National Aeronautics and Space Administration

SLS/MPCV/21CGS Status

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Topics

- Cross Program Integrated Plan
- Orion/MPCV Overview
- SLS Overview
- 21st Century Ground Systems Overview

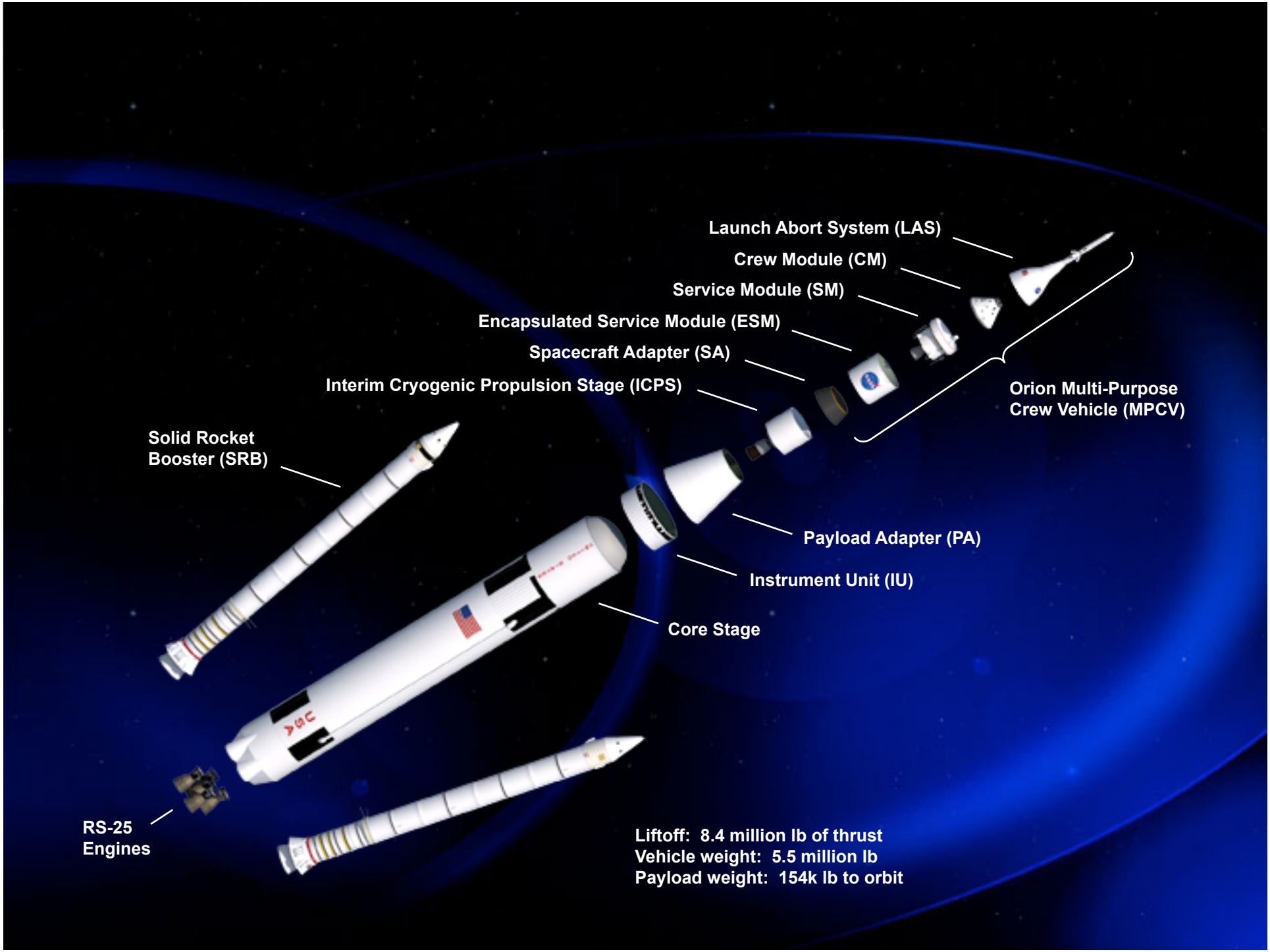
Cross Program Integrated Plan

Human Spaceflight Portfolio

The diversified portfolio of activities in human spaceflight are designed to maximize our use of current capabilities such as the International Space Station (ISS), execute innovative approaches to ensure U.S. leadership in low Earth orbit (LEO), and position the Agency to explore the frontiers of the inner solar system:

