NASA’s Space Launch System: Partnering For Tomorrow

Chris Crumbly
Manager, Advanced Development Office
Space Launch System Program
March 4, 2013
SLS Program Organization at MSFC

Hard line programmatic
Matrix relationship

Procurement Manager
Earl Pendley

Engines Manager
Mike Kynard

Stages Manager
Tony Lavoie

Chief Engineer (CE)
Garry Lyles

Chief Safety Officer (CSO)
Rick Burt

Deputy CSO
Dan Mulane

Procurement Manager
Earl Pendley

Deputy CE
John Honeycutt

Program Manager
Todd May

Deputy Manager
Jody Singer

Associate Program Manager

Assistant Program Manager
Sharon Cobb

Strategic Development Manager
Steve Creech (XP01)

Deputy Manager
Daryl Woods

Program Planning & Control Manager
Keith Hefner

Boosters Manager
Alex Priskos

Deputy Manager
Bruce Tiller

Engines Manager
Mike Kynard

Deputy Manager
Sheryl Kittredge

Stages Manager
Tony Lavole

Booster Manager
Alex Priskos

Deputy Manager
Bruce Tiller

Engines Manager
Mike Kynard

Deputy Manager
Sheryl Kittredge

Stages Manager
Tony Lavole

Spacecraft & Payload Integration Manager
David Beaman

Ground Operations Liaison Manager
Brian Matisak

Assistant Manager
Andy Warren

Advanced Development Office Manager
Chris Crumbly

Assistant Manager
Fred Bickley

Vacant

Assistant Manager

www.nasa.gov/sls
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
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
## NASA Life Cycle Phases

<table>
<thead>
<tr>
<th>Program Life Cycle Phases</th>
<th>Approval for Formulation</th>
<th>FORMULATION</th>
<th>Approval for Implementation</th>
<th>IMPLEMENTATION</th>
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<tr>
<td>Pre-Phase A: Concept Studies</td>
<td>KDP A ✔</td>
<td>KDP B ✔</td>
<td>KDP C</td>
<td>KDP D</td>
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<tr>
<td>Phase A: Concept &amp; Technology Development</td>
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<tr>
<td>Phase B: Preliminary Design &amp; Technology Completion</td>
<td>EFT-1 Launch</td>
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<td>EM-1 Launch</td>
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<td>Phase C: Final Design &amp; Fabrication</td>
<td>CDR ✔</td>
<td>SR</td>
<td>FRR</td>
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<td>Phase D: System Assembly, Int. &amp; Test, Launch &amp; Checkout</td>
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<td>Phase E: Operations &amp; Sustainment</td>
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<td>Phase F: Closeout</td>
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### Program Life Cycle Gates and Major Events

- **MCR**: Mission Concept Review
- **SRR/SDR**: System Requirements / System Definition Review
- **PDR**: Preliminary Design Review
- **CDR**: Critical Design Review
- **EM**: Exploration Mission
- **EFT**: Exploration Flight Test
- **FRR**: Flight Readiness Review
- **KDP**: Key Decision Point

### Human Space Flight Project Reviews

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tr>
<td>2011</td>
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**The Road to First Flight in 2017**
Most Capable U.S. Launch Vehicle

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<th>Payload Volume (m³)</th>
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<td>300</td>
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- **ULA Atlas V 551**: 105 t
- **SpaceX Falcon 9**: 130 t
- **ULA Delta IV H**: 130 t
- **NASA Space Shuttle**: 130 t
- **NASA Saturn V**: 70 t
- **NASA 105 t**: 105 t
- **NASA 130 t**: 130 t

As of January 4, 2013

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SLS: Being Built Today in the USA

- 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

www.nasa.gov/sls
Building on the U.S. Infrastructure

INITIAL CAPABILITY, 2017–21

- Orion Multi-Purpose Crew Vehicle (MPCV) • Lockheed Martin
- Launch Abort System
- 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
- Core/Upper Stage • Common design, materials, & manufacturing • Boeing Avionics • Builds on Ares software • Boeing

EVLLOVED CAPABILITY, Post-2021

- 130 t 384 ft
- Fairings (27.5’ or 33’) • Right-sized for the payload • Received industry input 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
- 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

www.nasa.gov/sls
SLS 70t Expanded View

Hardware Progress:
- RS-25 Core Stage Engines In Stock
- Solid Rocket Boosters in Testing
- Interim Cryogenic Propulsion Stage in Development
- MPCV and Launch Vehicle Adapters in Development
- Core Stage PDR Completed
- Avionics in Development

