Plans for Human Exploration Beyond Low Earth Orbit

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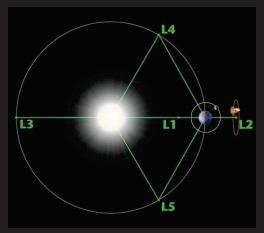
Exploration Outcomes

- Discovery
  - By addressing the grand challenges about ourselves, our world, and our cosmic surroundings
- Innovation
  - By providing opportunities to develop new technologies, new jobs, and a new market
- Inspiration
  - By encouraging students to explore, learn, contribute to our nation's economic competitiveness, and build a better future

A Bounty of Opportunity for Human Explorers



HEO/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 observers

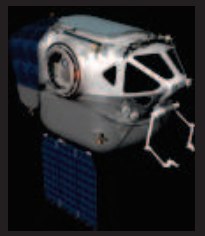
Mars and its Moons:
- A premier destination for discovery: Is there life beyond Earth? How did Mars evolve?
- True possibility for extended, even permanent, stays
- Significant opportunities for international collaboration
- Technological driver for space systems

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

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

A New Path: The NASA Authorization Act of 2010

- Congress approved and the President signed the National Aeronautics and Space Administration Authorization Act of 2010
  - Bipartisan support for human exploration beyond Low Earth Orbit
- The law authorizes:
  - Extension of the International Space Station until at least 2020
  - Strong support for a commercial space transportation industry
  - Development of a multi-purpose Crew Vehicle and heavy lift launch capabilities
  - A “flexible path” approach to space exploration opening up vast opportunities including near-Earth asteroids (NEA) and Mars
  - New space technology investments to increase the capabilities beyond low Earth orbit



FY 2012 President's Budget Overview

- Funds Exploration Programs at $3,949M-$243M above FY 2011 Authorized Level
- The President's FY 2012 Budget Request funds a diversified portfolio of activities in human spaceflight that 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
  - Funds key systems development for exploration through the Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV) capable of traveling to multiple destinations beyond LEO
  - Provides for key human research and critical capability development required for future human exploration beyond LEO

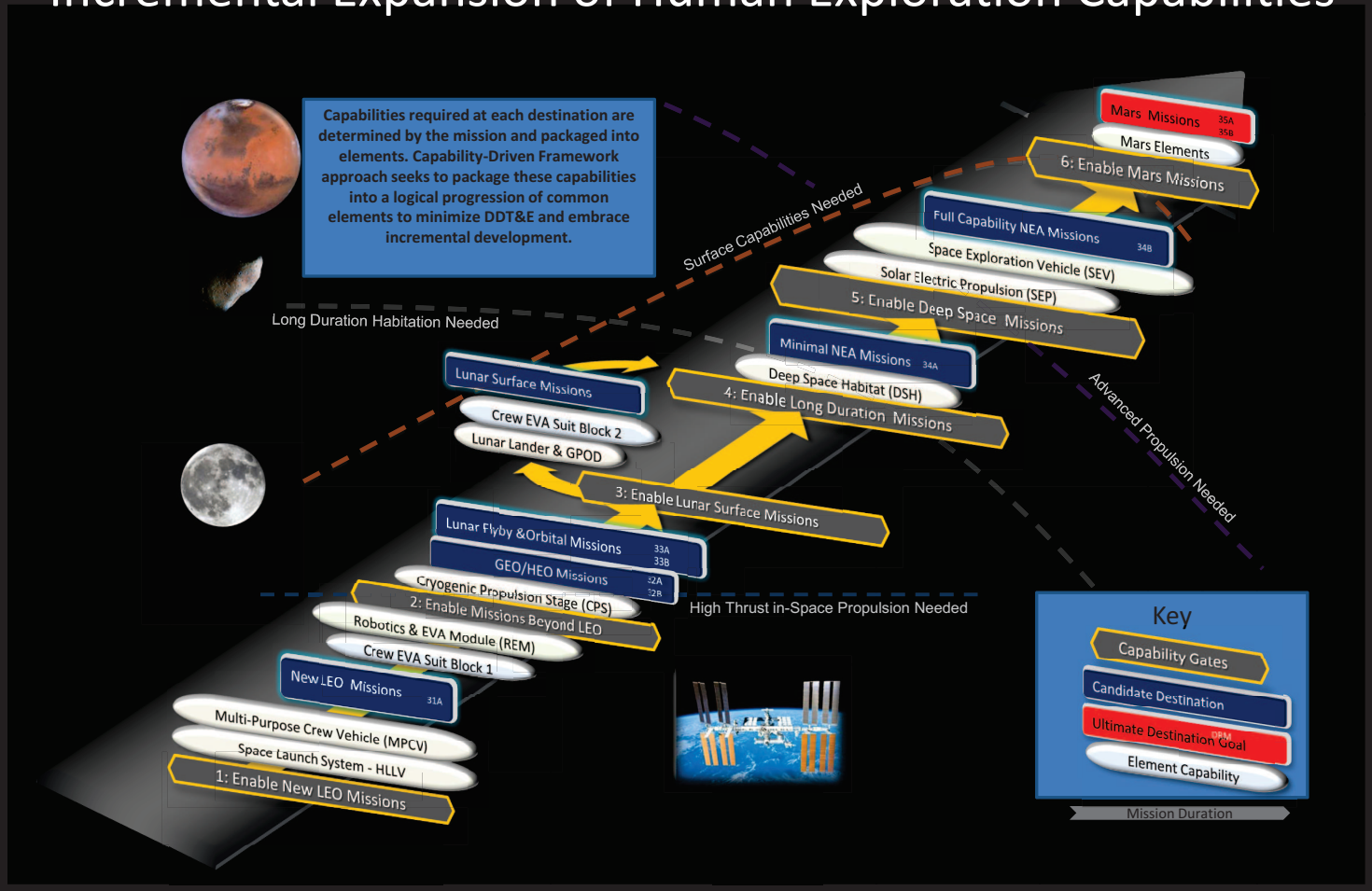
Budget Enables Significant Progress on Key Human Spaceflight Activities