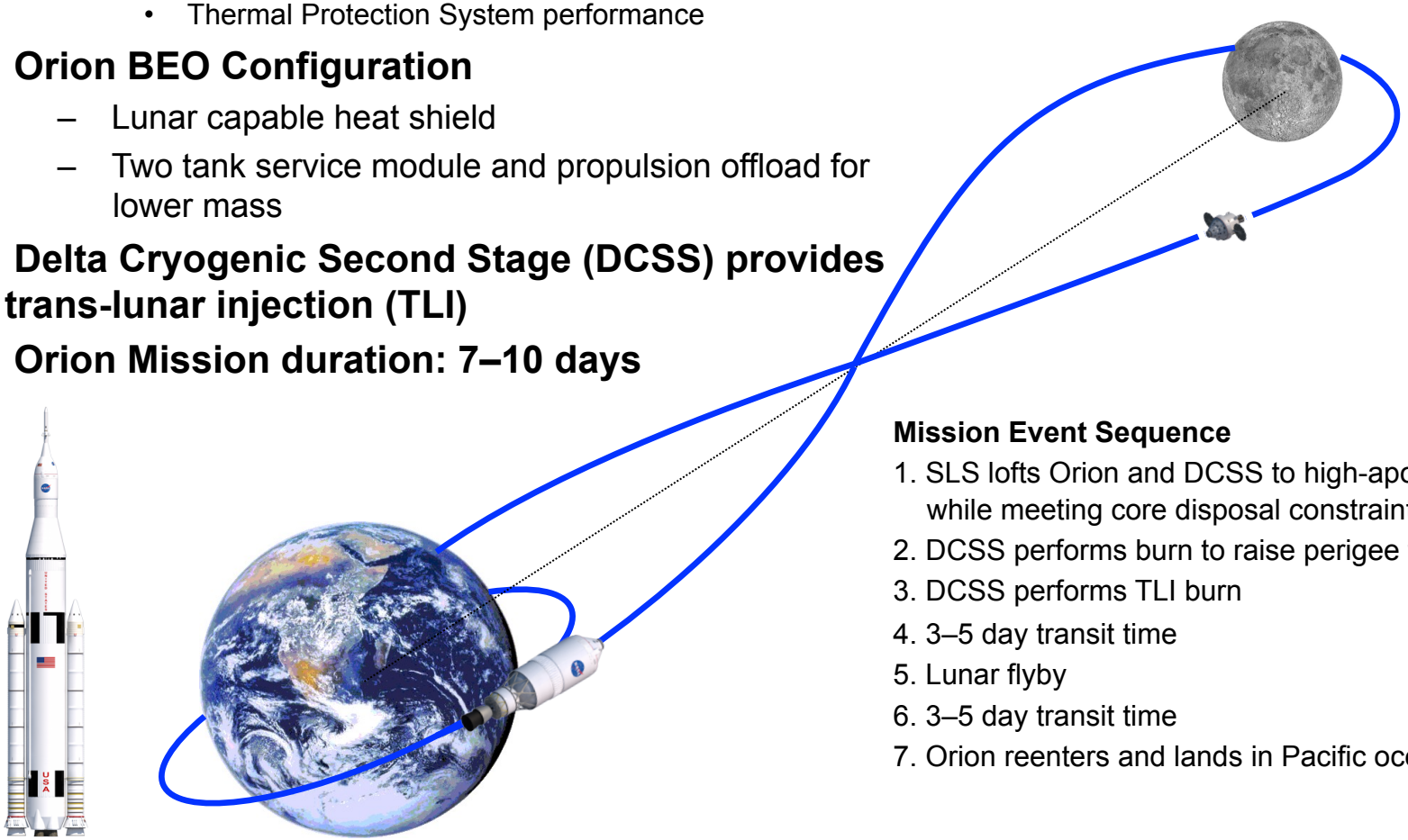
- Enables substantial partnership with the commercial space industry to provide safe and cost effective human access to LEO
- Develops key systems for exploration through the Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV) capable of traveling to multiple destinations beyond LEO
- Pursuing cutting edge human research and innovative development of needed life support, crew habitat and other future exploration capabilities
- Leveraging the best of NASA, industry, academia, and partner capabilities while planning innovative, cost-effective approaches to development and future operations

Capability Driven Approach


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

Notional 2017 Mission

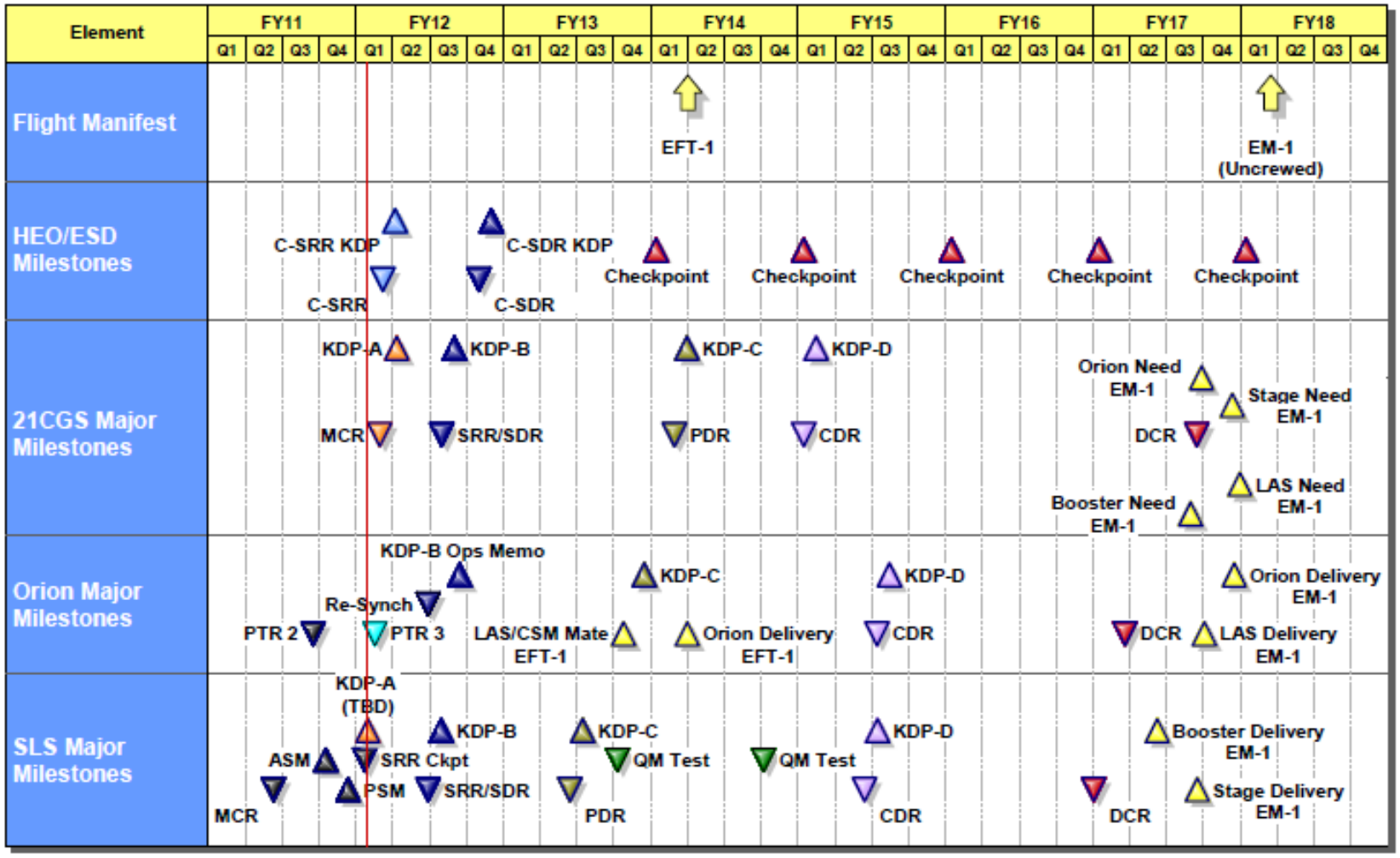
- **Objectives**
  - Demonstrate spacecraft systems performance prior to crewed flight
    - High-speed entry (~11 km/s)
    - Thermal Protection System performance
- **Orion BEO Configuration**
  - Lunar capable heat shield
  - Two tank service module and propulsion offload for lower mass
- **Delta 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

