SLS Flight Software Agile Development Process

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**Space Launch System (SLS)**

**Safe**
- Human-rated to provide safe and reliable systems
- Protecting the public, NASA workforce, high-value equipment and property, and the environment from potential harm

**Affordable**
- Maximum use of common elements and existing assets, infrastructure, and workforce
- Constrained budget environment
- Competitive opportunities for affordability on-ramps

**Sustainable**
- Initial capability: 70 metric tons (t), 2017–2021
  - Serves as primary transportation for Orion and human exploration missions
- Evolved capability: 105 t and 130 t, post-2021
  - Offers large volume for science missions and payloads
  - Reduces trip times to get science results faster
  - Minimizes risk of radiation exposure and orbital debris impacts

*Designed for Beyond Earth Orbit Missions of National Importance*
SLS Evolution Overview

322 ft.
- Launch Abort System
- Orion
- Interim Cryogenic Propulsion Stage
- Launch Vehicle Stage Adapter
- Core Stage
- Solid Rocket Boosters
- Interstage
- SLS Block 1 70t

364 ft.
- Universal Stage Adapter
- Exploration Upper Stage
- SLS Block 1B Crew 105t
- Solid Rocket Boosters
- Interstage

327 ft.
- Cargo Fairing
- Exploration Upper Stage
- SLS Block 1B Cargo 105t
- Advanced Boosters
- RS-25 Engines

365 ft.
- Cargo Fairing
- Exploration Upper Stage
- SLS Block 2 Cargo 130t
Where is SLS Avionics Located?

- **Booster Avionics**
- **Interim Cryogenic Propulsion Stage Avionics**
- **Launch Vehicle Stage Adapter**
  (Two Cameras for ICPS Separation)
- **Core Stage Avionics**
  (Flight Computers, Command and Telemetry Controller, Inertial Navigation Equipment, RF Transmitter)
- **Core Stage Avionics**
  (Command and Telemetry Controller, Power Distribution, Data Acquisition, Camera Equipment, Liquid Level Sensors, Rate Gyro, RF Transmitter)
- **Core Stage Engine Controllers**
- **Core Stage Avionics**
  (Main Propulsion System Valve Control, Core Stage Thrust Vector Control, Rate Gyro)
SLS Block I Software Providers

System: Flight Computer (FC)
Type: Byzantine Fault Resilient 3 String Voting Architecture
Developer: MSFC In-House
Category: Flight Critical
Function: Primary SLS Vehicle Flight Control System

System: Redundant Inertial Navigation Unit (RINU)
Type: Internally Self-Checking Architecture
Developer: Stages Subcontractor (Honeywell)
Category: Flight Critical
Function: Provide Navigation and Flight Control inputs to FCs

System: Rate Gyro Assembly
Type: Internally Self-Checking Architecture
Developer: Stages Subcontractor (Honeywell)
Category: Flight Critical
Function: Provide vehicle rate inputs to FCs

System: Core Stage Engine Controller (CSEC)
Type: Self-Checking Pair of Pairs (Prime/Backup)
Developer: Engines Contractor - Aerojet Rocketdyne (AR)
Category: Flight Critical
Function: Control/Monitor of RS-25 Engine

System: ULA Common Avionics Based
Developer: ULA
Function: Primary ICPS Flight Control and Health Monitoring

Function: Provide Navigation and Flight Control inputs to FCs

Function: Control/Monitor of RS-25 Engine
Flight Computer Application Software (FCAS) CSCI is designated as Flight Computer Application Software (FCAS) and provides the flight and pre-flight critical and non-critical software functions necessary for on-pad prelaunch, launch, and ascent of the SLS vehicle.

Green Run Application Software (GRAS) CSCI is designated as Green Run Application Software (GRAS) and executes a pre-defined thrust vector control actuator position profile for the Core Stage (CS) Thrust Vector Controller (TVC) actuators and a pre-defined Core Stage Engine throttle position profile.
**Flight Software Development Approach**

- **Release 11 Delivered to End Users on 9/29/2015 (SLS ASCB Delivery Date)**
  - Successful design implementation and test
- **Flight Software (FSW) Release 12**
  - FSW Release 12 Mission and Fault Management (M&FM) Model delivered on 5/20/2015
  - ARTEMIS 10.2b delivered for Release 12 development
  - FSW Release 12 Sprint 4 in progress
  - FSW Release 12 Test Readiness Review scheduled for 12/9/2015
- **Development Approach**
  - FSW Release 12 [fully functional version of both GRAS and FCAS – Engineering Release (ER) for both]
  - FSW Release 13 (initial FQT version of GRAS / FCAS)
  - FSW Release 14 (updated FQT version of GRAS / FCAS)
  - FSW Release 15 (defect repairs – as needed)
The Software Test Report contains detailed test results, as-run test procedures, and associated analysis for FSW Release under test.

