PRESENTER NOTES:

- This is an 10-min briefing provided to the Space Propulsion 2012 Conference in Bourdeaux, France. This is primarily an international audience
- Thank the organizers and welcome the audience.
- SLS will be America’s new super-heavy-lift human-rated system slated to fly in 2017.

PRESENTER NOTES:

Our strategy for building SLS uses available assets (RS-25, ICPS) as well as hardware in development (five-segment SRBs, J-2X) to meet our 2017 launch date. Future evolutions of SLS will include advanced boosters that will be competed and could use liquid or solid propellants.

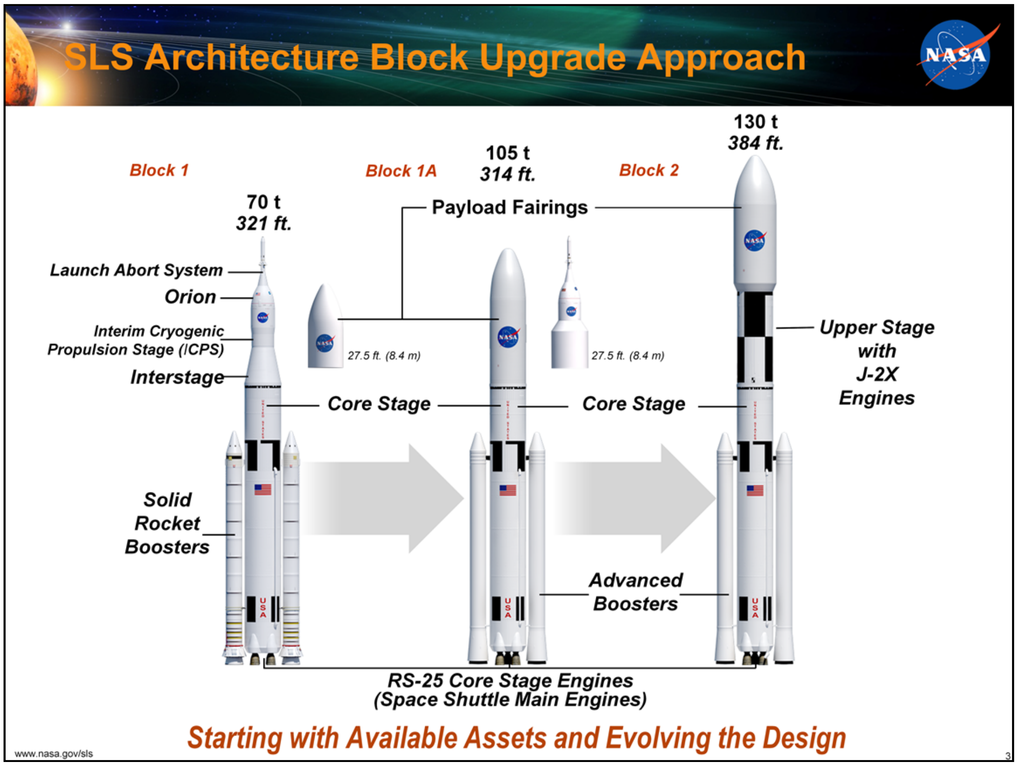
The Agency carefully studied options and made decisions based on fulfilling policy and law, combined with the optimum approach to support the U.S. aerospace industry's talented workforce and unique infrastructure.

Maintains U.S. leadership in LOX/LH2 technology

- LOX/LH2 Core Stage uses RS-25E engines; LOX/LH2 Upper Stage uses J-2X engine
- Establishes fixed central design path, with logical use of existing strength in design and modern manufacturing approaches
- Harnesses existing knowledge base, skills, infrastructure, workforce, and industrial base for existing state-of-the-art systems