- Specific content of human spaceflight portfolio as reflected in FY 2012 budget request validated by NASA framework studies and highly consistent with the NASA Authorization Act of 2010
  - ISS being utilized for critical exploration research and demonstrations
  - Cargo and crew access to ISS being developed through innovative partnerships with private sector
  - SLS and MPCV are initial essential capabilities required for NASA and the U.S. to lead exploration beyond LEO
    - These vehicles provide capabilities needed for exploration of many destinations, including cis-lunar space, the moon, asteroids and Mars and its environs
    - Formulation of these Programs is proceeding aggressively and progress will be significant in FY 2012

Budget Enables Significant Progress on Key Human Spaceflight Activities

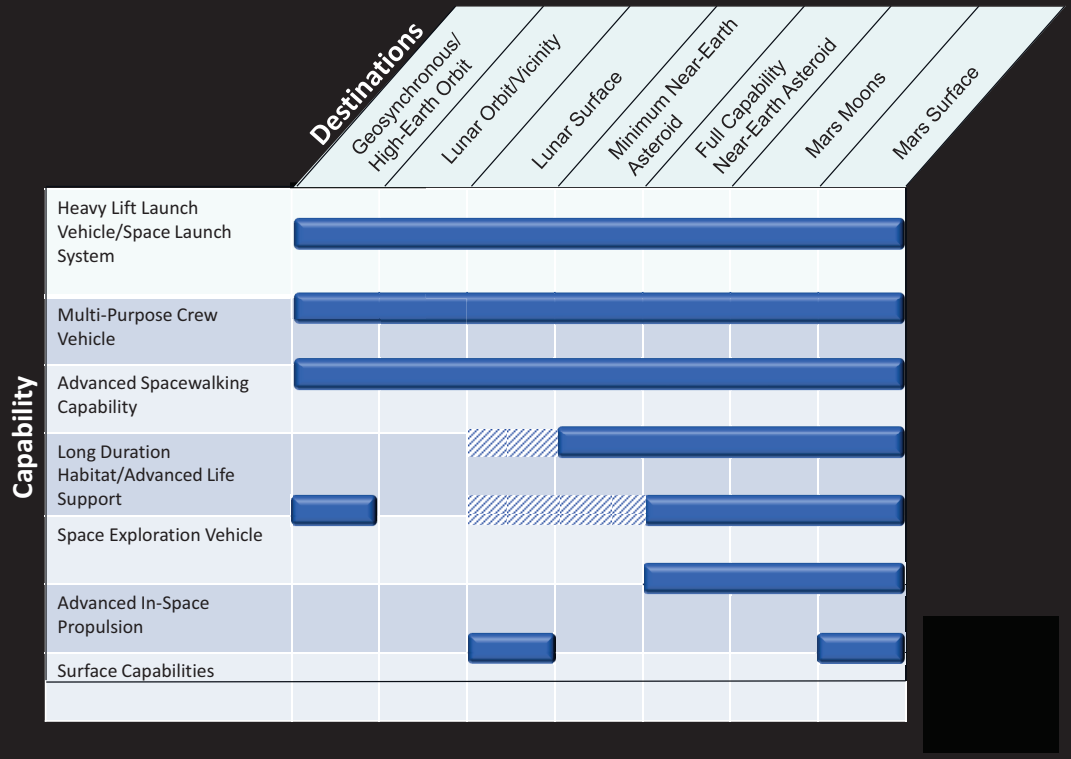
- Pursuing cutting edge human research and innovative development of needed life support, crew habitat and other future exploration capabilities
  - Exploration of more complex destinations will be enabled as key capabilities are developed over time
- Leveraging the best of NASA, industry, academia, and partner capabilities while planning innovative, cost-effective approaches to development and future operations

Incremental Expansion of Human Exploration Capabilities



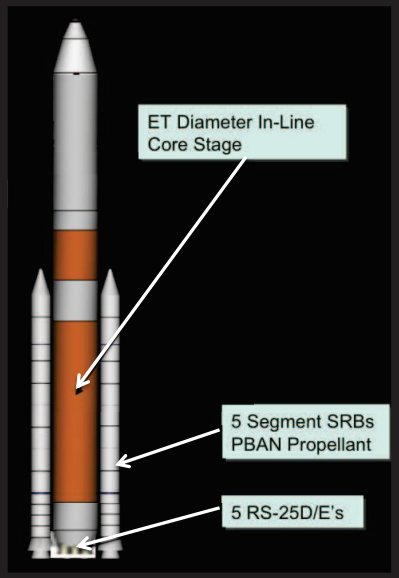
Capability-Enabled Framework

NASA will open the inner solar system to human explorers via investments in capabilities that will enable more complex missions over time.