Solid Rocket Boosters (2)  
(TRL 6)

RS-25/J-2X Engine Control Unit

MSA Barrel Panel Segment

Encapsulated Service Module Panels

Spacecraft Adapter

Interim Cryogenic Propulsion Stage (ICPS)

MPCV/Stage Adapter (MSA)

Launch Vehicle/Stage Adapter

Core Stage and Avionics

Launch Abort System

Crew Module

Service Module

Orion Multi-Purpose Crew Vehicle (MPCV)

Solid Rocket Booster Development Motor Test
Promontory, Utah, September 2011

RS-25 Engines (4)  
TRL 9

Orion

Multi-Purpose Crew Vehicle

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SLS 130t Expanded View

Hardware Progress:
- J-2X Upper Stage Engine in Testing
- Advanced Boosters Risk-Reduction in Progress
- Payload Fairings Request for Information in FY13
- Core Stage & Upper Stage Derived from 70-t Core Stage

Payload Fairing
Cargo Payload Adapter
Upper Stage with J-2X Engines (2)
Interstage
Core Stage
Advanced Boosters (2)
RS-25 Engines

J-2X Upper Stage Engine Testing
Stennis Space Center, February 2012
Three-Phase Booster Development

Advanced Booster Design, Development, Test, and Evaluation (DDT&E)
- Scope: Follow-on procurement for DDT&E of a new booster
- Date: RFP target is FY15
- Capability: Evolved at 130 t
- Contract: Full and Open Competition (Liquids or Solids)

Advanced Booster Engineering Demonstration And/Or Risk Reduction NRA
- Scope: Award contracts that reduce risks leading to an affordable Advanced Booster that meets the evolved capabilities of SLS and enable competition by mitigating targeted Advanced Booster risks to enhance SLS affordability
- Date: Contracts awarded Oct 1, 2012
- Capability: Leading to 130 t
- Contract: NRA Demonstrating Specific Technologies and Affordability Risk Reduction for Advanced Boosters
  - Liquid Rocket Boosters or Solid Rocket Boosters

Booster Fly-out for Early Flights through 2021
- Scope: Build two 5-segment SRB Flight Sets
- Date: In progress
- Capability: Initial 70–100 t
- Contract: Mod to Ares contract with ATK

Moving Forward from Initial to Evolved Capability
The Advanced Booster Engineers Demonstration and Risk Reduction (ABEDRR) effort will reduce risks and enable competition, leading to an affordable Advanced Booster that meets the evolved capabilities of SLS and enable competition.
Proposed Booster configuration for SLS would have three newly developed AJ1E6 engines

Proposed engine configuration:
- 1.1M lbf class Oxygen Rich Staged Combustion (ORSC) engine
- Liquid Oxygen and RP-1 propellants
- Dual chamber design - Single turbopump assembly connected to 550k size preburners and main injectors/thrust chambers
Aerojet ABEDRR Task

- Single full scale main injector / thrust chamber fed by two preburners
  - Preburners GFE from AFRL to Aerojet
- FFP Contract for Design, analysis, & fab
  - ATP Feb 11, Cost = $23.3M
- Plan to mod contract to add testing when AF funding received – Spring 2013
- Plan to test at SSC E-1 (NRPTA recommendation)
- Estimated test costs ~ $23M
  - 70-85% of test costs is facility build-up

Demonstrates main chamber combustion stability at AJ1E6 full scale
Affordable Upper Stage Engine

- Partnership between NASA and U.S. Air Force to support the development of an affordable upper-stage engine that could reduce launch costs for Evolved Expendable Launch Vehicles and could potentially provide an alternative for the SLS cryogenic propulsion stage.
SLS Contractor Support

270 Subcontracts in 34 States

- Engaging the U.S. Aerospace Industry
- Strengthening Sectors such as Manufacturing
- Advancing Technology and Innovation

