Overview

The President's FY 2011 Budget request outlines an innovative new path for human space exploration and strengthens the capability to extend human presence throughout the solar system. NASA is taking a new approach to this long-term goal; by laying the ground work that will enable humans to safely reach multiple potential destinations, including the Moon, asteroids, Lagrange points, and Mars and its environs. The research and technology investments described in this budget describe the many near-term steps NASA will be taking to create the new knowledge and capabilities required for humans to venture beyond low Earth orbit to stay. This strategic approach is designed to more efficiently further and sustain the course of human exploration.

The Exploration Systems Mission Directorate (ESMD) will lead the Nation on a course of discovery and innovation that will provide the technologies, capabilities and infrastructure required for sustainable, affordable human presence in space. Investment in gaining critical knowledge about future destinations for human exploration, as well as transformational technology development and demonstration will serve as the foundation of NASA's ongoing space exploration effort, broadening opportunities for crewed missions to explore our solar system. In order to allow NASA to focus on the space frontier, the Agency will also invest aggressively in the commercial sector so that they will, in the near-term, develop the capability to transport people and supplies to and from the International Space Station. This approach will strengthen America's space industry, and could provide a catalyst for future business ventures to capitalize on affordable access to space. It will also leverage a broader range of American ingenuity to keep our nation on the leading edge of human space exploration capabilities.

The transformational technologies highlighted in this budget for development and demonstration address critical capabilities for sending crews to a variety of exciting destinations beyond low Earth orbit. By allowing for flight demonstrations, some at a flagship caliber, this ESMD budget resolves the achievement gap between lab demonstration and flight testing that might otherwise prevent NASA from implementing exciting new technologies. Prior to baselining them for crewed missions, these demonstrations will validate new technologies that are not yet fully developed, but are essential for mission success, such as automated and autonomous rendezvous and docking, in situ resource utilization, aero capture, large mass entry descent and landing, highly efficient in-space propulsion, precision landing and hazard avoidance, cryogenics storage and transfer, lightweight/inflatable modules, and others. And before sending humans on extended missions beyond low Earth orbit, accelerated biomedical research will help us to ensure crew health and safety.

A major thrust of this research and development activity will be related to space launch propulsion technologies. This effort will include first stage engine development, in-space engine demonstrations, and foundational propulsion research in areas such as new or largely untested propellants that can result in more capable and less expensive future rockets, including heavy-lift rockets. In addition, NASA will provide $25 million annually to fund commercial, university, and other non-governmental research organizations to conduct foundational propulsion research.

The technology investments outlined in this budget are just one component needed to enable sustained and affordable human exploration endeavors. An additional key contributor to a robust exploration program will be the acquisition of critical knowledge gained through the pursuit of exploration precursor robotic missions. These missions will provide vital information—from soil chemistry to radiation dose levels to landing site scouting to resource identification—necessary to plan, design and operate future human missions. These missions will help us determine the next step for crews beyond low Earth orbit, answering such questions as: Is a particular asteroid a viable target for crewed mission? Do the resources at the lunar poles have the potential for crew utilization? Is Mars dust toxic?

The intent of this exploration portfolio is not only to significantly improve capability, performance, and flexibility relative to current human space flight capabilities, but also to demonstrate that the resulting mature systems meet NASA's goals in terms of cost effectiveness, risk reduction, and operability. As part of this new direction, ESMD will provide technology maturation analysis, which will focus on the life cycle cost perspective and risk

mitigation strategies. ESMD will also develop multi-mission operational concepts for future human space flight campaigns to such targets as the Moon, asteroids, Martian moons, and Mars itself, ensuring that the investments made today will have maximum utility in decision support for future missions into the solar system. ESMD will develop design reference missions (DRMs) for human exploration, setting priorities based upon the needs and requirements of the various DRMs. These DRMs will evolve as enabling technologies are defined, developed, and demonstrated, and as data from exploration precursor robotic missions are analyzed.

Depending on the investment, implementation responsibility for new projects may be directed to in-house civil servants or competed within industry and academia. For example, a given flagship technology demonstration mission may be designated to a human space flight center in order to benefit from the unique skills of NASA civil servants who will be well-positioned to develop a productive, near-term mission with high relevance to future human spaceflight. In such a case, however, ESMD would expect to compete segments of the payloads and data analysis teams. Similarly, portions of the engine technology development effort may be competed within industry, where significant launch vehicle experience can augment NASA expertise.

