National Aeronautics and Space Administration

Exploration Systems Mission Directorate: FY 2011 Budget Highlights

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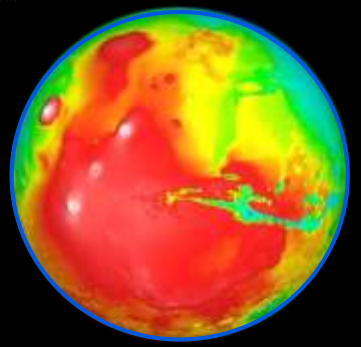
March 8, 2010

Exploration: Blazing a Trail Into the Solar System

- NASA’s human spaceflight program seeks to extend human presence throughout the solar system
- The President's FY2011 Budget Request takes a new approach to this goal, focusing on developing the capabilities that will allow us to reach multiple potential destinations, including the Moon, Asteroids, Lagrange points, and Mars and its environs
- The investments seek to create the new *knowledge* and *capabilities* required for humans to venture beyond low Earth orbit to stay
- Approach expands alternatives available for human exploration, currently limited by lack of strategic investment in technology development over past decades



FY 2011 President's Budget Overview

The President's budget will invest an additional $6 billion in NASA over the next five years- an overall $100 billion commitment to the agency

- President's Budget challenges NASA to embark on a new human space exploration program that invests near-term in obtaining key knowledge about future destinations and demonstrating critical enabling technologies for human spaceflight and exploration, including:
  - Research and development of heavy-lift and propulsion technologies
  - Transformative technology development and flagship technology demonstrations to reduce cost and expand capabilities of future human exploration activities
  - Precursor robotic missions to multiple destinations in the solar system to cost-effectively scout human exploration targets and identify hazards and resources for visitation and habitation
  - Expanded efforts to develop U.S. commercial human spaceflight capabilities, making space travel more accessible and affordable
  - Increased investment in Human Research to prepare for long human journeys beyond Earth
- Budget submission cancels Constellation Program, builds on research and technology investments in Advanced Capabilities and Constellation Systems

Exploration FY 2011 Budget Request

Budget Authority ($ millions)	Actuals	Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	**3,905.5**	**3,779.8**	**4,263.4**	**4,577.4**	**4,718.9**	**4,923.3**	**5,179.3**
Exploration Research and Development			1,551.4	2,577.4	3,318.9	3,623.3	3,979.3
Exploration Technology and Demonstrations			652.4	1,262.4	1,807.9	2,013.3	2,087.3
Heavy Lift and Propulsion Technology			559.0	594.0	597.0	598.0	754.0
Exploration Precursor Robotic Missions			125.0	506.0	699.0	797.0	923.0
Human Research			215.0	215.0	215.0	215.0	215.0
Commercial Spaceflight			812.0	1,400.0	1,400.0	1,300.0	1,200.0
Commercial Cargo			312.0				
Commercial Crew			500.0	1,400.0	1,400.0	1,300.0	1,200.0
Constellation Transition			1,900.0	600.0	0.0	0.0	0.0
Constellation Systems	3,433.2	3,325.8					
Constellation Systems	3,190.1	3,286.7					
Commercial Crew and Cargo	243.0	39.1					
Advanced Capabilities	472.3	454.0					
Human Research Program	151.9	151.5					
Exploration Technology Development Program	264.1	283.4					
Lunar Precursor Robotic Program	56.3	19.1					
FY 2010 President's Budget Request	**3,905.5**	**3,963.1**	**6,076.6**	**6,028.5**	**5,966.5**	**6,195.3**	**-**
Constellation Systems	3,433.2	3,505.4	5,543.3	5,472.0	5,407.6	5,602.6	-
Advanced Capabilities	472.3	457.7	533.3	556.5	558.9	592.7	-
Total Change from FY 2010 President's Budget Request		**-183.3**	**-1,813.2**	**-1,451.1**	**-1,247.6**	**-1,272.0**	

FY 2010 Activity

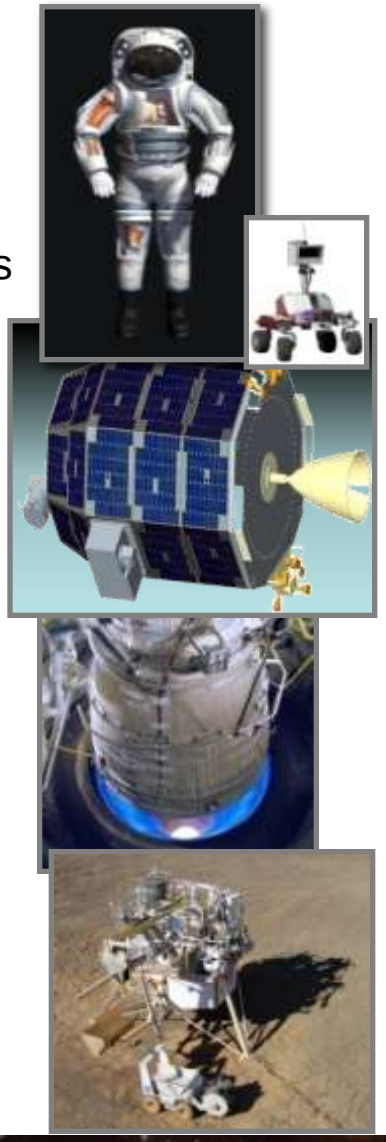
- Constellation is currently proceeding per the enacted FY 2010 appropriation
  - Program working to complete Preliminary Design Review and major tests scheduled for FY 2010 (e.g. Pad Abort 1)
  - ESMD will continue incremental funding of contracted tasks for existing contracts; in order to ensure the availability of funds for termination liability as required by law, addition of new tasks will require Headquarters approval
- Study teams are in place to plan transition from large, mission operations program to a diverse technology development, demonstration, and precursor focus
- New programs will leverage work performed in Constellation, Exploration Technology Development, Human Research, and Lunar Precursor Robotic Programs
- NASA will maximize use of civil service workforce expertise as we shift roles of those currently supporting the Constellation Program

