

Given at a Full Committee Hearing:
Future of NASA

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The Testimony of

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Mr. Chairman and Members of the Committee:

I am grateful for the opportunity to testify before you today on my view of the future of this planet's human space flight program. The public wants an adventurous space program, a Mission From Planet Earth to new exciting destinations in the solar system and beyond. The public wants to know where we are going, how we are going to get there and wants to go along for the ride even if only virtually. America has the right stuff, but today's human space flight program isn't giving the public what it wants.

Old Legacies

The challenge for NASA is to throw off the yoke of the Apollo program legacy and to move outward beyond Earth to exotic places in the solar system, those places where we have been given tantalizing glimpses from our robotic exploration program. The Shuttle and Space Station are the legacy of a long-past era in which the space program was a weapon in the Cold War. The Apollo program was not primarily the science or exploration program we are all fond of remembering, it was a demonstration of power and national will intended to win over hearts and minds around the world and to demoralize the Soviet Union. Exploration is not what motivated Kennedy to open the public purse. Beating the Russians did. It worked. Apollo accomplished what was intended and the nation moved on to other priorities, which did not include what space enthusiasts and much of the public thought would happen—lunar bases and on to Mars.

The Space Shuttle and International Space Station (ISS) are the products of NASA attempting over the decades to preserve the Apollo era of human space flight already passed by. These are complex, expensive projects that produce enormous strain on NASA's budget and corresponding stress on the heroic people who work so hard to preserve the enterprise. The current human space flight program is barely affordable with what NASA is appropriated. The Apollo era is gone, the imperatives for space exploration are very different now than they were in the 1960s, and three decades of wishful thinking and building space ambitions on an inadequate funding basis has led the nation into a blind alley. The ISS is not the expected transportation node for missions beyond Earth orbit that it was supposed to be; it has become an Earth-orbital end unto itself. And the Space Shuttle is not the low-cost, low-risk operational space transportation system that it was supposed to be.

The legacy of the Columbia accident should be to create a new pathway and sense of purpose for human spaceflight. We should provide a more robust transportation system for our astronauts and a more rewarding program of exploration for these heroes. They should be assured of a reliable, safe system for transporting them a distance no farther than the distance between New York and Washington. And if space explorers are to risk their lives it should be for extraordinarily challenging reasons—such as exploration of the Moon, Mars, and asteroids, and for construction and servicing space telescopes—not for making 90 minute trips around the Earth. The whole point of leaving home is to go somewhere, not to endlessly circle the block.

Just as for Apollo, the Shuttle and ISS were developed for political imperatives; not so much for space exploration but to keep humans flying and to serve a foreign policy agenda. The Shuttle and ISS have not proven to be the next steps to human deep space exploration as advertised, instead they have become an impediment—serving only to maintain a human presence in near-Earth space until society finally decides to undertake missions to destinations beyond Earth orbit. Immediately after the Columbia accident, Charles Krauthammer, a noted columnist put it far better than my scientist training allows:

“We slip the bonds of Earth not to spend 20 years in orbit studying zero-G nausea, but to set foot on new worlds, learn their mysteries, establish our presence...After millennia of dreaming of flight, the human race went from a standing start at Kitty Hawk [almost exactly 100 years ago] to the moon in 66 years. And yet in the next 34 years, we’ve gone nowhere...For now, we need to keep the shuttle going because we have no other way to get into space. And we’ll need to support the space station for a few years, because we have no other program in place...If we are going to risk that first 150 miles of terrible stress on body and machine to get into space, then let’s do it to get to the next million miles—to cruise the beauty and vacuum of interplanetary space to new worlds...the problem is not manned flight. The problem is this kind of manned flight, shuttling up and down at great risk and to little end.”