ESD Summary Milestone Schedule



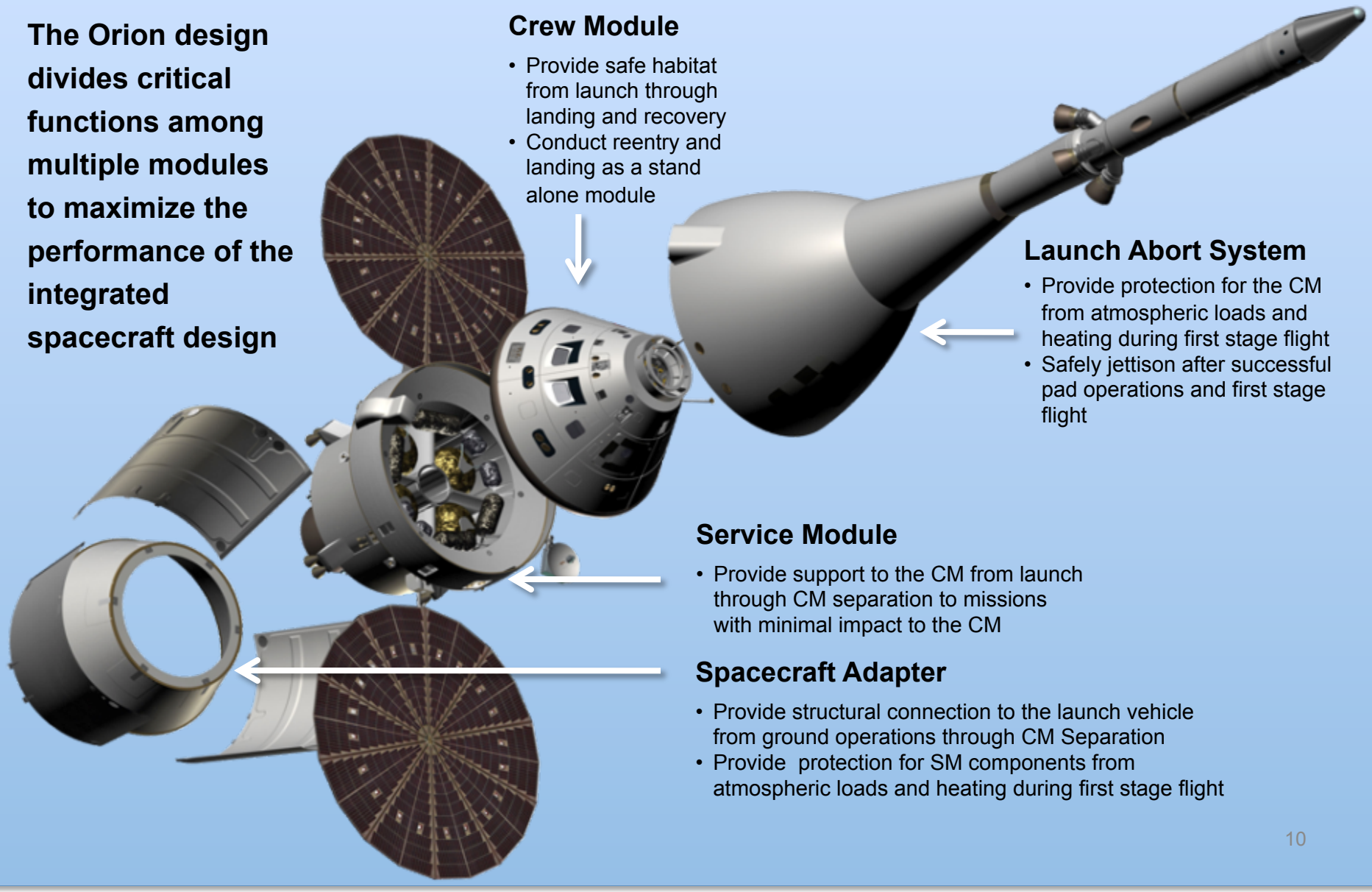
KDP - Key Decision Point
C – Cross Program
CDR – Critical Design Review
DCR – Design Certification Review
MCR – Mission Concept Review
PDR – Preliminary Design Review
PTR – Program Technical Review
SDR – System Definition Review
SRR – System Requirements Review

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

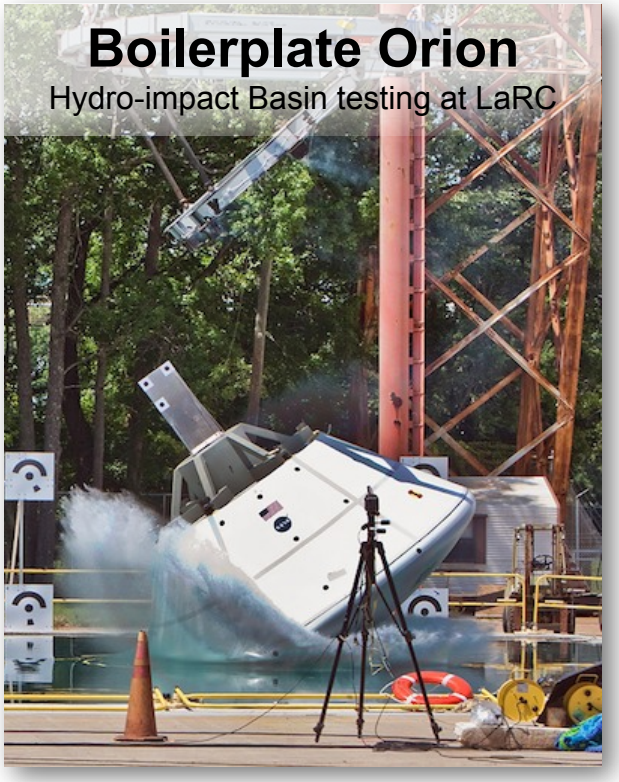
Service Module

- 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 Highlights



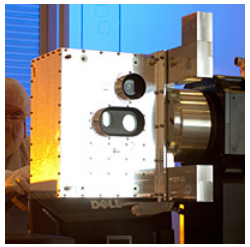
- **Orion testing is underway**
  - Three test articles of increasing fidelity, now with the first welds of the first flight test article
  - Ground test campaign aimed at reducing highest risks addressed by these articles
  - Flight test campaign being developed as part of integrated SLS/Orion/21CGS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