ESMD Approach to Budget Response

- Total of Ten Teams Stood Up
  - 6 pre-formulating new/expanded programs:
    - Commercial Crew and Cargo Development Program
    - Exploration Precursor Robotic Program
    - Flagship Technology Demonstrations Program
    - Enabling Technology Development and Demonstrations Program
    - Heavy Lift Propulsion Technology Program
    - Human Research Program
  - 1 team assessing transition of Constellation Program
  - 3 cross cutting for international, participatory exploration, integration
    - International - Seeking potential international opportunities within the content of new programs
    - Participatory Exploration – Standing up Agency-wide office to ensure maximum public participation of NASA missions
    - Integration – Internal team ensuring coordination across all ESMD programs

Exploration Research and Development Theme

- Theme includes three robust new exploration activities:
  - Exploration Technology and Demonstrations - $7.8 billion over five years
    - Development and demonstration of technologies to reduce costs and expand capabilities for future exploration
  - Heavy-Lift and Propulsion Technology - $3.1 billion over five years
    - Research and development of new propulsion systems, propellants, materials and combustion processes
  - Exploration Precursor Robotic Missions - $3.0 billion over five years
    - Cost effective means to scout exploration targets and identify resources for human visitation and habitation
- Theme budget also increases Human Research Program funding by 42% and supports Participatory Exploration Program at $5 million per year (for activities across many NASA programs)



Strategy for Potential Future Human Missions

Potential Destinations

Common Capabilities

Mission Analyses

System Design(s)

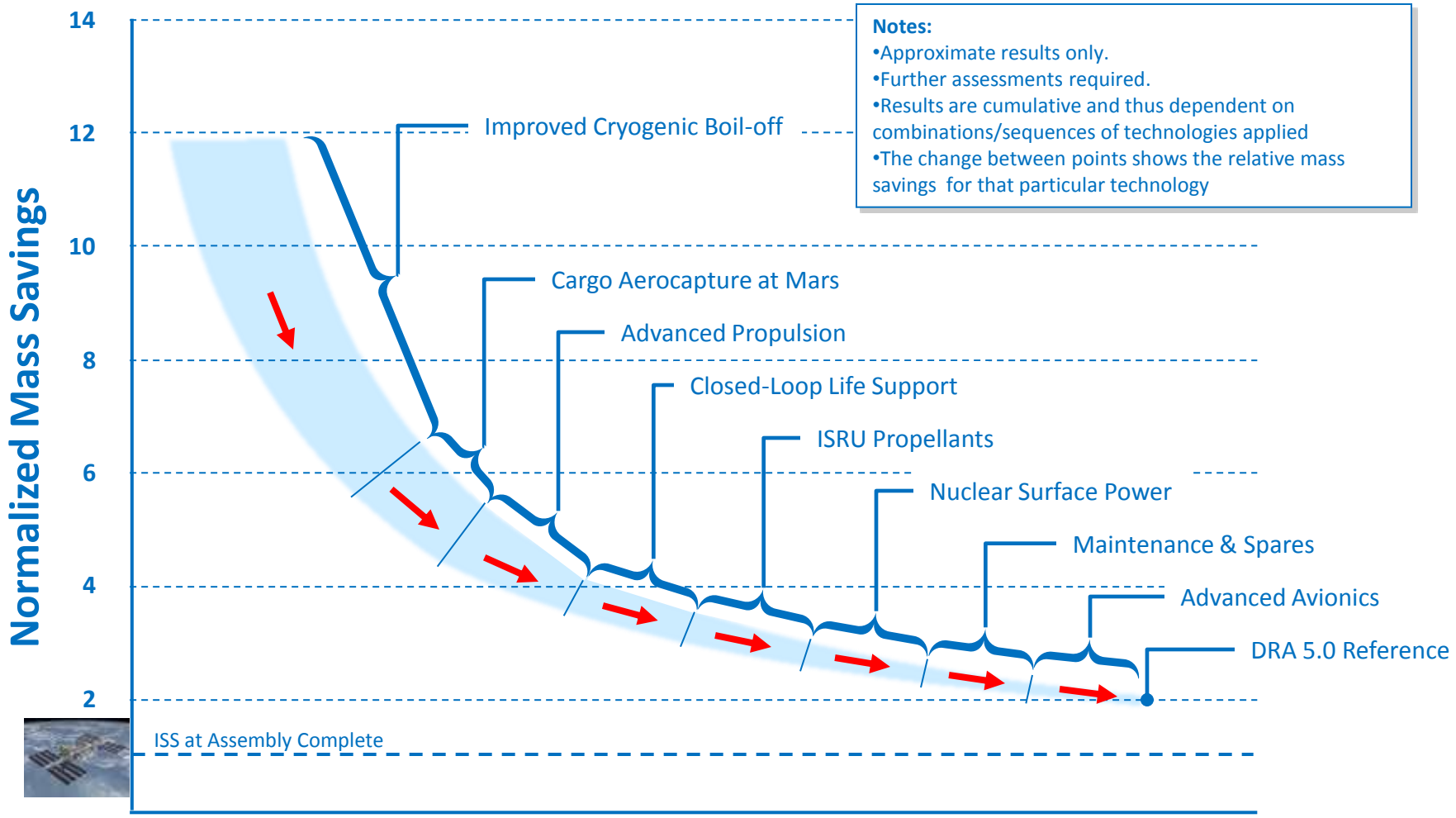
Technology Building Blocks

- Efficient In-Space P
- Aeroassist
- Low-cost Engines
- Cryo Fluid M
- Robust/Efficient P
- Lightweight S
- Radiation Research
- Zero/Low-g Research
- Regenerable Life S
- Advanced Lightweight EVA

