S. HRG. 108–837

NASA: HUMAN SPACE FLIGHT

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

APRIL 2, 2003

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

97–061 PDF WASHINGTON : 2006

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

JOHN McCAIN, Arizona, *Chairman*

TED STEVENS, Alaska	ERNEST F. HOLLINGS, South Carolina
CONRAD BURNS, Montana	DANIEL K. INOUYE, Hawaii
TRENT LOTT, Mississippi	JOHN D. ROCKEFELLER IV, West Virginia
KAY BAILEY HUTCHISON, Texas	JOHN F. KERRY, Massachusetts
OLYMPIA J. SNOWE, Maine	JOHN B. BREAUX, Louisiana
SAM BROWNBACK, Kansas	BYRON L. DORGAN, North Dakota
GORDON SMITH, Oregon	RON WYDEN, Oregon
PETER G. FITZGERALD, Illinois	BARBARA BOXER, California
JOHN ENSIGN, Nevada	BILL NELSON, Florida
GEORGE ALLEN, Virginia	MARIA CANTWELL, Washington
JOHN E. SUNUNU, New Hampshire	FRANK LAUTENBERG, New Jersey

JEANNE BUMPUS, *Republican Staff Director and General Counsel*
ROBERT W. CHAMBERLIN, *Republican Chief Counsel*
KEVIN D. KAYES, *Democratic Staff Director and Chief Counsel*
GREGG ELIAS, *Democratic General Counsel*

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

SAM BROWNBACK, Kansas, *Chairman*

TED STEVENS, Alaska	JOHN B. BREAUX, Louisiana
CONRAD BURNS, Montana	JOHN D. ROCKEFELLER IV, West Virginia
TRENT LOTT, Mississippi	JOHN F. KERRY, Massachusetts
KAY BAILEY HUTCHISON, Texas	BYRON L. DORGAN, North Dakota
JOHN ENSIGN, Nevada	RON WYDEN, Oregon
GEORGE ALLEN, Virginia	BILL NELSON, Florida
JOHN E. SUNUNU, New Hampshire	FRANK LAUTENBERG, New Jersey

CONTENTS

NASA: HUMAN SPACE FLIGHT

WEDNESDAY, APRIL 2, 2003

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:35 p.m. in room SR–253, Russell Senate Office Building, Hon. Sam Brownback, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. SAM BROWNBACK, U.S. SENATOR FROM KANSAS

Senator BROWNBACK. The hearing will come to order.

Thank you all for joining us today. I think we'll be joined by some other members a little bit later on. There's a briefing going on right now by Secretary Rumsfeld that a number of people have gone over to, and I certainly don't blame them. I was tempted, myself, to postpone the hearing for an hour's period of time, but finding an hour during the day is just tough to find. I decided to go ahead and go forward with the hearing. I would anticipate we'll probably be joined by some other members here a little bit later on.

America has consistently proven her leadership in space science and technology. Predominance of America in space came from the charge set forth by President Kennedy to land a man on the moon and return him safely to earth. The technological advances made during the Apollo era were a result of the U.S. space program pushing forward in human space exploration. Today, I hope to take a look back briefly at the recent history of human space exploration, specifically the Space Shuttle, as well as a look forward at what the vision of NASA should be.

This is going to be one of a number of hearings that I anticipate we'll do in this Subcommittee looking at the future of NASA. Moving towards a reauthorization bill for NASA hasn't been done for now some 10 years. Through these hearings I hope to mold together an effective effort to move forward a reauthorization bill for NASA.

Recently, the Shuttle has been a topic of many discussions and debates in the wake of the Columbia Shuttle disaster. As these debates continue, I hope we'll be able to add to that discussion today.

In the wake of the Columbia tragedy and the decision to not replace Columbia, we must take a close look at our efforts in developing the next launch vehicle for NASA. It is imperative that we make our way to space and do so as quickly and as safely as possible. As tempting as it is to accelerate the process of developing our next launch vehicle, we must do so as safely as we possibly can.

I cannot say right now whether more money is the answer to the problems NASA has encountered in their quest for a new launch vehicle. I fully intend to look at the budget of NASA and determine where they are hurting, where they are operating successfully, and where they are involved with projects that could be better accomplished by another agency or by the private sector. I certainly hope that today we can bring to light some of the issues behind the future of human space flight and help determine where NASA needs to go.

When President Kennedy challenged America to send a man to the moon and return him safely to earth by the end of the decade, NASA was sent on a mission in which the only option for the outcome was success. It seems it is going to take that same kind of dedication and determination to successfully accomplish the next step in human space exploration.

The future of the space program is also contingent upon the role that private businesses play in the process. As the government looks at ways to save costs, NASA will have to rely more heavily on private investment and commitments. Spurring competition within the private sector could reduce the pressure on NASA to accomplish everything in space. For example, Trans Orbital, a California company, is working on the first commercial project to the moon. They're calling it the Trailblazer. It is exactly what this country needs right now, someone or something to blaze the trails between the earth and the stars in human exploration.

Currently, NASA and Russia are the only countries successfully launching humans into space. We are continually hearing comments by the Chinese and reports that, as early as October, they, too, will be launching its first astronaut into space. If China does become the third space-faring nation, we are faced with a more complicated and urgent matter here in America.

Today, I hope to learn more about how NASA came to the decision of using the Shuttle and if the Shuttle is the best means of space transportation for the future. Additionally, I'd like our witnesses to comment on the role of human space exploration and the overall goals of NASA. Just a few weeks ago, members of NASA's Advisory Council announced their concerns that NASA's decision to build an orbital space plane lacks vision. I hope that today we can help determine what a vision for human space flight in the U.S. should look like and bring focus where we are currently lacking.

In the days immediately following the Columbia tragedy, I stated that we needed to step back and take a close look at where NASA has been, where they are currently, and where they need to go in the future. That's exactly what we'll be discussing today.

Marcia Smith, with the Congressional Research Service, will talk with us about the fundamental question of, how did we get here. That is, how did the U.S. get to the current point of using the Space Shuttle as our means of transportation to and from space. I welcome her to the Committee and her years of expertise in studying this issue.

Mr. Brian Chase, with the National Space Society, will discuss access to space and human space flight initiatives related to new space transportation systems. Mr. Chase will lay out access to space as the most critical part of any space exploration effort. This is something that the founders of this organization, Dr. Von Braun, would agree with.

And, finally, we'll hear from Dr. Alex Roland, a former NASA historian and current professor at Duke University. Dr. Roland will discuss the flaws of the current space program and present his recommendations on how NASA should proceed with space exploration.

We look forward to hearing from all of our witnesses in this first hearing.

Before we go there, I'd like to turn to my colleague from Louisiana, where I guess KU will be going, but Duke won't. I don't mean to rub it in, Dr. Roland. But to New Orleans on Saturday, we're excited about that. We normally lose to Duke, but we finally got over it this time.

[Laughter.]

Senator BREAUX. Sure. Well, we welcome you to New Orleans, and the team, and wish you the very best. It's going to be a great event.

STATEMENT OF HON. JOHN B. BREAUX, U.S. SENATOR FROM LOUISIANA

Senator BREAUX. I thank you for having this hearing. I think it's timely, and it's important. Hopefully, it will be very informative. I think this country is, indeed, at the crossroads of where we're going to be in the future with regard to exploration of space.

There are many who look at the Space Shuttle's recent disaster as a reason to call for the termination of space exploration. I think that is not a correct conclusion, I think that we obviously need to find out what went wrong. I think NASA and the independent board are looking at that, will find out what happened, and take the necessary steps to correct it.

We will explore space because it is there and because we learn a lot and develop new technology from those efforts, which benefit all of us in ways that we could only dream of a couple of generations ago.

I do think that it's important to have this opportunity to assess where we are, where we're going to be, and what needs to be done. I have no doubt that all the workers and the thousands of employees and contractors that are all part of what we call space exploration will continue to do a remarkable job.

I look forward to the witnesses' testimony.

[The prepared statement of Senator Breaux follows:]

PREPARED STATEMENT OF HON. JOHN B. BREAUX, U.S. SENATOR FROM LOUISIANA

Mr. Chairman, as Ranking Member of the Subcommittee on Science, Technology, and Space, I look forward to working with you this Congress, particularly as the Subcommittee examines issues related to the Space Shuttle Columbia tragedy, NASA, and the future of space flight.

Today, we are at a critical juncture for manned space flight, and perhaps a turning point in its history. I am a strong supporter of human space flight and of the thousands of workers who enable it. Their efforts have taken us to the very edge of what was dreamed possible forty years ago, and to the doorstep of a new era of exploration and development. I have no doubt that the United States will continue to send people to space. However, we must do so with a full acknowledgment of the risks, a commitment to continue to minimize those risks, and a vision for what humans can and should aim to accomplish in space.

The discussion about the future of space which we are beginning today will not come to focus solely on Columbia and its loss. The future of the Space Shuttle has broad implications for the International Space Station—a program in which the United States and its International partners have already made a significant investment. Without the Shuttle, it will be difficult to keep the Station fully supplied and further construction will be halted.

