What is the Value of Space Exploration?

A Symposium

Sponsored by the

Mission From Planet Earth Study Office, Office of Space Science

NASA Headquarters

and the

University of Maryland at College Park

July 18-19, 1994
National Geographic Society
Washington, D.C.

"Space exploration has become an integral part of our national character, capturing the spirit of optimism and adventure that has defined this country from its beginnings." *National Apollo Anniversary Observance, A Proclamation by the President of the United States of America, July 19, 1994*

"There is frequently a tendency to generalize 'exploration' into a universal expression of the human gene, to equate 'discovery' with 'curiosity' or with 'human spirit.' That it is, but not uniquely…. Exploration…appears to be a cultural invention…. Its vitality as an institution depends on the vitality of the whole civilization with which it interacts. To survey the motives for exploration is to survey all the motives that animate a thriving civilization….

"The point is that exploration must share and participate in a moral universe with its civilization. This is not a question of purpose so much as legitimacy. In this sense exploration is a shared act of faith. It reinforces and reinterprets in updated garb myths, beliefs, and archetypes basic to its originating civilization." *Stephen Pyne, "The Third Great Age of Discovery,"* The Scientific and Historical Rationales for Solar System Exploration*, Space Policy Institute, George Washington University, Washington, D.C., 1988*

TABLE OF CONTENTS

Preface

What value have we gleaned from past exploration initiatives, and what is the real value of space exploration in the post-Cold War world? Does it enrich human existence? Fulfill a cultural imperative? Offer critical additions to knowledge? Enhance economic strength and technological competitiveness? Improve international relations? Advance education? Improve the quality of life? Feed spiritual needs? If so, why, and how? If not, why not?

With these kinds of questions in mind, NASA's Mission From Planet Earth Study Office conceived a symposium to address the question, "What is the Value of Space Exploration?" This event took place July 18-19, 1994, in Washington, D.C. Today, without a motive so compelling as the Cold-War competition that propelled the civil space program from its beginnings into the 1980s, space exploration has no clearly defined purpose, critics say. Thus, the purpose of the symposium was to stimulate public discussion about the scientific, economic, and cultural value of space exploration in the post-Cold War world and expand the community of people participating in this discussion.

Given that the symposium took place during the week of the 25th anniversary of the Apollo 11 lunar landing, speakers reflected on how the context for the civil space program has changed since the 1960s. Apollo, a product of geopolitical competition, turned out to be a hard act to follow. The space program has produced many practical benefits, but in the post-Cold War world of intense geoeconomic competition, spinoffs are not a sufficient justification for space spending. As one speaker noted, NASA now needs to establish goals and objectives that are economically relevant. Another asserted that while fear drove the space program during the Cold War, today's relevant motive for space exploration might be love: "we have a lot of things that we can do out of love…we can love the planet, we can love exploration, we can love the adventure, we can love leaving knowledge to our descendants, and we need to use that word."

Most speakers agreed that the economic value of space exploration does not lend itself to quantitative assessment. Tallies of benefits over the years since Apollo have not created a compelling rationale for a federally-funded space exploration program. Several speakers touched on the idea that what space exploration is all about is the realization of human potential. What's currently needed, some noted, is a greater focus on the intangible benefits of space exploration. One enthused, for example, about the tremendous aesthetic value of images of other worlds. Others said that space exploration must be a multicultural, multinational, inclusive enterprise in the post-Cold War world. Another asserted that civil space exploration is necessary to effect a successful defense conversion in the United States and Russia.

NASA needs bold human exploration missions, beyond Earth orbit, to provide focus and inspiration to scientific research and technology development, others said. In the end, as the following summary of the symposium's proceedings reveals, no clear-cut answers to the question, "What is the value of space exploration?," materialized out of two days of vigorous discussion. One speaker even suggested that the question cannot be answered. But others seemed to indicate that advocates and skeptics should continue to try….

"What is the Value of Space Exploration?"
July 18-19, 1994
Gilbert H. Grosvenor Auditorium, National Geographic Society, Washington. D.C.

Monday July 18

9:00am	**Welcome**	Gilbert M. Grosvenor—*President and Chairman of the Board*, National Geographic Society
	Introduction	Robert McC. Adams—*Symposium Chairman and Secretary*, Smithsonian Institution
9:30am	**Remarks**	William Kirwan—*President*, Univ. Maryland at College Park
		M.R.C. Greenwood—*Associate Director for Science*, White House Office of Science and Technology Policy
10:00am	**Opening Keynote**	Carl Sagan—Cornell University

11 :00am **Session 1:** Scientific Value
Chair Roald Sagdeev—*Distinguished Professor of Physics*, Univ. Maryland
Richard Garwin—*IBM Fellow Emeritus*, Thomas J. Watson Research Center
Stephen Jay Gould—*Dept. of Earth and Planetary Sciences*, Harvard University

2:00pm **Session 2:** Economic Value, Part I
Chair: Molly K. Macauley—*Senior Fellow*, Resources for the Future
W. Bowman Cutter—*Deputy Assistant to the President for Economic Policy*
Daniel F. Button, Jr.—*President*, Council on Competitiveness

3:30pm **Session 3:** Cultural Value
Chair: Patricia Nelson Limerick—*Department of History*, Univ. Colorado
Valerie Neal—*Department of Space History*, National Air and Space Museum
Timothy Ferris—*Department of Journalism*, Univ. California, Berkeley

Tuesday July 19

9:00am **Session 4:** Economic Value, Part II
Chair: Matthew M. Matsunaga—*Hawaii State Senator*
Jeffrey Mamber—Managing Director, *American Operations*, NPO Energia
Frederick S. Humphries—President, *Florida A&M University*

10:30am **Session 5:** Education and Scientific Literacy
Chair: James Trefil—*Robinson Professor of Physics*, George Mason University
Charles F. Golden, Jr.—*Deputy Commandant of Midshipmen*, U.S. Naval Academy
Priscilla Cortelyou Little—*Senior Program Associate*, AAUW Educational Foundation

1:30pm **Session 6:** Scientific and Cultural Value
Chair: Joanne Gabrynowicz—*Department of Space Studies*, Univ. North Dakota
Paul Gray—*Director of Environment and Marine Science*, European Commission
Majel Barrett Roddenberry
John Calvin Batchelor—*Author*

4:00pm **Closing Keynote Address**
Daniel S. Goldin—*NASA Administrator*

Monday July 18

Welcome
Gilbert M. Grosvenor
President and Chairman
National Geographic Society

Introduction
Robert McC. Adams
(Symposium Chairman)
Secretary
Smithsonian Institution

Remarks
William Kirwan
President
University of Maryland at College Park

M.R.C Greenwood
Associate Director for Science
White House Office of Science and Technology Policy

"A fundamental difficulty that we face" in attempting to answer the question, "What is the Value of Space Exploration?", said *Symposium Chairman* **Robert McC. Adams**, is the tendency "to talk past one another…. Coming away from this symposium…we all [should] have arrived at a clearer understanding of the question's breadth and complexity."

"This symposium is about the rationale for space exploration," Adams continued, "the ways in which it has changed since the Apollo days…and the ways it will continue to change. It is an attempt to stimulate public discussion and public awareness of how the context of public discussion is itself changing as the nation confronts new domestic and international realities…. Through discussion, we hope to come closer to an understanding of what degree of consensus exists on what should…be the scale of space exploration efforts and the balance within those efforts of short- and long-term goals."

One view is that, in the post-Cold War world, space exploration is an unaffordable indulgence of a technological elite…. Another view is that the human exploration and settlement of other worlds and the search for life elsewhere will contribute to the development of "an emerging cosmic perspective." This symposium will bring different perspectives into focus on the question at hand.

White House official **M.R.C. Greenwood**, *Associate Director for Science at the Office of Science and Technology Policy*, delineated "the values we can derive from space exploration." They include "looking outward in exploration of new worlds; looking inward at our own world for discoveries vital to our environmental security; and finding a way to live and work together in space." International cooperation is playing an expanding role in space activities as well, and "the results… will lead to greater national security and improve international science for generations to come."

Another way in which space exploration provides value, Greenwood said, is that it "has contributed perhaps more than any other scientific venture to an increased level of scientific curiosity throughout society. This is a measure the Administration is dedicated to improving, since public understanding of space exploration, and of science and technology in general, will ensure that the public understands the value of investing in knowledge for the future."

"We are…probing the expanses of space in new ways, seeing our universe as we never have before…provoking new ideas and new theories about our physical reality" that add to the canon of science, she continued; "they cause us to revise our notions of how life began, and they provide new innovations that contribute to the evolution of society, as well as providing the intellectual challenges that draw talented people to science and mathematics…."

"Space exploration can be seen as the modern-day continuation of the 'Age of Exploration and Discovery' that began to transform our world some 500 years ago," Greenwood concluded. "And it may not be reaching too far to suggest that its lineage is part of an ancient heritage of the human race…. [I]t may well be that deep in the human psyche and perhaps in our genes is the drive to explore and discover the 'new'—and for reasons that transcend the more observable economic, political, and religious motivations."

Opening Keynote Address

Carl Sagan
Laboratory for Radiophysics and Space Science
Cornell University

The space community faces a dilemma today, said Astronomer Carl Sagan in his opening address— some people feel the emotional appeal of space exploration, and some do not. Can advocates make a case for space exploration that is meaningful both to those who feel this appeal and to those who do not?

"For 99.9 percent of our tenure 'til now on Earth," [humans were] "wanderers…hunter- gatherers…. It must be that the hunter-gatherer lifestyle is built into us," he said in trying to explain that appeal. "It's in some people more than others, it's hard to express in this citified and highly populated age, but it must be there."

"The only obvious vent for the exploratory urge is the exploration of other worlds." However, since the end of the Apollo program, NASA's missions "have become… unexciting, fundamentally dull. No risks are taken of the exploratory sort…."

"Apollo 11 was exploration." Orbiting Earth in the Space Shuttle "is not exploration. [It is a] dreary bus ride over the same dull route, and…this fact," he said, is responsible for lagging public interest in NASA. Attempting to make human missions in space risk-free might be counter-productive; "the hazard is an inseparable component of the glory."

Sagan made the case for space exploration in the robotic mode: robotic planetary missions account for "dazzling" yields of data that are of great value in comparing our planet with others. To study fundamental issues in physics and astronomy, instruments in Earth orbit can best do the job. Nonetheless, human space flight may still be of some value."

"…[T]here is a desperate need for a positive vision of the future. We need it for our children," he said. "What organization in the U.S. Government, in the natural course of doing business, offers a positive view of the future? What agency is future-oriented by its very nature? What agency excites the visions of young people, makes their hearts beat a little faster, makes them imagine doing exciting exploratory things when they grow up? As far as I can tell, there's only one such organization, and that's NASA," he said, asserting that the agency could be more effective in performing this "very important social function" if it "did more exploration."

The Apollo program was a product of the East-West nuclear arms race. But "there were side effects…. There was the stunning view of the Earth, fragile against the immense black backdrop of space, no national boundaries visible, all of us in the same boat," an image that motivated many people to dedicate themselves to environmental protection.

The United States "achieved greatness" through Apollo, but since then, the space program has been without a driving mission. In the '70s, the Nixon Administration considered Mars exploration as a goal, but the cost of pursuing that goal was deemed unacceptable. In the '80s, NASA promoted the international space station program as "the next logical step," and it continues to do so today. However this goal only makes sense in the context of planning for the human exploration of other worlds. NASA's current program of human space flight is "a capability without a mission…."

"Is it unworthy to stay at home? Or is it unworthy to go [into space], with all the suffering that we have here on Earth? Or have I posed a false dichotomy?" he asked. "Isn't it possible to make a better life for everyone here on Earth…and at the same time to reach for the planets and the stars? … [T]he cost of even a very ambitious program of human space flight is not that much…."

"What should the goal be?," he continued. "The scientific lure of Mars…is very strong," but not strong enough to justify human space flight. "What is human space flight for? What is a space station for? … [W]hat do we get back? Spinoff arguments are very dangerous… [they] can't justify the program." The government could invest money directly in technology development. The same reasoning applies to educational benefits. The need to maintain our aerospace industry is important, but it is not a strong enough argument to justify a program of human space flight. The same applies to promoting international cooperation.

However, one argument might be adequate to justify human exploration of the planets, Sagan proposed: with

a 1-in-1,000 chance that an object (comet or asteroid) 1.5 km. in diameter could collide with Earth within the next 100 years, “a significant human presence in the inner solar system beyond the Earth is mandated…. It is safer for the human species if we’re on many worlds than if we’re on only one….” The present understanding is that a 1.5-km. object hitting Earth would release the energy equivalent to 100,000 megatons of TNT, likely killing more than a billion people. What we need to do is to inventory objects that could come close enough to Earth to be a threat and develop technology to deflect them.

Session 1:
What is the Scientific Value of Space Exploration?

Roald Sagdeev (Session Chair)
Distinguished Professor of Physics
University of Maryland at College Park

Richard L. Garwin
IBM Fellow Emeritus
Thomas J. Watson Research Center

Stephen Jay Gould
Department of Earth and Planetary Sciences
Harvard University

Although historically the primary motivation for exploration has not been discovery but the desire for dominion, a winning position in a global power struggle, science often has benefited as a side effect, said *University of Maryland Physics Professor* **Roald Sagdeev** in opening Session 1.

The geopolitical power struggle that initiated East-West rivalry in space exploration promoted "tremendous development in rocketry" in the Soviet Union, and the science community ultimately was able to take advantage of this development, said Sagdeev. Because scientists miscalculated weight requirements for the nuclear warhead to be launched on the first Soviet intercontinental ballistic missile, they asked ICBM developers for 8-10 times more throw weight than they actually needed.

Thus, by the mid-1950s, the Soviet Union had produced a "tremendously powerful" launcher that Soviet space visionary Sergei Korolev realized could be used to launch a satellite into space—and that's how the Soviets began "to build tremendous momentum" in space flight, he said. "Science started to benefit from space launches. Not immediately—the very first few Soviet Sputniks were essentially empty of scientific instruments." However the government kept promising, and finally, in the spring of 1958, a Sputnik was launched with cosmic ray experiments aboard.

Overall, Soviet science was "rather a junior partner" in the space race, Sagdeev said, but scientists nevertheless felt they were providing an essential component and "much of the excitement" in the space program. By the time of the Apollo 11 lunar landing in 1969, many Soviets saw the U.S. accomplishment "not as a sign of their national humiliation but as a symbol of universal unification, grand reconciliation, long before the Cold War was ended…."

In the end, the answer to the question, "What is the scientific value of space exploration?" is not "one big answer [but] many smaller answers…." The space science community generally is "not in a position to find a balanced justification for tremendous space budgets…. If we are to continue the steps which were started by [space exploration pioneers Konstantin] Tsiolkovsky and [Robert] Goddard, by [Yuri] Gagarin and Neil Armstrong, we need something else besides science. We need determination, we need the feeling of a mission …we need some kind of faith" in what we're doing, he said. "Without such an inner urge, we would be unable to take important next steps."

In line with Sagdeev's suggestion, *IBM Fellow Emeritus* **Richard L. Garwin** said that we have to invest in science with some faith that, in the long term, it will pay off, because returns on such investments are not predictable or measurable.

"Where does science in general, and space exploration in particular, fit in the modern world of needs and opportunities? My own view of science is a utilitarian one, in which society as a whole advances by supporting science effectively in order to obtain the long-term benefits. But this by no means limits the support of science to those fields and projects that give immediate benefit, since some of the most important returns to… society…come from abstract or seemingly inapplicable science," Garwin said.

"You don't have to go on a sailing ship or into space to explore, you don't have to visit for the first time, only with insight," said Garwin, noting that he considers scientists to be true explorers. "Not only don't we know all of the answers, but we don't even know some of the questions…. We can ill afford to limit our knowledge too narrowly."

