Exploration Systems Mission Directorate: FY 2010 Budget

Dr. Gale J. Allen
Director,
Strategic Integration and Management
Exploration Systems Mission Directorate

May 13, 2009
Overview

- NASA’s near term plan remains the same: maintain March 2015 goal for the first crewed Orion/Ares flight to the International Space Station
- Lunar Reconnaissance Orbiter/Lunar CRater Observation Sensing Satellite ready for launch
- Technical progress to date is substantial; Constellation is preparing for system level Preliminary Design Review (PDR)
  - Ares I PDR has been completed, and we are preparing for Orion PDR as testing continues on critical components and subsystems
  - Abort motor static test for the launch abort system (LAS) that will sit atop Orion (11/08)
  - LAS attitude control motor high thrust test firings #6 and #8 (1/09 and 3/09)
  - Orion post landing and recovery testing (1/09-4/09)
  - Ares drogue parachute drop test #2 (2/09)
  - Completed KSC operations and checkout facility renovation and modification for Orion spacecraft assembly, modification, integration and test (1/09)
  - Completed launch pad lightning protection towers (2/09)
  - Mobile launcher platform-1 handover for Ares I-X test flight modifications (3/09)
- Continued technology infusion and human research to support Cx and ISS research
  - Will complete the launch of all planned ISS research facilities
  - Technology development and Infusion continues reducing CxP technical risks
  - Human Research focusing on maximal use of ISS to reduce human health risks
Overview (continued)

• We are maximizing existing resources to reduce risk against schedule for the March 2015 launch. Funding increases in FY09 and FY10 improve ability to meet schedule

• Challenges remain:
  – Continuing to assess fixed costs and plans to efficiently transition key elements of the Space Shuttle workforce, infrastructure and equipment to Constellation in support of U.S. space exploration objectives
  – Working to reduce steady state operations costs for Orion/Ares and supporting systems
  – Continuing to scrub program content, e.g.
    • Seeking maximum commonality between Orion ISS and lunar configurations
    • Deleting requirement for zero crew mission to ISS
    • Deleting Ares I Nozzle extension
    • Reduced Orion crew size from 6 to 4 for ISS missions
    • Reassessing test strategy to ensure most efficient mix
    • Reviewing need for Ares 1-Y test as part of overall test strategy

• Pending Human Spaceflight Review
  – Lunar goal is still in place
  – But current FY10 budget does not support near term lunar work; given later start date for significant lunar funding stream, need to assess what can be accomplished post 2015 to achieve earliest possible landing date
    • Assessment must consider effects of possible ISS extension and should evaluate opportunities for increased international participation

• Following independent human spaceflight review, Administration will provide updated budget request for Exploration activities to reflect results
The Obama Administration has launched an independent review of planned U.S. human spaceflight activities, to be conducted by a blue-ribbon panel of experts led by Norman Augustine.

The panel is to examine NASA’s ongoing and planned human space flight development activities, as well as potential alternatives, and options for ensuring that the nation’s human space flight program will be safe, innovative, sustainable, and affordable in the years following Space Shuttle retirement.

The panel is to present its results in time to support an Administration decision on the way forward by August 2009. At that time, if any changes are recommended to FY 2010 plans, an updated set of plans will be submitted to the Congress.

While the study is ongoing, NASA will continue to work on all of its current exploration projects, including Ares I, Orion, Commercial Crew and Cargo efforts, and lunar systems.

Consideration of architecture options will take into account:
– expediting a new U.S. capability to support utilization of the International Space Station
– supporting missions to the moon and other destinations beyond low Earth orbit
– stimulating commercial space flight capabilities
– fitting within the current budget profile.

Potential outcomes of the study could be continuation of the current program or changes to it.
Global Plan: Exploration Strategy

- Human Civilization
- Exploration Preparation
- Economic Expansion
- Scientific Knowledge
- Global Partnerships
- Public Engagement
Systems of Constellation

Initial Capability
- Ares I
- Orion
- EVA

Mission Operations
- Ground Operations
- Mission Operations

Lunar Capability
- Ares V
- Altair
- Lunar Surface

EVA (Extravehicular Activity)
Exploration Systems Mission Directorate
## ESMD FY10 Budget Content

<table>
<thead>
<tr>
<th></th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FY 2010 President's Budget Request</strong></td>
<td>3,905.4</td>
<td>3,963.1</td>
<td>6,076.6</td>
<td>6,028.5</td>
<td>5,966.5</td>
<td>6,195.3</td>
</tr>
<tr>
<td>Constellation Systems</td>
<td>3,433.1</td>
<td>3,505.5</td>
<td>5,543.3</td>
<td>5,472.0</td>
<td>5,407.6</td>
<td>5,602.6</td>
</tr>
<tr>
<td>Program Integration &amp; Operations</td>
<td>645.5</td>
<td>642.5</td>
<td>1,423.9</td>
<td>1,405.4</td>
<td>1,501.5</td>
<td>1,813.9</td>
</tr>
<tr>
<td>Crew Exploration Vehicle</td>
<td>1,387.2</td>
<td>1,383.5</td>
<td>1,938.9</td>
<td>2,056.1</td>
<td>1,931.0</td>
<td>1,751.7</td>
</tr>
<tr>
<td>Crew Launch Vehicle</td>
<td>1,067.4</td>
<td>1,415.4</td>
<td>2,143.3</td>
<td>1,985.5</td>
<td>1,950.1</td>
<td>2,012.0</td>
</tr>
<tr>
<td>Ares V</td>
<td>30.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Commercial Crew and Cargo</td>
<td>303.0</td>
<td>39.1</td>
<td>12.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Advanced Capabilities</strong></td>
<td>472.3</td>
<td>457.6</td>
<td>533.3</td>
<td>556.5</td>
<td>558.9</td>
<td>592.7</td>
</tr>
<tr>
<td>Human Research Program</td>
<td>151.9</td>
<td>151.5</td>
<td>151.9</td>
<td>157.4</td>
<td>161.4</td>
<td>166.2</td>
</tr>
<tr>
<td>Exploration Technology Development</td>
<td>264.1</td>
<td>287.0</td>
<td>381.2</td>
<td>399.0</td>
<td>397.5</td>
<td>426.5</td>
</tr>
<tr>
<td>Lunar Precursor Robotic Program</td>
<td>56.3</td>
<td>19.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Notes:**
- FY 11 and out may be re-adjusted pending outcome of U.S Human Space Flight Review
- FY09 represents FY09 operating plan with Economic Recovery Act funds
Candidate tasks for the Economic Recovery Act ($400M)