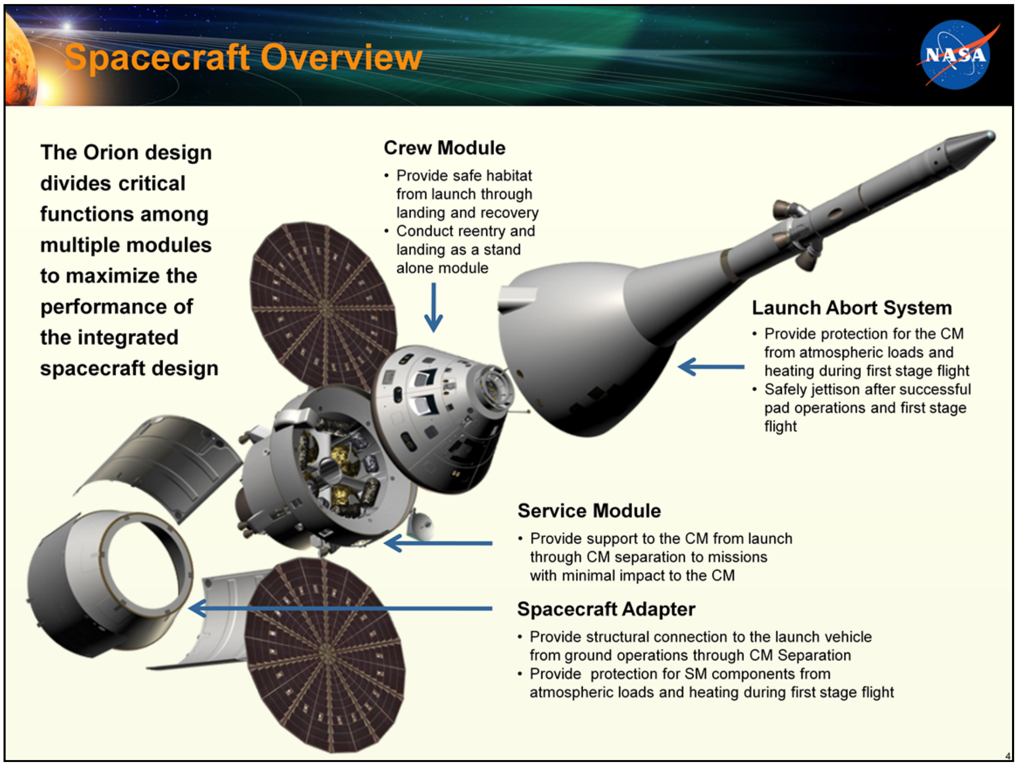
Minimizes unique configurations during vehicle development

- Evolutionary path to 130 t allows incremental development; thus, progress will be made, even within constrained budgets
- Allows early flight certification for MPCV
- May be configured for MPCV or science payloads, providing flexible/modular design and system for varying launch needs
- Gains synergy, thus reducing design, development, test, and evaluation (DDT&E) costs and schedule by building the Core Stage and Upper Stage in parallel, thereby leveraging common tooling and engine-feed components



PRESENTER NOTES:

- In order to evolve the SLS configuration to its full 130-t potential, we are phasing development to stay within our budget and to include innovations offered by large and small businesses and academia.
- Affordability goals are being met by starting where we are and making the most of what we have, while giving competitive opportunities for advancing SLS performance in a way that offers the best return on investment for an initial 70-t capability in 2017 and for block upgrades after 2021.
- The 70 t configuration will provide 10 percent more thrust than the Saturn V Moon rocket, and the 130 t configuration will provide 20 more thrust.


Spacecraft Overview
NASA
The Orion design divides critical functions among multiple modules to maximize the performance of the integrated spacecraft design
Crew Module
• Provide safe habitat from launch through landing and recovery
• Conduct reentry and landing as a stand alone module
Launch Abort System
• Provide protection for the CM from atmospheric loads and heating during first stage flight
• Safely jettison after successful pad operations and first stage flight
Service Module
• Provide support to the CM from launch through CM separation to missions with minimal impact to the CM
Spacecraft Adapter
• Provide structural connection to the launch vehicle from ground operations through CM Separation
• Provide protection for SM components from atmospheric loads and heating during first stage flight
4

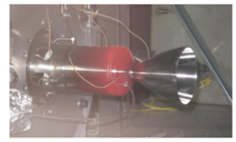
Crew/Service Module Propulsion

CM RCS
Thrust: 160 lbf
Isp: 219 lbf-s/lbm
Quantity: 12
Propellant: Hydrazine
Propellant Wt: 374 lbs

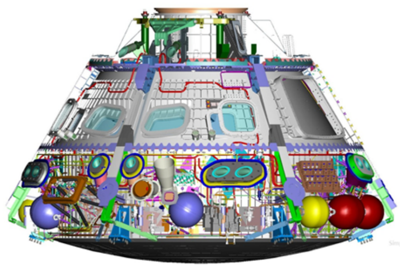
SM Integrated Propulsion
RCS Thruster: 25 lbf each – – Isp: 275 lbf-s/lbm -- Quantity: 16
Auxiliary Engine: 110 lbf each — Isp 308 lbf-s/lbm -- Quantity: 8
Main Engine Thrust: 7,500 lbf – Isp: 326 lbf-s/lbm -- Quantity: 1
Propellant: MMH/N2O4
Propellant Wt: 18,965 lbs

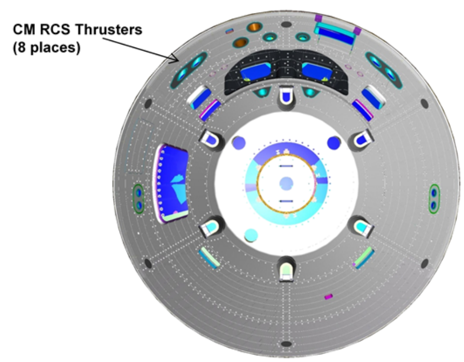
Crew Module Propulsion

- Propulsion system consists of components to provide thrust for orbital maneuvering, entry, descent, and landing activities
- Pressure-fed, monopropellant system, using 2 high pressure helium tanks, 4 propellant tanks, 2 strings of 6 thrusters oriented in roll, pitch, and yaw directions
- Components passed critical design reviews for EFT-1 mission
- Thruster verification testing underway



