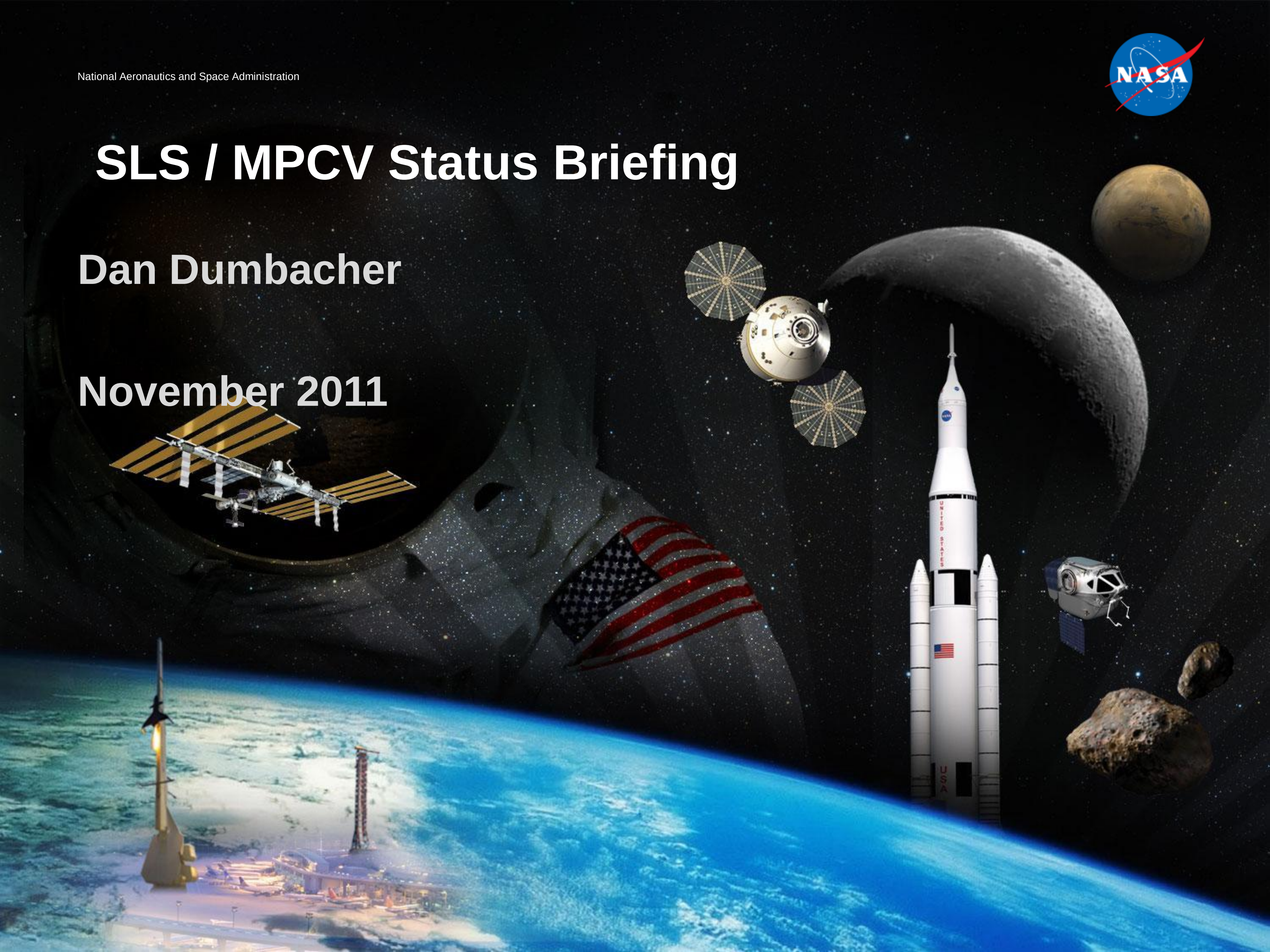
National Aeronautics and Space Administration

SLS / MPCV Status Briefing

Dan Dumbacher

November 2011



Topics

- **Review of Previous NAC Briefing**
- **Orion/MPCV Overview**
- **SLS Overview**
- **System Overview**
- **Independent Cost Analysis Findings**
- **Forward Work**

Review

Review from August 2 NAC Briefing

- **Background**
  - NASA Authorization Act 2010
  - Possible Destinations
  - Capability Driven Architecture

- **Overall Strategy to Achieve Integrated SLS/MPCV Plan**
  - Planning Activities
  - Guidance for SLS and MPCV from Authorization Act
  - Independent Cost Assessment

- **MPCV Decision**
  - Functional Requirements
  - Key Decision to use Orion

Review from August 2 NAC Briefing (cont)

- **SLS Alternatives**
  - Analysis Approach
  - RAC Study Results
  - SLS Concepts SLS/MPCV

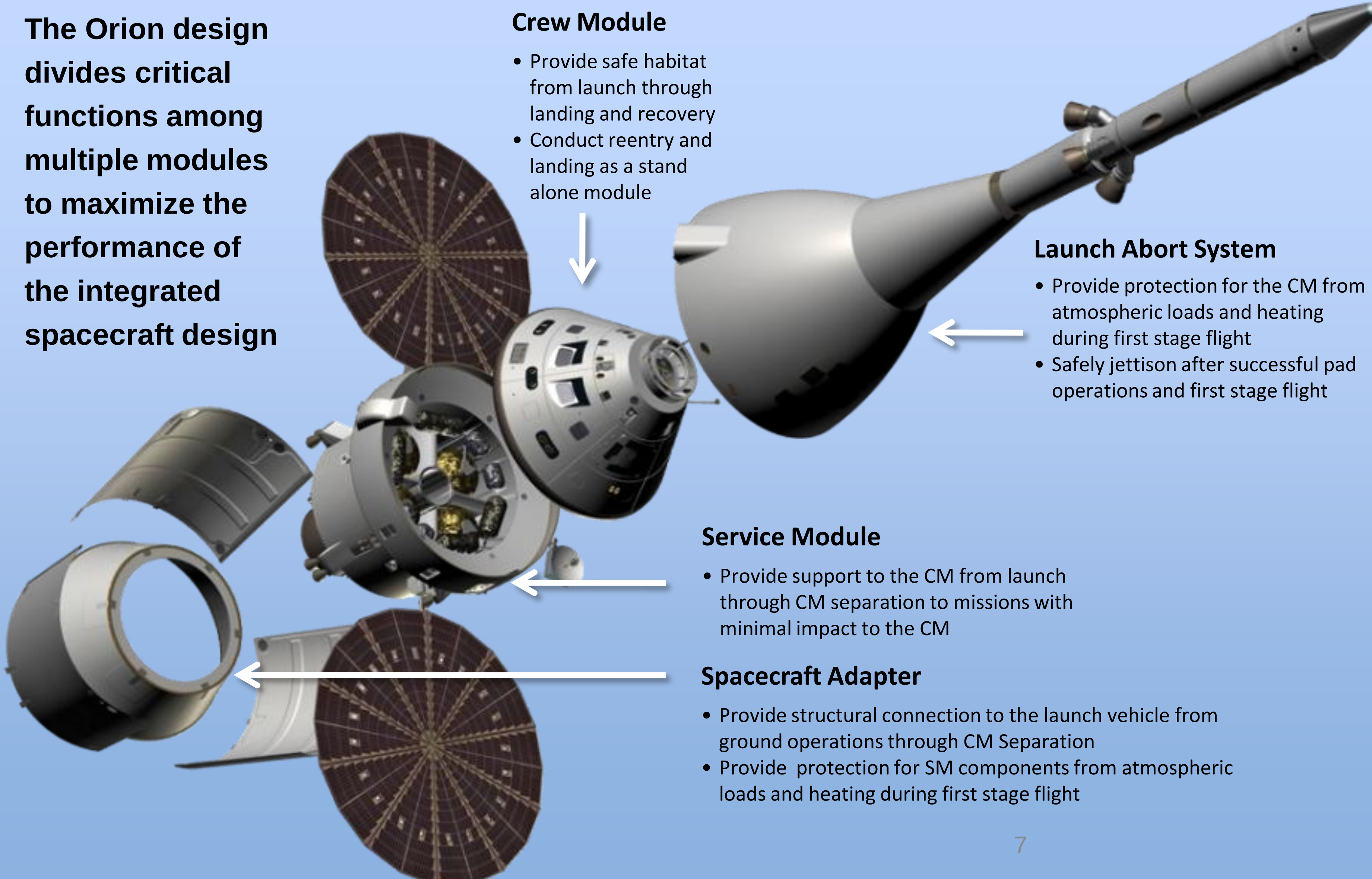
- **Integrated Analysis Process**
  - Trade Study and Attributes; Importance of Affordability
  - Current status of SLS to use common LoX/H2 propulsion for core and upper stages; evaluate existing engines, boosters, procurement strategies and contracts