These programs present many opportunities for government-private sector-academic teams to collaborate and bring the best expertise from across the Nation to bear on future human space exploration needs. To tackle difficult design issues, ESMD will be responsive to innovations from outside NASA's purview, whether from the academic community, industry, international sources or the defense/security sector. The additional emphasis on technology and human research will result in increased demonstration and research efforts on the ISS and an increased launch and mission tempo to support those efforts. Exploration robotic precursor efforts will benefit from collaboration with scientific and international communities, while smaller scale technology demonstrations could benefit from university-developed satellites. This greater diversity of missions and increased tempo will enhance opportunities for engineers and scientists to work on projects from end-to-end, gaining invaluable experience and learning from mistakes on demonstration efforts, not full-scale operational development programs where risk has not yet been adequately retired for key components and technologies. At the same time, technology will be able to evolve at a more rapid pace, as new techniques can be tested on successive demonstrations. Using a variety of contributors and platforms, ESMD will show significant results from this investment portfolio within a 5-year horizon. And to more fully engage the public in these efforts, NASA will establish a Participatory Exploration Office, funded at $5 million a year, with the goal of making NASA missions more participatory and even more collaborative.

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 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**	

Mission Directorate:	Exploration Systems
Theme:	Exploration Research and Development

Theme Overview

The Exploration Research and Development Theme is focused on investment in expanding fundamental knowledge key to human space exploration, launching robotic pathfinders, and demonstrating technology trailblazers that will enable humans of all nations to explore space in a significantly more sustainable and affordable way than current capabilities allow. In addition to a significant boost in ongoing Human Research, three new programs will drive these efforts to provide the building blocks for a more capable, forward-looking approach to human exploration of space.

Program Overview

Activities within ESMD's Technology Demonstration Program will be aimed at advancing technologies needed to expand our human exploration opportunities, reduce mission costs, and contribute NASA innovation to broader national challenges and applications. This will be accomplished through investment in demonstration of flagship technology projects, as well as enabling technology development and demonstration. NASA will provide an assessment of the highest leverage technologies and demonstrations.

Flagship Technology Demonstrations

Projects selected as in-space, flagship demonstrations will be significant in scale, and offer high potential to demonstrate new capability and reduce the cost of future exploration missions. These missions will demonstrate such critical technologies as in-orbit propellant transfer and storage, inflatable modules, automated/autonomous rendezvous and docking, closed-loop life support systems, and other next generation capabilities key to sustainably exploring deep space.

In FY 2011, NASA will initiate several Flagship Technology Demonstrators, each with an expected lifecycle cost in the $400 million to $1 billion range, over a lifetime of five years or less, with the first flying no later than 2014. In pursuit of these goals, international, commercial, and other government agency partners will be actively pursued as integrated team members where appropriate. NASA will not give responsibility for all demonstrations to any single NASA center but rather looks forward to engaging with the expertise of various centers to accomplish these objectives. Specific architecture and approach for missions to demonstrate key capabilities will be developed for initiation in FY2011. Technologies targeted for demonstration will likely include:

In-Orbit Propellant Transfer and Storage: The capability to transfer and store propellant—particularly cryogenic propellants—in orbit can significantly increase the Nation's ability to conduct complex and extended exploration missions beyond Earth's orbit. It could also potentially be used to extend the lifetime of future government and commercial spacecraft in Earth orbit. This technology demonstration, building on previous ESMD technology investments and prior demonstrations such as Orbital Express, could test technologies and processes such as long-term storage of cryogenic propellant, automated physical connections between fuel lines in orbit, and verification of fuel acquisition, fuel withdrawal, and fuel transfer.

Lightweight/Inflatable Modules: Inflatable modules can be larger, lighter, and potentially less expensive for future use than the rigid modules currently used by the International Space Station (ISS). Working closely with industry and international partners who have already demonstrated a number of capabilities and interest in this arena, and building on previous ESMD investments, NASA will pursue a demonstration of lightweight/inflatable modules for eventual in-space habitation, transportation, or even surface habitation needs. The demonstration could involve tests of a variety of systems, including closed-loop life support, radiation shielding, thermal control, communications, and interfaces between the module and external systems. Use of the ISS as the testbed for this technology is an option being considered to potentially benefit both programs.