Orion Technology Advancements

Propulsion

Abort Motor, Attitude Control Motor, High Burn Rate Propellant for Solid Rocket Motors

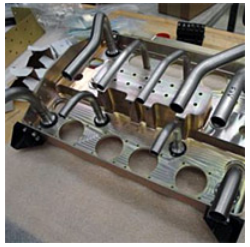
Benefits: High reliability launch abort, steerable solid rocket motors



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



Life Support & Safety

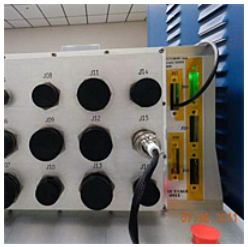
Solid Amine Swing-Bed, Backup and Survival Systems, Closed Loop Life Support, Contingency Land Landing, Enhanced Waste Management, Environmental Control, Hazard Detection, Isolation and Recovery

Benefits: Low consumables, long mission duration, high reliability, low operations cost

Thermal Protection System

Ablative Heatshield with Composite Carrier Structure

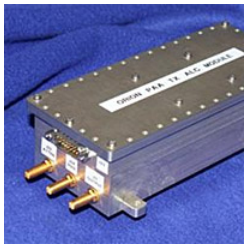
Benefits: Low cost, high reliability, high energy (Beyond LEO) entry



Avionics

Algorithmic Autocode Generation, ARINC-653/ DO-178 Standard Operating System, Baseband Processor, High Speed/High Density Memory Devices, Honeywell HX5000 Northstar ASIC

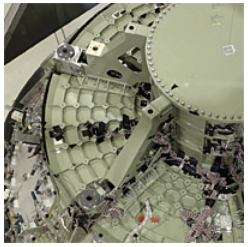
Benefits: Low cost, high performance, open architecture



Communications

Interoperable Communications, Communication Network Router Card, Digital Video Recorder, Phased Array Antennas

Benefits: Low cost, high reliability, open architecture



Structures

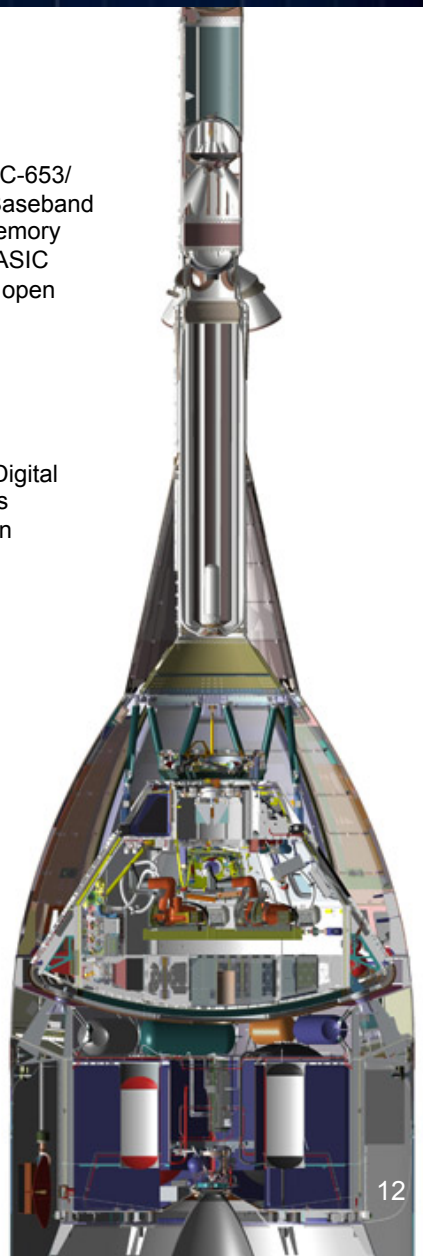
Composite Spacecraft Structures, Human Rated Spacecraft Primary Structures Development, Advanced Manufacturing