MPCV/Orion Overview

Announced May 24

Orion Overview

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

Orion Program Status

The Orion Program provides the spacecraft that will serve as the primary crew vehicle for missions beyond low Earth orbit (BEO)

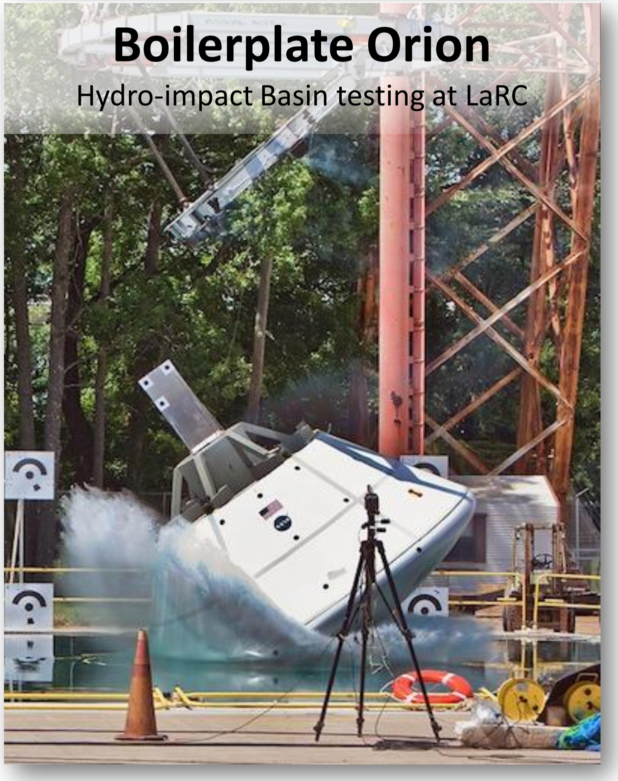
Orion Program Objectives

- Sustain four crew during space travel and provide safe re-entry from deep space return velocities
- Provide capability to conduct regular in-space operations (rendezvous, docking, extravehicular activity) in conjunction with payloads delivered by the Space Launch System (SLS)
- Provide emergency abort capability
- Provide capability to be a backup system for International Space Station cargo and crew delivery
- Key Elements include
  - Launch Abort System (LAS)
  - Crew Module
  - Service Module

Schedule

- Flight test in 2013-14, with trade study underway to determine integrated test strategy as part of joint SLS / Orion / 21CGS strategy
  - Option: Orbital Flight Test 1 (EFT-1): December 2013 – Early 2014
  - Option: Ascent Abort Test 2 (AA-2): Early 2014
- Ground Test Article Environmental Correlation Tests (acoustic chamber, vibration tables, etc.) from July 2011 to February 2012 at Denver.

Orion Program Highlights

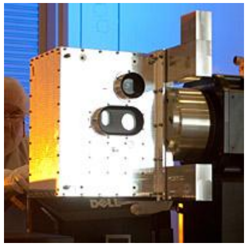


- **Orion testing is underway**
  - Three test articles of increasing fidelity, now with the first welds of the first flight test article
  - Ground test campaign aimed at reducing highest risks addressed by these articles
  - Flight test campaign being developed as part of integrated SLS/Orion/21CGS strategy

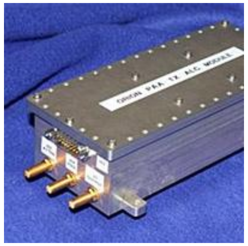
Orion Technology Advancements

Propulsion
Abort Motor, Attitude Control Motor, High Burn Rate Propellant for Solid Rocket Motors
Benefits: High reliability launch abort, steerable solid rocket motors

Avionics
Algorithmic Autocode Generation, ARINC-653/DO-178 Standard Operating System, Baseband Processor, High Speed/High Density Memory Devices, Honeywell HX5000 Northstar ASIC
Benefits: Low cost, high performance, open architecture

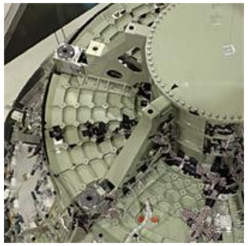


Navigation
Atmospheric Skip Entry, Flash Lidar, Vision Navigation Sensors, Autonomous Rendezvous and Docking, Fast Acquisition GPS Receiver, High Density Camera Sensors
Benefits: Low cost, high reliability, autonomous docking



Communications
Interoperable Communications, Communication Network Router Card, Digital Video Recorder, Phased Array Antennas
Benefits: Low cost, high reliability, open architecture

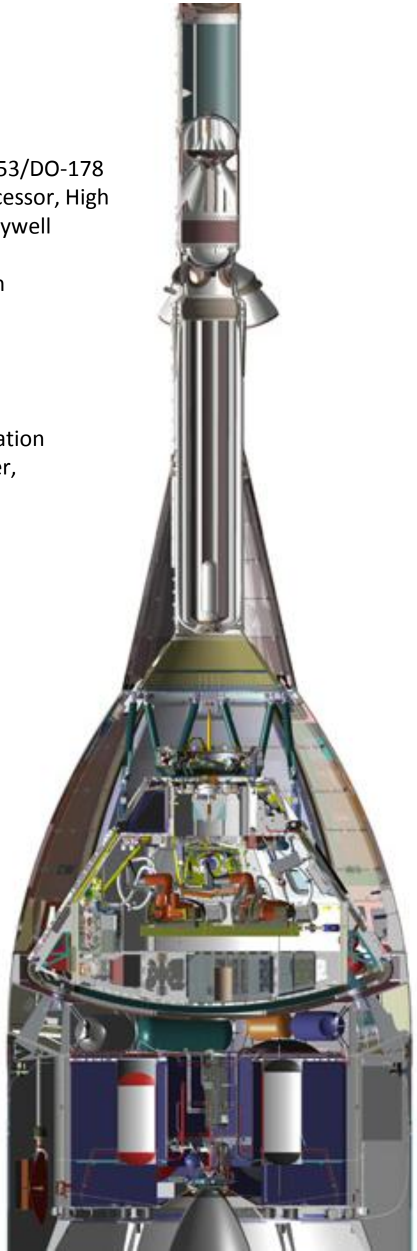
Life Support & Safety
Solid Amine Swing-Bed, Backup and Survival Systems, Closed Loop Life Support, Contingency Land Landing, Enhanced Waste Management, Environmental Control, Hazard Detection, Isolation and Recovery
Benefits: Low consumables, long mission duration, high reliability, low operations cost



