**Remarks for U.S. Space Foundation**
**National Space Symposium**
**Colorado Springs, CO**

**Michael D. Griffin**
**Administrator,**
**National Aeronautics and Space Administration**

**6 April 2006**

When I became NASA's 11th Administrator a year ago, I had several goals that I wanted to accomplish by the end of my term of service. As I stated at my Senate confirmation hearing, my priorities in executing the duties of my office, consistent with the President's Vision for Space Exploration, are:

1. Flying the Shuttle as safely as possible until its retirement, not later than 2010.
2. Bringing a new Crew Exploration Vehicle into service as soon as possible after Shuttle retirement.
3. Developing a balanced overall program of science, exploration, and aeronautics at NASA, consistent with the redirection of the human spaceflight program to focus on exploration.
4. Completing the International Space Station in a manner consistent with our International partner commitments and the needs of human exploration.
5. Encouraging the pursuit of appropriate partnerships with the emerging commercial space sector.
6. Establishing a lunar return program having the maximum possible utility for later missions to Mars and other destinations.

Thanks to the hard work and technical excellence demonstrated by so many of you in this audience, we are well on the way to meeting these objectives. We've established an architecture for lunar return. We have a solid plan for completing ISS. We've received proposals from contractors in response to our request for proposals for the new Crew Exploration Vehicle. And with such achievements as the Cassini's discovery of icy geysers on Enceladus, the successful orbital insertion of Mars Reconnaissance Orbiter, and the launch of our 13th expeditionary crew to the International Space Station, 2006 is shaping up to be an eventful year.

But there are enormous challenges ahead, and a lot left to do to meet them. So, today, I'd like to talk with you about the larger rationale for our collective efforts. In short, why are we doing all this? How does space exploration serve the nation's essential interests?

When President Bush set a new course for America's space program two years ago, the White House issued a supporting document explaining why. Quoting from that policy, "The fundamental goal of this vision is to advance U.S. scientific, economic, and security interests through a robust space exploration program." I believe that this is exactly right, and that the benefits to be derived in these respects from such a program will extend well beyond our current imagination.

This last statement is out of character for an engineer, mathematician, or scientist, because it is neither provable nor refutable. But because a conjecture is scientifically unverifiable does not mean that it is not important.

Some of you will know of the considerable body of scientific work which has been accomplished over the last generation or so concerning the study of complex systems, and the so-called "emergent" properties of such systems. Complex systems have, among others, the property that their behavior, while of course consistent with the laws of physics, is not at all predictable, and can be

understood only after the fact, in a historical sense. In this sense, atoms and molecules, planets and stars and galaxies, flowers and humans and the course of history, are all emergent properties of the subatomic particles which comprise our universe. But no one can predict the existence of humans even given a complete description of the properties of such particles.

I believe that the benefits of exploration are, similarly, an emergent property of our inquisitive human behavior. We can study the great explorations of the past, and we can conclude that such ventures did in fact benefit the societies which sponsored them. But no society can reasonably predict that a given venture will prove to be worth its cost. Sponsorship of such a quest is always an act of faith, not an act of science.

In this regard I enjoy recalling that, as expressed in his instructions to the Lewis and Clark Expedition, President Jefferson's primary goals for that venture concerned the expedition's diplomatic mission to the Indian nations, the establishment of the United States as the sovereign power in the region, and the enhancement of the fur trade. Particularly important to the latter was the effort to find a route between the headwaters of the eastward-flowing Missouri River and the westward-flowing Columbia, thus (it was hoped) enabling a water-borne route for the fur trade between the east and west coasts. Who, today, believes that these purposes – though they were accomplished – constitute the most significant results to have come from the Lewis and Clark expedition?

I believe that the exploration and exploitation of the solar system will bring about similar unforeseen benefits, as the President has said, to America's scientific, economic, and national security interests. But our foreknowledge of these benefits will always be incomplete, and to envision them at all will require much deeper and more creative and synergistic thinking than that in which we usually indulge.

So let's examine these three factors in a bit more detail, and let's begin with science.