New Options

We have reached a point now where we reflect fondly on a time past when America shined brilliantly in human space exploration, but can only lament our retreat while others climb a path we pioneered and abandoned. We can shine again. We are a wealthy and capable nation. We have the resources. The required technology is at hand or just around the corner of development. These are not the issues. The issue is national will. Space exploration has become a part of our culture. The public believes that flying in space is part of who we are as a nation. “Space exploration is an element of our national being” [Harrison Schmidt, former astronaut and former Senator from New Mexico]. Our robotic explorers generate enormous interest when they fly and land on other planets. But the public expectation is that these robotic missions are a prelude to sending humans.

What the public wants is clarity of purpose. A Space Station advertised as “the next logical step” without filling in the blank “to what?” doesn’t do it. There is a growing chorus of leaders inside and outside of government concerned that NASA’s post-Columbia-investigation posture is business as usual. The consensus of many is that a coherent vision for human spaceflight over the next several decades is required, one that has a clear sense of purpose and destination. According to Neil Lane, former NSF Director and Presidential Science Advisor, “Unless we can get a clear, stated mission, we should step back and not risk further lives.”

Sooner or later we must have a clear destination for human spaceflight or it will not survive, and America will be much the poorer for it. And a new option doesn’t have to be funded like Apollo, it can proceed at a steady pace. The country needs the challenge of grander exploration to justify the risk, lift our sights, fuel human dreams, and advance human discovery and knowledge. **WE NEED TO GO SOMEWHERE!**

There are organizations outside NASA and the U.S. Government that are addressing this issue. The International Academy of Astronautics is conducting a study entitled “The Next Steps in Exploring Deep Space”. Its purpose is to provide a logical and systematic roadmap for the long-term scientific exploration of the solar system beyond Earth orbit with a goal to land humans on Mars sometime in the next 50 years. The study will be completed this coming spring and envisions the establishment

of a permanent human presence in space using an evolutionary approach to the development of space transportation infrastructure utilizing well-defined intermediate destinations as stepping-stones to Mars.

In addition, a workshop this past spring run by three organizations—The Planetary Society (TPS), the American Astronautical Society (AAS) and the Association of Space Explorers (ASE)—has made recommendations for near-term actions to solve our post-Columbia problems in human transportation to Earth orbit. My testimony draws heavily on the results from this joint workshop and from the IAA study. The workshop statement and a short briefing on the interim results of the IAA study are attached.

The Exploration Imperative

Beginning in 1952, a series of symposiums on space travel were held at New York City's Hayden Planetarium that attracted the greatest visionaries of the day, including Werner von Braun, Willey Ley, and the space artist Chesley Bonestel. That vision of our future was subsequently captured in a series of illustrated articles for Collier's Magazine, launching a national dream of space exploration. As a nation of people who make dreams happen, and who explore to provide for a better life, we didn't do too badly with making that mid-Century dream of space travel come true. But after the Apollo missions the dream to move on was put on hold. So why should we revive that dream to explore space in this new 21st Century? For the same reasons that we explored and developed air travel in the 20th Century. Because it challenges us! At the beginning of the 20th Century in America the great public adventures were exploration of the polar regions of Earth and powered flight through the air. A century later, millions of humans travel in comfort through the air to destinations around the planet. No one in 1900 could have dreamed it possible to fly in comfort from New York to Paris in just over six hours.

And so it will be in the 21st Century. At the beginning of this century we know how to travel in space, but are only just on its edge. We fly into space on dangerous, unwieldy, bolted-together hunks of thin metal and bulky propellant, spinning around our own planet in a fragile metal can strung together with cables and trusses. In one of history's major anomalies, we even flew men to the Moon and back 30 years ago, but are unable to do it now. By the end of the 21st Century, space travel will be as commonplace as air travel is at the end of the 20th. We just can't predict the details right now, just as the Wright Brothers could never have imagined a Boeing 747 in 1903.