Structures
Composite Spacecraft Structures, Human Rated Spacecraft Primary Structures Development, Advanced Manufacturing
Benefits: Low cost, low mass

Thermal Protection System
Ablative Heatshield with Composite Carrier Structure
Benefits: Low cost, high reliability, high energy (Beyond LEO) entry

Power
High Energy Density Lithium Ion Batteries, Column Grid Array Packaging (CGA), Direct Energy Power Transfer System
Benefits: Low cost, high reliability, low mass, long mission duration



Orion Launch Abort System

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.

Orion Center Roles

Ames Research Center

- TPS Advanced Development
- Support for Aero/Aero-thermal, Flight Software, and GN&C
- Mission Operations Tools, Training Applications, and Simulation Capabilities

White Sands Missile Range

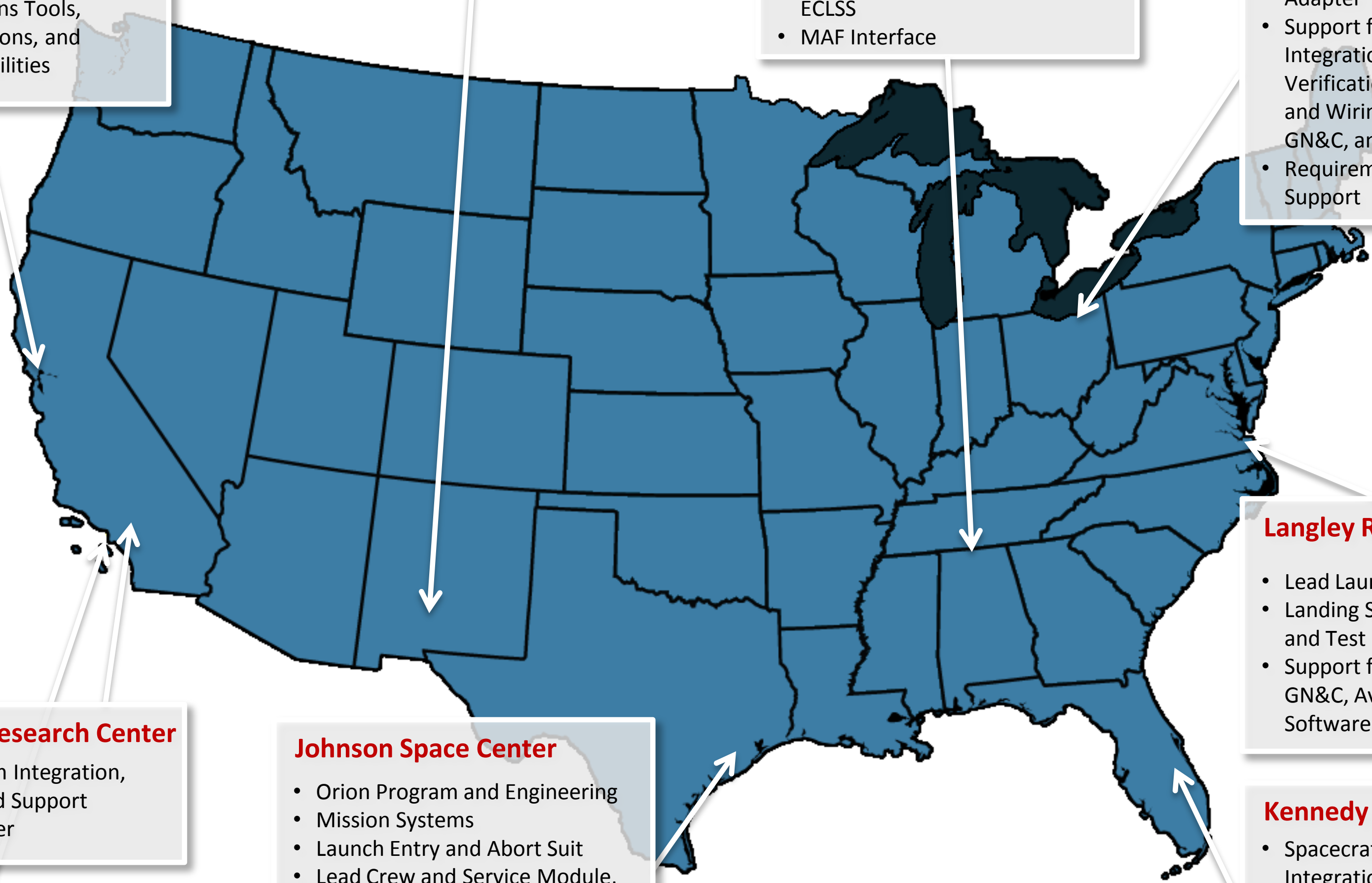
- Materials Testing

Marshall Space Flight Center

- Orion/SLS Integration
- Co-Lead Launch Abort System
- Support for Propulsion and ECLSS
- MAF Interface

Glenn Research Center

- Co-Lead Crew and Service Module and Spacecraft Adapter
- Support for Vehicle Integration, Test and Verification, Avionics, Power and Wiring, Flight Software, GN&C, and EVA
- Requirements and Interface Support



Langley Research Center

- Lead Launch Abort System
- Landing System Development and Test
- Support for Aero/Aero-thermal, GN&C, Avionics, and Flight Software

Dryden Flight Research Center

- Flight Test System Integration, Development and Support
- Abort Test Booster

Johnson Space Center

- Orion Program and Engineering
- Mission Systems
- Launch Entry and Abort Suit
- Lead Crew and Service Module, Vehicle Integration, Flight Tests, GFE
- Crew Habitation and Life Support Systems

