National Aeronautics and Space Administration

# Technical Feasibility Panel for the Human Space Flight Study

National Research Council

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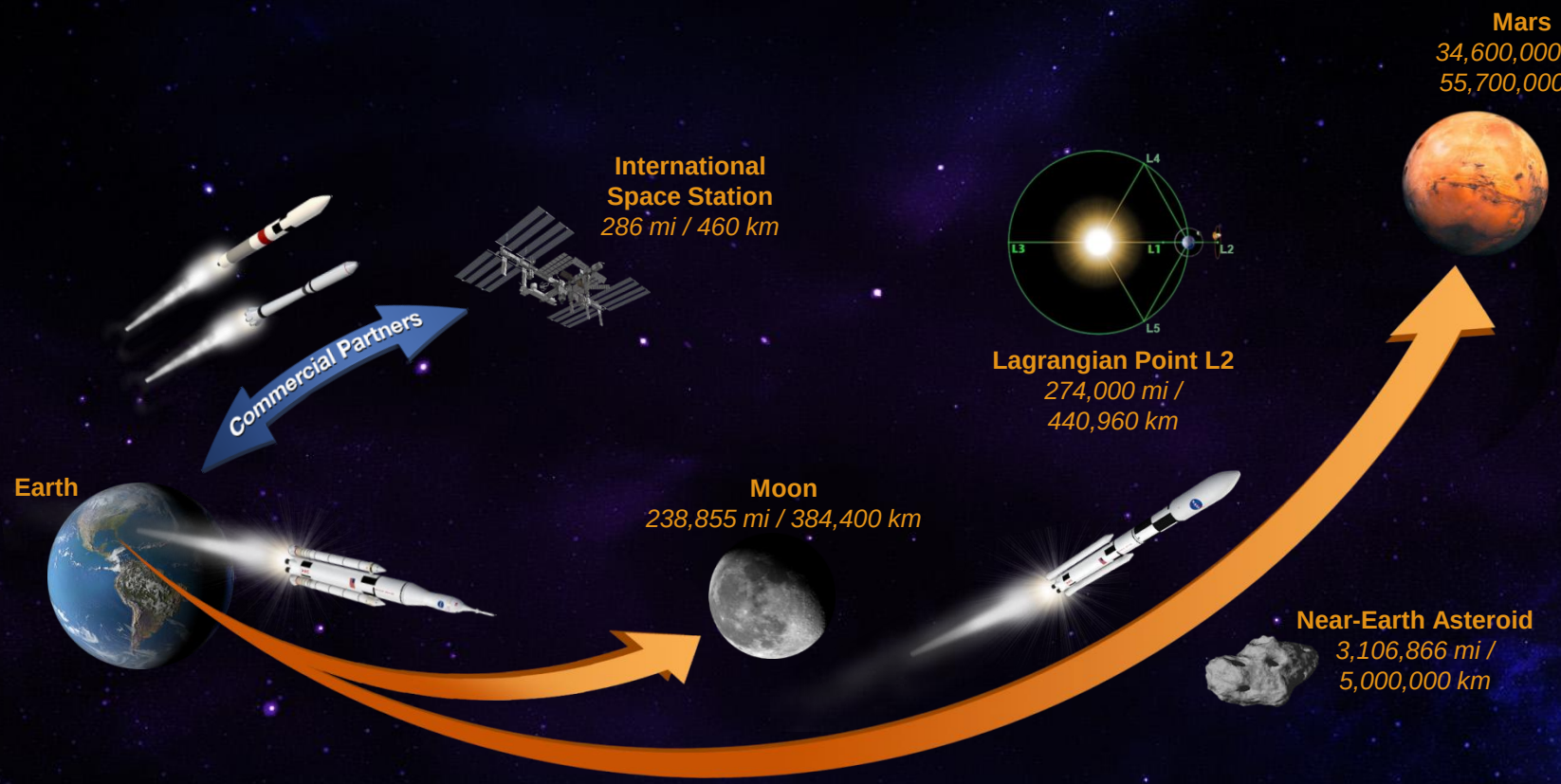
**February 4, 2013**

# Introduction

Overview

- Human Space Exploration
- Exploration Systems Development Overview
- Space Launch Systems
- Orion Multi-Purpose Crew Vehicle
- Ground Systems Development and Operations
- Missions
- Challenges

# The Future of Exploration




## Human Spaceflight Capabilities


Mobile Extravehicular Activity and Robotic Platform


Deep Space Habitation


Advanced Spacesuits


Advanced Space Communications


Advanced In-Space Propulsion


In Situ Resource Utilization


Human-Robotic Systems

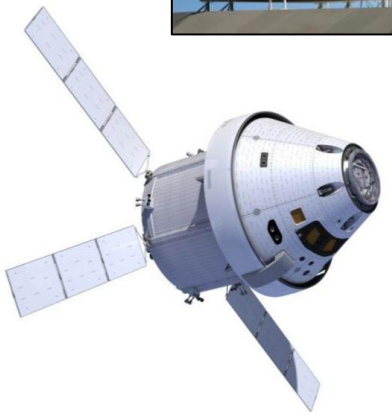
# Exploration Systems Development

**These programs will develop the launch and spaceflight vehicles that will provide the initial capability for crewed exploration missions beyond LEO.**

- **Space Launch System (SLS) Program:**
  - Initial capability: 70 tonnes (t), 2017–2021
  - Evolved capability: 105 t and 130 t, post-2021

- **Orion Program**:
  - Initial test flight (no crew) on Delta IV in 2014 – vehicle assembly underway
  - First Orion/SLS (no crew) flight in 2017
  - First crewed Orion/SLS flight in 2021

- **Ground Systems Development and Operations (GSDO) Program:**
  - Developing launch site infrastructure to prepare, assemble, test, launch and recover the SLS and Orion flight systems



