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Statement of
Richard J. Gilbrech, Ph.D.
Associate Administrator
Exploration Systems Mission Directorate
National Aeronautics and Space Administration

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Committee on Science and Technology
U.S. House of Representatives

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to make my first appearance before you today as the Associate Administrator for the Exploration Systems Mission Directorate (ESMD) to discuss NASA's Exploration program.

In 2007, ESMD delivered on its promises, and we will continue to do so in 2008. Major development work is underway; contracts are in place, and our future Exploration plan is executable. By the end of 2008, NASA will see its first lunar spacecraft launched from the Agency's Kennedy Space Center (KSC) in Florida. This Lunar Reconnaissance Orbiter (LRO) and the Lunar Crater Observation Sensing Satellite (LCROSS) will help NASA scout for potential lunar landing and outpost sites. Additionally, in 2008, NASA will continue to plan how best to transition any needed Shuttle workforce and infrastructure to the Constellation program.

The FY 2009 budget request of $3.5 billion for ESMD will support continued development of new U.S. human spaceflight capabilities and will enable sustained and affordable human space exploration after the Space Shuttle is retired at the end of FY 2010. The budget request provides stable funding to allow NASA to continue developing our next-generation U.S. human spaceflight vehicles while also providing research and developing technologies for the longer-term development of a sustained human Exploration of the Moon and other destinations. Budget stability in FY 2009 is crucial to maintaining a March 2015 Initial Operational Capability (IOC) for the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle. There is minimum flexibility through 2010, so Congressional support for the full FY 2009 budget request is critical. In addition, NASA will continue to work with other nations and the commercial sector to coordinate planning, leverage investment, and identify opportunities for specific collaboration on lunar data collection and lunar surface activities.

The FY 2009 budget request continues our National momentum toward returning American astronauts to the Moon by 2020. NASA plans to build an outpost on the Moon to advance U.S. scientific, security, and economic interests as part of a sustained and affordable human and robotic program of solar system Exploration. Astronauts will learn to use resources already on the Moon, preparing for possible future journeys to Mars or other destinations in the solar system. Successful lunar exploration is not just about developing a lander or a habitat. It will require development of a system of Exploration elements, including a transportation system, habitation, rovers, spacewalking systems, surface power, and communication. NASA has put together a team of some of its best scientists and engineers to work on these projects. We also are working with 13 international partners and the commercial sector to

coordinate planning, leverage investment, and identify opportunities for specific collaboration on lunar data collection and lunar surface activities.

Much has happened since Americans first landed on the Moon, but in particular the scope, breadth and importance of space activity has grown significantly. Today, the global space economy exceeds more than $220 billion annually, and that figure is growing rapidly each year. NASA is a small, but integral component of this critical global economic engine. Today, we live in a time when space has become a globally utilized resource and when other nations have the ability to launch humans into space. Today, the skies are filled with satellites that impact the lives of billions of people on planet Earth. Today, American astronauts are living in space with international colleagues aboard the International Space Station (ISS), and scientists worldwide are studying our solar system via robotic missions. Simply put, space affects everything we do.

Thanks to the support of the President and Congress, our Nation once again has a vision for the future that addresses space Exploration on all fronts. It is therefore only fitting that we have begun on an adventure to return Americans to the Moon as part of that broader policy and vision. This adventure will drive us toward new technologies; will enable a new area of economic activity; will strengthen our National security; will engage our technical and engineering workforce; will provide an opportunity to collaborate on important missions with our international partners; and, will inspire a new generation of scientists and engineers to participate in America's space program. NASA's Exploration program will also ensure that our Nation's space program continues to organize and inspire the best of our energies and skills for generations to come.

NASA is committed to carrying out our Nation's civil space program, and we pledge to keep the Congress fully informed about our efforts and achievements. As requested in the invitation to testify today, the remainder of my testimony outlines NASA's progress, and some of the Agency's challenges, in implementing the Orion and Ares projects. My testimony also addresses NASA's evolving lunar architecture, which will return Americans to the Moon by 2020 in preparation for human Exploration of Mars and other destinations.

Constellation Program Status

The FY 2009 budget request for Constellation Systems is approximately $3.0 billion. The Constellation program includes funding for the Orion and Ares projects, as well as for ground operations, mission operations, and extravehicular activity projects and a dedicated in-house effort for systems engineering and integration. NASA recognizes that challenges lay ahead for the Agency, and we are making progress in managing these challenges. Our greatest challenge is safely flying the Space Shuttle to complete assembly of the ISS prior to retiring the Shuttle in 2010, while at the same time, developing new U.S. human spaceflight capabilities of the Constellation program and successfully transitioning our workforce between Shuttle and Constellation activities. Full funding of NASA's FY 2009 budget request for Constellation is needed so that we can continue successful transition between the Shuttle and the Orion and Ares I. The FY 2009 budget request maintains Orion IOC in March 2015 at a 65 percent confidence level and full operational capability (FOC) in FY 2016, though NASA is striving to bring this new vehicle online sooner.

The FY 2009 budget request for Constellation will support a total of three uncrewed test flights prior to IOC in FY 2015. The IOC is defined as the first crewed flight of Orion to the ISS, enabling fight test astronauts to fly the Orion on its maiden voyage. Following IOC, there will be one additional crewed test flight of Ares I and Orion to the ISS before NASA declares FOC. The FOC milestone is defined as the

date when Orion transports crew to the ISS; remains at the ISS for up to 180 days; and then safely returns the crew to Earth.