"Breakthrough" Technologies (Examples)

- Wireless Power Transmission
- Regenerative Aerobraking
- Revolutionary ETO Rockets
- Innovative Mission Concepts

The Value of Technology Investments
Mars Mission Example



Commercial Crew and Cargo

	2011	2012	2013	2014	2015
Commercial Crew	$500	$1,400	$1,400	$1,300	$1,200
Commercial Cargo	$312	--	--	--	--

- Budget invests $6 billion over five years to spur development of U.S. commercial human spaceflight vehicles
  - Support potential commercial crew transportation providers to whom NASA could ultimately award a competitive crew transportation services contract analogous to the CRS cargo services contract
  - Tasks include human rating existing vehicles, development of capsules that can fly on multiple launch vehicles, and/or developing new high-reliability rocket systems
- NASA will allocate funds through competitive solicitations to support higher and lower risk systems and system components
  - NASA will ensure that all commercial systems meet stringent human-rating and safety requirements before we allow any NASA crew member to travel aboard a commercial vehicle
  - NASA will work with the community to get the broadest range of competitors, from established aerospace companies to emerging companies (as with Commercial Crew Development awards)
- In addition to the $6 billion, invest $312 million for incentivizing NASA's current commercial cargo program to expedite the pace of development
- ISS Commercial Resupply Services (contract carried in the Space Operations budget) will benefit from the additional cargo investment

Commercial Orbital Transportation Services Overview

- Commercial Crew and Cargo Program established in November 2005
  - Implement U.S. Space Exploration policy with investments to stimulate commercial space industry
  - Facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with goal of achieving safe, reliable, cost effective access to low-Earth orbit
  - Create market environment where commercial space transportation services are available to Government and private sector customers
- $500M initially budgeted in FY 2006-FY2010 as investment for demonstration of commercial orbital transportation capabilities
  - First round competition for funded Space Act Agreements (SAAs) awarded August 2006
    - SpaceX awarded $278 million
    - Rocketplane Kistler awarded $208 million (terminated October 2007 for failure to meet milestones)
  - Second round competition awarded February 2008
    - Orbital Sciences Corporation awarded $170 million
  - NASA has two unfunded partners: PlanetSpace and SpaceDev
    - NASA provides limited technical guidance to unfunded partners and periodically reviews progress of unfunded milestones
    - Unfunded partners have access to NASA technical libraries, specifications and ISS visiting vehicle requirements sets

Exploration Precursor Robotic Missions

	2011	2012	2013	2014	2015
Exploration Precursor Robotic Missions	$125	$506	$699	$797	$923

- Program will send precursor robotic missions to locations such as the Moon, Mars and its moons, Lagrange points, and Near Earth Objects
- Small and medium class flight projects with life cycle costs below $800 million
- Missions driven by Exploration Objectives:
  - Quantify value of targets for deep space human destinations
  - Identify hazards and resources to guide course of human exploration
  - Make critical observations and measurements providing engineering boundary conditions to enable cost effective human spaceflight
  - Test technologies and operational concepts that benefit future human activities in space
- Missions to include small and medium class missions, and missions of opportunity on science and international partner spacecraft