# Hardware / Test / Mission Milestones

## 2008

## 2009

Ares 1-X Launch

Water Recovery Training

## 2010

Attitude Control Motor Test

Pad abort 1 stacking

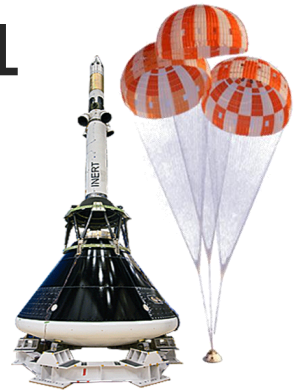
Pad abort 1 test

## 2011

First Orion Environmental Testing

Parachute Tests

Solid Rocket Booster development motor test



## 2012

EFT-1 Crew Module

Solid Rocket Booster development motor test

RS 25 Processing KSC Facility delivered to KSC

First MSA Ring Forging, Cudahy, Wisconsin

MSA Pathfinder Hardware

Exploration Flight Test-1

Final Assembly in VAB

Launch Pad B

Mobile Launch Platform and Tower

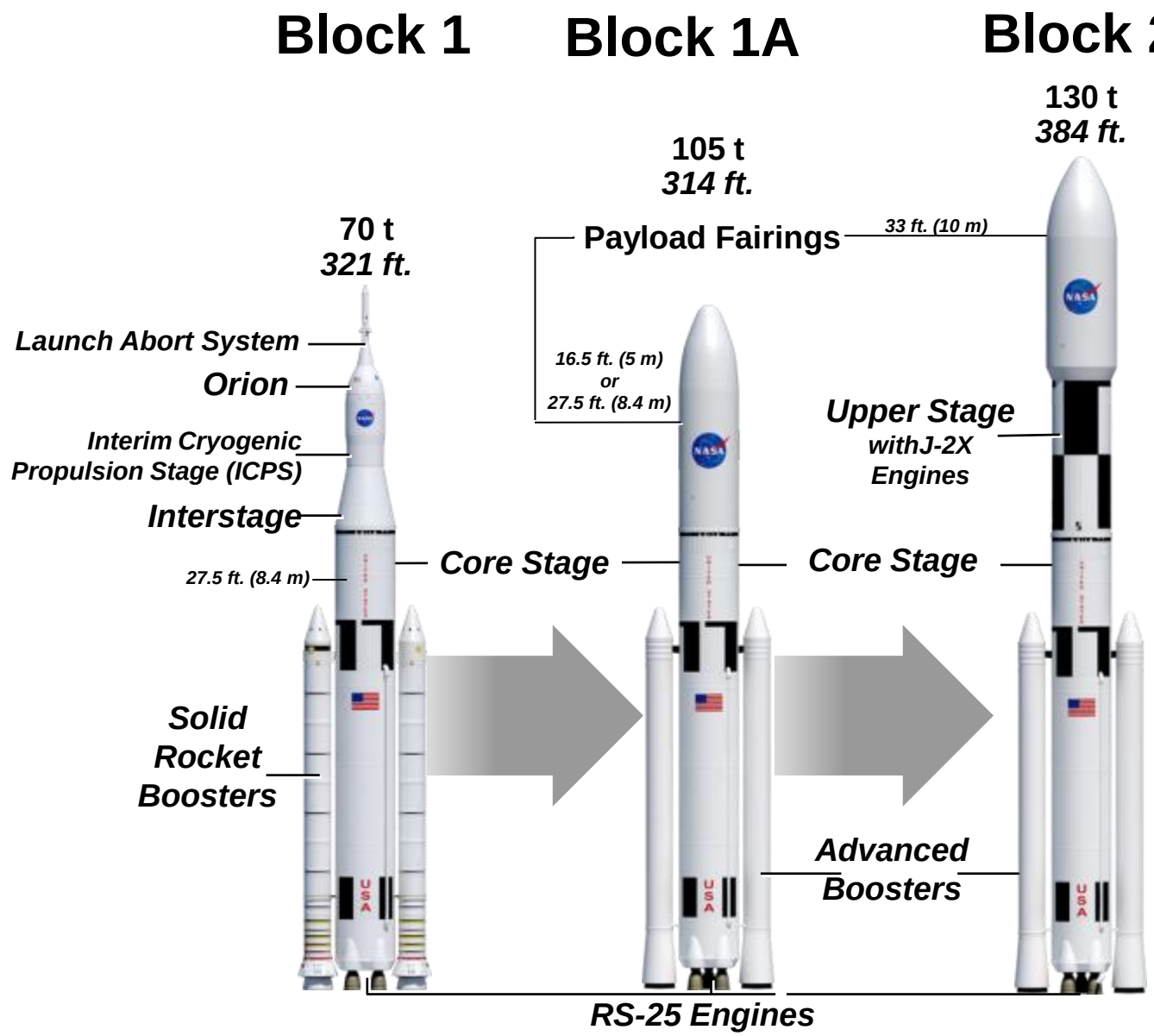
Exploration Mission-1

## LOOKING AHEAD 2013 - 2017

# The Space Launch System (SLS)

- **Affordable & Sustainable**
  - Maximum use of common elements and existing assets, infrastructure, and workforce
  - Competitive opportunities for affordability insertion
- **Safe : Human Rated**
- **Initial capability: 70 tonnes (t), 2017–2021**
  - Serves as primary transportation for Orion and exploration missions
  - Provides back-up capability for crew/cargo to ISS
- **Evolved capability: 105 t and 130 t, post-2021**
  - Can enable scientific payloads with requirements beyond commercial lift capabilities
  - Modular and flexible, sized to mission requirements
- **Liquid hydrogen and liquid oxygen propulsion system**
  - RS-25 from the Space Shuttle Program for core stage
  - Upper Stage trades in work
- **Solid rocket boosters for the initial flights**
  - Competition for follow-on boosters based on performance requirements and affordability considerations