NASA has planned and paced the multi-decade Constellation program to live within its means, while carefully identifying and mitigating the threats to mission success. Within the Constellation program, NASA is making important decisions to stay within budget and on schedule by striving for the lowest life-cycle costs possible. NASA has established an initial plan for Constellation's designs and integrated flight tests to ensure that the Agency adequately tests systems prior to their operational use and allows appropriate time to implement critical lessons learned from these tests.

NASA's Constellation program has moved beyond being just a mere concept on paper; we are making real progress. We have tested hardware; we have tested landing systems; and we have logged thousands of hours in wind tunnels. So far, the Ares I project has conducted more than 4,000 hours of wind tunnel testing on subscale models of the Ares I to simulate how the current vehicle design performs in flight. These tests support development of the J-2X engine for the Ares I and the Earth Departure Stage of the Ares V. By December 2007, all major elements of the Orion and Ares vehicles were placed under contract. This year, Constellation will be busy with hardware activities which include fabrication of the First Stage Development Motors 1 and 2 for Ares I; complete construction of the Upper Stage Common Bulkhead Demonstration article and also deliver the first Ares I-X demonstration test flight hardware to KSC in October 2008. Orion will be just as busy, culminating the year with a test of its launch abort system at the U.S. Army's White Sands Missile Range (WSRM) in New Mexico.

NASA has a dedicated group of civil servants and contractors who work together to check and cross-check the multiple variables that go into designing and eventually operating these future Exploration vehicles. Constellation also has an integrated schedule and we are meeting our early milestones. In 2007, Constellation completed a "Season of System Requirements Reviews" for the program and its projects. Design reviews are essential to good engineering practice. The year culminated with an Orion Point of Departure (POD) design and a green light to move forward to the Preliminary Design Review (PDR). An Integrated Stack Technical Interchange Meeting also was a great success with all top issues being resolved. Thus, the Constellation program was able to strike a technical baseline from which integrated assessments can be formed. The program closed the architecture for going back to ISS; has identified the areas necessary to do the same for lunar; and now has a clearer understanding of its growth path toward that goal. Constellation also has the green light to move forward in developing systems for a lunar capable vehicle that meets our budgets and schedule needs. Agency leadership has embraced the results of this season of reviews and has approved the Constellation program to move forward to PDR for both Orion and Ares I by this fall.

For background, a PDR is a crucial milestone because it is the first major review of the detailed design and is normally held prior to the preparation of formal design drawings. During a PDR, the program verifies that the preliminary design meets all requirements within acceptable risk limits and within the cost and schedule constraints. The completion of the PDR and the closure of any actions generated by the review become the basis for the start of the detailed drafting and design effort and the purchase of parts, materials, and equipment needed.

Currently, NASA has civil servants and contractors on board for the Constellation program serving at all ten field Centers. Last fall, the Agency assigned new leadership roles and responsibilities for Exploration and Science missions to NASA's ten field Centers in order to help restore the core technical capabilities across the Agency as we transition from the Space Shuttle to new capabilities. This action included assigning preliminary work assignments covering elements of the Altair human lunar lander and lunar surface operations, as well as the Ares V and Earth Departure Stage necessary for lunar Exploration. This year, NASA will continue efforts to define the specific work the field Centers will perform in order to

enable astronauts to again explore the Moon, while paving the way for human Exploration of Mars and other destinations. It is also important to note that NASA's Constellation program involves industry partners from more than 20 states across the country, which makes Constellation a truly Nationwide effort.

In addition, NASA is making infrastructure improvements at many of our Centers including:

- Modifications to the Space Power Facility (SPF) at Glenn Research Center's Plum Brook Station (Ohio) in support of Orion environmental testing, enabling the SPF to perform vibration and vibro-acoustic testing;
- Construction of a new high-altitude test stand at Stennis Space Center (SSC) in Mississippi for testing the J-2X Upper State engine under simulated high-altitude conditions;
- Construction of Orion abort system testing facilities at WSMR;
- Major refurbishment of the Operations and Check-out Building at KSC in support of Orion final assembly and test;
- Major refurbishment of building 29 at Johnson Space Center (JSC) in Texas to support a Constellation Avionics Integration Lab in support of Orion; and,
- Minor and major modifications to Arc Jet Heaters located at JSC and Ames Research Center in California in support of Orion heat shield development and qualification.

Status of the Orion Crew Exploration Vehicle

By 2020, America will send a new generation of explorers to the Moon aboard the Orion crew module, thereby enabling a sustained human presence beyond low-Earth Orbit (LEO). With its IOC of March 2015, Orion is a critical capability for the Nation to support Exploration and to ensure U.S. access by American astronauts to all regions of LEO and the Moon. The Orion also opens the door to Mars and other destinations.

NASA is continuing the design process for the Orion and is pleased with the progress made so far. The current design configuration establishes a robust vehicle and meets the weight requirements, including meeting the more demanding lunar configurations. Orion's design borrows its shape from the capsules of the past, but takes advantage of 21st century technology in computers, electronics, life support, propulsion, and heat protection systems. Orion will carry up to four crew members on lunar missions and up to six crew members to and from the ISS. By 2020, the new capsule will be able to rendezvous with a lunar landing module, which will carry astronauts to the Moon's surface. Orion also will be the vehicle that returns our astronauts safely to Earth.