We see and applaud NASA's actions to recover the space agenda. Even as the Columbia Accident Investigation Board continues its work on the causes of the accident, NASA has begun to plan for the Shuttle's return to flight. And there are discussions underway among the international partners, too, on the use and servicing of the Space Station for the foreseeable future. We judge these to be prudent and necessary actions. In addition, and now in parallel to the Columbia investigation, last fall NASA instituted a Service Life Extension Program (SLEP) plan to assure the long term future of the Space Shuttle. This newly implemented annual planning process culminated in a SLEP summit a few weeks ago at which NASA and its human spaceflight stakeholders identified a series of proposed initiatives that they deemed necessary to ensure the Shuttle's ability to effectively support the International Space Station. Finally, this team of senior NASA and industry managers also defined the criteria to be used by the NASA leadership to evaluate the proposed programs and make investment decisions and recommendations necessary to assure the long term viability of the Shuttle.

When the results of the investigation are known, NASA will make any modifications needed to make the Shuttle safer and will consider how it will proceed to complete the assembly and support the crew and logistics needs of the International Space Station. In the mean time, the Agency will need to retain the critical skills of the current Shuttle and Space Station workforces, both inside and outside the agency. For thirty years, these workers have been a critical part of NASA's successes, and they will be needed for the continued success of the human space flight program.

In addition, we must begin planning for a time beyond the current era of the Space Shuttle and Space Station. Although the answer to the question, "Why fly humans in space?" may have required no better response than, "Because it is there", the loss of Columbia chastens each of us to ask the harder questions before us: "At what risk, towards what ends, and in what time frame can we do it safely and securely." Mr. Chairman, I thank you for convening this first of many discussions this Committee will have on this subject over the coming year, and I hope that today's discussion can begin to lay out the agenda we need to pursue in examining these questions.

Senator BROWNBACK. Thank you, Senator Breaux.

First will be Ms. Marcia Smith, specialist in aerospace technology policy from the Congressional Research Service. The floor is yours. Welcome.

STATEMENT OF MARCIA S. SMITH, RESOURCES, SCIENCE AND INDUSTRY DIVISION, CONGRESSIONAL RESEARCH SERVICE

Ms. SMITH. Mr. Chairman, Senator Breaux, thank you for inviting me here today to discuss the history of the human space flight program in the context of the Space Shuttle Columbia accident. I ask that my written statement be made part of the record.

Senator BROWNBACK. Without objection.

Ms. SMITH. You asked that I address the fundamental question of how did we get here. The answer has two components. Why does the United States have a human space flight program? And why did we decide to build the Space Shuttle?

Senator BROWNBACK. Ms. Smith, pull that microphone up a little closer to you, if you would. Thanks.

Ms. SMITH. The dream of people journeying into space has been the lore of science fiction for centuries. By the time Sputnik 1 ushered in the space age in 1957, a cadre of enthusiasts was ready to make such dreams a reality.

Congress passed the National Aeronautics and Space Act in 1958, creating NASA and establishing as one objective the "preservation of the role of the United States as a leader in . . . space science and technology."

In 1959, NASA selected the first group of astronauts, the Mercury 7. Two years later, the first human orbited the earth.

But it was not one of the Mercury 7; instead it was a Soviet cosmonaut, Yuri Gagarin. Gagarin's flight added new impetus to the U.S. program. America's leadership in space science and technology, its international prestige, and, many believed, its national security, were at stake.

Three weeks later, Alan Shepard became the first American in space, but it was a suborbital flight. The United States did not match Gagarin's feat until 10 months later, when John Glenn became the first American in orbit.

The risks were high in those early flights, yet the Nation was willing to accept those risks, and pay the costs, to ensure American preeminence. Indeed, only 3 weeks after Alan Shepard's flight, President Kennedy called on the nation to commit itself to the goal of landing a man on the moon by the end of the decade, and the Nation said yes. Although the space program has changed in many ways since then, human space flight as an indicator of technological preeminence appears to remain a strong factor in its support.

And there are other reasons. President George H. W. Bush, the first President Bush, may have articulated them best in July 1989, when, on the 20th anniversary of the first Apollo lunar landing, he announced a commitment to returning humans to the moon and going on to Mars. He said, "Why the moon? Why Mars? Because it is humanity's destiny to strive, to seek, to find, and because it is America's destiny to lead."

That is not to say that human space flight is without controversy. The debate over the need to send humans into space is as old as the space program itself. And over the past 42 years, little progress seems to have been made in bridging the divide between those who believe human space flight is essential, and those who believe it is a waste of money and an unnecessary risk to human life. Since your other witnesses here this afternoon are going debate that topic, I will not.

Suffice it to say that, to date, the United States and other countries have decided that human space flight *is* worth the costs and the risks. Representatives of 31 countries have traveled into space over the past 42 years on American and Russian spacecraft. And later this year, China is expected to launch its own astronaut into space for the first time.

The next question is, why the Shuttle?

As 1969 dawned and the first Apollo lunar landing neared, President Nixon took office and faced the question of what goals should guide the space program in the post-Apollo years. He established a Space Task Group chaired by Vice President Agnew that developed a plan to build a space station, a reusable space transportation system to service it, and to send humans to Mars.

But after America won the moon race, support for expensive human space missions waned. NASA found that it had to pick just one of those new projects. It chose the reusable space transportation system—the Space Shuttle. One goal of the Shuttle program was to significantly reduce the cost of launching people and cargo into space.

The reusable Space Shuttle was intended to replace all other U.S. launch vehicles, so-called "expendable launch vehicles" that can only be used once. By transferring all space traffic to the Shuttle, NASA projected that the Shuttle's development and operations costs would be amortized over a large number of launches, 48 per year, with resulting cost efficiencies.

Senator BROWNBACK. How many per year?

Ms. SMITH. Forty eight.

Senator BROWNBACK. Per year?

Ms. SMITH. Per year.

Dr. ROLAND. At one time, they said 60.

Ms. SMITH. That premise has not held true, however. The costs were higher, and the flight rate lower. Today, many point to the Shuttle as a technical success but an economic failure.

NASA has initiated several attempts to develop successors to the Shuttle, with the continued goal of reducing costs. Each attempt has failed in turn, in large part because anticipated technological advances did not materialize. Late last year, NASA announced that it would continue operating the Shuttle until at least 2015 and perhaps 2020 or longer. Despite the Columbia tragedy, NASA officials have made clear that plan is unchanged.

Congress is now again assessing the costs and benefits of human space flight. Based on past experience, many expect that the decision will be made to continue the human space flight program essentially unchanged once the cause of the Columbia accident is determined and fixed; but there are a number of options to consider, from returning the Shuttle to flight as soon as possible to terminating the human space flight program entirely. I summarize those options in my written statement and would be happy to discuss them with you if you wish.

Thank you, and I'd be happy to answer any questions that you have.

[The prepared statement of Ms. Smith follows:]

PREPARED STATEMENT OF MARCIA S. SMITH, RESOURCES, SCIENCE AND INDUSTRY DIVISION, CONGRESSIONAL RESEARCH SERVICE

Mr. Chairman, Members of the Subcommittee, thank you for inviting me here today to discuss the history of the human space flight program in the context of the Space Shuttle *Columbia* accident. You asked that I address the fundamental question of "How did we get here?" The answer has two components: Why does the United States have a human space flight program, and why did we decide to build the Space Shuttle? These are complex issues and my brief statement cannot do them justice. But I will try to provide an overview of some of the factors that shaped those decisions in the past, and summarize options as you reassess those decisions for the future.

Why Human Space Flight?

The dream of people journeying into space was the lore of science fiction for centuries. By the time Sputnik 1 ushered in the Space Age on October 4, 1957, a cadre of enthusiasts was ready to make such dreams a reality.

Congress passed the National Aeronautics and Space Act in July 1958, creating NASA and establishing as one objective "the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere." NASA opened its doors on October 1, 1958, and 6 months later the first group of astronauts—the Mercury 7—was selected.

Two years later, on April 12, 1961, the first human orbited the Earth. But it was not one of the Mercury 7. Instead, it was a Soviet cosmonaut, Yuri Gagarin.

Gagarin's flight added new impetus to the U.S. program. America's leadership in space science and technology, its international prestige, and, many believed, its national security, were at stake. Three weeks later, Alan Shepherd became the first American in space, but it was a suborbital flight. The United States did not match Gagarin's feat until 10 months later, when John Glenn became the first American in orbit.

The risks were high in those early flights. We had little experience with launching rockets into space, and with the spacecraft that protected the astronauts. Yet the nation was willing to accept those risks, and pay the cost, to ensure American preeminence. Indeed, only three weeks after Alan Shepard's flight, President Kennedy called on the nation to commit to the goal of landing a man on the Moon by the end of the decade, and the nation said yes. Although the space program has changed in many ways over the past four decades, human space flight as an indicator of technological preeminence appears to remain a strong factor.

Human space flight is risky. It has claimed the lives of 17 American astronauts and four Russian cosmonauts in spaceflight-related accidents so far. [1] While this is a relatively small percentage of the more than 400 people who have made space journeys, their loss is felt deeply. Human space flight also is quite expensive. NASA will spend about $6 billion on the Space Shuttle and Space Station programs in this fiscal year. Yet we persevere. President George H.W. Bush articulated what many consider a guiding impetus. In July 1989, on the 20th anniversary of the first Apollo lunar landing, he stood on the steps of the National Air and Space Museum and announced a commitment to returning humans to the Moon, and going on to Mars. He said:

> Why the Moon? Why Mars? Because it is humanity's destiny to strive, to seek, to find, and because it is America's destiny to lead.