Benefits: Low cost, low mass

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



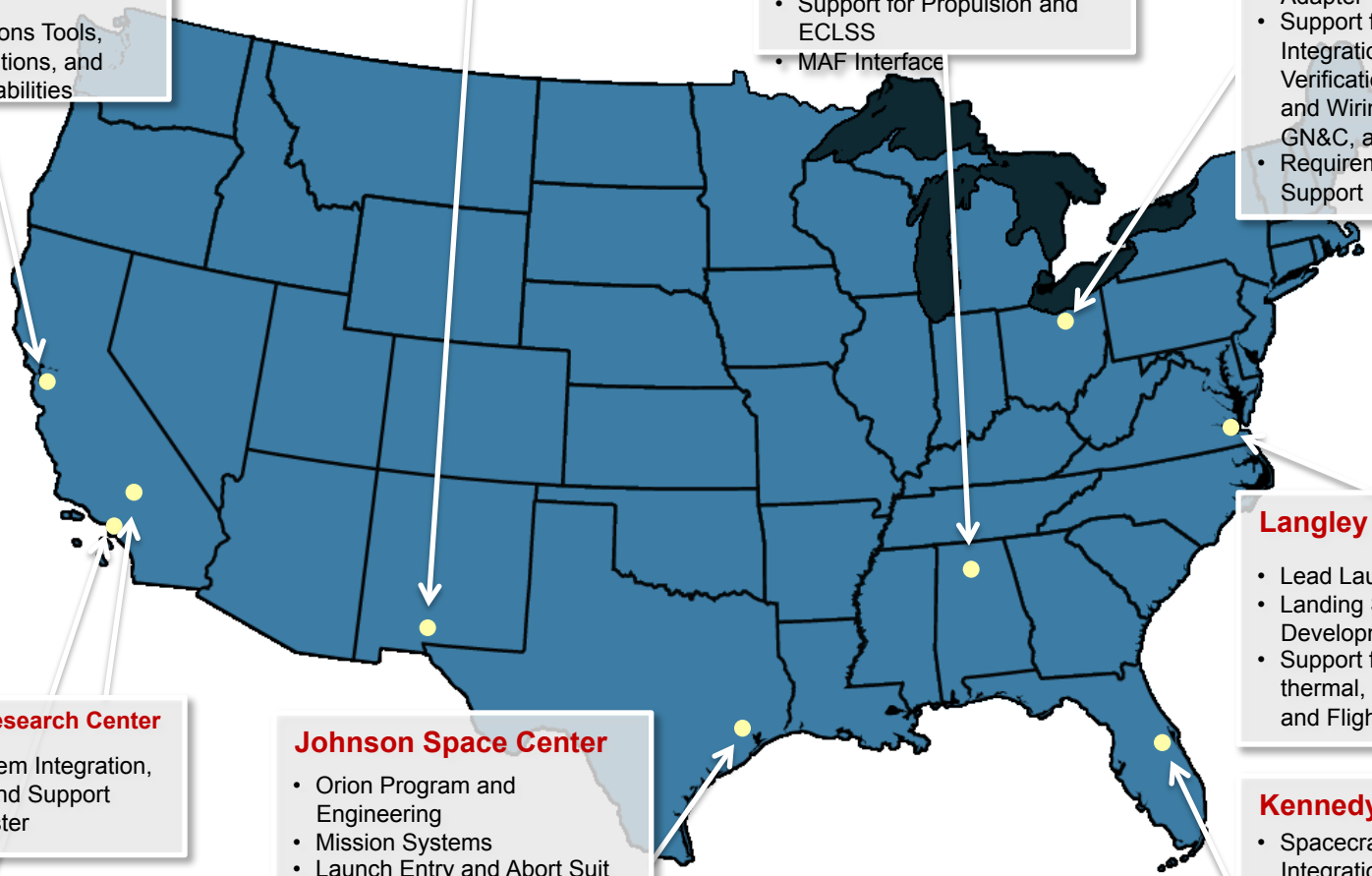
Orion Launch Abort System

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

Jet Propulsion Laboratory

- Independent Validation for CPAS and TPS

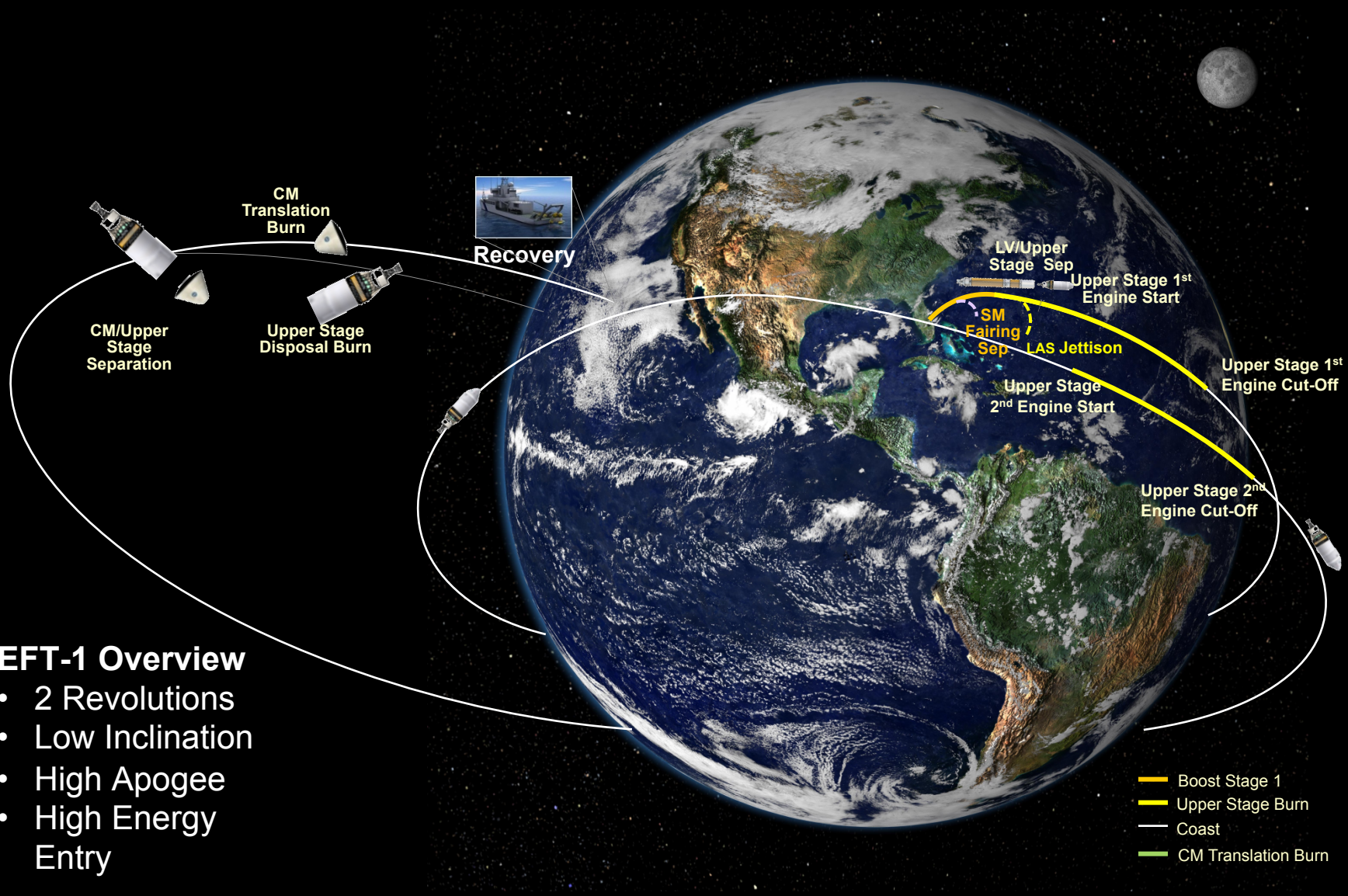
Johnson Space Center

- 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

Kennedy Space Center

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

Exploration Flight Test 1



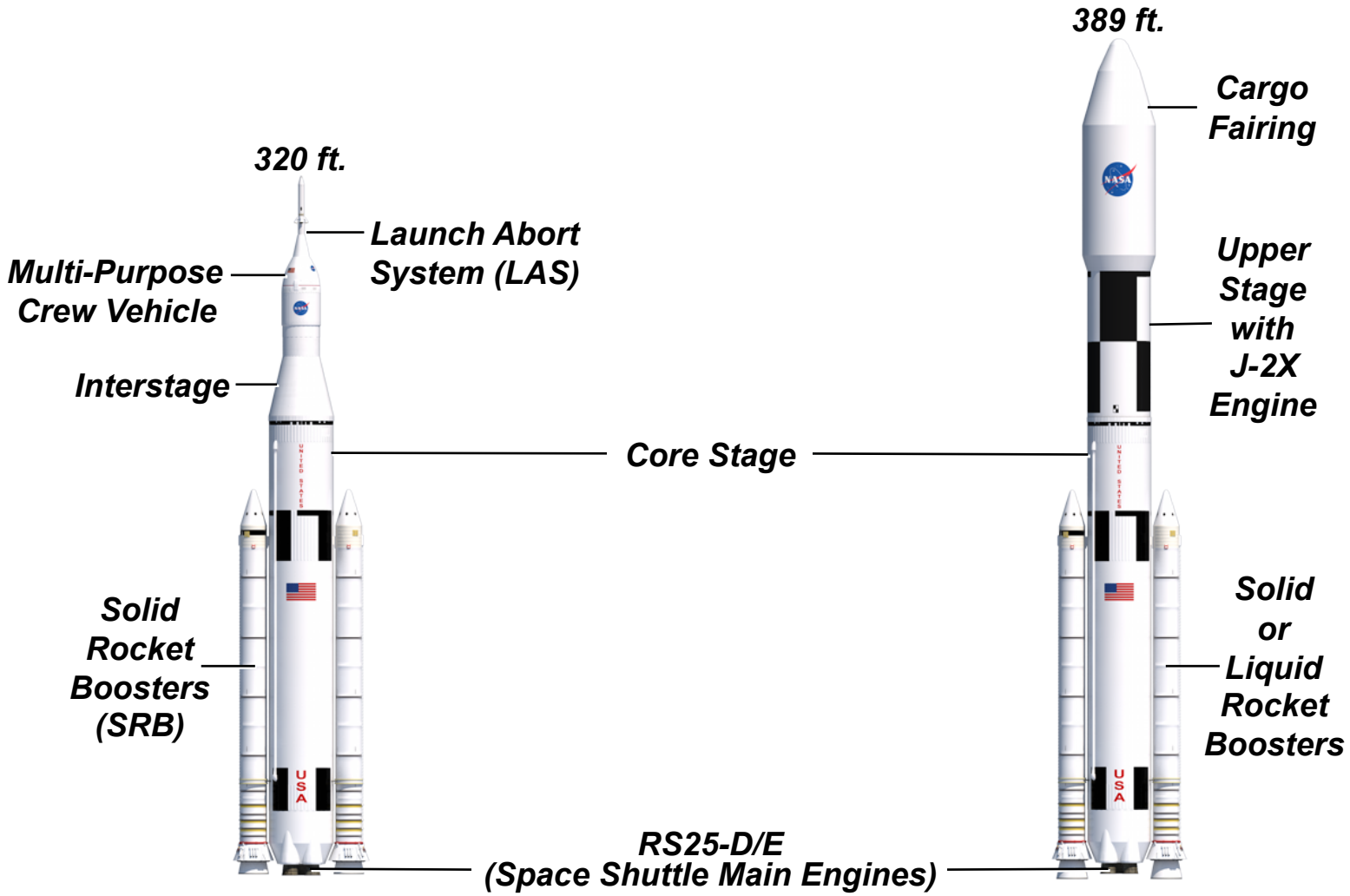
EFT-1 Overview

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

SLS Overview

Announced September 14

SLS Program Overview



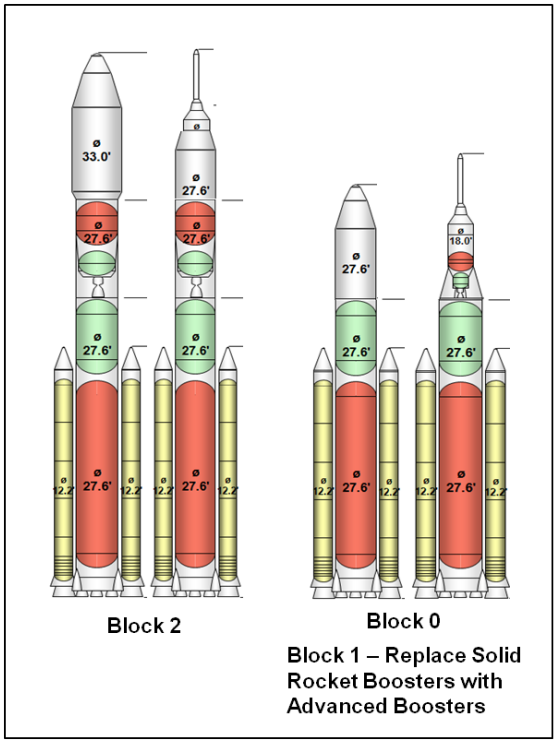
SLS Program Overview

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
- Payload adaptor
- Kick 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, competitivly 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



SLS Program Status:

Highlights and Upcoming Events

- **SLS Highlights**
  - Design Analysis Cycle 1 initiated with defined Point of Departure – Aug. 8th
  - First stage main chute drop test 4 – Aug. 24th
  - 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
  - DM-3 Test successfully completed at ATK/ Utah – Sept. 8th
  - SLS Industry Day – Sept. 29th
  - SRR Checkpoint Review completed – Oct. 24th
  - Upper Stave J-2X Engine 10001 complete 500 second test – Nov.9
    - Total number of J-2X tests = 7
    - Total seconds of testing = 725