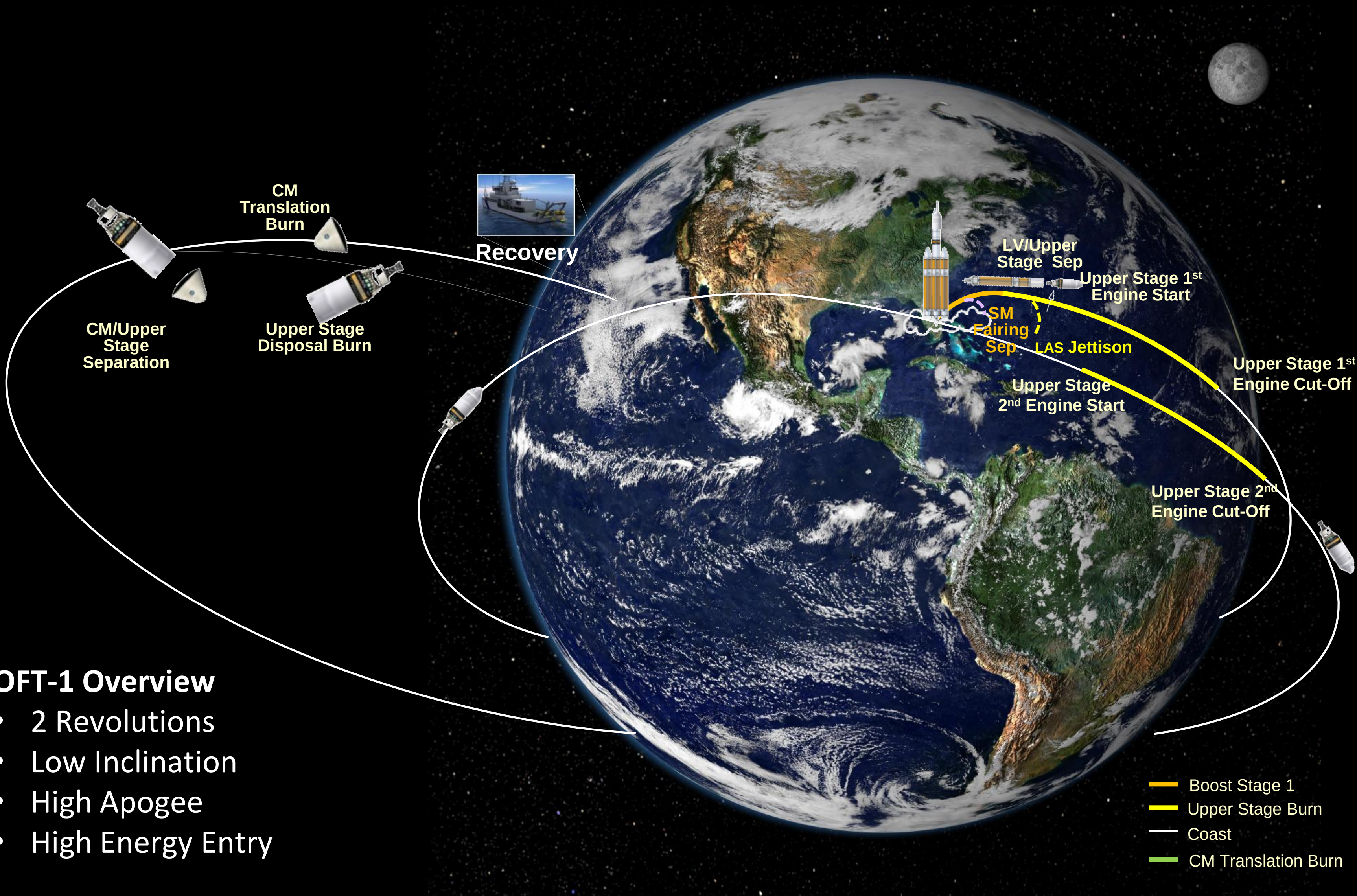
Jet Propulsion Laboratory

- Independent Validation for CPAS and TPS

Kennedy Space Center

- Spacecraft Assembly, Integration and Production
- Ground Processing, Launch, Landing, and Recovery Planning and Operations
- Air Force Eastern Range