Exploration and the drive to discover and understand are qualities that have allowed the humans to survive and become the dominant species on the planet. Human beings strive to know and understand what surrounds them. By exploring the unknown, humans gain security and dispel fear of the unknown, of what is beyond. This survival mechanism is encoded in our genes. Just as human civilization uses the challenge of exploration to hone scientific and technological skills for survival, and exploits the adventure to provide hope for the future, human populations also have a need for heroes to provide inspiration. This is particularly important for our youth, who need to be provided with a positive vision for their future. Every generation has had its heroes. Today, the astronaut is a hero figure because astronauts carry out adventurous work that achieves exciting goals, personifying the kind of life that our youth would like to lead. Space exploration presents a positive image of the future and inspires our youth towards achievement.

The Science Imperative

In the 1960s, the space program was popular in the U.S. because the public knew precisely what the goal was, how the game was played and followed every play. Today, the public's innate acceptance of the abstract notion of exploration as a human imperative does not necessarily extend to their checkbook without clear articulation of goals and benefits. Today the public benefit can be expressed as a clear set of goals because science and technology has progressed to the point where it can dare attempt answer some of the most burning questions that human beings have been asking since they started gazing upward at the sky. Questions such as 'Where do we come from?' and 'What will happen to us in the future?' and 'Are we alone in the Universe?' These very fundamental human questions can be recast as scientific challenges—goals to be achieved in the course of exploring space. And from these scientific goals, plans can be formulated for both robotic and human explorers including the destinations and the exploration objectives of each.

Where did we come from? This is a question that approaches the contemplation of existence. Even so, astronomers can address the question by determining how the Universe began and evolved, and learning how galaxies, stars and planets formed, and searching for Earth-like planets around other stars. The answers require large and complex space telescope systems made possible by human construction and servicing in space.

What will happen to us in the future? Every human wonders about the future. One form of this question asks if there is any threat to us from space, especially from earth-crossing asteroids. The answer will come from surveys of the earth-crossing asteroid population in space and space missions that determine their composition and structure. Another form of this question asks what future humans have in traveling to and living on other planets. Is our species destined to populate space? Ultimately I believe the answer is yes, and the information will come from exploring space and utilizing the resources we can find in the most promising places in space such as Mars.

Are we alone in the Universe? Every human being wants to know the answer to this question. We are compelled to find its answer. Some find comfort in the notion that we should be alone; others are fearful of the potential for other life "out there". Most scientists see the possibilities and are overwhelmed by the notion that the universe might be teeming with life; at least microbial life and perhaps even intelligent forms. We will find the answer by searching for life in the most promising places in the solar system such as Mars, and by looking for signs of life on planets outside the solar system with space telescopes.

Destinations

The IAA study starts with these public questions and defines the scientific objectives required to answer them. The scientific objectives in turn determine what kind of exploration is required at which destinations in the solar system. Four destinations for human exploration result from this exercise: the Sun-Earth Lagrangian point L2, the Moon, Near-Earth Asteroids, and Mars.

Mars, the most distant and most challenging of these destinations, is also the most scientifically rewarding and the one place that can galvanize human interest like no other. It is the logical destination for humans in the next decades of our new century. Mars is the most Earth-like of all the other planets in our solar system. It may have had life in its early history, it might possibly harbor microbial life below its surface today, and one day in the distant future it may become a new home for human kind. It has fascinated humans for centuries and it is within our reach.

A brief description of the scientific and exploration utility of the four identified human destinations are described below, arranged in order of energetic difficulty for a systematic, progressive approach to exploration beyond Earth orbit.

Sun-Earth Lagrangian Point L2 (SEL2) is a point about 1 million miles from the dark side of the Earth opposite the Sun that is the site of choice for future space astronomical telescopes that will search for and image Earth-like planets around other stars. These telescopes will of necessity be large, complex systems requiring servicing by astronauts in a manner similar to the Hubble Space Telescope. SEL2 is easy to get to, with round trip times on the order of 2-3 weeks and could serve as the initial step in developing a deep space transportation capability.

The Moon is a scientifically rewarding destination where we can obtain information on the probability for impact of asteroids on the Earth, on the history of the Sun and its effect on the Earth's environment, and perhaps on the earliest history of the Earth itself. The proximity of the Moon makes it attractive as a potential proving ground for surface systems, habitats and other technologies, possibly including the use of lunar resources, but it is not necessarily on the critical path to Mars exploration.