Human Exploration Capabilities Theme Overview

- Theme budgeted at $2.8B in FY 2012 (with labor)
- The Human Exploration Capability (HEC) theme will develop launch and spaceflight vehicles that will provide initial capability for crewed exploration missions beyond LEO
  - Funded at $1.8B (with labor) in FY 2012, the Space Launch System (SLS) program will develop the heavy lift vehicle that will launch the crew vehicle, other modules, and cargo for these missions
  - Funded at $1.0B (with labor) in FY 2012, the Multi-Purpose Crew Vehicle (MPCV) program develops the vehicle that will carry the crew to orbit, provide emergency abort capability, sustain the crew while in space, and provide safe re-entry from deep space return velocities
  - Required Ground Operations and Mission Operations will largely be funded from these budget lines

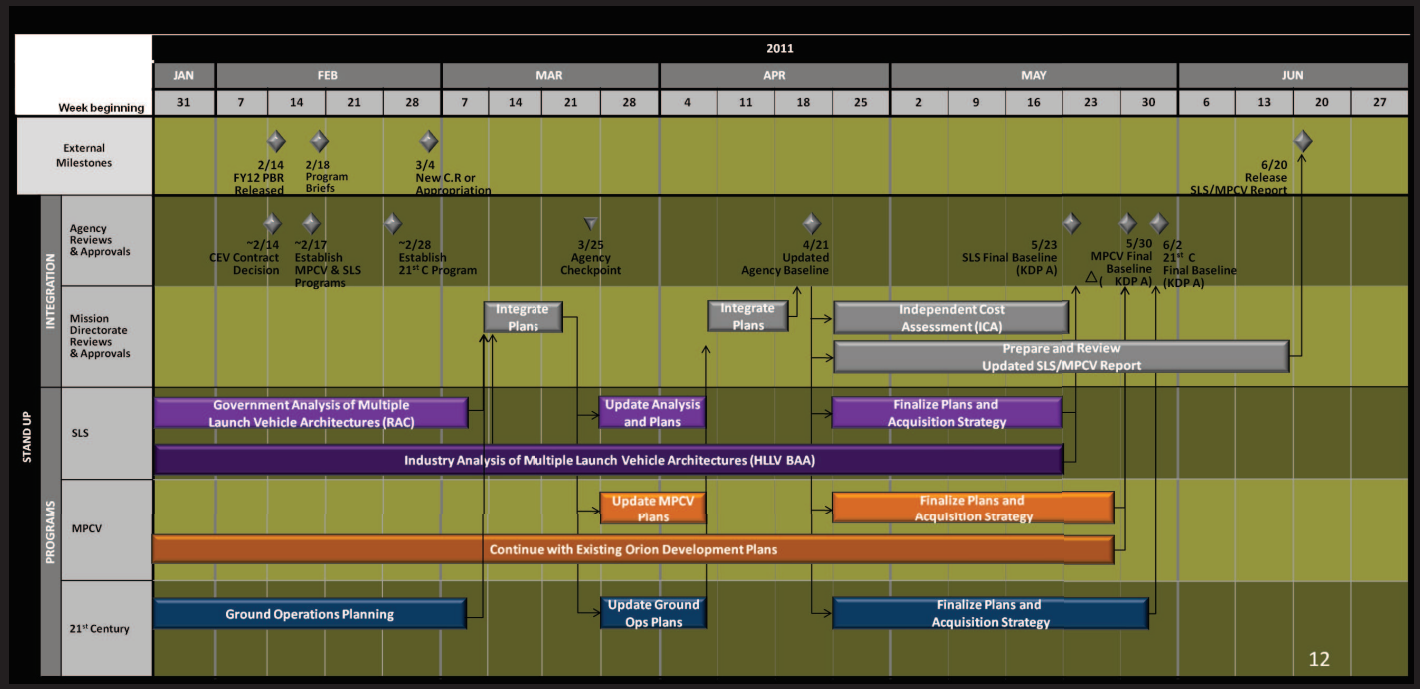


Human Exploration Capabilities Theme:
Significant Recent Progress

- Planning Teams for MPCV at Johnson Space Center and SLS at Marshall Space Flight Center are in place and active
  - Over 200 people working SLS
  - MPCV team is prior Orion team
  - ESMD is in the process of standing up SLS and MPCV Program Offices
- The SLS team is developing the Program requirements working towards Mission Concept Review and System Requirements Review in FY 2012
  - Developing full vehicle concept that can be delivered within the available budget
  - Using internal study teams and external Broad Agency Announcements (BAAs) for input
  - Evaluating existing contract scope against SLS requirements (as required by Federal Acquisition Regulations)
  - Considering early test flight timing and content
- The MPCV team continues to implement the current Orion Project plan
  - Documenting that MPCV requirements same as current Orion/Lockheed Martin scope
  - Technical progress continues – Orion Ground Test Article recently shipped from Michoud Assembly
  - Facility to Lockheed Martin Denver for testing
  - Considering early test flight timing and content

SLS and MPCV are moving out aggressively and deliberatively: On track for delivering updated SLS/MPCV Authorization Act report in Spring/Summer 2011