That is not to say that human space flight is without controversy. The debate over the need to send humans into space is as old as the space program itself. Over the past 42 years, little progress seems to have been made in bridging the divide between those who believe human space flight is essential, and those who believe it is a waste of money and an unnecessary risk to human life. The Senate Committee on Aeronautical and Space Sciences—the predecessor to this Subcommittee—held hearings on that debate forty years ago, and little has changed. I know your other witnesses today will resume that dialogue, so I will not devote much of my statement to it. Briefly, critics of human space flight believe that robotic probes can gather the needed scientific data at much less cost, and that humans contribute little to space-based scientific research. They point out that no ground-breaking scientific discoveries have emerged from 42 years of human space flight that can be uniquely attributed to the presence of humans in space. Proponents insist that human ingenuity and adaptability are essential for some types of basic research in space, and can rescue an otherwise doomed mission by recognizing and correcting problems before they lead to failures. While proponents point to the value of "spin-off" technologies that were developed for human space flight but found broader application in medicine or other fields, critics argue that those technologies probably would have been developed in any case. Past economic studies that attempted to quantify the value of spin-offs were criticized because of their methodologies, and critics suggest that investing federal monies in non-space areas might have yielded equally valuable spin-offs or led directly to new scientific knowledge or technologies. The two sides of this debate have been, and remain, quite polarized. To date, the United States and other countries have decided in favor of human space flight, despite its risks and costs.

---

[1] The 17 American astronaut spaceflight-related fatalities counted here include the three Apollo 204 astronauts who were killed in a pre-launch test in 1967. Some sources exclude these astronauts because they were not killed in an actual spaceflight. The table at the end of this statement provides more information on the space tragedies that ended in death: the 1967 Apollo fire (3 deaths), the 1967 Soyuz 1 mission (one), the 1971 Soyuz 11 mission (three), the 1986 Space Shuttle *Challenger* accident (seven), and the 2003 Space Shuttle *Columbia* accident (seven). The *Columbia* accident is also discussed in CRS Report RS21408 and CRS Issue Brief IB93062.

While a desire for preeminence has been one motivation in pursuing human spaceflight, it has not precluded cooperation. Even at the height of U.S.-Soviet space competition in the early days of the Space Race, the United States and Soviet Union also worked together—at the United Nations through the Committee on Peaceful Uses of Outer Space, and through bilateral cooperative agreements as early as 1962. In 1963, President Kennedy proposed that the two countries cooperate in sending astronauts to the Moon, but the Soviets did not accept the offer. Human space flight cooperation between the two countries, and with other countries, grew as the space programs matured.[2] The United States and Soviet Union agreed to a joint docking of a Russian Soyuz and an American Apollo in 1975 to demonstrate "detente in space." The United States brought Canada and the European Space Agency (ESA) into the Space Shuttle program, with Canada building a remote manipulator system ("Canadarm") and ESA building the Spacelab module for conducting scientific experiments in the Shuttle's cargo bay. In 1977, the Soviet Union began launching cosmonauts from allied countries to its space stations, and the United States included representatives of many other countries in Space Shuttle crews beginning in 1983. To date, astronauts and cosmonauts from 29 other countries[3] have journeyed into space on American or Russian spacecraft. And today, of course, 15 nations—the United States, Russia, Canada, Japan, and 11 European countries—are partners in building the International Space Station.

The international landscape has influenced the course of human space flight over these decades. But fundamentally, the desire to pursue such activities seems based on a quest for national technological preeminence and a yearning to explore new frontiers.

Why the Shuttle?

The first decade of the U.S. human space flight program saw the execution of the Mercury, Gemini, and Apollo programs. As 1969 dawned and the first Apollo lunar landing neared, President Nixon took office and faced the question of what goals should guide the space program in the post-Apollo years. He established a "Space Task Group," chaired by Vice President Agnew, to develop recommendations. The group's report laid out a plan that called for developing a space station, a reusable space transportation system to service it, and sending humans to Mars. But after America won the Moon Race with the Apollo 11 landing in July 1969, it became apparent that support for expensive human space missions was waning. Attention turned to other national priorities, and NASA found that it had to pick just one of those new projects. It decided that the first step should be development of the reusable space transportation system—the Space Shuttle. One goal of the Shuttle program was to significantly reduce the cost of launching people and cargo into space. President Nixon announced the Shuttle program in 1972. It was quite controversial in Congress, but ultimately was approved.

The reusable Space Shuttle was intended to replace all other U.S. launch vehicles, so-called "expendable launch vehicles" (ELVs) that can only be used once. By transferring all space traffic to the Shuttle, NASA projected that the Shuttle's development and operations costs would be amortized over a large number of annual launches—48 flights per year— with resulting cost efficiencies.

That premise has not held true, however. The costs were higher than expected, and the annual flight rate much lower. Since 1981 when the Shuttle was first launched, the greatest number of launches in a single year has been nine. One factor in the lower launch rate was policy changes in the aftermath of the 1986 Space Shuttle *Challenger* accident. The Reagan White House reversed the decision to phase out ELVs and announced that, with few exceptions, the Shuttle could be used only for missions requiring the Shuttle's "unique capabilities" such as crew interaction. Commercial communications satellites, expected to comprise a large share of Shuttle launches, no longer could be launched on the Shuttle. While that provided a market for the resurrected ELVs, the effect on the Shuttle program was many fewer launches and a higher cost-per-launch. Today, many point to the Shuttle as an outstanding technical success, but an economic failure.

In the 22 years since the Shuttle's first flight, NASA (sometimes working with DoD) has initiated several attempts to develop a successor to the Shuttle—a "second generation reusable launch vehicle"—with the continued goal of reducing costs.

[2] There has been extensive cooperation in other space activities as well since the beginning of the Space Age.

[3] Afghanistan, Austria, Belgium, Bulgaria, Canada, Cuba, Czechoslovakia, France, Germany, Hungary, India, Israel, Italy, Japan, Kazakhstan, Mexico, Mongolia, Netherlands, Poland, Romania, Saudi Arabia, Slovakia, South Africa, Spain, Switzerland, Syria, Ukraine, United Kingdom, and Vietnam.

Each attempt has failed in turn, in large part because anticipated technological advances did not materialize. Thus, the Shuttle continues to be the sole U.S. vehicle for launching people into space, and the only launch vehicle capable of meeting the International Space Station's requirements for taking cargo up and back. Late last year, NASA again reformulated its plan to develop a successor to the Shuttle, asserting that an economic case could not be made at this time for investing as much as $30–35 billion in such a vehicle. Instead, NASA plans to continue operating the Shuttle until at least 2015 (instead of 2012), and perhaps 2020 or longer.

That decision was made prior to the *Columbia* tragedy, but NASA officials have subsequently made clear that no change is expected. NASA plans to build an "Orbital Space Plane" that could supplement (but not replace) the Shuttle early in the next decade, and there are discussions about potentially flying the Shuttle with as few as two crew members, or perhaps autonomously (without a crew), in the long term future. For the present, however, NASA asserts that the Shuttle is needed to support the International Space Station program, and to service the Hubble Space Telescope.

Options for the Future

In the wake of the *Columbia* tragedy, Congress is again assessing the costs and benefits of human space flight. Congress has faced these questions before—in the early days of the Space Age, after the 1967 Apollo fire that took the lives of three astronauts, after the United States won the "Moon Race", and after the 1986 Space Shuttle *Challenger* tragedy that claimed seven lives. Based on past experience, many expect that the decision will be made to continue the human space flight program essentially unchanged once the cause of the *Columbia* accident is determined and fixed. But there are a number of options to consider, each with its own set of advantages and disadvantages. The major options and some of the associated pros and cons are discussed next.

1. Terminate the U.S. human space flight program, including the Space Shuttle, U.S. participation in the International Space Station (ISS) program, and plans to develop an Orbital Space Plane.

Pros: The annual budget for the Space Shuttle is approximately $4 billion, and for the Space Station is approximately $2 billion. That amount of funding, plus whatever would be spent on the Orbital Space Plane (which is still in the formulation phase) could be saved, or redirected to other space or non-space priorities such as robotic space flight, scientific research, homeland security, or the costs of the Iraqi war. Human lives would not be at risk. Human spaceflight might remain a long term vision.

Cons: To the extent that human space flight is still perceived as a measure of a nation's technological preeminence, that advantage would be lost.[4] Although the United States is the leader of the International Space Station (ISS) program, ISS could continue without U.S. involvement, as long as the other partners had the requisite funds.[5] Thus, the more than $30 billion U.S. investment in the Space Station could be lost for American taxpayers, while the other partners could continue to use it for their own purposes. Without servicing missions by the Space Shuttle, the Hubble Space Telescope might not achieve its scientific potential, and non-Shuttle options for disposing of it at the end of its life would have to be developed.[6] There also could be consequences for the U.S. aerospace industry, particularly Boeing and Lockheed Martin.[7]

Terminate the Shuttle and Orbital Space Plane programs, but continue participation in the ISS program, relying on Russian vehicles for taking U.S. astronauts to and from space when possible.

---

[4] Some would find this ironic at a time when China is about to become only the third country capable of launching people into space. It has launched four test spacecraft as part of that goal; the first launch carrying a Chinese astronaut, or "taikonaut," is expected late this year.