• Constellation
  – Ground Operations: $25M
    • Mobile launcher ground support equipment design
  – Ares I: $48.9M
    • J-2X engine assemblies - initiate long lead engine procurements
  – Orion: $165.9M
    • Initiate the acquisition of ground test articles
    • Accelerate delivery schedules for engineering development units
    • Technology/development testing for improved crew safety
  – Small Business Innovation Research: $10.2M

• Commercial Crew and Cargo: $150M for commercial crew enabling initiatives
  – +$80.0M for commercial development of crew concepts and technology demonstrations and investigations
  – +$42.0M to accelerate development of docking system and communication interfaces between ISS and commercial vehicles, enabling commercial crew demonstrations and use
  – +$20.0M for testing and enhancing cargo launch systems to lower risk for commercial crew capability
  – +$8.0M for human rating requirements development
Constellation Program
Constellation Program enters its 4th year:
The Initial Capability phase has the five Initial Operational Capability (IOC) projects active

- Major procurements are complete
- Hardware design, development, and tests underway
- Construction of key facilities initiated
- Ares and Orion’s PDRs are scheduled to complete in 2009
- Ground Ops, Mission Ops, and EVA System Design Reviews (SDR) and Pre-Non-Advocate Reviews (NAR) complete
  - Preliminary Design Reviews (PDR) scheduled to occur in FY10
- Ares I-X test flight progressing with launch not earlier than August ‘09
- Orion Pad Abort-1 test flight preparations for Fall 2009 flight
## Constellation Program Major Acquisitions

### Orion:
- **Orion Contract Award**: August 31, 2006

### Ares I:
- **J-2X Contract Award (PWR)**: July 16, 2007
- **1<sup>st</sup> Stage Contract Award (ATK)**: August 10, 2007
- **Upper Stage Production Contract Award (Boeing)**: August 28, 2007
- **Instrument Unit Avionics Production Contract Award (Boeing)**: December 12, 2007

### EVA Systems:
- **Space Suit System Contract Award**: June 12, 2008 (later terminated as a result of a bid protest)
- **Space Suit System Letter Contract Award (Oceaneering International, Inc)**: February 27, 2009
  - Space Suit System Contract Definitization: August 2009

### Ground Operations:
- **Mobile Launcher Contract Award (Hensel-Phelps)**: May 2008
- **Ground Support Equipment IDIQ Contract Award (multiple)**: May 2008

### Mission Operations:
- **Integrated Mission Operations Contract (IMOC) (United Space Alliance)**: Award October 2008
- **Facilities Development & Operations Contract (FDOC) (Lockheed Martin)**: Award November 2008

### Altair (Lunar Lander):
- **Concept Development Broad Area Announcement (BAA) Award (multiple)**: March 2008
- **Concept Development BAA Completion**: October 2008
- **Altair Industry Day**: November 2008
- **Altair Conceptual Design Contract RFP Release**: January 28, 2009
- **Altair Conceptual Design Contract Proposals Received**: February 27, 2009
  - Altair Conceptual Design Contract Award: On Hold pending Human Spaceflight Review

### Ares V:
- **MSFC Ares V Industry Day**: November 2008
- **Concept Definition & Requirements Development RFP Release**: January 2009
  - Concept Definition & Requirements Development Support Award: On Hold Pending Human space flight review

### Lunar Surface Systems:
- **Concept Development Broad Area Announcement (BAA) Award (multiple)**: July 2008
- **Concept Development BAA Out brief**: February 25-27, 2009
Constellation Leverages Unique Skills and Capabilities Throughout NASA and the Aerospace Industry

Ames
- Lead Thermal Protection System Advanced Development Program
- Ares Abort simulations
- Mission operations simulation capabilities
- Software & Guidance, Navigation & Control support
- Support lunar in-situ resource utilization systems
- Support lunar surface mobility
- Subsystem lead for lunar lander and lunar surface systems integrated health management

Dryden
- Lead Abort Flight Test Integration/Operations
- Abort Test Booster procurement
- Flight Test Article
- Support mission operations simulation capabilities
- Support ground and flight test operations for lunar projects

Jet Propulsion Laboratory
- Thermal protection system support
- Lunar lander support including spacecraft design; guidance, navigation and control; life support systems, and avionics
- Lead specific robotic surface mobility
- Environmental monitoring and control and surface system local element communications