Automated/Autonomous Rendezvous and Docking: The ability of two spacecraft to rendezvous, operating independently from human controllers and without other back-up, requires advances in sensors, software, and real-time on-orbit positioning and flight control, among other challenges. This technology is critical to the ultimate success of capabilities such as in-orbit propellant storage and refueling, complex operations in assembling mission components for challenging destinations, in-space construction, and exploration operations far from Earth where the communications delay does not allow for effective human involvement.

NASA will also begin work in 2011 on an additional Flagship Technology Demonstrator mission to be selected within the Agency, and map out a sequence of Flagship missions to be initiated in 2012 and later. Potential candidates include but are not limited to:

Closed–loop life support system demonstration at the ISS: This would validate the feasibility of human survival beyond Earth based on recycled materials with minimal logistics supply. A follow-on demonstration could involve an integrated inflatable module/closed-loop life support system demonstration.

Aerocapture, and/or entry, descent and landing (EDL) technology: This could involve the development and demonstration of systems technologies for: precision landing of payloads on "high-g" and "low-g" planetary bodies; returning humans or collected samples to Earth; and enabling orbital insertion in various atmospheric conditions. Demonstrations could be ground-based or flight experiments.

Enabling Technology Development and Demonstration

Smaller scale development and testing of key, long-range exploration technologies will be pursued as part of the Enabling Technology effort. Projects will range from laboratory experiments to Earth-based field tests and in-space demonstrations and will be aimed at transitioning relevant technologies from lower to higher technology readiness levels. Although some work may be assigned to specific centers or other work groups in this program, we expect the majority of projects developing long-range, enabling technologies to be selected through full and open competition, including NASA centers, industry, academia, and international partners. International, commercial, and other government agency partners will also be actively pursued as integrated team members as appropriate;

In some cases, once technologies have been matured, the NASA centers will manage their integration into prototype systems for demonstration of advanced capabilities. These projects will be designed to take full advantage of available assets such as wind tunnels, ground-based analogs, flight test aircraft, suborbital sounding rockets, commercial reusable suborbital vehicles, robotic spacecraft, ISS, and other test platforms.

In FY 2011, NASA will initiate demonstration projects in the areas of in situ resource utilization (ISRU), autonomous precision landing and hazard avoidance, and advanced in-space propulsion, leading to demonstrations on either robotic precursor or flagship missions.

In Situ Resource Utilization: NASA will fund research in a variety of ISRU activities aimed at using lunar, asteroidal, and Martian materials to produce oxygen and extract water from ice reservoirs. A flight experiment to demonstrate lunar resource prospecting, characterization, and extraction will be considered for testing on a future Flagship Technology Demonstration or robotic precursor exploration mission. Concepts to produce fuel, oxygen, and water from the Martian atmosphere and from subsurface ice will also be explored.

Autonomous Precision Landing: In FY 2011, NASA will initiate development of a flight experiment to demonstrate an autonomous precision landing and hazard avoidance system. NASA will pursue use of this system on the first robotic precursor exploration mission to the Moon or other planetary body.

Advanced In-Space Propulsion: NASA will work with partners in industry as appropriate, to conduct foundational research to study the requirements and potential designs for advanced high-energy in-space propulsion systems to support deep-space human exploration, and to reduce travel time between Earth's orbit and future destinations for human activity. These technologies could include nuclear thermal propulsion, solar and nuclear electric propulsion, plasma propulsion, and other high-energy and/or high-efficiency propulsion concepts. One or more concepts may mature to the level of a demonstration on a robotic precursor or Flagship mission.

In addition, the enabling technology projects line will consider a broad range of other technology development and demonstration projects in areas including:

Closed-loop life support systems: NASA will demonstrate technologies for recycling air, water, and solid waste on the ISS to validate the feasibility of human survival beyond Earth on long-duration missions with minimal logistics supply. A follow-on demonstration could involve an integrated inflatable module/closed-loop life support

project. Combined with ISRU, mastering this capability will enable extended exploration missions that are more fully and effectively based on a self-reliant, "live off the land" approach proven essential during centuries of terrestrial exploration.

Extravehicular Activity Demonstrations: Building on current EVA technology projects, NASA will work with industry and academia to develop advanced spacesuits to improve the ability of astronauts to assemble and service in-space systems, and to explore the surfaces of the Moon, Mars, and small bodies. Spacesuit technologies such as life support systems, thermal control, power systems, and improved fabric materials will be demonstrated in EVA operations in space, including from the ISS.