"My direct experience with government and industry shows the very substantial degree to which underinvestment takes place, simply because there's no mechanism for the investor to capture the return on the investment," he said. In some cases where the benefit of an investment can be shown, "there may be benefits to

others, freeloaders, which typically although not logically appears to reduce the incentive…to make the investment…."

Negative externalities, such as environmental pollution, routinely factor into investment decisions. "But benefits to others are major positive externalities that have to be taken into account" as well. Yet another hindrance to investment in science for long-term gain is managerial "actions that are self-preserving, self-advancing, and do not serve the broader goals."

Echoing Carl Sagan, Garwin rejected the "spinoff" justification for investments in space exploration. Direct investment in technology development would be more sensible, he said, noting with his tongue in his cheek that there are spinoff benefits to be reaped from investments in "Mafia activities…hiring accountants [and] lawyers, buying cars and public officials."

"There is a good future for space exploration, but in its contributions to…science, the cost must be commensurate with the returns, according to the standards for Earth-based science," Garwin said, but at the same time he dismissed "arguments that would characterize wise investment strategy as a blind and cowardly avoidance of technological risk…. NASA…should indeed accept prudent technological risk in return for the great benefits of using modern technology…." NASA should adopt a "results-oriented approach" for the Mission From Planet Earth.

NASA's space station program, he offered, does not appear to be as results-oriented as it should be. The primary purpose of a space station should be to prepare for long-duration human missions in space. "But the [current space station] program does not contain the essentials for such preparation…. A program that takes seriously a potential…opportunity for people to live or travel in space for a long time" ought to provide for artificial gravity. "Space exploration will take place more and more with instruments as human capabilities are more and more potentiated," he also observed, adding that "the United States would have benefited more from the space program had greater emphasis been placed on instrumentation and robotics."

"I fear that we are making major program commitments, especially for the space station, which have the potential to eat our NASA lunch. Like the savings and loan disaster, a large and visible program can be too big to be allowed to fail, and propping it up…can consume the real science program on which future benefits depend," he concluded.

"The thrill, the wonder, the aesthetic value" of seeing Earth, and other planets, from space has made solar system exploration well worth the effort, said *Natural Historian* **Stephen Jay Gould**.

"Those first photographs of our entire planet, the very notion of an Earthrise over the moon, or the concept of a crescent Earth rising over the moon," he said, provided "a thrill…which is still with me."

"But while there's thrill, there's also philosophy, and there's also scientific advance. After all, futurist Buckminster Fuller's famous metaphor of Spaceship Earth… did fuel the environmentalism of the 1970s and onward. I don't mean to exaggerate the power of an icon, but I wouldn't underplay it either," Gould said. "This is a philosophically and intellectually transforming icon as well as an aesthetic thrill."

"Knowledge, I remind you, has its own aesthetic frisson," he continued. "Think, for example, of the back side of the moon. Many of us grew up not knowing what it looked like." But now, thanks to spacecraft, "that most invisible yet nearest bit of cosmic wonder is put before us so that the increment of knowledge also has its aesthetic side."

"Of course the greatest thrill of all, the greatest pure joy of recent history, has to be…the first human landing on the moon…. For that hour or so, everybody put aside their immediate concerns and gave rapt attention to an omnipresent object otherwise almost always ignored," he said. "For a sublime moment, we all cared passionately about the moon."

"I approach space from an odd professional perspective," Gould explained, that of a natural historian "interested in the rules of diversity and individuality of the objects of nature…in the pathways of history and the contingency of its results." The space program has thrilled him as a natural historian, he said, by revealing "planets as persons" and Mars as a possible home to life.

His early thinking about planets was simplistic, he said.

He believed that the size of a planet would determine its characteristics: that is, small bodies would not have plate tectonics, volcanoes, or atmospheres and thus would preserve a record of the early history of the solar system. This hypothesis held up to a certain point where scientists had enough data in hand to determine that no one physical principle could explain why the various solar system bodies are the way they are. It turns out that "planets are like organisms, not water molecules. They have irreducible personalities built by history…. Getting back to aesthetics," Gould noted, "knowledge and wonder are the dyad of our worthy lives as intellectual beings." The Voyager mission "did wonders for our knowledge but performed just as mightily in the service of wonder…." Voyager images of the outer planets "fill me with joy for their fierce beauty."

Turning to "the perennial issue of life on Mars," he said, "I do want to go fossil hunting…. I do hope the possibility of Martian paleontology will be at the forefront of international efforts in space. The issue of life on other planets has always been paramount in our thoughts about the cosmos…."

"Martian geology does offer substantial reasons to suspect that life in its simplest cellular form may once have emerged and spread on the planet's surface. [But] if the history of life is chancy, contingent, and unpredictable…then why should life emerge elsewhere, even if conditions were appropriate? Even if life did emerge, why should we maintain any hope of finding fossil evidence? Even if conditions were once appropriate on Mars, this period of possibility ended long ago," he said. So why believe they persisted long enough to let life begin?

"The interplay of chance and necessity, contingency and predictability, defines the complexity and fascination of the natural world," he offered, explaining that although the evolution of life beyond the point of origin appears to be governed by contingency, prebiotic chemistry and the origin of life appear to fall into the realm of "predictable pattern." Ancient Mars had surface water long enough to let life start on that planet.

"It's more than just simple curiosity" that lies behind our interest in the possibility of life elsewhere, he said. "The basic logic of certain problems requires knowledge from extraterrestrial sources…." All life on Earth is the product of one single experiment, and we can't fully understand how that experiment proceeded "until we find another experiment independent from Earthly life," Gould concluded. "That other experiment is as close to a Holy Grail for biology as anything else we could conceptualize or ever know or find."

Session 1:
Questions & Answers

Q: "Why do we only have one beginning type of life on earth?" asked an audience member. "Why couldn't there have been three, four, ten, or a hundred beginnings, each one of those going off in its own direction?"

A: "Well, perhaps there were," Gould responded, noting that although the biochemical similarities uniting all living forms are profound, they are "apparently not absolutely necessary." One could conceive of other ways for life to begin, he said. "The classic question is why do amino acids come in right- and left-handed forms? All life uses the left one. Why does all life use ATP as the energy storing compound? There are such profound biochemical similarities that nobody knows what to do except ascribe it to common art. No matter how many times life evolves you always have the same set. But once a set gets so complex and so intricate, the hypothesis of common genealogical origins seems best."

Q: "If you go into an audience of 400 parents, students, and teachers and you tell them that we sent a small robot outside of the solar system, one of four that has left the solar system, and in February of 1990 you look back and look at the solar system from outside for the first time in history and you ask that group of 400, how many of you know that this happened and maybe three or four hands are raised, what's the point? If nobody knows that these things have happened, if parents don't pass on to their children that we landed on the moon, what was the point? NASA has to speak to education, NASA has to recognize that not just the space science community, but all of us need to go along for the ride. Exploration and science doesn't make sense unless the people have a sense of ownership. If NASA is going to do that, then education on the NASA side can't be just public relations trying to get people to support specific missions. There's got to be a sense of morality here where NASA says look at the wonderful things we're

doing and our mandate is to make you feel the same way we do."

A: Sagdeev responded, "I could not agree more with you. I think we should treat these types of events like our cosmic space D-day."

Session 2:
What is the Economic Value of Space Exploration? (Part I)

Molly Macauley (Session Chair)
Senior Fellow,
Resources for the Future

W. Bowman Cutter
Deputy Assistant to the President for Economic Policy
National Economic Council

Daniel F. Burton, Jr.
President
Council on Competitiveness

While economic research has attempted to assess the dollar benefits of space exploration, it has not addressed the value of intangible benefits, said *Economist* **Molly Macauley** in opening Session 2, which addressed the weakness of econometric assessment in valuing investments in space exploration to date and the difficulty of assessing any intangible benefits.

"What is on the list of values that ultimately are determining what we do in space? And…what has been their economic import? Like beauty, the value of space exploration is in the eye of the beholder," she observed. "To some, the value may be intrinsic scientific merit; to others, it may be technical accomplishment. To some, it is a sense of pride, a stirring of the spirit, an opportunity for vicarious wandering, wondering, or entertainment. To yet others, maybe it's a pragmatic expectation of tangible economic gain in the quality of life [or] a means of attracting young people to study science or engineering. To some, it's competition. To others, it's cooperation. To many, the value is an a la carte combination of these. To others, there may be very little or no value associated with exploration. Which of these should guide federal space activities? Whose values should count? Whose should be weighted most heavily?"

The original objectives of the space program, detailed in the National Aeronautics and Space Act, include expansion of space science and space transportation, international leadership, and international cooperation. Since 1958, the Act has been amended to incorporate new objectives manifesting the values of "economic relevance, pragmatism, and concerns with social welfare, environmental understanding, and commercial opportunity," Macauley noted. While the Space Act does not directly address intangible values such as pride and inspiration, "these intangible values have come to be so presumed in public debate that it is as if they are expected ends of space activities," Macauley asserted. "For this reason, they probably should be included in our list of values that matter."

"What can be said for the economic import and realization of this very long list of values?" Standard econometric models have not proven very useful in measuring even the more tangible benefits of space spending, let alone intangible benefits, she continued. "Spinoffs have become part of the mythology of the economic benefit of space [but] the role of spinoffs for rationalizing and determining the level of investment to make in space activities is far from clear…. It's generally cheaper and faster to directly fund" research and development rather than anticipating spinoffs. Recent studies have debunked the multiplier effect of investments in space. Quantitative analyses have not yielded any evidence of short- or long-term gains in economic productivity from space spending, though such assessments may not reveal any qualitative benefits derived from new and improved products, for example.

"A gap in economics research to date is that no studies have yet focused on measuring values like national prestige, geopolitical influence, enjoyment," Macauley said. "To overlook these values may be to greatly underestimate" the value of our investments in space. Intangible benefits should be estimable, to some extent—perhaps with a new econometric tool, contingent valuation, employing "sophisticated survey…designed to elicit accurate estimates of individuals' valuations of… goods for which we don't have market prices."

With regard to public perceptions of the economic benefits of space exploration, it appears that the American people "seem to like having a space program," though many would like to alter its budget and most don't understand space science and technology very well. This situation "poses a dilemma for decision makers and by default…makes it very easy for space activities to be judged on other bases such as their job-creating potential. Of course, space-related jobs are a cost, not a benefit, to the 179,500,000 taxpayers who aren't employed in the federal space program," she noted, so new jobs probably should not count toward the economic value

of space exploration.

"A necessary context for discussion of either values or costs…is that what ultimately matters is their difference—net value, if you will." In applying the method of contingent valuation to space investments, the first step is to identify close substitutes for values associated with the space program. The next step is to assess the value of an investment in space and a similar alternative. "Articulating these gains…is the responsibility of anyone…who is an advocate," she said.

"Probably no other federal program is expected to address as many disparate activities as the civil space program," Macauley noted in closing, "nor has any other program been directed to do so while at the same time being directed to pursue as many possibly conflicting objectives." The bottom line is that "balancing costs and benefits, including those which have traditionally been hard to measure, is information that…must inform debate."

"I've never been remotely influenced or convinced…by most of the stories that are put together by the friends of the space program about the values developed by the space program," observed *White House Official* **W. Bowman Cutter,** a self-described advocate of space exploration. The case for spinoff benefits from our investments in space "has seemed, to me, forced. Very little of it ever deals with the counter-factual: what would have been the case had we not spent the money this way and had we spent it on something else? It also creates the danger that NASA will be judged and, maybe even more importantly, will judge itself by the wrong set of metrics."

We should be concerned that if NASA focuses on producing new jobs and new products, then its managers will organize their programs "around those bottom lines; and that, in the end, is not what NASA is about." The space program is "a particular kind of long-term investment in space exploration, space technology, and space science," and the value of space exploration must be articulated in this context "or we shouldn't spend the money," he said. "NASA expenditures represent a bet" that a marginal investment of one percent of the federal budget will yield a set of benefits over time which is "sufficiently convincing to allow us to continue that bet."

According to standard econometric models, there's no good reason to argue that a dollar invested in NASA will yield anything more than a dollar of value elsewhere, in the short- or long-term. But given that economic growth depends on innovation in the long run and that our economy is increasingly dependent on knowledge, we need some way of driving innovation and expanding knowledge, Cutter said, and NASA seems to serve these purposes.

Today, NASA and its advocates need to think about change in the purpose and content of the space program rather than the size of its budget. "If the real question for NASA is really the demonstration of value on an ongoing basis," then it's important that the space program adapt to the times—growing integration of the global economy, faster rates of change, and greater competition.

"NASA has to see itself as a critical part" of the new technology enterprise that is intended to maintain our economic competitiveness. "Partnerships and alliances are becoming much more central, and better linkages throughout the technical enterprise are becoming more and more important," he said. "The competencies that NASA develops have to be seen as a critical part of what NASA does, not as a simple by-product of other kinds of investments…. NASA may be about creating competencies in its particular area, and the actual products of NASA may be the by-products."

NASA needs to change its relationship with the private sector as well. "The commercial space sector is at last becoming important," and "NASA has to see itself as complementary to, and integrated with," the launch business, the remote sensing industry, and other sectors "in a way in which it simply didn't have to 10 years ago because these sectors didn't really exist," Cutter noted.

"There's an increasingly high value to increasing international collaboration" in space as well, for "obvious foreign policy reasons," he added. With the end of the Cold War, we need a new kind of glue…a new basis on which to work together." If innovation is occurring all over the world and ideas are spreading more rapidly, then the United States can benefit from cooperation to aid the flow of information.

Further, "institutional re-creation and rethinking have to be considered as central to policy," Cutter said. NASA

"has an obligation to work and create faster and better…. Productivity and quality matter enormously to its capacity to sustain that one percent bet…. NASA faces a horribly difficult transition" from the rigid institution it has been to the flexible and responsive and relevant agency it must become.

Assessing the economic value of space exploration is not a matter of calculating what the space program contributes to the gross domestic product. Rather, it is a matter of determining how NASA, "by seeing itself at the center of technology policy…integrated with the private space sector," can raise the value of that sector. What NASA needs to do is complement the private sector by taking on investments that are too risky for business. "To build value for the future that makes that marginal bet convincing," he concluded, NASA "has to see itself as much as a catalyst as a prime mover."

We don't have to justify everything we do in space on the basis of its economic value, observed *Council on Competitiveness* **President Daniel F. Burton, Jr.** Economic value is nonetheless a primary consideration. People are more insecure about the future these days than they were in the '60s, and NASA must make its plans with this point in mind; that is, NASA must pay attention to the economic value of its programs. "To think that it can simply focus on a space mission…and not have to concern itself with economic payoffs…is politically naive."

Landing a man on the moon "ranks with containment as a guiding principle that helped focus our national energies, helped shape an institution, helped establish priorities, and in fact, ultimately was met with success…. We won the race to space, but the follow-up was really unclear," he said, proposing that economic relevance should be NASA's new guiding principle.

We need to consider that the U.S. aerospace industry spends more on research and development than any other business sector. "The R&D process is undergoing a massive transformation both on the product and the process side…. Aerospace is both a user and a driver of multiple product and process technologies," Burton said, "and in this respect…its importance to the economy far outweighs what the data of simple market size would suggest…. It has a huge role not only in creating and forcing the application of technology, but also in creating markets."

This analysis indicates that "the economic clarion call for this industry [is] to drive the development of new technology and stimulate the practical application of this technology [and] to serve existing markets and to help plant the seeds for new ones." With the Cold War over and economic insecurity a fact of life, "accountability is key…. What we are faced with here is not a broad new policy thrust but a new policy wrinkle," he said: "science and economic relevance…expanding frontiers and economic relevance…accelerating technology and economic relevance…adventure and economic relevance…imagination and economic relevance…national security and economic relevance."