Marshall
- Home for Ares Project
- Ares I and V development and integration lead
- Support LAS and Service Module, Ares V EDS development, test and oversight
- Core stage development, test and oversight
- Element lead for lunar lander descent stage
- Subsystem lead for lunar lander ascent stage propulsion, propulsion testing, avionics, life support, and structures

Glenn
- Lead Service Module and Spacecraft Adapter integration
- Flight Test Article “Pathfinder” fabrication
- Ares I-X upper stage simulator lead
- Lead Ares V power, thrust vector control and payload shroud development
- Lead EDS orbital environments testing at Plum Brook
- Lead lunar lander ascent stage propulsion, ascent and descent stage power generation
- Passive thermal systems and surface element communications
- J-2X thermal and vacuum testing at Plum Brook

Goddard
- Lead program requirements for unpressurized cargo carriers
- Subsystem lead for lunar lander avionics
- Lunar surface systems avionics and surface element communications
- EVA tools and equipment

Langley
- Lead Launch Abort System integration
- Ares I-X vehicle integration
- Ares aerodynamics lead
- Lead Ares V aerodynamics
- Subsystem lead for lunar lander structures and mechanisms including ascent and descent stages
- Lunar lander and lunar surface radiation protection

Johnson Space Center
- Home for Program and Projects: Orion, MOP, EVA, Altair, Lunar Surface
- Element lead for lunar lander crew module/ascent stage
- Lead lunar surface crew habitation, environmental control/life support systems, human mobility
- GFE projects management
- Orion Flight Test Program

Michoud Assembly Facility
- Manufacturing of Ares I Upperstage, Ares V Stages and Orion Primary Structure

White Sands Test Facility
- Orion Abort Test site

Stennis
- Rocket propulsion testing
- Lead Ares V liquid rocket systems and stage testing at sea level and altitude
- Lead altitude development and certification testing for upper stage engine

Kennedy
- Home for Ground Ops Project
- Ground processing
- Launch operations
- Recovery operations
- Final assembly, ground processing for human lunar lander
- Lead for lunar surface in-situ resource utilization systems

Stennis
- Rocket propulsion testing
- Lead Ares V liquid rocket systems and stage testing at sea level and altitude
- Lead altitude development and certification testing for upper stage engine

White Sands
- Orion Abort Test site

Constellation Leverages Unique Skills and Capabilities Throughout NASA and the Aerospace Industry
Technical Progress
Hardware Fabrication and Testing – Ares I

- J2X Workhorse Gas Generator Test
- Deceleration Subsystem (DSS) Drogue Parachute Drop Test (DDT–1)
- Friction Stir weld being performed on the new Vertical Weld Tool at MSFC, AL
- Common Bulkhead Dome Delivery
- Shell Buckling Test 2/5/09, MSFC
- A3 Test Stand Subscale Diffuser Test
Ares I-X

- Is an uncrewed, sub-orbital development flight test
- Is the first flight of the Constellation Program
- Provides the opportunity to test ground facilities and operations at Kennedy Space Center
- Provides the opportunity to test flight operations
  - 1st stage recovery
  - Guidance and Navigation
  - Aero acoustics
- Is on track for a 2009 launch date
Technical Progress
Ares I-X
The boilerplate Orion crew module used for the Orion Launch Abort System Pad Abort-1 flight

I-X Crew Module and Launch Abort System Arrive at KSC

Nose Cone

Adapter Cone

PA-1 Launch Abort Systems Composite Structural Elements

Launch Abort System (LAS) PA-1 Modal Test 12/11/08
Technical Progress
Hardware Fabrication and Testing – Orion

Downselect of Avcoat & Thermal Protection System Transition

Arc Jet Testing

Ascent Abort Gantry Construction

Operations and Checkout Facility
Technical Progress: Orion PORT Test
Technical Progress
Construction of Facilities

J2X A3 Altitude Test Stand Construction

Launch Complex 39B Lightning Protection System Construction

High Bay looking west

Basement

Orion Manufacturing Facilities at KSC

Hangar AF Mods & Upgrades (Phase I) ~ 90% complete

FSAM installed onto RSS
Technical Progress
Hardware Fabrication and Testing – EVA Systems

- Handrail Translation Demonstration
- Altair Hatches Ingress/Egress Test
- Orion Hatch Ingress/Egress
- Suit Don/Doff Volume Assessment
# Constellation Summary Schedule – Initial Capability

As of April 2009

<table>
<thead>
<tr>
<th>Flight Plan</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ares I / Orion Launches</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRR</td>
<td>PPAR</td>
<td>SDR</td>
<td>SDR</td>
<td>CxPDR Checkpoint</td>
<td>CxPDR</td>
<td>Cx SW &amp; Operability Sync</td>
<td>CDR</td>
<td>SAR (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRR</td>
<td>PDR</td>
<td>SDR</td>
<td>PDR</td>
<td>CDR</td>
<td>SAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCTAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRR</td>
<td>PDR</td>
<td>SDR</td>
<td>PDR</td>
<td>Ares Thrust Osc</td>
<td>CDR 1</td>
<td>CDR 2</td>
<td>Fit Test DCR</td>
<td>DCR</td>
<td>DCR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ares I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCTAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVA (Suit 1 Config)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCTAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mission Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCTAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Construction of Facilities – FY10