2011 Data

270 Subcontracts in 34 States
Other ADO Activities

In-house Tasks:
- Cryogenic Propulsion Stage (CPS) Systems Analysis & Definition
- AL2195 T8 Gore Development
- Characterization of SLM Materials for SLS Engine Components
- Cryoinsulation Mat’ls & Process Development - Mitigate Obsolescence
- Hexavalent Chromium Free Primer for Cryo
- MPS Low Profile Diffuser
- SLM Integral Valve/Injector - Valve Proposal
- SLM Integral Valve/Injector - Injector Proposal
- SLM Integral Valve/Injector Integrated Hot Fire Testing in 2013
- Affordable Upper Stage Engine Program (AUSEP)
- Advanced Passive Avionics Cooling
- Advanced Telemetry System
- H2 Gas Sensor
- Fluid-Structure Coupling Damper
- Shell-Buckling Knockdown Factors
- Ullage Collapse & Capacitance Probe
- Advanced Booster Combustion Stability (NESC funded)
- Pyroshock Characterization of Composite Materials (NESC funded)
- Booster Interference Loads (NESC funded)

Awarded Industry Tasks:
- Exquadrum, Inc: Affordable Upper Stage Engine (AUSE) Requirements Study
- MOOG, Inc: AUSE High Press LOX Flow Control Valve Manuf Study
- Northrup Grumman: System Requirements and Affordability Assessment for an AUSE
- Pratt & Whitney Rocketdyne: Requirements, Logistics, and System Assessment of an AUSE

Selected Industry Tasks:
- ATK Engineering: Development of a Fluid-Structure Interaction Methodology for Predicting Engine Loads
- ATK Space Systems: Affordable Composite Structures
- Ball Aerospace & Technologies Corp.: Ball Reliable Advanced Integrated Network (BRAIN)
- Collier Research and Development Corp.: Affordable Structural Weight Reduction for SLS Block 1A
- Orbital Technologies: Hybrid Precision Casting for Regeneratively Cooled Thrust Chamber Components, Manufacturing Study
- Reynolds Systems: Advanced Ordnance Systems Demonstration
- Sierra Lobo: Cryo-Tracker®-Mass Gauging System
- Streamline Numerics: Efficient High Fidelity Design and Analysis Tool for Unsteady Flow Physics in Space Propulsion Geometries
- The Boeing Company: Robust Distributed Sensor Interface Modules (DSIM) for SLS
- United Launch Alliance: Integrated Vehicle Fluids (IVF)

Academia Tasks:
- Auburn University: High Electrical Density Device for Aerospace Applications
- Louisiana State University: Improved Friction Stir Welds Using On-Line Sensing of Weld Quality
- Massachusetts Institute of Technology: Modeling Approach for Rotating Cavitation Instabilities in Rocket Engine Turbo pumps
- Mississippi State University: Algorithmic Enhancement for High Resolution Hybrid RANS-LES and Next Generation Simulation Infrastructure on Large Scale Multicore Architecture
- University of Florida: Development of Subcritical Atomization Models for Liquid Rocket Injectors and Determination of Heat Transfer Coefficients for Two-Phase Flows of Cryogenic Propellants During Line Chilldown and Fluid Transport
- University of Maryland: Validation of Subsonic Film Cooling Numerical Simulations Using Detailed Measurement and Novel Diagnostics and Validation of Supersonic Film Cooling Numerical Simulations Using Detailed Measurement and Novel Diagnostics
- University of Utah: Acoustic Emission Based Health Monitoring of Structures

www.nasa.gov/sls
How does NASA Partner with Academia?

- NASA partners through contracts, grants, fellowships, internships, and other research opportunities

- Although methods are constantly updated, and/or changed some typical examples are:
  - NASA Research Announcements
  - Fellowship awards and Research Grants
  - Small Business Innovative Research

- Information from various sources
  - [https://nspires.nasaprs.com](https://nspires.nasaprs.com)
  - [http://prod.nais.nasa.gov/cgi-bin/nais/index.cgi](http://prod.nais.nasa.gov/cgi-bin/nais/index.cgi)
NASA is actively seeking the brightest minds in Academia to partner with in conducting space technology research.

Fellowship awards and NASA Research Grants are available.

Currently, 148 awards to 57 colleges and universities representing 29 states and 1 US territory.
NASA Space Technology Research Fellowships: Solicitation Characteristics

Eligibility Requirements for NSTRF13

1. Pursuing or seeking to pursue advanced STEM degrees.

2. Are U.S. citizens or permanent residents of the U.S.

3. Are or will be enrolled in a full-time master’s or doctoral degree program at an accredited U.S. university in fall 2013.