Radiation Shielding Technology: NASA will test the feasibility of existing concepts, and also develop new concepts, to protect astronaut crews from the harmful effects of radiation, both in low Earth orbit and while conducting long-term missions away from Earth. This is one of the most critical areas for technology investment and demonstration in support of long-duration human missions beyond Earth.

Human-Robotic Interactive Systems Demonstrations: NASA will advance the state of the art in areas like tele-operation, autonomy, human-robot interaction, robotic assistance, and other advanced robotic concepts aimed at significantly increasing human and robotic efficiency and productivity in space.

High-Efficiency Space Power Systems: NASA will develop technologies to provide low-cost, abundant power for deep-space missions, including advanced batteries and regenerative fuel cells for energy storage, power management and distribution, wireless power transmission, thermoelectric and Stirling power conversion, solar (photovoltaic and solar-dynamic systems), and nuclear power systems. A major focus will be on the demonstration of dual-use technologies for clean and renewable energy for terrestrial applications.

Entry, Descent, and Landing (EDL) Technology: NASA will develop and test concepts for large aeroshells and advanced thermal protection system materials to enable aero-capture and atmospheric entry of heavy payloads. These technologies will enable the demonstration of EDL capabilities on future robotic precursor and flagship missions.

High-Performance Materials and Structures: NASA will develop high-temperature materials for propulsion and power systems, nano-structured materials to increase strength-to-weight fabric materials for spacesuits, and super-lightweight composite structures for exploration vehicles and crew habitats. New materials and structures will be tested in the space environment as components of other system-level flight experiments.

Also within this budget line, NASA will establish a Participatory Exploration Office funded at $5 million a year, charged with encouraging public involvement and interaction in the experience of discovery. NASA understands that a primary goal of participatory exploration is making the Agency's research, development and related discoveries more open and transparent so that the general public can understand why NASA is important to their everyday lives. We recognize that participatory exploration covers a spectrum of activities and audiences ranging from directed hand-on activities with students building flight hardware, to collaborating on interpretation of data and discoveries.

This activity will focus on maximizing the strong efforts NASA already places on reaching various audiences, as well as leveraging open Government initiatives for public engagement, tying the two together for the maximum benefit of the public. Each year, NASA sponsors hundreds of programs, activities, events and resources, including award-winning educational Web sites, major exhibitions in museums and science centers, partnerships with minority universities, and research projects that allow the public to participate in NASA missions. NASA recognizes that when we do a better job at explaining the excitement and relevance of our missions to our stakeholders and to the public, they will want to be a part of those missions.

Mission Directorate:	Exploration Systems
Theme:	Exploration Research and Development
Program:	Heavy Lift and Propulsion Technology

Program Overview

ESMD will lead research and development (R&D) activities related to space launch propulsion technologies. This propulsion R&D effort will include development of a U.S. first-stage hydrocarbon engine for potential use in future heavy lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, and engine health monitoring. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense (DOD) and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations.

First-Stage Launch Propulsion: NASA's efforts in this area will focus on development of a U.S. core stage hydrocarbon engine that would be suitable for use in a future heavy-lift rocket or as the first stage of a future launch vehicle. A strong candidate would be a hydrocarbon (liquid oxygen/kerosene) engine, capable of generating high levels of thrust approximately equal to or exceeding the performance of the Russian-built RD-180 engine. Other key target characteristics for this new capability include improvements in overall engine robustness and efficiency, health monitoring, affordability, and operability. In every aspect of the design, NASA will seek to incorporate features that will reduce manufacturing and operating costs for this engine, once it achieves nominal production status. The level of funding for this project is intended to result in a fully operational engine by the end of this decade or perhaps sooner if a DOD partnership is established.

In-Space Engine Demonstration: NASA will initiate development and in-space testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and potentially also low-cost liquid oxygen/liquid hydrogen engines. This work will build from NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be restartable and capable of high acceleration and reliability. Where appropriate, NASA will seek to leverage technologies that are under development in industry.

Foundational Propulsion Research: As noted in a recent OSTP assessment of the state of the U.S. launch propulsion industry base (as well as other related reports); there has been a significant downturn in U.S. industry and governmental investment in foundational R&D regarding space launch propulsion technologies. This has led to concerns about sustaining U.S. expertise in this area and the related potential to identify potential breakthrough propulsion technologies for reducing the costs and improving the performance of future systems. Accordingly, NASA will allocate funds to performing foundational research in chemical propulsion technologies in areas such as new or largely untested propellants, advanced propulsion materials and manufacturing techniques, combustion processes, and engine health monitoring and safety.

