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

- Earth
  - International Space Station: 286 mi / 460 km
  - Commercial Partners
- Moon: 238,855 mi / 384,400 km
- Mars: 34,600,000 mi / 55,700,000 km
- Lagrangian Point L2: 274,000 mi / 440,960 km
- Near-Earth Asteroid: 3,106,866 mi / 5,000,000 km

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
- Ares 1-X Launch
- Water Recovery Training

2009
- Attitude Control Motor Test
- Pad abort 1 stacking
- Pad abort 1 test

2010
- First Orion Environmental Testing
- Parachute Tests
- Solid Rocket Booster development motor test

2012
- EFT-1 Crew Module
- Solid Rocket Booster development motor test
- First MSA Ring Forging, Cudahy, Wisconsin

LOOKING AHEAD 2013 - 2017
- Final Assembly in VAB
- Mobile Launch Platform and Tower
- Exploration Mission-1
- Launch Pad B
- Exploration Flight Test-1

RS 25 Processing KSC Facility delivered to KSC
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

**Block 1**
- Launch Abort System
- Orion
- Interim Cryogenic Propulsion Stage (ICPS)
- Interstage
- Solid Rocket Boosters
- 70 t (321 ft.)

**Block 1A**
- Upper Stage with J-2X Engines
- 105 t (314 ft.)
- 16.5 ft. (5 m) or 27.5 ft. (8.4 m)
- Payload Fairings
- 33 ft. (10 m)

**Block 2**
- Advanced Boosters
- 130 t (384 ft.)

**Saturn**
- 118 t (363 ft.)

**Core Stage**
- RS-25 Engines

**Core Stage**
- Core Stage
- Core Stage
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

RS-25 Core Stage Engines Stored at SSC
Jan 2012

SLS Nozzle Nose Rig

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

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

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

MPCV Stage Adapter Production
Major Tool and Machine, IN
The Orion MPCV design divides critical functions among multiple modules to maximize the performance of the integrated spacecraft design.

**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

**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
Orion Hardware Accomplishments

- Master Data Acquisition Unit harnesses on prototype pallet fixture
- EFT1 Service Module panels being assembled at the Operations and Checkout Building
- EFT1 Crew Module being moved into the Birdcage tool at the Operations and Checkout Building
- Heatshield Skeleton Assembly at Lockheed Martin in Denver
- Lori Garver visits Lockheed Martin Denver to review the heatshield carrier structure
- Spacecraft Adapter Jettison fairings at the Michoud Assembly Facility
- 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

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

## Element Tests

**MPCV**

- **FY11**
  - Q1: PTR 2
  - Q2: PTR 3
  - Q3: MCR
  - Q4: SRR/3DR

- **FY12**
  - Q1: MCR
  - Q2: PDR
  - Q3: CDR
  - Q4: ORD

- **FY13**
  - Q1: ORD
  - Q2: ORD

**GSDO**

- **FY11**
  - Q1: VAB Door
  - Q2: PAD

- **FY12**
  - Q1: PAD
  - Q2: PAD

**Offline Proc.**

- **FY11**
  - Q1: PAD
  - Q2: PAD

**Command, Ctrl, Comm & Range**

- **FY11**
  - Q1: Basic C&C

## Milestones

- **FY11**
  - Q1: Validation Complete
  - Q2: ORD Capability Assessment

- **FY12**
  - Q1: EM-1 Core
  - Q2: EM-2 Core
  - Q3: EM-2 Alt Segment

- **FY13**
  - Q1: EM-1 Alt Segment

## Funding

- **FY11**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY12**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY13**
  - Q1: EM-1 Ops

**FY14**

- **FY15**
  - Q1: EM-1 Ops

- **FY16**
  - Q1: EM-1 Ops

- **FY17**
  - Q1: EM-1 Ops

- **FY18**
  - Q1: EM-1 Ops

- **FY19**
  - Q1: EM-1 Ops

- **FY20**
  - Q1: EM-1 Ops

- **FY21**
  - Q1: EM-1 Ops

### Progress to Date

- **FY11**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY12**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY13**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY14**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY15**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY16**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY17**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY18**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY19**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY20**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops

- **FY21**
  - Q1: EM-1 Ops
  - Q2: EM-2 Ops
### 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

EXPLORATION FLIGHT TEST ONE

OVERVIEW

TWO ORBITS • 20,000 MPH ENTRY • 3,571 MILE APOGEE • 28.6 DEGREE INCLINATION

LAUNCH ABORT SYSTEM (LAS)
ORION CREW MODULE (CM)
UPPER STAGE
DELTA IV HEAVY ROCKET

LAUNCH CONFIGURATION

Upper Stage Disposal
Orion Translation Burn
Orion/Upper Stage Separation
LANDING & RECOVERY

Launch Vehicle/Upper Stage Separation
Launch Abort System (LAS) Jettison
Upper Stage Engine Burns

2014
Orion Risk Mitigation:
EFT-1 exercises 10 of top 16 Loss of Crew Risks

Lunar Sortie LOC Top Risk Drivers
(95% of Total Risk)
Offline LOC/LOM Assessment
(Leveraging Jan. 2010 Sortie PRA and Oct. 2010 ISS PRA)

The EFT-1 flight will exercise 10 of the top 16 LOC risks

EFT-1 Applicable Risks
Risk mitigations to be demonstrated in other gnd/flt tests

- MMOD – EFT1 duration not sufficient to show risk mitigation. Mitigations to be validated in ground tests, and later flight tests.
- Ascent Aborts – EFT1 design will not abort. Aborts validated through ground testing (WTT, sys demos) and analyses, and through planned flight tests (PA-1, AA-2)
- Flight demonstration reduces risk uncertainties prior to full human rating certification
Summary

• Significant progress has been made, and is being made, in design and development, testing, and programmatic.

• 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.”

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