The Apollo-era race for space may not have produced such valuable space spinoffs, he said, noting that Tang, Teflon, and Velcro were not products of the space program but inventions predating NASA. "What the race for space did do…was to encourage people to explore ideas that were at the forefront of science and technology…. The need in the future is to organize this activity to the extent that we can."

NASA now needs to establish tighter links with private industry; figure out "how to balance the development of critical technologies with megascience and megatechnology projects"; and establish continuity and purpose in R&D funding. Finally, space exploration needs to link "national security with economic merit" and establish a strong R&D perspective "which helps to organize consumers somehow."

In conclusion, Burton said, NASA goals must combine inspiration, education, technology, and national security with the national goal of economic performance. "Without this combination, the budget pressures on NASA will be…difficult to fight off."

Session 2:
Questions & Answers

Q: Carl Sagan opened the questioning by commending the panel members on their skepticism about economic spinoff, raising the possibility that there was no "significant first-order short-term economic benefit from NASA activities." Past NASA administrators have used the argument that an increased benefit is returned to the economy for each dollar that NASA invests. Sagan stated that the Chase econometric models used in the

past were completely inadequate to predict the economic downturn in the eighties. "What's your collective sense about these arguments that one dollar invested by NASA develops many dollars elsewhere, and are these econometric models sufficient for predicting such issues?"

A: Macauley responded on two levels. First, she said, "econometrics, like any other research technique, has advantages and disadvantages, depending on the quality of the data. It's an evolving discipline. The study you referred to was done some time ago, and its original conclusions of significant multipliers have since been refuted. We've come far since then as a discipline." On the other hand, she continued, "it appeals to one's intuition to think that a dollar of spending does generate additional spending. The establishment of space facilities in a locale generates jobs, housing, restaurants, and schools. That is generally what has been the multiplier, but any federal or industrial spending does that. It's really not a net augmentation to the nation's productivity as a whole. It's just resources that are being reallocated within the budget."

A: Burton followed by saying that "what I hear is not so much econometric justifications, but anecdotal evidence. What the private sector likes is skilled people, and to the extent that the space program creates that, they think it's good. They like infrastructure projects—they would like to see more wind tunnels here. They like the aeronautics budget—they think that has some direct payoff. Of course, they like the specific projects they contract for, with which they can employ their people. But I think those are more anecdotal justifications than econometric ones."

A: Cutter then stated that there was no good reason to argue that "a dollar invested by NASA is going to yield any more than a dollar invested anywhere else." Putting that aside, he said, economic growth, in the long run, depends on innovation which requires both knowledge and knowledge-based skills, as well as increased investment. "Over the last twenty years, the Federal Government budget has shifted dramatically in favor of transfer payments and consumption, away from investment. In comparison to other developed nations, our private sector does not invest anywhere near as much." The space program resides in an "area which is extremely dynamic, and is one of the sources of innovation. It's worth spending one percent of the Federal budget on it. That is the general kind of spending we as a society need. That is investment-like spending. … [B]ut having decided you are going to spend a dollar in the area of space is not sufficient. You have to spend that dollar in a way that is appropriate to the economy of this time and this day."

Q: An audience member asked the panel if Germany and Japan's "information industries might be growing in addition to their manufacturing sector, instead of replacing it like in the United States."

A: Cutter responded that in those countries "the information sector does not seem to be as intensively developed as in the United States, nor to have created as much innovation, economic value, or as many jobs. The big difference between these societies is in the nature of the labor markets. Our society has created value in manufacturing to a higher degree than in Europe, but it hasn't created the same jobs. While there are many arguments about that, it doesn't have much to do with the nature of the information sector."

Q: Joanne Gabrynowicz followed up on Cutter's comments, saying, "our institutions are based on eighteenth-century timelines and eighteenth-century rates of change, and very fundamental concepts like sovereignty are being tattered. It used to be the hallmark of a sovereign nation was the ability to control information within its borders. Now we are in an age where both money and information are traveling at faster speeds and in different channels than our governing institutions function. My question to you is what do you now see as a practical example of where this push-pull between eighteenth-century institutions and twentieth-century information dissemination is occurring and where do you think it may go? And what might we have to do?"

A: "That's a profound question about the whole nature of government," responded Cutter. "It's absolutely clear that the flows of information and the flows of finance have altered what government is." For example, Cutter pointed out that today the United States' financial markets move 750 billion dollars a day, compared to only 1.5 billion in 1971. "Most governmental organizations, and NASA is no exception to this, were modeled after what were the most successful institutions of their time in the sixties: the major American corporations. Those, however, grew up in a period in which they were themselves a major social invention and flourished in an era

in which the United States had essential dominance in every economic sector that one could name. Now we are in a period where information flows so much more readily and speed matters so much more, a period in which other nations have a capacity to innovate and invest equivalent to our own. The ability to be nimble, to collect information and innovation from a variety of sources, to combine it and recombine it, to integrate and link with what are now thriving industries in this area that didn't even exist twenty years ago, is far more important than in the somewhat more monolithic model of the past.

"NASA faces a horribly difficult transition," Cutter continued. "I think the ultimate answer to the question that all of us are considering—what is the value of exploration—winds up being a question that you cannot answer. It winds up being a question about a new kind of relevance, but more and more, it's a problem that you work on every day. It's not one you answer. I wish there was a new mission that combined economic relevance, adventure, science, national security, and international affairs,…but there isn't…."

Session 3:
What is the Cultural Value of Space Exploration?

Patricia Nelson Limerick (Session Chair)
Department of History
University of Colorado, Boulder

Valerie Neal
Curator
Department of Space History
National Air and Space Museum

Timothy Ferris
Professor of Journalism
University of California, Berkeley

"We are in urgent need of an informed and thoughtful public discussion of both science and space exploration," and advocates of the space program should strive for a "heightened power of expression," said *Historian* **Patricia Limerick** opening Session 3. "What has this enterprise meant to the American public? What might it mean? What could it mean in the future?"

One step the space community should take to secure public support is to expand the curriculum by which it trains personnel, she said. "Require engineers and scientists to take writing, literature, and history classes. The future of the space program…depends on this." Substantial public support for the space program will not materialize until large numbers of space scientists and policy makers develop some "literary grace and range" in speaking about the rationale for space exploration. "It is virtually impossible to speak about the cultural value of space exploration in anything but the most accessible language since the whole point is to talk about the meaning of the space program to people who are not specialists in space technology or space science…."

NASA planners "should have more in the way of practical ballast giving weight to their thoughts," she continued, suggesting that "one of the best ways to give the space program grounding and ballast is to pay attention to Western American history. Nearly every supporter of space exploration and colonization has at some time used the frontier metaphor or analogy…. The westward expansion of the United States in the nineteenth century becomes the model, the precedent, the justification, for expansion into space in the twentieth and twenty-first centuries."

"To the many advocates of space development, American history is a straight line, a vector of inevitability and manifest destiny linking the westward expansion of Anglo-Americans directly to the exploration and colonization of space. In using this analogy, space advocates have built their plans for the future on the foundation of a deeply flawed understanding of the past, [and] the blinders worn to screen the past have proven to be just as effective at distorting the view of the future," she asserted.

Given the expense and risk of space exploration, "the space program needed an analogy and a metaphor that would keep its managers and workers alert, regularly examining their own behavior and their own assumptions. Instead, with the comfortable and unexamined image of the frontier, they took up a metaphor with exactly opposite properties."

Thus, it might be best for the space community to abandon the frontier analogy. "The image and idea of the frontier is an enormously persistent and determining pattern of thought…. Debunk it, and it is instantly back in the bunk. The idea of the frontier is clearly here to stay in the minds of space enthusiasts." Given this reality, she said, what the space community should do is "keep the frontier comparison, but try taking it seriously."

"What would happen if those who have been eager to refer to space as the next frontier, the final frontier, the last frontier, actually thought about the lessons of Western history?" she asked. "Leaving home and going West proved to be a very ineffective way of leaving…problems behind and an even less effective way of solving those problems…. The American West proved to be no escape at all from ethnic and racial tensions, from urban and industrial conflicts, from the…depletion of natural resources…or from frustration and failure." Advocates promote space exploration as an escape from Earthly problems, colonization as a safety valve for social stresses, "technical solutions for all dilemmas." The problem is that they run the risk of believing their own hype. "Space boosters promise a wide and open distribution of benefits [but] in situations of colonization and settlement, occasions in which everyone gains and no one loses have been extremely rare," Limerick pointed out.

"Whether it occurs in terrestrial space or celestial space, expansion has been tough on the ideals and practices of democracy," she continued. "Principle takes a beating and expediency triumphs…. One would not expect the American Civil Liberties Union to prosper on the space frontier."

"Based on the frontier analogy, the space program was guaranteed an awkward middle age…. In its rapid pacing and absorbing intensity, the Apollo…initiative resembled very closely fevered phases of Western expansion like the California gold rush. Like the gold rush, the Apollo program was perfectly designed to breed nostalgia and a sense of loss and decline," she said.

"Explorers, the history of expansion shows, have a way of aging badly," she added, citing figures such as Christopher Columbus and his ilk. The great explorers "did not have the word or concept 'enough' in their vocabularies, but they certainly had the word 'more'." Thus, she concluded, "the frontier comparison does a great deal to explain…the current dilemmas of NASA."

"However the frontier analogy does carry the encouraging lesson that slowing down can carry real advantages…. Used in the conventional…way," she said, "the frontier comparison condemns caution and demands frenzied and precipitate action. Used seriously and thoughtfully, the frontier comparison calls for thoughtful, measured, and deliberate approaches to enterprises full of risk."

Following Limerick, *Historian* **Valerie Neal** examined the premise "that the nations and epochs marked by the greatest flowering of exploration are also marked by the greatest cultural exuberance" and that space exploration is an expression of that exuberance. Is this true? she asked, "and, if so, what does it mean?"

Neal considered whether space exploration has made its mark on the arts and, if so, whether it has been of cultural value. These questions are of interest because "the arts express our cultural values, ideals, hopes, aspirations, concerns, and myths…. They reflect who we are and what life is like, what we question, what we value as beautiful and true. Sometimes the arts look beyond these realities to visions of who we might become and what life might be like."

"Through art, the material, particular historical past and present are often transformed into spiritual, universal, timeless insights into human nature and…experience. The arts not only embody traditional values" but also challenge "ideals of meaning and value and beauty in response to currents of change in the culture at large…."

"Interestingly, space exploration has often been described as if it were art rather than a scientific and technological enterprise. In our civic discourse, space exploration is deemed to be an expression of our culture's vision, energy, optimism, and aspirations." In Europe, the Renaissance encompassed a great flowering of the arts and a great age of transoceanic exploration.

But a century elapsed before artistic treatments of the great exploratory expeditions of that period appeared; and it's more likely that exploration was prompted by the Renaissance rather than vice versa. "In the aftermath of exploration there were great mental adjustments to be made, ideals and values to be reevaluated, before these new perspectives would be evident in literature and the arts," Neal said.

The nineteenth century brought an American renaissance "in large part inspired by exploration of the continent." The art of Frederic Remington and Charles Russell, the music of Aaron Copland, the architecture of Frank Lloyd Wright, and the poetry of Walt Whitman "indicate a genuine cultural exuberance fueled by exploration."

In the 1940s and '50s many painters, composers, and other artists "were already responding to the domain of space in their subject matter or in their artistic style," influenced by twentieth-century advances in physics and astronomy. "Some were coming to see art as an expression in space and time, and they were beginning also to work in large formats suggestive of boundless space. When space exploration began in earnest, the pump was primed for an outpouring of attention to space exploration."

By then, American literature had established a tradition of "the journey as a framework for moral drama." Voyages to the moon inspired writers to explore the themes of "celebration of the adventurous leap into the future, an awe-inspiring adventure of the mind and spirit; nostalgia for the lost mystery of the moon…and a new-

found appreciation for the fragility and beauty of our home planet," said Neal.

"If nothing else had happened in space, a single image of Earth, seen by humans from the Moon, probably would have prompted all of these responses to exploration. That one image had profound impact. It provoked new perceptions and new emotions, jarring people out of complacency about our knowledge, our place in the universe, and our security," she said. Once humans set foot on it, the Moon lost some of its mystery, but Earth "became a thing of wonder and beauty, newly seen from space as a jewel, set in a vast black void. With this image, the literary imagination turned homeward and inward…."

In general, Neal noted, literary artists "have been cautious in assessing the value of space exploration. They have engaged, but have not yet committed, to treating space exploration as a culture-defining epic…. [They] consider whether space exploration represents an increase in human stature or an unnatural dependence on technology, whether it's an attempted escape from the human condition or an enlarged conception of what humanity can be, whether space exploration is so thoroughly scripted and emotionally restrained as to deprive explorers of their essential humanity, or whether it's a modern version of the heroic, breathing life on and into other worlds…."

Space exploration "has prompted a rich response" in painting. "Today, painters more than writers are smitten with space exploration," she said, inclined "to see beyond the actual events to a visionary future." Contemporary architecture reflects the influence of space exploration as well and I.M. Pei seems most responsive in his crystalline structures that seem to rise into space. "It isn't a rational response, it's intuitive and emotional; but a building made of soaring glass, flooded with light thrusting toward the sky, is resonant with the spirit of space exploration. That spirit also resonates in contemporary popular music, [where] the influence of space exploration has been tremendous," especially in what's called New Age music.

"The era of space exploration has," Neal said in closing, "been a time of cultural exuberance in the arts…. The arts have been enriched, and thereby the culture has been enriched; that is valuable." Without space exploration, the arts would not have stagnated, she noted. "However, I think we can make at least two defensible observations. One is that the arts have not yet fully come to terms with space exploration…." Artistic response has been uneven to date, "with the greatest attention in painting and music, and the greatest ambivalence in literature…."

"The second observation is that space exploration has generally stirred a positive response among artists," she said, affirming "positive values, a sense of human potential, and of beauty, a serene cosmic consciousness, soaring inspiration and optimism…. Much of the art inspired by space exploration defies the cynicism of our age. It does what the liberal arts and humanities are supposed to do: capture beauty, celebrate human achievement, lift the spirit into the realm of the universal. For this antidote to intellectual malaise and spiritual drift, space exploration has been of value in our culture."

Journalist **Timothy Ferris** took up the subject of the value of space exploration in providing young people a means of rocking the boat. "Exploration by its nature has to do with innovation, with introducing not only new data but new paradigms, new ways of thinking, and this job is often the work of the young who both serve and are served by the exploratory enterprise…."

"Young people have often been criticized for stirring things up, they're said to lack respect for their elders…and they're assailed for failing to have something better with which to replace the old," Ferris said. "Such criticisms miss the point, which is that young people, if they're worth their salt, ought to be shaking things up, questioning dogma, upsetting their elders. That's their job." Stirring things up is one task that youth share with explorers.

It's often said that "we humans are born explorers…I think there's something to all that," he said, "but it's also true that we're a stay-at-home species, stick-in-the-mud parochialists who seldom even get to know our neighbors…. Much of our history has been one of an oscillation about some intermediate point on a spectrum."

In the 1960s, "exploration took place not only with the Apollo project but also in a variety of areas of the arts, specifically to levels not attained since, as with Apollo," Ferris observed, but while "in the '60s we had Apollo and the Beatles, in the '90s we have the

Space Shuttle and Vanilla Ice…. Since the '60s… we have swung back toward the more conservative, less exploratory side of the spectrum…." Today, NASA portrays its Space Shuttle flight program "as if it were exploration"—but low Earth orbit is nothing more than the equivalent of a 90-minute automobile drive.

Our urge to explore is "a deep-seated personal or cultural yearning that is felt even though it's not understood…. We today who want to keep expanding our frontiers often are unable to articulate the reasons why, and when we do try to articulate them—for instance, when we talk about the practical benefits of exploration—we often find ourselves speaking in a rather hollow fashion," Ferris said. Another problem exploration advocates face in advancing future missions, to other planets, for example, is that our institutions are not prepared to address the long time scales involved.