# SLS Evolution and Block Upgrade Approach




## Saturn

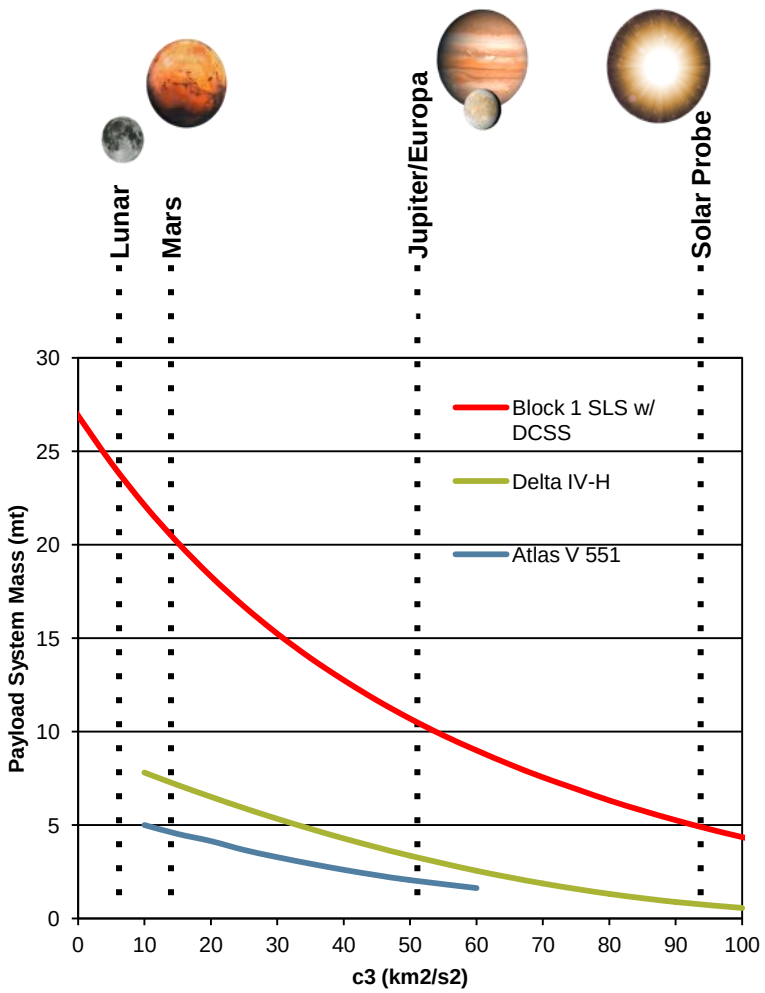
118t
363 ft.

# SLS Performance Supports Deep-Space Operations

- SLS Enables Exploration Missions
  - Greater volume and mass capability/margin
    - Increased design simplicity
    - Fewer origami-type payload designs needed to fit in the fairing
  - Single launch of multiple elements means fewer launches, deployments, and critical operations
    - Simplifies on-orbit operations
    - Reduced risk
  - High-energy orbit and shorter trip times
    - Less expensive mission operations
    - Reduced risk - Maximize mission reliability via Increased lift capacity and payload margin

- SLS investment can be leveraged for other missions requiring large volume or up mass
  - Deep Space Exploration
  - Planetary Landers
  - Human Habitats
  - Great Observatories
  - Space Solar Power
  - Outer Planet Missions
  - Department of Defense/ NRO Payloads

## SLS Block 1 C3 Performance



# SLS Accomplishments

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)

## System Requirements Review/System Definition Review Completed

RS-25 Engines at Stennis Space Center Oct 2012, shown with future RS-25 Test Stand A1

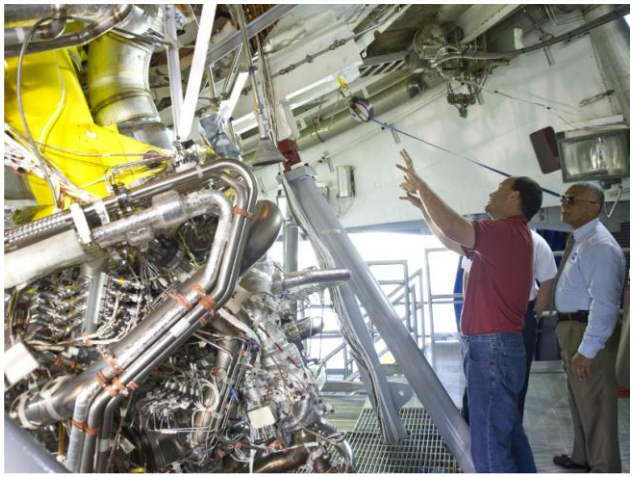
F-1 engine gas generator hot fire test at Marshall Space Flight Center, Jan 2013 – technology development for an optional Advanced Booster concept

Qualification Motor 1 casting at ATK (Oct 2012)

# SLS Hardware

Stages Industry Day at Michoud Assembly Facility Nov 2011

SLS Nozzle Nose Rig



J-2X Upper Stage Engine at Stennis Space Center (SSC), April 2012

Solid Rocket Booster development motor test in Promontory, Utah, Sep 2011

RS-25 Core Stage Engines Stored at SSC Jan 2012

Subscale Solid Rocket Motor firing at Marshall Space Flight Center, March 2012

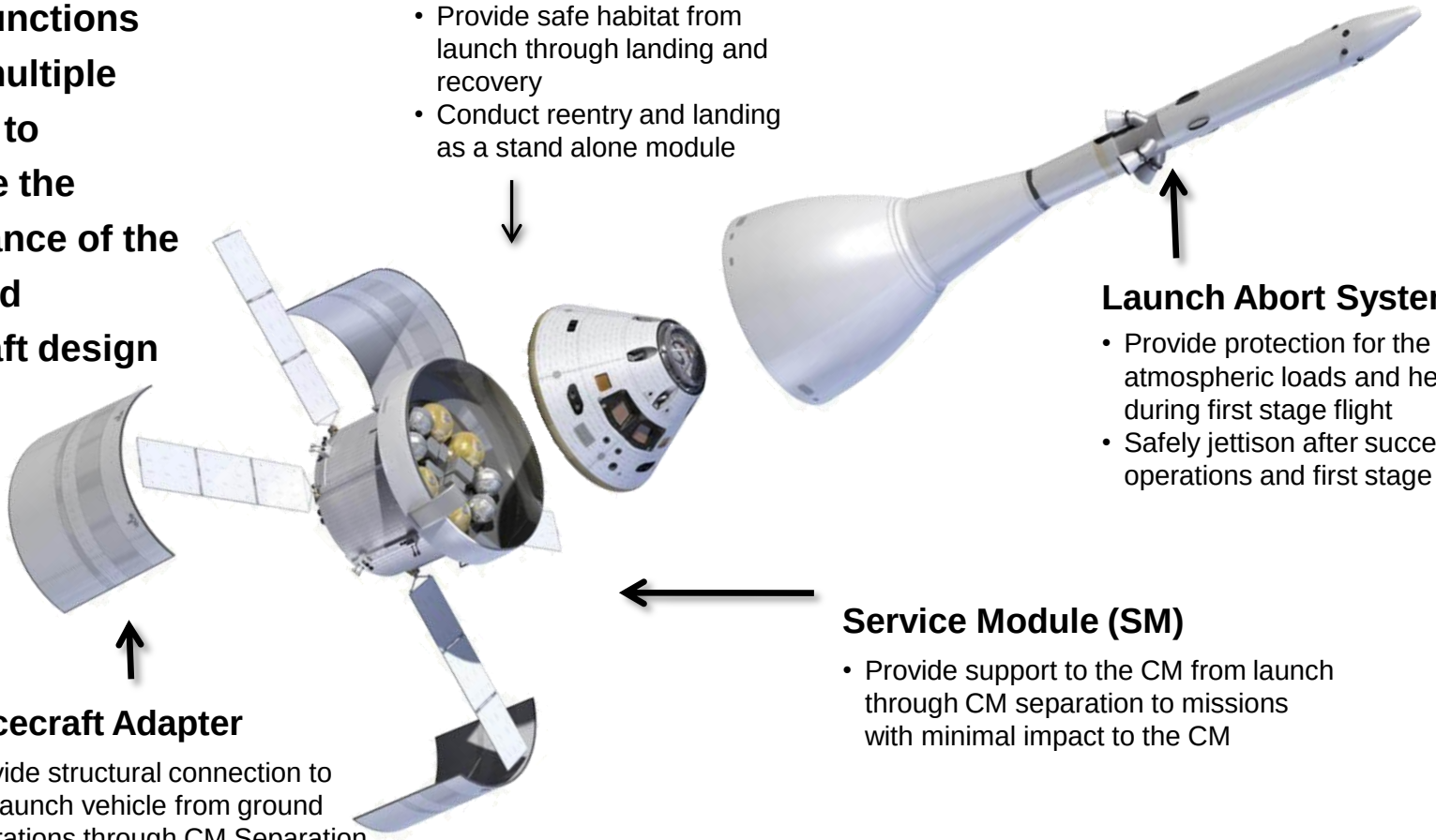
MPCV Stage Adapter Production Major Tool and Machine, IN