Exploration Precursor Robotic Missions - Approach

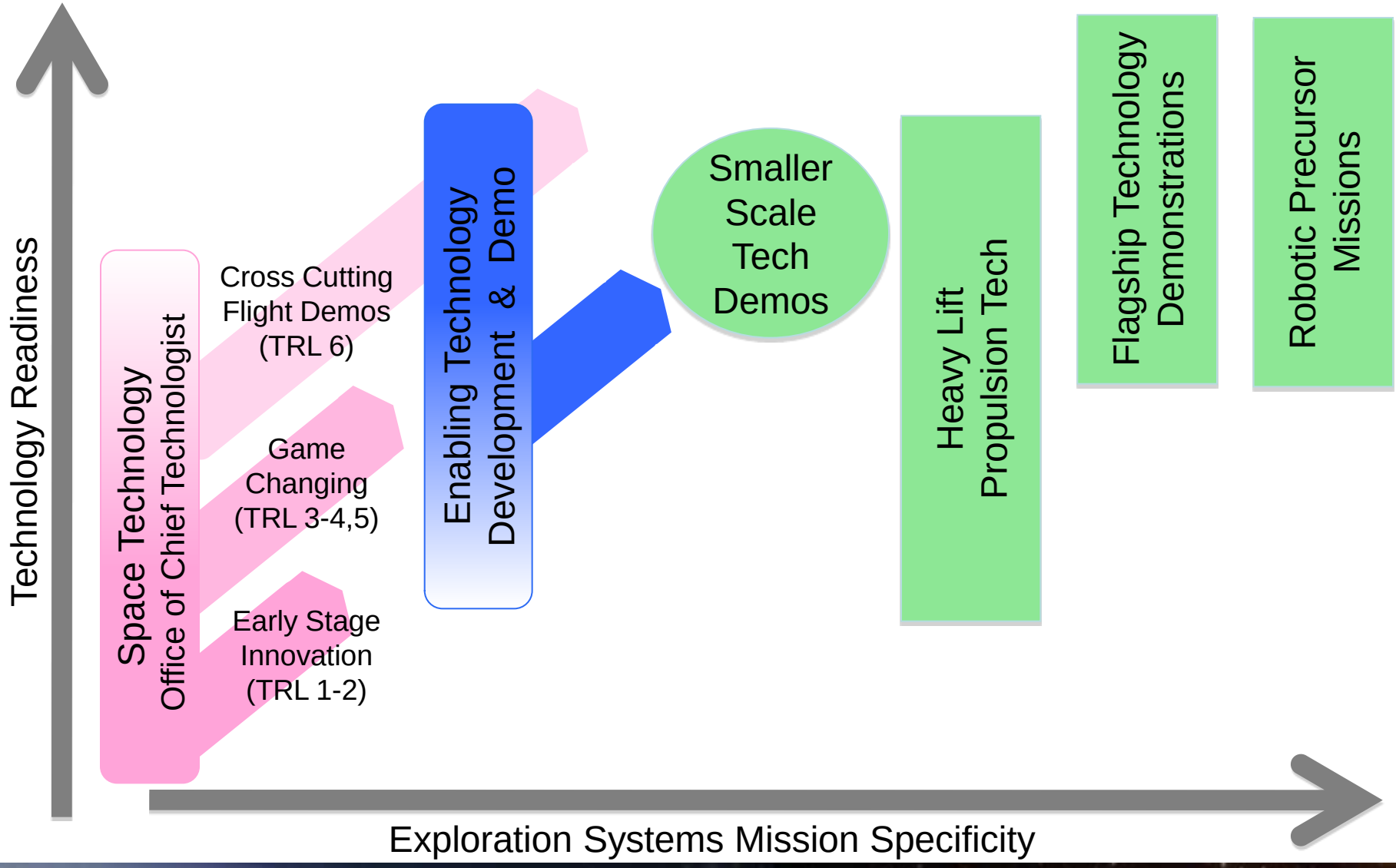
- Maintain steady tempo of exploration missions and investigations to address priority needs and objectives in preparation for human exploration
- Initiate at least two mission formulations in FY 2011
  - Lunar mission demonstrating tele-operation capable of transmitting near real-time video to Earth, investigations for validating availability of resources for extraction
  - Additional candidate missions may include
    - Landing on near-earth asteroids or on the moons of Mars (Phobos and Deimos)
    - Landing in situ resource utilization capability to process lunar or asteroid materials into fuel and/or other exploration enabling materials
- Emphasize partnerships, coordination, and collaboration (inter-Directorate, international, interagency, etc.)
- Provide venue for flight validation and infusion of developed technology and for Participatory Exploration opportunities
- In FY 2010, develop approach and objectives for first missions, develop long-term roadmap
- FY 2012/2013, continue with additional missions and instrument development to provide steady campaign of exploration precursor missions

Exploration Technology and Demonstrations

	2011	2012	2013	2014	2015
Exploration Technology and Demonstrations	$652	$1,262	$1,808	$2,013	$2,087

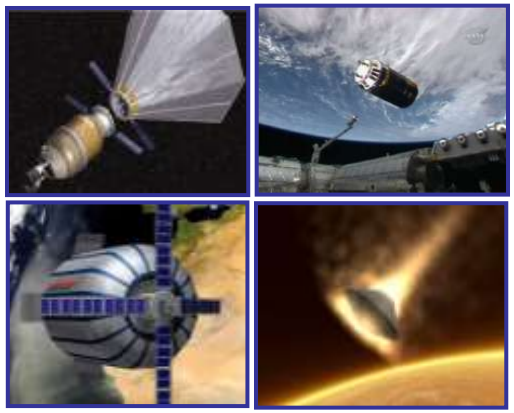
- Flagship Demonstration Program
  - Projects funded at $400 million to $1.0 billion over less than five years; may include partnerships with international, commercial and other government entities
  - In-space demonstrations with high potential to demonstrate new exploration capabilities
    - Validate next generation capabilities key to sustainably exploring deep space
    - Reduce cost and risk of future exploration missions
    - Demonstrate critical technologies such as: in-orbit propellant transfer and storage, inflatable modules, automated/autonomous rendezvous and docking, closed-loop life support systems, advanced in space propulsion, and other next-generation capabilities
- Enabling Technology Development Program
  - Shorter duration projects funded at $120 million or less, ranging from laboratory experiments to Earth-based field tests and in-space technology demonstrations, including in-situ resource utilization and advanced in-space propulsion
  - Near-term development and demonstration of prototype systems to feed flagship and robotic precursor missions
  - Long-range development/maturation of technologies critical to future human exploration missions
  - Infusion path for promising, game-changing technologies developed by Space Technology Program

Space and Exploration Technology Development



Flagship Technology Demonstrations - Approach

- In FY 2010, develop long-term roadmap and approach for near-term missions
- Evaluation underway of highest leverage demonstrations; Mars destination is a driving case for high leverage demonstration and technology
- First three primary technology targets for single or combined missions to include:
  - In-orbit propellant transfer and storage
  - Lightweight/inflatable modules
  - Automated/autonomous rendezvous and docking
- Fourth flight program such as
  - Aerocapture/entry, descent and landing
  - Advanced life support
  - Advanced in-space propulsion (ion/plasma, etc)



- Identify potential partnerships with industry, other agencies, and international partners and leverage ISS for technology demonstrations, as appropriate
- Initiate four technology demonstrations in FY 2011
- Follow-on demonstrations informed by emerging technologies