[5] The ISS program is an international partnership among the United States, 11 European countries, Japan, Canada, and Russia. The Russians have three decades of experience in operating space stations without a Space Shuttle. Most of the remaining segments of the Space Station are designed to be launched on the Shuttle, so construction would remain stalled until and unless some other launch vehicle becomes available to launch the remaining segments, but operation of the existing space station could continue using Russian Soyuz and Progress spacecraft if funds are available.

[6] At least one more servicing mission is planned in 2004 to enable the telescope to operate until 2010. At that time, NASA plans to use the Shuttle to return the telescope to Earth because it does not want it to make an uncontrolled reentry into the Earth's atmosphere. Such a reentry could pose hazards from falling debris.

[7] The two companies operate the Space Shuttle (under a joint venture called United Space Alliance). Boeing is also the prime contractor for the Space Station program.

Pros: The annual budget for the Space Shuttle is approximately $4 billion, so that amount of funding, plus whatever would be spent on OSP, could be saved or redirected to other space or non-space priorities (as above). The lives of fewer astronauts would be at risk. Compared to Option 1, this would leave open the possibility of U.S. use of the Space Station whenever NASA could obtain flight opportunities on Russia's Soyuz spacecraft.

Cons: Similar to Option 1, but if the United States wanted to continue using ISS, it would need to work with the other partners to solve the problem of how to deliver cargo to and return it from ISS.[8] If only the Soyuz spacecraft is used to take crews to and from the Space Station, agreements would have to be reached with Russia on how often American astronauts would be included in the Space Station crews and how much it would cost.[9] The issues related to the Hubble Space Telescope and the U.S. aerospace industry (discussed above) would remain.

3. Terminate the Shuttle program, but continue participation in the ISS program and continue to develop the Orbital Space Plane or another replacement for the Shuttle.

Pros: The annual budget for the Space Shuttle is approximately $4 billion, so that amount of funding could be saved, or redirected to other space or non-space priorities (as above). Costs for developing and operating an Orbital Space Plane or a successor to the Shuttle are not yet known, however, so there might not be any net savings over the long term. A new vehicle might be safer and more cost effective.

Cons: The disadvantages of this option would be similar to those for Option 2, except that at some point in the future, a U.S. human space flight vehicle would become operational, ameliorating questions about access to the Space Station by American crews.

4. Continue the Shuttle program, but with fewer missions—perhaps limiting it to space station visits—and as few crew as possible.

Pros: Would limit the risk to Shuttle crews. If the Space Station was equipped with a system to inspect the Shuttle prior to undocking,[10] problems could be identified and possibly repaired. Continues U.S. leadership in space and any resulting benefits therefrom.

Cons: There would be little, if any, financial savings from this option.[11] Astronaut lives would remain at risk. The question of what to do with the Hubble Space Telescope (discussed above) would remain if flights were limited only to space station visits.

5. Resume Shuttle flights as planned.

Pros: Allows construction and utilization of the Space Station to continue as planned. Allows the Hubble Space Telescope to be serviced and returned to Earth. Continues U.S. leadership in space and any resulting benefits therefrom.

Cons: There would be no financial savings, and costs would be incurred to fix the Shuttle. The risk to human life would remain.

Options 4 and 5 could be coupled with directives to NASA to:

- equip the Space Station with a system that could inspect the Shuttle while it is docked;

---

[8] Vehicles other than the Shuttle are available, or are expected to become available in the next few years, to take cargo to the Space Station, but none can bring cargo back to Earth. Russia's Progress spacecraft is the only other cargo craft available today. Russia has indicated that it cannot afford to build more than about three per year, however, which is insufficient to resupply even a two-person crew (this problem is being addressed currently). Under the Iran Nonproliferation Act, NASA is prohibited from making payments to Russia in connection with the Space Station program unless the President certifies that Russia is not proliferating certain technologies to Iran. Without such a certification, NASA could not pay Russia for Progress flights. Europe and Japan are both developing spacecraft that will be able to take cargo to the Space Station, but they will not be available for several years, and cannot return cargo to Earth. U.S. expendable launch vehicles potentially could be used to take cargo to the Space Station, although a cargo spacecraft equipped with autonomous rendezvous and docking systems would have to be developed. These also probably would not be able to return cargo to Earth.

[9] The Iran Nonproliferation Act (discussed in the previous footnote) would also prohibit U.S. payments to Russia for Soyuz flights unless the President certifies that Russia is complying with the Act.

[10] This would be in addition to inspections that could be accomplished using Department of Defense ground- and space-based sensors.

[11] There are only two non-space station missions on the Shuttle's schedule today, both to the Hubble Space Telescope. At NASA's current estimate of the marginal cost of a Shuttle launch ($115 million), that would save only $230 million. The costs for fixing the problems that caused the *Columbia* accident are unknown, but seem likely to exceed that amount.

- upgrade the Shuttle to make it safer, perhaps including additional crew escape systems or making the crew cabin survivable if the vehicle breaks apart;
- develop systems to enable the Shuttles to fly autonomously (without a crew); and/or
- accelerate efforts to build a successor to the Shuttle with the emphasis on improved safety, even if that meant not reducing costs as much as desired.

Summary

Mr. Chairman, as I said, this brief statement provides only a cursory review of these complex issues. As the world readies to celebrate the 42nd anniversary of Yuri Gagarin's historic flight 10 days from now, the future of the U.S. human space flight program is in question. Apart from the broad questions of whether the U.S. human space flight program should continue, a more specific focus may be the cost of returning the Shuttle to flight status and how long it will take. Those answers will not be known until the cause of the *Columbia* accident is determined, and remedies identified. If the costs are high, difficult decisions may be needed on whether to use the funds for the Shuttle, for other space initiatives, or for other national priorities such as paying for the Iraqi war and homeland security. While many expect that the United States will once again rally behind NASA, only time will tell if the past is prologue.

BRIEF HISTORY OF HUMAN SPACE FLIGHT: 1961–2003

United States

Mercury (1961–1963)

Purpose: To demonstrate that humans can travel into space and return safely.

Flights: Six flights (two suborbital, four orbital). Alan Shepard, first American in space (on suborbital flight), May 5, 1961. John Glenn, first American in orbit, Feb. 20, 1962.

Gemini (1965–1966)

Purpose: To prepare for lunar missions by extending the duration of spaceflight (to 14 days), developing experience in rendezvous and docking, and demonstrating ability to work outside the spacecraft (extravehicular activity—EVA)

Flights: 10 flights. Ed White conducted first U.S. EVA (June 1965).

Apollo Lunar Program (1967–1972)

Purpose: To land men on the Moon and return them safely to Earth.

Flights: Eleven flights, nine to the Moon. Of the nine, two (Apollo 8 and 10) were test flights that did not attempt to land, one (Apollo 13) suffered an in-flight failure and the crew narrowly averted tragedy and were able to return to Earth, and six (Apollo 11, 12, 14, 15, 16, and 17) landed two-man teams on the lunar surface. Neil Armstrong and Buzz Aldrin were the first humans to set foot on the Moon on July 20, 1969, while Mike Collins orbited overhead.

Space Tragedy The Apollo program saw the first spaceflight-related tragedy when the three-man crew (Gus Grissom, Ed White, and Roger Chaffee) of the first Apollo mission was killed on January 27, 1967, when fire erupted in the Apollo command module during a pre-launch test. The Apollo program resumed flights 21 months later.

Skylab (1973–1974)

Purpose: First U.S. Space Station

Flights: The Skylab Space Station was launched in May 1973. Three three-person crews were launched to Skylab using Apollo capsules from 1973 to 1974, extending the duration of human space flight to a new record of 84 days. A wide variety of scientific experiments were conducted. Skylab was not intended to be permanently occupied. It remained in orbit, unoccupied, until 1979 when it made an uncontrolled reentry into the Earth's atmosphere, raining debris on western Australia and the Indian Ocean.

Apollo-Soyuz Test Project (1975)

Purpose: Cooperation with the Soviet Union.

Flight: A three-man Apollo crew docked with a two-man Soyuz crew for two days of joint experiments to demonstrate "detente in space." This was the last flight in the Apollo series. No Americans journeyed into space for the next six years while waiting for the debut of the Space Shuttle.

Space Shuttle (1981–present)

Purpose: Reusable launch vehicle for taking crews and cargo to and from Earth orbit.

Flights: *Pre-Challenger*. Twenty four successful Shuttle missions were launched from 1981–1986. The Shuttles were used to take satellites into space; retrieve malfunctioning satellites (using "Canadarm," a remote manipulator system built by Canada); and conduct scientific experiments (particularly using the Spacelab module built by the European Space Agency). Sally Ride became the first American woman in space in 1983, Guion Bluford became the first African American in space in 1983, and Kathy Sullivan became the first American woman to perform an EVA in 1984. Senator Jake Garn and then-Representative (now Senator) Bill Nelson made Shuttle flights in 1985 and 1986 respectively.

Space Tragedy: On January 28, 1986, the Space Shuttle *Challenger* exploded 73 seconds after launch when an "O-ring" in a Solid Rocket Booster failed. All seven astronauts aboard were killed: Francis (Dick) Scobee, Mike Smith, Judy Resnik, Ellison Onizuka, Ron McNair, Gregory Jarvis, and Christa McAuliffe (a schoolteacher). The Space Shuttle returned to flight 32 months later.

