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Statement of

Maria T. Zuber

E.A. Griswold Professor of Geophysics
Head of the Department of Earth, Atmospheric and Planetary Sciences
Massachusetts Institute of Technology

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Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today to provide perspectives on the Future of Human Spaceflight. I lead NASA's Gravity Recovery and Interior Laboratory (GRAIL) dual-spacecraft mission to the Moon that lifted off successfully from Cape Canaveral Air Force Station on September 10, 2011. The mission, which launched on spec, on time and under budget, is the first robotic demonstration of precision formation flying around another planetary body. The last time precision formation flying was performed at the Moon was during the Apollo 17 mission under the command of Captain Eugene Cernan. As a space scientist and educator, I am an enthusiastic supporter of the human exploration of space, as detailed in the following testimony.

Rationales for and Benefits of Human Exploration

History teaches us that great civilizations explore and dare not cease exploration. As a case in point in the early to mid 1400's China had arguably the greatest navy on Earth under the command of Zheng He. During the Ming Dynasty Chinese expeditions established trade routes in the Indian Ocean to Arabia and Africa, until the voyages were canceled and the fleet was burned, in part to save money. Late in the same century (1497) Vasco da Gama led four small ships around the Cape of Good Hope on first successful expedition from Europe to India. World history may have been very different had da Gama's handful of ships encountered Zheng He's fleet of over 250 large junks. But the Chinese stayed home and their influence waned, while the nations of Western Europe went on to dominate world affairs.

The rationales for human exploration of space are numerous and have been oft articulated, from the practical to the sublime:

- The human space program produces advanced technologies and high-paying jobs. Like some other government programs it provides considerable economic benefit to many regions of the U.S.; not a cent of the NASA budget has ever been spent in space.

- The human spaceflight program contributes markedly to the viability of a series of our economic sectors. There are numerous commercial, scientific and military interests in space, such as communications, GPS, weather and climate monitoring, intelligence and surveillance that benefit from investments and technological advances made in the human space program. As a space scientist who develops robotic missions I believe that a significantly reduced human space program would be devastating in terms of technological base needed to design future robotic experiments.

- Human space exploration inspires our youth to pursue careers in science and technology. The influential report "Rising Above the Gathering Storm" elucidated eloquently a national imperative for increased education in Science, Technology, Engineering and Math (STEM). Key decision points are early in middle school when children need to decide to take advanced math that leads to calculus and Advanced Placement science courses in high school. Arguments have been made that there are other great challenges, like energy, that will attract our best and brightest students. This is true. But children aren't thinking about energy at early ages – they're inspired by space and dinosaurs. Having served on President Bush's Moon Mars Commission I spoke to innumerable citizens who ultimately became telecom engineers, biologists and computer scientists because they watched astronauts walk on the Moon.

- Human exploration will contribute to our understanding of the vastness and makeup of the universe, the tenacity of life and the age-old question of whether life exists beyond Earth. In the near term, I look forward to an increased emphasis on scientific inquiry on the International Space Station. I believe that Nobel Prize-caliber discoveries can be made there. Whenever investigation takes place in a new environment, with new sensors, extraordinary discovery is assured.

- Asking whether the human space program is worthwhile is like asking whether the voyages of da Gama, Magellan or Columbus were worthwhile. As for the Chinese, they've rethought their national strategy. Despite pressing social concerns of the present they're not staying at home anymore. They're going to the Moon.

Charting a Viable Path Forward

In light of economic challenges, fiscal responsibility is essential as is the need for sustained forward progress. An important component of a successful program is the articulation of near- and long-term national goals that are non-partisan. I support the recommendation of

the Review of Human Spaceflight Plans Committee that the eventual goal should be the human exploration of Mars.

As a university professor who interacts frequently with students at all levels I can say with confidence that the goal of human exploration of Mars is also the consensus opinion of the next generation who will carry out this challenge. I cannot estimate the number of students who have found their way to me to tell me that they want to help America go to Mars, in many cases wanting to go themselves. On the wall of my office is a picture of Earth taken from the surface of Mars by the Opportunity rover and I remind the students that everything they know and love is on that dot in the sky, and do they still want to go? Of course they do. I then dutifully explain the challenges – technical, scientific, psychological and political – do they still want to go? They wonder what's wrong with me; of course they do. Never tell a young person that something they want to do is impossible. NASA should do what I do with these students. Start working on those parts of the challenge that are possible to address within the constraints that exist and keep moving forward; when the time is right to start planning a mission to Mars in earnest the starting base of knowledge must be as robust as it can be.