Enabling Technology Development and Demonstration - Approach

- Build on technology development investments within current ESMD portfolio
- In FY 2011, initiate demonstrations leading to flagship/precursor missions
  - In situ resource utilization (ISRU)
  - Autonomous precision landing and hazard avoidance
  - Advanced in-space propulsion
  - Tele-operation of advanced robotic systems
- By FY 2012, ground test demonstrations of prototype ISRU and autonomous precision landing systems
- Other potential long-range technology development
  - Extravehicular activity technology
  - Radiation shielding
  - Human-robotic systems
  - Advanced avionics and spaceflight software systems
  - High-efficiency space power systems
  - Entry, descent, and landing technology
  - High-performance materials and structures
- Select projects through open competition, including NASA centers, industry, academia, and international partners
- Projects to utilize available assets (wind tunnels, ground-based analogs, flight test aircraft, suborbital sounding rockets, commercial reusable suborbital vehicles, robotic spacecraft, ISS, and other test platforms)

Heavy-Lift and Propulsion Technology

	2011	2012	2013	2014	2015
Heavy-Lift and Propulsion Technology	$559	$594	$597	$598	$754

- Investigate a broad scope of research and development activities related to space launch propulsion technologies, including:
  - First stage propulsion
  - In-space engine demonstrations
  - Foundational propulsion research
- Program goal: provide new National capabilities, reduce costs, and shorten development time for future heavy-lift propulsion systems
- Projects may include commercial, academic and international partnerships

Heavy-Lift and Propulsion Technology - Approach

- Leverage expertise in rocket design and test capabilities at NASA centers and collaborate with ongoing Air Force research activity
- Help industry to design, develop and test engines with low life cycle cost and high robustness to enable exploration and help the U.S. compete in the global launch industry
- Target research and development activities to gain knowledge and develop capabilities necessary to enable sustainable and affordable human access to space beyond low Earth orbit
- In FY 2010, initiate program planning and perform systems analyses to identify optimum propulsion systems and research/technology thrust areas
- In FY 2011, initiate development of first stage hydrocarbon engine(s) and academia-led research

Human Research Program

	2011	2012	2013	2014	2015
Human Research Program	$215	$215	$215	$215	$215

- Program funds space biomedical research areas critical to crew health and safety
- 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 biomedical laboratory
  - Enhance science, technology, engineering and mathematics (STEM) education, projects that return Earth benefits, and international collaborations
- Research and Technology Priorities:
  - Technologies with advanced medical care capabilities and bioinformatics, capable of being integrated into ISS as demonstration of remote medical suite for long-duration space missions
  - Innovative biomedical technologies to enable solutions to problems of human spaceflight
  - Space radiation research to reduce risks of carcinogenesis, central nervous system disease, degenerative tissue effects, and acute radiation syndromes
  - Behavioral health research enhancing study related to behavioral factors and physiological implications of long-duration missions

Human Research Program - Approach

- Use space biomedical research framework endorsed by National Research Council and Institutes of Medicine to establish priority areas
- Decouple existing research plans from Constellation products and schedules; emphasize emerging technologies and systems that use ISS as testbed
- Augment National Space Biomedical Research Institute (NSBRI) to leverage national biomedical research infrastructure
- Identify cooperative activities involving other national (NIH, DOE, DOD) and international agencies (NASA, ESA, JAXA, DLR, CNES, CSA, ASI)
- Use existing acquisition strategies to openly and competitively solicit, review, and select new research content
- Coordinate with National Lab activity in Space Operations Mission Directorate (SOMD)
- In FY 2010, complete detailed augmentation planning by end of budget formulation process; broaden planned research solicitations in space radiation research and biomedical technology development
- In FY 2011, select and fund new research projects in space radiation research and biomedical technologies
- In FY 2012, develop and implement biomedical technology flight instruments and implement space radiation research at NASA Space Radiation Laboratory

Constellation Transition and Closeout

	2011	2012	2013	2014	2015
Constellation Transition and Closeout	$1,900	$600	--	--	--

- FY 2011 Budget cancels the Constellation Program
  - Provides $2.5 billion over two years for related facility and closeout costs
  - Potentially includes increased cost to Shuttle transition due to Program cancellation
- Near-term actions in alignment with FY 2010 appropriations
  - No new work will be added to existing contracts
  - Available funds to be directed toward existing termination liabilities
- Pending consultation with Congress, NASA plans to close out existing Constellation contracts as quickly as feasible; no termination actions will be taken prior to FY 2011
- Study team in place to assess workforce, facilities/infrastructure, property, hardware, procurement, security and other issues

Path Forward and Guidance

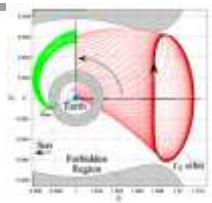
- Constellation is currently proceeding per the enacted FY 2010 appropriation
- Program working to complete Preliminary Design Review and major tests planned for FY 2010 (e.g. Pad Abort 1)
- Transition Team established to develop a plan for Constellation closeout, consistent with all statutory requirements; team working with Program to develop near-term plan, and processes necessary to receive authority prior to acting
- NASA team will develop best plan possible to account for and provide resources required for future program direction
- Consistent with the current FY 2010 appropriations language, Program directed not to terminate existing contracted activity
  - NASA will not award or initiate new activities, nor add any new tasks to contracts or expand the scope of existing tasks, unless approved by ESMD DPMC and coordinated with the Office of Procurement and the Office of the General Counsel
- Team will continue incremental funding of contracted tasks for existing contracts; in order to ensure availability of funds for termination liability as required by law, every effort will be made to reduce or defer non-critical spending