During 2007, the Orion project tested numerous options for landing systems, including air bag systems of varying configurations, and the project began fabrication of a flight test article for Pad Abort Test-1. Both the Orion and Ares projects also conducted numerous recovery parachute drop tests in Yuma, Arizona to better understand the reefing performance of the drogue, pilot and main chutes. Last year also included a season of design reviews for the Orion project. After completing a System Definition Review (SDR) in August, the Orion team realized that the Orion configuration was too heavy, so NASA began an effort to establish a POD configuration for the Orion spacecraft that would meet requirements for mass, power and cost. In November 2007, NASA senior leaders, including Administrator Michael Griffin, approved the POD and approved Orion to move forward into the PDR design cycle, which is scheduled to conclude this fall.

As approved in November, the POD configuration:

- Establishes a robust vehicle;
- Meets weight requirements for lunar and ISS missions; and
- Meets the more demanding lunar configuration with 2,000 lb of Manager's Reserve (MR) and 15 percent average Weight Growth Allowance; This MR covers the 90th percentile of mass threats and opportunities identified.

Between now and the conclusion of PDR this fall, NASA will continue to work these issues:

- Crew support for safety;
- Ensuring the vehicle adequately supports the crew in the event of contingency landings when the crew may have to spend an extended period of time in the vehicle prior to recovery by ground support teams;
- Assessing landing scenarios, leading to a final decision about whether Orion will land on land or water during nominal landings;
- Assessing mass threats and opportunities against the Orion PDR POD configuration; and
- Understanding the vulnerabilities of the POD vehicle and understand the Loss of Crew and Loss of Mission probabilities.

Another integral part of the Orion project is a Launch Abort System (LAS), which will offer a safe, reliable method of moving the entire crew out of danger in the event of an emergency on the launch pad or during the climb to Earth orbit. Mounted at the top of the Orion and Ares I launch vehicle stack, the abort system will be capable of automatically separating the Orion from the rocket and positioning the Orion for a safe landing. The planned LAS implementation uses a solid rocket motor that is positioned on a tower atop the crew module that will pull the Orion and its crew to safety. NASA plans a series of tests to characterize the LAS. Pad Abort (PA)-1 is the first of these tests and will address what happens if an emergency occurs while the Orion and the launch vehicle are still on the launch pad. This test is scheduled for December 2008 at WSMR. The Orion crew module test article was shipped to Dryden Flight Research Center, California, on March 27 for outfitting. It will then be shipped to White Sands for integration with the launch vehicle and LAS for the December 2008 PA-1 test.

Status of the Ares I Crew Launch Vehicle

Ares I is an in-line, two-stage rocket that will carry Orion to LEO and will becomes NASA's primary vehicle for human exploration in the next decade. Ares I will be able to lift more than 25 metric tons (55,600 pounds) to LEO. Its First Stage will use a single five-segment solid rocket booster -- a derivative of the Space Shuttle's solid rocket booster, which also will be a critical element of the Ares V heavy lift launch vehicle. The Ares V will consist of two five segment strap-on boosters, which will enable the Ares V to carry up to 65 metric tons (143,299 pounds) of payload to trans-lunar injection orbit or 135 metric tons (297,624 pounds) to LEO. The Ares V represents a capability far beyond that of today's global launch systems, opening the door to exploration and to a range of national and scientific applications in all regions of space. The Second Stage of the Ares I, also known as the Upper Stage, will provide the navigation, guidance, control and propulsion required for the Second Stage of the rocket's ascent. It will consist of a J-2X engine, a fuel tank for liquid oxygen and liquid hydrogen propellants and associated avionics. Like the solid rocket booster, the J-2X will contribute to our plans for human lunar exploration by powering the Earth Departure Stage (the vehicle carrying the Orion and a human lunar lander) to the Moon.

The J-2X is an evolved version of two historic predecessors: the powerful J-2 engine that propelled the Apollo-era Saturn I-B and Saturn V rockets, and the J-2S, a simplified version of the J-2 that was developed and tested in the early 1970s. By utilizing the J-2X, NASA eliminates the need to develop, modify, and certify an expendable Space Shuttle engine for the Ares I. NASA expects the J-2X to be less expensive and easier to manufacture than the Space Shuttle main engine. Changing from the four-segment First Stage solid rocket motor to the five-stage segment for the Ares I also represents a significant and direct down payment on the Ares V, enabling an earlier delivery date for Ares V.

Although the J-2X is based on the J-2 and J-2S engines used on the Saturn V, it also leverages knowledge from the X-33 and RS-68. NASA also is planning significant upgrades to the engine, which essentially makes the J-2X a new engine development program. Therefore, NASA has taken steps to mitigate J-2X risks by increasing the amount of component-level testing; procuring additional development hardware; and working to make a third test stand available to the contractor earlier than originally planned. On August 23, 2007, NASA broke ground on a new rocket engine test stand at Stennis Space Center in Mississippi. The test stand will provide altitude testing for the J-2X engine and will allow engineers to simulate flight conditions at different altitudes. Testing on the A-3 stand is scheduled to begin in late 2010.

