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.
  - Initial capability, 2017–21

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

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

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

- **Fairings (27.5’ or 33’)**
  - Boeing

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

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

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

- **RS-25 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

EVOLVED CAPABILITY, Post-2021

- **130 t 384 ft**

- **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

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

www.nasa.gov/sls
SLS Program Organization at MSFC

Chief Engineer (CE) Garry Lyles
Deputy CE John Honeycutt
Procurement Manager Earl Pendley

Chief Safety Officer (CSO) Rick Burt
Deputy CSO Dan Mullane

Program Manager Todd May
Deputy Manager Jody Singer
Assistant Program Manager Sharon Cobb

Strategic Development Manager Steve Creech (XP01)

Deputy Manager Daryl Woods
Program Planning & Control Manager Keith Hefner

Booster Manager Alex Priskos
Deputy Manager Bruce Tillor

Engines Manager Mike Kynard
Deputy Manager Sheryl Kittredge
Stages Manager Tony Lavoie
Deputy Manager Julie Bassler

Ground Operations Liaison Manager Brian Matisak
Assistant Manager Andy Warren
Advanced Development Office Manager Chris Crumbly
Assistant Manager Fred Bickley
Spacecraft & Payload Integration Manager David Beaman

Vacant
Assistant Manager

1/09/13
www.nasa.gov/sls
**Communication Integration**

**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

- **Lower Risk**
- **Higher Risk**

**Non-Specific**
- MCR (Mission Concept Review)
- SRR (System Requirements Review)
- SDR (System Definition Review)
- PDR (Preliminary Design Review)
- CDR (Critical Design Review)
- DCR (Design Certification Review)

**Design Maturity**
- Mean Risk Increases and Decreases are Notional
- Production Unknowns
  - Manufacturing processes
  - QA levels
  - Real-time changes
- Vehicle Unknowns
  - Thresholds/tolerances
  - Mitigation strategies
  - Operational modes
  - Margins
  - Integration
- Flight Unknowns
  - Random events
  - Process lapses

**Configuration Unknowns**
- Configuration
- Geometry
- Trajectory
- Materials

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

Source: FAA Launch Vehicle Failure Mode Database, May 2007

**1980 – 2007 Worldwide Launch Failure Causes**

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
SLS: A Year of Accomplishments

- Systems Engineering and Integration SLS model undergoes wind tunnel testing at Langley Research Center Nov 2012
- J-2X power pack assembly hot fire test at Stennis Space Center Nov 2012
- Multi-Purpose Crew Vehicle Stage Adapter (MSA) Pathfinder Hardware at Marshall Space Flight Center June 2012
- Kennedy Space Center Complex 39B ready for a 2017 SLS launch (artist's concept)
- 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**

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<tr>
<th>NASA Life Cycle Phases</th>
<th>Approval for Formulation</th>
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<th>Approval for Implementation</th>
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<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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Program Life Cycle Gates and Major Events

- KDP A
- KDP B
- KDP C
- KDP D
- KDP E
- KDP F

Focused Toward

- 2011 MCR ✔
- 2012 SRR/SDR ✔
- 2013 PDR
- 2015 CDR ✔
- 2016 SR ✔
- 2017 FRR ✔
- 2021

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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