Near-Earth Objects travel in orbits between the Earth and Mars and represent both a potential resource in space and a potential impact hazard to Earth. Robotic missions to these objects will be necessary to assess these potentials. The jury is out on whether human missions would be necessary for these purposes, but there is no doubt that a one-year human mission to a Near-Earth Object would serve as an excellent intermediate step before any mission to Mars. An NEO human mission would provide a lower-risk test flight of the systems necessary to reach Mars.

Mars is the ultimate destination for humans in the first half of this century. It is on this most Earth-like planet that humans can establish a permanent presence—utilizing resources the planet has to offer from its atmosphere, soil and subsurface ice and water. The scientific goals will be to understand the similarities and differences between Earth and Mars, particularly the history of water and its distribution on Mars, the geological and climatological histories of Mars and a search for evidence of past or present life. The question of possible life on another world is probably the largest driver for humans in space and particularly for Mars exploration.

Our ultimate ability to reach these destinations requires that architectures developed today for transportation from the Earth's surface to orbit have a top-level requirement to consider the future needs for space transportation to deep space. Otherwise, it is likely that a solution will be derived that is useless for the next step beyond Earth orbit.

The Architecture

The IAA study proposes an architecture for enabling this vision. Mars is the goal, but intermediate destinations are identified that comprise a progressive approach to this long-term objective. The approach is science-based to address key questions of public interest. These science goals provide the context for destinations, capabilities and technology investments. It is a stepping-stone approach in which there is a logical progression to successively more difficult destinations. This approach requires incremental investments to maintain progress, rather than huge new budgets, and destinations can be adjusted to manage cost and risk. Major new technology developments early in the program are avoided to reduce cost. Solar electric and nuclear electric propulsion, which are already under development, along with improved chemical propulsion can meet early transportation needs. Cargo and crew are separated to minimize crew risk and flight time. Cargo, supplies, and

exploration equipment travel slower on more efficient electric propulsion systems in advance of the crew, who use faster but less efficient chemical propulsion systems.

The IAA study proposes development first of a chemically propelled Deep Space Transportation Vehicle (DSTV) initially capable of carrying astronauts from low-Earth orbit to SEL2. The DSTV would be equally capable of carrying astronauts to lunar orbit if it is decided that lunar missions are an important step toward Mars. Later this vehicle could be upgraded for the much longer trips to NEOs and Mars. A separate electrically propelled Deep Space Cargo Vehicle (DSCV) would be developed to carry equipment and supplies to these same destinations.

The IAA study does not address Earth-to-orbit infrastructure requirements. This has been done by the TPS/AAS/ASE workshop that recommends the retirement of the Shuttle after the ISS has been completed. Both the IAA study and the TPS/AAS/ASE workshop recognize the potential of utilizing non-US launch systems to carry crew and cargo to low Earth orbit. In addition, new vehicles for Earth to orbit transportation, separating crew from cargo, would be developed that take into account crew and cargo Earth-to-orbit lift requirements for further exploration beyond Earth orbit.

The Space Station is not on the critical path in the IAA transportation architecture. Its high inclination orbit creates a severe penalty for Station-launched missions to the Moon and planets. However, the Space Station is required in order to study the effects of space travel on humans and to develop the technologies required for human support during long-term space flight.

Robots and Humans

So how do we implement such a plan, do we use human or robotic missions? The answer has always been: both. The robotic and human space exploration enterprises have co-existed and cooperated during the space program's entire history. The relevant question is whether any potential investigation requires using human explorers, with their associated cost. The argument often used to dismiss humans is that technology will produce a machine with sufficient intelligence and dexterity to render a human unnecessary. The time to develop such a machine, however, may be either unpredictable or too long to meet a reasonable schedule. No matter how clever or useful the robots we make, they will always be tools for enhancing human capabilities.