Last year, the Ares project office conducted a season of SDRs for its major elements: First Stage, Upper State and Upper Stage engine. These activities concluded with the integrated Ares I SDR in October 2007. In support of Orion and Ares I SDRs, a series of integrated vehicle analyses were conducted to characterize performance of the Orion/Ares I stack. During these reviews, NASA discussed a thrust oscillation issue during First Stage operation. Thrust oscillation is not an uncommon risk in solid rocket motors because thrust oscillation or resonant burning is a characteristic of all solid rocket motors, like the First Stage of the Ares I launch vehicle. It is caused by vortex shedding inside the solid rocket motor, similar to the wake that follows a fast moving boat. When the vortex shedding coincides with the acoustic modes of the motor combustion chamber, pressure oscillations generate longitudinal forces that may impact the loads experienced by the Ares I during flight, and may exceed allowable loads on various portions of the vehicle and allowable forces on the astronaut crew.

In November 2007, NASA chartered the Thrust Oscillation Focus Team to precisely define the frequency spectrum and oscillation amplitudes that the five segment motor is expected to produce. These analyses are being accomplished using a combination of available ground test motor data as well as early Shuttle solid rocket motor flight data. Efforts are underway to update the existing data set by adding instrumentation on several upcoming Shuttle flights. In parallel, the team is evaluating vehicle structural assessments in order to provide additional vibration isolation to critical launch vehicle systems and uncouple the vehicle's natural frequency from motor induced loads. Since upper stage elements and the command/service module are not yet fully designed, this is an excellent time to factor in thrust oscillation load mitigation should that be required. The team's analysis has already led to several mitigation strategies, including the removal of a significant amount of conservatism from within existing models, correlating to significantly lower loads by a factor of almost two. Additionally the team was able to remove the first longitudinal mode as an issue – the remaining effects are now in a narrow, manageable region in the 12Hz frequency range. NASA will conduct additional analysis coupled with upcoming flight test on the Shuttle (STS 125, planned for August 2008) and Ares I-X (planned for April 2009) to better characterize this phenomenon, which may further reduce loads. In summary, NASA is confident in its ability to mitigate the risks associated with thrust oscillation, and we will keep the Congress and this Subcommittee informed of our progress.

Last year, the U.S. Government Accountability Office (GAO) acknowledged that NASA has taken steps toward making sound investment decisions for the Ares I launch vehicle. GAO reported that NASA is relying on established technology to support the project and is adopting an acquisition strategy that

emphasizes attaining knowledge on cost, schedule and technical and development feasibility before commitments are made to long-term investments. The GAO also rightly identified many of the challenges that still remain for the Ares I project -- requirements complexities, design details, and a challenging schedule are particularly highlighted, among others. NASA has made a great deal of progress to date on Ares I; we have accomplished much in a short period. However, I am well aware that there is still much to be done. The GAO recommends that NASA develop firm requirements, a preliminary design, and realistic cost estimates in time for the Ares I PDR late this summer. This is exactly our intent – to make sure that all of our projects, not just Ares I, reach the appropriate level of maturity at each milestone before they proceed further. I have every confidence that our team will build on our recent progress, overcome the challenges immediately before us, and successfully reach our next goal.

In December 2008, NASA will complete the integrated stack sync point for Orion and Ares I, which is a key milestone in the development progress of these projects. The integrated stack sync point will demonstrate that Ares I and Orion preliminary designs, as well as the integrated stack analyses, have met all system requirements within acceptable risk and within the cost and schedule constraints. The sync point establishes the basis for proceeding to the Constellation Program-level PDR. The integrated sync point also will show that the correct design options have been selected; interfaces have been identified; and verification methods have been described. The Orion and Ares I project offices are currently finalizing data products required to meet their individual project-level PDRs. Should key information not be available by December 2008, the program will evaluate delinquent data product status and provide a strategy to ensure products are available to support the program PDR. The program office would then apply appropriate resources to mitigate delinquent product risks.

Let me re-emphasize that the Constellation program has moved beyond just drawings and into real hardware fabrication and testing. For example, beginning in late 2006 and continuing into 2008, subscale main injector hardware underwent hot-fire testing to support development of the Upper Stage engine for NASA's Ares I crew launch vehicle and Earth Departure Stage of the Ares V cargo launch vehicle. The hot-fire tests are part of efforts to investigate design options for, and maximize performance of, the J-2X Upper Stage engine. NASA engineers also have conducted more than 4,000 hours of wind tunnel testing on subscale models of the Ares I to simulate how the current vehicle design performs in flight. These tests will lay the ground work for NASA's first scheduled demonstration test flight for Ares I, called Ares I-X, scheduled for April 2009. That is just a mere 12 months from now.

Ares I-X will be the first demonstration flight of the technologies for and components of the new U.S. Exploration launch vehicle system. Important technical highlights of the Ares I-X test flight are: demonstration of First Stage separation sequencing; an assessment of First Stage atmospheric reentry characteristics; an assessment of vehicle roll torque while in flight; and a demonstration of assembly and recovery activities for a new launch vehicle at KSC. NASA recognizes that there are technical challenges related to parachute testing, modal testing and loads and environments, and we are working to mitigate those risks.

The Commercial Crew and Cargo Program

In FY 2009, NASA is requesting $173 million for the Commercial Crew and Cargo Program and its associated Commercial Orbital Transportation Services (COTS) projects. Full funding is essential to maintaining NASA's promised $500 million investment in this program to spur the development of U.S. commercial space transportation services to and from low-Earth-orbit (LEO) while also providing substantial savings to the taxpayer compared to NASA Government-owned and operated capabilities.