Post-Challenger. From September 1988–January 2003, the Shuttle made 87 successful flights. Nine of these docked with the Russian Space Station Mir. Since 1998, most Shuttle flights have been devoted to construction of the International Space Station.

Space Tragedy: On February 1, 2003, the Space Shuttle *Columbia* broke apart as it returned to Earth from a 16-day scientific mission in Earth orbit. All seven astronauts aboard were killed: Rick Husband, William McCool, Michael Anderson, David Brown, Kalpana Chawla, Laurel Clark, and Ilan Ramon, an Israeli. The cause of the accident is under investigation.

International Space Station (1998–present)

Purpose: Space Station

Flights: The United States initiated the Space Station program in 1984. In 1988, nine European countries (now eleven), Canada, and Japan formally became partners with the United States in building it. In 1993, the program was restructured due to cost growth, and Russia joined the program as a partner. Construction began in 1998 and is currently suspended pending the Space Shuttle's return to flight. Successive three-person crews have permanently occupied ISS since November 2000. The three-person crews are alternately composed of two Russians and one American, or two Americans and one Russian. ISS is routinely visited by other astronauts on Russian Soyuz spacecraft or the Space Shuttle (prior to the *Columbia* accident) some of whom are from other countries.

Soviet Union/Russia

Vostok (1961–1963)

Purpose: To demonstrate that humans can travel into space and return safely.

Flights: Six flights (all orbital). Yuri Gagarin, first man in space (made one orbit of the Earth), Apr. 12, 1961. Valentina Tereshkova, first woman in space, June 16, 1963.

Voskhod (1964–1965)

Purpose: Modified Vostok spacecraft used to achieve two more space "firsts": first multi-person crew, and first EVA.

Flights: Two flights. Vokhod 1 carried three-person crew. On Voskhod 2, Alexei Leonov performed the first EVA (March 1965).

Soyuz (1967–present)

Purpose: To develop a spacecraft for taking crews back and forth to Earth orbit. Early flights extended the duration of human space flight (to 18 days) and practiced rendezvous and docking. Flights since Soyuz 10 (1971) have been largely devoted to taking crews back and forth to Soviet Space Stations (Salyut and Mir, see below), and to the International Space Station.

Flights: The Soyuz is still in use today, although it has been modified several times. The original Soyuz was replaced by Soyuz T in 1980, by Soyuz TM in 1987, and by Soyuz TMA in 2002. There were 40 flights of Soyuz, 15 of Soyuz T, 34 of Soyuz TM, and one flight of Soyuz TMA to date. (A few of these missions did not carry crews.)

Space Tragedy: The Soyuz program saw the first Soviet space tragedy when Vladimir Komarov was killed during the first Soyuz mission on April 24, 1967. The craft's parachute lines tangled during descent and he was killed upon impact with the Earth. The Soyuz program resumed flights 18 months later.

Salyut 1 (1971)

Purpose: First Space Station

Flights: Salyut 1 was launched in April 1971. This was a "first generation" Soviet Space Station with only one docking port. Two crews were launched to the Space

Station. The first docked, but was unable to open the hatch to the Space Station, and returned home.

Space Tragedy: The second crew, Soyuz 11, docked and entered the Space Station, and remained for three weeks. When they returned to Earth on June 29, 1971, an improperly closed valve allowed the Soyuz's atmosphere to vent into space. The three cosmonauts (Georgiy Dobrovolskiy, Vladimir Volkov, and Viktor Patsayev) were not wearing spacesuits and asphyxiated. The Soviets had eliminated the requirement for spacesuits because they had confidence in their technology, and three space-suited cosmonauts could not fit in the Soyuz as it was designed at that time. The Soyuz returned to flight 27 months later. The Soviets have required spacesuits since that time, and launched only two-person crews for the next 10 years until the Soyuz T version was introduced which could accommodate three cosmonauts in spacesuits.

Other "First Generation" Salyut Space Stations (1974–1977)

Unnamed launch (1972) did not reach orbit.

Salyut 2 (1973) broke apart in orbit.

Kosmos 557 (1973) broke apart in orbit.

Salyut 3 (1974) hosted one crew (another was unable to dock) and was designated in the West as a military space station dedicated to military tasks.

Salyut 4 (1974–1975) hosted two crews, and was designated in the West as a civilian space station. A third crew was launched to the Space Station, but the launch vehicle malfunctioned and the crew landed in Siberia (the so-called "April 5th anomaly" or Soyuz 18A).

Salyut 5 (1976–1977) hosted two crews and was designated in the West as a military space station. A third crew was unable to dock.

Soyuz-Apollo Test Project (1975)

Purpose: Cooperation with the United States

Flight: A three-man Apollo crew docked with a two-man Soyuz crew for two days of joint experiments to demonstrate "detente in space." This was the last flight in the Apollo series. No Americans journeyed into space for the next six years while waiting for the debut of the Space Shuttle.

"Second Generation" Salyut Space Stations (1977–1986)

Purpose: Expand space station operations. The second generation space stations had two docking ports, enabling resupply missions and "visiting" crews that would remain aboard the Space Station for about one week visiting the long duration space station crews, who remained for months. These space stations were occupied intermittently over their lifetimes.

Salyut 6 (1977–1982) hosted 16 crews (two others were unable to dock). The Soviets increased the duration of human space flight to 185 days. The visiting crews often brought cosmonauts from other countries. The first non-U.S., non-Soviet in space was Vladimir Remek of Czechoslovakia in 1978.

Salyut 7 (1982–1986) hosted 10 crews. A new duration record of 237 days was set. Among the visiting crews was the second woman to fly in space, Svetlana Savitskaya. She visited Salyut twice (in 1982 and 1984), and on the second mission, become the first woman to perform an EVA. One crew that was intended to be launched to Salyut 7 in 1983 suffered a near-tragedy when the launch vehicle caught fire on the launch pad. The emergency abort tower on top of the launch vehicle propelled the Soyuz capsule away from the launch pad to safety. Unlike all the previous Soviet Space Stations, which were intentionally deorbited into the Pacific Ocean, Salyut 7 made an uncontrolled reentry in 1991, raining debris on Argentina. There was insufficient fuel for a controlled reentry.

"Third Generation" Mir Space Station (1986–2001)

The Mir Space Station was a modular space station with six docking ports. The core of the Space Station was launched in 1986. Additional modules were added through 1996. Mir hosted a large number of crews, and inaugurated the era of "permanently occupied" space stations where rotating crews were aboard continuously. Mir was permanently occupied from 1989 to 1999. A new duration record of 438 days was set. In 1991, following the collapse of the Soviet Union, the United States and Soviet Union increased cooperative activity in human spaceflight, including Russian cosmonauts flying on the U.S. Shuttle, and American astronauts making multi-month stays on Mir. Nine U.S. Space Shuttles docked with Mir from 1995–1998. In 1997, a fire erupted inside Mir when a "candle" used to generate oxygen malfunctioned. That same year, a Russian cargo spacecraft (Progress) collided with Mir during a failed docking attempt. These events called into question the wisdom of keeping crews on Mir, but both the Russians and the Americans continued to send crews to the Space Station. Mir was intentionally deorbited into the Pacific Ocean in 2001.

International Space Station (1998–present)
Purpose: Space Station
Flights: The United States initiated the Space Station program in 1984. In 1988, nine European countries (now eleven), Canada, and Japan formally became partners with the United States in building it. In 1993, the program was restructured due to cost growth, and Russia joined the program as a partner. Construction began in 1998 and is currently suspended pending the Space Shuttle's return to flight. Successive three-person crews have permanently occupied ISS since November 2000. The three-person crews are alternately composed of two Russians and one American, or two Americans and one Russian. ISS is routinely visited by other astronauts on Russian Soyuz spacecraft or the Space Shuttle (prior to the *Columbia* accident) some of whom are from other countries.

Senator BROWNBACK. Thanks, Ms. Smith. And I appreciate your expertise that's been available for many years to Congress to help us look at this overall issue. We will get into a lot of this in the questions and answers.

Mr. Chase, executive director of The National Space Society, welcome, and the floor is yours.

STATEMENT OF BRIAN E. CHASE, EXECUTIVE DIRECTOR, NATIONAL SPACE SOCIETY

Mr. CHASE. Thank you, Mr. Chairman, Senator Breaux.

Robust low-cost access to space is the key to expanding our opportunities in space, whether in low-earth orbit or beyond, and this issue is even more critical in the wake of the loss of the Space Shuttle Columbia.

NASA's 2004 budget submission contains important elements of an integrated space transportation plan to begin addressing this important issue. The first element of the plan is the Service Life Extension Program which addresses the need to upgrade the Space Shuttle fleet and its supporting infrastructure. The Space Shuttle is the only vehicle that can complete the International Space Station, so we need to return the fleet to service as quickly as is feasible to let it complete that mission.

Although the original estimates for the Shuttle's costs were very optimistic, as has already been said, the Space Shuttle's capabilities remain unmatched today. But we cannot escape the need for a backup to the Shuttle, so the second element of the plan is to provide a complementary capability to transfer crews to and from the Space Station.