Human Exploration Capability
Near-Term Plans



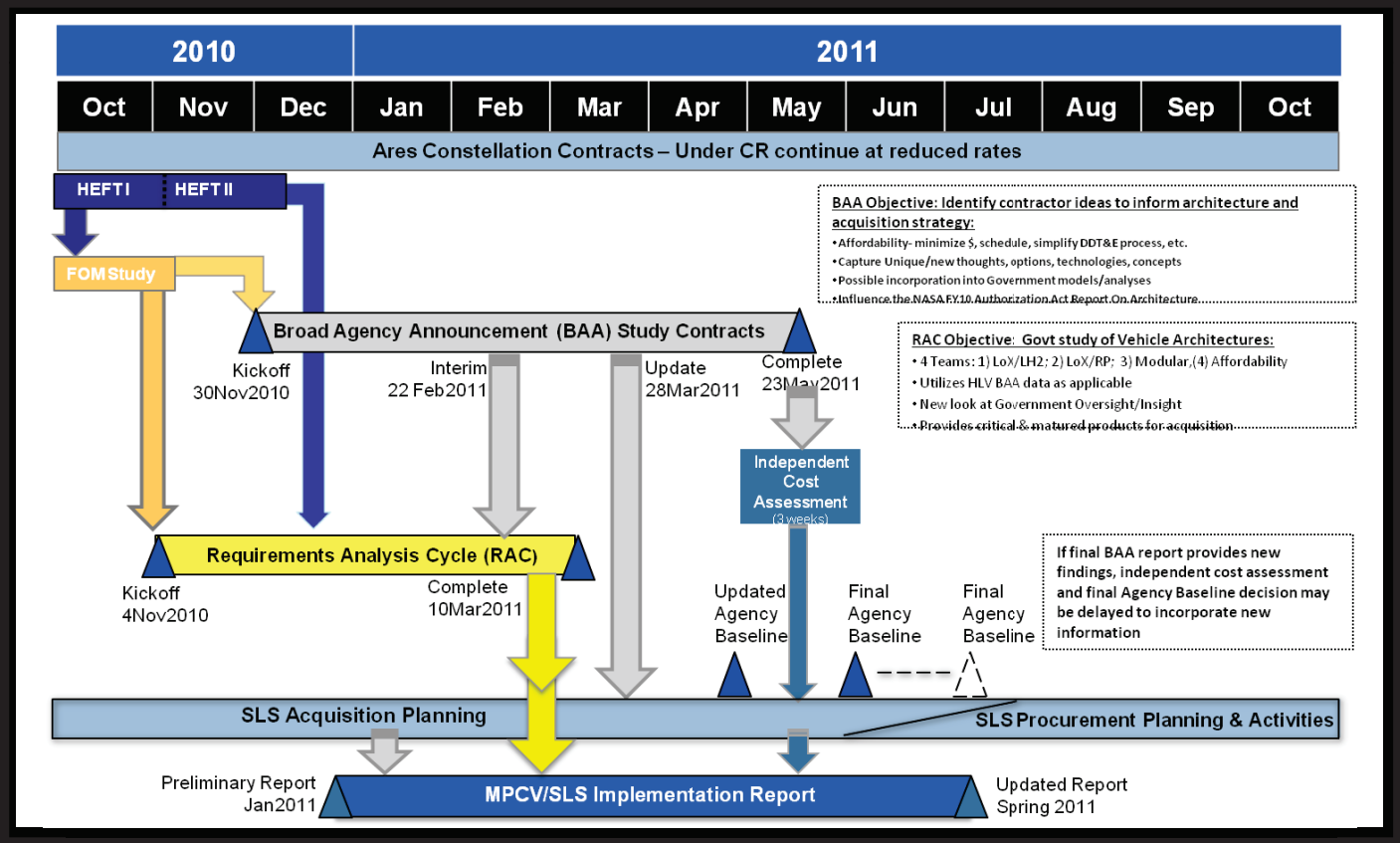
Space Launch System Overview
Ares/Shuttle-derived Reference Vehicle Design

- NASA has selected a Reference Vehicle Design that aligns with the NASA Authorization Act as a starting point for assessment of an affordable, sustainable, and realistic Space Launch System
  - Heavy Lift Launch Vehicle (HLLV) with an initial lift capability of 70-100mt evolvable to the ultimate capability of 130 mT
  - Reference Vehicle Design is derived from Ares and Shuttle hardware
  - Capability to lift the MPCV
- SLS Reference Vehicle Design
  - 27.5' Diameter LOX/LH2 Core Stage
  - Five RS25 based engines using Shuttle assets then RS25E expendable derivative
  - Two 5-Segment Ares derived SRBs
  - Delivers 108.6 tons to 30x130 nmi orbit
- Performing trades on evolving system to 130mT
  - Add Upper Stage with one or two J-2X Upper Stage Engines

Space Launch System Approach

- Pursuing multiple activities that will enable a robust and cost effective SLS Program
  - Government Requirements Analysis Cycle (RAC)
    - Validate decisions through rigorous technical, management, acquisition and process assessments
    - Develop and validate vehicle-level requirements and provide a concept that meets the requirements and available budget
  - SLS Study Contracts (HLLV BAA)
    - In November 2010, NASA awarded 13 study contracts for a 6-month period of performance
    - Working with industry on innovative ideas for implementing affordable HLLV architectures
    - Results will feed into NASA's decision process for SLS
  - Evaluating current contracts for applicability to meeting SLS requirements
- Constellation Ares contracts will continue during near-term SLS formulation activities to minimize workforce disruptions until decisions are finalized

Space Launch System Near-term Activities



Ares Progress Applicable to Space Launch System

DM-2 Static Motor Firing in Utah

J-2X Gas Generator Testing at Marshall Space Flight Center

Meeting the Challenge:
Delivering an Affordable and Achievable Space Launch System

- Given these constrained economic times, NASA has embraced the challenge to deliver human spaceflight systems for lower cost, and the opportunity to become more efficient, innovative and agile in our Programs, including SLS
  - The SLS team is examining multiple strategies to increase efficiency and agility while maximizing the creative use of existing capabilities
- Examples being considered in formulating SLS plans:
  - Smart infrastructure consolidation, both in NASA and our contractors
  - Use of common parts/common designs – encourage bulk buys
  - Design for efficient operations from the beginning of the Program
  - Ensure requirements are at appropriate level of specificity to ensure ability to apply innovative approaches to meeting them
  - Right size and right focus for Government insight/oversight activities
- NASA has reviewed affordability initiatives by our industry partners:
  - Pratt and Whitney Rocketdyne infrastructure consolidation, manufacturing and supply chain approach
  - Alliant Techsystems infrastructure and cost reduction initiatives
  - NASA estimates incorporate these potential savings where appropriate, and an affordable SLS will require such measures