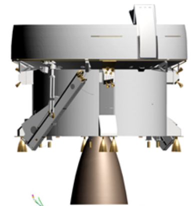
Thruster Acceptance Hot Fire in Vacuum

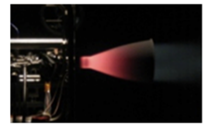




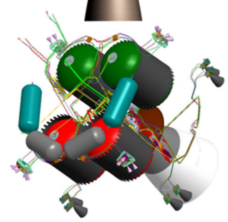
Service Module Propulsion

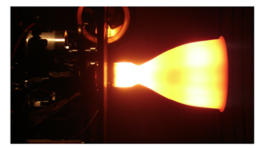
- Propulsion system consists of components to provide thrust for orbital insertion, maneuvering, on-orbit operations, and earth return
- Pressure-fed, bipropellant system, using 4 high pressure helium tanks, 4 propellant tanks
- Integrated propellant system supplying the main engine and 2 strings of RCS and auxiliary engines
- Components passed preliminary design reviews
- Development activity stopped in 2010, resumption pending
- Use of Shuttle OMS engines to be employed to aid affordability





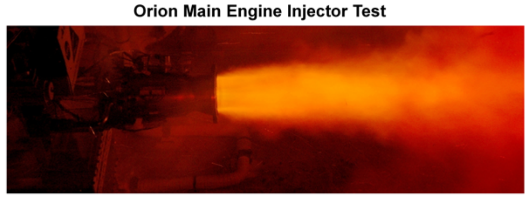
RCS Development Thruster in Vacuum

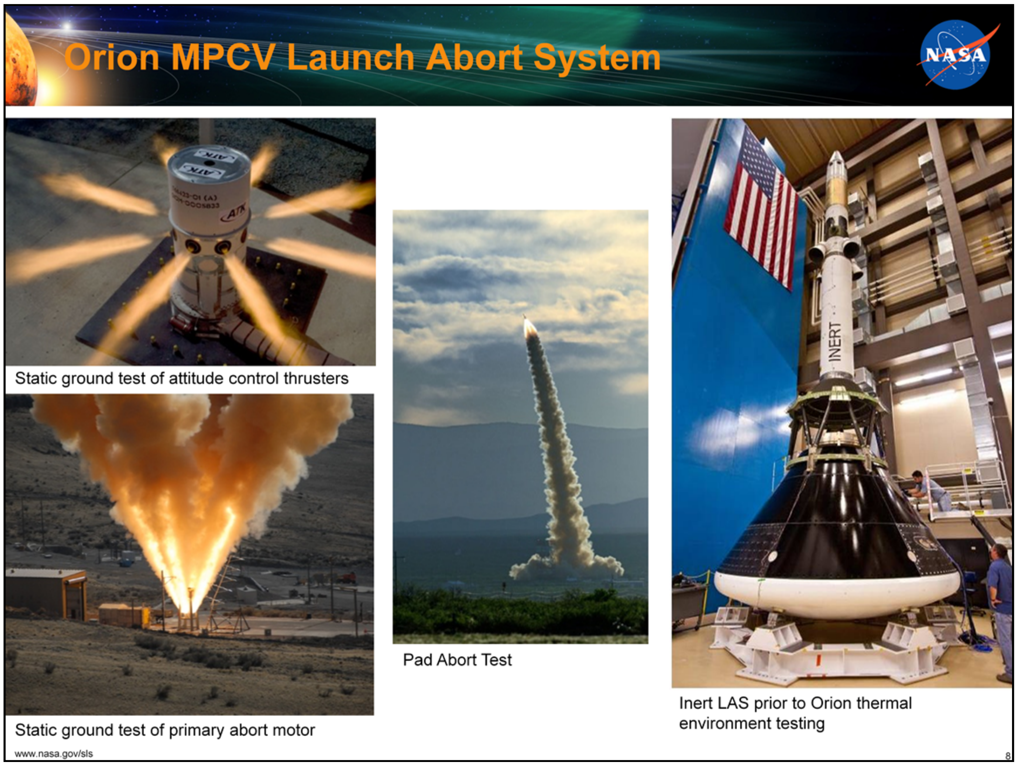




Auxiliary Development Engine in Vacuum

Orion Main Engine Injector Test





PRESENTER NOTES:

Development of the three motors includes an abort motor that pulls the Orion capsule from danger, an attitude control motor to provide directional control and the jettison motor that separates the system from the crew module.