Given these obstacles, "what I'd like to invite you to do is look forward to a time when exploration will be the province of everyone…when it will be possible to explore" by remote sensing in a way that provides the same information humans would provide. Already, he said, "we're starting to see real [space] discoveries being made by school kids," using Earth-based exploration technologies such as telescopes. More and more of these kinds of discoveries will be possible using those technologies that we call virtual reality.

"Let's take the example of Mars…. We're going to need to reconnoiter the planet…." In the future, geology students will be able "to do real geology on Mars, in their classroom…. We're going to see the potential for a greatly expanded role for exploration precisely where we need it: among young people, who traditionally have had so much to do with those roles in society that exploration fulfills."

In conclusion, he said, "exploration is inherently unpredictable and, as such, potentially upsetting, but it's also vitally necessary for our society…. Young people have always had a lot to do with playing this unwelcome but essential role…. We need to get on with it, and that… calls for confidence in the future, a sense that we can do it and we ought to do it."

Session 3:
Questions & Answers

Q: An audience member raised the issue of human safety in space, citing a senior scientist at Martin Marietta who commented that "it won't be planetary exploration until we can accept losing people by the dozens." In most major exploration campaigns conducted in the past, "the rare expedition that returned was the exception rather than the rule. Could you comment on going slow and safe in our efforts?"

A. "Well, that's a key point," said Limerick. "Exploration is a risky undertaking. I would just like to hear a clear statement on the part of the space policy people that they're aware of that and they face up to it." Limerick stated further that she would like to see NASA respond to previously "fudged" mortality rates in the space program. "As a child," she said, "I found it agonizing to know that John Glenn or Allen Shepard were in such precarious positions. It was a terrifying thing for me as a sixth grader…." She questioned the possible sacrifice of human life in a cause that may or may not be progress. "It's a theological question. God knows, it's not an economist's question, it's not a statistician's question, it's a theological and moral and ethical question."

A: A member of the audience who was one of the teachers involved in the space program with Krista McAuliffe, pointed out that she and her colleagues were fully briefed about the risks of the Challenger launch. All involved were given the option to "gracefully remove their names from consideration," she said.

A: Limerick responded by saying there was one more level of consideration: "Did Krista McAuliffe's children want this? Did her parents want this? Did the classes where she taught want it? In what situations should government risk citizens' lives, even if it has the citizens' consent and full and happy participation?"

Q: Lou Friedman raised the question of exploring planets via virtual reality and telerobotics. "It seems very hard to compete with fantasy and video games and the ability of the imagination to create the exploration." He added that with robotic data and computers we could explore Mars right in our homes and schools. "It seems quite an exciting possibility, except you really can't compete with what is almost available in the fantasy

world. I think some of the unreality that is coming up could doom exploration rather than open it up."

A: "It doesn't have to completely win against fantasy," Ferris responded. "I'm thinking primarily here of an educational tool. In the classroom, your competition hopefully is not video games. The competition is textbooks and other ways in which science is currently being taught. So you're going to a better tool. You don't have to win; all you have to do is capture some amount of attention. Your point about whether virtual reality and telerobotics would doom exploration, I don't know. If the pre-Columbian Europeans had fifty gigabytes of information about North America, would they not have eventually gone to North America?"

Q: An audience member made a case for categorizing science in the humanities and argued that there was a need for scientists to become better versed in communication skills. Sagan then made the point that it is just as important for poets to understand science. Responding to Neal's comments, Sagan expressed his frustration with "the sense of disillusionment and disappointment of poets who would prefer to have the moon be unstructured, a kind of Rorschach test in the sky. As long as we don't know what it is, we can project whatever feelings we have on it. And when we find out what it really is, how disappointing. Oh, lifeless, airless rock. But if we look closer, we can find poetry there. The magnificent wasteland, as Buzz Aldrin called it, is in fact a record of how worlds are formed. We see the birthing of worlds in the desolation of the lunar landscape, and it applies to every world in the solar system. So what surprises me is that there has not been a poet adequate to this fairly minor challenge to be inspired by the moon to describe the birth of worlds. And better science education of poets is part of the answer to this problem."

A: "Right, but you don't want to take the poetic opportunities away from scientists," Limerick responded. "I would just say that scientists could be poets. That the distinction between scientists and poets need not hold and that there should be more creative writing courses for scientists, then they could write the poems on their own. I think what I've missed the most in space exploration is the really glorious folk poetry of the nineteenth-century explorers or the eighteenth-century maritime explorers. Those people were not trained to be writers, they did not think of themselves as writers, but they had a kind of education that permitted them to make music of words without doing it in a self-consciously poetic manner, and I think that would be my hope for the poetry of space. I certainly agree with your notion that poets could get a better science education, but I think the highest hope is that the people who know this firsthand could write in a manner that would sing in the way of the nineteenth-century explorers, and some of them do it [as it] turns out."

Q: Joanne Gabrynowicz said there were two major challenges facing scientists who would write poetry and poets who would write about science: "One is language. Everyone takes great pride in the language of their disciplines and is loath to give that up, and when you wrap that in the incomprehensible acronyms we take great pride in, the information becomes even further removed. The second obstacle is the hierarchy of values we have established for kinds of knowledge, and all you have to do is look at your local university to see where that hierarchy is: on the science and technology-related area of the campus you can see the money that goes into the buildings and equipment, then if you visit the English or the history department you see four or five professors sharing one wordprocessor. You begin to sense how we have decided that all information can be broken down into discreet units, and we fund those units based on a hierarchy that we probably haven't revisited since the Middle Ages when universities first started breaking information down into bits and pieces. So I would encourage the notion of exploration through data because, for one thing, maybe we will revisit this hierarchy and have a new societal value for all kinds of knowledge."

A: Ferris remarked that "there are many people in higher education who think that universities in their current organizational structure will not survive very far into the twenty-first century. A major reorganization is mandated by the many changes in the state of human knowledge that have occurred during the twentieth century. The term that's usually applied to this is interdisciplinary, but that, of course, isn't adequate to represent the necessary changes. Some of these changes are already going on. We've had quite a reorganization in the sciences at Berkeley, but clearly we need to do this in the humanities as well. There's a growing sense that what you say is true, that the structures are now dead wood and we need to prune the trees."

Q: "We see in today's society the seeming decline of the quality of individuals," remarked an audience member. "We see our society at a very fundamental, cultural level going through a lot of changes. Could you comment a little bit more on the role of science and exploration in terms of a hopeful restoration or reform of the culture at a more basic level?"

A: "David Mamet uses the phrase 'tribalization' to describe what's happening to our country," Ferris responded. "We're changing into some kind of a more efficient, rigorous, poorer, less-civilized kind of sociology. In fact, so many students know so little science, it is a terrible deprivation simply because that's where so much of the action is. Western society in the twentieth century will not, I think, be remembered for its music or art. More than anything else it'll be known for its science, and to be in school and not know—to be 'turned off' by science—is like living in the Renaissance and not knowing anything about fresco painting. It's just an unnecessary deprivation. We've done much too little about it, but I have to admit I'm discouraged because I've been participating in panels like this for twenty years now and we've known this for twenty years, and we sure don't seem to have done much about it."

A: "I think Carl Sagan's point about how difficult it is to offer anything in the way of a positive vision to young people these days is really the core of it," offered Limerick, who went on to express her exasperation with teaching American history to twenty-year-olds when all she can offer them is a legacy of "toxic waste dumps and the inability to believe in political leadership." She said she might be able to see past her cynicism if the space program were able to "give young people a sense of purpose and direction and something worth working for." Right now, the crisis for young people lies in that there is nothing more to say to them than "just pitch in and you can make less than your parents made, you can inherit the waste dumps of our post-World War II prosperity. Happy planet to you!"

A: Ferris concluded by pointing out that computers will be a tremendous agency for help in the area of education. "We have seen just a fractional light in the revolution that computers are going to bring about," he said. "We're going to see enormous changes in education and we do, I think, have some hope of getting out of this, getting through this bottleneck in which the mass media and social neglect and all these other ills have deprived our own children of the education that should have been the highest of our priorities."

Tuesday July 19

Session 4:
What is the Economic Value of Space Exploration? (Part II)

Matthew M. Matsunaga (Session Chair)
Hawaii State Senator

Jeffrey Mamber
Managing Director, American Operations
NPO Energia

Frederick Humphries
President
Florida A&M University

The symposium's second session on the economic value of space exploration emphasized the need to develop the infrastructure—both hardware and human—required to mine the full potential of space exploration and development in the future.

"The self-questioning and self-examination currently under way among space proponents is extremely healthy," said *Hawaii State Senator* **Matthew Matsunaga** in opening the session. "The Cold War framework in which our space program…developed was too narrow, too confining, for a theme so transcendent in its aspirations and its practical applications," he commented, crediting his father, the late U.S. Senator Spark Matsunaga, for first promoting this point of view.

The late Senator's calls for U.S.-Soviet cooperation in space and an International Space Year were intended to create "a more comprehensive context for space exploration," Matsunaga said, observing that our time "will be interpreted by future historians as the time when the full scope and significance of the space age came to be recognized and incorporated into national and international policy making and [when], as a result, space exploration acquired a far more solid foundation to carry it into the twenty-first century and beyond."

In today's tight budgetary environment, however, "proving the immediate economic relevance of preparing for missions to the Moon or Mars and beyond is no easy task, to put it mildly." Addressing public opinion and policy decisions about the space program, he suggested that the economic value of space exploration is about as easy to determine as the economic value of health care or crime prevention. Or, alternatively, what is the economic cost of no space exploration, no health care, no crime prevention?

"Considering the economic value of space exploration from that same broad contextual perspective, we can ask ourselves, how can economic value best be derived from space exploration? To foster economic value, when and where should government step in, and when and where should government step out? … [T]he determination, and also the pursuit, of space exploration's economic value demands more sophisticated examination than merely a recitation of spinoffs or grand invocations of the payoffs of answering the age-old impulse to explore new worlds," he said.

"At this early stage in its development, space exploration needs down-to earth, political-economic strategies that expand the context both for perceiving and pursuing long-term economic value and benefits," Matsunaga argued. "It is absolutely fundamental to recognize that the biggest economic payoffs from space exploration will come only after basic space infrastructure investments that are so monumental that no nation can hope to undertake them alone." Thus, in considering economic value, "national economic competition must be pursued within a broader framework of international cooperation."

Local initiatives can contribute to the development of the infrastructure needed for continuing space exploration, he asserted. In Hawaii, for example, where tourism accounts for 40 percent of the gross state product, the state is trying to link its science and technology enterprise with tourism to attract international conference business. "How do those capabilities tie into exploration of the Moon and Mars? If you ask that question, then I believe your strategic context for getting to the Moon and Mars is much too narrow….

"Modest, yet interconnected and evolutionary local initiatives," ranging from astronomical research projects to space business initiatives and even space-oriented tourism, can "introduce the kind of grassroots connections that space exploration needs if it is to acquire sustained, broad-based public support for a very, very expensive agenda. In fact," he concluded, "I strongly believe that hundreds of thousands of such grass-roots connections of that nature, in which local communities put their own

spin on the economic value of space activities, are absolutely essential for deriving full economic value from space exploration."

In his remarks, *NPO Energia Official* **Jeffrey Mamber** addressed "the need for space exploration in the transition from a wartime to a robust commercial space economy."

"There is something ironic and quite sad" about a nation whose history is rich with exploration and discovery "having…to debate the value of exploration into a new frontier…. Most of the people of the world understand that those who explore do better than those who do not," Mamber observed. To reframe the question, "What is the value of space exploration?", does a society founded by explorers just 200 years ago "have what it takes to continue as a nation of explorers?"

With the Cold War over, the United States and Russia must continue downsizing their military infrastructure, and "downsizing must take place in the context of a project of sufficient size, complexity, and challenge…to bring together the former adversaries and create an industrial infrastructure based on peace and not war," he asserted. "The appropriate response to these premises is a long-term civilian, indeed, commercial, space exploration program."

"The maturation of American-style capitalism" has led to a global economy that thrives on transactions not among nations but among multinational corporations. "No area is more poised to further blur the traditional political boundaries than tomorrow's space exploration, [which] will require the resources of a multiplicity of corporations, working with international organizations, all powered by international capital," Mamber said. "Thus engaged, and perhaps only thus engaged, can we dare to think about a defense conversion that can bring about an era of job creation and not just the downsizing now inflicting both the former Soviet Union and the United States.

"The mobilization for Apollo was a war-time effort. The war is over, the question today is how to advance our society's values of democracy, of trade, of equality. That is the value today of human space exploration," he said. "Put differently, a robust exploration of space… has the potential to finally separate space exploration from military exploitation. Until that separation takes place, the space programs of Russia and the U.S. will remain in the shadow of our military programs as they have done since the beginning of the Space Age."

"The [way] to a robust space industry is not to have Martin Marietta or Deutsche Aerospace or NPO Energia make only toasters…. That is not a doable defense conversion," he continued. We need to build a truly commercial space infrastructure that can stand apart from the military-industrial complex. "A true space exploration program is such a project: new space transportation vehicles unrelated to ballistic missiles, cargo ships from low Earth orbit to moon orbit,…housing on the moon for hundreds of workers, astronomy centers on the far side of the moon."

"A proposal this large will engage the Russians. It will allow them to further develop Western-style trade practices…. It will keep a generation of American engineers employed…. It allows us to dream as one people, not as a multitude of nations…. It is impossible to depict the specific value of space exploration in the near term," he said, so "we must learn to accept the concept of long-term rewards…." Who knows how strong the U.S. and Russian civilian aerospace industries might be today "if, instead of downsizing, they had begun the retooling for a mission to Mars years ago and how [much] sooner…the Cold War would have ended?"

Florida A&M President **Frederick Humphries** addressed the interplay between the educational and economic value of space. Asserting that space exploration may be the kind of challenge we need to solve the problem of under-representation of minorities in science and technology, he said that the only way we can fully develop our national human resources is to take action to bring more minorities into science and technology fields.

The Apollo 11 lunar landing was proof of our national resolve and determination "to do it…. America's monumental response" to the Soviet launching of Sputnik I "produced monumental results…[of] tremendous economic benefit to this nation, and tremendous educational growth." We need to muster up the same kind of determination to solve the problem of educational equity.

After Sputnik, the government provided "a great infusion of money to build the infrastructure" to compete

with the Soviet Union in science and technology: high school curriculum development, elementary science teaching, and graduate centers of excellence, including facilities, equipment, and faculty. NASA itself financed research programs and even buildings on college campuses.

All these actions, he said, "helped to expand and broaden the base, economically and strategically, of certain Americans' cooperation." As a result, the nation produced more engineers, physicists, mathematicians, and so on, creating "the human capabilities required to meet the technical requirements of the emphasis to get to the Moon…."

Although critics today may be questioning spending on the space program, Humphries said, we should forge ahead with space exploration. "We have no choice but to remain a pioneer nation…. America is a nation that thrives on challenges…. We focus and develop and get better when we are faced with a challenge…."

Thanks to space exploration, "we have moved from the industrial age to the information age. There can be no information age without space. The issue for the space program in the future is not survival but infrastructure, particularly in the form of research centers, training facilities, and the selection of the men and women who will be the engineers, managers, scientists, and astronauts of the twenty-first century," he said. "Can we continue to work on human resource development issues of the nation, the inclusion of minorities in the scientific and technical work force?"

"The narrow focus of scientific and technical merit can no longer be sufficient to fund an entity for an activity; we must insist that there be broader goals…in the expenditure of huge sums of dollars…." In addition to scientific and technical merit, requirements must include plans for human resources development.