Multi-Purpose Crew Vehicle Overview
Orion-derived Reference Vehicle Design

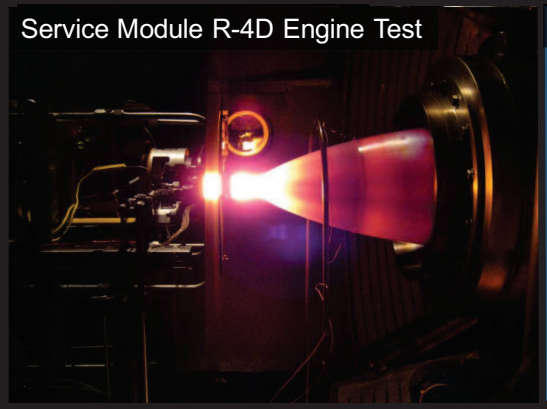
- NASA has selected the beyond-LEO version of the Orion design ("block 2") as the MPCV Reference Vehicle Design
  - Spacecraft to serve as the primary crew vehicle for missions beyond LEO
  - Capable of conducting regular in-space operations (rendezvous, docking, extravehicular activity [EVA]) in conjunction with payloads delivered by SLS for missions beyond LEO
- Preliminary trace of top-level MPCV requirements suggests that MPCV is within scope of current Orion contract (see next slide)
- Final decisions on NASA's plans for the MPCV will be made during the Acquisition Strategy review process by Summer 2011

Key Multi-Purpose Crew Vehicle Driving Requirements

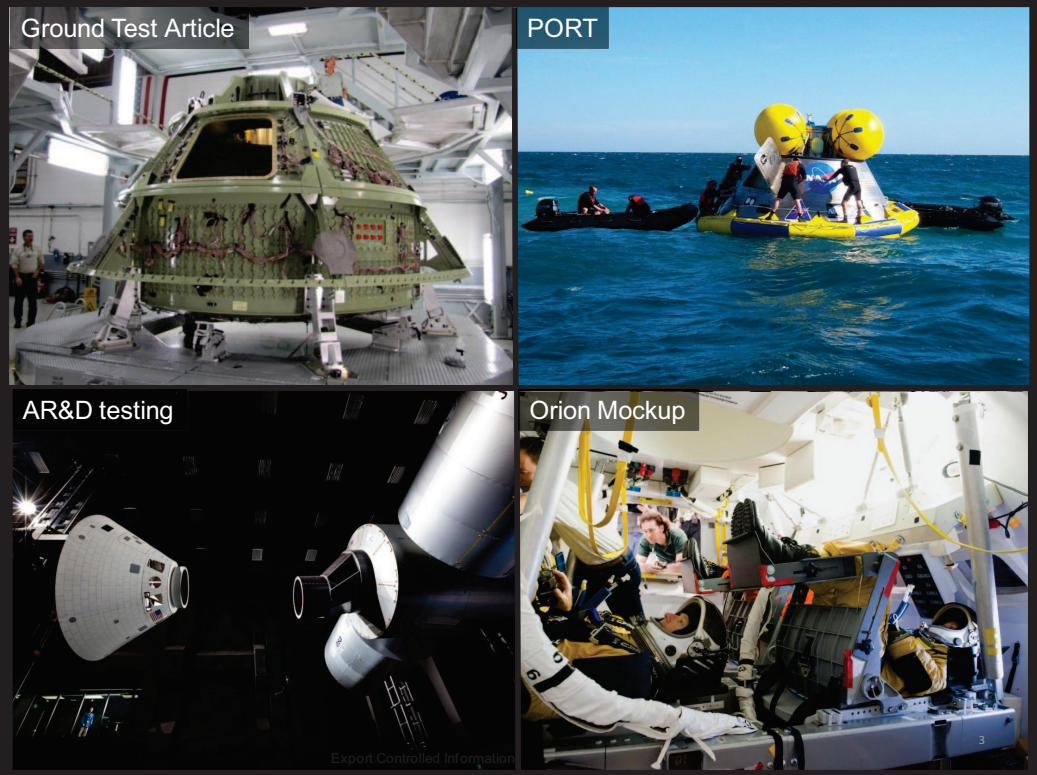
(preliminary) Similar to Orion's Capabilities

Key Driving Requirement	Preliminary MPCV Performance Required for Exploration	Current Orion Design Capability
Entry Velocity (km/s)	11.5	11
Crew Size	3	4
Propulsive ΔV (km/s)	1.5	1.5
Ascent Aborts	Required	On-Pad, Ascent; Crew-initiated, Ground-initiated, Automatic
Emergency Return	Return crew from E-M L1; minimize Black Zones	Return crew from E-M L1. Survival functions including breathable atmosphere, auxiliary comm, capability to return to Earth without comm
Active Mission Days (drives consumables, systems, mass, and volume)	21	21.1 (solar array power, regen ECLSS, Waste Mgmt System all driven by duration)
Crew Protection from Radiation	Acute Dose Limit 150 mSEV	Acute Dose Limit 150 mSEV
Crew Survival After Landing	20 hr	24 hr
Contingency EVA	Contingency EVA crew transfer between Elements	2 EVA ops @ 4 hrs ea.
Environments	LEO, cis-Lunar, Deep Space, Mars	LEO, cis-Lunar, and Lunar
Comm Range	Deep space	DSN
Navigation	Beyond-LEO inertial nav	Beyond-LEO inertial nav
AR&D (Automated Rendezvous & Docking)	Cannot rely on GPS beyond LEO	Laser-based VNS (Visual Navigation System) with manual backup
LOC/LOM	TBD, assessments currently in work	Lunar Sortie DRM: LOC 1 in 200, LOM 1 in 50
Destination Cargo to/from (kg)	250*/100 (TBR) to from Beyond-LEO	362 / 100 to / from Lunar
Unpressurized Operations	TBD, assessments currently in work	144 hr