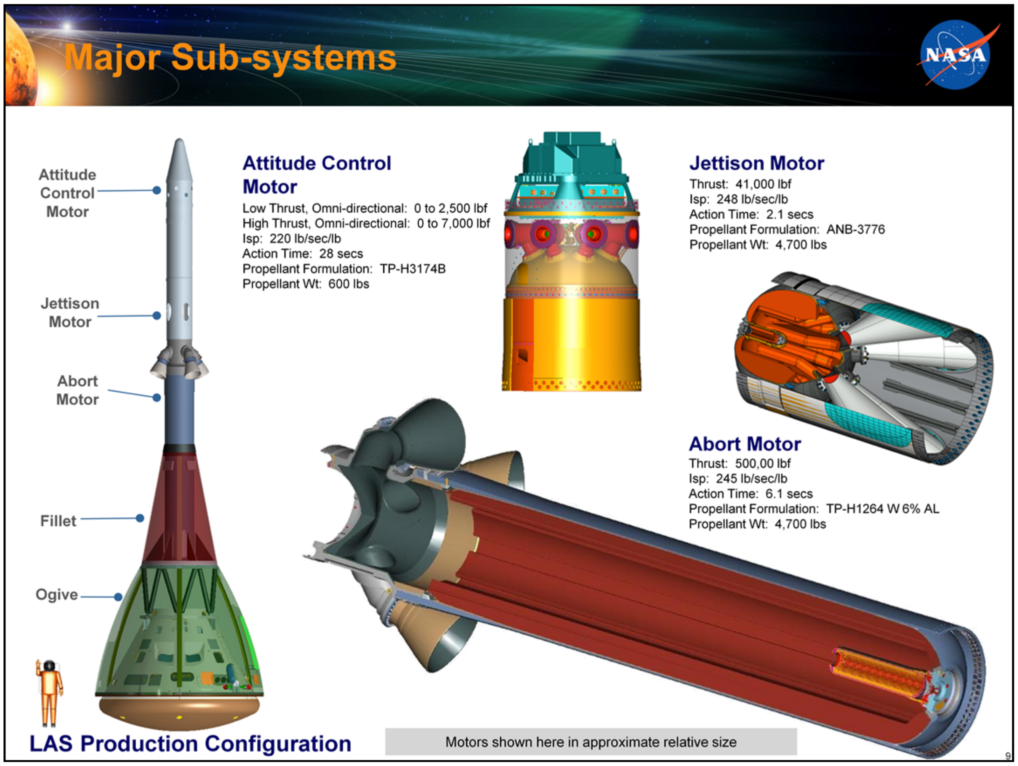
LAS:

- Enhances crew safety by providing crew escape capability in the event of pad or ascent emergencies
- Includes 3 new solid rocket motors, each successfully fired and operated together as a system during the successful Pad Abort 1 flight test
- Expands the envelope of survivable abort conditions over previous abort systems by providing active attitude control during aborts.

Marshall Space Flight Center partnering with lead center Langley Research Center to provide propulsion oversight

Marshall also supporting thermal analysis, structures, mechanisms, avionics, systems engineering, flight test and ground operations

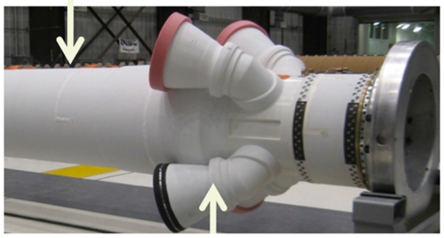
A static ground test and pad abort test were conducted on the LAS. The ground tests included the primary motors and attitude control thrusters.


Major Sub-systems
NASA
Attitude Control Motor
Jettison Motor
Abort Motor
Fillet
Ogive
Attitude Control Motor
Low Thrust, Omni-directional: 0 to 2,500 lbf
High Thrust, Omni-directional: 0 to 7,000 lbf
Isp: 220 lb/sec/lb
Action Time: 28 secs
Propellant Formulation: TP-H3174B
Propellant Wt: 600 lbs
Jettison Motor
Thrust: 41,000 lbf
Isp: 248 lb/sec/lb
Action Time: 2.1 secs
Propellant Formulation: ANB-3776
Propellant Wt: 4,700 lbs
Abort Motor
Thrust: 500,00 lbf
Isp: 245 lb/sec/lb
Action Time: 6.1 secs
Propellant Formulation: TP-H1264 W 6% AL
Propellant Wt: 4,700 lbs
LAS Production Configuration
Motors shown here in approximate relative size
9