<table>
<thead>
<tr>
<th>EXPLORATION</th>
<th>91.88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modify Launch Complex 39B for Ares I Vehicles (KSC)</td>
<td>6.8</td>
</tr>
<tr>
<td>Modify Vehicle Assembly Building (KSC)</td>
<td>35.80</td>
</tr>
<tr>
<td>Modify Multi-Payload Processing Facility (MPPF) for Orion (KSC)</td>
<td>1.00</td>
</tr>
<tr>
<td>Modify Building 103 to Support Upper Stage Manufacturing, MAF (MSFC)</td>
<td>2.50</td>
</tr>
<tr>
<td>Construct A-3 Propulsion Test Facility (SSC)</td>
<td>16.79</td>
</tr>
<tr>
<td>Modify Space Power Facility for Orion Integrated Environmental Testing (GRC)</td>
<td>2.26</td>
</tr>
<tr>
<td>Minor Revitalization of Facilities at Various Locations</td>
<td>23.20</td>
</tr>
<tr>
<td>Facility Planning and Design</td>
<td>3.53</td>
</tr>
</tbody>
</table>
Construction of Facilities – Project descriptions

• Modify launch complex 39B for Ares I vehicles

Modifies and upgrades Launch Complex 39B to support launch of the Orion crew exploration vehicle on the ARES I crew launch vehicle. LC 39B is currently configured to support launch of the Space Shuttle. The differences in vehicle architecture between ARES I and Shuttle are significant enough to necessitate considerable changes to the existing launch complex. The $38.4 million first phase of this project is already underway and is funded using fiscal year 2006 and 2007 resources. This second increment of $6.8 million increases funding to $45.2 million. Projected costs for FY 2011 and FY 2012 phases are $48.2 million and $3.5 million respectively. Total project cost is estimated to be $97 million.

• Modify Vehicle Assembly Building (VAB)

Modifies the VAB to accommodate assembly of the ARES I crew launch vehicles. This is the second increment of a multi-year funded project. The first increment of this project is funded with $2.5 million of FY 2009 resources. The original description provided to Congress for the first increment reflected plans at the time to modify the existing work platforms, lifting devices, lighting, and other building infrastructure systems. Trade studies performed as part of preliminary engineering work determined it would be more cost effective to replace the existing platforms rather than modify them. Additional facility modifications are required and are critical to enable the safe and affordable operation of the ARES I crew launch vehicle. This second increment of $35.8 million increases funding to $38.3 million. Projected costs for FY 2011 and FY 2012 phases are $23 million and $2.6 million respectively. Total project cost is estimated to be $64 million.

• Modify Multi-Payload Processing Facility (MPPF)

Modifies and upgrades the MPPF to enable off-line Orion spacecraft processing for hazardous fueling operations, as well as non-hazardous cargo loading and system testing. The capability to conduct hazardous operations of the Orion spacecraft off-line will provide a safer environment for personnel conducting the hazardous operations, a four day critical path reduction for launch processing, and a rollback and de-servicing capability for contingency operations. These capabilities are critical requirements to enable safe and affordable deployment of the Orion Crew Exploration Vehicle, and cannot be economically accommodated in any other facility. The first phase of this project is $1 million, and the second phase is projected to be $9.5 million. Total project cost is estimated to be $10.5 million.
Construction of Facilities – Project descriptions

• Modify building 103 to support Upper Stage manufacturing

Modifications to Building 103 at MAF for horizontal welding, reaction control system assembly, avionics integration, test and assembly, machining, and common bulkhead assembly and cleaning. This is the second increment of a multi-year funded project. The first increment of this project is funded in FY09 for $11M. This second increment of $2.5 million increases funding to $13.5 million. Projected cost for FY 2011 phase is $5.2 million. Total project cost is estimated to be $19 million.

• Construct A-3 Propulsion Test facility

Construction of a new propulsion test facility at Stennis Space Center A-complex including Test Stand, Test Control Center, Operations Support Building, and auxiliary buildings. The new test facility will enable long duration altitude testing of the J-2X engine. The facility will have the capability to simulate high altitude testing, sea-level testing, and engine gimbaling. This is the third increment of a multi-year funded project. The first and second phases of this project are already underway and are funded using fiscal year 2006 and 2007 resources. This third increment of $16.79 million increases funding to $88.5 million. Projected cost for FY 2011 phase is $5.6 million. Total project cost has grown by $22 million from the 2009 President’s Budget, and is now estimated to be $94 million. The cost growth is due to increased program requirements, as well as an increase in labor and material costs.

• Modify Space Power facility for Orion Integrated Environmental testing

Modifications to the Space Power Facility at Plum Brook Station to enable thermal vacuum, electromagnetic, acoustic and vibration testing of the Orion and Altair space crafts. New construction within the existing facility creates a radiant acoustic test chamber and a mechanical vibration test position. Changes related to technical and testing requirements maturation for the Orion crew module have increased the complexity and cost of this project, since first presented. The first and second phases of this project are already underway, and are funded using fiscal year 2007 and 2008 resources totaling $55 million. This third increment of funding increases total funding to $57.3 million. Two additional phases of construction and funding are planned for $30.8 million in FY 2011 and $15 million in FY 2012 for a total project cost of $103 million. The state of Ohio is funding $5 million for construction services.
Expanding NASA Partnerships