The objectives of this program are to: 1) implement U.S. Space Exploration policy with an investment to stimulate commercial enterprises in space; 2) spur the development of U.S. commercial space transportation services to and from LEO; and, 3) enhance U.S. access to LEO and the ISS while also providing substantial savings to the taxpayer compared to NASA Government-owned and operated capabilities. The availability of safe, reliable and economical service to LEO will help NASA achieve the Nation's goals of retiring the Space Shuttle, servicing the ISS (designated as a National Lab pursuant to the NASA Authorization Act of 2005, 109-155), and building a new transportation system that expands our Nation's sphere of economic and scientific influence on the Moon and beyond.

COTS is envisioned for execution in two phases. Phase 1 is a period of development and demonstration by private industry, in coordination with NASA via funded and unfunded Space Act Agreements (SAAs), of various space transportation capabilities to and from low Earth orbit determined to be most desirable for the government and other customers. Once a capability is demonstrated, NASA will enter into the second phase, which will be a competitive procurement of orbital transportation services to supply the ISS. A commercial services resupply contract will be managed by NASA's Space Operations Mission Directorate. A draft Request for Proposals for this contract was issued on February 28, 2008, and a final RFP is on track to be issued later this month.

As part of Phase I, NASA has negotiated funded SAAs with two partners. Each SAA has individualized milestones and objective criteria that spell out in detail a schedule of performance milestones that each participant is expected to achieve along with a fixed payment to be made upon completion. These milestones culminate in a flight demonstration where the participant's vehicle will launch, rendezvous and berth with the ISS, and in the case of one partner's demonstration, return safely to Earth. The funded partners are paid a pre-negotiated fixed amount only if they successfully complete a milestone. If they do not complete the milestone to NASA's satisfaction, they are not paid. These milestones can be technical (for example, a successful design review or hardware test) or financial (i.e., raising a certain amount of private funding).

Altogether, NASA is providing about $500 million over five years to stimulate the commercial space transportation market to help develop safe, reliable and cost-effective access to and from LEO:

- In August 2006, NASA signed a funded SAA with Space Exploration Technologies Corp. of El Segundo, Calif., also known as SpaceX. The company is scheduled to receive $278 million to supplement its privately funded efforts and is planning to conduct a demonstration flight to the ISS in March 2010. In early February, SpaceX formally notified NASA that it was projecting a six to nine month delay in the launch of the Falcon 9 launch vehicle and Dragon spacecraft demonstration missions. On Feb. 28, 2008, NASA executed an amendment to the SpaceX SAA, renegotiating milestones to align the current development and demonstration schedule with ISS integration activities. Also, several milestones were added and others modified to allow additional insight and clarification of objective measures of progress of the demonstration program. SpaceX has met all milestones to date and continues to make excellent progress in the development of its launch vehicle and cargo capsule. The total NASA investment in this agreement of up to $278 million remains unchanged, although individual performance payments for some milestones have been adjusted. SpaceX has received a total of $139 million for successfully completing the first eight milestones.

- On Feb. 19, 2008, NASA announced the selection of Orbital Sciences Corporation of Dulles, Va., for a second funded SAA to replace the Space Act agreement that NASA terminated with Rocketplane-Kistler (RpK) in October 2007 for RpK's failure to perform under the terms of the agreement. Orbital will receive approximately $170 million to supplement its privately funded

efforts and is planning to conduct a demonstration flight to ISS in December 2010. The funds made available for Orbital's award were funds not previously used by RpK.

- NASA also has entered into unfunded SAAs with five other companies – Constellation Services International, PlanetSpace, SpaceDev, SpaceHab, and Transformational Space Corp (t/Space).

Lunar Implementation

A human spaceflight program with no plan to send people beyond the orbiting ISS certainly is not in our Nation's best economic or strategic interest. The *Columbia* Accident Investigation Board (CAIB), which examined the 2003 loss of the Shuttle and its crew, acknowledged that for the foreseeable future, space travel is going to be expensive, difficult and dangerous, but emphasized that U.S. human spaceflight is not only strategic, but also what makes us a great Nation. The report noted that not developing a replacement vehicle for the Space Shuttle demonstrated a failure of National leadership and also declared that if we are going to send humans into space, the goals ought to be worthy of the cost, the risk and the difficulty.

President Bush responded to the CAIB report. The Administration looked at where we had been in space and concluded that we needed to do more, to go further. The result was the Vision for Space Exploration, announced nearly four years ago, which commits the United States to using the Shuttle to complete the ISS, then retiring the Shuttle and building a new generation of spacecraft to venture out into the solar system. Congress ratified that position with an overwhelming bipartisan majority, making the Vision the law of the land in 2005 upon the adoption of the NASA Authorization Act of 2005. Congress specifically directed NASA "to establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. pre-eminence in space, and as a stepping stone to future exploration of Mars and other destinations."

As NASA Administrator Michael Griffin eloquently outlined in a 2007 speech, NASA is moving forward with a new focus for its human space program -- to go out beyond LEO for purposes of human Exploration and scientific discovery. If humans are indeed going to travel to Mars, if we're going to go beyond, we have to learn how to live on other planetary surfaces, to use what we find there and bend it to our will. If we are to maintain our global leadership as a spacefaring Nation, we have to survive in other forbidding, faraway places across the vastness of space. The Moon is a crucially important stepping stone along that path; it is an alien world, yet one that is only a three-day journey from Earth.