There are two attributes necessary to any implementation plan. First, the program must be managed responsibly, with a balance between infusion of new technology and a sensible risk and cost profile. Unfortunately Congress is cutting back NASA's advanced technology work and it is not clear how the agency will be able to unfold new advanced missions without a more concentrated effort to develop new technologies. "Off the shelf" technology will not meet all future needs and some significant advances will be required if costs are to be managed. Second, a balanced program of science and technology is necessary; the thought that it is possible to cut out major parts of the industry or scientific enterprise and that people will return at some TBD time in the future is unsound.

Job 1 in the next phase of human spaceflight is to develop reliable, routine access to low Earth orbit. Most of the energy in spaceflight is in getting off the surface of the Earth. NASA should be doing the technically challenging task – transporting humans to unexplored destinations. While it is possible to quibble about details of lift capacity, etc. the plan for the Space Launch System (SLS) announced by Administrator Bolden last week is responsive to this objective, as is the intention to develop a new crew vehicle. When the time comes that one or more reliable commercial launch vehicles are available, these entities should transport cargo, and ultimately humans, to low Earth orbit. Such capabilities would free NASA to focus on exploration beyond Earth orbit.

Landing on a planetary body with significant gravity is especially complex (and therefore expensive) but expeditions to a Lagrange point or to rendezvous with an asteroid would be more straightforward to accomplish, and would have the advantage of providing much needed experience for humans to function beyond Earth orbit. To ultimately explore Mars humans need to learn to live and work on a planetary body with gravity. New space suits and surface instrumentation will be necessary. Some of this required technology is under preliminary development.

Synergies Between Human and Robotic Exploration

The American public, and by extension NASA, grows ever more risk averse. Today I cannot imagine that we would send a mission to the Moon if lightning struck the launch vehicle, like we did with Apollo 12. In human spaceflight we require a full understanding of the technology we launch and the environments we traverse. Information returned from NASA's space science missions provides the context of the space environment that will enable future human exploration beyond low Earth orbit. Robotic observations provide information on radiation fluxes in space, surface hazards that jeopardize landings (Apollo 11 being a case in point), and atmospheric variability that will be relevant to landing on Mars. Robotic reconnaissance also provides guidance as to the most interesting areas to explore, for example the detection of pits that that provide access to subterranean lava tubes on the Moon and Mars. One such pit on the flank of the Pavonis Mons volcano on Mars was discovered by seventh graders from Evergreen Middle School, Cottonwood, California, via the Mars Student Imaging Project operated by NASA and Arizona State University.

My mission GRAIL will provide a higher resolution gravity field of the Moon than currently exists for Earth. This mission was selected solely on the basis of its scientific goal of understanding the structure and evolution of the Moon and its ability to advance similar understanding of all the rocky planets including Earth. However, the new understanding of gravity it will enable also provides distinct benefits for future robotic and human exploration on many different missions. Combined with elevation measurements from the altimeter on the Lunar Reconnaissance Orbiter spacecraft that is currently mapping the Moon, GRAIL will provide a precise gravity field and an accurate latitude-longitude grid that will greatly facilitate orbital navigation and in addition enable any future lunar spacecraft to land exactly where desired, thereby reducing risk and maximizing scientific return.

Human exploration will also be an enabler for planetary exploration. While remote activities like antenna deployment and surface traverses can be accomplished remotely, humans could do such activities far more efficiently. The repair of the Hubble Space Telescope is perhaps the most obvious example of humans contributing significantly to the advance of science. My colleague Steve Squyres, while celebrating the longevity of his Mars Exploration Rovers, has on more than one occasion reflected wistfully of how much more could have been learned if humans and robots were exploring in concert. A human will always be able to adapt a plan when confronted with new or unexpected information.

A forward-looking endeavor that would be particularly suited to humans on another planet would be deep drilling. Imagine exploring below the surface of Mars to search whether life retreated beneath the surface when the planet lost its atmosphere early in its history. Imagine drilling deep into the Moon to understand the role of solar heating over the past several hundred years, an activity that would elucidate the role of the sun in Earth's climate history.

In Closing

The human spaceflight program has been a source of enormous pride and the achievements and can do-spirit of the employees of NASA and its industrial and academic partners exemplify much of what makes America great.

I am grateful for the opportunity to contribute to the national discussion of how to implement a future sustainable human spaceflight program, and I look forward to responding to your questions.