The current proposal, called the orbital space plane, would be launched aboard evolved expendable launch vehicles, EELVs, developed jointly by the Department of Defense and industry and now operated commercially by Boeing and Lockheed Martin as the Delta 4 and Atlas 5. While the orbital space plane could serve as a component for a next-generation launch vehicle, it serves only as a complement to, not a replacement for, the Shuttle during this phase. The additional benefit of the orbital space plane would be its utility in future human missions, all of which will require crew transfer capabilities.

The third element of NASA's plan is the development of a next-generation launch system that would ultimately replace the Space Shuttle. The next-generation launch technology program, which is being conducted jointly with the Department of Defense, focuses on new technologies that can lead to launch systems with much greater reliability and much lower costs. This NASA/DoD partnership is one that should be encouraged and fostered.

These three elements are all important efforts to improve our access to space, and I believe NASA's initial plan is a prudent step in that direction. However, there are also several critical factors that could be major stumbling blocks to its success.

First, the loss of Columbia dramatically underscores the urgency to develop a secondary capability to launch crews to and from the Space Station. The orbital space plane can be built using today's technology, and most of the designs under consideration have been studied in several variations for the last 20 to 30 years, so there needs to be a very serious effort to accelerate this program while keeping it focused on its core mission of launching and retrieving crews.

Second, NASA has to reexamine a backup capability to launch unmanned cargo to the International Space Station. NASA's Alternate Access to Station initiative was doing just that, but that program is slated to be terminated this summer without moving into the test or development phase. The Alternate Access to Station program should get a fresh look from NASA.

Third, once the orbital space plane and some form of a backup cargo capability are activated, we should not rush to an artificial deadline to develop a new launch system. While it's important for us to continue making investments in new launch technology, it's equally important that we develop a strategic plan for our space exploration efforts and not waste time and money jumping from program to program.

Finally, I believe a key, yet overlooked, element in this debate is the evolved expendable launch vehicle I mentioned earlier. Although designed initially for unmanned missions, the fleet of EELVs represent significant improvements in safety, reliability, and efficiency over their predecessors. Once modified for human launch requirements to handle orbital space plane missions, the EELVs will represent a formidable and versatile fleet of vehicles that can fulfill an even wider range of missions than they perform today. Importantly, by expanding the EELVs' market to include crew and cargo to ISS, that improves our Nation's competitiveness in the commercial space arena, as well.

In summary, I believe NASA's plan to be a reasonable approach. We should begin making the investments now to ensure we can complete the International Space Station and then build a robust, yet simple, secondary capability to transfer crew and cargo to and from orbit. Beyond that, though, we should carefully consider our next steps as part of a long-term space architecture that provides a bold vision for the future. We can certainly begin building some of that infrastructure today, but we need a roadmap to put that infrastructure to work.

I thank you for the opportunity to appear today and look forward to your questions.

[The prepared statement of Mr. Chase follows:]

PREPARED STATEMENT OF BRIAN E. CHASE, EXECUTIVE DIRECTOR, NATIONAL SPACE SOCIETY

Chairman Brownback, Senator Breaux and Members of the Subcommittee, thank you for inviting me here today.

I am pleased to present testimony to the Subcommittee on behalf of the National Space Society, a nonprofit organization dedicated to promoting space exploration. NSS has approximately 22,000 members around the world, including space professionals, astronauts, business leaders, elected officials, and, most important, everyday citizens without ties to the space industry who support the exploration, development, and eventual settlement of space.

The Subcommittee has asked NSS to provide its perspective on NASA's human space flight programs and how those initiatives relate to efforts to develop new space transportation systems. In our view, access to space is the most critical part of any future space exploration efforts, so I appreciate the opportunity to share our thoughts today.

NASA's Integrated Space Transportation Plan

Robust, low cost access to space is the key to expanding opportunities in space, whether in Low Earth Orbit or beyond. In light of the loss of the Space Shuttle Columbia, it is more important than ever for our nation to address the issue of how we transport people and cargo to and from space. Indeed, although the Columbia investigation and now the war in Iraq occupies the nation's attention, NASA's generally overlooked FY 2004 budget submission contains important elements of an Integrated Space Transportation Plan to begin addressing this critical issue.

The first element of the Integrated Space Transportation Plan is the Service Life Extension Program, which addresses the need to upgrade the Space Shuttle fleet and the infrastructure that supports it. The Space Shuttle is the only vehicle that can complete the International Space Station, so we need to return the fleet to service as quickly as is feasible to let it complete that mission.

Although the original estimates for the Shuttle's cost and performance were very optimistic—which means today we have a system that is significantly more expensive and more challenging to operate than was ever envisioned—the Space Shuttle remains a very unique and important asset in our nation's launch inventory. It combines the capabilities of a heavy lift launch vehicle, a small Space Station, an on-orbit repair depot, and a system that can return cargo to Earth, among other functions. Its capabilities, despite being conceived 30 years ago, remain unmatched today by any vehicle flying or by anything even on the drawing board. So any mention of a "replacement" of the Shuttle has to be viewed as only a partial replacement, since future vehicles will likely not be as versatile as the Space Shuttle is today.

But we cannot escape the realities of the need for a backup to the Shuttle, regardless of its impressive capabilities. The second element of the plan is to provide a complementary capability to transfer crews to and from the Space Station. The current proposal, called the Orbital Space Plane (OSP), would be launched aboard Evolved Expendable Launch Vehicles developed jointly by the Department of Defense and industry, and which are now operated commercially by Boeing and Lockheed Martin as the Delta IV and the Atlas V, respectively. The requirements laid out by NASA call for the OSP to be able to launch at least four crew members to ISS, stay on orbit for long periods of time, and to serve as a "lifeboat" to evacuate the ISS crew in the case of emergencies, replacing the Russian Soyuz capsules that perform that function today.

While the OSP could serve as a component of a next generation system, it serves only as a complement to—not a replacement for—the Shuttle during this phase of the Integrated Space Transportation Plan. The OSP would relieve much of the Shuttle's burden of launching crew to and from ISS and allow the Shuttle fleet to focus on the launch of heavy cargo and components, but both vehicles would be flown during this time period. The additional benefit of the development of the OSP or similar vehicle would be its utility in future human missions, all of which will require crew transfer capabilities.

The third element of NASA's plan is the development of a next generation launch system that would ultimately replace the Space Shuttle, meaning it would launch both crew and cargo. The Next Generation Launch Technology program, which is being conducted jointly with the Department of Defense, is a restructured element of the Space Launch Initiative (SLI), and focuses on new technologies and new systems that can lead to launch systems with much greater reliability and much lower costs than systems today.

The Challenges

These three elements—upgrading the Space Shuttle, developing a backup system to launch crews to and from the Space Station, and investing in next generation launch technologies—are all critical components in a national plan to significantly improve our access to space, and I believe NASA's initial outline is a prudent step in that direction. However, there are also several critical factors that can be major stumbling blocks to the success of this plan.

First, the loss of Columbia dramatically underscores the urgency to develop a secondary capability to launch crews to and from ISS, and it is not clear that this sense of urgency is shared by all of NASA's managers at the program level. Additionally, the natural inclination for NASA's talented engineers will be to develop the latest technology for use in the Orbital Space Plane—but that urge must be strongly resisted. The OSP can be built using today's technology, and most of the designs under consideration have been studied in several variations for the last 20–30 years. NASA's stated goal of a fully operational system by 2012 must be accelerated, and it must also be done as simply as possible by focusing on its core mission of launching and retrieving crews.

Second, NASA has to reexamine a backup capability to launch cargo to the International Space Station. A program to do just that—NASA's Alternate Access to Station initiative—was examining several potential options to launch unmanned cargo to ISS using expendable launch vehicles, but that program is slated to be terminated this summer without moving into the test or development phase. The AAS program should get a fresh look from NASA so that, when combined with the Orbital Space Plane program, we will have both assured crew and cargo access to the International Space Station. The European Space Agency is working on the Automated Transfer Vehicle, which is designed to be a robotic cargo vessel for ISS. That system may offer the capabilities to fulfill this need, but it is an option which may or may not be viable depending on the state of international affairs. But both the crew and cargo launch capabilities are needed regardless of what long-term choices we make about human space exploration, so it is advisable to fund and begin these programs as soon as possible.

Third, once the Orbital Space Plane and some form of backup cargo capability are activated, the United States will possess a significant launch capability that can meet multiple needs. With these complementary capabilities available, we should not rush to an artificial deadline to develop and field a new launch system. The Shuttle and existing fleet of expendable launch vehicles, coupled with the OSP and a cargo delivery system, can meet many of our nation's needs for the near term, and the Shuttle still possesses capabilities that should be carefully reviewed before we decide to retire the entire fleet. While it is important for us to continue making investments in new launch technology, it is equally important that we develop a strategic plan for our space exploration efforts and not waste time just jumping from program to program.

Fourth, the nascent partnership between NASA and the Department of Defense in developing next generation launch technology should be encouraged and fostered. For years, an adversarial relationship existed between the two agencies, yet the skills and experience each brings to the space arena have been recognized as critical to both civil and national security needs.