In support of this research initiative, NASA will also establish a transparent and equitable process for distributing $25 million in funds annually to commercial, university, and other non-governmental research organizations for foundational research in this area, with the goal of encouraging a broad range of innovative approaches and helping to develop the next generation of scientists and engineers in the space launch propulsion arena. This research effort will be coordinated to the extent possible with the broader Agency technology initiative led by the Chief Technology Officer in an effort to identify and leverage potential synergies between these programs.

Mission Directorate:	Exploration Systems
Theme:	Exploration Research and Development
Program:	Exploration Precursor Robotic Missions

Program Overview

Led by ESMD, NASA will send precursor robotic missions to candidate destinations for human exploration such as the Moon, Mars and its moons, Lagrange points, and nearby asteroids to scout targets for future human activities, and identify hazards and resources that will determine the future course of expanding human civilization into space. Projects will make critical observations, test approaches and operations concepts, and identify specific target destinations directly beneficial to future human space activities. Instruments, destinations and missions will be prioritized based on their utility to future human activities. These will be evaluated in a study of potential demonstrations. While there may be some synergies between this program and the Planetary Science theme within SMD, care will be taken to avoid unnecessary duplication. Dedicated precursor exploration missions are planned to remain below $800 million in total cost, and most will be considerably less expensive.

The Exploration Precursor Robotic Missions will springboard from the successes of the Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS), ESMD's first two robotic missions. Key programmatic and technical management lessons learned will be applied to future robotic precursors. While mission, spacecraft, and instrument selection processes will be derived from those used on LRO/LCROSS, mission objectives will be derived from the priorities of the Exploration Community internal and external to NASA, to assure relevancy and high value. Risk Management approaches developed on LCROSS to achieve mission goals under-budget will be applied to precursor robotic missions.

ESMD will join with other NASA Directorates and international partners to fly precursor instruments aboard partner spacecraft as missions of opportunity, and provide opportunities for partners to fly instruments on ESMD's exploration precursor missions. ESMD is already contributing to the Mars Science Laboratory mission with surface radiation measurement and entry instrumentation for atmospheric data collection. Similarly, ESMD and SMD will coordinate objectives for missions with similar destinations, such as the lunar South Pole and future Mars missions. This inter-directorate coordination will assure non-duplication of effort where appropriate, and the enhancement of robust common data sets elsewhere. However, the exploration precursor robotic missions will be unique—designed and developed to be relevant to the needs of future human exploration as the primary rationale.

NASA will begin funding at least two dedicated precursor missions in 2011. One will likely be a lunar mission to demonstrate tele-operation capability from Earth and potentially from the International Space Station, including the ability to transmit near-live video to Earth. This will also result in investigations for validating the availability of resources for extraction. NASA will provide opportunities to participate in the payloads and observation teams, and potentially portions of the spacecraft, through open competition.

NASA will also select at least one additional robotic precursor mission to initiate in 2011, and identify potential future missions to begin in 2012 and/or 2013. Potential missions may include:

Landing on asteroids or the moons of Mars rather than orbiting these bodies would allow us to better determine whether they pose safety hazards to astronauts or contain materials useful for future explorers. Landing can also test technologies that could help future human missions.

Landing a facility to test processing technologies for transforming lunar or asteroid materials for fuel could eventually allow astronauts to partially "live off the land."

These precursor exploration missions will cooperate closely with ESMD's Technology and Demonstrations Program, potentially serving as test-beds for new technologies. Additionally, the Exploration Precursor Robotic Missions will leverage its experience from the successfully co-manifested LRO and LCROSS missions to seek other co-manifesting opportunities in an effort to save launch vehicle costs and to encourage collaboration.

Mission Directorate:	Exploration Systems
Theme:	Exploration Research and Development
Program:	Exploration Precursor Robotic Missions

Program formulation will define processes and criteria for implementation. Leveraging LRO and LCROSS experience, formulation activities will define processes for destination and mission selection, methodology for risk and project management, acquisition strategies, and metrics against which program and project success will be defined. The Exploration Precursor Robotic Missions will foster open competition in procurements, accommodation for partnerships, and actively engage the public in coordination with Participatory Exploration efforts.

