Space Launch System (SLS) Safety, Mission Assurance, and Risk Mitigation

AIAA Civil Space 2013
February 13, 2013

Todd May, Program Manager
NASA Marshall Space Flight Center
The Space Launch System [will] be the backbone of its manned spaceflight program for decades. It [will] be the most powerful rocket in NASA’s history…and puts NASA on a more sustainable path to continue our tradition of innovative space exploration.

President Obama’s Accomplishments for NASA
May 22, 2012
SLS Driving Objectives

♦ Safe
  • Human-rated to provide safe and reliable systems for human missions
  • 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 exploration missions
    - Provides back-up capability for crew/cargo to ISS
  • Evolved capability: 105 t and 130 t, post-2021
    - Offers large volume for science missions and payloads
    - Modular and flexible, right-sized for mission requirements

Flexible Architecture Configured for the Mission
Block Upgrade Approach

**INITIAL CAPABILITY, 2017–21**

**Orion Multi-Purpose Crew Vehicle (MPCV)**
- Orbital Sciences Corp.

**Launch Abort System**
- Right-sized for the payload
- Industry input received in FY13

**Interim Cryogenic Propulsion Stage**
- Early flight certification for Orion
- Flexible for a range of payloads
- **Boeing**

**Core Stage Engines**
- Using Space Shuttle Main Engine inventory assets
- Building on the U.S. state of the art in liquid oxygen/hydrogen
- Initial missions: Pratt & Whitney Rocketdyne
- Future missions: Agency is determining acquisition strategy

**Core/Upper Stage**
- Common design, materials, & manufacturing
- **Boeing**

**Avionics**
- Builds on Ares software
- **Boeing**

**5-Segment Solid Rocket Boosters**
- Upgrading Shuttle heritage hardware
- **ATK**

**RS-25**

**EVOLVED CAPABILITY, Post-2021**

**130 t 384 ft**

**Fairings (27.5’ or 33’)**
- Right-sized for the payload
- Industry input received in FY13

**J-2X Upper Stage Engine**
- Builds on Apollo Saturn J-2 heritage
- **Pratt & Whitney Rocketdyne**

**Advanced Boosters**
- Competitive opportunities for affordable upgrades
- **Risk-reduction contracts awarded in FY13**

**Evolutionary Path to Future Capabilities**
- Minimizes unique configurations
- Allows incremental development
- **Advanced Development contracts awarded in FY13**

**Working with Industry Partners to Develop America’s Heavy-Lift Rocket**

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### Accountability and Responsibility

- Strong focus on leadership at all levels
- Organized to balance functional expertise and cross-functional integration
- Chief Safety Officer and staff provide guidance, analysis, and oversight/insight
- Chief Engineer serves as lead designer, with staff focused on technical integration
- Early integration of production considerations
- Entire organization focused on stakeholder value

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Safety Risks - Identification and Mitigation

♦ Qualitative [Hazard Analyses (HA) and Failure Modes and Effects Analysis/Critical Item Lists (FMEA/CIL)] and Quantitative (PRA) tools are used to identify, characterize and mitigate safety risks.

♦ Probabilistic Risk Assessment (PRA) complements HAs, FMEA/CILs, reliability predictions and abort capabilities to estimate aggregate risk for Loss of Mission (LOM) and Loss of Crew (LOC).

♦ Safety Assessments are also used to support trade studies.
  • Example: Main Propulsion Test Article vs Green Run vs Flight Readiness Firing Trade study

Safety Review Process
♦ SLS is using a modified safety review process concurrent or more inline with milestone reviews.
  • Assures products are renewed by independent eyes and key stakeholders
  • Uses Table Tops
  • Top Risks are reported out

Proven Processes in the Hands of Experienced Personnel
Notional Probability of Failure Uncertainty Decreases with Maturity

CDR – Critical Design Review
PDR – Preliminary Design Review
DCR – Design Certification Review
SDR – System Definition Review
MCR – Mission Concept Review
SRR – System Requirements Review