In order to accomplish this goal, a change in the means of distributing federal space spending will be necessary, he proposed. "If we continue to do business the way that we have always done it, in the context of purely scientific and technical merit, we will miss one of the greatest opportunities we've had to have economic reform and increase the quality of life…."

"Today in America, there is a segment of our nation that is not achieving at its full economic and social potential." The socioeconomic status of this nation would be far better if every citizen were able to achieve at full potential. "So it seems to me that we have to have the challenge of the next step in space. But it's not enough to have [this] challenge, because America…has become kind of soft, and the softness shows…that we're not willing to work hard in the development of the talent of the nation," Humphries said. "Our scientific and technical community takes the road that it will look for the talent of the world, and in looking for the talent of the world, it then overlooks the hard work that has to be done to develop the talent within the boundaries of the country."

In the United States today, Ph.D. production in science, math, and engineering—for global competitiveness and even effective global cooperation—over 60 percent of Ph.D.'s obtained with NASA, DOD, DOE, or NSF funding go to international students. In computer science, 70 percent of Ph.D.'s go to foreign students; in math, 75 percent; in physics and chemistry, 50 percent.

"Inside of that problem is the critical problem of the under-representation of African Americans and Hispanics in these disciplines." The highest number of Ph.D.s in engineering granted to African Americans in any given year is forty six.

The United States' ability to produce minority graduates at the highest level "is in a crisis state…. [It] is not enough to set a technical and scientific challenge to go into space, to mobilize the nation around that challenge and to look at all the spinoff that will flow," Humphries said.

As we face the challenge of building a space station, going back to the Moon, and sending people to Mars, it's time to ask agencies like NASA, DOE, DOD, NSF, to launch "programs to create new research infrastructure, including buildings and equipment, on the campuses of HBCU's, to do something…about rectifying" the under-representation of minorities in the scientific and technical work force and thus in the space program. Humphries proposed creating at least 10 new centers of excellence on BCU campuses over the next 10-15 years, to enable "full and inclusive participation in the space effort."

"We are all aware," he said in conclusion, "of the pos-

sibility that life may exist on other planets…. There's an even greater possibility that if we do find intelligent life in the universe, that this life form will not look like the average American white male. It may be wise, even safe, to make sure that the Americans who land on planets in the future are a multicultural mix so that we will be in a better position to negotiate our arrival if we land on a planet that has already solved its race problems….

"Just as we travel to the Moon to learn more about the Earth, I hope it is not necessary to engage in intergalactic travel to learn the value of an inclusive society…. The economic wherewithal for the future will be dependent on an intelligent, highly informed, educated, and wise nation…. The greatest way to benefit economically from space exploration is to develop all of America's people."

Session 4:
Questions & Answer

Q: An audience member commented that since money spent on space returns at about the same rate as money spent on almost any other government expenditure, and since it is much more efficient to fund technology development than a mission, "perhaps NASA should change its program by deemphasizing missions and emphasizing technology development. On the other hand, we've heard from almost all of the speakers that the intangible values may be the most important part of space exploration. Things like education, science, cultural prestige, the feeling that there is something better in the future. Would you comment on where NASA should be putting its emphasis—missions and intangible returns, or strict technology development and more immediate economic returns?"

A: "I don't know that ideas will flow in the absence of a specific application," said Humphries. "I happen to believe that because we accept the challenge of answering a specific problem, we learn things that we don't know, and then we have to create something to overcome that because it's within the context of a specific challenge. I don't know if we didn't have a challenge and we were just looking for things that would help commercially that we would be as effective in finding solutions. I think we should have technology transfer and technology development for the sake of doing that," he continued. "But I don't think we ought to get out of solving the specific challenges that lead us to a level of science and technology. I wish we hadn't abandoned the super collider, for example. That's the specific kind of challenge that allows us to work with some urgency to get practical solutions that have larger ramifications. There's nothing like putting America to work on a challenge in terms of its scientific and technical manpower."

A: Mamber agreed with Humphries, adding "you can't create anything in a vacuum, and you really do need a completely tangible goal in order to give the engineers direction."

A: Responding to an audience member's point that if industry isn't willing to invest in a program, then it probably isn't worth doing for commercial benefit, Matsunaga said that "there might be some projects where industry might not be willing to put its money where its mouth is because the benefits might not be short-term. In long-term projects, which eventually will have economic benefit, I think it's necessary for government to step in and lend a helping hand."

A: Humphries said he would "personally favor our government staying involved in space in a very significant way. I don't think it's an appropriate time to turn over the exploration of space and make it dependent on purely profit motives. I do think that business ought to be involved and concerned about the implications of space exploration for commercial activity—but not at the exclusion of the government. That way we can get better results for the whole nation."

A: "I share some of the thought that there should be a role for government," responded Mamber. "I'm unconvinced whether NASA is the correct government agency. I wasn't suggesting all or nothing, NASA versus the private sector. It's clear that in these huge exploration programs, government plays an appropriate role. The question is, is this particular agency the right way to go, or should it be a technology agency?"

Session 5:
What is the Value of Space Exploration to Education and Scientific Literacy?

James F. Trefil (Session Chair)
Clarence J. Robinson Professor of Physics
George Mason University

Charles F. Bolden, Jr., USMC
Deputy Commandant of Midshipmen
U.S. Naval Academy

Priscilla Cortelyou Little
Senior Program Associate
American Association of University Women
Education Foundation

"What is the mobilizing role of the vision of space exploration…in creating in the minds of young people the sense of valuable, rewarding careers that involve… training in science and engineering? You can't map that easily, [but] that may in fact be one of the most important contributions" that space exploration can make, noted symposium chairman Adams in opening Session 5.

Science literacy expert *Physics Professor* **James Trefil** addressed the educational value of space exploration to the vast majority of the population which is not professionally engaged in science and engineering. We live in a society driven by changes in science and technology, and thus everyone needs to understand science and technology. "Yet our educational system has not responded" to this fact. Even in the university system, science is still treated as "one of these frills that an educated person has, it's not seen as something essential…."

"People have to make decisions about their personal lives, about political issues, that are based, at least in part, on science and technology, and yet…they have not been given the tools by the educational system to make those choices. This situation has profound implications for the future of democracy," Trefil said, "because if you carry it to its extreme, you get into a situation where decisions are being made by an elite without even the informed consent of the people who are being affected by these decisions…."

"When I talk about scientific literacy, what I'm talking about is the preparation…of a citizenry that is capable of understanding scientific issues at the level they need…to participate in public debate…. You don't have to go to…scientific literature to find examples of the use of…scientific terms in general public debate," Trefil noted. "The point is that you can't understand…the context of a debate unless you bring to it a well filled out matrix of information that is appropriate to your society and your time. Now, part of that matrix in the twentieth century has to do with science and technology." The space program can contribute to improving scientific literacy by contributing to that matrix of knowledge

"What are people supposed to know about science? I think it's here that the educational system has in fact failed most badly, in science education," he observed. "The reason is that we are motivated by-and-large by the idea that the proper education for anyone in science is to become" a full-fledged Ph.D. "This idea is based on a number of fallacies. First of all, it's based on the idea that somehow there is something called 'the scientific method' which, once you learn it, suddenly opens this magic box that tells you everything about the world…. It doesn't work that way." Simply put, Trefil said, the way it works is that "if somebody is to know something, you have to tell it to them."

"In order to be scientifically literate, in order to confront the issues, you have to have a wide, broad picture of how the world works, what the sciences are about. Education for the 99 percent who are not going to be scientists has to be quite different from the education for engineers and scientists." He then posed the question, "Where does space exploration fit in….?"

Once students leave the university, he said toward answering the question, you can't make them learn. They "have to be convinced that there is information here that is interesting to them and that they want to know. And that means that you have to have what editors call a 'hook'…. For me, the greatest contribution that the space program has made to education beyond the formal education that you get in universities is in this area of getting people interested…. The space program is an enormous motivator in getting people past that first initial rejection of science and getting them into understanding a little bit more about it…."

"The part of the space program that is of most use in motivating people to come into science is the manned

space program." People are the "hook." Thus, "the idea that you're going to send robots to Mars and that people are going to be just as excited after the first week of pictures as they were at the beginning…is very unrealistic." In fact, Trefil said, the only reason most people are interested in robotic missions to Mars "is because people will someday follow…."

Think about *Star Trek*, he continued; the reason why *Star Trek* is so popular and the reason why human space flight is NASA's most effective hook for interesting people in science is that "in some way, they tap into the dream…. [Thus] the future of the space program really lies with the people who understand that it's about a dream and who understand how to tap into the power of that dream."

"Without a vision, the people perish," said *Former Astronaut* **Charles Bolden**, taking up the subject of the educational value of the inspirational quality of space exploration. Also noting that "necessity is the mother of invention," he said that it is important for NASA to maintain its mission orientation—"if there is no need, then there generally is nothing done…."

NASA and the nation need a mission to which they aspire. Therein lies the nature of "our crisis today, because we don't know what we want. As a nation, we are confused," Bolden said, and "one of the reasons… that we are confused is because of the lack of…scientific education.

On post-flight tours of other countries, Bolden (a veteran of several Space Shuttle missions) indicated he had learned some lessons about the value of space exploration in advancing education and scientific literacy. He described a visit with 200 school children in a remote Costa Rican village. The village had no running water or electricity, yet "the children are quite literate when it comes to talking about space and space exploration." The reason why is that astronaut Franklin Chang-Diaz, who grew up in Costa Rica, had visited this village.

Bolden also related his impressions from a recent visit to Russia with a Space Shuttle crew mate, Russian cosmonaut Sergei Krikalev. Poverty and antiquated technology were two things that he noticed wherever he went in Russia. However, he said, "when you walk around and talk to people, they all are very oriented and educated on space and space exploration and the need for it. They learn it in their schools regularly." And while most monuments in the U.S. capital of Washington, D.C., are war memorials, in contrast Russia's capital city of Moscow is full of monuments to space flight. "The things that matter to them are space and exploration and getting on with the future. I had a hard time understanding that."

"I still have a hard time understanding that, how they can be so forward-looking [while] we are still trying to decide where we want to go." Finally, he described a trip to Europe during which he met with the King and Queen of Belgium—"most of their questions were about space exploration and its importance…." People in other countries seem to have gotten the point, he said, "whereas we still muddle around." He also noted that getting to know people from such diverse backgrounds "who had the same dreams and aspirations and desires that I did taught me a lot as a career Marine…."

At the U.S. Naval Academy, he reported he's found that many students are there because they want to be space explorers. "What infuses that quest for knowledge into [students]? It's the space program. It's watching people be willing to go off and take risks…in pursuit of what's out there." We don't know what's out there, he said, and finding out will require educational preparation.

Education "is considered as important as it is today because we do have missions that the kids perceive as very, very important. They are a people who have a vision of what they want to do, and they understand what is necessary to get them where they want to go. I think the message they are trying to get to us as parents and as leaders in this country is [that] exploration is very, very important. Understanding our world is very, very important. Tying all of us together is very, very important because we can't do any of this stuff alone. And the only way we're going to get there is by study and exercise and trial and error and performance."

Speaking on behalf of the *AAUW, Senior Associate* **Priscilla Little** stressed the importance of including girls in science, math, and engineering. AAUW's vision is that "women will have an equal education and be a part of the scientific community. But we are concerned…that girls and women are still dropping out of the math and science pipeline…at critical points in their education."

"Math and science education will be an important lifeline to employment in the future technological work force…. Women will be active members of the future work force." By the year 2005, 47.5 percent of the work force will be women, according to the Bureau of Labor Statistics. "AAUW wants those women to be participating to the best of their talents and skills, not relegated to a new underclass of workers. In 1990, 22 million mothers were in the labor force, six million of whom were single parents. The future depends on those mothers being educated, especially in having critical thinking and problem-solving skills," Little said.

"We are concerned, too, that women will not have that technological skill to expand their horizons, will not be able to keep apace of technological demands." Despite ongoing efforts to improve our educational system, "the pipeline continues to leak." Despite mentoring programs, teacher institutes, and a host of other special programs, girls are still bypassing science. Despite all these efforts, "the flow of female talent out of the science pipeline is serious."

Why is the pipeline still leaking? It starts "as early as preschool and kindergarten," Little said, when many girls continue to play with toys that appear "socially acceptable" for girls, rather than with building blocks, erector sets, and other toys that develop spatial skills essential to math and science. As early as the fourth grade, girls show a preference for biological over physical sciences, while boys already have more experience with mechanical and electrical science activities. Boys do science experiments, while girls tend to take notes.

"When girls reach middle school, the situation intensifies." Research has shown a correlating drop in math achievement and self-confidence among girls in their middle school years. "Many girls drop out of math even though they know they can do the work," she noted. An AAUW study has found that 81 percent of elementary school girls said they liked math, but by middle school the percentage of girls who reported they liked math had dropped to 68 percent.

Gender differences show up in career plans, too. "High school girls choose math and science careers in disproportionately low numbers." A Rhode Island study showed that 64 percent of male high school students who had taken math and science planned to major in math or science in college, compared to 18.9 percent of girls who had taken math and science.

These few examples indicate the pipeline is still leaking. "Four different possibilities that NASA might consider" to staunch the leak are to support research in educational equity, help change public perceptions of what girls and women can do, distribute information on science education programs that work and ensure equity enforcement in the work place.

(1) Much research data on education lumps girls and boys together, but girls and boys do not always experience education in the same way, especially in math and science. What's needed is more research on girls and women in science, and more disaggregated data that reflects differences due to gender, race, and socioeconomic status.

NASA could be a source of disaggregated data about women in space. For instance, is training for male and female astronauts the same or different? Are men and women drawn toward working on different types of projects in space? "Would these findings have relevance for the education of girls and women in public schools?" Little asked. "NASA's enormous resources could be used to channel even more funding toward longitudinal research on girls and women in science to ascertain good intervention projects for public education."

(2) NASA could help to distribute research findings on issues of educational equity, she added. For instance, AAUW will be completing a study in 1995 on promising principles for girls of all races, ethnic groups, and socioeconomic classes. "It would be helpful to have assistance in distributing this information to your constituency, your technicians, your policy makers, and the general public."

(3) NASA could also help to change the stereotypical image of the scientist for public school students. Altering the stereotype won't be easy, "but if NASA commits itself to that goal, it could be changed in our lifetime. It would require using all your media resources, your visibility, your public relations talent, to project a possibility for women. NASA has done a good job in giving the public excellent role models for women that are highly visible, but still more needs to be done. The NASA space program has the glamour to change stereotypes that keep women from participating in the sciences."

(4) Enforcement of equity in the work place "begins at home. If it has not already been done, equal representation of women on all NASA committees, task forces, and visible glamour projects must be implemented. Female memberships of national science academies, journal articles, and books written by women featured in academic presses are just a few of the initiatives that can be implemented…." As NASA expands international cooperation with Russia and other countries, "it should consider if those countries are offering equal employment opportunity for women in space…."

"In conclusion," she said, "the space program has done a great deal for the education of women and girls. A whole generation of girls and women have been inspired by the space initiative, but more must be done…to use the full talent of half of the population in the future. The capacity NASA has to excite the public…should offer promising hope that while exploring space in the future, [NASA] will also be a major partner in assuring equity for girls and women…in this country and abroad.

"Connecting science to the needs of girls and women may require [a reexamination of] the whole premise for [its] existence, but it's a risk worth taking…. If the space program could inspire full participation in its activities, it will, I am sure, have reverberating effects throughout the pipeline."

Session 5:
Questions & Answers

Q: An audience member asked the panel: "What kind of changes would you like to see at the university level to address education in science, and also, would you comment on the notion of scientists needing to be better communicators and better articulators to expand scientific literacy?"