• NASA is expanding domestic and international partnerships to achieve lunar exploration
  – International Partnerships
    • Worked with 13 International Space Agencies to develop the Global Exploration Strategy
    • Europe and Japan most likely strategic partners; dialogue with Russia, China and India still immature
    • Strong international interest in prime, subcontracts for Altair lunar lander and crew launch systems
  – Commercial Partnerships
    • Strong commercial interest in cargo/logistics, power, communications, robotics, habitation and surface mobility (e.g. Google, Caterpillar)
  – Other Government Agencies
    • Identifying and leveraging existing government technologies to minimize development costs of the lunar architecture (e.g. DoD, DARPA, NOAA, NSF)
Challenges

- Constellation Program has continued to manage within a non-optimal budget phasing vs. normal development curve
  - Profile constrained by shuttle retirement schedule
  - Minimal early year program/project reserves to mitigate current and future risks
  - Available funding has driven aggressive, success-oriented plan for ground and flight testing that defers facilities construction, manufacture of engineering development units, tooling and ground support equipment, wind tunnel testing
  - Funding plan stability essential to maintaining schedule and limits need for contract renegotiation
- External influences on LRO/LCROSS and Ares I-X launches in 2009
- Integrating SOMD operations with ESMD design and development amid Space Shuttle Program transition
- $630M in Recovery Act and FY10 request help to mitigate these issues
- Continuing to work and resolve technical challenges that are normal in R&D effort of this magnitude—for example...
Orion Crew Module Predicted Mass (at Liftoff)

**Summary ISS**
Predicted Mass = 9485 kg  
Requirement = 9707 kg

**Summary Lunar**
Predicted Mass = 8786 kg  
Requirement = 8913 kg

**Status/Trend***
- Project Margin (ISS) → 222kg
- Project Margin (Lunar) → 127kg

**Notes:**
- Red point is the 90%-tile T/Os.
- The unencumbered margin continues to have a negative trend; 4 crew CM estimated show positive unencumbered margin
- CM predicted mass increased by 165 kg for both missions (heatshield, MMOD), both missions had a net reduction in T/O of ~50 kg

[Graph showing predicted mass over performance intervals for ISS and Lunar with trendlines and project margins.]
Thrust Oscillation Mitigation

- Technical solutions in-work reduce loads using only Ares mitigations, reducing effects to within "crew performance limit" (~0.25 g at crew seats) on the Ares side of the interface.
- Longer-term technical solutions focused on the First Stage will reduce/eliminate the source of oscillations.
- A System Design Technical Interchange Meeting was conducted April 2009 and a Preliminary Design Review is scheduled for Fall 2009 to integrate TO designs into vehicle design.

Isolator Module
- Module includes 136 isolators
- Isolation between the Ares first stage and upper stage is intended to reduce the coupling between the solid motor frequency and the natural dynamic frequency of the integrated Ares and Orion vehicle
- By moving the natural frequency of the vehicle (by reducing the structural stiffness), the response to the solid motor frequency is greatly reduced

Baseline Mitigation includes Isolator and Tuned Oscillation Array

Propellant Damping (low TRL)
- Assessing passive propellant damping as a thrust oscillation mitigation option
- Analogous to tuned mass damper with large damping ratio
- Broad band damper operational frequency range

Aft Skirt Tuned Oscillator Array (TOA)
- The Tuned Mass Absorber (TMA) is a Spring-mass-damper system with light damping
- Multiple TMA’s in an array comprise the Tuned Oscillator Array (TOA)
- TOA provides passive force-cancellation of motor thrust oscillation
- Five locations, attached to upper and mid bay rings, or skin inside the aft skirt
- Mitigation from 11 to 12.5 Hz: 10 evenly spaced frequencies
Liftoff Clearance and Launch Drift

- The Requirement
  - Ares I shall provide liftoff clearance between the Ares I integrated vehicle and the launch facility.

- The Problem
  - All launch vehicles experience drift during launch.

- The Analysis
  - Ares I preliminary drift analysis shows contact with the top of the MLP and certain heavy plume damage under certain off nominal conditions if mitigation steps are not taken.
  - The driving issue (34 kt winds from the south) is only 0.3 % of time

- The Solution
  - Combination of steering and wind placarding to levels used on ELVs and Shuttle today will be used to eliminate liftoff tower contact and minimize plume damage.

Our proposed solutions are standard operating procedures since Saturn V.
Commercial Crew & Cargo Program
COTS FY 2008/09 Accomplishments

• Commercial Orbital Transportation Services (COTS)
  ➢ SpaceX completed
    ✓ Demonstration Flight 3 System Requirements Review – Oct 07
    ✓ Demonstration Flights 2 and 3 Preliminary Design Reviews - Dec 07/Jun 08
    ✓ Draco Reaction Control System Thruster Initial Hot Fire – Mar 08
    ✓ Financing Rounds 2 and 3 – Mar 08/Feb 09
    ✓ Nine engine test firing simulating full mission duration – Aug 08
    ✓ Demonstration Flights 2 and 3 System Critical Design Review – Dec 08
    ✓ Completed the Falcon 9 Pad 40 preliminary fit check – Jan 09
    ✓ Completed Draco Thruster Qualification Testing
    ✓ Completed Dragon Propulsion Tank Qualification
    ✓ DragonEye DTO installed in Endeavour Payload Bay

  ➢ Orbital Sciences Corporation completed
    ✓ Program Plan Review – Mar 08
    ✓ Demonstration Mission System Requirements Review – Jul 08
    ✓ Unpressurized and Pressurized Cargo Module Preliminary Design Reviews – Aug 08/Oct 08
    ✓ COTS Integration and Operations Wallops Flight Facility Review – Sep 08
    ✓ Delivery of Instrumentation Program and Command List for ISS software integration – Feb 09
    ✓ ISS Phase 1 Safety Review – Mar 09
    ✓ System PDR completed May 09
COTS Funded Space Act Agreements