Proposed Exploration Flight Test 1



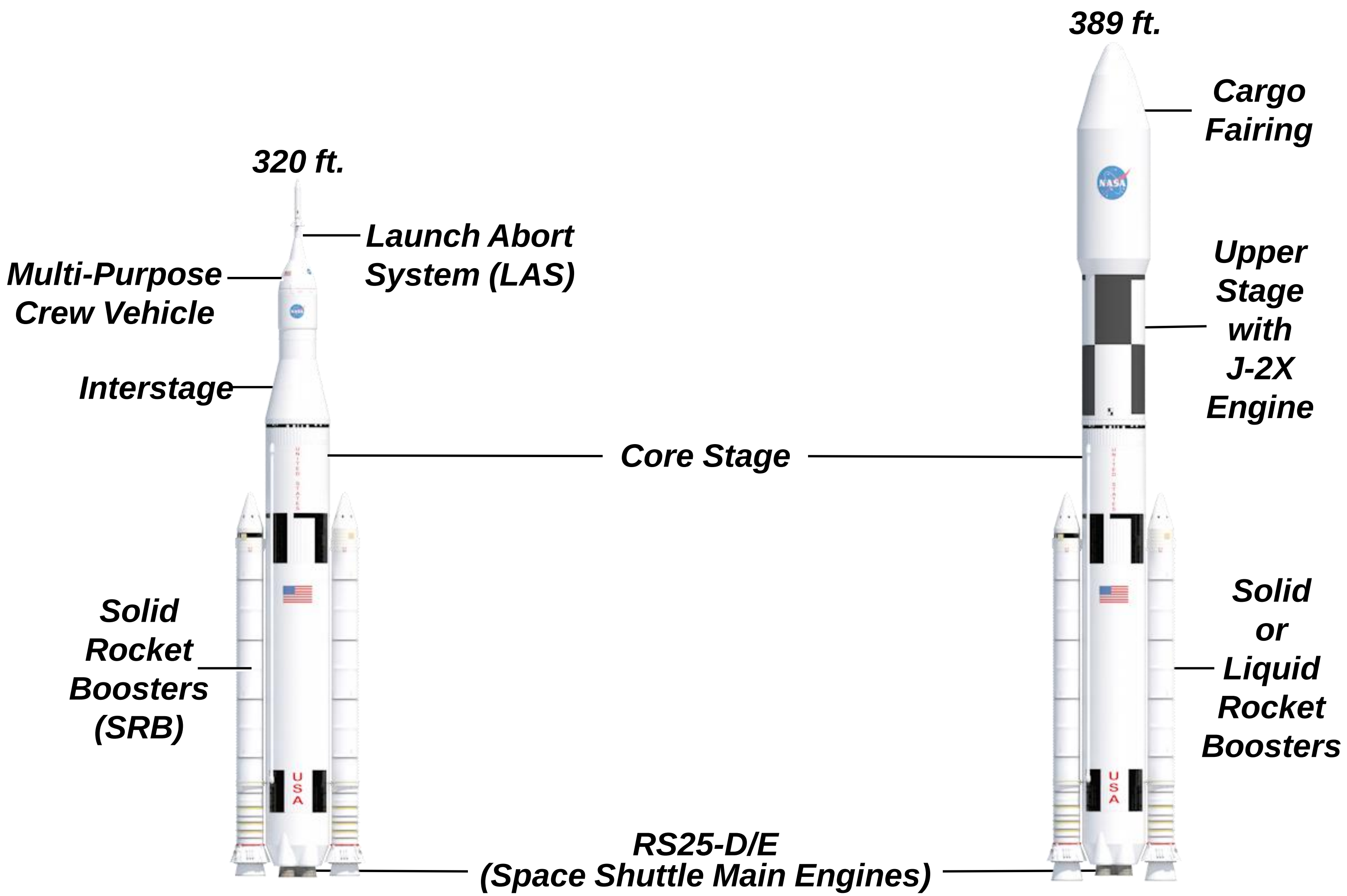
OFT-1 Overview

- 2 Revolutions
- Low Inclination
- High Apogee
- High Energy Entry

SLS Overview

Announced September 14

SLS Program Overview



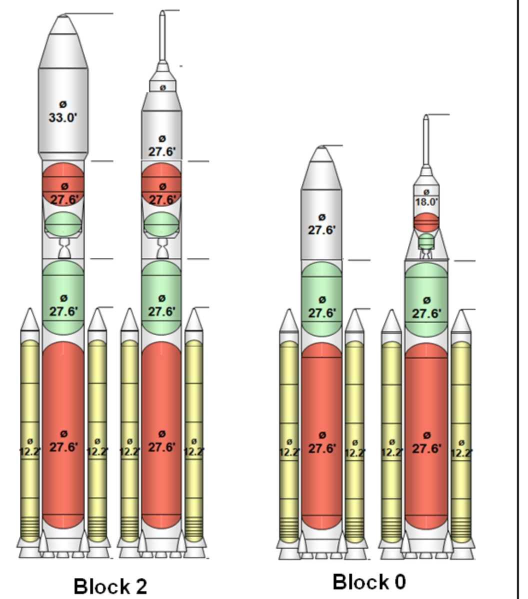
SLS Program Overview

Initial Configuration – 70mt

- Heritage based 27.6' diameter liquid hydrogen (LH) liquid oxygen (LOX) Core Stage
- Three heritage RS-25D Space Shuttle Main Engine (SSME)s initially using remaining SSME inventory (16 engines)
- Two 5-segment Solid Rocket Boosters (SRBs) using heritage polybutadiene acrylonitrile (PBAN) propellant
- Delta IV adaptor
- Delta IV upper stage
- Primary initial payload: Orion

Evolved Configuration – 130mt

- Heritage based 27.6' diameter liquid hydrogen (LH) liquid oxygen (LOX) Core Stage
- Five heritage RS-25Ds or evolved RS-25Es (with upgrades for increased operability and reduced costs)
- Two Advanced Boosters, competitively procured, with propellant(s) TBD
- LH/LOX Upper Stage with 27.6' diameter common to Core Stage
  - Three J-2X-288 engines
- 33' x ~100' Payload Fairing



Block 1 – Replace Solid Rocket Boosters with Advanced Boosters

SLS Program Status:
Highlights and Upcoming Events

- **SLS Highlights**
  - Design Analysis Cycle 1 initiated with defined Point of Departure – Aug. 8th
  - DM-3 Test successfully completed at ATK/ Utah – Sept. 8th
  - Upper Stage J-2X Engine 10001 completed first ground test & removed from Test stand A-2 at SSC – Aug. 25th
  - Stage Element conducted a 100% design review at Michoud Assembly Facility (MAF) - Aug. 25th
  - First stage main chute drop test 4 – Aug. 24th
  - Installation of Vertical Assembly Tool for Friction Stir Welding of barrels in building 4707 at MSFC – Aug.
  - Procurement Strategy Meeting occurred 9/13-15
  - KDP A Approval – Oct. 7th
  - SLS Industry Day – Sept. 29th
  - Continue Upper Stage Engine E10001 engine testing at SSC
  - SRR Checkpoint Review – Oct. 24th

SLS Heritage Hardware and Facilities

J-2X Test Firing/Space Shuttle Main Engine Testing
Stennis Space Center

Payloads
Goddard Space Center

Orion Integration
Johnson Space Center

Composite Structures
Glenn Research Center

Ground and Launch Operations
Kennedy Space Center

Physics Based Analysis
Ames Research Center

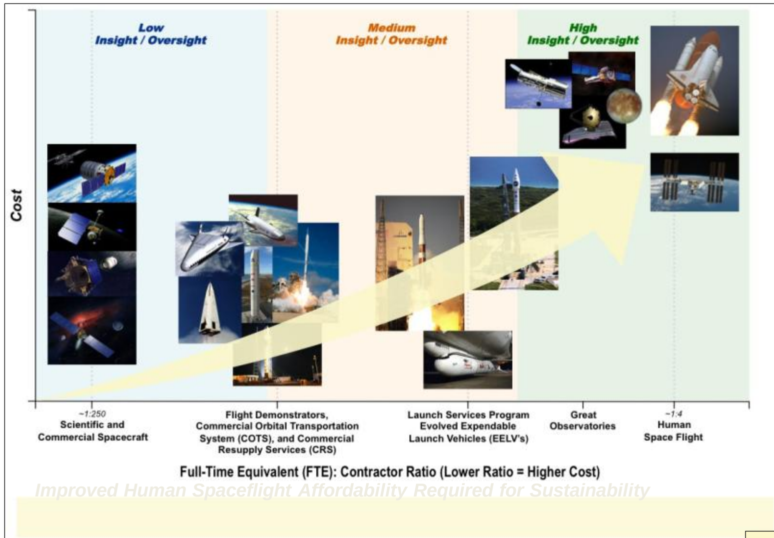
Manufacturing and Transportation
Michoud Assembly Facility

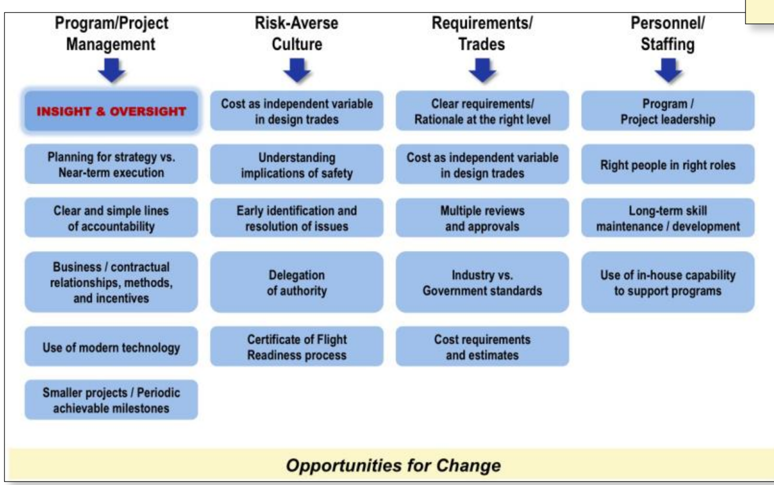
Wind Tunnel Testing
Langley Research Center

Standing Review Team
Jet Propulsion Lab

J-2X Upper Stage Engine Injector Firing
Marshall Space Flight Center

SLS Affordability Tenets





- **Evolvable Development Approach**
  - Manage Within Constrained / Flat Budgets
  - Leverage Existing National Capabilities
  - Infuse New Design Solutions for Affordability
- **Robust Designs and Margins**
  - Performance Traded for Cost and Schedule
- **Risk-Informed Government Insight/ Oversight Model**
  - Insight Based On:
    - Historic Failures
    - Industry Partner Past Performance/Gaps
    - Complexity and Design Challenges
  - Judicious Oversight:
    - Discrete Oversight vs Near Continuous
    - Decisions Made Timely and Effectively
- **Right Sized Documentation and Standards**
  - Reduction in the Number of Program Documents
  - Industry Practices and Tailored NASA Standards
- **Lean, Integrated Teams with Accelerated Decision Making**
  - Simple, Clear Technical Interfaces with Contractor
  - Integrated SE&I Organization
  - Empowered Decision Makers at All Levels

SLS Solid Rocket Testing
Development Motor 3 (DM-3)