In 2006, NASA and 12 international partners established the Global Exploration Strategy (GES) team to identify primary themes and objectives for lunar Exploration. These objectives were grouped into six themes: 1) human civilization; 2) scientific knowledge; 3) Exploration preparation; 4) global partnerships; 5) economic expansion; and 6) public outreach. These themes and objectives serve as the foundation for the development of the lunar architecture currently under development. More specifically, NASA identified several guiding principles for the lunar architecture which include:

- Human lunar missions will be used to build an outpost initially at a polar site;
- Preserve the option for an outpost at other lunar locations;
- Preserve the ability to fly human sorties and cargo missions with the human lander;
- Initial power architecture will be solar with the potential for augmentation with nuclear power later;

- The United States will build the transportation infrastructure, initial communication and navigation infrastructure, and initial surface extravehicular activity (EVA) capability (i.e. Moonwalk);
- Open Architecture: NASA will welcome parallel development and development of lunar surface infrastructure by international and commercial interests;
- Early exploration: Reduced assembly through pre-integrated habitats;
- Modular mobile habitation:
    - Facilitates "super sortie" mobility for 100's km distances from the outpost
    - Facilitates greater lunar access to capture exploration and science objectives beyond LAT1 results; and,
- Early small pressurized rover
    - Augments EVA operations by allowing astronauts to explore in shirt sleeve environment using EVA judiciously.

Utilizing these guiding principles, NASA is conducting early concept studies for an outpost on the Moon. An Agency-wide team has been hard at work, looking at concepts for habitation, rovers and space suits. When NASA returns Americans to the Moon in 2020, astronauts will set up a lunar outpost, possibly at the south pole, possibly at a site called the Shackleton Crater, where they will conduct scientific research, as well as test technologies and techniques for Exploration of Mars and other destinations. The architecture concept utilizes a building block approach to maintain the maximum amount of flexibility should NASA want to be able to land at varying locations on the lunar surface

Data from the LRO and LCROSS missions will enable future outpost site selection and new information about resources within the permanently shadowed craters at the lunar poles. The LRO/LCROSS missions also represent NASA's first steps in returning to the Moon. More specifically, the LRO will develop a highly detailed, topographic map of the lunar surface to help prepare the way for humans to return in the next decade. Information from the robotic spacecraft will be used to select safe landing sites for the next generation of lunar explorers. LRO also will provide valuable information about the environment and resource availability on the lunar surface. While the Apollo missions focused on gaining Science from the area around the Moon's equator, the LRO will circle the poles. It will spend at least one year in low, polar orbit, with instruments working simultaneously to collect detailed information about the lunar environment. The mission objective is to collect the highest resolution and most comprehensive data set ever returned from the Moon. The LRO, which is being built at NASA's Goddard Space Flight Center in Maryland, will carry six instruments and a technology demonstration payload. The LRO is scheduled to be launched atop an Atlas 5 rocket from KSC by the end of the year. The same rocket also is scheduled to loft the LCROSS spacecraft, which is designed to detect water in a permanently-shadowed crater at the lunar south pole.

In response to Congressional direction contained in the Explanatory Statement accompanying the Consolidated Appropriations Act, 2008 (P.L. 110-161), NASA will fund a robotic lander project managed by the Agency's Marshall Space Flight Center in Alabama as a pathfinder for an anticipated network of small science robotic landers based on requirements for NASA's expanded lunar Science program. The first robotic lander mission is planned to fly in 2013-2014. NASA's Exploration and Science Mission Directorates will continue to work together, as they do on numerous projects, to combine resources to ensure that the goals of the Science robotic lander are achieved.

Work on the human lunar lander also is progressing. On March 17, 2008, NASA's Constellation Program awarded a 210-day study contract to five space-related companies to independently evaluate NASA's in-house design concept for the lunar lander that will deliver four astronauts to the surface of the moon by 2020. The awards total approximately $1.5 million, with a maximum individual award of $350,000. The

study recommendations will be used to increase the technical maturity of the existing design, in preparation for the development of vehicle requirements. These studies will provide valuable input for developing a sound set of requirement for the Altair lunar lander.

Once astronauts set foot on the Moon, they will need some place to live. NASA had been considering integrated habitation units emplaced by a cargo lander. The team is also discussing the possibility of a mobile habitat module that would allow one module of the outpost to relocate to other lunar destinations as mission needs dictate. The outpost approach provides the flexibility needed to incorporate international and commercial contributions to the lunar outpost architecture. International collaboration can help achieve global exploration objectives faster than if NASA attempted to deploy the entire lunar Exploration architectural elements alone.

As part of the lunar architecture, NASA is considering utilizing small, pressurized rovers that would be key to productive operations on the Moon's surface. Engineers envision rovers that could travel in pairs – two astronauts in each rover – and could be driven nearly 100 kilometers away from the outpost to conduct Science and other activities. Astronauts inside the rovers wouldn't need special clothing because the pressurized rovers would have what's called a "shirt-sleeve environment." It is envisioned that the spacesuits would be attached to the exterior of the rover. Astronauts could crawl directly from the rovers into the suits to begin a moonwalk.

NASA has been engaged with its international partners since 2005, particularly following the GES team's establishment in 2006. Since then, NASA has worked hard to effectively communicate our plans to our international partners about our efforts to develop the transportation systems required to travel between the Earth surface and the lunar surface. We also have clearly communicated our desire and interest in open collaboration on outpost elements. After several months of collaboration, NASA and 12 other international agencies developed a joint document titled, *The Global Exploration Strategy: The Framework for Coordination*. The *Framework Document*, as it is commonly referred to, identifies the common themes that all nations can identify with in the course of exploring space and establishes some basic principles for cooperation. During future discussions, NASA will work with our partners to define standard interface information to minimize to the greatest extent possible integration costs. We have recently completed discussions with our international partners on lunar communication standards.