Summary

- NASA ambitiously continues to explore space and open new frontiers
- Agency is launching a vigorous new technology development and test program that will pursue game-changing technology development, which will more efficiently further the course of human space exploration
- We will make key investments in new and innovative technologies that
  - Expand our exploration opportunities,
  - Reduce mission costs,
  - Contribute NASA innovation to broader national needs
- We will revitalize an excitement for NASA in young people across the nation to engage and participate in this 21st century space program through education and outreach

Backup

Enabling Human Exploration Across the Solar System


	ISS	Cis-Lunar	Moon	NEO	Mars and Moons
Science Benefits	Microgravity sciences Human health	Telescope servicing and construction Helio and Earth Science observations	Implications of water Solar system evolution Comparative geology	Origin of solar system Planetary building blocks	Search for life Planetary comparison studies
Exploration Benefits	Demo ops approaches Test technologies Commercial markets Crew safety and health for long duration flight	Propellant depots Architecture enablers	Resource utilization techniques Surface mobility Test technologies Planetary protection	Resource utilization techniques, Test technologies Demo radiation protection	Leading a global effort to expand human presence and technological innovation
Stimulate/Inspire Benefits	Many opportunities near-term, particularly strategic diplomacy and STEM	Telescope systems Near-term beyond LEO human activities	Many opportunities for new discoveries Tele-operation	Planetary defense Many unvisited objects – for robots and humans	Exciting destination Search for evidence of past or extent life
Needed Capabilities	Crew and Cargo to LEO	Low Energy Transfer Heavy-lift Inflatable Structures	Habitats, Mobility Extended Power Medical Diagnostics	Rendezvous, Crew Health on medium to long missions Closed-loop life support	Advanced propulsion and power Aerobraking Improved EDL Tele-robotics

- ISS is a stepping stone to exploration, international participation, and commercial and technology development
- Near-term beyond LEO destinations will inform capability and technology investment priorities, and stimulate the workforce
- Leading global space exploration endeavor requires consulting potential partners in setting destinations/timetables
- Enabling competitive LEO commercialization will increase commercial space arena

Flagship Technology Demonstrations - Approach

- In FY 2010, develop long-term roadmap and approach for near-term missions
- Evaluation underway of highest leverage demonstrations; Mars destination is a driving case for high leverage demonstration and technology
- First three primary technology targets for single or combined missions to include:
  - In-orbit propellant transfer and storage
  - Lightweight/inflatable modules
  - Automated/autonomous rendezvous and docking
- Fourth flight program such as
  - Aerocapture/entry, descent and landing
  - Advanced life support
  - Advanced in-space propulsion (ion/plasma, etc)
- Identify potential partnerships with industry, other agencies, and international partners and leverage ISS for technology demonstrations, as appropriate
- Initiate four technology demonstrations in FY 2011
- Follow-on demonstrations informed by emerging technologies

Flagship Technology Demonstrations

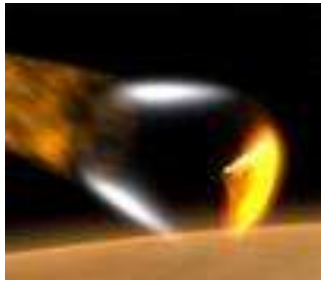
- In-orbit Propulsion Transfer and Storage
  - Capability to transfer and store propellant in orbit; enables complex, extended human missions beyond Earth's orbit
  - Zero boil-off cryogenic propellant storage and cryogenic fluid transfer; enables in-space depots to refuel human exploration vehicles
  - Test technologies and processes for:
    - Long-term cryogenic propellant storage
    - Automated physical connections between fuel lines in orbit
    - Fuel acquisition, withdrawal and transfer

- Automated/Autonomous Rendezvous and Docking
  - Two spacecraft rendezvous independently from human controllers/other back-up; requires advances in sensor design, software, real-time on-orbit positioning and flight control
  - Critical for in-orbit propellant storage and refueling, complex assembly operations, and in-space construction

Flagship Technology Demonstrations

- Lightweight/Inflatable Modules
  - Larger, potentially less expensive than rigid modules used by ISS
  - Leverage work of industry and international partners who have demonstrated capabilities; build on previous ESMD investments
  - Applicable to in-space habitation, transportation, surface habitation
  - Potential test bed for closed-loop environmental control and life support system and other emerging technologies (radiation shielding, thermal control, communications, interfaces between the module and external systems)

Flagship Technology Demonstrations – Potential Candidates



- Entry, Descent and Landing (EDL)
  - Large aeroshells, advanced thermal protection system materials for aerocapture and atmospheric entry of heavy payloads
  - Enables demonstration of EDL capabilities on future robotic precursor and flagship missions
  - Essential to improving safety during human spaceflight re-entry

- Closed-Loop Life Support Systems
  - Recycles air, water and solid waste to validate the feasibility of human survival on long-duration missions with minimal logistics supply
  - Demonstration could involve integrated inflatable module/closed-loop life support

- Advanced In-space Propulsion
  - Integrate emerging complementary technologies into operational spacecraft
  - Quick system demonstrations enabling new space transportation within Earth orbit, cis-lunar, near Earth objects, deep space robotic science missions
  - New capability will enhance competitiveness of existing U.S. launchers by minimizing requirement for in-space propellant

Enabling Technology Development and Demonstration: In Situ Resource Utilization

Key Question: Can we locate and access in situ resources?