As I've said before, the *Vision for Space Exploration* re-establishes NASA as an exploration-driven, science-enabling agency. I have been frustrated for a very long time by the way that we in the larger space community have treated two of our major disciplines, science and human spaceflight. We act as if they were two circles on a Venn diagram that never intersect. To draw an analogy from C.P. Snow's memorable essay on the "two cultures" of science and literature, we've treated science and human spaceflight like two cultures foreign to each other.

We've learned from history that when cultures interact, sometimes one destroys the other. But many examples are to be found in which such interactions serve to enrich each culture. The latter example should be our model. Human spaceflight and space science at NASA should be thought of as intersecting circles on that Venn diagram. There will always be science at NASA that is unrelated to exploration. And the nation will always have certain objectives for human spaceflight that are unrelated to science. Yet there is a large area of potential overlap between these "two cultures", and we've not been very proactive in trying to define what the intersection between human exploration and science might be or should be, or in taking advantage of that synergy.

It is useful to recall that one of the greatest science-enabling endeavors of all time, the voyage 175 years ago of HMS *Beagle*, was in reality an exploration mission to chart the coast of South America. The twenty-two year old amateur naturalist Charles Darwin was recruited as a passenger for the voyage at the last moment, mainly to provide company for *Beagle's* aloof and moody captain.

I hope and believe that we've learned since then to include scientists as integral members of such ventures, not as an afterthought. Yet it has been obvious

to me, and I am sure to others, that many in the space science community consider a renewal of manned exploration beyond Earth orbit to be a threat, and primarily a budgetary threat, to science. I view it as a huge opportunity for science.

Recall how, 35 years ago this summer, NASA moved beyond the initial lunar missions, limited to relatively brief forays within sight of the lunar modules, to the bolder missions enabled by the lunar rover. Beginning with Apollo 15 astronauts David Scott and James Irwin, the rover allowed exploration for miles around Hadley Rille, with many deviations from the planned course when intriguing features were spotted. It is no accident that the Apollo program's most significant scientific returns came from the last three missions, all featuring the lunar rovers.

Now, the robotic science community has worked for years, at great expense and with considerable success, to develop relatively small-scale rovers. But we will need to develop a new generation of much larger human rovers for use on the moon and later on Mars. Such rovers can be adapted by the science community for missions to places well beyond anywhere we can send people anytime soon, or maybe ever. I ask you to imagine what might be accomplished on a remote solar system moon with a larger rover that can substitute robotic guidance for human, and can "think" its way out of tight spots.

During Apollo, astronauts had to assemble and deploy science instruments and packages. Consider what can be achieved this time around, when we will be able to automate these functions to give us no-assembly-required "suitcase science". With the advances we have seen and continue to see in miniaturization, sensitivity, and reduced power requirements, suitcase science will be much more powerful than anything we could have done even ten years ago. The Science Mission Directorate hopes to issue a request for studies on this kind of science by the end of the year, with all comers invited to present their most creative ideas.

Looking further out, as we consider the science that the Vision will enable, our aspirations should not be limited to the moon and Mars. As an example, recall that budgetary constraints have forced us to call a halt in planning for a Europa mission. But sometimes when you close one door, others open. Our focus on Europa was due in part to the National Academy's decadal survey, which recommended a "follow the water" planetary exploration strategy. We've recently discovered liquid water geysers on Saturn's moon Enceladus and, who knows? Maybe Europa is still the right target. But because Enceladus exists in a much lower radiation environment, it may be an easier target to explore. We shall see.

So, imagine what kinds of Europa or Titan or Enceladus missions we could plan in 2016, if we know that we will have the 100 metric ton Cargo Launch Vehicle available to put them out there. Maybe the 25 metric ton Crew Launch Vehicle would suffice for such missions. That's more capability than anyone was planning on having to low earth orbit until exploration came around. So, let's think creatively about what we could do with these launch vehicles, which would never be built to support robotic science missions alone.

My frustration with the way we have looked at science and exploration also extends to the unimaginative way we have treated the potential intersections of aeronautics, science and exploration, and Earth science and exploration. Again, rather than thinking outside the box, I challenge you to think inside the Venn diagram.

