

**46<sup>th</sup> Robert H. Goddard Memorial Symposium  
Greenbelt, Maryland  
March 6, 2008  
Keynote Address**

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Two years ago this month I spoke at the 44<sup>th</sup> Goddard Memorial Symposium, and I appreciate the opportunity to speak again this year as NASA's 50<sup>th</sup> anniversary approaches. We are living through a period of great change in the world, and conditions seem to fluctuate dramatically in the course of a few years. The enterprise that Robert Goddard launched with his rocket eighty-two years ago this month necessarily spans lifetimes. In the face of such rapid and momentous change, what can we say of the likely fate of his vision?

Just yesterday Mike Griffin told us his favorite Goddard quote: "It is difficult to say what is impossible," said Goddard, "for the dream of yesterday is the hope of today and the reality of tomorrow." Mike also said it is in his nature to be a realist. I'm a realist too, and I very much appreciate the straightforward way Mike has dealt with the difficult issues that cross his desk every day. He deals with them honestly, openly, and brings to bear an unusually deep technical and management experience. Although Mike likes to "tell it like it is," which suggests unpleasant facts of life, the text of his message yesterday tells me that he thinks the reality of today's space program, both science and exploration, is on the whole a positive one. I agree with that assessment, and here at the outset of my own remarks I would like to join Mike in congratulating and thanking the large community of people in the most diverse fields of work who have brought America's space enterprise to this point. Today's NASA and today's demonstrated successes throughout the Solar System and back to the very threshold of time itself stand as an inspiration to the world. Dr. Goddard would have been proud, and I am proud too to be associated even remotely with this great accomplishment and the people like yourselves who achieved it.

Today I too want to talk about the hope of today and the reality of tomorrow. If you heard or read my remarks at the 44<sup>th</sup> Goddard Symposium, you know that I believe the choices of space policy at the strategic level are highly constrained by physical and economic realities. The stars, for example, are out of reach for the foreseeable future, and we will have to learn about them through their radiation from the distant past. Earth will always be the primary but not the exclusive focus of space applications because Earth is where the people are, and also the possibly unique and fragile surface phenomenon we call the biosphere. The sun is certainly important for us, but we do not have to travel there to reap its benefits. The Moon is the most massive near-Earth object – massive enough to have a useful surface gravity, but substantially out of Earth's gravity well and therefore of great interest to deep space operations. I think it is inevitable that the Moon will eventually become a space station and a source of mass for space applications. Between Earth and Moon there are interesting places: low Earth orbits, geostationary orbits, Lagrange points. Whatever operations we perform in these places have to be conducted from platforms we construct and launch from Earth or Moon. With respect to

human presence, all the other objects trapped by sun's gravity, including Mars, are necessarily in a different category because of their remoteness, and yet they are close enough for us to touch, and we are already doing so with robotic missions.

Space exploration, if it proceeds at all, will proceed from Earth outward. And so it has. According to a nice review by Ralph McNutt, Jr. in a recent issue of the APL Technical Digest, "less than 3% of all space missions launched through 2004 had gone beyond Earth orbit." There have been nearly 4,000 launches since 1957, and fewer than 150 beyond Earth orbit. Some commentators are depressed by these figures, suggesting that we are somehow in a rut "just going around and around the Earth – how boring." The reality of today is that those launches are occurring because we have found commercially viable uses of near-Earth space, and nothing could be better for the long term viability of the entire space enterprise. Earth orbit is where you expect the overwhelming majority of launches to lead because Earth is by far the most interesting planet in our system. Humanity has succeeded in incorporating Low and Geostationary Earth orbit in its economic sphere.

The one big question any vision of space exploration must answer is "Are we going to do it at all?" As I put it in my speech two years ago, "Questions about the vision boil down to whether we want to incorporate the Solar System in our economic sphere, or not." If we are serious about this, then our objective must be more than a disconnected series of missions, each conducted at huge expense and risk, and none building a lasting infrastructure to reduce the expense and risk of future operations. If we are serious, we will build capability, not just on the ground but in space. And our objective must be to make the use of space for human purposes a routine function.

Just last month a group of distinguished stakeholders in the space enterprise participated in a Workshop at Stanford University and issued a six-point communiqué. Two points were process-oriented and one was budget-oriented (it was oriented pointing up). The remaining three points contain substantive policy statements that need to be taken seriously. (I am quoting from the communiqué.)

- "It is time to go beyond LEO with people as explorers. The purpose of sustained human exploration is to go to Mars and beyond. The significance of the Moon and other intermediate destinations is to serve as steppingstones on the path to that goal."
- "Human space exploration is undertaken to serve national and international interests. It provides important opportunities to advance science, but science is not the primary motivation."
- "Sustained human exploration requires enhanced international collaboration and offers the United States an opportunity for global leadership."