Orion Progress Applicable to MPCV



Orion Progress Applicable to MPCV



Meeting the Challenge:
Delivering an Affordable and Achievable Multi-Purpose Crew Vehicle

- Given these constrained economic times, NASA has embraced the challenge to deliver human spaceflight systems for lower cost, and the opportunity to become more efficient, innovative and agile in our Programs, including MPCV
- Numerous innovative affordability measures are already being implemented by the Orion Project which could carry over into MPCV. Examples include:
  - Significant streamlining government insight and oversight activities
    - 70% reduction in NASA oversight – use risk-driven oversight approach
  - Implementing an incremental building of vehicle capabilities: Phase costs to fit within annual budget allocations while continuing to make significant progress
  - Planning a more innovative and cost effective qualification plan, utilizing distributed test labs and more component-level qualifications
- In partnership with the Orion prime contractor and its subs, additional affordability measures are being explored, including:
  - Consolidating facilities
  - Reuse of test assets
  - Partnerships

Commercial Spaceflight Theme Overview

- Theme is budgeted at $850M in FY 2012 (with labor)
- The Commercial Spaceflight theme provides incentives for commercial providers to develop and operate safe, reliable and affordable commercial systems to transport crew and cargo to and from the ISS and LEO
- In FY 2012, activities will transition from completing commercial cargo capability milestones* to expanding NASA's efforts to develop commercial crew

  capability to the ISS and LEO
- Objectives of Commercial Crew:
  - Facilitate the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable and cost effective access to and from LEO and the ISS
  - Once the capability is matured and expected to be available to the Government and other customers, NASA could purchase commercial services to meet its ISS crew transportation needs

*Any Commercial Orbital Transportation Services (COTS) activity in FY 2012 will be funded with prior year dollars

Recent Commercial Spaceflight Accomplishments

Commercial Cargo/COTS:

- Orbital Sciences Corporation completed several milestones over the past year including a Critical Design Review, completion of the space capsule service module core and a successful cargo integration demonstration with NASA astronaut participation
- Space Exploration Technologies completed many challenging milestones culminating in the first successful COTS demonstration flight in Dec. 2010 which demonstrated launch of the Falcon 9, separation of the Dragon space capsule, two orbits, orbital maneuvering, safe reentry and descent, and space capsule recovery after splashdown

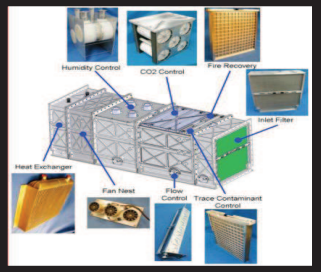
Commercial Crew Development (CCDev):

- Sierra Nevada Corporation (SNC) completed space vehicle propulsion hybrid motor testing and the Dream Chaser spacecraft composite test article and structural testing
- Blue Origin completed multiple pusher launch abort motor tests and the manufacture, assembly and structural testing of their crew composite pressure vessel
- Paragon Space Development Corporation manufactured and tested an air revitalization system engineering development unit, and successfully completed a Preliminary Design Review
- Boeing matured their commercial crew system architecture and design through a Systems Definition Review. They demonstrated crew module mockup, heat shield fabrication, avionics testing, the landing attenuation system, air bags and crew module pressure shell fabrication
- United Launch Alliance (ULA) developed and demonstrated a prototype system to provide real time launch vehicle health monitoring, providing the earliest warning of impending launch failures

NASA published the *Commercial Crew Transportation System Requirements for NASA LEO Missions* on Dec. 9, 2010 and is on schedule to meet all 2010 NASA Authorization Act requirements for Commercial Crew

Commercial Crew Development Accomplishments

Boeing Air Bag Test Article



Paragon Life Support System Components

SNC Motor Firing

ULA Emergency Detection System Prototype and Test Bed

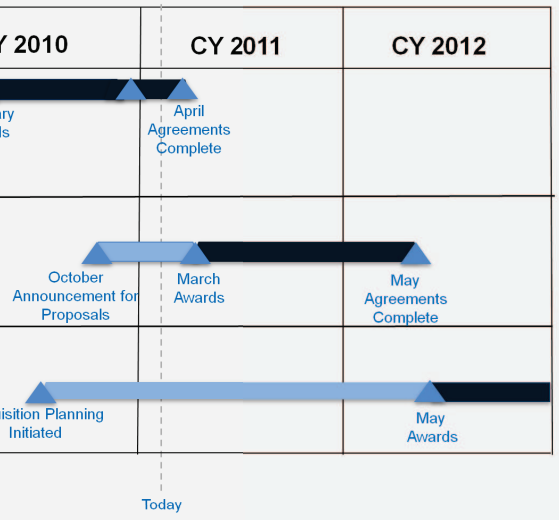
Blue Origin Composite Crew Pressure Vessel

Commercial Crew Development Round 2

- CCDev 2 Announcement for Proposals was released to industry on October 25, 2010. Proposals were due on December 13, 2010
- The goals of CCDev 2 investments are to:
  - Advance orbital commercial crew transportation system (CTS) concepts
  - Enable significant progress on maturing the design and development of elements of the system, such as launch vehicles and spacecraft, while ensuring crew and passenger safety
  - Ultimately accelerate the availability of U.S. CTS capabilities
- New competition open to all U.S. commercial providers for NASA Space Act Agreements (SAAs)
- Pay-for-Performance milestones, April 2011 to no later than May 2012
- CCDev 2 awards are planned to coincide with the FY11 appropriation which will determine the exact amount available for awards
- **NASA is currently in a BLACK-OUT period regarding CCDev 2. All information above is public and has been previously disclosed.**

Commercial Crew Structure and Timeline

Title	Purpose
Commercial Crew Development (CCDev)	Develop and demonstrate technologies that enable commercial human spaceflight capabilities.
CCDev Round 2	Mature the design and development of elements of the system, such as launch vehicles and spacecraft.
CCDev Round 3	Facilitate the development and demonstration of multiple, integrated, end-to-end commercial crew systems.