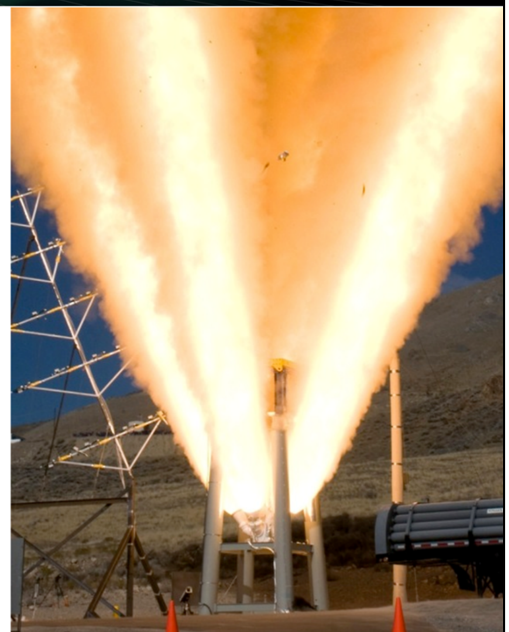
Abort Motor

- First reverse-flow motor fielded in an American rocket system
- First use of a composite motor case in a crewed spaceflight system
- Thrust vector adjustment for vehicle center-of-gravity variances
- Max Thrust 500,000 lbs; 6 second action time
- 2 sub-scale, 1 full-scale and PA-1 test firings successfully completed

Graphite epoxy (IM-7/CLRF-100) composite case



4340 steel–reverse-flow (155 degree turn) manifold



Abort motor full-scale static test

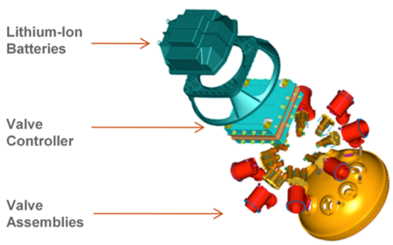
Jettison Motor

- **Designed to be reliable (0.9995) as this motor must work on every flight**
- **Proven technologies**
  - Titanium case
  - Steel nozzles
  - Graphite nozzle throats
  - Pyrogen Igniter
  - Titanium Shroud
- **High Surface Area grain design and fast burn rate propellant yield short life, high thrust.**
- **41,000 lbs thrust over 2.1 sec**
- **4 sub-scale Bates, 2 full scale and PA-1 test firings successfully completed**
  - Last Bates test successfully demonstrated thrust erosion fix

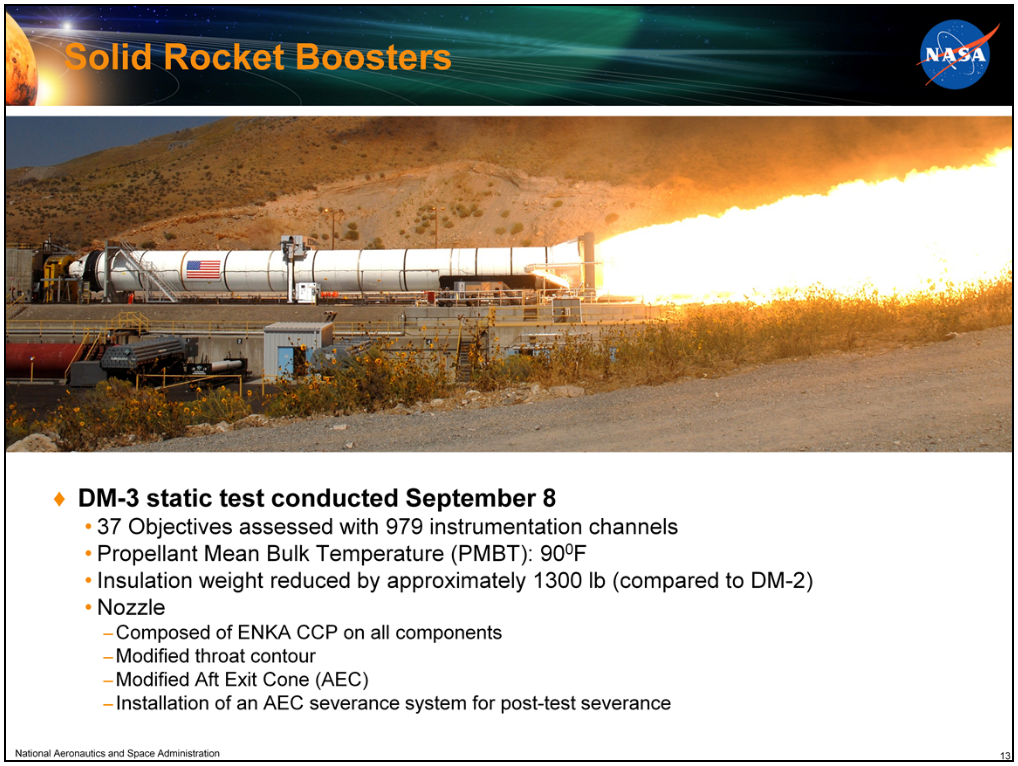
Jettison motor full-scale static test

Attitude Control Motor

- Largest ever throttled solid rocket motor
- Provides active control of the Launch Abort Vehicle in nose-forward flight, reorientation, and heat-shield-forward flight
- First flight application of Carbon/Carbon-Silicon Carbide (C/C-SiC)
- Eliminates the mass penalty of using ballast
- Low thrust (2500lbs) and high thrust (7000lbs) over 28 seconds
- Several subscale (single and dual pintle), 2 full scale and PA-1 test firings completed