A: "I think the university twenty years from now is not going to look very much like the university today," Trefil said. "The university as it's structured today is basically a nineteenth-century organization. It's modeled after a factory. You took the raw material, ran it through a couple of machines, stamped it, shipped it out, and you never saw it again. It doesn't work that way anymore. I see changes going on, but we need more of them." At George Mason, for example, many of our students are returning adults. People are coming back to upgrade their skills in hopes of changing jobs or getting better ones. "The education just goes on forever," Trefil continued. "You never stop the connection with the university. This is a rather new role."

A: "I think women are going back to college in greater numbers and are looking for a nontraditional education," Little added. "I think it has reshaped a lot of the higher education areas. They come back with energy and enthusiasm, but, in some instances, the university is not as welcoming as it could be. Just trivial things, like having classes at night or letting people come for two weeks of concentrated work so they could come during their vacations, would be a great help. We need things like that outside the realm of the traditional university."

Q: An audience member addressed the panel, espousing the need for more diversity in the space program. Inspired in the sixties, she said she found the space program gave her a vision that helped her to overcome the obstacles of being a woman interested in science. One of the things women bring to the scientific workplace is that they allow "feminine energy to emerge and to influence the process of what's happening." She noted that those "feminine values" are in men as well and that it is "good for all of us if the women become greater participants." She also said that while there is a lot of science illiteracy on the part of those involved in the social sciences and the humanities, there is also a lack of conceptual literacy on the part of those being trained in science and engineering, which leads to "ignorance of the social context in which they are operating, potential ethical questions, and a barrier to communication." She pointed out that undergraduate programs should not separate people involved in technical training from those in the humanities, but rather they should bring them together "based on that common vision of space and let their talents begin to cross-fertilize one another."

A: Bolden responded to the questioner's comment about scientific principals by explaining that at the Naval Academy, there are "four things we tell the midshipmen they need to remember." First, they need to know the basics, "because if they don't learn the basics on the elementary level, when they get to high school, or especially college, they become overwhelmed." Second, they have to know themselves. "You have to understand where your strengths and weaknesses lie and you have to have some 'feminine' characteristics, if you will. You have to be a person, I mean, a touchy-feely, caring kind

of person. This is the only way you can understand how good you are at counseling people, which is what a military person has to do." Third, once students learn the basics they must then learn the details in the most minute terms. "When you get aboard a space shuttle, that's not the time to start thinking about what you should have learned." Finally, students must be taught to do what is right ethically. "If there is one giant weakness in our nation right now," Bolden said, "it's because we are a nation that is very unethical. We seem to have lost connection with doing what's right. We do what's expedient and that's what we teach our kids. I see a nation of kids coming in at the Naval Academy. We have the brightest and the best, but they have been taught to do what's expedient, not what's right, and that is something we certainly have to go back and work on."

Q: Phil Culbertson addressed the panel, saying that NASA is in an excellent position to create educational material and to "create a dream and a sense of excitement." However, the problem is that NASA's educational program is prepared too much from within. Perhaps the nation would be better served if "the educational community approached NASA with a joint venture so that NASA could have some guidance from experts in the field of education. NASA has had very close relationships with about fifty universities in the past; NASA has prepared material for high schools and for young children; NASA has encouraged speakers. The most challenging thing I ever did," he said, "was to speak to three-year-olds about space. I'd rather face a congressional budget committee than those three-year-olds. I didn't even know how to start. It was amazing to me the kind of questions and responses you can get from three-year-olds. I have no education at all in how to educate people. I talked from my experiences with NASA. But have those of you who are professionals in education ever thought to sit down with NASA and work out how NASA can most effectively contribute its experience, its operations, and the material it has so that you can use it in the educational field?"

A: "This will probably raise the ire of some people," responded Bolden, "but NASA has made an attempt, feeble though it may be, at calling upon the experts by way of the teacher-in-space program. Krista McAuliffe was a very good friend of mine and Krista was an excellent, excellent teacher, an excellent motivator, mainly because she was so energetic in what she did, and she really believed in what she was about to do as a member of the 51L crew. We have a number of teachers from across the country who attempt to help NASA combine the material such that it is presentable and usable in a classroom. There are a couple of excellent programs to educate teachers—not to tell them what to teach, but just to let them know what material is available, so that they can then reformat it into an acceptable curriculum that is useful in their particular community or in their particular area of expertise."

Session 6:
What is the Scientific and Cultural Value of Space Exploration?

Joanne Gabrynowicz (Session Chair)
Department of Space Studies
University of North Dakota, Grand Forks

Paul Gray
Director of Environment and Marine Science, Research, and Development
European Commission

Majel Barrett Roddenberry

John Calvin Batchelor
Author

Session 6 presented "diverse, new, and important perspectives" on the scientific and cultural value of space exploration, in the words of Symposium Chairman Adams. *Space Studies Professor* **Joanne Gabrynowicz** opened the discussion by describing how science influences culture and how culture influences science. "Culture is a ubiquitous force that affects everything that occurs in it, including science." Right now, for instance, feminist scholars are debating how science may change as more and more women become scientists.

Newtonian physics established that observing nature would reveal the laws of existence; those laws were applied to human endeavors as well, "including governing institutions." The founders of our country applied the principles of Newtonian science to the creation of our government. "What makes the Constitution of the United States a revolutionary document is a very important Newtonian concept which is separation. Everything in the Constitution that made it revolutionary is based on that one idea…."

"Separation is the thing that gives us power. For the framers of the…Constitution, political power was atomistic. It could be divided into discrete [elements]. The mechanisms that are contained in the Constitution, checks and balances, [are] very Newtonian…." The result of this interplay between science and culture, said Gabrynowicz, has been "the most successful democracy the planet has seen…."

"However, for those of us who are…dealing with government institutions, we feel that something is changing…. Is the idea of separation still viable in a world where it is becoming more and more difficult to resolve political conflicts and reach political consensus?" Perhaps, she suggested, "the concept of separation needs to be supplemented with another idea. So what is that idea that is beginning to emerge, what is that idea that perhaps may be shaping today's science and today's culture and today's governing institutions? I'll suggest to you that idea is interdependence…."

As separation was a revolutionary idea for the founding Americans, "interdependence has become a revolutionary idea for us. We see it everywhere…. In science, where we're seeing this concept of interdependence…in remote sensing, Earth system science…. So in remote sensing, our policy decisions are becoming more and more premised on this concept of interdependence, and yet the institutions that make these policy decisions are primarily eighteenth-century institutions premised on the concept of separation…."

The next generation of remote sensing systems, she said, will be "interdisciplinary, international systems," and "the purpose for this era of remote sensing is to…acquire and maintain a global data base…." The Founding Fathers "allowed geography to guide them in creating their governing institutions, and here we are 200 years later, having to make similar decisions about geography and our governing institutions…. We are now at a point where we've decided that global change research…by nature involves the planet. Yet we don't have the institutions to carry that out…."

She then addressed some things that will have to happen in order to create "the institutional foundations on which we can carry out multi-decadal missions…. The first thing we have to do is think globally." We've been talking about it for years, "but now it's time to walk the walk, not just talk the talk, and by this I mean making transnational political decisions…." Instead of letting special interests sway decisions, "we have to start urging [politicians] to think as an entire unit, to make political decisions based on that entire unit."

In order to build a global data base, we have to reevaluate the utility of annual budget cycles and "get serious about our relations with the developing world…." We also need to consider whether NASA is the right institution to oversee the construction of this global data base.

We have to open up more classified capabilities. "Sovereignty is another issue we're going to have to come to grips with." Our concept of sovereignty requires updating in the face of the need for global data collection and distribution.

Another concept we need to reevaluate, she said, in considering the future value of space exploration is the idea of leadership. "Since the beginning of the Space Age…it has always been a clear…purpose of the space program to be THE leader, and leadership meant dominance, and leadership meant being alone and solitary. There could only be one leader in that…model of leadership." The United States is now one of many spacefaring nations. "First among equals [or] leadership as a joint function among equal entities" may be better definitions of leadership in space today…."

Quoting Thomas Jefferson, she said in conclusion that "laws and institutions must go hand-in-hand with the human mind. As that becomes more developed, more enlightened, as new discoveries are made, new truths discovered, and manners and opinions change, with the change in circumstances, institutions must advance also, to keep pace with the times." As we attempt to define our role in the global community for the twenty-first century, "if we remember what Mr. Jefferson has to tell us, I think we can do brilliantly."

The *European Commission's* **Paul Gray** turned to the value of space science and technology in opening up the world. "Space exploration and technology have been instruments which have led not only to great advances in natural science, but contributed to fundamental changes in human society"; for example, space-based data gathering contributed to nuclear disarmament, European unification, and the collapse of communism.

The Soviet government denied the Chernobyl nuclear accident, Gray noted, until other nations produced satellite imagery of the damaged reactor, this incident was a final contributor to "lack of confidence in a system which couldn't exist in the modern world with space technology and the diffusion of information."

"The awe of the first space voyagers…as they looked at the Earth from space was described prophetically by the American poet Walt Whitman: 'Oh vast rondure swimming in space, covered all over with visible power and beauty, alternate light and day and the teeming spiritual darkness, unspeakable high processions of sun and moon and countless stars above, below the manifold grass and waters with inscrutable purpose, some hidden prophetic intention. Now first it seems my thought begins to span thee.' That's, I think, what the astronauts saw as they looked back toward the Earth from space.

"In politics," Gray continued, "Walt Whitman argued for the shifting of authority from the favored few to the many, from the traditions of the past to the claims of the future. He saw history as a growing process of continuous evolution following the tenets of natural law. While this placed natural sciences in the forefront as they sought to explain the concrete and the real, they had to be viewed within a more general framework of an infinite continuous scheme of progress. To some extent, developments in the peaceful uses of space technology have reflected this vision."

Not only did the Cold War race into space "open new avenues to science and human knowledge," he said, but it also led to many practical applications of space research—for instance, space-based communications, meteorology, navigation, and geodesy. "These new developments are being embodied in government space programs which no longer have political prestige as their main driving force. Reflecting a deep-felt concern for humanity and its survival," national prestige these days no longer depends on "grand technological demonstrations but [on] themes closer to the citizen such as freedom, economic well being, health, and culture," he said. "Scientific and political prestige is fast giving way to socioeconomic rationalism, thus fulfilling Whitman's vision of politics as well as his poetic vision of space travel."

Space exploration has led to "the globalizing of environmental concerns…. In the political sphere, the planetary scope of environmental phenomena is leading to command and control regulations by international protocols," such as the Montreal agreement to eliminate chlorofluorocarbon production, agreements that "will need policing, and they will need Earth observation to police."

"In Earth observation the priority task is to move from a technology-driven to a user-driven situation…. The increasing importance of Earth observation underlines the need for a medium- and long-term European policy involving all players, governments, space agencies,

users, and industries…. Earth observation has been technology-driven, and it's now high time to harness it to the exploration downwards into the planet's 'Inscape'," a term coined by the English poet Gerard Manley Hopkins "to describe the true essence of the natural world…."

"It's the scientist's duty to listen to nature and to interpret what it is saying in terms which can be understood by the people. Without this understanding there can be no acceptance of policies that are necessary to deal with the changes which are being wrought in the world by human activities….

"The Moon landing brought us face-to-face with our own fragility and the fragility of our planet. The diversity of life on this planet is based on the weakly bonded but versatile chemistry of carbon in an aqueous environment. Its fragility and versatility was an essential component of evolution," Gray said, "but it is rapidly damaged by confrontation with the fundamental atomic forces which are loose in space. This confrontation with fragility requires humility from persons, institutions, and even nations, but from this humility can arise a great strength if we realize that the true exploration, space exploration, is a voyage of the human spirit…."

Using Earth observation to evaluate these changes "is undoubtedly the priority task for space exploration for the next 25 years [but] will be of little use if in the same period we have not developed and put into application a new politico-economic system which takes into account the value of environmental goods and services and allows us to live in harmony with our planet in a sustainable way…. If we can achieve sustainability, then we will…perhaps free the human race from a bondage to materialism in which mankind considers that he has an unalienable right to unlimited consumption of the resources of this planet."

"When [the mythical] Pandora's box was opened, following the vast swarm of human afflictions, the last spirit to fly out was hope. Let us all hope that by the 50th anniversary of the Moon landing, the exploration of the planet's Inscape will have led us to a true spiritual jubilee."

Introducing the role of fiction and science fiction in considering the value of space exploration, **Majel Barrett Roddenberry**—the self-described "first lady of *Star Trek*"—offered her thoughts on the tapping of human potential through space exploration, both real and imagined.

"We think in pictures, we dream in images, and we create from what we imagine…. What we imagine becomes our world. So here we are, hovering on the edge of the twenty-first century…." What lies in store for us? We have no way of knowing, Roddenberry said. "Or do we? *Star Trek* depicts a future in which the very research that we humans are conducting now becomes an intrinsic part of our lives…. From the Star Fleet communicator to our cellular telephones, and from the phaser to the taser, *Star Trek* continues to influence the future with the sheer energy of its dreams…." On the early *Star Trek* shows of the 1960s, for instance, small computers showed up all over the starship Enterprise, while in reality computers were massive machines that filled whole rooms. But now the small, personal computer is ubiquitous.

Star Trek's creator, the late Gene Roddenberry, believed "that the role of science fiction was not merely to entertain but to engage the imaginations of the viewers, to generate ideas, acceptance of change, and to inspire those whose exposure to these ideas would lead them into the future," Roddenberry said. "He believed that once these ideas captured the imagination of the viewers, it would be obvious that they were good, and that they would help solve humanity's current problems, that in attempting to turn dreams into reality for the future, progress would result today. Well, it has…."

"What about those ideas which still seem impossible today? What about the matter-antimatter pods which propel the starship Enterprise? Well, an antimatter factory in Geneva, Switzerland, is producing millions of antiprotons a second in an effort to create a new rocket fuel. NASA and the United States Air Force currently are studying the concept of antimatter propulsion, a system that is admittedly far in the future but which will never be a part of our journey into space if it is never attempted," she noted. At the University of California at Berkeley, "a renowned scientist is experimenting with photons in a variety of capacities, and when asked what inspired him, the answer was, Star Trek…. The holodeck? What do we call it? Virtual reality…."

"Soon we're actually going to be able to say, 'Phasers on stun.' The development of a new generation of nonlethal weapons, *Star Trek*-like phasers, is now under

way for the first time in U.S. military history…. The seed was planted in outer space…. At MIT, I'm told, someone's even attempted the creation of a transporter…."

"People say that our space program is a luxury and that we should really be concerned about food for the hungry and medical aid for the needy, that to those whose stomachs are empty, the space program is merely a waste of money, it's not only a waste of money but it's an insult to the human race," she observed. "Well, I happen to have the good fortune to spend most of my time among people who recognize the invaluable contribution that space research has made to our daily lives. If somebody were to ask me that question…I would reply that I know of a geomorphologist who travels…to Third World countries in order to maximize land use, to grow crops that will feed millions where only thousands were fed before. His tools are not the hoe and the spade…his tools are satellite transmissions from space, his knowledge comes from highly sophisticated computers perfected by NASA…. The people he feeds, in fact, are fed by the space industry."

"In the *Star Trek* universe, present and future inventions and discoveries meet and give rise to that unique blend of science and imagination that Einstein once called art…." Think about "what may be possible simply because scientists, too, believe in dreams…."

Gene Roddenberry believed his "responsibility was to portray these concepts as achievable realities, in hopes that some day, someone, somewhere, would take them seriously and make them so. '*Trek*' doesn't pretend to be an accurate representation of the future. Rather, it's an accurate representation of our present wishes, hopes, and dreams for the future, a future that is better than the present…. [It's] one of my fondest hopes that *Star Trek* may help people see the importance of our present-day exploration of space, not just the possibility of contact with alien intelligences but in a myriad of benefits far closer to home…."

"Space exploration helps us to better understand both our home planet and our neighbors in our solar system…." On the Enterprise, "science preserves, not destroys humanity…. The Enterprise is a symbol…of what it means to imagine, to dream, to create a future…."