- **DM-3 static test conducted September 8**
  - –37 Objectives assessed with 979 instrumentation channels
  - –Propellant Mean Bulk Temperature (PMBT): 90^{0}F
  - –Insulation weight reduced by approximately 1300 lb (compared to DM-2)
  - –Nozzle
    - Composed of ENKA CCP on all components
    - Modified throat contour
    - Modified Aft Exit Cone (AEC)
    - Installation of an AEC severance system for post-test severance

SLS J-2X
50-Second Engine Test

Procurement Status

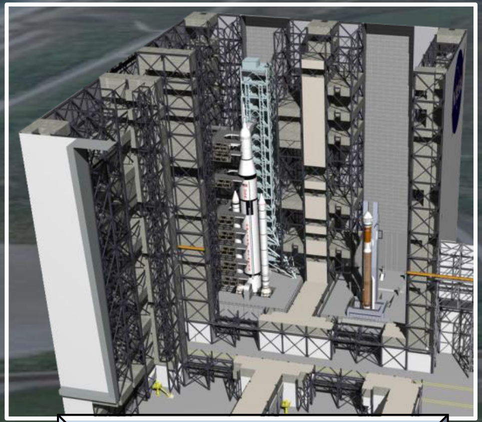
- **SLS Public Announcement on September 14**
- **Synopsis Posted to Federal Business Opportunities on September 22**
  - Boosters – utilization of the five segment Ares First Stage Boosters under the existing contract for the initial flights, the first of which is targeted for the end of 2017
  - Advanced Boosters – to be utilized for missions beyond the initial flights
  - Stages – utilization of the existing Ares Upper Stage contract for the integrated SLS Core Stage and Upper Stage for the initial SLS capability through 2021
  - Avionics – utilization of the existing Ares Instrument Unit Avionics contract for the initial SLS capability through 2021.
  - Engines – for the Core and Upper Stages
    - Core Stage Engine - utilization of the existing inventory of RS-25Ds for the initial SLS capability.
    - Upper Stage Engine – utilization of the existing Ares J-2X development contract
  - Spacecraft and Payload Adaptors, and Payload Fairing– initial in-house design efforts followed by competitive acquisitions beginning in the 2013 timeframe
  - Advanced development - a combination of in-house tasks and competitive opportunities for industry and academia beginning in 2012
  - Systems Engineering and Integration – NASA led at least through SLS critical design review (CDR) in 2014
- **Industry Day at Marshall Space Flight Center on September 29**

21st Century Ground Systems Overview

Horizontal Launch & Landing

Clean Floor Processing

Small Vehicle Launch



Multi-Use Integration (VAB)

Flexible Launch Capability

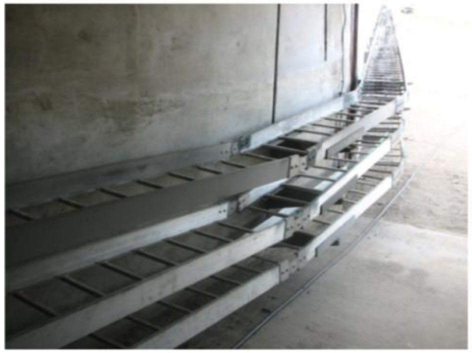
Heavy Class Launch Capability

Flexible Approach

Pad 39B Modifications – Before and After

- Demolished FSS/RSS
- Installed Lightning Protection

- Cable trays repaired and replaced



- Shuttle instrumentation racks removed
- Weather instrumentation racks installed

Mobile Launcher Construction - Before and After

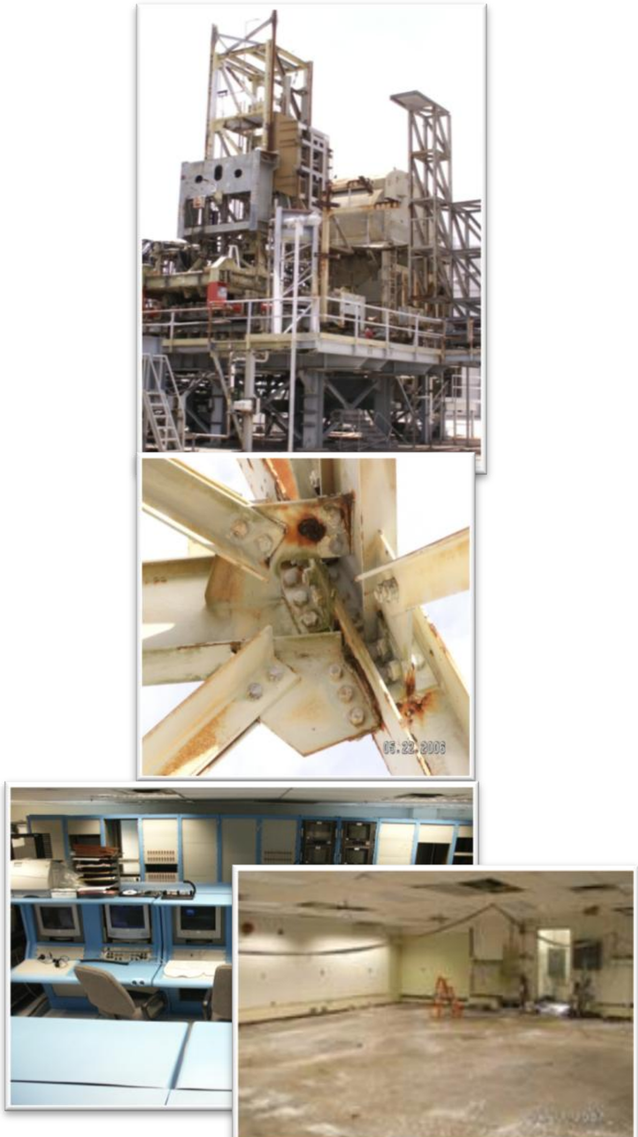
Launch Control Center – Firing Room 1 Before and After

Apollo Program

Space Shuttle Program

21st Century Ground Systems Program

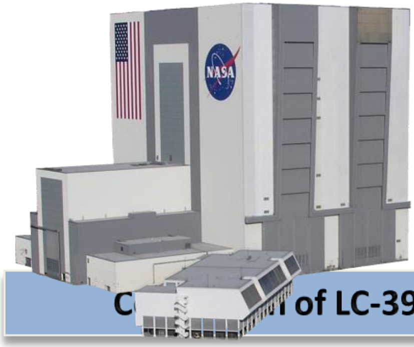
Launch Equipment Test Facility Modifications Before and After



- **Vehicle Motion Simulator**
- **Tower Refurbishments**
- **Control Room Refurbishments**