ACM Ground Test Demonstrating Performance with Valve Control System



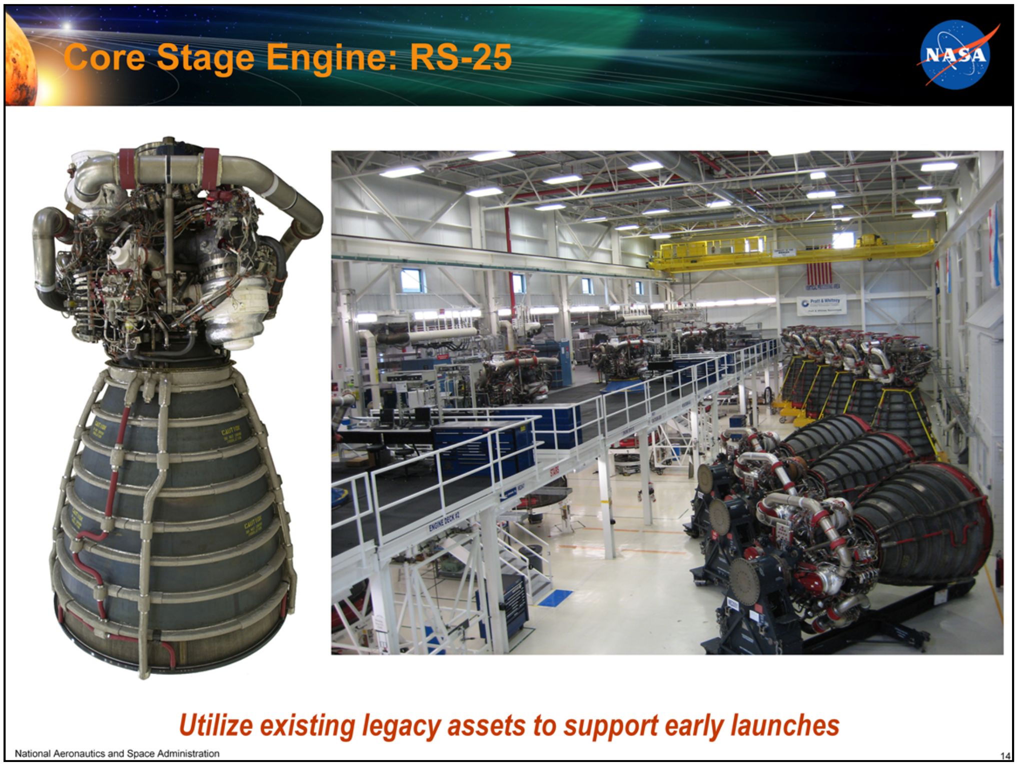
PRESENTER NOTES:

The 70 metric ton version of the SLS will use ATK's five-segment solid rocket boosters, which were originally designed for the Ares launch vehicles. The five-segment SRB has now undergone three full-duration static tests, the most recent being September 8. A flight qualification static test is scheduled for spring 2013.

In Sep 2011, a full-scale static firing test was successfully conducted for Development Motor 3, the largest and most powerful solid rocket motor ever designed. This five-segment solid rocket motor is designed to produce up to 3.6 million lb of thrust at liftoff, about 30 percent more power than its four-segment predecessor.

This is highly visible evidence of forward progress.

It also means that our development curve is flatter because we are taking advantage of development work done to date.



PRESENTER NOTES:

One of the reasons we have confidence in our path forward is that we are using proven hardware and available assets.

SLS has received 17 Space Shuttle Main Engines (15 flight engines, 2 development engines), which will be used to power the core stage.

A future versions of the RS-25, the RS-25E, could be designed to be expendable, unlike the reusable SSME, reducing future costs

High Performance System

- 492K lbs nominal thrust
- 453 sec Isp (avg. flight derived)