# Orion MPCV Spacecraft Overview

**The Orion MPCV design divides critical functions among multiple modules to maximize the performance of the integrated spacecraft design**

### Crew Module (CM)

- 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 (SM)

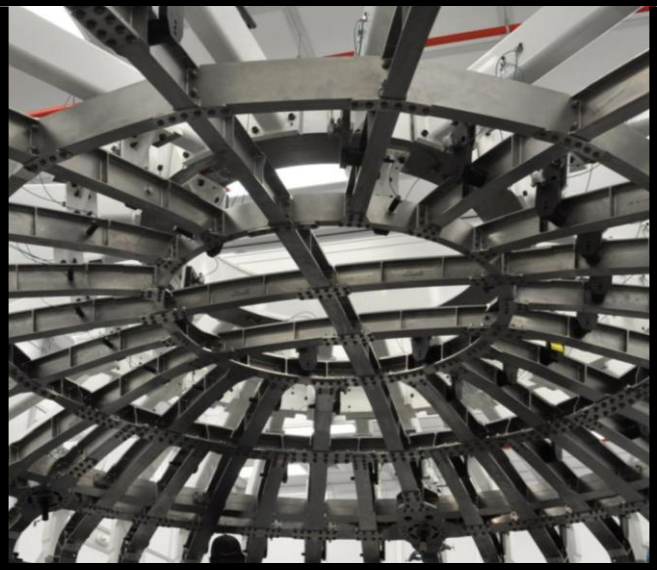
- Provide support to the CM from launch through CM separation to missions with minimal impact to the CM

### 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

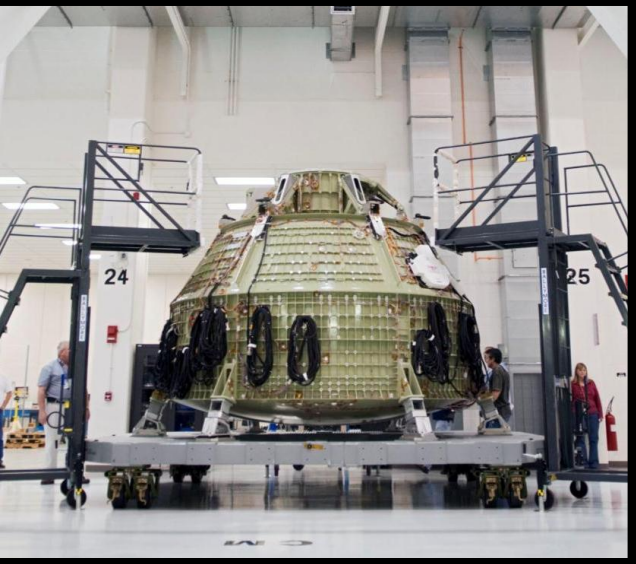
# Orion Hardware Accomplishments

Lori Garver visits Lockheed Martin Denver to review the heatshield carrier structure



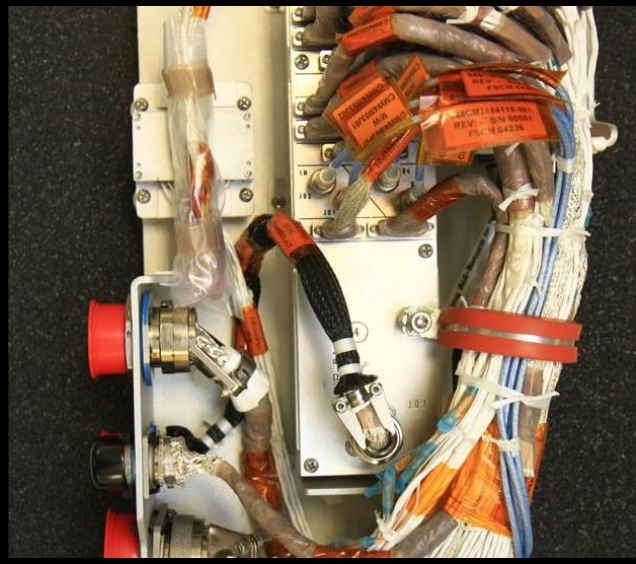
Heatshield Skeleton Assembly at Lockheed Martin in Denver

Spacecraft Adapter Jettison fairings at the Michoud Assembly Facility




EFT1 Crew Module being moved into the Birdcage tool at the Operations and Checkout Building

EFT1 Service Module panels being assembled at the Operations and Checkout Building



