Evolving the Vehicle

SLS Evolution

Near Earth Asteroid

Block 1 Flights

Industry Tasks

In-House Development

Academia Research

Advanced Booster

130t

National Benefits

Technical Benefits

- New Launch Capability
  - Advanced Booster
  - Upper Stage Engine
  - Engine Development

- Partnership
  - Industry
  - Universities
  - Other Government Agencies
  - International
  - Small Business

- Advanced Manufacturing
- Advanced Composite Structures
- Obsolescence Mitigation
- Advanced Analytical Design Tools

Mars

www.nasa.gov/sls
THE WORLD’S MOST POWERFUL ROCKET

Orion

Interim Cryogenic Propulsion Stage

Block I
70 metric tons

Five-Segment Solid Rocket Boosters

Core Stage
4 RS-25 Engines

Upper Stage

Block II
130 metric tons

Liquid or Solid Advanced Boosters

5, 8.4 or 10 Meter Payload Fairings

THE WORLD’S MOST POWERFUL ROCKET
Technology Transition

Valley of Death

Level of Development

Operational Phase

Product Development

Advanced Development

Technology Development

Ideas Research

Advanced Development

Product Development

TRL

1

2

3

4

5

6

7

8

9
SLS Approach to Block Upgrades

**Improvements in Performance, Safety, Reliability, Cost, and Operations**

Notional Schedules

*SLS Approach to Block Upgrades*

* NASA, Office of Chief Technologist (TRL 1-6)
Technology Needs

Formulation/Evolvability
- Mission Requirements
- Mission Capture
- Concept Definition/Benefits

Advanced Development
- Technology Tasks for Government, Industry & Academia
- Identified Obsolescence
- Technology Demonstrations

Products
- Payload Requirements
- Mission Capture
- Concept Definition/Benefits
- Cost
- Safety/Reliability

End User
- SLS Element Offices
- Payload Integration

Products
- Mature Technologies for Block Upgrades
- Data Package for Technologies
- Support for Transition Process
Current Advanced Development Tasks

In-house Tasks:

- Cryogenic Mat’l & Process Development–Mitigate Obsolescence
- Hexavalent Chromium Free Primer for Cryo
- MPS Low Profile Diffuser
- Solide State Ultracapacitor to Replace Batteries Lattice
- Boltzmann Modeling Zero-G Propellants
- Hot fire Test LOX/H2 Additively Manu’f Injector Affordable for EUS
- Testing of Additively Manu’f Turbomachinery
- Additive Manufacturing Infrared Inspection
- Computed Tomography Sensitivity & Verification of Engine Components
- Additive Manuf. Propellant Ducts, Manifolds & Bellows
- Adv. Manuf. Of Lightweight C-C Nozzle Ext. for Upper Stage
- Performance Improvement of Friction Stir Welds by Better Surface Finish
- Composite Dry Structure Cost Improvement Approach
- Q2 Inconel 625 Mat’l Properties Development
- Q4 titanium 6-4 Mat’l Properties Development
- Pyroshock Characterization of Composite Materials (NESC funded)
- Booster Interference Loads (NESC funded)
- Advanced Booster comp. Case/PBI NBR Insulation Dev (NESC funded)
- Advanced Booster Combustion Stability (NESC funded)

Academia Tasks:

- Auburn University: High Electrical Density Device Survey 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 Turbopumps
- Mississippi State University: Algorithmic Enhancement for High Resolution Hybrid RANS-LES and Large-Scale Multicore Architectures
- University of Florida: Development of Subcritical Atomization Models for Liquid Rocket Injectors and Two-Phase Flow Heat Transfer
- University of Maryland: Validation of Supersonic Film Cooling Numerical Simulations Using Detailed Measurement and Novel Diagnostics
- Flame Stabilization and Combustion Instabilities University of Utah: Acoustic Emission Based Health Monitoring of Structures
- Pennsylvania State University: Characterization of Aluminum/Alumina/Carbon Interactions under Simulated Rocket Motor Conditions

Awarded Industry Tasks:

- Aerojet: AUSEP Engine Study
- Exquadrum, Inc: AUSEP/DESLA Concept Development
- Moog: AUSEP High Press LOX Flow Control Valve Manufacturing Study
- Northrup Grumman: System Requirements and Affordability Assessment for an AUSE
- Pratt & Whitney Rocketdyne: Requirements, Logistics, and System Assessment of an AUSE
- ULA: Integrated Vehicle Fluids (IVF) Testing

Advanced Booster Engineering Demonstration and Risk Reduction Tasks (ABEDRR):

- Dynetics & Aerojet: Modernization of the F-1B Engines, Combustion Stability, and Cryotank Manufacturing
- ATK: Demonstration of a FWC for High-Energy Propellant SRB
- Northrop Grumman: Demonstration of a Common Bulkhead LOX/RP Composite Cryogenic Tank

Details of individual tasks can be found at www.ntrs.nasa.gov (search for NASA/TM-2015-218201) in the SLS SPIE Advanced Development FY14 Annual Report.
SLS Advanced Development Group Technology Focus Areas

**SLS Industry Task Focus Areas**
- Exploration Upper Stage (EUS)
  - Light weight structures and materials, including composites
  - Advanced LOX/LH2 engine
  - Cryogenic storage for long duration missions
  - Advanced/Additive Manufacturing (Selective Laser Melting)
- Universal Stage Adapter
  - Light weight structures and materials, including composites
  - Design

**SLS In-House and Academic Task Focus Areas**
- Propulsion
- Stages, including upper stages
- Advanced boosters
- Shrouds
- Operations
- Payload accommodations
- Analytical modeling
- Advanced manufacturing
- Materials development