Operational Capability

- ~ 67% to 109% throttle range

Physical Characteristics

- Weight: 7,750 lbs

- Size: 96” D X 168” L

Mature Design, Manufacturing and Operational Knowledge Base

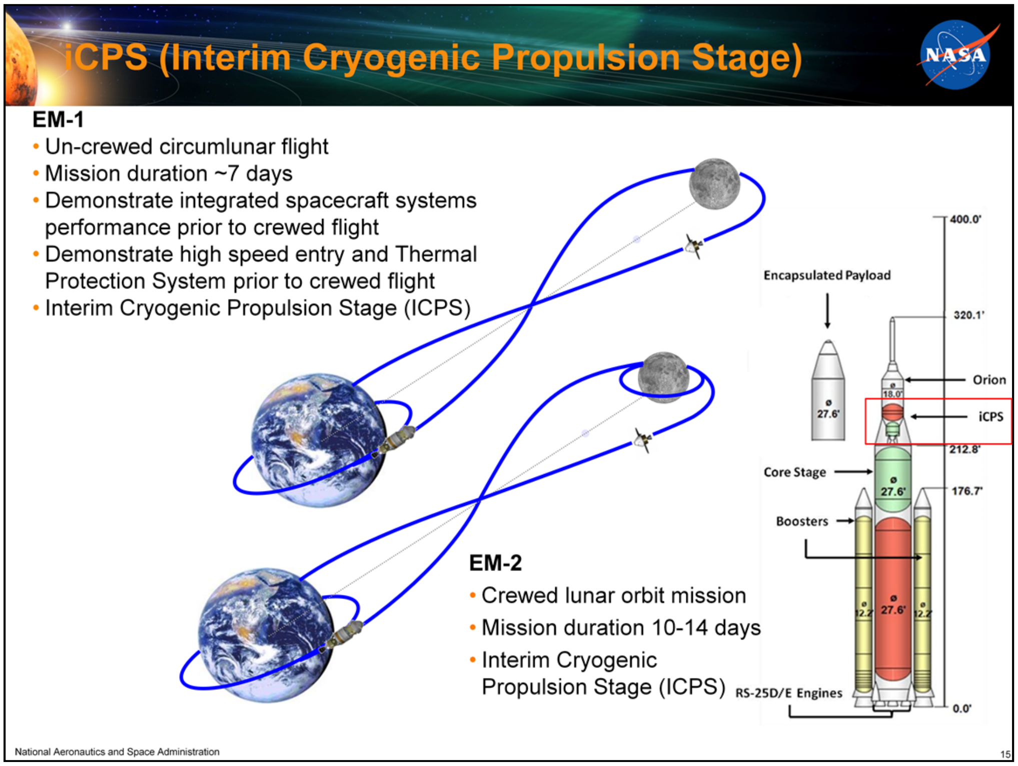
- >1,200,000 sec hot-fire time

Catastrophic Failure Risk

- 1/1956 starts

Human Rated per Shuttle Program Requirements

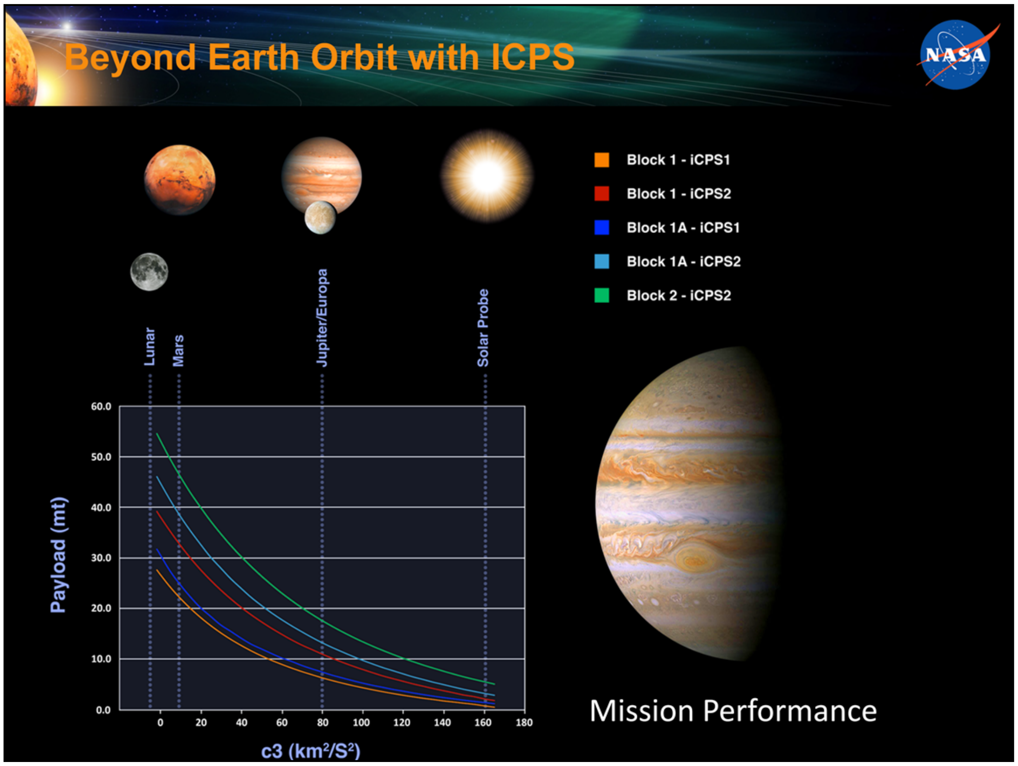
Significant U.S. Investment in SSME capabilities