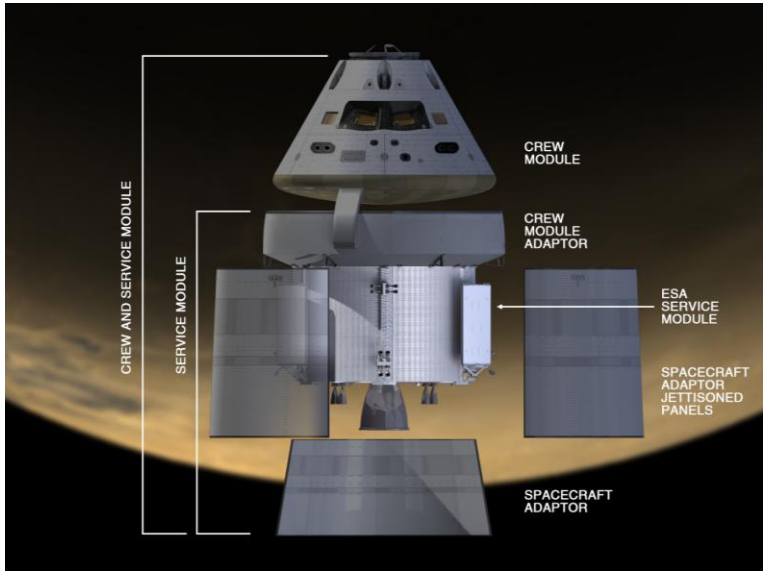
Master Data Acquisition Unit harnesses on prototype pallet fixture

# Orion Demonstration Tests Completed

- Launch Abort System
- Parachute Drop
- Water Drop
- Human Factors - Suit
- Acoustic Vibration
- Up-righting System
- Thermal Protection System
- Landing & Recovery
- Controls Evaluation

# Orion Service Module/ESA Partnership

- NASA signed an agreement in December 2012 for the European Space Agency (ESA) to provide a service module for the Orion spacecraft's Exploration Mission-1 in 2017.
- The agreement primarily maps out a plan for ESA to fulfill its share of operational costs and additional supporting services for the International Space Station by providing the Orion service module and necessary elements of its design for NASA's Exploration Mission-1 in 2017.
- The service module will house Orion's power, thermal and propulsion systems. It will contain the in-space propulsion capability for orbital transfer, attitude control and high-altitude ascent aborts. It also will generate and store power and provide thermal control, water and air for the astronauts. It will remain connected to the crew module until just before the capsule returns to Earth.



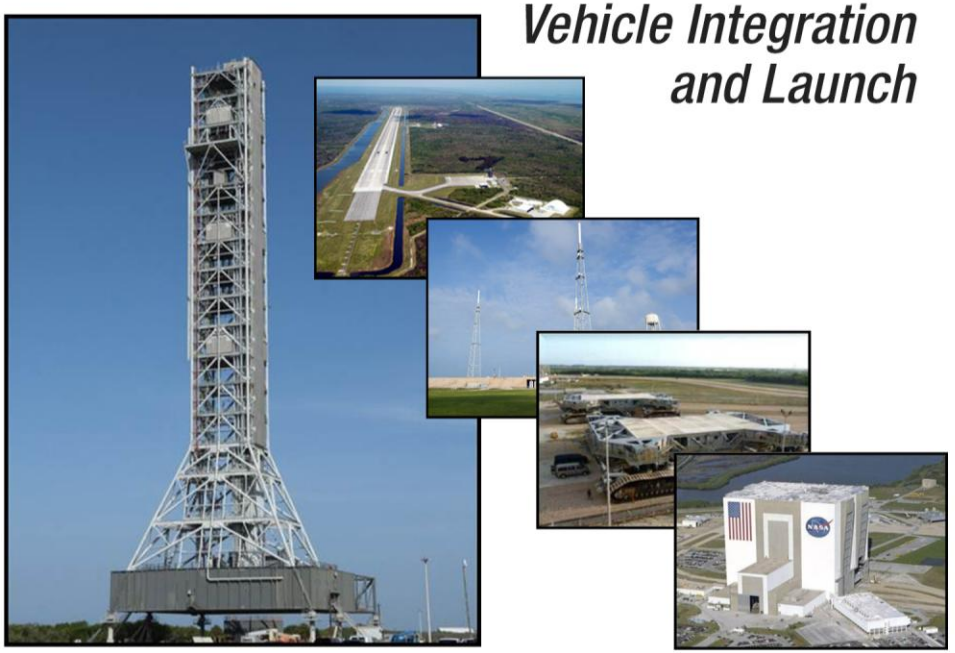
# Ground Systems Development and Operations

Mobile Launcher Arriving at Pad 39B

# GSDO Accomplishments

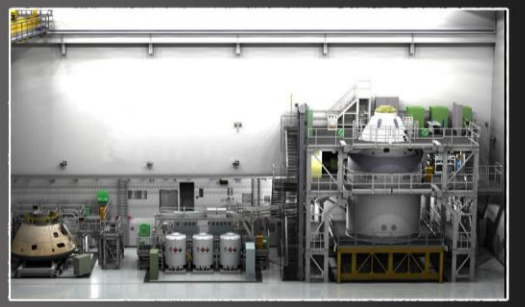
*Kennedy Space Center Evolution, 1950-2020*