"What really is *Star Trek*?" One answer is that it's our twentieth-century mythology. Another answer is that "it's 79 episodes of a television show made for the purpose of selling soap and toothpaste…. You and I really know it was more than that. It had a message…." Gene Roddenberry once claimed that he wanted his epitaph to say: "He loved humanity."

"If there's anything that characterizes *Star Trek*, it's the celebration of infinite diversity and infinite combinations…. If we cannot appreciate the small variations between our own kind here on Earth," we'll be in trouble when we get out into space. Gene Roddenberry "knew that there would be wonders in our future, not just the wonders of technology [but] the marvels of human evolution. He believed in the greatness of the human spirit, our sense of discovery, our ability to go beyond the limitations of the present into a glorious future…."

Quoting her late husband, Roddenberry said in conclusion, "Why are we now traveling into space? Why indeed did we trouble to look past the next mountain?"

Author **John Calvin Batchelor** offered the judgment that "big space" programs are now history. "It's over…. Folks, NASA, it's over, it's done—the conquest thing, the thrust thing, the go-no-go thing, the translunar trajectory thing, the splashdown thing, it's over, done, good-bye, it's not coming back, it's gone." People in the White House are now telling NASA it must learn to be "nimble and adaptable," he said; what they mean is "turn out the lights, have a nice life, you're out of here…."

"What do I think of NASA? … I think of the moon landing as *Moby Dick*, and I think of where we are right now as the end of *Moby Dick*. The pursuit of *Moby Dick* had no value," Batchelor said. "Ahab wanted to do it, the 'Pequod' was signed on to do it…. Ahab used his masters…to get what he wanted. He lied to them. He said he was going out to make them money…. He went out to kill *Moby Dick*—of no economic value whatsoever…. Well, that's the moon landing to me…. When I get around to thinking literally about the moon landing, I get stuck on *Moby Dick*, and I can't get past it…. You put a lance in its heart and it goes to the bottom of the ocean and it never comes up. That's not what I want to tell [you]."

Instead, "I'm going to talk about the value of space

travel very specifically, for my family"—a four-year-old son and one-year-old daughter. "What is the value to them?" Before he left home, he said, he showed his children the moon in the sky and said he was going off to talk about the moon landing, adding that "[cartoon character] Rita Repulsa lives on the moon." So "what is the value of space travel to my family? I can explain where Daddy's going on the basis of the moon…. This is the power of imagination, it's the power of the moon…." NASA is responsible for making the moon an accessible place, even a fun place, and thus NASA is "partly to blame for Rita Repulsa…. The moon is right there, and she can live there…."

But for his own generation, Batchelor said, "1969 was not all Rita Repulsa and the Moon and 'we win'; 1969 was also another acronym, 'MACV', Military Assistance Command, Vietnam…. Vietnam was part of NASA for me, it was the same thing, it was the same war. It's not possible now for me to lie to myself [and] say 'the Moon was good, Vietnam was bad, therefore I don't have to think about Vietnam when I think about the Moon'…I don't do it that way."

"So soon enough…I want to explain to [my children] that landing on the Moon was tough, and it was a tough time for me to be happy about it, because the same people who were landing on the Moon, as far as I was concerned at 21 years old, were fully intending to draft me…. And the value of space travel to my family will be forever caught up in the fact that politics are not simple, and nostalgia, which I would argue is the willful distortion of history…does not permit me…to forget Vietnam…."

Ultimately, he said, while he was able to talk to his children about the Moon landing, he was unable to explain what the space exploration symposium was all about. Having sat through two days of proceedings, he'd decided that he would not be able to explain it to them after the fact, either "We're not getting our message across. Not explaining 'what is the value of space travel?' to a four-year-old is a failure for NASA. It's a failure for me, it's a failure for everyone who wants to get involved in this talk about where the heck we're going. You've got to be able to have something to say to a four-year-old and a one-year-old because there are very few things that are certain, but one of them is that they're going to run this bloody place when we need them to take care of us. So if we're not getting through to them, I don't blame them for not trying to take care of us some day…."

Fifty years from now, "what am I going to say to [my children] about the moon…? When I tell them what was NASA about, why was I there 50 years ago today, what was I doing…well, I'm going to say this: I'm going to say that it was necessary, 50 years ago, for us to accept that it was over That that's part of growing up, to accept that things are finished: end of relationships, end of marriages, end of love affairs…that it was over, and it didn't hurt, nobody died, and now it's 50 years later, and you see how it worked out…."

"Fifty years from now, I'm going to say this: that anything's possible…. There's definitely, distinctly, I promise you, children, more fun ahead than there ever has been behind, so stop me from worrying about losing what I've had, there's more ahead, relax. I'm going to say that we should have seen, in 1994, that the way back to the moon, the way to Mars…was to stop planning, stop funding, stop hoping, stop dreaming. Stop it. Relax. That was the way to do it," he said.

"That's why NASA 50 years from now will be the success that we cannot imagine, because it's impossible to stop all those things, isn't it…? If I say to NASA, 'Go away, just leave…do us a favor, cut the budget by one percent, go home, have a life'—well, you're not moving…."

"Back to *Moby Dick*…. Ahab…kills *Moby Dick*…. By the end of the novel…Ahab goes away, the 'Pequod' goes down, and our hero Ishmael is left floating on that coffin, and a ship picks him up…. Melville says the 'Pequod' was never seen again, and all of her crew, all of her dreams, all gone, along with *Moby Dick*.

"I don't think that it's very far-fetched for me to say that if NASA was never seen again, if the Moon landing was never seen again…all that enterprise would still be as momentous an assignment to every high school student, forever, as *Moby Dick* is now…. It's the same with NASA. We can kill you, we can send you to the bottom of the ocean…we'll still have to deal with you forever. And if you don't think that's victory, you haven't checked recently."

Session 6:
Questions & Answers

Q: "To a great extent, people have described the Apollo program as the golden age of NASA, the golden age of space exploration," an audience member commented. "In reality, being jammed inside of something a little larger than a Volkswagen, eating out of tin cans and squeeze tubes, really wasn't all that golden. To me the golden age of space flight will be when you have fat guys in polyester suits smoking cigars en route to their destinations. When Charles Lindbergh was flying across the Atlantic, that was described as the golden age of flight. But to me, a 747 to California is really pretty gold-plated. It's much more comfortable, at least. I was wondering if any of you want to comment on that. Maybe we're dreaming about a sort of pioneering era, maybe we should really be looking at a more developed future."

A: Gabrynowicz responded by referring to the Advanced Telecommunication Satellite, a program that was supposed to demonstrate advanced satellite communication capability. Despite the Administrations' attempts to cut it, she said, Congress continually funded it because it was seen as telecommunications rather than space, and telecommunications makes money. "I think that's exactly the sort of thing we want to happen," she continued. "We want space to become so successful, so ubiquitous, so much a part of everyday life—like weather satellites, communication satellites—that it does become normal and it gets funded and it gets supported and it becomes part of human life."

"That's part of what we're struggling with today, because if we can only tell Congress and the American people that this is about a fantasy, a golden age of discovery, that's not enough. It is that, and more. We have to find a way to keep that fantasy alive and make it normal at the same time."

Q: Steve Fogelman commented on the conflict between NASA's need to compete for scarce financial resources and the ideal that "we should be visionaries and dreamers." He said that some would say Apollo was a "crash program" which we should not repeat. Rather, they say, we should go forward in a very evolutionary, systematic, classical engineering approach. "Should NASA proceed in an evolutionary manner or in an expeditious manner?"

A: Gabrynowicz said that though Apollo was a crash program, we have to be "very honest about what drove the space program during the Cold War: fear. We were afraid of the Soviets, the Soviets were afraid of us. But fear is a very short-term phenomenon. It wears people out. And every time you want to get them to do something again, if you're going to base it on fear, you have to get them more scared than they were the last time. Eventually, they stop playing that game. One of the things we have to do is find a relevant basis for our space program and our space activities that are not fear-based. I'll take the risk of sounding like one of those touchy-feely people that somebody alluded to this morning, but we have a lot of things that we can do out of love in space activities. We can love the planet, we can love exploration, we can love the adventure, we can love leaving knowledge to our descendants, and we need to use that word. Nobody would use the word fear during the Apollo era because then it showed we were weak. I think we just need to get real honest about that."

Closing Keynote Address

Daniel S. Goldin
Administrator
National Aeronautics and Space Administration

NASA Administrator **Daniel Goldin** began his closing keynote address with a quote from President Theodore Roosevelt: "Far better it is to dare mighty things, to win glorious triumphs even though checkered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much because they live in the great twilight that knows not victory nor defeat."

"I think that's what exploration is all about," he said. "It's a combination of things. It's a little science, it's a little inspiration, but most of all, exploration is doing very risky things without guaranteed results, and sometimes it's difficult to put down on a sheet of paper all the rationale for doing it. We sometimes intellectualize too much, and when we intellectualize too much we sometimes go down the wrong streets, we try and grab on to what might be popular to sell a program, and that isn't what we want to do. We really want to keep in mind what Teddy Roosevelt said, because when you go to the frontier, you don't know what the payoff will be…and that's okay, that's what life's about. I really look upon exploration as intellectual nourishment."

Our society is focused on the present, always in a hurry, he observed. "But as we go into time compression, we lose sight of the horizon, and we focus our attention toward surviving in the present, and we have to get very pragmatic…. In the process of doing that, we may be doing society a disservice. So we've got to keep our eyes focused on the horizon and understand that intellectual nourishment is something we shouldn't apologize for…. Life would be very dull if all we do is try to survive…."

Americans spend billions and billions of dollars every year on beer, pornography, and other nonnecessities, Goldin noted. "Then there's a tremendous focus on that quarter of a percent of the gross national product that looks out into the future" that is, NASA's budget. "I think about it as an investment in the future for our children, to explore the unknown for them. But the children never get a vote, the adults get to vote, so the adults make sure the lion's share of the resources of the nation go into protecting the adults…. The fact of the matter is, our first priority in the expenditure of funds is to survive…."

"If you take a look at the federal budget in 1965, we spent five percent…on non-defense R&D, and now we're down to two percent…. I submit, soccer is fine, Superbowls are fine, but if we train our children that recreation and entertainment are the industries of the future in America…, and if our children are going to spend their lives on video games and watching TV and thinking about consumption…and worshipping people who are not necessarily adding value, we have to rethink where we're going," he said. "We don't have to apologize for the space program. We ought to set our goals on doing bold and noble things…and we ought to have some failures…."

Some think the loss of the Challenger crew was too great a cost for exploration, but astronauts lost their lives in the Apollo program, and yet we went on to the moon. "As we reflect on Apollo, we reflect only on the real positive things that happened and forget the failures." Apollo showed America's genius in high technology, Goldin said. "The brilliance is [still] there, and… NASA will take the…public as far and as fast and as high as they want to go."

"We're a reflection of America. We are not going to do anything the American public doesn't want to do, and if America is in the intellectual doldrums, our space program reflects that. For about 20 years, America was in the intellectual doldrums. We had the Vietnam war, and we lost our bearings. The world was changing, the Soviet Union was coming apart. We were focusing on the weapons of war, and we lost sight that there were other things, and NASA…drifted into a program that was based upon sowing the seeds, not eating the fruit. So we focused on the jobs that went into the program, and how could NASA spread those jobs around the country to guarantee continuity…. We're now coming out of those doldrums…[and] gaining a sense of purpose again…."

"So we have great possibilities" in space, but right now we have to consider "what's the appropriate mix of human and robotic spacecraft? … [H]ow will space benefit the quality of life? … [H]ow much can we afford? Right now NASA is preparing for the next logical step, and…America ought to have consensus on what the next great move ought to be…."

Several issues warrant consideration in identifying the next logical step in space, Goldin said. First, beating the Russians is no longer a goal for the space program; now "relevance is the key word, relevance to what the future will bring, and to be an innovation tool…. The second principle I think we have to go by is 'less is more'." We should be judging the value of the space program by "what [we are] delivering, not how much [we are] getting…. It's not the seeds you sow but the fruits you bear that count in the end…. We cannot do things that are so big that it takes decades to complete them…. If we go forward with a new program, it should not be two or three decades, it should be no more than two presidential terms…. We could do anything in eight years…."

Third, revolution should be an option for future programs, he said. "Don't just limit yourself to evolution…. It would be better to lose the program by doing revolutionary things and having failure than perpetuating mediocrity…. So we're going to push to do more revolutionary things, and we're going to have failures…. When you go to the edge, you could have technical failure, corporate failure, personal failure, sometimes loss of life, and America should be strong enough and resilient enough so we shouldn't…search for the guilty and punish them. If we have a failure, what we want to do is say, let's find out the cause of the failure, let's go fix [it]…." If we insist on punishing people for failure, "we send a chilling message to our children that [is] going to turn them into vegetables faster…."

Another issue is that NASA has a peer review system, but it is governed by those who are already a part of the space community. "It almost guarantees that you will lop off the new ideas. It guarantees some level…of technical excellence in the details, but it may be mediocrity in the concepts. It prevents women and minorities from entering in…. We have to change and open up the whole process to allow new places, new faces, and revolutionary new ideas. Then…we have to communicate, communicate, communicate the relevance of the program…. Public sentiments are that 'in our hearts we love the space program, but we need you to communicate with us'," Goldin said. "We haven't collectively done this job—the scientists, the engineers…."

Turning to the long-term goal of human exploration of the planets, Goldin cited some basic conditions that must be met in order to reach that goal. First, "we have to understand how humans could live and work efficiently and safely in space…." Second, we cannot go alone; human exploration will have to be a collaborative enterprise. Third, "we must master the technologies that meet [the] 'less is more' [criterion]. We have to have system concepts, we have to have technologies that allow us to do it in eight years [and for] an order of magnitude less money."

In the current fiscal environment, "NASA is not going to get four percent of the national budget…. In the glory days, we did Apollo…to beat the Russians, not for science…and we spent four percent of the federal budget to do it…. We can't go to the American people [today], given all the problems in America today, and say 'we've got to go off to Mars because we want to go explore.' I think we have to be responsible and be part of the solution, not the problem. So given that we're going to live with…one percent of the federal budget, we've got to utilize the brilliance that we have, and the teamwork that we have, to do it [for] less…."

In addition, "we need precursor missions with robots…. We have to learn how to live off the land by generating fuels, perhaps on asteroids [or] on Mars," he said, adding, "we need a spacecraft on a chip. We have to have the technology down to the point that by the year 2000, we could do a low-cost sample return mission to an asteroid, or perhaps even Mars, for hundreds of millions, not billions. The technology is available if we have the courage to do the right things…. By the year 1998, 2000, we could literally have an armada of small spacecraft that could do the lion's share of the missions…." For current missions to the outer planets, he noted, "we're using 20- to 30-year-old technology…. It's unconscionable…. It's not a question of money" but a question of risks. "NASA exists to be innovative, inspirational," he asserted; and the agency should be signaling researchers in academia, industry, and inhouse that failure is not unacceptable. "When people fail, we've got to reward them, and tell them…'thank you for trying', not, 'you've failed, I'm going to destroy your career'."

Goldin suggested that "maybe a little less than a third of the budget ought to go to science…maybe a little bit more than a third…into human exploration—but *bold* human exploration, not just circling the Earth. We've got to get out of Earth's orbit…." Another third should go toward technology and infrastructure and communi-

cations. "Less than one percent of the federal budget, I think, would be awfully good" as a steady diet for the civil space program.

In closing, Goldin concluded, the value of space exploration lies in sustaining hope for the future—"hope is what NASA is all about."

Closing Keynote:
Questions & Answers

Q: "Mr. Goldin, this is the first time I've heard you talk about bold human exploration, not just circling the Earth," said Carl Sagan. "Where do you think we ought to go?"