I agree completely with the third point about international collaboration and the opportunity for United States leadership, but there are phrases in the other points that make me uneasy. Yes, it is time to go beyond LEO with people as explorers. But no, the purpose of sustained human exploration is not "to go to Mars and beyond." The purpose of sustained human exploration is, as the second point states "to serve national and international interests."

And I think of those interests as much broader than simply going somewhere and coming back. Our current space exploration policy says "The fundamental goal of this vision is to advance U.S. scientific, security, and economic interests through a robust space exploration program." Exploration that is not in support of something else strikes me as somehow selfish and unsatisfying, and not consistent with the fact that we are using public funds for this enterprise, no matter how small a fraction of the total budget they may be.

This sense of something missing is reinforced in the last sentence of the first point. While "the significance of the Moon and other intermediate destinations" is to some extent "to serve as steppingstones to that goal," that is not the whole story, and the part that is missing is the lesson of all the activity in Low Earth Orbit. What are we going to do with those stepping stones once we have planted flags on Mars and beyond? I read in these points a narrowing, not an expansion, of the vision of space exploration. They ignore the very likely possibility that operations on the Moon "and other intermediate destinations" will "serve national and international interests" other than science, but including science as an important objective. Our current experience with space, dramatically portrayed by the existence today of a commercial space industry, is that it is useful in ways not imagined even by the early visionaries.

To me this is an important point. Exploration by a few is not the grandest achievement. Occupation by many is grander. Not necessarily in the sense of permanent human occupation, but in the sense of routine access to resources. The future I look for in the human space enterprise is one in which exploration has long since ceased and our successors reap the benefits of the new territories.

You might say "well, of course such economically beneficial occupation would naturally occur if the exploration phase discovered something of commercial value." But that's not the way it works. If the architecture of the exploration phase is not crafted with sustainability in mind, we will look back on a century or more of huge expenditures with nothing more to show for them than a litter of ritual monuments scattered across the planets and their moons. Initially, and for a long time to come, science may indeed be the primary beneficiary of the exploration phase, and it ought to be a primary motivator in the selection of destinations. And a manifesto on space exploration ought to say so.

It seems to me that few people have actually read the official space exploration policy summary, published and publicized as a fact sheet shortly after President Bush's speech on the subject in January 2004. The speech is an important policy document, but it is not THE policy document. I've already read you the Goal statement from the Goal and Objectives section. Here are the objectives. There are four of them: "In support of this goal, the United States will:

- Implement a sustained and affordable human and robotic program to explore the solar system and beyond;
- Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and

- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests."

In the interest of bringing the actual policy to the attention of a wider audience, I will append it to the published version of my remarks today. It is also available on the OSTP website, but as I discovered in preparing this talk, it has been difficult to identify among the other documents. Among its important features are an explicit reference to robotic exploration, requirements for sustainability and affordability, a consistent linking of Mars with "other destinations," and a mandate to promote commercial as well as international participation "to further U.S. scientific, security, and economic interests." Exploration is not a goal in itself, but an activity to support other important objectives.

I confess to being uncomfortable also with the great enthusiasm a number of space advocates show for getting on with a trip to Mars. We do not at this time know how to send humans to Mars and bring them back safely, and the enthusiastic and detailed concepts that are widely discussed do not dwell on the difficulties. The current space vision sets no date on a return to Mars, although it does acknowledge Mars as an eventual destination for human presence. It is a logical destination, but much of what I read about how and when we can get there is unrealistic. The current policy emphasizes a step-by-step approach, and advances the concept that deep space exploration is necessarily "a journey, not a race."

As we think about the future of the space exploration enterprise, we need to keep in mind how unusual its early history was. I think we are psychologically conditioned to want to model national policy on the highly successful Apollo program, starting with its huge budget. But the Apollo program was a unique response to a singular set of events at the height of the cold war. I cannot prove it except by pointing to the history, but it seems that the pace and scale of the Apollo program was unsustainable. In any case it was not sustained, and its rapid demise created serious long term difficulties for NASA management. We definitely need stable budgets that grow with inflation in order to avoid costly interruptions of multi-year programs and construction schedules.

It was not only the Apollo budget that was unsustainable. The entire motivation for Apollo was a product of a unique time. It was magnificent, but utterly anomalous, and if we want to sustain the expansion of human activity into space we have to operate in a more normal way of doing business. I recently read some essays that Wernher von Braun wrote in the early 1950's about space exploration – the Collier Magazine series – and was impressed by how carefully he had thought through the details of a step-by-step exploration of the Solar System. In some ways the Apollo program that began a decade later was even more impressive than von Braun's vision, but in terms of scope and lasting impact it fell far short. I came away with the impression that if we had followed the methodical approach von Braun advocated fifty-five years ago, and Apollo had never happened, our space program would be no less impressive today, and its momentum might be greater.