*Vehicle Integration and Launch*



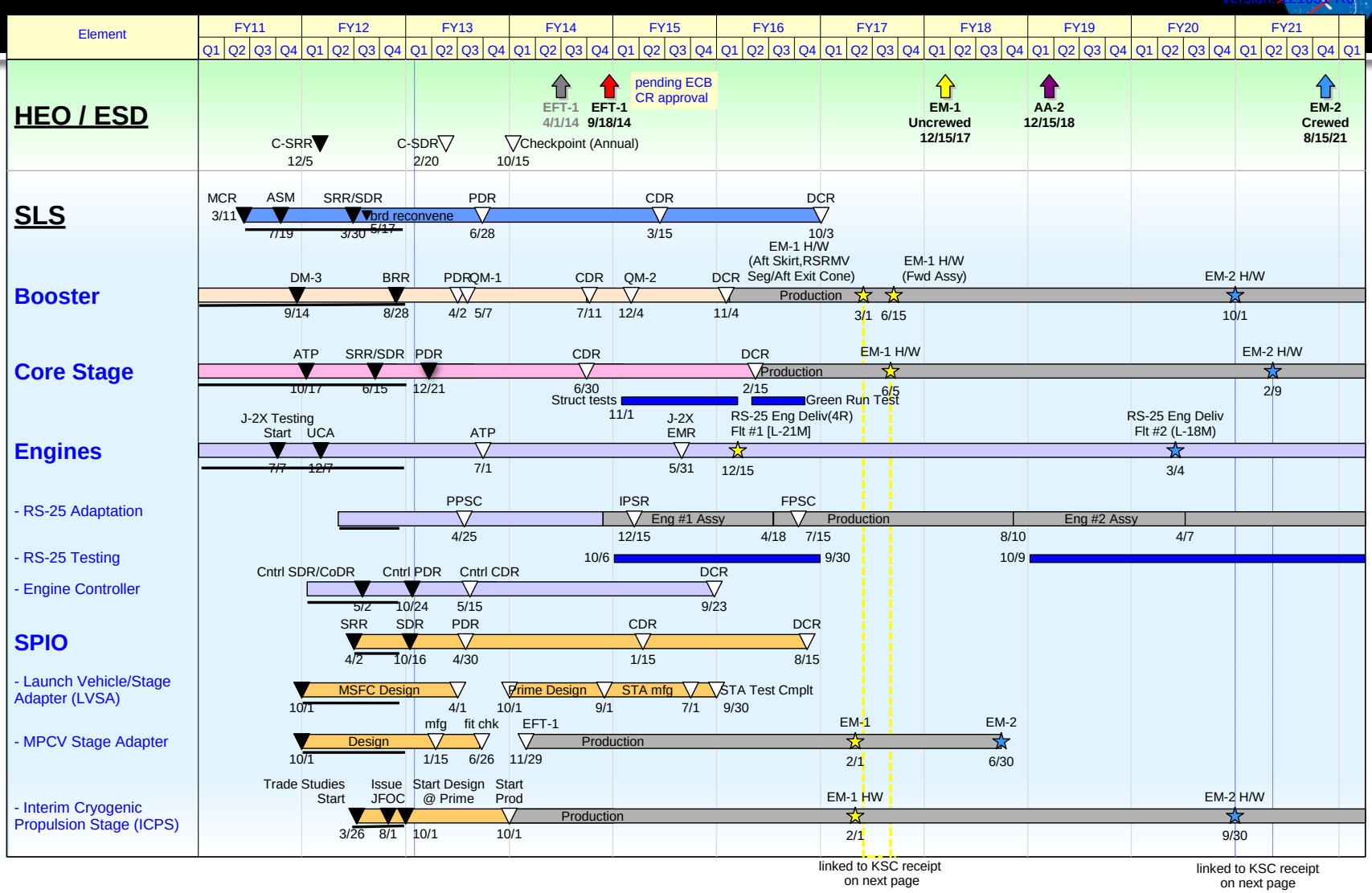
*Command Control Communications & Range*

*Offline Processing & Infrastructure*



# ESD EM-1 / EM-2 PPBE14 Integrated Schedule

version: ~~121031 R0~~




EFT-1 flt h/w
EM-1 flt h/w
EM-2 flt h/w
Progress to date
Element Tests
Milestones are "complete" milestones unless noted

# ESD EM-1 / EM-2 PPBE14 Integrated Schedule

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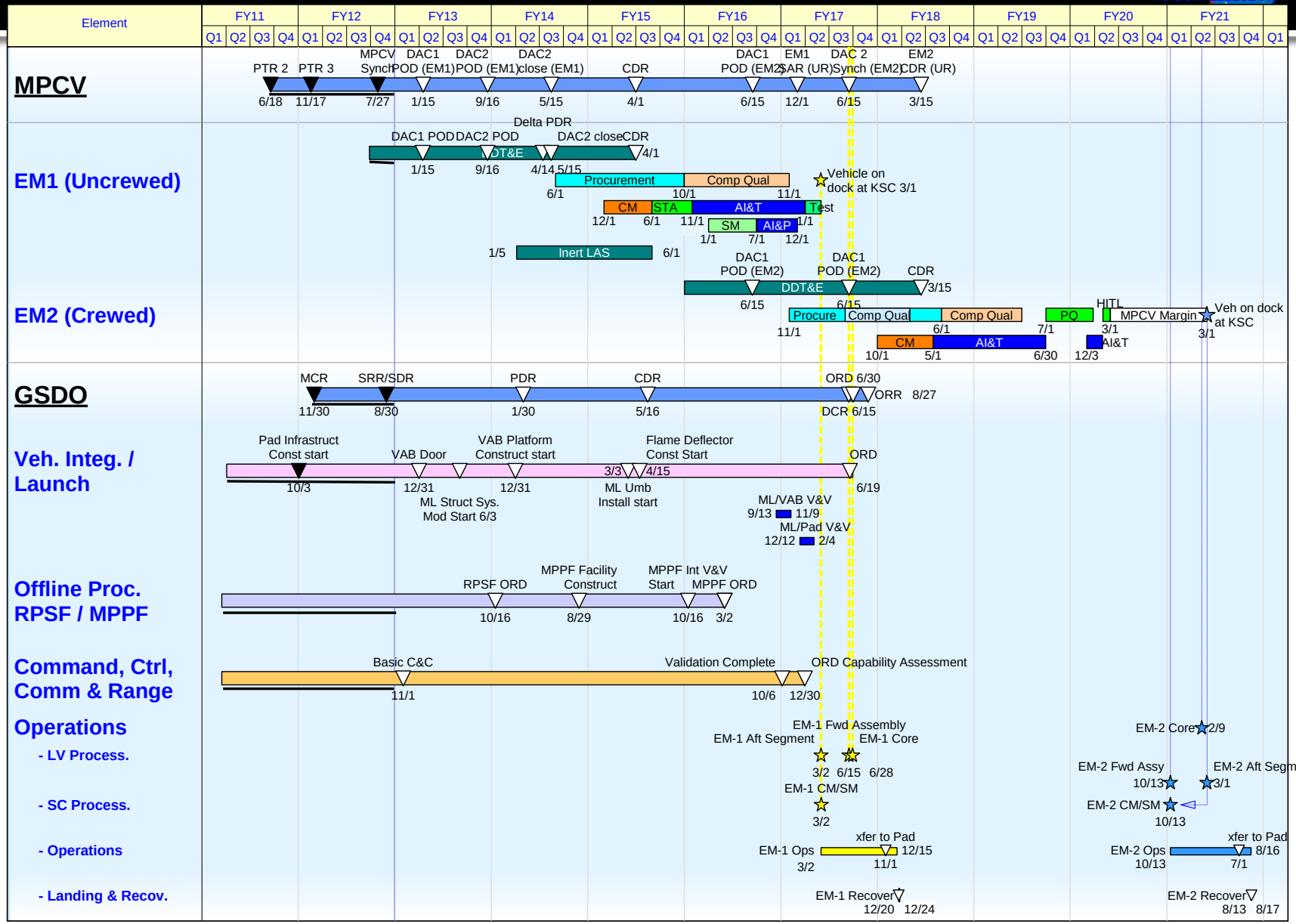
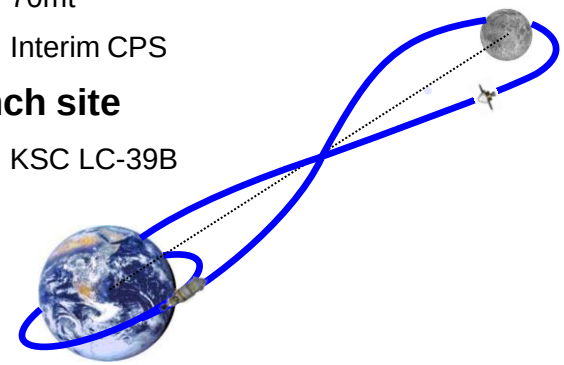