21st CGSP Planned Project Investments

Convert CxP Mobile Launcher for SLS

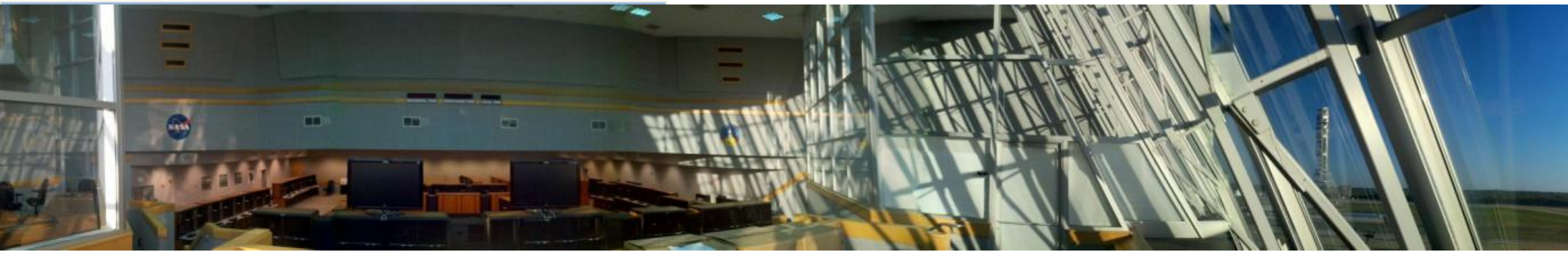


C… of LC-39 to support SLS and commercial use

Modernize Range Infrastructure

Convert MPPF fo… PCV and commercial use

…F for horizontal launch and landing



System Overview

Transitioning to Exploration System Development

Ares Project

Shuttle Program

Orion Project

Mission Operations Project

Extravehicular Systems Project

Ground Operations Project

SPACE LAUNCH SYSTEM (SLS) PROGRAM

- Heavy Lift Launch Vehicle with an initial lift capability of 70-100mt evolvable to the ultimate capability of130mt
- Primarily derived from legacy hardware
- Capability to lift Orion
- Capability to back up International Space Station (ISS) commercial crew and cargo delivery
- Ultimate missions beyond low-Earth orbit (BEO)

HOST CENTER: Marshall Space Flight Center, Alabama

ORION PROGRAM

- Serves as the primary crew vehicle for missions beyond low Earth orbit (BEO)
- Capable of conducting regular in-space operations (rendezvous, docking, extravehicular activity) in conjunction with payloads delivered by SLS for missions beyond LEO
- Capability to be a backup system for ISS cargo and crew delivery

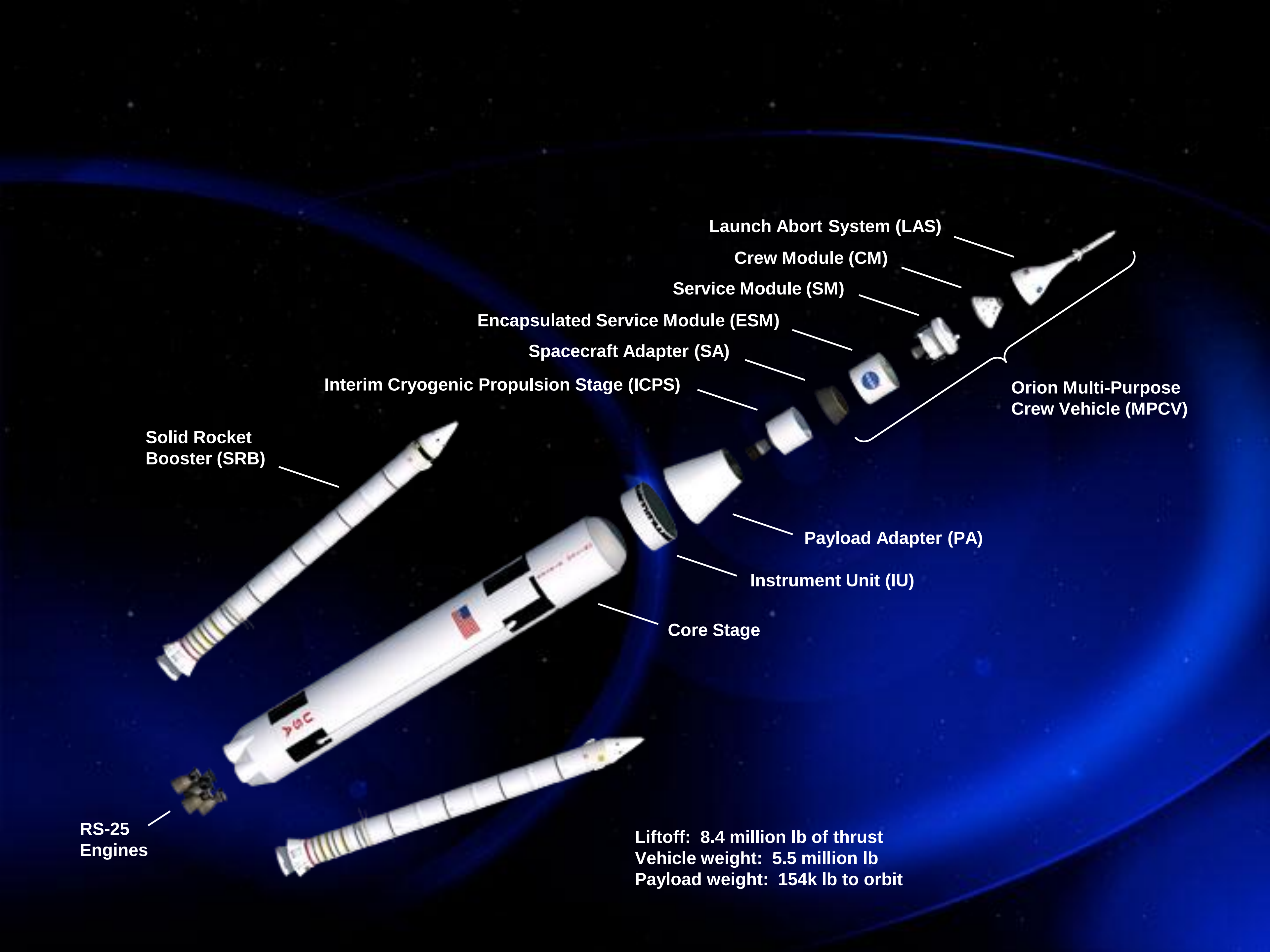
HOST CENTER: Johnson Space Center, Texas

21st CENTURY GROUND SYSTEMS PROGRAM

- ,Capability to perform SLS and Orion flight hardware processing, .testing, launch operations, crew recovery, and Orion recovery.