A: "First let me say that where we go is probably not as important as setting up a process that involves a cross section of America in figuring out where we go," Goldin responded. "Second, we should have a very simple unifying vision. Saying that as a condition because I wouldn't want anyone to feel I'm being presumptuous in selecting a site—there are a whole host of possibilities."

"I'll admit one of my favorites is an astrophysical laboratory on the moon." It would present a tremendous opportunity to obtain a high-resolution picture of a planet and the appropriate analysis that goes along with it.

"Another fascinating possibility is Mars," Goldin continued. "Mars lures us because it might give us some clue about finding some ancient form of fossilized life. It would change how we feel about who we are and what we are. It would even be more wonderful if we found subsurface water on Mars because that would allow us to do much more robust, live-off-the-land exploration. Then clearly there is the whole issue of asteroids. If we could find an asteroid that has some reasonable content of water, that might be a great space station. I don't really care which it is. What's more important is that we interact not with the space community, but with a broad cross-section of America."

Goldin said one of his proudest moments was when the House of Representatives voted for the space station. "I think it was a vote of confidence that NASA was on track," he said. "We got a large percentage of the black and Hispanic caucus and we got a lot of people that had nothing to do with the space program to switch their votes. These are the people we have to engage because the future in this country is not going to be white middle-aged males. It's going to be women, it's going to be African Americans, Hispanic Americans, Asian Americans, Native Americans. These are the people that are going to form a large part of the work force—if they don't participate in the vision and it doesn't satisfy their needs, it won't be there. So, to me, the most important feature is not where we go, but how we decide how to get there. We don't have to make this decision today or tomorrow. It isn't necessary. We have time."

Q: Tim Eastman of the University of Maryland then asked what percentage of NASA's budget is used for data analysis.

A: While Goldin didn't know the exact figures off hand, he said that "even in the good old days, we had too many people in mission operations and not enough in data analysis. In mission operations and data analysis, we ought to approach a robust budget where mission operations approaches zero in the limit and data analysis approaches 100%. Now, space science has a budget of $1.6 billion. I think almost $800 million is mission operation and data analysis. That's appalling. What we're doing is living off past achievements and we're not blazing new trails. Data analysis is important, but we have a very, very bad situation in that a lot of people who perform data analysis deeply believe what they do is the most important thing that's going on. You almost can't shut anything down because if the NASA team wants to shut something down, the 'science community' goes to Congress and it gets turned back on. What's happening is the mission operation and data analysis budget of space science continues to grow and the investment account shrinks. So we don't get new places, new faces and new ideas. If we get a real agile peer review, not the existing peer review, I think we may get a better balance. I can get you the exact numbers if you'd like, but I wanted to put those conditions on it."

Q: Following Goldin's last comment about data analysis, Joanne Gabrynowicz asked how he saw the ground component, the Earth Observing System Data Information System (EOSDIS), and the mission to Planet Earth unfolding. "How do we move, if we do, from this to international systems?"

A: Goldin explained that EOS is a constellation of satellites being put into place in an attempt to try to understand the Earth's environment. "We're trying to find some cohesive way of bringing the data down, processing it, making it user-friendly, and literally making it available to anyone who wants it," he said. "There are 500 NASA scientists and roughly 10,000 other scientists and about a billion people that are interested in this data."

"One of the problems with EOSDIS is it was focused on those that planted and nourished the seeds, not those that eat the fruit. We're going through trauma on the system right now because we want the system to be available to all. It is a struggle, it is a battle.

"Let me a get little controversial. The scientists have got to understand they don't run the NASA program. The American people run it, and the scientists have to develop a consciousness that they owe them, that they are working for the American people. That's part of the problem in the design of the EOSDIS systems. I have some high-level concerns and I hope we make it through. We're on the right track. We're getting it more distributed, we're getting it more compatible with new technology. But I have some very serious misgivings.

"The President has asked us to cut our budget, and the interesting thing is the budget's coming down, and each community in NASA that sows the seeds and doesn't eat the fruit argues we need more money. The Earth and space scientists say they need more money. The aeromission says they need more money. We need more money for research and analysis but they all say their missions are so much more important than the others that their budget must go up and the other budgets must go down.

"The American people aren't going to put up with this. We have to live with a declining budget for the next five years. But I want to tell you, our budget is 30% leaner and we have a better program with more new starts now than we did just a few years ago. So, I'm not lecturing. I'm pleading with the scientists to let go of the bat. Let's redistribute the resources and recognize your science work is important, but what's more important is the people that get the product."

Q: "You said that we could do anything in eight years," commented an audience member. "If by some miracle the American people or Congress decide we want a human mission to Mars, is it realistic to think we could do it in eight years? Regardless of what that answer might be, why not entertain longer planning cycles and possible budget cycles?"

A: Goldin replied you have to deal with the political reality. If you reach beyond two presidential terms, you lose the coherency of your mission. "The Romans took four centuries to build 50,000 miles of highways," he said. "We took only four decades. Remember, there's time compression going on. There's no excuse for why it should take three decades to go to Mars besides a great jobs program, big contracts, and job continuity. We don't owe anyone anything on job continuity. We owe the American public results. We have the capability. There's no reason we can't do it."

"Now, I don't think we could start it right now because we still have to figure out how people could live and work in space. There's no reason to go blasting off for Mars today. We have to learn to work and play well with others. We have to develop technologies and concepts. Time is a very precious commodity. You can only make withdrawals on it.

"I submit in the remainder of the decade we could solve the technology problems. We don't have to spend tens of billions to do it. There are system concepts that we could work on. So there is no excuse that we couldn't do it in eight years. None. I don't see that it has to be twenty, thirty years. It's unhealthy for the people working on the job to take two or three decades, and the American public won't tolerate it. That's just my sense. Maybe someone else has a better idea. I really thank you for your patience. Sometimes I come across a little harsh, but I'm trying to raise some issues that are limiting our ability to soar into the heavens and I hope you've taken it in a positive sense."

July 18-19, 1994
"What is the Value of Space Exploration?"
Symposium

Speakers

Gilbert M. Grosvenor has been President of the National Geographic Society since 1980 and Chairman of the Board since 1987. The Society, founded in 1888 with a charter to "increase and diffuse geographic knowledge," now has a membership of 9.4 million. Mr. Grosvenor, a graduate of Yale University, has been with the Society since 1954. He is the fifth-generation member of his family to serve as Society president; his great-grandfather Alexander Graham Bell was the second president.

Robert McCormick Adams was Secretary of the Smithsonian Institution for a decade until his retirement in late 1994. Dr. Adams, who is a member of the National Academy of Sciences and a trustee of the Santa Fe Institute, among other things, chaired the NASA Advisory Council's Exploration Task Force from 1989–92. He earned his Ph.D. from the University of Chicago in 1956 and served as a member of the faculty there until 1984. Dr. Adams now has a book in preparation entitled *Transforming Technology*.

M.R.C. Greenwood is Associate Director for Science at the White House Office of Science and Technology Policy. Dr. Greenwood served as Dean of Graduate Studies at the University of California at Davis from 1989 to 1993. She also has been a professor at Vassar College and Columbia University. She is a member of the National Academy of Sciences' Institute of Medicine. Dr. Greenwood received her Ph.D. from Rockefeller University.

Carl Sagan is David Duncan Professor of Astronomy and Space Sciences and Director of the Laboratory for Planetary Studies at Cornell University. Dr. Sagan is cofounder and president of the Planetary Society and a recipient of the Pulitzer Prize and NASA's *Apollo* Achievement Award, among other honors. He has been a consultant and adviser to NASA since the 1950s, briefed the Apollo astronauts before their flights to the Moon, and was an experimenter on the *Mariner, Viking, Voyager*, and *Galileo* missions.

Roald Z. Sagdeev is Distinguished Professor of Physics at the University of Maryland at College Park. He recently published a book, *The Making of a Soviet Scientist*. During his career in the Soviet Union, Dr. Sagdeev served as science advisor to President Mikhail Gorbachev and director of the Space Research Institute (IKI). Dr. Sagdeev is a recipient of the Tate Medal from the American Institute of Physics. He earned his degree in physics from Moscow State University in 1956.

Richard L. Garwin is IBM Fellow Emeritus at the Thomas J. Watson Research Center in Yorktown Heights, NY. Dr. Garwin joined IBM Corporation in 1952. He is a consultant to the U.S. Government on military technology, arms control, and other matters. Dr. Garwin is a member of the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the Council on Foreign Relations. He earned his Ph.D. in physics from the University of Chicago in 1949.

Stephen Jay Gould is a Comparative Zoologist and the author of books on evolution. Dr. Gould teaches biology, geology, and the history of science at Harvard University. He is a member of the National Academy of Sciences and the recipient of a MacArthur Foundation Prize Fellowship (1981–86). In 1986, the International Platform Association gave him the Glenn T. Seaborg Award for his contributions to public interest in science. Dr. Gould earned his Ph.D. from Columbia University in 1967.

Molly K. Macauley is a Senior Fellow at Resources for the Future, a nonprofit and nonpartisan research institution in Washington, D.C. Dr. Macauley also is a professor of economics at Johns Hopkins University. She directs RFF's research program on economics and policy issues of space, focusing on the relationship between public and private endeavors in U.S. space research, development, and commercial enterprise. Dr. Macauley earned her Ph.D. in economics from Johns Hopkins University.

Daniel F. Burton, Jr. is President of the Council on Competitiveness. Prior to joining the Council in 1987, he was executive director of the Economic Policy Council, UNA-USA. Mr. Burton has edited three books on the global economy, most recently *Vision for the 1990s: U.S. Strategy and the Global Economy*; and he has written numerous articles about the international economy. He is a member of the Council on Foreign Relations. Mr. Burton earned his M.A. in political economy from Columbia University.

W. Bowman Cutter is Deputy Assistant to the President for Economic Policy. In this capacity, Mr. Cutter is responsible for managing the operations of the National Economic Council. In his private sector career, Mr. Cutter was a Senior Partner at Coopers & Lybrand. In the Carter Administration, he served as Executive Associate Director of the Office of Management and Budget. Mr. Cutter holds degrees from Harvard, Oxford, and Princeton Universities.

Patricia Nelson Limerick is a Professor of History at the University of Colorado-Boulder. Dr. Limerick is a noted historian of the American West and an editor of *Trails: Toward a New Western History* (1991). She also is the author of *Desert Passages: Encounters with the American Deserts* (1989) and *The Legacy of Conquest: The Unbroken Past of the American West* (1987). Dr. Limerick earned her Ph.D. in American studies from Yale University.

Valerie Neal is a Curator for Skylab, Space Shuttle, and Spacelab in the Department of Space History at the National Air and Space Museum, where she also serves as space history exhibits coordinator. She joined the Museum in 1989 to develop the "Where Next Columbus?" exhibition. Before joining the Museum, Dr. Neal spent a decade as a writer, editor, and manager, producing more than 50 publications for NASA. She earned her Ph.D. in American studies from the University of Minnesota.

Timothy Ferris is a Professor of Journalism at the University of California-Berkeley and the author of six books, among them *The Mind's Sky* and *Coming of Age in the Milky Way*. He has published widely in *Esquire, Harper's, The New Yorker, Rolling Stone,* and other magazines and newspapers. Mr. Ferris was selected as a candidate for NASA's Journalist in Space Project in 1986. He is now working on two new books, about cosmology and stargazing. Mr. Ferris is a graduate of Northwestern University.

Matthew Masao Matsunaga represents Hawaii's District 9 in the State Senate, where he chairs the Science, Technology, and Economic Development Committee. An attorney with Carlsmith Ball Wichman Murray Case & Ichiki in Honolulu, Senator Matsunaga is also a member of the Democratic National Committee's Asian Pacific American Advisory Council and chairman of the Spark M. Matsunaga Peace Foundation. He earned his law degree from Georgetown University Law Center in 1985.

Jeffrey Mamber is Managing Director of NPO Energia Ltd., the U.S. subsidiary of NPO Energia, Russia's largest aerospace design bureau and the builder of Russian space station hardware. Mr. Mamber, who is based in Alexandria, Virginia, has worked with business and government organizations in the commercial space arena since 1980.

Frederick S. Humphries has been President of Florida A&M University in Tallahassee since 1985. He also has served as president of Tennessee State University in Nashville (1974–85) and professor of chemistry at the University of Minnesota (1966–67) and FAMU. Dr. Humphries is a member of the NAACP and a member of the board of directors of the American Cancer Society. Dr. Humphries earned his Ph.D. in physical chemistry from the University of Pittsburgh in 1964.

James Trefil is Clarence J. Robinson Professor of Physics at George Mason University. Dr. Trefil has written extensively about science for the general public. His books include *Science Matters: Achieving Scientific Literacy* (with Robert Hazen), *A Scientist in the City*, and *The Facts of Life: Science and the Abortion Controversy* (with Harold Morowitz). He is at present working on a college textbook about scientific literacy. Dr. Trefil earned his Ph.D. in theoretical physics from Stanford University.

Charles F. Bolden, Jr. (Colonel, USMC) is Deputy Commandant of Midshipmen at the U.S. Naval Academy. Col. Bolden left NASA in June 1994 after flying four Space Shuttle missions; he joined the astronaut corps in 1980. Col. Bolden graduated from the Naval Academy in 1968 and the U.S. Naval Test Pilot School in Patuxent River, MD, in 1979. He was a combat pilot in Vietnam. Col. Bolden earned his M.S. in systems management from the University of Southern California in 1977.

Priscilla Cortelyou Little is Senior Associate for Gender Research at the American Association of University Women Educational Foundation. Ms. Little has been staff coordinator for the Foundation's K-12 research agenda, including the reports The *AAUW Report: How Schools Shortchange Girls* and *Hostile Hallways: Sexual Harassment in America's Schools*. She is the recipient of the Virginia Women's Forum Woman of the Year award. Ms. Little earned her M.A. from the University of Virginia.

Joanne Irene Gabrynowicz is an Associate Professor in the Department of Space Studies at the University of North Dakota-Grand Forks, where she teaches graduate classes in space law and policy. She writes and speaks regularly on space law and has published a number of papers on the subject. Ms. Gabrynowicz practiced law in New York City for seven years. She holds a J.D. degree from Yeshiva University's Benjamin N. Cardozo School of Law.

Paul Shapter Gray is Director of Environment and Marine Science, Research, and Development for the European Commission, where he is responsible for the direction of European Union-financed environmental research. Mr. Gray has held posts in the chemical and nuclear industry and was operations controller of the OECD Dragon High Temperature Experimental Reactor for eight years. Mr. Gray earned his M.S. from Birmingham University and is a fellow of the Royal Society of Chemistry.

Majel Barrett Roddenberry, "the First Lady of *Star Trek*," starred as Christine Chapel in the original *Star Trek* series and two of the six *Trek* movies. She also has portrayed Lwuxana Troi in *Star Trek: The Next Generation* and *Star Trek: Deep Space Nine*. In her acting career, Ms. Roddenberry has performed on stage and television as well as in films. She earned her degree in theater arts from the University of Miami (Florida) and attended law school for a year before moving to New York to become an actress.

John Calvin Batchelor is the Author of *Peter Nevsky and the True Story of the Russian Moon Landing: A Novel* (1993), *Gordon Liddy is My Muse* (1990), and other books. Mr. Batchelor published his first novel, *The Further Adventures of Halley's Comet*, in 1981. He best explains his work as the secret history of America. Mr. Batchelor graduated from Princeton University in 1970 and from Union Theological Seminary in 1976, with a Master of Divinity degree.

Daniel S. Goldin became the ninth Administrator of NASA in April 1992. Before coming to NASA, Goldin was Vice President and General Manager of the TRW Space & Technology Group. He began his career as a research engineer at NASA's Lewis Research Center in 1962, working on electric propulsion systems for human interplanetary travel. Mr. Goldin earned his B.S. in mechanical engineering from the City College of New York in 1962.