Additionally, a new portfolio of explorer scouts will execute small, rapid turn-around, highly competitive missions to exploration destinations. Generally budgeted at between $100M and $200M lifecycle cost, these missions will allow NASA to test new and innovative ways of doing robotic exploration of destinations of interest to future human exploration. Selected projects may provide multiple small scouting spacecraft to investigate multiple possible landing sites, or provide means of rapid-prototyping new spacecraft approaches. These missions will be fully and openly competed in a Principal Investigator mode.

Mission Directorate:	Exploration Systems
Theme:	Exploration Research and Development
Program:	Human Research Program

Program Overview

This budget increases Human Research funding to $215 million per year to support effort focused on solving the long-term problems that need to be addressed for humans to safely live and work at various locations in the inner solar system (e.g., Earth orbit, Mars transfer orbit, lunar surface).

The Human Research Program conducts research, develops countermeasures, and undertakes technology development to inform and support compliance with NASA's health, medical, human performance, and environmental standards. The Program will continue to address human health and performance risks endorsed by the National Research Council and Institute of Medicine within the existing portfolio elements structure:

- Human Health Countermeasures
- Space Radiation
- Space Habitability and Human Factors
- Behavioral Health and Performance
- Exploration Medical Capabilities
- ISS Medical Project

These risks address space radiation health concerns, behavioral health and team cohesion challenges associated with confinement and isolation, inadequate human-machine interfaces, emergency medical care issues, and effects of microgravity on the human body. Microgravity health effects include rapid muscle atrophy, bone loss, neurovestibular system changes that produce motion sickness, and significant fluid shifts that affect intracranial pressure, cardiovascular function, blood volume, and cause orthostatic intolerance.

This funding will enhance current HRP work and enable creation of more robust exploration-enabling projects, with an increased focus on the following areas:

Space radiation research to expand the knowledge base and reduce the uncertainty inherent in current radiation exposure limits for astronauts, leading to the development of radiation countermeasures. This work will be in coordination with space radiation protection demonstration projects by providing the latest progress on human vulnerabilities to the space environment.

Biomedical technology research and development that supports long-duration human spaceflight (and may also have applicability to public health care needs) in areas like advanced medical care technology and bioinformatics.

Research into human behavioral factors and psychological implications of long-duration spaceflight, and development of countermeasures to mitigate the risks of degraded human performance.

In addition, the funding will enable:

- Development of research and technology projects that fully utilize ISS as a space biomedical laboratory
- Enhancement of STEM education and projects that return Earth benefits
- Enhanced National Space Biomedical Research Institute leveraging of their U.S. National biomedical research infrastructure to address space related health risks
- Additional collaborations involving other National (NIH, DOE, DOD for example) and International agencies (ESA, JAXA, DLR, CNES, CSA, ASI for example)
- Additional National research solicitations to openly and competitively solicit, review, and select new research content

Mission Directorate:	Exploration Systems
Theme:	Commercial Spaceflight

Theme Overview

NASA's newly established Commercial Spaceflight Theme represents more than a $6 billion investment increase in America's space industry. Building on established partnerships with the emerging commercial space sector through the Commercial Orbital Transportation Services (COTS) effort, the Agency will expand the market to include a range of both cargo and crew vehicles.

One of NASA's strategic goals is to encourage the pursuit of appropriate partnerships with the emerging commercial space sector. The Agency's major activity in this area is the COTS effort, overseen by the Commercial Crew and Cargo Program. This Program is aimed at encouraging the development of commercial space transportation services and an associated market, with multiple suppliers and customers. NASA would be one of these customers, purchasing transportation services on the open market.

COTS is being executed in two phases. The first is a period of private industry development and demonstration of the various space transportation capabilities to and from low Earth orbit determined to be most desirable for government and other customers. During this phase, NASA is providing $500 million of seed capital and technical assistance to promising space firms via funded and unfunded Space Act Agreements (SAA) to stimulate the commercial space transportation market. These COTS partners are to demonstrate capabilities that can be used for ISS resupply: Capability A, delivery of unpressurized cargo; Capability B, delivery of pressurized cargo; and Capability C, delivery and return of cargo to and from orbit. The second phase is a competitive procurement of orbital transportation services to supply ISS, and is the responsibility of the Space Operations Mission Directorate (SOMD). In addition, with Recovery act funding in FY 2009, NASA initiated development activities under the Commercial Crew Development (CCDev) effort to enable future commercial crew launches to the ISS. Space Act Agreements were awarded to five companies in February 2010 to demonstrate various technologies and capabilities necessary to reduce the risk of flying crew on commercial vehicles, with completion milestones in the November/December 2010 timeframe.

