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.
- 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
  - Orbital Sciences Corp.

EVOLVED CAPABILITY, Post-2021

- Core/Upper Stage
  - Common design, materials, & manufacturing
  - Boeing Avionics
    - Builds on Ares software
    - Boeing
- 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
- Fairings (27.5’ or 33’)
  - Right-sized for the payload
  - Industry input received in FY13
- Integral 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

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

Balancing cost, schedule, and technical/safety risk

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

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

**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

www.nasa.gov/sls
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

Focuses on the Data Content and Access to the Data
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

Focused on Block I Flight in 2017

1980 – 2007
Worldwide Launch Failure Causes

Source: FAA Launch Vehicle Failure Mode Database, May 2007
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
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
- **Systems Engineering and Integration** SLS model undergoes wind tunnel testing at Langley Research Center, Nov 2012
- **F-1 engine gas generator hot fire test** at Marshall Space Flight Center, Jan 2013 – technology development for an optional Advanced Booster concept
- **RS-25 Engines** at Stennis Space Center, Oct 2012, shown with future RS-25 Test Stand A1
- **Qualification Motor 1 casting** at ATK, Oct 2012
- **Kennedy Space Center Complex 39B ready for a 2017 SLS launch** (artist’s concept)
- **System Requirements Review/System Definition Review Completed**
The Road to First Flight in 2017

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

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<table>
<thead>
<tr>
<th>NASA Life Cycle Phases</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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<td>Program Life Cycle Gates and Major Events</td>
<td>KDP A</td>
<td>KDP B</td>
<td>KDP C</td>
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<td>MCR</td>
<td>SRR/SDR</td>
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FOCUSED TOWARD

EFT-1 Launch
EM-1 Launch
EM-2 Launch

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

www.nasa.gov/sls
www.twitter.com/nasa_sls
www.facebook.com/nasasls
U.S. Launch Vehicle Fleet

Payload Volume (m³) vs Payload Mass (mT)

- **ULA**: Atlas V 551
- **SpaceX**: Falcon 9
- **ULA**: Delta IV H
- **NASA**: Space Shuttle
- **NASA**: Saturn V
- **NASA**: 70 t
- **NASA**: 105 t
- **NASA**: 130 t

As of November 8, 2012

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