Orbital

Cygnus Visiting Vehicle

Avionics section

Dragon Capsule & Trunk

Draco RCS Thruster

F9-001 1st stage tank

Falcon 9
### Commercial Crew & Cargo Program
#### COTS Project Summary

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Dollars $M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY09 President's Budget</td>
<td>130.5</td>
<td>173.0</td>
<td>31.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Changes</td>
<td>0.0</td>
<td>(20.0)</td>
<td>7.8</td>
<td>12.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>FY10 PPBE</td>
<td>130.5</td>
<td>153.0</td>
<td>39.1</td>
<td>12.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- **Cargo Demonstration Flights**
  - SpaceX first of 3 COTS launches currently projected for late 2009
  - Orbital launch scheduled for Mar 2011

- NASA currently supports 2 unfunded SAA commercial partners – PlanetSpace and SpaceDev

- **FY09:**
  - $20M Congressional reduction to COTS
  - $150M Recovery funds for commercial crew enabling initiatives

- **FY10:** $7.8M partial restoration of $20M reduction; remainder planned for FY11
Advanced Capabilities
Programs in Advanced Capabilities

- **Exploration Technology Development (ETDP)**
  - Keystone technology development aligned and prioritized with Lunar Architecture and Constellation requirements in multiple technology areas

- **Human Research (HRP)**
  - HRP created to focus research investment on investigating and mitigating highest risks to astronaut health and performance in support of human exploration

- **Lunar Precursor and Robotic (LPRP)**
  - Provide knowledge of Lunar environment and reduce risk of crewed lunar landing via precursor robotic missions
## Advanced Capabilities Budget ($M)

<table>
<thead>
<tr>
<th>FY 2010 President's Budget</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>472.3</td>
<td>457.7</td>
<td>533.3</td>
<td>556.5</td>
<td>558.9</td>
<td>592.7</td>
</tr>
</tbody>
</table>

| Human Research Program    | 151.9| 151.5| 151.9| 157.4| 161.4| 166.2|
| ISS Medical Project       | 19.9 | 20.3 | 20.3 | 21.6 | 22.4 | 23.9 |
| Research Infusion         | 131.9| 131.2| 131.6| 135.8| 139.0| 142.3|

| Exploration Technology Development Program | 264.1 | 287.0 | 381.2 | 399.0 | 397.5 | 426.4 |
| ISS Research               | 44.8  | 24.6  | 25.2  | 25.4  | 27.1  | 27.8  |
| Technology Infusion Projects | 219.3 | 262.4 | 356.0 | 373.6 | 370.4 | 398.6 |

| Lunar Precursor Robotic Program | 56.3 | 19.1 | 0.2 | 0.1 | 0.0 | 0.0 |
Exploration Technology Development Program
Exploration Technology Development Program

Goals:

- Reduce human and robotic exploration mission risk by developing advanced technologies and capabilities.
- Mature critical near-term technologies to support development of the Orion Crew Exploration Vehicle and Ares I launch vehicle.
- Develop long-lead technologies to support a sustainable lunar outpost.
- Conduct fundamental microgravity research and test technologies for exploration on the International Space Station.

Projects:

- ETDP consists of 22 focused technology development projects managed by the NASA Centers.
- Major projects include power and propulsion, structures and materials, life support, robotics, in-situ resource utilization, and microgravity research.
Exploration Technology Development Program
Research & Technology Highlights

Conducted helicopter flight test of flash lidar sensor for autonomous landing and hazard avoidance system.

Demonstrated Lunar Electric Rover and suit-port concept for enabling exploration far beyond the lunar outpost.

Developed prototype in-situ resource utilization systems to produce oxygen for the lunar outpost.

Launched Combustion Integrated Rack and E-Nose instrument to ISS on STS-126.

Tested deep throttling cryogenic engine for Lander descent stage

Developed thermal protection system materials and delivered prototype 5-m heat shield for Orion.
Primary Changes:

- Start up of the Advanced Composite Technology Project, in support of Ares V design (FY09-13)
- Contribution to support Entry, Descent and Landing technologies (FY10-14) and critical skill retention.
- Contribution to support Agency priority for demonstration of optical communications.

Upcoming Activities

- 14-day desert field test of Lunar Electric Rover
- Demonstration of Tri-ATHLETE rover for unloading lunar lander
- Testing of a pintle injector (LOX-Hydrogen) for lunar lander descent engine
- Testing of LOX-Methane engine for lunar lander ascent stage
- Complete PDR for fission surface power system technology demonstration unit
## Exploration Technology Development Program