When we think about the impressive work our Earth Observation System is doing in obtaining data characterizing our home planet as a complete system, we need only to recognize that our solar system is filled with places that have active volcanoes, geysers, dynamic atmospheres, and potentially, water ice in great quantities, to realize the opportunities for synergies between Earth and planetary science. Indeed, both fields have already complemented each other. The late Carl

Sagan conducted his doctoral work on the subject of Venus' greenhouse effect, and provided insights that later helped us to understand the dynamics of climate change here on Earth. And two years ago, within 48 hours of the first Mars Exploration Rover's landing on Mars, we learned that atmospheric conditions were not as calculated. Based on their knowledge of the layering of Earth's atmosphere, NASA Earth scientists provided the information needed to adjust the landing sequence for the second rover. In so many ways, everything we do at NASA has the potential to benefit so many other things that we do, if only we will look, and think about what we see.

With respect to aeronautics, we missed a great opportunity with our recent Genesis and Stardust missions. We could have instrumented these spacecraft to gather information useful for aeronautical science at the highest mach numbers ever recorded during atmospheric entry. So think about the kinds of synergies that we can achieve between the science, aeronautics and exploration if we can obtain on our next Mars missions a better characterization of its atmosphere. Such information would allow us to design better entry vehicles to allow more landed mass at Mars, rather than having to use conservative Viking-era entry system designs. And, last summer, we realized that we knew very little about the effect of Shuttle tile gapfillers on the high-speed, rarified gas flow which characterizes a Shuttle reentry. How many aeronautics experiments could have been done over the years using the Shuttle as the world's highest performance aerodynamic vehicle, and how many have been?

These are all small things. Are there big payoffs that could result from a broader view? I'll bet there are, but I know that we don't yet know what they are, and we won't find them unless we look.

In addition to being science enabling, an exploration-driven program can be commercially enabling. We are beginning to see a glimmer of the robust economic activity that the Vision will bring about, in the plans and actions of the existing large aerospace companies, as well as in the emerging entrepreneurial companies. We are on the verge of incorporating the Solar System into mankind's economic sphere, in a way that will vastly expand the economic opportunities provided for all people.

Most obviously, the sheer tonnage that we will need to put in orbit invites and necessitates the development of a truly commercial space industry. There are many things needing to be done that NASA could purchase from an exploration-enabled space industry, including in-space fuel delivery, lunar resource prospecting, the development and maintenance of lunar surface systems and infrastructure such as lunar habitats, power and science facilities, surface mobility units, logistics and resupply, communications and navigation services, and *in situ* resource utilization equipment. Considering the example of in-space fuel delivery alone, and recognizing that fuel on orbit is valued at about $10 K per pound with today's technology, a more efficient commercially-operated fuel depot in low Earth orbit can service a multi-billion dollar market, one that will grow as long as we fly.

Our first step in spurring the development of a space economy is already underway, through our half-billion dollar Commercial Orbital Transportation Services demonstration, or COTS. This funding will go to the companies offering the best proposals for Earth-to-orbit space flight demonstrations of any of four crew and cargo delivery requirements for the International Space Station. We're encouraged to have received Phase One proposals for these demonstrations from a wide variety of organizations across the industry, and expect to announce the proposals selected to receive funded agreements this summer.

The economic opportunities we will create through the Vision will help our nation in many other ways. Our investment in exploration will be an investment in the highest of high-tech sectors, and will help maintain America's position as the preeminent technical nation on Earth. Space exploration is a lens that brings a focus to the development of key technologies in a way that simply would not occur without the "demand pull" that arises when trying to accomplish the near-impossible.

In my thinking on the overall relationship between government as a sponsor of frontier activities, and commercial industry as a provider of capability within the state of the art, I am once again drawn to the legacy of the Jefferson Administration, two hundred years ago.