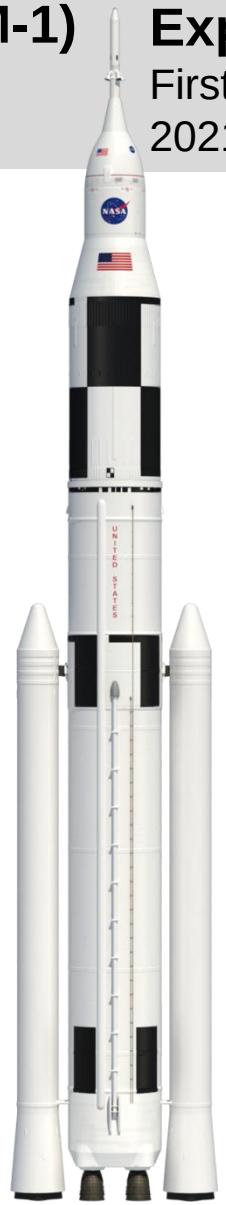
# ESD Mission Overview

## Exploration Mission One (EM-1)

First Uncrewed BEO Flight
2017

- **Mission objectives**
  - Demonstrate integrated spacecraft systems performance prior to crewed flight
  - Demonstrate high speed entry (~11 km/s) and TPS prior to crewed flight
- **Mission description**
  - Un-crewed circumlunar flight – free return trajectory
  - Mission duration ~7 days
- **Spacecraft configuration**
  - Orion Uncrewed
- **Launch vehicle configuration**
  - SLS Block 1, 5-segment RSRMV, 4 RS-25, 70mt
  - Interim CPS
- **Launch site**
  - KSC LC-39B