The SAAs NASA has in place with the COTS partners are written to maximize the flexibility of private development efforts. Partners are paid when the Agency certifies that they have passed a series of discrete developmental milestones; if they fail to make progress, they are not paid. Government requirements are kept to a minimum, and are only concerned with assuring safe interaction with the ISS. The partners are not required to follow the standard NASA Program and Project Management Processes and Requirements, NPR 7120.5. Rather, the relationship is intended to encourage innovation and allow partners to use alternatives to the standard NASA program management approaches, while still being held accountable for safety and ISS visiting vehicle requirements that NASA would impose were that partner being utilized for commercial transportation services.

In addition to providing a conduit for funding, the Commercial Crew and Cargo Program coordinates the COTS Advisory Team, made up of over 100 technical experts located throughout NASA. Funded and unfunded partners can utilize these experts as necessary; if a partner requires extensive assistance, NASA helps arrange reimbursable agreements with NASA centers to acquire the expertise they need. Commercial crew activities build upon the COTS and CRS successes, realizing that transporting cargo is different than transporting crew. NASA is in the process of developing an acquisition strategy that accounts for the additional insight and oversight necessary, allowing commercial companies to benefit from the vast experience NASA has amassed over fifty years of human spaceflight, without placing undue burden on the commercial partners. NASA will also work with the commercial partners to clearly articulate human rating processes and requirements that will contribute to the safe flight and safe return of NASA crew members on commercial space vehicles.

Mission Directorate:	Exploration Systems
Theme:	Commercial Spaceflight
Program:	Commercial Cargo

Program Overview

This budget allocates $312.0 million in FY 2011 for incentivizing NASA's current commercial cargo program to improve the chance of mission success by adding or accelerating 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 activities may include adding milestones to complete the Probabilistic Risk Assessment (PRA) to identify early risks. Accelerating enhanced capabilities may include adding milestones for early development of items such as the high energy engine for Orbital's Taurus II upper stage, and Block 2 engine upgrades SpaceX's Falcon 9; a demonstration flight may be added to validate the upgrades. NASA will continue to evaluate the Cargo Resupply Services (CRS) contract to determine if funds can be used to accelerate hardware fabrication and assembly of the CRS vehicles.

Commercial Orbital Transportation Services (COTS)

The Commercial Orbital Transportation Services (COTS) partner agreements are not projects by the standard NASA definition of the term, but individual firms that have entered into Space Act Agreements with the Agency. "Funded partners" are those receiving progress payments and technical assistance from NASA, while "unfunded partners" receive technical assistance, but are not paid. NASA has unfunded agreements with PlanetSpace of Chicago, IL and SpaceDev of Poway, CA, while our funded COTS partners are SpaceX, of Hawthorne CA, and Orbital Sciences Corporation of Dulles, VA.

SpaceX is developing new launch vehicles with the goal of providing reliable, globally cost competitive U.S. space transportation capabilities. Their Falcon 9 launch vehicle is an evolution of their clean sheet design of the Falcon 1 launch vehicle. Their "Dragon" spacecraft and launch vehicle are being designed for either cargo or crew transport. Both launch vehicle and spacecraft offer flexible configurations based on mission requirements, and are currently planned to be recoverable for refurbishment and reuse. SpaceX has chosen Cape Canaveral's launch complex 40 as the site for their launches, with the first ISS demonstration flight planned for completion by February 2011. For Phase 1, SpaceX will demonstrate cargo transportation Capabilities A-C. Additionally, SpaceX currently has an unfunded SAA option to demonstrate Capability D.

Orbital Sciences Corporation is developing a launch system concept comprised of a Taurus II launch vehicle, a new medium class booster using two Aerojet AJ-26 engines and an ATK Castor 30 second stage. Taking advantage of heritage systems, Orbital will use a standard service module derived from the STAR and Dawn spacecraft for all missions and the pressurized cargo module will be based on the ISS multi-purpose logistics module. The Wallops Flight Facility will serve as Orbital's launch site for an ISS demonstration flight, currently scheduled for March 2011. For Phase 1, Orbital will demonstrate cargo transportation Capability B.

Mission Directorate:	Exploration Systems
Theme:	Commercial Spaceflight
Program:	Commercial Crew

Program Overview

The Commercial Crew Program will provide $6 billion over the next five years to support the development of commercial crew transportation providers to whom NASA could competitively award a crew transportation services contract analogous to the Cargo Resupply Services contract for ISS.