- ISRU activities using lunar, asteroidal, and Martian materials to produce oxygen and propellants, and extract water from ice reservoirs
- Capability will reduce mass of consumables to be launched into support of long-duration human exploration missions
- Flight experiment will demonstrate lunar resource prospecting, characterization, and extraction will be developed for testing on flagship or robotic precursor mission

Proof-of-concept ISRU system using concentrated solar energy to produce oxygen from soil being tested in Hawaii

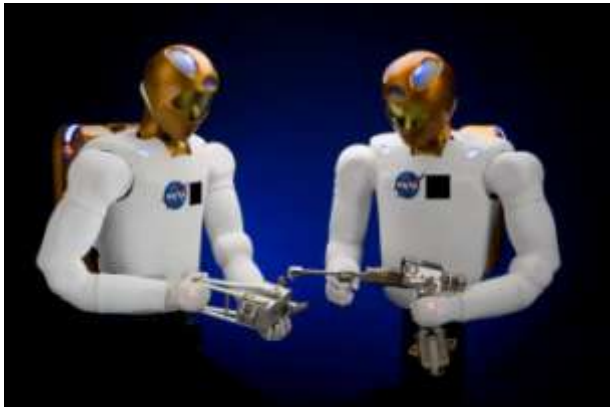
A small rover designed to prospect for ice in lunar craters

Enabling Technology Development and Demonstration: Human-Robotic Systems

Key Question: How do we use human-robotic partnerships to increase productivity, reduce costs, and mitigate risks?

- Advances in human-robotic systems enable safe interactions in situ, and the opportunity to extend human presence before human missions are ready
- Enable more robust teams of humans and robots, partnering robots with humans in space, and humans supervising robots from the ground
- Specific interest areas include human-robot safety, tele-operations, human-computer interactions, human-robotic interfaces, robotic assistance technologies, and other technologies that advance the ability for humans and robots to work together

Opportunities to use ISS for demonstration of advanced robotics and to control robots in Earth analog missions



Robonaut 2 on ISS will be operated from Earth, using software and other upgrades to test dexterous manipulation in reduced gravity

Enabling Technology Development and Demonstration: Autonomous Precision Landing

Key Question: Can we land autonomously, precisely, and safely on an extra-terrestrial surface in uncertain environments ?

- In FY 2011, develop flight experiment to demonstrate autonomous precision landing and hazard avoidance system for use on U.S. or international robotic precursor mission to the Moon or other planetary body
- Capability will enable autonomous cargo landers for future human exploration missions

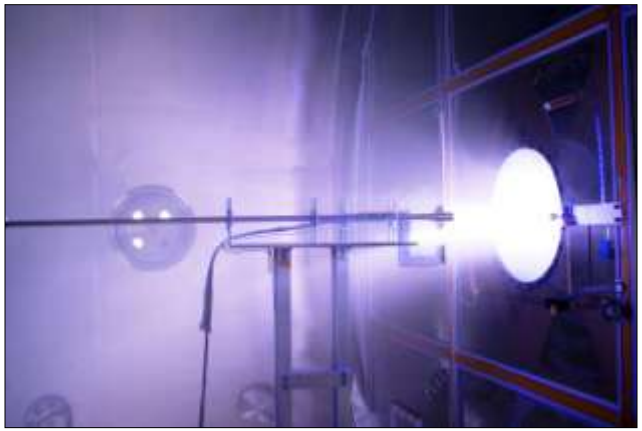
Flash lidar sensor provides a 3D image of hazards such as rocks and craters in the landing zone

NASA will conduct atmospheric flight tests of an autonomous precision landing and hazard avoidance system on a small lander test bed

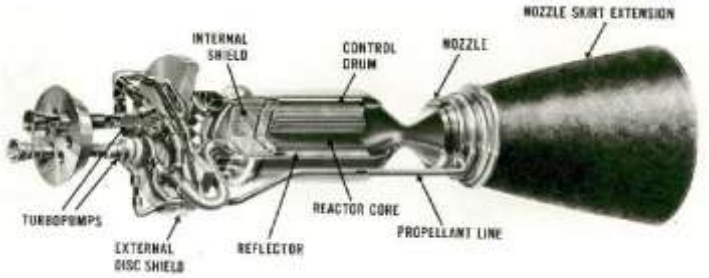
Enabling Technology Development and Demonstration: Advanced In-Space Propulsion

Key Question: How can we reduce travel time and cost for deep-space human exploration?

- Foundational research in advanced high-power, in-space propulsion systems to support deep-space human exploration
- Capability will reduce human travel time between Earth's orbit and future destinations
- Technologies may include nuclear thermal propulsion, solar and nuclear electric propulsion, plasma propulsion, and other high-power and high-efficiency propulsion concepts



Will explore methods to use ISS to demonstrate variety of advanced electric and plasma propulsion systems, such as the Variable Specific Impulse Magnetoplasma Rocket (VASIMR)



NASA will begin concept development for nuclear thermal rockets, and conduct laboratory testing of critical technologies and components

Heavy-Lift and Propulsion – Candidate Technologies

- Research and Development for First Stage Launch Propulsion
  - Hydrocarbon first stage engine with thrust level equal to or greater than RD-180 for use in future heavy lift vehicles, and potentially other uses
  - Low cost, robust enhancements to LOX/Kerosene core stage engine employing manufacturability enhancements
- In-Space Engine Demonstration(s)
  - LOX/CH4 engine development
  - LOX/H2 development for efficiency, low cost
- Foundational Propulsion Research
  - New propellants such as nano-aluminum propellant
  - Advanced propulsion systems materials and manufacturing techniques such as shell buckling and friction stir welding
  - Enhanced combustion processes
  - Engine health monitoring technologies

Exploration Precursor Robotic Missions – Descriptions

- Medium Exploration Class Missions
  - Generally capped at $800 million or less (life cycle cost)
  - Destinations selected according to priority data needs of human exploration
  - Payload capability to maximize return of priority information critical to human exploration preparation
  - Payload allocations for partners (inter-Directorate, international, interagency, etc.)
- Small Exploration Scout Missions
  - $100 million to $200 million life cycle cost
  - Small, rapid turnaround, risk tolerant missions
  - Demonstrate new, innovative ways of conducting robotic exploration while providing highly relevant measurements and operational experiences
  - Openly competed
- Mission of Opportunity Instrument/Capability Development
  - $15 million to $75 million life cycle cost
  - ESMD developed instruments/investigations to be flown on non-ESMD spacecraft
  - Venue for partnerships (inter-Directorate, international, interagency, etc.)