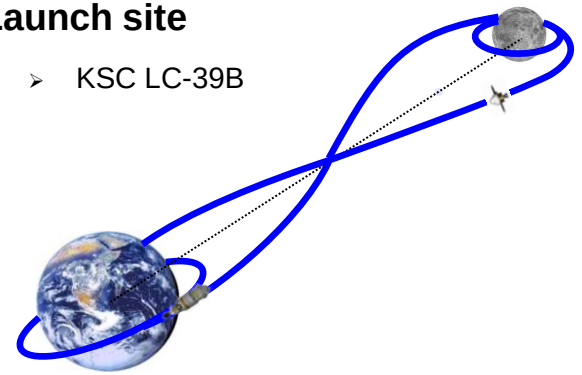




## Exploration Mission Two (EM-2)

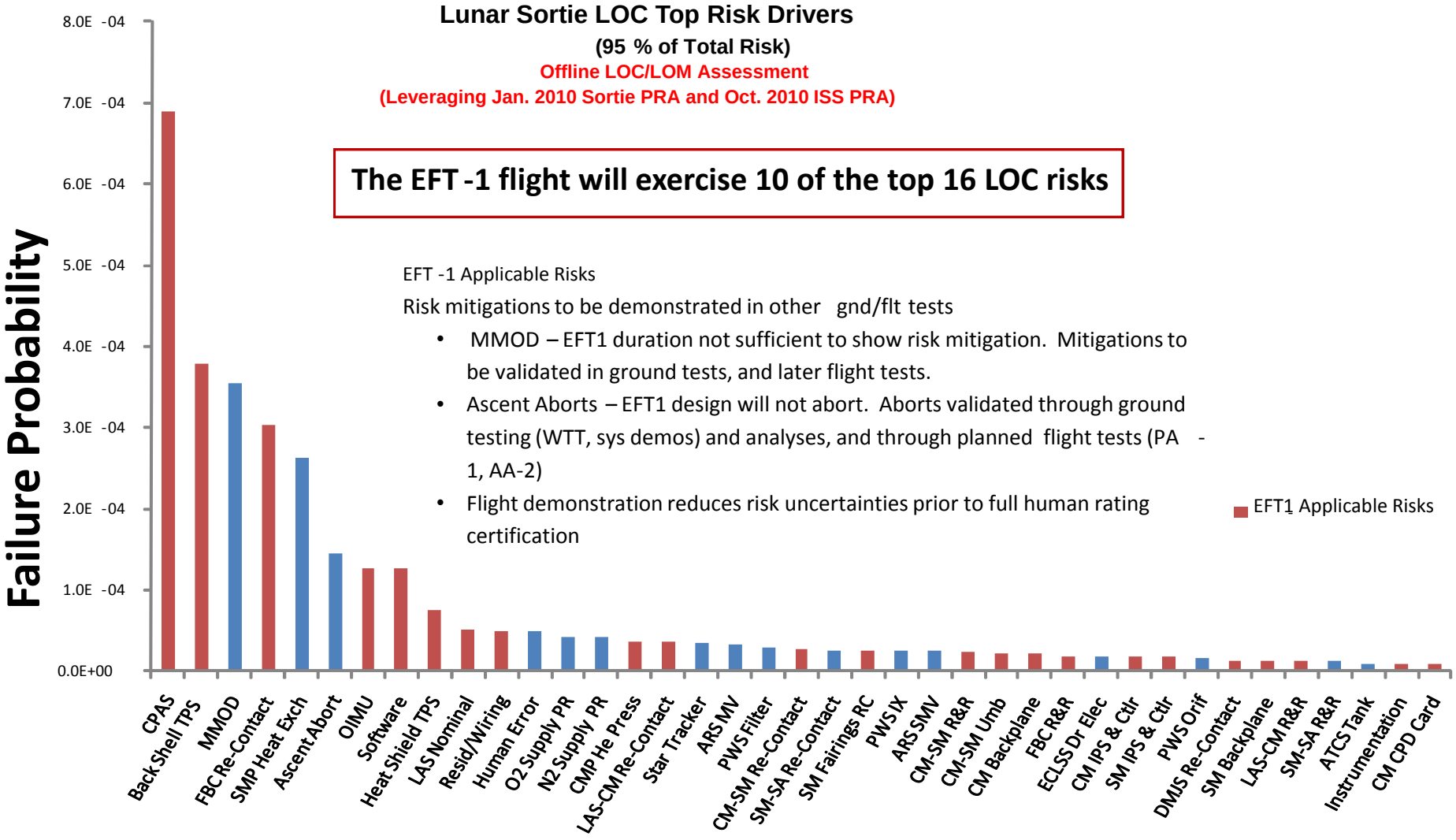
First Crewed BEO Flight
2021

- **Mission objectives**
  - Demonstrate crewed flight beyond LEO
- **Mission description**
  - Crewed lunar orbit-capable, or other destinations
  - Mission duration 10-14 days
- **Spacecraft configuration**
  - Orion Crewed
- **Launch vehicle configuration**
  - SLS Block, 5-segment RSRMV, 4 RS-25, 70mt
  - Interim CPS
- **Launch site**
  - KSC LC-39B



# Exploration Flight Test – 1

# Orion Risk Mitigation:
# EFT-1 exercises 10 of top 16 Loss of Crew Risks



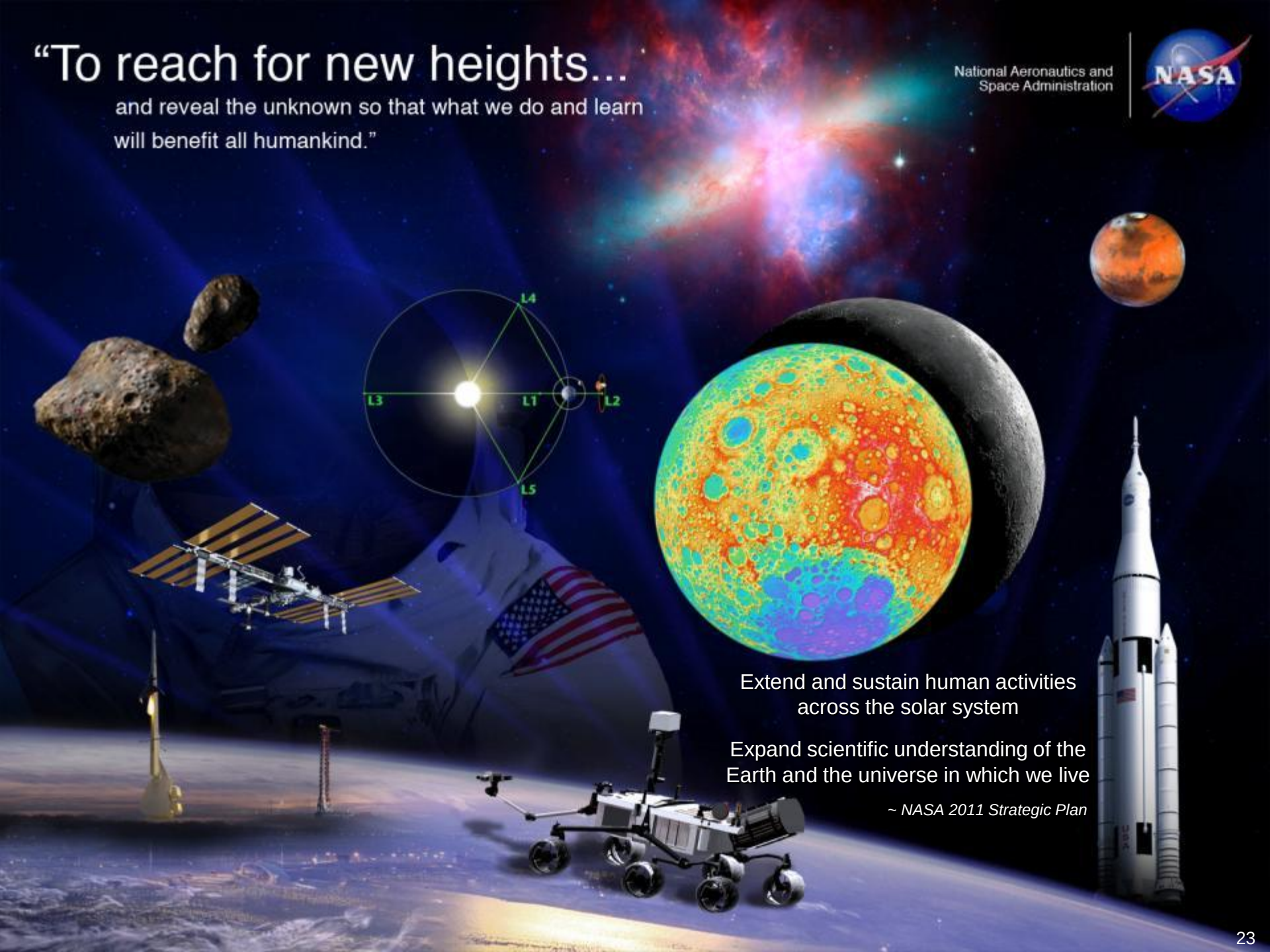
# Summary

- Significant progress has been made, and is being made, in design and development, testing, and programmatics.
- We are talking with stakeholders, independent review teams and technical authorities to ensure technical excellence in a cost and schedule constrained environment
  - NAC
  - ASAP
  - ESD Standing Review Board
  - Office of the Chief Engineer
  - Safety and Mission Assurance Office
  - Crew Health and Medical Office

# “To reach for new heights…

and reveal the unknown so that what we do and learn will benefit all humankind.”

National Aeronautics and Space Administration




Extend and sustain human activities across the solar system

Expand scientific understanding of the Earth and the universe in which we live

*~ NASA 2011 Strategic Plan*