These funds will be competed through COTS-like, fixed-price, milestone-based Space Act Agreements that support the development, testing, and demonstration of multiple commercial crew systems. As with the COTS cargo program, some amount of private investment capital will be included as part of any Space Act Agreement and NASA will use this funding to support a range of higher- and lower-programmatic risk systems. Unlike the COTS program, which exclusively funded entirely new and integrated systems (launch vehicles plus capsules), this program will also be open to a broad range of commercial proposals including, but not limited to: human-rating existing launch vehicles, developing spacecraft for delivering crew to the ISS that can be launched on multiple launch vehicles, or developing new high-reliability rocket systems.

NASA will leverage existing COTS and Commercial Crew Development (CCDev) activities to engage a broad spectrum of private industry, from emerging to established companies, with a full and open competition for commercial development activities at the conclusion of the CCDev activities. The competition will result in a targeted portfolio of up to four companies with a mixed risk balance consisting of launch vehicles, crew capsules, and supporting technologies, similar to the Commercial Crew Development awards from Recovery Act funds announced on February 2, 2010. The number of awardees will be based on such factors as technical competency and available funds. Firm-fixed-price awards will be issued for production of crew services after a key progress review of the down-selected commercial companies as necessary, within the available budget.

At no point in the development and acquisition of commercial crew transportation services will NASA compromise crew safety. NASA has unique expertise and history in this area, and a clearly demonstrated record of success. NASA will bring that experience to bear in the appropriate way to make sure that commercial crew transportation services are a success both programmatically, and with respect to safety. In that regard, NASA agrees with the Aerospace Safety Advisory Panel, which stated, “it is crucial that NASA focus on establishing the certification requirements, a certification process for orbital transportation vehicles, and a process for validating compliance. The performance and safety requirements must be stated promptly and clearly to enable NASA and non-NASA entities to proceed in the most productive and effective manner possible.” NASA will work to complete an agency and industry-coordinated human rating draft by the end of 2010.

Mission Directorate:	Exploration Systems
Theme:	Constellation Transition

Theme Overview

All funding within this theme provides for transition and closeout activities for the Constellation Program. This cancellation effort represents a fundamental strategic shift from a large, contract oversight and mission operations program to a more diverse development, demonstration, and precursor focus that will require significant realignment across the Agency. Constellation closeout will involve a comprehensive planning effort for the termination and resolution of existing contracts; safing, disposition and reallocation of facilities; workforce assessment and skills cross-mapping; and cataloguing and disposition of real and personal property.

In addition to direct Constellation Program closeout activities, the transition and retirement plans for Space Shuttle assumed Constellation would receive and utilize assets that will no longer be required. Also, some Shuttle capabilities that Constellation was not going to use may be used by new programs, such as the Space Launch Complex Modernization effort. Although the total amount of Agency facilities to be retired and dispositioned will likely be increased versus the plan to date, existing Shuttle transition and retirement processes and planning will be leveraged for maximum efficiency and cost effectiveness. The $600 million provided to enable the Shuttle to fly into the first quarter of FY 2011 if necessary may also become available to aid in transition if the Shuttle completes its manifest on time.

The funds allocated to Constellation closeout in FY11 and FY12 will be applied to such activities as:

- Termination and liability for existing contracts (including severance pay)
- Closeout costs of content and property disposition
- Costs to safe facilities no longer in use, mothballed, or targeted for demolition
- Potential remediation of Agency direct and support contractor facilities no longer in use
- Coverage for transitional civil servants as new programs are being initiated

NASA will work with Congress to initiate and complete these transition activities as quickly as possible. To that end, the Agency has established a Constellation Transition Team, leveraging expertise from across the Agency to develop a rapid and cost effective ramp down plan that will free the resources required for new programs. As part of the early characterization and integrated planning effort, this team has initiated a broad survey of current workforce, contracts, facilities, property, security, knowledge capture, information technology, and other government agency interface issues. The transition plan will outline three phases as part of an action plan for initial deliverables:

- Near term actions
- Primary termination of Constellation
- Transition of assets/resources to new Exploration focus areas, where appropriate

The study team will initiate this planning effort and prepare for transfer to a Constellation Transition and Closeout Project. As planning matures, new focus area requirements will be iteratively applied to Transition Study Team efforts to refine workforce, facilities, infrastructure, and property assessments, and their associated budget and transfer schedules.

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