Proposed Augmentations

- Biomedical Technologies
  - Develop medical technologies to prototype system on ISS that supports human planetary exploration
  - Develop innovative biomedical technologies to solve problems of human spaceflight
- Research in Space Radiation Effects
  - Radiation exposure from space environment increases cancer and non-cancer morbidity or mortality risk
  - Biological effects of space radiation exposure including cancer and non-cancer effects (central nervous system disease, degenerative tissue effects, and acute radiation syndromes)
  - Results to date have illuminated biological effects of high-energy particles and improved understanding of radiation-related cellular, molecular and tissue damage
- Enhanced ISS Utilization
  - ISS utilization capabilities significantly increased
  - ISS as Mars Mission Simulator: six month increment with dedicated crew (option requires additional study/coordination and international partner buy-in)

Proposed Augmentations

- Behavioral Health and Performance
  - As humans venture further from Earth confined in spacecraft, probability of behavioral problems increase
  - NASA committed to developing best methods and tools to monitor and assess mood, predict risk/management of behavioral and psychiatric conditions prior, during, and following spaceflight
  - NASA and NSBRI will enhance research in understanding risk of behavioral and psychiatric conditions, specifically in team cohesion and behavioral medicine methodologies
- Enhanced Education Focus
  - NASA and NSBRI continue to stress importance of space research and exploration through education and outreach
  - Budget augmentation will expand ongoing projects to involve larger numbers of students, teachers, and general public

Commercial Orbital Transportation Services Overview

- SpaceX COTS System
  - New Falcon 9 launch medium class launch vehicle along with Dragon cargo spacecraft
  - Pressurized and unpressurized cargo transportation to ISS, pressurized cargo return to Earth
  - SpaceX scheduled to conduct COTS demonstration missions from their launch facility at Cape Canaveral no earlier than July 2010, November 2010 and February 2011
  - SpaceX scheduled to conduct non-COTS inaugural mission using Falcon 9 launch vehicle and Dragon test unit no earlier than March 22, 2010; all inaugural flight hardware being processed at Cape Canaveral

- Orbital COTS System
  - New medium class Taurus II launch vehicle along with Cygnus service module and pressurized cargo module
  - Pressurized cargo transportation to ISS, subsequent cargo disposal upon re-entry
  - COTS system Critical Design Review (CDR) currently in process; transition from system design into manufacturing and test
  - Orbital scheduled to launch COTS demonstration mission from Wallops Flight Facility Launch Site no earlier than March 2011

Commercial Cargo Augmentation - Approach

- Invest $312 million for incentivizing NASA's current commercial cargo program to expedite the pace of development
- Add or accelerate the achievement of already-planned milestones, adding additional capabilities, or tests that may ultimately expedite the pace of development of cargo flights to the ISS
- Risk reduction may include adding milestones to complete the Probabilistic Risk Assessment (PRA) to identify early risks
- Acceleration may include adding milestones for early development of high energy engine for Orbital's Taurus II upper stage, and Block 2 engine upgrades for SpaceX's Falcon 9
- Evaluate benefits of accelerating hardware fabrication and assembly of Cargo Resupply Services vehicles long lead items
- Additional risk reduction or acceleration activities will be identified in FY 2010 for initiation in FY 2011

Commercial Crew Development - Approach

- Leverage existing COTS and Commercial Crew Development (CCDev) activities
  - Maintain broad spectrum of private industry, from emerging to established companies
- Full and open competition for commercial crew development activities
  - Competition through COTS-like, milestone-based agreement for development, testing, and demonstration of multiple commercial crew systems
  - Support range of higher and lower programmatic risk systems
  - Some amount of private investment capital assumed as part of any agreement
  - Clearly and promptly state NASA's performance and safety requirements to enable NASA and non-NASA entities to proceed productively and effectively
- In FY 2010, complete definition of human rating requirements
- In FY 2011, make awards for development and demonstration of commercial crew systems
- Timing for crew demonstration milestones and award of services contracts will be dependent upon development awards made in FY 2011

Commercial Crew Development

- $50 million budgeted for development of commercial space transportation concepts and enabling capabilities
  - Funding provided from the American Recovery and Reinvestment Act of 2009 (ARRA) economic stimulus
- Competition for funded Space Act Agreements (SAAs) awarded February 1, 2010
  - Blue Origin of Kent, Washington awarded $3.7 million to mature pusher escape system and composite pressure vessel
  - The Boeing Company of Houston awarded $18 million to mature commercial crew transportation system architecture and design through SDR and demonstrate key technologies and capabilities
  - Paragon Space Development Corporation of Tucson, Arizona awarded $1.4 million to mature air revitalization system concept
  - Sierra Nevada Corporation of Louisville, Colorado awarded $20 million to further develop its space transportation system
  - United Launch Alliance of Centennial, Colorado awarded $6.7 million to mature a launch vehicle Emergency Detection System

Pull (tower) escape system

Pusher escape system