There is a role for both robots and humans. The strategy is to use robotic means for reconnaissance and scientific exploration to the full extent that robots can accomplish the desired goals. At the point when human explorers are sent, robotic missions can be used to establish local infrastructure before the arrival of humans. This is implemented using robotic outposts, which are later occupied and utilized by the human explorers. During human occupation, robots provide required support services and become sensory extensions and tools for human explorers.

In any case, science cost effectiveness is not a good exclusive metric for assessing human vs. robotic modes for scientific exploration because the decision to proceed with human exploration will not be made on scientific grounds alone. Human exploration of space is motivated by societal factors other than science. Nonetheless, when a decision is made to continue human exploration beyond Earth orbit, it will provide a tremendous opportunity for scientist-explorers and science should be a motivating force in defining human space exploration goals.

A space exploration enterprise that satisfies the public requires humans in space. In the minds of the public, robotic exploration is an extension of the human experience and a prelude to human

exploration itself. Robotic exploration is the method of choice for reconnaissance and scientific investigation to the extent that robots can accomplish the desired goals. However, only human explorers will ultimately fulfill the public's sense of destiny in space.

The Bottom Line

The human spaceflight program needs to be set on a new path that leads to a future that the public has been expecting for decades—a path that takes humans beyond Earth orbit to new, important destinations in the solar system.

WE NEED A NATIONAL VISION THAT SETS A DESTINATION FOR HUMAN EXPLORATION AND SYSTEMATICALLY PURSUES ITS FULFILLMENT WITH BOTH ROBOTIC AND HUMAN SPACEFLIGHT.

Drawing heavily on the IAA study, I believe this vision should involve:

1. The goal of establishing a permanent human presence in the solar system with the stated objective to establish human presence on Mars by the middle of this Century.
2. Recognition that exploration beyond Earth orbit is intrinsically global, and should involve cooperation with other space-faring nations.
3. A progressive, step-by-step approach for human exploration beyond Earth orbit that does not require an Apollo-like spending curve. Any requirements for increased spending can then be made incrementally on an annual basis.
4. A set of exciting and rewarding destinations in this step-by-step approach to Mars including the Sun-Earth Lagrangian Point L2, the Moon and Near-Earth Asteroids.
5. Re-invention of our Earth-to-orbit transportation and on-orbit infrastructure to support the goals for exploration beyond Earth orbit. The current Space Shuttle and International Space Station are not on that critical path other than research on human physiology in space.
6. Development of new in-space systems for transporting humans and cargo from low Earth orbit to deep space destinations. No large technological breakthroughs are necessary.
7. Continued use of robotic missions for scientific research and preparation for future human flights. Robotic precursor missions will be required to reduce the risk for human explorers and to provide on-site support for humans. Human explorers will be required for intensive field exploration and for in-space servicing of complex systems.

Drawing heavily from the TPS/AAS/ASE workshop, some near-term actions to enable this policy (specifically number 5 above) are:

1. The Shuttle should be retired after flying only those missions necessary to complete the International Space Station in favor of a simpler, safer and less costly system for transporting humans to and from Earth orbit.
2. Human transport to and from space, and within space, should be separated from related cargo transport. New Earth-to-orbit transportation systems for humans and cargo should be designed

and built, but not until the requirements for human exploration beyond Earth orbit are understood and can be accommodated.

3. The U.S. should carry out its obligations to its international partners to complete the International Space Station. The goals of the ISS should be refocused to those specific purposes required to enable human exploration beyond Earth orbit.

None of this will happen if we go on as we are. The national will to carry out a new option for space exploration already exists in the people of the United States. The nation has the necessary wealth. It is only a matter of leadership by the Administration and Congress. The architecture advocated here does not require an immediate large increase in the NASA budget. It does require a commitment to the resources required as the space program gradually and systematically increases in scale and scope, but not so much in any one year as would be required for an Apollo-like initiative.

WE NEED A COMMITMENT FROM THE ADMINISTRATION AND CONGRESS TO A
MANIFEST DESTINY FOR AMERICA IN SPACE.

Respectfully submitted,

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Study "The Next Steps in Exploring Deep Space"