions will be performed to ensure there are no unanticipated consequences associated with the limited change. An analysis will be performed to determine the extent of the proposed regression test operations based on the isolated nature of the change to take full advantage of the partitioned design of the FSW. Internal SW changes that do not affect published data consumed by another SW partition will determine the scope of additional test operations.

5.0 SLS FLIGHT SOFTWARE TEST ENVIRONMENTS

5.1.1 Software Development Facility

The SDF is used to provide a target platform that closely approximates the actual Flight Computer Operating Group (FCOG) configuration used on the vehicle. SLS FSW developers use the configuration established in MSFC building 4487, while the SLS FSW T&V team primarily uses the facility in MSFC building 4476. In both cases, simulations are used to isolate the three Flight Computers for development and test operations. The simulation hardware and environment is the responsibility of the ES53 (ARTEMIS) organization and includes sufficient fidelity interfaces to stimulate the FCOG to perform its intended operations. Additionally, ES53 (MAESTRO) provides an environment configuration interface to orchestrate the simulation and data acquisition devices and provide real-time display monitoring.

Detailed test-specific information related to the lab configuration is provided to the T&V team and is documented in the Software Test Report (STR) for each test event and is addressed at TRR. All of the necessary information needed to re-create a test with the same environmental conditions is contained in the STR and may be used, if the need arises, to re-run a test event.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 28 of 31
Title: SLSP Flight Software Verification & Validation Plan	

5.1.2 System Integration Lab (SIL)

The SIL is used as a validation resource for the integration of FSW and other avionics components. The SIL is located in MSFC building 4205. This facility will provide FSW access to the highest fidelity representation of the integrated vehicle prior to MAF integration. SIL validation testing is performed by the ES61 branch in accordance with their defined process'.

6.0 SLS FLIGHT SOFTWARE VERIFICATION AND VALIDATION SCHEDULE OF ACTIVITIES

V&V schedule activities that support external program milestones are tracked on an internal schedule and reviewed on a weekly basis to ensure that they support the SLS program needs. The FSW internal schedule alignment with the SLS-SCHE-064, SLS Integrated Master Schedule is the responsibility of the SLS Software Project Lead (SPL) operating within the control guidelines established in section 4.3 of the SDP.

7.0 REQUIREMENTS TRACEABILITY

SLS FSW requirements traceability is mandated by NPR 7150.2 for Class A software as shown in appendix D of that document. Compliance with this Agency procedure is mandatory and supports the NASA Policy Directive NPD 7120.4. Project-specific tailoring of the SDPDD requirements methodologies are outlined in section 5.3.1 of the SLS SDP. Detailed operations related to requirements development and traceability are further refined in SLS-FSW-WI-002.

Bi-directional traceability is maintained throughout FSW development. System/Program level requirements are mapped to the SRS requirements. SRS level requirements are mapped to the FSW design-level requirements and into the FSW code. Evidence of traceability is an integral part of overall FSW validation. Additionally, it is a necessary part of ensuring adequate verification coverage for SRS formal test operations. Bi-directional traceability to source documentation is provided in the SRS in accordance with the defined DRD, STD/SW-SRS.

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 29 of 31
Title: SLSP Flight Software Verification & Validation Plan	

APPENDIX A ACRONYMS AND ABBREVIATIONS

A1.0 ACRONYMS AND ABBREVIATIONS

ARINC	Aeronautical Radio, Incorporated
ARTEMIS	Advanced Real-Time Environment For Modeling, Integration, and Simulation
BSP	Board Support Package
C&DH	Communications & Data Handling
CDR	Critical Design Review
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
	Concept of Operations
Con Ops	Commercial Off The Shelf
COTS	Change Request
CR	Core Stage
CS	Computer Software Configuration Item
CSCI	Computer Software Unit
CSU	
DLE	Discipline Lead Engineer
DRD	Data Requirement Document
DRM	Design Reference Mission
DSNE	Design Specification for Natural Environments
FC	Flight Computer
FCAS	Flight Computer Application Software
FCOG	Flight Computer Operational Group
FCSW	Flight Computer Software
FQT	Formal Qualification Test
FSW	Flight Software
GN&C	Guidance, Navigation & Control
GSDOP	Ground Systems Development & Operations
IAS	Integrated Avionics Software
IATF	Integration Avionics Test Facilities
ICD	Interface Control Document
IMACS	Integrated Measurement and Command System
IRD	Interface Requirements Document
IV&V	Independent Verification & Validation
M&FM	Mission & Fault Management

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 30 of 31
Title: SLSP Flight Software Verification & Validation Plan	

MAESTRO	Managed Automation Environment for Simulation, Test, and Real-time Operations
MCR	Monitored Conditions Report
MPCV	Multi-Purpose Crew Vehicle
MS	Mission Systems
NDT	NASA Design Team
OPR	Office of Primary Responsibility
P3ICM	Program Management Plans, Processes, Integration and Configuration Management
PDR	Preliminary Design Review
POS	Partitioned Operating System
PTH	Partition Test Harness
RTOS	Real-Time Operating System
S&MA	Safety & Mission Assurance
SA	Software Assurance
SBAS	Standby Application Software
SBM	Serena Business Manager
SBU	Sensitive But Unclassified
SCM	Software Configuration Management
SCMP	Software Configuration Management Plan
SCR	Software Change Request
SDD	Software Design Description
SDF	Software Development Facility
SDP	Software Development Plan
SDPDD	Software Development Process Description Document
SEMP	Systems Engineering Management Plan
SIL	System Integration Lab
SITF	System Integration and Test Facility
SLS	Space Launch System
SLSP	Space Launch System Program
SMP	Software Management Plan
SPL	Software Project Lead
SRB	Software Review Board
SRS	Software Requirements Specification
STAS	Special Test Application Software
STP	Software Test Plan
STPr	Software Test Procedure
STR	Software Test Report

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*

Space Launch System (SLS) Program	
Version: Draft for PDR	Document No: SLS-PLAN-075
Draft Date: 3/14/13	Page: 31 of 31
Title: SLSP Flight Software Verification & Validation Plan	

SVVP	Software Verification and Validation Plan
SwS	Software Safety
T&V	Test & Verification
TBD	To Be Determined
TBR	To Be Resolved
TRR	Test Readiness Review
V&V	Verification & Validation
WI	Work Instruction

Approved for Public Release; Distribution is Unlimited

*The electronic version is the official approved document.
Verify this is the correct version before use.*