FSW Test Plan will contain (for each Release):
- Success Criteria (DVO Equivalent)
- Test Procedures
- Test Approaches
- Data Analysis Required
- Environment

FSW Verification - Single DVO Closure (Verification of Entire SRS)

SLSP Flight Software Requirements Specification

SLS FSW Build Content Definition

SLS FSW Test Plan
FSW-SLS-STP

SLS FSW Test Report
FSW-SLS-STR

Requirement Allocation
Development Process

Release N

Build Definition Mgmt Cycle

SW Design/Code/Integrate (6 Month)

Informal Testing (4 Months)

Build Definition Mgmt Cycle

SW Design/Code/Integrate (6 Month)

Formal Testing (2 Mo)

FSW FQT Release For SITF Testing

Release N + 1

Build Definition Mgmt Cycle

SW Design/Code/Integrate (6 Month)

Informal Testing (4 Months)

Formal Testing (2 Mo)

FSW FQT Release For SITF Testing

Configuration controlled build definition/mgmt. process part of ongoing Build Definition Mgmt. Cycle. Maintained by FSW Deputy Project Lead, controlled by Level II Project Control Board.

Product content for release driven by:

- Functional capabilities needed for release identified
- Available source product maturity evaluated
- Gap analysis performed between items (1) and (2)
- Deficiencies/issues identified and addressed
- Capability/content included in release (or provided in later release) depending upon outcome of item (4) analysis
Agile Development

Incremental Development Activities

Plan

Program

Projects

Build Definition Mgmt Cycle

Project Planning

Develop Requirements

External Stakeholder input Integration

Backlog

Requirements

Requirements Decomposition

Integrate & Test

Detail Design

Implement

Static Analysis & Unit Test

Peer Review

Integrate & Test

Plan

Execute

Deliver

Formal Testing (4 Mo)

Informal/ Formal Testing (SDF)

Release to SITF/SIL

Develop Test Approaches/ Procedures

Execute testing

Informal Testing (4 Months)

SW Design/Code/Integrate (6 Month)
Dry run development and peer evaluations ensure STPr(s) are ready for FQT

STPr release planning and tracking module contains requirements and STPr trace

STPr consolidated module containing requirement logical groupings and test cases

Heritage STPrs become candidates for future regression FQT activities

SRB: System Review Board
STPR: Software Test Procedures
**FSW Release Activities**

<table>
<thead>
<tr>
<th>Activity</th>
<th>2015</th>
<th>2016</th>
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<tbody>
<tr>
<td><strong>FSW Release 12.0</strong></td>
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<tr>
<td>Preparation Planning for Release 12.0</td>
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<tr>
<td>Planning and Content Definition Complete</td>
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<tr>
<td><strong>FSW Release 12.0 Code, Integration and Test</strong></td>
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<td>M&amp;FM Algorithms for FSW 12.0</td>
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<td>GN&amp;C Algorithms for FSW 12.0</td>
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<td>ARTEMIS 10.2 Deliveries</td>
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<td>Software Sprints</td>
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<td>Sprint Integrations</td>
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<td>Test Dry Runs and Integration for FSW 12.0</td>
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<td>SDF Ready for Test</td>
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<td>Functional Test Report for Release 12.0</td>
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<td><strong>FC Software Version Description Document (SVD)</strong></td>
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<td>FSW 12.0 Product Release (FCA/PCA)</td>
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<td>Release 12.0 FSW FQT to SRB</td>
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<tr>
<td>Release 12.0 Buy-off, CM/DM</td>
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<tr>
<td>Release 12.0 FQT Software (Delivery to ASCB)</td>
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Defect Tracking

Defects

- Captured in the Serena Business Manager (SBM) Change Requests (CRs) System managed by development organization.
  - Analysis for root cause performed
  - Assigned to appropriate team to resolve
  - Assigned to a release
  - Closed with release testing
FSW Release 11 Test Results

Test Approach Development

R11 FQT Execution

26 STPrs require unique test runs
The remaining 24 STPr use data from common test run

R11 Blackbox STPr Dry Run

6/19/15 97% BG
TP complete

R11 FQT Analysis and Archive Complete

FQT Complete: 8/12/15
# Flight Software Maturity (R11 – R13)

Data as of 9/16/15

<table>
<thead>
<tr>
<th>Module/Element</th>
<th>Planned Maturity</th>
<th>Actual Maturity</th>
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<tbody>
<tr>
<td>FSW</td>
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- Each cell is a measure of completeness (maturity)
- Weight sum of each major FSW process area
  - Requirements
  - Design
  - Implementation
  - Verification

### Key
- **Low Maturity (<33%)**
- **Medium Maturity (34% - 65%)**
- **High Maturity (66% - 100%)**