4. Are early in their graduate careers.

Application Components

1. Proposal Cover Page
2. Personal Statement
3. Project Narrative
4. Degree Program Schedule
5. Curriculum Vitae
6. Transcripts
7. GRE General Test Scores
8. Three Letters of Recommendation

Award Value

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<tr>
<th>Fellowship Budget Category</th>
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<tr>
<td>Student Stipend</td>
<td>$36,000</td>
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<tr>
<td>Faculty Advisor Allowance</td>
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<td>On-site Experience Allowance</td>
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<td>Health Insurance Allowance</td>
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<td>Tuition and Fees Allowance</td>
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<td>TOTAL</td>
<td>$68,000</td>
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NSTRF11: http://tinyurl.com/NSTRF11-OCT
NSTRF12: http://tinyurl.com/NSTRF12-OCT
NASA Space Technology Research Fellowships: Current Portfolio

Covering 13 Technology Areas

26 states, 1 U.S. territory... and 50 universities

NSTRF 11 and 12
128 graduate students conducting space technology research

www.nasa.gov/sls
Broad-based Research
• NASA’s Office of Chief Technologist
• Space Technology Mission Directorate

Focused/Applied Research
• Human Exploration and Operations Mission Directorate

Review the technology areas of interest to NASA in this and other NASA publications

Review the Technology Area Breakdown System (TABS)

Watch for research announcements from NASA Headquarters and the NASA centers specific to your field of research
The NASA SBIR and STTR programs fund the research, development, and demonstration of innovative technologies that fulfill NASA needs and have potential for successful commercialization.

These programs provide opportunities for Small Business and Research Institutions to participate in Government sponsored research and development efforts.

Each year NASA issues its annual NASA SBIR/STTR Phase I Program Solicitations which provide all information and forms needed to submit proposals.

Solicitations for both programs are available online only and potential bidders are strongly encouraged to review the website often.

NASA SBIR/STTR Homepage – [http://sbir.nasa.gov](http://sbir.nasa.gov)
## MSFC Major Competitive Acquisitions

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<th>Acquisition</th>
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<th>CY13</th>
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<td></td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
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<tr>
<td>Office of Strategic Analysis &amp; Communication (OSAC) Services - $55M</td>
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<td>Marshall Integrated Program Support Services (MIPSS) - $150M</td>
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<td>SLS Booster Risk Reduction NRA - $200M</td>
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<td>Engineered Solutions &amp; Prototyping (ESP) - $350M Max per award</td>
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<td>Office of Human Capital (OHC) Support Services - $25M</td>
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<tr>
<td>Marshall Engineering Technicians &amp; Trades Services (METTS) - $200M</td>
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## MSFC Major Competitive Acquisitions

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<td>Facilities Operations &amp; Maintenance Support Services (FOMSS) - $200M</td>
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<td>Occupational Health/Medical Services- $25M</td>
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<td>Manufacturing Support and Facilities Operations (MSFOC)- $315M</td>
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<td>Center Administrative Support Services (CASS) - $25M</td>
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<td>MSFC Information Technology Services (MITS)- $300M</td>
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**Timeline**

- **Q3:** Acq Team
- **Q4:** DRFP RFP
- **Q1:** Award

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Visit [www.nasa.gov/sls](http://www.nasa.gov/sls) for more details.
SLS Acquisition Summary

- SLS contract activity continues to evolve per the initial acquisition strategy

- Acquisition strategy meets key SLS requirements of safety, affordability, and evolvable performance

- SLS continues to work closely with NASA’s Office of Small Business Programs to maximize opportunities for all parts of the Agency’s socio-economic programs

- Contact information: Earl Pendley
  - Phone: 256–544–2949
  - email: george.e.pendley@nasa.gov

Launching 2017
NASA’s Space Launch System

- **Vital to NASA’s exploration strategy and the U.S. space agenda**

- Key tenets: safety, affordability, and sustainability

- Booster risk reduction efforts will make evolved capabilities more affordable

- Advanced development increases affordability, reliability and performance

- Initial advanced booster contracts are already underway

- Industry and academic contracts and grants are being awarded

For More Information

www.nasa.gov/sls

www.twitter.com/nasa_sls

www.facebook.com/nasasls
Back-Up