HOST CENTER: Kennedy Space Center, Florida

Beginning With Available Resources and Technologies

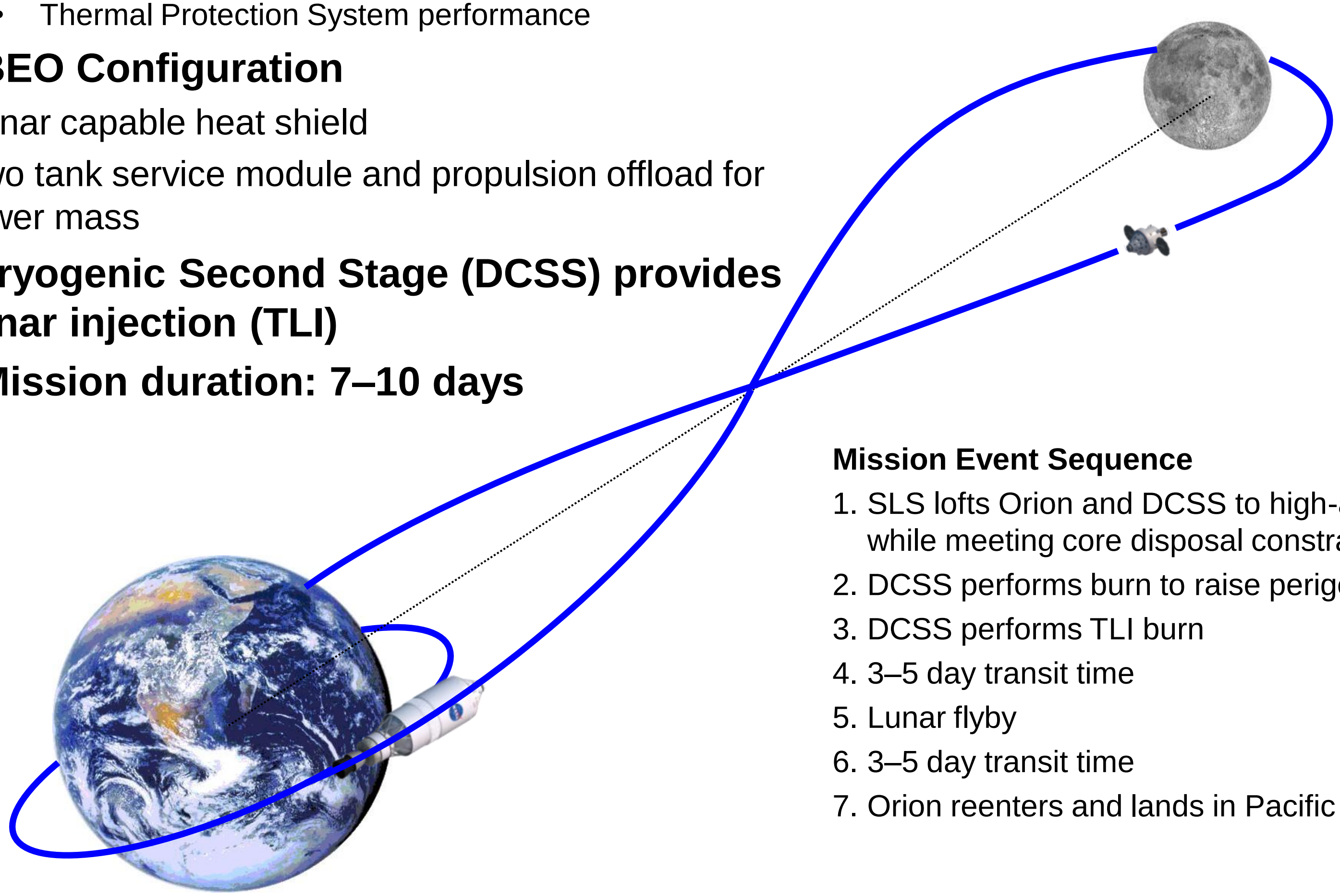


Launch Abort System (LAS)
Crew Module (CM)
Service Module (SM)
Encapsulated Service Module (ESM)
Spacecraft Adapter (SA)
Interim Cryogenic Propulsion Stage (ICPS)
Orion Multi-Purpose
Crew Vehicle (MPCV)
Solid Rocket
Booster (SRB)
Payload Adapter (PA)
Instrument Unit (IU)
Core Stage
RS-25
Engines
Liftoff: 8.4 million lb of thrust
Vehicle weight: 5.5 million lb
Payload weight: 154k lb to orbit

SLS Notional Mission Design

for First Flight in 2017

- **Objectives**
  - Demonstrate spacecraft systems performance prior to crewed flight
    - High-speed entry (~11 km/s)
    - Thermal Protection System performance
- **Orion BEO Configuration**
  - Lunar capable heat shield
  - Two tank service module and propulsion offload for lower mass
- **Delta Cryogenic Second Stage (DCSS) provides trans-lunar injection (TLI)**
- **Orion Mission duration: 7–10 days**



Mission Event Sequence

1. SLS lofts Orion and DCSS to high-apogee orbit while meeting core disposal constraints
2. DCSS performs burn to raise perigee to safe height
3. DCSS performs TLI burn
4. 3–5 day transit time
5. Lunar flyby
6. 3–5 day transit time
7. Orion reenters and lands in Pacific ocean

ICA Findings

Independent Cost Assessment (ICA) Status

Tracking Number	ICA Finding	Description of Specific Findings	NASA Response / Action	Target Completion
1	Reserves	ICA report noted there were insufficient reserves to cover BAH-identified project scenarios/risks	ESD and/or programs will meter resources for elements with lower priority to provide resources elsewhere when needed and ensure sufficient reserves are available	ongoing
2	New Inflation tables	Programs did not use most recent NASA New Start Inflation tables in their estimates	Update to current inflation tables; issue as part of the HEOMD PPBE 14 guidance	January 2012
3a	Standard WBS	ICA report noted that estimates were not aligned to standardized Cost Element Structure	Programs to develop lower level WBS elements, aligned to IMS for each program	1st Qtr FY 2012
3b		ICA report noted that the lack of standardized CES/WBS made it difficult to map the cost estimate to a schedule	HQ working to move programs to standardized CES/WBS	1st Qtr FY 2012
4a	Life Cycle Costs	Program cost estimation was shaped to fit the flat-line budget approach of FY2012 PBR. ICA report recommended that NASA initiate a full program life cycle cost estimate immediately upon approval of SLS architecture.	In the near-term, NASA has performed cost analyses of several budget scenarios that represent different fiscal environments. These were developed in parallel with the ICA, and have been presented to NASA management and OMB/OSTP. See item 4c for longer term action on completion of an ICE.	Complete
4b		The ICA report recommended establishing a common practice across Programs for generating cost and schedule estimates once the SLS architecture has been approved.	NASA will incorporate the ICA findings into the FY2014 PPBE budget formulation process.	February 2012
4c		The ICA report recommended an independent cost estimate once the SLS architecture has been approved.	NASA will develop a plan and associated milestones for performing an ICE in accordance with NASA's policy for Program management, likely associated with KDP-C	February 2013

Independent Cost Assessment (ICA) Status (cont.)

Tracking Number	ICA Finding	Description of Specific Findings	NASA Response / Action	Target Completion
5	Adjustments +/-5%	The ICA report pointed out several areas in which aggressive cost savings assumptions were used, as Programs have been encouraged to explore new management paths to reduce costs and be affordable. The report recommends that the justifications for significant savings projections be properly documented, and if not sufficient to support the assumption, program reserve postures be adjusted to reflect the increased risk.	Programs are continuing to identify/substantiate opportunities for savings. Program estimates will be updated, refined, and properly documented as part of the PPBE14 data call. It will address the affordability challenges, and properly document the approaches and basis of estimate.	June 2012
6	Integrated Schedules	The ICA report stressed the need for an integrated schedule across the three Programs.	NASA has established a program-to-program schedules working group to develop, maintain, and provide configuration control of the IMS. NASA's analysis and assessment of the IMS will be implemented in the first half of FY 2012.	February 2012
7	Quantitative Risk / Sensitivity Analysis	The ICA report recommends a quantitative risk / sensitivity analysis be performed on all three Programs in conjunction with their full-scale life-cycle cost estimates and that reserves positions be established based on risk analysis findings.	Each Program will establish an initial quantitative risk analysis (QRA)/sensitivity analysis based on significant risk scenarios. This analysis will be updated and refined throughout the normal project maturation process and PPBE planning process.	May 2012

Forward Work

In Progress

- **Report to Congress required in Section 309 of the Authorization Act of 2010 is in the Agency concurrence cycle.**
- **Formulation Authorization Documents for SLS/MPCV and 21CGS are ready for signature**
- **Cross-Program System Requirements Review to take place Nov. 2-3**

ESD 18 Month Look-Ahead