Finally, I believe a key yet overlooked element in our nation's space launch capabilities is the Evolved Expendable Launch Vehicle mentioned earlier. Although designed for unmanned missions, the two vehicles represent significant improvements in safety, reliability, and efficiency over their predecessors. Indeed, both the Delta IV and Atlas V represent, in many ways, revolutionary improvements in access to space. These systems are already in production and operation, and they are capable today of meeting the launch requirements for unmanned scientific, national security, and commercial missions. Once modified for human launch requirements, the EELVs will represent a formidable and versatile fleet of vehicles that can fulfill an even wider range of missions. Importantly, by developing a crew and perhaps cargo capability that can be launched aboard EELVs, that improves our nation's competitiveness in the commercial space arena by strengthening the market for those vehicles.

The reason it is important to highlight the potential role of EELVs is because expendable launch systems are usually ignored in the discussion of next generation launch systems—most people assume that only reusable launch vehicles can fulfill that role. But the economics of reusable versus expendable systems is not as simple as it first appears. The key to low cost reusable vehicles is routine use that allows expenses to be amortized over a large number of flights. For an expendable vehicle, the key is low cost production, which can be achieved in part through launch rates that are high enough to maximize the efficiency of the production and assembly operation. Generally speaking, the launch rate for a reusable system has to be very high before it effectively competes with the cost of an expendable launcher. The best option for a next generation system may indeed turn out to be a reusable launch system, but it could also be a further evolution of the EELV or a derivative of the Space Shuttle.

The Future of Human Space Exploration

The choices made today in space transportation investments will obviously impact our capabilities for future space exploration missions, but there are decisions that can and should be made even as we work to develop a long term vision for our future in space. We know that completing the International Space Station requires the Space Shuttle, and that in order to successfully operate the Space Station we need a robust yet simple backup capability for crew and cargo. So those are two elements of space transportation planning that should proceed as quickly as possible and accelerated where feasible.

Beyond those elements, we should carefully consider our next steps. Focusing exclusively on reusable launch vehicles may be the right choice if we seek routine access for crew and low-to-medium weight cargo. But if we opt to launch heavy cargo (such as components for a mission to Mars), then expendable launch vehicles may better fill that role. So the nation needs to develop a long-term space exploration architecture to provide a clear direction for the future to help direct these efforts. NASA has begun an initiative to accomplish this important task, but it needs public and political support to remain a key part of the NASA agenda. Without that underlying vision for tomorrow, it makes it more difficult to make the right decisions today.

So the choice before our nation is complex, but, importantly, it is not an "either-or" proposition. In order to fund future launch systems, we do not have to cannibalize the Shuttle program, and in order to fund the Shuttle we do not have to forgo future investments in next generation launch technology. I also know you have to wrestle with difficult budget choices in a wide range of areas and, as stewards of the public's money, I know you consider it important to make investments that are worthwhile and have a benefit to the taxpayers.

Space exploration is worthwhile endeavor and a sound investment in the future, and it is an investment that can be made even while meeting other needs in our nation. It is important to invest in the future, and it is important, as a society, to continue opening frontiers. History teaches us that societies that have pushed their frontiers outward have prospered; those that have not have withered and faded into the history books. No society has ever gone wrong opening up the frontier, and we shouldn't stop now.

Thank you for the opportunity to appear before you today.

Senator BROWNBACK. Thank you, Mr. Chase, and I look forward to discussion as well.

Dr. Alex Roland is professor of history at Department of History, Duke University, and a former historian for NASA. Thank you for joining us today. The floor is yours.

STATEMENT OF ALEX ROLAND, PROFESSOR OF HISTORY, DUKE UNIVERSITY

Dr. ROLAND. Thank you.

Senator Brownback, Senator Breaux, thank you for the opportunity to share with you my views on human space flight, which will be considerably different than what you've heard so far, though there are many points of convergence.

The Columbia accident confirmed what the Challenger accident made clear; systemic flaws in the Space Shuttle render it unsustainable as a safe, reliable, and economical launch vehicle. The Rogers Commission issued two critical injunctions to NASA—do not rely on the Space Shuttle as the mainstay of your launch capability; begin at once to develop a next-generation launch vehicle. Sixteen years later, NASA is massively dependent upon the Shuttle; no replacement is in sight.

I have appended to my written remarks an article explaining how and why the Shuttle program became systemically flawed. Briefly stated, NASA made two mistakes in Shuttle development in the late 1960s and early 1970s. First, it traded development costs for operational costs. Second, it convinced itself that a recoverable launch vehicle would be inherently more economical than an expendable. NASA promised savings of 90, even 95 percent in launch costs. In practice, it costs more to put a pound of payload in orbit aboard the Shuttle than it did aboard the Saturn launch vehicle that preceded it.

These mistakes produced a program that cannot work. NASA could conceivably operate the Shuttle safely and reliably, but it dares not admit what it would cost.

The evidence for this was abundant before the Challenger accident. Instead of listening to that data, NASA consistently allowed its judgment to be clouded by its hopes and predictions for human activities in space. The agency cares about astronaut safety, but it's trapped by its own claims about Shuttle costs. And, unlike expendable launch vehicles, the Shuttle grows more dangerous and more expensive to fly with each passing year.

In what it euphemistically called success-oriented management—that is, hoping for the best—NASA assumed, in 1970, that each orbiter would fly 50 times. In those heady days, NASA was expecting 60 Shuttle flights a year by 1985, meaning that a fleet of five Shuttles would be completely replaced every 5 years. No one imagined that a Shuttle would be in service after 20 years, let alone 30 or 40 years.

Unfortunately, nothing practical can be done now to save the Shuttle program. A crew escape system would help reduce the risk to human life, but it cannot eliminate it. It is not clear that crew escape could have saved the astronauts aboard either Columbia or Challenger. Nor will an infusion of new money suffice. The United States spends more on space then the rest of the world combined. NASA has ample funding to support a robust space program. It has simply wasted too much of that money flying astronauts on unnecessary missions aboard a ruinously expensive spacecraft.

We should drastically curtail human space flight until we have a safe, reliable, and economical launch vehicle. In the meantime, anything we want to do in space, except having humans there as an end in itself, we can do more effectively and efficiently with automated spacecraft controlled from earth. Whenever we put people in a spacecraft, we change the primary goal, be it reconnaissance or communication, science or exploration, to bringing the astronauts back alive. Most of the weight, and, hence, the cost, of manned missions comes from safety and life-support systems. The astronauts contribute little. Even had the astronauts aboard Columbia known of the damage to their spacecraft, they could not have saved themselves.

NASA should begin at once to carry out the recommendations of the Rogers Commission. It should limit Shuttle flights to a bare minimum. It should convert the Space Station into a space platform to be visited, but not inhabited. And it should use the savings from these actions to fund development of a new launch vehicle.

I have enormous confidence in NASA's ability to achieve a vital and productive space program, including both human and automated missions. But to achieve that goal, it must do the right thing. That means phasing out the Shuttle. It is a death trap and a budgetary sinkhole. NASA must develop a stable of launch vehicles that will open up the promise of space.

I believe that we should send people into space only when they have something to do there commensurate with the risk and cost of sending them. Given the liabilities of the Shuttle, I do not know of any mission now that meets that criterion.

Thank you.

[The prepared statement of Dr. Roland follows:]

PREPARED STATEMENT OF ALEX ROLAND, PROFESSOR OF HISTORY, DUKE UNIVERSITY

Senators, thank you for the opportunity to share with you my views on human spaceflight.

The *Columbia* accident confirmed what the *Challenger* accident made clear. Systemic flaws in the Space Shuttle render it unsustainable as a safe, reliable, and economical launch vehicle. The Rogers Commission issued two critical injunctions to NASA. Do not rely on the Space Shuttle as the mainstay of your launch capability. Begin at once to develop a next-generation launch vehicle. Sixteen years later NASA is massively dependent on the Shuttle; no replacement is in sight.

I have appended to my written remarks an article explaining how and why the Shuttle program became systemically flawed. Briefly stated, NASA made two mistakes in Shuttle development in the late 1960s and early 1970s. First, it traded development costs for operational costs. Second, it convinced itself that a recoverable launch vehicle would be inherently more economical than an expendable. NASA promised savings of 90 percent, even 95 percent, in launch costs. In practice, it costs more to put a pound of payload in orbit aboard the Shuttle than it did aboard the Saturn launch vehicle that preceded it.

These mistakes produced a program that cannot work. NASA could conceivably operate the Shuttle safely and reliably, but it dares not admit what it would cost. The evidence for this was abundant before the *Challenger* accident. Instead of listening to the data, NASA consistently allowed its judgment to be clouded by its hopes and predictions for human activities in space. The agency cares about astronaut safety, but it is trapped by its own claims about Shuttle costs. And, unlike expendable launch vehicles, the Shuttle grows more dangerous and more expensive to fly with each passing year. In what it euphemistically called "success-oriented management," i.e., hoping for the best, NASA assumed in 1970 that each orbiter would fly fifty times. But in those heady days, NASA was expecting sixty Shuttle flights a year by 1985, meaning that a fleet of five Shuttles would be completely replaced every five years. No one imagined that a Shuttle would be in service after twenty years.

Unfortunately, nothing practical can be done now to save the Shuttle. A crew escape system would help reduce the risk to human life, but it cannot eliminate it. It is not clear that crew escape could have saved the astronauts aboard either *Columbia* or *Challenger*. Nor will an infusion of new money suffice. The United States spends more on space than the rest of the world combined. NASA has ample funding to support a robust space program. It has simply wasted too much of that money flying astronauts on unnecessary missions aboard a ruinously expensive spacecraft.