In the short run, the single most important next step for human space exploration is the termination of the shuttle program at the end of 2010. The shuttle technology is too old, both in concept and in physical age, to risk flying any more than is absolutely required to perform essential work on the space station and on the Hubble telescope platform. A decision to keep the

shuttles flying is a decision to postpone indefinitely a new and even more exciting phase of space exploration.

The good news for space exploration is that a very large number of Americans want to pursue it, and identify strongly with the NASA image of accomplishment in the most difficult technical fields. Certainly the Apollo program taught us just how resourceful and courageous men and women could be when faced with dauntingly complex and risky tasks. It brought us together in support of technical prowess through science and engineering, and got us started on a path to the future.

I tried to interpret the significance of the Apollo program for the path forward on the occasion of the 35<sup>th</sup> anniversary of Apollo 11, and in looking over the short speech I gave then I thought it would be appropriate for this occasion too. Here it is in its entirety:

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"It is a great privilege for me to participate in this important commemoration. I am going to provide a very long view of the significance of Apollo 11.

More than fifteen thousand years ago, as the glaciers of the last ice age receded, our ancestors moved quickly to reclaim the newly unfrozen territory. What motivated them to probe the limits of their livable space? What attracted them to the margins of the icy wasteland? This was well before any dream of agriculture, of city-states, or of forms of government that would unleash the power of unified action by a people. But there must have been men and women whose inner vision pressed them forward. And among them there must have been a few who studied the risks, and prepared themselves for adventure, and returned with a message of hope. It would have been their example, the obvious fact of their survival and the precautions that made it possible, that encouraged their clans to follow after them and create a new way of life in a new land.

We have only our imagination to reconstruct the distant past. That and our experience with the present. The widely known history of the Apollo program has become a paradigm of human will in the age of technology. The Apollo 11 mission is evidence of the power of an idea coupled with technical know-how, supported by a resourceful people. The dramatic culmination of the Apollo program in the unique event we are celebrating tonight, the first footsteps on the moon by Armstrong and Aldrin (with Collins floating above), is a symbol of the capacity of the human race to move beyond its apparent limits and break new ground. Everyone who helped to make this happen – the people at NASA, the teams and crews of astronauts, their families, legislators, even auditors and budget officials – deserve our praise and our thanks for showing us what we can do as a people if we put our minds to it.

Singular events are like opening nights – they attract plenty of attention in their own time, but their significance can only be judged by what comes afterward. Neil Armstrong's words "*... one giant leap for mankind*" suggest something more than the culmination of a tremendous effort. They evoke the metaphor of a journey, where great things are accomplished by individual human beings, one small step at a time. Immediately after Apollo 11 came six more lunar missions, five of them reaching the surface, the final one in December 1972 carrying geologist

Harrison Schmitt, the first scientist-astronaut and the last – I should say the most recent – of the 12 men who have left their footprints in the lunar dust. But these were all part of the beginning phase of exploration and discovery and demonstration of what humans could do beyond the surface of the Earth. The true significance of the Apollo program still lies ahead.

Now that the beginnings are behind us, we are accumulating experience in space-based operations, both human and robotic. We are learning difficult lessons about managing complex space programs in a sustained mode over many years and across different Administrations. We are facing up to the realities of cost and risk, and to the challenge of responding to our society's remarkable desire to lead in space. Our next efforts will be judged by their impact on the future – and this is an important thing to keep in mind. Will future generations thank us for breaking down the barriers to space, or will they regret that our actions were too short-sighted to be of much help in the long run? We are the inheritors of Apollo, and our actions are part of a long chain of events that lead into a future in which the region of space accessible to us will be included in humanity's sphere of activity.

This is what the vision means that is crystallized in President Bush's January address. We have embarked on a long journey. We have an obligation to the future to invest our resources wisely to reduce the cost and risk of operations in space, step by step. We are not racing for transient glory, or even to stake a claim to territory, but to enable the use of space for all future generations. Thirty five years ago our nation broke the ground for the way to space, and now we will broaden that way, one step, one mission, at a time, and render it accessible to human use.

We only have our imagination to foresee the distant future, but we can picture others looking back and guessing at the logic of these first ventures into space. Our wish today is that our followers would say about us, a thousand years from now, "They opened space for us, and then won it, step by step over many years, to make it productive for the future." Our successors may not remember all the steps along the way, but they will certainly remember that first small step of Apollo 11 that showed it could be done. The Apollo program is a legacy, not to us, but to the future, and it is up to us to increase its value and pass it on.