### Budget Content ($M)

<table>
<thead>
<tr>
<th>FY 2010 President's Budget</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>287.049</td>
<td>381.168</td>
<td>399.029</td>
<td>397.508</td>
<td>426.450</td>
</tr>
<tr>
<td>EDL Study (194666)</td>
<td>5.0</td>
<td>9.5</td>
<td>10.0</td>
<td>10.5</td>
<td>11.0</td>
</tr>
<tr>
<td>Intelligent Software Design (640337)</td>
<td>2.3</td>
<td>2.7</td>
<td>3.3</td>
<td>3.0</td>
<td>3.2</td>
</tr>
<tr>
<td>AR&amp;D Sensors (795369)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Exploration Life Support (439906)</td>
<td>13.7</td>
<td>28.6</td>
<td>36.0</td>
<td>33.4</td>
<td>35.1</td>
</tr>
<tr>
<td>Fire Prevention, Detection &amp; Suppression (344397)</td>
<td>1.4</td>
<td>2.0</td>
<td>2.0</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Supportability (431767)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Human Robotics Systems (431731)</td>
<td>14.2</td>
<td>17.8</td>
<td>22.5</td>
<td>25.7</td>
<td>28.8</td>
</tr>
<tr>
<td>Integrated System Health Management (425180)</td>
<td>5.9</td>
<td>9.1</td>
<td>14.4</td>
<td>17.1</td>
<td>17.8</td>
</tr>
<tr>
<td>EVA Technologies (903184)</td>
<td>14.5</td>
<td>17.4</td>
<td>20.1</td>
<td>19.8</td>
<td>13.3</td>
</tr>
<tr>
<td>Adv Env Monitoring &amp; Cntrl (838533)</td>
<td>4.6</td>
<td>10.7</td>
<td>10.4</td>
<td>13.9</td>
<td>10.7</td>
</tr>
<tr>
<td>Auto Land &amp; Haz Avoid Technologies (079749)</td>
<td>8.9</td>
<td>10.5</td>
<td>10.6</td>
<td>4.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Rad Hard &amp; Low Temp Elec (198059)</td>
<td>3.0</td>
<td>5.4</td>
<td>5.9</td>
<td>7.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Automation for Operations (015792)</td>
<td>2.5</td>
<td>4.1</td>
<td>6.6</td>
<td>7.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Cryogenic Fluid Management (095240)</td>
<td>18.7</td>
<td>21.6</td>
<td>20.9</td>
<td>24.4</td>
<td>23.3</td>
</tr>
<tr>
<td>Mini-RF/LRO (226981)</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Dust Mitigation (936374)</td>
<td>5.4</td>
<td>10.7</td>
<td>11.5</td>
<td>9.6</td>
<td>9.7</td>
</tr>
<tr>
<td>High-Bandwith Communications (438741)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Advanced Navigation Sensors (680079)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Advanced Composite Technologies (727950)</td>
<td>21.9</td>
<td>27.2</td>
<td>28.0</td>
<td>13.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Advanced Lunar Propulsion Technologies (937873)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Habitation Systems Technologies (200770)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>6.3</td>
<td>9.5</td>
</tr>
<tr>
<td>Radiation Protection Technologies (925255)</td>
<td>0.4</td>
<td>1.6</td>
<td>3.6</td>
<td>6.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Surface Power Systems (784788)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Thermal Protection Systems (092837)</td>
<td>2.2</td>
<td>1.7</td>
<td>1.8</td>
<td>1.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Non-Toxic (Green) Propulsion Systems (253225)</td>
<td>24.2</td>
<td>30.6</td>
<td>18.5</td>
<td>7.8</td>
<td>12.3</td>
</tr>
<tr>
<td>Energy Storage and Power Systems (038957)</td>
<td>10.1</td>
<td>12.8</td>
<td>11.7</td>
<td>12.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Thermal Control (119103)</td>
<td>3.3</td>
<td>4.8</td>
<td>4.9</td>
<td>4.9</td>
<td>1.2</td>
</tr>
<tr>
<td>In-Situ Resource Utilization (387498)</td>
<td>5.5</td>
<td>12.3</td>
<td>14.1</td>
<td>15.6</td>
<td>17.5</td>
</tr>
<tr>
<td>Structures, Materials, &amp; Mechanisms (441261)</td>
<td>6.7</td>
<td>6.3</td>
<td>4.7</td>
<td>9.4</td>
<td>23.5</td>
</tr>
<tr>
<td>ETDP Special Projects (825855)</td>
<td>14.1</td>
<td>35.3</td>
<td>35.2</td>
<td>36.3</td>
<td>46.9</td>
</tr>
<tr>
<td>ETDP ESMD Program Support (329231)</td>
<td>67.3</td>
<td>59.4</td>
<td>61.3</td>
<td>61.7</td>
<td>64.3</td>
</tr>
<tr>
<td>Advanced Fission Based Power Systems (463169)</td>
<td>4.9</td>
<td>12.8</td>
<td>15.4</td>
<td>15.4</td>
<td>7.8</td>
</tr>
<tr>
<td>ISS Research (825080)</td>
<td>24.6</td>
<td>25.2</td>
<td>25.4</td>
<td>27.1</td>
<td>27.8</td>
</tr>
</tbody>
</table>
## ISS Non-Exploration Research

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration ISS Research</td>
<td>$135</td>
<td>$151</td>
<td>$132</td>
<td>$139</td>
<td>$138</td>
<td>$145</td>
<td>$138</td>
</tr>
<tr>
<td>Non-Exploration ISS Research</td>
<td>$41</td>
<td>$44</td>
<td>$31</td>
<td>$29</td>
<td>$28</td>
<td>$28</td>
<td>$27</td>
</tr>
<tr>
<td>Total</td>
<td>$177</td>
<td>$195</td>
<td>$164</td>
<td>$168</td>
<td>$166</td>
<td>$173</td>
<td>$165</td>
</tr>
<tr>
<td>% of Non-Exploration to Total</td>
<td>23%</td>
<td>23%</td>
<td>19%</td>
<td>17%</td>
<td>17%</td>
<td>16%</td>
<td>16%</td>
</tr>
</tbody>
</table>