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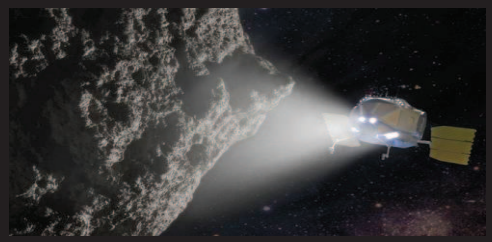
Exploration Research and Development Overview

- Theme budgeted at $289M in FY 2012 (with labor)
- The Exploration Research and Development theme is comprised of the Human Research Program (HRP) funded at $164M in FY 2012(with labor), and the Advanced Exploration Systems Program (AES) funded at $124M in FY 2012 (with labor)
- These Programs provide the knowledge and advanced human spaceflight capabilities *required* to undertake human exploration beyond Earth
  - HRP provides countermeasures, diagnostics, technologies and design tools to keep crews safe and productive on long-duration space missions, and makes extensive use of the ISS
  - AES will focus on continuing current development of key required capabilities for future human exploration beyond the SLS and MPCV including advanced life support, EVA, and prototyping of other beyond LEO exploration systems
    - In future years, AES will support robotic missions of opportunity to obtain required precursor measurements of human spaceflight destinations

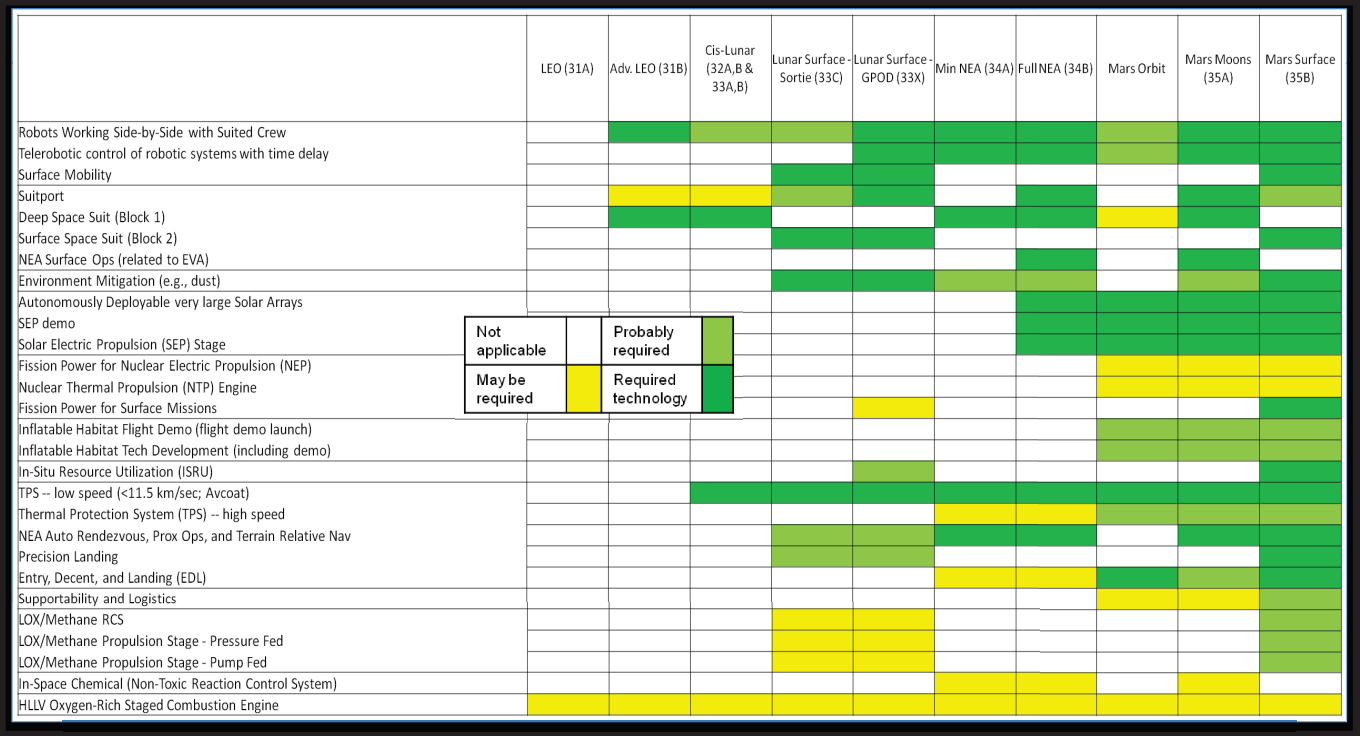


Exploration Research and Development
Changes from FY 2011

- In FY 2012, the Exploration Technology Development and Demonstration (ETDD) Program will be transferred to the Office of Chief Technologist (OCT) to place it in a technology-focused organization
  - ETDD includes technology demonstration flight missions and long-range exploration technology development projects that will be integrated with similar activities in the OCT Space Technology Program.
  - AES activities remaining in Exploration are uniquely related to crew safety and strongly coupled to current and future vehicle development
- Exploration Precursor Robotic Missions have been deferred in FY 2012
  - In FY 2013, a new activity, jointly funded by ESMD and Science Mission Directorate (SMD) will pursue missions of opportunity to gather required data on potential destinations for human exploration