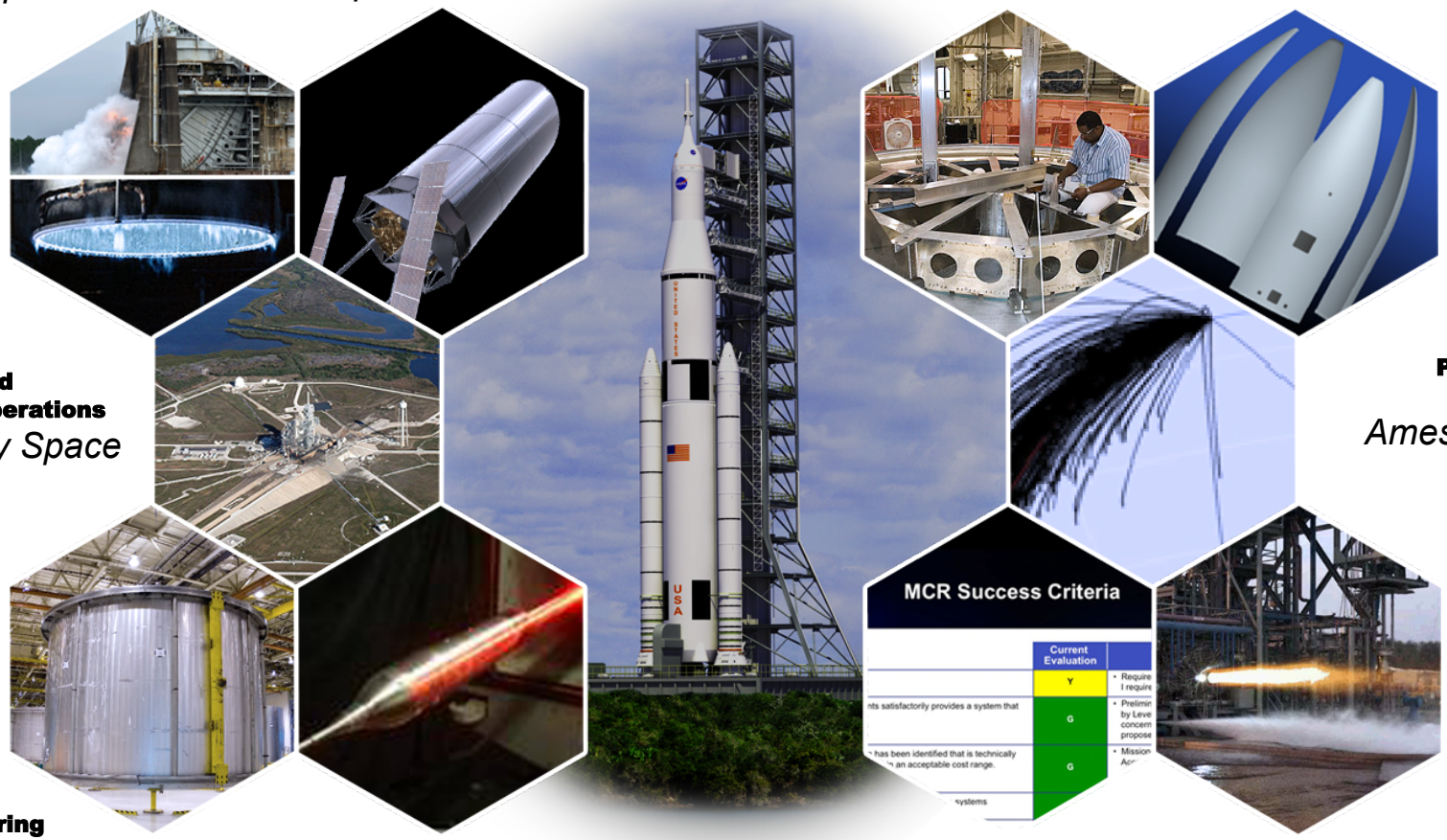
SLS Heritage Hardware and Facilities

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

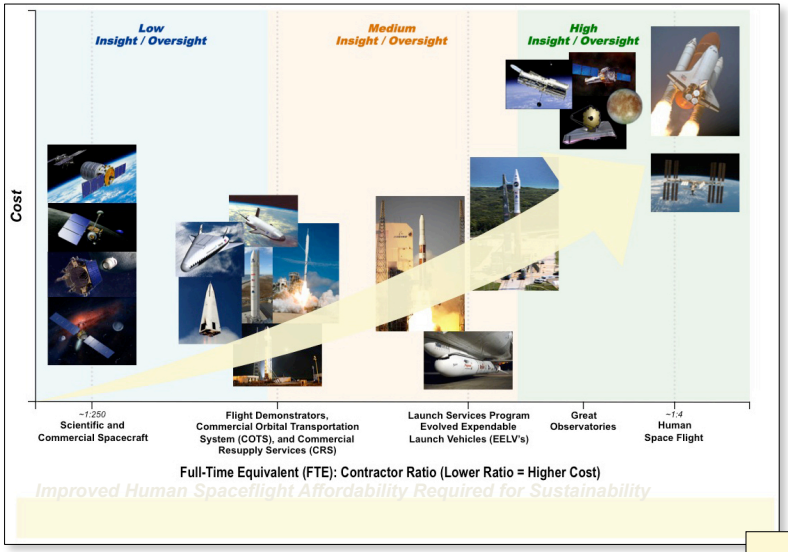
Manufacturing and Transportation
Michoud Assembly Facility

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



Program/Project Management	Risk-Averse Culture	Requirements/ Trades	Personnel/ Staffing
INSIGHT & OVERSIGHT	Cost as independent variable in design trades	Clear requirements/ Rationale at the right level	Program / Project leadership
Planning for strategy vs. Near-term execution	Understanding implications of safety	Cost as independent variable in design trades	Right people in right roles
Clear and simple lines of accountability	Early identification and resolution of issues	Multiple reviews and approvals	Long-term skill maintenance / development
Business / contractual relationships, methods, and incentives	Delegation of authority	Industry vs. Government standards	Use of in-house capability to support programs
Use of modern technology	Certificate of Flight Readiness process	Cost requirements and estimates	
Smaller projects / Periodic achievable milestones			

Opportunities for Change

- **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
    - Industrial Base/Supply Chain Management
  - 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

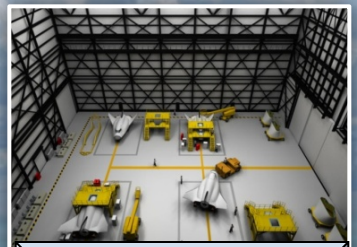
Development Motor 3 (DM-3)

- **DM-3 static test conducted September 8**
  - 37 Objectives assessed with 979 instrumentation channels
  - Propellant Mean Bulk Temperature (PMBT): 90^0F
  - 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