Additionally, NASA is already working with both the Japanese and Indian space agencies on two projects that will help better inform our lunar efforts. Last September, the Japanese Aerospace Exploration Agency launched its SELENE/Kaguya mission, which will provide NASA with altimetry data to help improve our targeting for the LCROSS mission. NASA also is planning to include two instruments this summer on the Chandrayaan-1 mission, which the Indian Space Research Organization plans to launch this summer. These instruments will help us better understand the formation and evolution of the Moon, for the needs of both NASA's ESMD and SMD programs and projects. Using radar, we will also be able to look into the permanently shadowed craters at the poles of the Moon, and since the LCROSS impactor will be sent to one of these craters, it is important for us to have an initial idea of the surface characteristics of the possible target sites for the LCROSS impact.

Advanced Capabilities

The Agency's FY 2009 budget request also provides $452 million for activities in ESMD's Advanced Capabilities theme, which seeks ways to reduce the risks for human explorers of the Moon and beyond by conducting research and developing and maturing new technologies. This year, NASA's Human Research Program will focus on the highest risks to crew health and performance during exploration missions. We also will develop and validate technologies that serve to reduce medical risks associated

with human spaceflight. For example, NASA will continue its work to understand the effect of space radiation on humans and to develop effective mitigation strategies. Next year, the Advanced Capabilities Exploration Technology Development program will conduct a range of activities, including testing prototype ablative heat shield materials; throttleable liquid oxygen/liquid hydrogen engines suitable for a human lunar lander; and lightweight life support systems for Orion. The program also will deploy and test advanced environmental monitoring systems on the ISS to advance the safety of crewmembers, and will continue to test in-situ resource utilization technologies as well as life support and cryogenic fluid management.

For ESMD, the Advanced Capabilities Division has the lead for research onboard the ISS. During 2008, NASA will continue to conduct research onboard ISS that will include experiments on human adaptation to microgravity, as well as biological and microgravity experiments. It is important to note that the ISS will support astronaut return to the Moon by providing a reduced gravity environment for studying human health effects and effective countermeasures. While the Moon does have gravity, it is unknown if its small fractional gravity will be enough so that normal physiological function can occur over longer durations. Information from ISS will provide a basis for the types of countermeasures that we will need to develop for long-range lunar habitation and the eventual long-transit journeys to Mars and beyond. NASA will adjust these countermeasures as we get additional data from initial lunar human explorers. In the meantime, we will use ground-based analogs to help us gain additional insight into fractional gravity and its effect on astronaut explorers.

NASA is balancing its portfolio to meet the requirements of the NASA Authorization Act of 2005, pertaining to non-Exploration research. In the FY 2009 budget, NASA budgeted $138 million for Exploration-related research and $30 million for non-Exploration research, resulting in 18 percent of the ISS research budget being spent on non-Exploration research.

NASA is developing long-range plans to utilize the ISS and free flyers beyond 2010. Non-Exploration payloads for ISS will use existing or soon to be delivered science facilities and racks. NASA is aggressively working to utilize the ISS for both Exploration and non-Exploration payloads. During 2007, NASA participated with a Russian biomedical institute to investigate fundamental biological processes in a number of living organisms through experiments using a Russian free flying spacecraft, the Foton M3. NASA continued development work on a nanosat that will investigate the effectiveness of antifungal agents on fungi in microgravity. That mission is scheduled to launch on the TacSat 3 mission this fall. On the ISS, fundamental physical science payloads, such as the Binary Colloidal Alloy Test and the Capillary Flow Experiment will provide fundamental information and validate hypotheses concerning the behavior of physical systems in microgravity.

NASA continues to integrate Science and Exploration initiatives on several fronts. For example, the two mission directorates are collaborating on plans for Radioisotope Power Systems. Additionally, ESMD and SMD are cooperating on the LRO. The LRO has been designed, developed, and will be launched and operated by ESMD for the first year in order to develop a topographic map of the Moon for the identification of lunar landing sites, and will later be transitioned to SMD for additional Scientific activities. In addition, ESMD and SMD have established an Outpost Science and Exploration Working Group to coordinate lunar exploration activities between the two directorates. One of the group's key objectives is to jointly identify Science requirements that could affect the Exploration architecture prior to lunar systems PDRs. Architecture considerations driven by Science community recommendations could include requirements such as telerobotic capabilities from both the outpost or ground stations and mobility greater than 100 km from the outpost.

Seeking Synergies Between Constellation and Lunar Architectures

In your invitation today, you asked me to address how NASA plans to accommodate its goals for the Constellation and lunar programs while also dealing with constrained budgets. As stated before, full funding of NASA's FY 2009 budget request for Constellation is needed so that NASA can continue successful transition between the Shuttle and the Orion and Ares I. The FY 2009 budget request maintains Orion IOC in March 2015 and FOC in FY 2016 and provides stable funding in the out years. NASA stands behind the President's budget and the Exploration roadmap that it supports. In doing so, NASA pledges to consistently look for ways to optimize performance, decrease costs, increase reliability and sustain safety, while also maintaining alignment with the goals and objectives outlined by the President and the Congress for this multi-decadal Exploration endeavor.