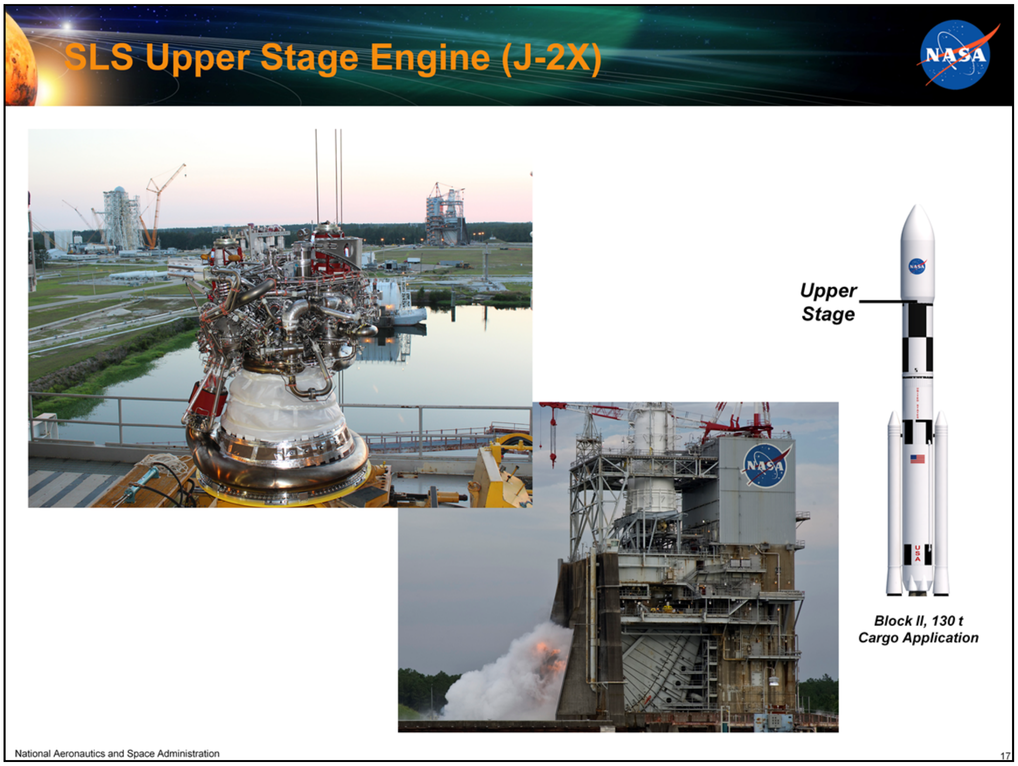
PRESENTER NOTES:

Currently, we are getting ready for the SLS system requirements and system definition review.

- In 2017, we will be on the launch pad and this will be our first mission. Exploration Mission 1 is slated for 2017 and EM 2 for 2021.
- In 2021, we plan to fly EM-2 on a similar mission with a crew aboard Orion.
- Exploration Missions (EM) 1 & 2 on the Block 1 SLS uses the iCPS, sometimes called “kick stage”
- iCPS is intended to be an existing stage with minor modifications
- iCPS does not have the full capability of the CPS
- SLS has issued an announcement for sources to meet the iCPS requirement



ICPS provides flexibility for exploration capabilities to multiple destinations beyond Earth orbit



PRESENTER NOTES:

The SLS plan calls for a series of block upgrades.

SLS Block 2 includes the SLS upper stage, powered by the J-2X engine

SLS upper stage is a large, high thrust stage required to increase the SLS capability to 130 t to LEO

For affordability, initial design work is funded for the Upper Stage to ensure commonality with the Core Stage

Due to funding, full-scale development of the Upper Stage is not currently planned in the SLS near-term budget

However, testing of the J-2X development engines is continuing at Stennis Space Center

BART: ADD J-2X TESTING SLIDE WITH NOTES FROM LATEST ALL-HANDS MEETING. ADD A J-2X TEST SHOT AND AN RS-25 MOVING SHOT. ADD YOUR SLS BENEFITS FROM EFT-1 TO TALKING POINTS.

PRESENTER NOTES:

SPIO: Signed bilateral exchange agreement (BEA) to provide an MPCV stage adapter (MSA) to be used during Orion's Exploration Test Flight 1 in 2014. Now preparing to begin fabricating the MSA in-house.

Boosters: Conducted Flight Control Test 1 for avionics at ATK on March 28 and a subscale solid rocket motor (SRM) test to evaluate nozzle liner insulation material at Marshall on March 14.

Core Stage: We have 15 RS-25 Space Shuttle Main Engines (SSMEs) ready to go and 2 additional test engines. Each RS-25 is capable of producing nearly 400,000 pounds of thrust at liftoff. They are engineered to burn liquid hydrogen and liquid oxygen, creating exhaust composed primarily of water vapor.

Upper Stage: On Feb 15, the J-2X upper stage engine Powerpack Assembly-1 (PPA-1) test was successfully completed at the Stennis Space Center (SSC). This was the first of a 10-test series that will take place on the A1 test stand. Data evaluation has been completed and all test objectives were achieved. The first J-2X nozzle extension is being shipped to SSC after completing emissivity coating application for testing in the A-2 test stand.

PRESENTER NOTES:

- Please visit our website for SLS news, images, and animation.

- *Thank audience for their attention and open the floor for questions.*