- NASA allocates at least 15% of it’s funds budgeted for ISS Research to ground-based, free-flyer, and ISS life and physical science research that is not directly related to supporting the human exploration program. NASA’s budget for ISS Non-Exploration research includes funding from the Exploration Technology Development program (ESMD), Alpha Magnetic Spectrometer (SOMD), and MUSS (SOMD).
- In FY 2009, the ISS Research budget under ESMD was increased by $20M per Congressional direction.
- Fundamental research sustains the existing United States scientific expertise and research capability in microgravity research.
- **Selected 27 proposals in non-exploration research through NASA Research Announcements (fluid physics, microbial, cellular and plant biology)**
- **Scheduled to release two more NASA Research Announcements (Combustion and Animal Physiology)**
Human Research Program
Human Research Program Overview

• Goals
  – Reduce spaceflight risks to humans and focus on the highest risks to crew health and performance during exploration missions
  – Enable development of human spaceflight medical and human factors standards
  – Develop and validate technologies that serve to reduce medical risks associated with human spaceflight

• Program Elements
  – Program Science Management/NSBRI (PSM)
  – ISS Medical Project (ISSMP)
  – Space Radiation (SR)
  – Human Health Countermeasures (HHC)
  – Exploration Medical Capability (ExMC)
  – Space Human Factors & Habitability (SHFH)
  – Behavioral Health & Performance (BHP)
Human Research Program
Highlights

Provided initial cockpit display and Caution & Warning design requirements for Orion

Delivered Space radiation risk assessment tool version 1.0 as a basis for further development of exploration models

Completed new capability to simulate Solar Particle Events at NASA Space Radiation Laboratory to reduce acute space radiation risks for lunar missions

Completed thermostabilized 3-year shelf life studies of 13 food items for extended duration exploration missions

Completed study on crew performance during combined acceleration and vibration for Constellation

Delivered CEV occupant protection recommendations that may be a significant driver in the Orion design
<table>
<thead>
<tr>
<th>FY10 President's Budget</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program/Science Management</td>
<td>35.5</td>
<td>35.7</td>
<td>36.5</td>
<td>37.9</td>
<td>38.1</td>
</tr>
<tr>
<td>Space Human Factor and Habitability</td>
<td>9.5</td>
<td>9.6</td>
<td>9.7</td>
<td>9.5</td>
<td>9.8</td>
</tr>
<tr>
<td>Human Health Countermeasures</td>
<td>36.7</td>
<td>37.3</td>
<td>38.4</td>
<td>37.8</td>
<td>38.7</td>
</tr>
<tr>
<td>Space Radiation</td>
<td>38.2</td>
<td>38.4</td>
<td>39.4</td>
<td>41.5</td>
<td>43.2</td>
</tr>
<tr>
<td>ISS Medical Project</td>
<td>20.3</td>
<td>20.3</td>
<td>21.6</td>
<td>22.4</td>
<td>23.9</td>
</tr>
<tr>
<td>Behavioral Health and Performance</td>
<td>3.0</td>
<td>2.7</td>
<td>3.1</td>
<td>3.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Exploration Medical Capabilities</td>
<td>8.3</td>
<td>8.0</td>
<td>8.6</td>
<td>9.0</td>
<td>9.2</td>
</tr>
</tbody>
</table>

- No changes to planned program content
- The Human Research Program continues to issue NASA Research Announcements to support all program elements
Lunar Reconnaissance Orbiter (LRO)

LRO spacecraft in the Goddard Space Flight Center cleanroom

LRO Ships to KSC

LRO - RF Absorber Wall

Lunar CRater Observation and Sensing Satellite (LCROSS)

LCROSS Completes Thermal Vacuum Testing

Shipment Preparations
Lunar Precursor Robotic Program Milestones 2009 & 2010

• Completed Mission Readiness Review (MRR) for LRO and LCROSS
  – May 2009

• Launch LRO and LCROSS
  – June 2009

• Begin successful science data collection from LRO and LCROSS in support of human lunar missions

• Complete LCROSS mission
  – Mission completion depends on trajectories and targets available for actual launch date and can vary from 2 to 6 months (August 2009 – March 2010)

• Complete LRO primary mission, deposit 50% available data to planetary data system
  – August 2010

• Transition of LRO mission to the Science Mission Directorate for the follow-on science mission

While the value is intangible, public interest in LRO/LCROSS can be measured by the 1.7 million people who registered to send their names to the moon on the LRO spacecraft—before launch and before any scientific data is returned from space.
### Lunar Precursor Robotic Program (LPRP)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar Precursor Robotic Program (LPRP)</td>
<td>18.4</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Lunar Precursor Robotic Program Mgmt</td>
<td>16.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lunar Reconnaissance Orbiter/LCROSS</td>
<td>2.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**LRO Life Cycle Cost**: 590.4 million

Current development cost estimate for LRO and LCROSS is $473.1 M. NASA does not anticipate that development cost will exceed 15% increase from $421M commitment.
Summary

• NASA’s near term plan remains the same: maintain March 2015 goal for the first crewed Orion/Ares flight to the International Space Station

• ESMD/Cx continues to deliver as promised on, but Challenges lie ahead
  – Contracts in place with milestones to be met
  – Technical content stabilizing as we approach the system Preliminary Design Review
  – Program plan is executable for Initial Operational Capability but flexibility is minimal

• ESMD/Technology and Research programs continue to deliver on the planned milestones

• Following independent human spaceflight review, Administration will provide updated budget request for Exploration activities to reflect results