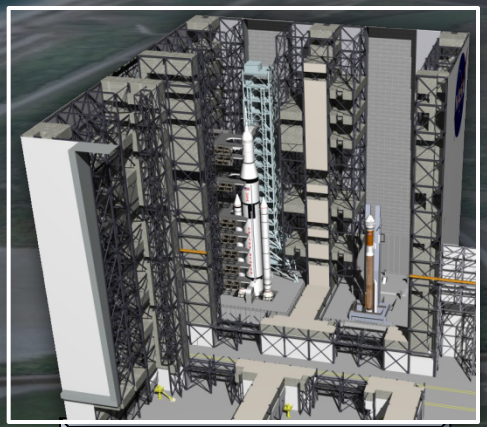
21st Century Ground Systems Overview

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

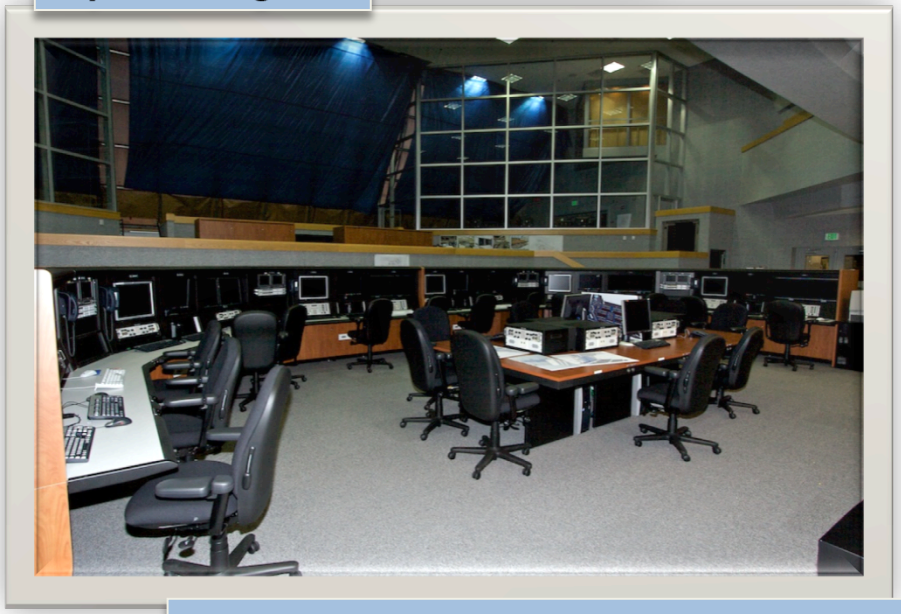
- Shuttle instrumentation racks removed
- Weather instrumentation racks installed

Mobile Launcher Construction - Before and After

Launch Control Center – Firing Room 1 Before and After

Apollo Program

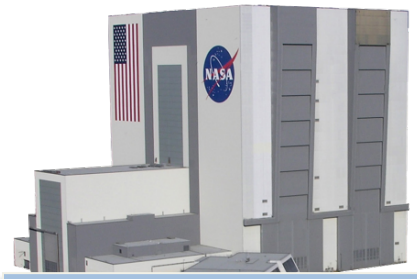
Space Shuttle Program



21st Century Ground Systems Program

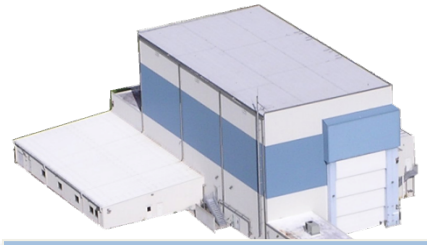
21st CGSP Planned Project Investments

Convert CxP Mobile Launcher for SLS



Conversion of LC-39 to support SLS and commercial use

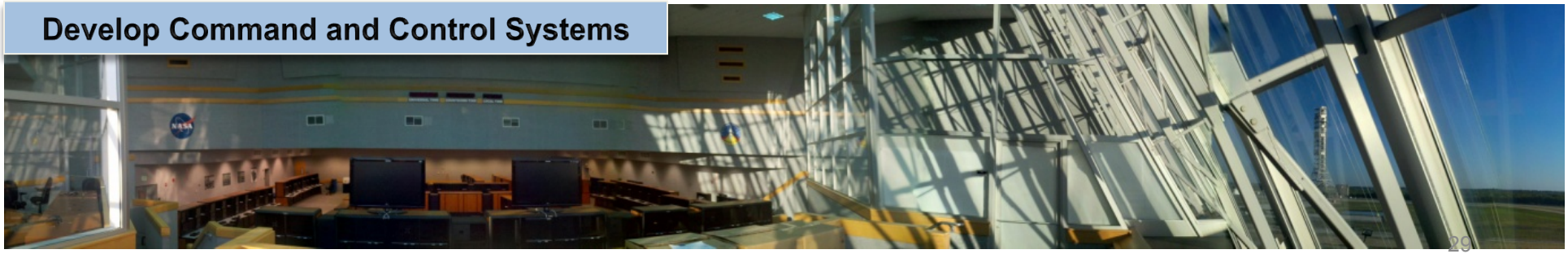
Modernize Range Infrastructure



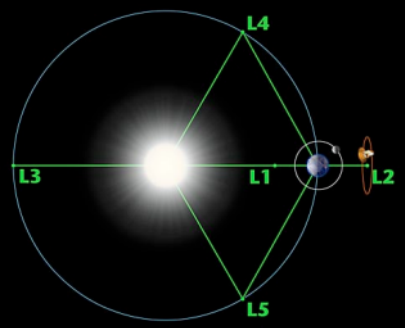
Convert MPPF for MPCV and commercial use

Convert SLF for horizontal launch and landing

Develop Command and Control Systems



Flexible Capability for Exploration Missions



High-Earth Orbit (HEO)/Geosynchronous-Earth Orbit (GEO)/Lagrange Points:
– Microgravity destinations beyond LEO
– Opportunities for construction, fueling, and repair of complex in-space systems
– Excellent locations for advanced space telescopes and Earth observatories

Mars and Its Moons, Phobos and Deimos:
– A premier destination for discovery: Is there life beyond Earth? How did Mars evolve?
– True possibility for extended, even permanent, stays
– Significant opportunities for international collaboration
– Technological driver for space systems

Earth's Moon:
– Witness to the birth of the Earth and inner planets
– Has critical resources to sustain humans
– Significant opportunities for commercial and international collaboration

Near-Earth Asteroids:
– Compelling science questions: How did the Solar System form? Where did Earth's water and organics come from?
– Planetary defense: Understanding and mitigating the threat of impact
– Potential for valuable space resources
– Excellent stepping stone for Mars

Increasing Our Reach and Expanding Our Boundaries

Questions?

www.nasa.gov