To mitigate some risk, NASA is consistently looking for synergies between the Constellation and lunar architectures. For example, NASA has defined a transportation architecture that maximizes subsystem commonality between crew access to ISS and the lunar program. Benefits of this common design approach include a comprehensive decrease in Design, Development Test & Evaluation (DDT&E) non-recurring expenses, and lower recurring vehicle manufacturing, logistics, processing, and maintenance costs realized through commonality of tooling, ground support equipment, launch pad interfaces, and mission scenarios. Developing common Ares I and Ares V propulsion systems means that manufacturing facilities, ground support systems, and launch site infrastructure modifications and improvements can be jointly applicable and leveraged to reducing both recurring and nonrecurring operations costs throughout the life cycle of each system.

NASA also plans to reap benefits and efficiencies by partnering with the Shuttle program and by deciding to utilize a five-segment reusable solid rocket booster (RSRB) for the Ares I First Stage. Specifically, developing the five-segment RSRB for the Ares I and later migrating it to the Ares V Core Stage propulsion system will result in significant out-year savings on DDT&E costs. Aside from cost savings associated with this approach, this approach may potentially enable earlier Ares V availability, given that the risks associated with developing the five-segment RSRB would have been resolved before embarking on other core stage propulsion element work.

Conclusion

Throughout history, the great nations have been the ones at the forefront of the frontiers of their time. Britain became great in the 17th century through its exploration and mastery of the seas. America's greatness in the 20th century stemmed largely from its mastery of the air. In this new century, those who effectively utilize space will enjoy added prosperity and security and will hold a substantial advantage over those who do not. In order to increase knowledge, discovery, economic prosperity, and to enhance National security, the United States must have robust, effective, and efficient space capabilities. We do not live in a static world -- other countries will explore the cosmos, whether the United States does or not, and those will be Earth's great nations in the years and centuries to come. Bold plans and strategies require bold leadership and robust follow-through. Together we can create a bold legacy for generations to come.

Today I have highlighted for you some of NASA's progress in developing the Constellation and lunar architectures – and some of the challenges that lay ahead. NASA knows it has a lot of hard work, but we are continuing to make steady progress. In the span of a few short years, we have already taken long strides in the formulation of strategies and programs that will take us back to the Moon and on to Mars and other destinations in our solar system. Indeed, a generation from now, astronauts on the Moon and Mars will be flying in and living aboard hardware America is funding and designing today, and will be

building in the near future. This is a heady legacy to which we can aspire as we develop the next U.S. human space exploration vehicles. The foundation of this legacy will include work we plan to carry out in FY 2009.

I want to stress the criticality to the Nation of meeting our goal of successfully transitioning from the retirement of the Space Shuttle to the operation of Orion and Ares I. NASA's Exploration Systems and Space Operations Mission Directorates are continuing to work closely to determine how best to transition our valuable infrastructure and workforce to the Constellation program in support of our Exploration plans. Our transition plan continues to be refined which will closely align Shuttle and Constellation activities and outline clear milestones to achieve the synergies required. I would like to ask this Subcommittee for your continued support as we effectively transition key elements of our Space Shuttle workforce, infrastructure and equipment for our Nation's Exploration objectives. Our efforts are complex and intertwined between ESMD and SOMD, and that is why sustained purpose, direction and budget stability are particularly important.

NASA is at the beginning of a new adventure. It is an adventure that presents challenges that are appropriate for the talents and resources of our Nation; fitting to the profound impact of space activities on a global scale; and respectful of the sacrifices that have been made in the continued pursuit of space Exploration. For my part, I look forward to the challenge of Exploration and to working with you and an energized NASA workforce to accomplish our goals.

Mr. Chairman, with your support and that of this Subcommittee, we are making the right strategic choices for our Nation's space program. Again, thank you for the opportunity to appear before you today. I would be pleased to respond to any questions that you may have.

Richard J. Gilbrech, Ph.D.
Associate Administrator for
The Exploration Systems Mission Directorate

Richard J. Gilbrech is associate administrator for NASA's Exploration Systems Mission Directorate. He leads the Agency in the development of the Nation's new spacecraft that will return astronauts to the moon and travel to Mars and other destinations in the solar system.

Gilbrech previously served as director of NASA's Stennis Space Center near Bay St. Louis, Missouri, where he provided overall leadership, planning, policy direction, management and coordination for all activities implementing NASA's mission directorates.

Before being named director of Stennis, Gilbrech served as deputy center director of NASA's Langley Research Center, Hampton, Virginia. Prior to that he was deputy director of the NASA Engineering and Safety Center, located at Langley.

Gilbrech started his NASA career in 1991 at Stennis in the area of propulsion test technology. In 1995, he was selected as the Stennis national aerospace plane project manager responsible for the construction, activation and operation of a facility to test actively-cooled structures. Later in 1995, he was named the X-33 project manager, responsible for converting the A-1 test stand at Stennis from space shuttle main engine testing to linear aerospike turbopump single- and dual-engine testing. From 1998 to 2000, he served as chief of the Propulsion Test Engineering Division within the Propulsion Test Directorate at Stennis.

Gilbrech earned a bachelor's degree in aerospace engineering from Mississippi State University. He earned master's and doctorate degrees in aeronautics from the California Institute of Technology with a minor in planetary science.

The recipient of numerous awards, Gilbrech has received NASA's prestigious Outstanding Leadership and Exceptional Achievement Medal.

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