On March 23, 1806 having exhausted the essential provisions of whiskey and tobacco, but still committed to their mission, Lewis and Clark abandoned their winter base camp on the Pacific Coast and began the long journey back to St. Louis, at that time the westernmost outpost of our young nation. That spring, Army Captain Zebulon Pike also returned to St. Louis, having concluded his voyage by keelboat to seek the headwaters of the Mississippi. Pike's exploration of Colorado, including his close passage to the magnificent peak west of this town that bears his name, began in July of that year. Many of you are familiar with these and similar milestones in our history. Less well remembered is the fact that, on 29 March 1806, Jefferson signed legislation authorizing a survey for America's first national road. This road from Cumberland to Wheeling was completed in 1818, and it opened a land that was beyond the western frontier at the time of Jefferson's birth to routine travel for citizens and commerce. Meanwhile, government exploration of the new frontier ranged outward to the Rockies. This was the proper division of responsibilities between government and the private

sector as our fledgling nation embraced the frontiers of its time, and it is the right approach today, as these frontiers expand into space.

Finally, I want to discuss perhaps the least-considered benefit of our civil space exploration program, and that is its contribution to national security. "Security" in the sense I wish to discuss it has three important components. In first place is the ability to prevail in any armed conflict which might reasonably be thrust upon us; the most expensive thing is the world is the second-best defense. I believe that we are in good shape on this point, but in any case this is not a NASA mission, and I will not comment further upon it, except to note the obvious – this is not an activity in which we wish to engage if it can possibly be avoided.

Because this first component of national security is so very depressing, a more enlightened approach is tempting. Thus, the second component of national security requires us to be so visibly strong that nobody else wants to fight, whether they are pleased with us or not. George Washington may have said it best when he observed, "To be prepared for war is one of the most effectual means of preserving peace." I've served my own time in pursuit of this objective, and I deeply honor all of you here who are engaged in the work of keeping our nation strong. And to the extent that our exploration program is helping to push the technological envelope, we at NASA can contribute to this aspect of national security.

But the most enlightened, yet least discussed, aspect of national security involves *being the kind of nation and, doing the kinds of things*, that inspire others to want to cooperate as allies and partners rather than to be adversaries. And in my opinion, this is NASA's greatest contribution to our nation's future in the world. At NASA, we beat swords into plowshares to fulfill one of the oldest, strongest, and most persistent dreams of mankind: to know and experience what lies beyond the horizon. We have reached the point where there are no more horizons on

Earth, and people everywhere know it. We see, repeatedly, that as nations and societies attain the technical capability to attempt spaceflight, first robotic and then human, they do so. And they will continue to do so. They don't go because we did, and they won't stop if we stop. They go because that is what people do, when they can.

Today, and yet not for much longer, America's ability to lead a robust program of human and robotic exploration sets us above and apart from all others. It offers the perfect venue for leadership in an alliance of great nations, and provides the perfect opportunity to bind others to us as partners in the pursuit of common dreams. And if we are a nation joined with others in pursuit of such goals, all will be less likely to pursue conflict in other arenas. No enterprise of national scale offers a more visibly attractive and interesting collaboration than does space exploration. This great enterprise threatens no one while enriching everyone. It is about the lure of the frontier; leaders occupy and extend the frontiers of their times. Indeed, it is this property of great nations that by itself and in the light of history, defines the great nations of whatever period.

This observation has a corollary. Imagine if you will a world of some future time – whether it be 2020 or 2040 or whenever – when some other nations or alliances are capable of reaching and exploring the moon, or voyaging to Mars, and the United States cannot and does not. Is it even conceivable that in such a world America would still be regarded as a leader among nations, never mind *the* leader? And if not, what might be the consequences of such a shift in thought upon the global balance of economic and strategic power? Are we willing to accept those consequences? In the end, these are the considerations at stake when we decide, as Americans, upon the goals we set for, and the resources we allocate to, our civil space program. Humans will go to Moon and Mars; the only questions are which humans, what values they will hold, what languages they will speak.

We here in America today have it uniquely within our power to determine the answers to all of these questions; we are the last generation of Americans that will have that opportunity. And I, for one, do not believe that the answers should depend in even the slightest degree upon which Administration is in office, or upon which Party controls the Congress.

I will conclude with that thought. Thank you again for the opportunity to address the Symposium, and for your hospitality today. And again, I extend my heartfelt thanks to all of you for your commitment to expanding our horizons.