Technology Applicability to Destination Overview (1)

Technology Applicability to Destination Overview (2)



	LEO (31A)	Adv. LEO (31B)	Cis-Lunar (32A,B & 33A,B)	Lunar Surface - Sortie (33C)	Lunar Surface - GPOD (33X)	Min NEA (34A)	Full NEA (34B)	Mars Orbit	Mars Moons (35A)	Mars Surface (35B)
Robots Working Side-by-Side with Suited Crew										
Telerobotic control of robotic systems with time delay										
Surface Mobility										
Suitport										
Deep Space Suit (Block 1)										
Surface Space Suit (Block 2)										
NEA Surface Ops (related to EVA)										
Environment Mitigation (e.g., dust)										
Autonomously Deployable very large Solar Arrays										
SEP demo										
Solar Electric Propulsion (SEP) Stage										
Fission Power for Nuclear Electric Propulsion (NEP)										
Nuclear Thermal Propulsion (NTP) Engine										
Fission Power for Surface Missions										
Inflatable Habitat Flight Demo (flight demo launch)										
Inflatable Habitat Tech Development (including demo)										
In-Situ Resource Utilization (ISRU)										
TPS -- low speed (<11.5 km/sec; Avcoat)										
Thermal Protection System (TPS) -- high speed										
NEA Auto Rendezvous, Prox Ops, and Terrain Relative Nav										
Precision Landing										
Entry, Decent, and Landing (EDL)										
Supportability and Logistics										
LOX/Methane RCS										
LOX/Methane Propulsion Stage - Pressure Fed										
LOX/Methane Propulsion Stage - Pump Fed										
In-Space Chemical (Non-Toxic Reaction Control System)										
HLLV Oxygen-Rich Staged Combustion Engine										

Not applicable		Probably required	
May be required		Required technology	

Human Research Program Overview

- HRP supports risk-driven space biomedical research critical to crew health and safety:
  - Investigates and mitigates the highest risks to astronaut health and performance to support NASA human exploration missions
  - Conducts fundamental and applied research on the human system to provide countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration
  - Uses the ISS and ground-based research facilities to study the effects of prolonged spaceflight on human physiology and behavior
- Objectives and research goals:
  - Exploration-enabling projects in biomedical technologies and development, space radiation research, behavioral health and performance
  - Research and technology to fully utilize ISS as a biomedical laboratory
  - Enhance science, technology, engineering and mathematics (STEM) education, projects that return Earth benefits
  - International collaborations

Human Research Program
Plans for FY 2012

- ISS utilization
  - ISS is critical for mitigating human health risks relevant to exploration and is an important test bed for space biomedical technology
  - Implement 15-20 ISS biomedical flight experiments per each 6-month mission
  - Deliver the next-generation space biomedical ultrasound device to enhance human research facility capability on the ISS
- Develop space biomedical capabilities
  - Provide space medical imaging capability for diagnosis of crew fractures
  - Submit approach for preventing bone loss in space by using pharmaceuticals in conjunction with an in-flight exercise
- Enhance crew radiation safety
  - Deliver design tool for vehicle radiation shielding assessments
  - Release the acute radiation risk model update
- Engage the national research community
  - NASA research announcements that address crew health risks and space radiation safety

Advanced Exploration Systems Program Overview

- Although a new title, AES continues ongoing work to develop and demonstrate prototype systems for human spaceflight capabilities critical for safe human exploration beyond LEO
  - Focus areas include life support, habitation, extravehicular activity
  - AES demonstrates these prototype systems in ground test beds, Earth-based field and underwater tests, and ISS flight experiments
  - In future years, AES will support robotic missions of opportunity to future human spaceflight destinations in collaboration with SMD and international partners
  - AES will leverage large numbers of civil servants on in-house, exciting development work

- AES Objectives:
  - Advanced development of required exploration capabilities and systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit
  - Use innovative approaches for rapid systems development and provide hands-on experience for the NASA workforce
  - Infuse new technologies into exploration missions
  - Support robotic missions of opportunity to characterize potential destinations for human exploration

Advanced Exploration Systems Program

Plans for FY 2012

- Develop a ground-based test bed for demonstrating highly-reliable life support systems to enable long-duration missions
- Develop and test components for an advanced spacesuit to improve the ability of astronauts to assemble and service in-space systems, and to explore the surfaces of the moon, Mars and asteroids
- Develop design concepts for future space exploration vehicles and deep space habitats
- Conduct ISS and ground-based analog testing to validate operational concepts for long endurance space missions including exploration of near-Earth asteroids
- Plan for future robotic missions of opportunity for precursor measurements with SMD and international partners

NASA Exploration: Going Beyond

- NASA's human spaceflight program seeks to extend human presence throughout the solar system
- The FY 2012 Budget Request supports all critical aspects of a vibrant human spaceflight program, and all components of the NASA Authorization Act of 2010:
  - Safe, affordable LEO access with Commercial Crew and leveraging ISS for future exploration
  - Significant progress on NASA's beyond-LEO vehicles – the SLS and MPCV
  - Investment in required research and capabilities development for beyond LEO human missions
- Affordability measures are key to a successful future
- NASA Exploration accepts the challenge to execute our programs within available budgets – we will leverage prior investments creatively to enable a sustained, exciting future for human exploration