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Mean Risk Increases and Decreases are Notional

Configuration Unknowns
- Configuration
- Geometry
- Trajectory
- Materials

Modeling Unknowns
- Physical phenomena
- Parameter values
- Model fidelity
- Flight modes

Vehicle Unknowns
- Thresholds/tolerances
- Mitigation strategies
- Operational modes
- Margins
- Integration

Production Unknowns
- Manufacturing processes
- QA levels
- Real-time changes
- Infant mortality
- Unexpected interactions
- Integrated environment

Flight Unknowns
- Random events
- Process lapses
Personal Accountability

- Lean, Integrated Teams with Accelerated Decision Making
- Robust Designs and Margins
- Right-Sized Documentation and Standards
- Evolvable Development Approach
- Hardware Commonality
- Risk-Informed Government Insight/Oversight Model

Safe, Affordable, Sustainable
Risk-Based Insight

- Based on vehicle risk and historic failures, concentrate/augment insight in key areas:
  - Risk-informed Concentration
    - Propulsion
    - Guidance, Navigation, and Control (GN&C)
    - Avionics
    - Software
    - Electrical
    - Crew Systems
    - Separation Systems
  - Nominal Concentration
    - Power and Thermal
    - Structures
    - Mission Operations
    - Ground Operations
    - Probabilistic
    - Environmental Control and Life Support

1980 – 2007 Worldwide Launch Failure Causes
Source: FAA Launch Vehicle Failure Mode Database, May 2007

Focused on Block I Flight in 2017
Initial Exploration Missions (EM)

EM-1 in 2017
• Un-crewed circumlunar flight – free return trajectory
• Mission duration ~7 days
• Demonstrate integrated spacecraft systems performance prior to crewed flight
• Demonstrate high speed entry (~11 km/s) and thermal protection system prior to crewed flight

EM-2 no later than 2021
• Crewed lunar orbit mission
• Mission duration 10–14 days
5-Segment Solid Rocket Booster
RS-25 Core Stage Engines In Stock

Common Engine Controller
Interim Cryogenic Propulsion Stage
J-2X Upper Stage Engine
SLS: A Year of Accomplishments

- Multi-Purpose Crew Vehicle Stage Adapter (MSA) Pathfinder Hardware at Marshall Space Flight Center, June 2012
- J-2X power pack assembly hot fire test at Stennis Space Center, Nov 2012
- RS-25 Engines at Stennis Space Center, Oct 2012, shown with future RS-25 Test Stand A1
- F-1 engine gas generator hot fire test at Marshall Space Flight Center, Jan 2013 – technology development for an optional Advanced Booster concept
- Qualification Motor 1 casting at ATK, Oct 2012

System Requirements Review/System Definition Review Completed

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The Road to First Flight in 2017

<table>
<thead>
<tr>
<th>NASA Life Cycle Phases</th>
<th>Approval for Formulation</th>
<th>FORMULATION</th>
<th>Approval for Implementation</th>
<th>IMPLEMENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program Life Cycle Phases</td>
<td>Pre-Phase A: Concept Studies</td>
<td>Phase A: Concept &amp; Technology Development</td>
<td>Phase B: Preliminary Design &amp; Technology Completion</td>
<td>Phase C: Final Design &amp; Fabrication</td>
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<td>Program Life Cycle Gates and Major Events</td>
<td>KDP A</td>
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We don’t do a good job… pointing out the monumental effort that has gone into this Program…. I don’t think anyone would have thought in September [2011] that this Program might be this far so fast.

Leroy Cain, Chair
Independent Standing Review Board
(NASA Space Shuttle Program Flight Director)
NASA Directorate Program Management Council
June 29, 2012
I have great respect for the Marshall Center and the workforce, and the progress with the Space Launch System is but one example of why that respect is well placed.

Vice Admiral Joseph W. Dyer, USN (Ret.)
Chair, NASA Aerospace Safety Advisory Panel
May 2012
For More Information

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