We should drastically curtail human spaceflight until we have a safe, reliable, and economical launch vehicle. In the meantime, anything we want to do in space, except having humans there as an end in itself, we can do more effectively and efficiently with automated spacecraft controlled from earth. Whenever we put people in a spacecraft we change the primary goal—be it reconnaissance or communication, science or exploration—to bringing the astronauts back alive. Most of the weight and hence the cost of manned missions comes from safety and life support systems. The astronauts contribute little. Even had the astronauts aboard *Columbia* known of the damage to their spacecraft, they could not have saved themselves.

NASA should begin at once to carry out the recommendations of the Rogers Commission. It should limit Shuttle flights to a bare minimum. It should convert the Space Station into a space platform, to be visited but not inhabited. And it should use the savings from these actions to fund development of a new launch vehicle. I have enormous confidence in NASA's ability to achieve a vital and productive space program, including both human and automated missions. But to achieve that goal, it must do the right thing. That means phasing out the Shuttle. It is a death trap and a budgetary sink hole. NASA must develop a stable of launch vehicles that will open up the promise of space.

I believe that we should send people into space only when they have something to do there commensurate with the risk and cost of sending them. Given the liabilities of the Shuttle, I do not know of any mission that now meets that criterion.

Discover, November 1985

THE SHUTTLE, TRIUMPH OR TURKEY?

BY ALEX ROLAND

The American taxpayer bet about $14 billion on the Shuttle. NASA bet its reputation. The Air Force bet its reconnaissance capability. The astronauts bet their lives. We all took a chance.

When John Young and Robert Crippen climbed aboard the orbiter *Columbia* on April 12, 1981 for the first Shuttle launch, they took a bigger chance than any U.S. astronauts before them. Never had Americans been asked to go on a launch vehicle's maiden voyage. Never had astronauts ridden solid-propellant rockets. Never had Americans depended on an engine untested in flight.

Next to the orbiter was an external tank holding 1.3 million pounds of liquid oxygen and liquid hydrogen, flanked by booster rockets containing two million pounds of solid propellant. Beneath Young and Crippen were the three main engines, which had failed with alarming regularity on the test stand. The escape system that would separate them from this pyrotechnic nightmare should the engines fizzle again had been scrapped—to save money.

The tiles that would protect the spacecraft from the consuming heat of re-entry had fallen off by the dozens on *Columbia's* comparatively gentle flight to Cape Canaveral atop a 747. None of them had been subjected to the rigors of a launch, when six million pounds of thrust would accelerate the Shuttle from zero to 4,000 feet per second in about a minute and a half.

If the tiles stayed on, they would begin to do their work as the Shuttle, traveling at 17,500 m.p.h., re-entered the atmosphere. At 50 miles up heat would begin to ionize the air molecules flowing around the vehicle, blocking communications and engulfing the spacecraft in a fireball that one astronaut has likened to the inside of a blast furnace. The orbiter, again provided the tiles stayed on, would pass out of this inferno at about 34 miles up, slowed now to 8,200 m.p.h., but still flying nose up, "with the glide ratio of a pair of pliers," as a NASA engineer put it. Finally, it would nose over and pass through 20,000 feet on a 22-degree glide slope, about seven times steeper than the normal angle for a commercial aircraft. If all went well, the Shuttle would flare out at about 2,000 feet and touch down on the runway moving at something like 200 m.p.h., five to ten percent faster than the supersonic transport, the fastest-landing commercial airplane. And the Shuttle would have to land on the first pass: the two jet engines that were to give it a fly-around capability had been jettisoned during development.

Tom Wolfe assures us that astronauts thrive on this sort of risk. And, indeed, Young and Crippen came up winners in their gamble. But what of the American people? Has their bet on the Shuttle paid off? And what of NASA and the Air Force? It's on these questions that any assessment of the success of the American Shuttle program turns.

And any such assessment must begin with the four critical years from 1969 through 1972. Both NASA and the country got new chief executives in 1969. Richard Nixon, an old friend of the space program, moved into the Oval Office determined to end the war in Vietnam, to restore domestic tranquillity, and to bring the federal budget under control. Thomas Paine became NASA administrator, determined to parlay the first moon landing in July 1969 into a mandate for NASA to take "the next logical step" in space. Paine envisioned himself as a latter-day Horatio Nelson, head of a "band of brothers" whom he encouraged to "swashbuckle" and "buccaneer" with him on the high seas of space. These true believers saw the Apollo landing as the sparkling achievement of a decade gone sour. It required an encore of even greater scope and daring. Nothing less than a manned mission to Mars would do.

Nixon might publicly call the voyage of Apollo 11 "the greatest week in the history of the world since the Creation," but he wasn't about to mortgage his administration and a distressed U.S. economy to a commitment that would look like an imitation of John Kennedy's famous man-on-the-moon proposal of 1961. Nixon appointed a

Space Task Group, chaired by Vice President Spiro Agnew, to lay out the options. Agnew quickly signed on with the band of brothers: he came out for the Mars mission, a manned space station in earth orbit, a Space Shuttle to ferry men and materials to the station, and a "tug" to move things around in space. His report presented choices of pace and sequence, but they all ended up on Mars.

Congress went into orbit, and Nixon went underground. Some liberals in both houses, claiming that the $25 billion Nixon spent on Apollo could have been put to better use in social programs on earth, assailed the Mars mission as the pipe dream of a bureaucracy gone mad. Many officials in the administration agreed. Nixon himself withdrew from the debate and let his subordinates fight it out.

Bereft of presidential support, NASA came down to earth—fast. First it abandoned the Mars mission, except as a long-term goal. Then it abandoned the Space Station. Finally, it settled on the Space Shuttle, a re-usable spacecraft designed to reduce by two orders of magnitude the cost of placing cargo in orbit.

The notion of re-usable spacecraft dates back to the 1920s in Germany. The U.S. was, in fact, moving in that direction with the X-series aircraft of the 1950s—until Sputnik set off the space race. The Soviets had used a modified intercontinental ballistic missile to launch Sputnik; the U.S. responded in kind, launching its first space shots and even the early manned missions of Mercury and Gemini on military rockets. Soon a stable of civilian launch vehicles was developed, dominated by the mighty Saturn, which could put more than 50 tons of payload into low earth orbit.

But all these launch vehicles were throwaways. They boosted one spacecraft into orbit and then fell back to earth to incinerate in the atmosphere. They were also expensive; a Saturn cost $185 million dollars. If Paine and his band of brothers were to swashbuckle in the "new ocean" of space, as Kennedy had called it, they had to find a cheaper way of getting out to sea.

The most logical solution was a re-usable launch vehicle to Shuttle men and cargo to and from orbit. There were several varieties of these. Those that received serious consideration in the U.S. would lift off vertically like rockets and fly back horizontally like airplanes. The simplest was the single-stage-to-orbit vehicle, which would carry all the fuel, engines, and aerodynamic features needed to power itself into orbit and fly back to earth. The two-stage fully re-usable Shuttle would consist of a spacecraft mounted atop a recoverable booster, both of which would be piloted, winged vehicles; the booster would power its cargo to near escape velocity and then glide back home. Finally, the partly re-usable Shuttle would have a returnable orbiter on an expendable rocket; you'd lose the rocket on each mission but you'd save the spacecraft.

The relative appeal of these configurations depended on three variables: payload, launch rate, and development costs. The bottom line was cost per pound of payload in orbit. With expendable launch vehicles NASA had achieved rates of $500 to $1,000 per pound. In 1969 George Mueller, NASA associate administrator for manned space flight, set the tone for the post-Apollo era when he called for a Shuttle that could take off and land at major airports and place as many as 50,000 pounds of payload in orbit at costs approaching $5 a pound.

Beyond those startling parameters, what kind of Shuttle would this be? Opinion within NASA ranged from a Chevy to a Cadillac. Swashbucklers at headquarters and elsewhere preferred a large Shuttle that would enjoy economies of scale and be capable of carrying the Space Station components of the future. They were seconded by officials of the Marshall Spaceflight Center in Huntsville, Ala., builder of the Saturn rocket. Marshall wanted a mandate to produce a large new engine. Flight specialists at the Manned Spaceflight Center in Houston knew that a smaller craft had more manageable aerodynamic characteristics on re-entry and landing. Each of these groups contributed to the designs that NASA ordered from contractors.

The din of competing proposals drowned out voices of caution within the agency. In a journal article now famous in NASA circles, A.O. Tischler, head of the chemical propulsion division of NASA's office of advanced research and technology, argued for an evolutionary approach to the next generation of launch vehicles, as opposed to the quantum leap favored by the band of brothers. The principal cost in space transportation, he said, isn't hardware but people. The salaries of the 30,000 people NASA employed at the Kennedy Space Center were almost half a billion dollars a year, imposing an overhead cost of about $500 per pound on all launches. Add to that the personnel costs at mission control in the Johnson Space Center, at the tracking and telemetry stations around the world, and at all the other NASA facilities, and the cost of a manned mission in space was higher than the projected costs of the Shuttle, regardless of which sort of hardware was developed. What was needed, Tischler insisted, was a better understanding of the cargo of the future, for the type of launch vehicle would be determined primarily by the volume of traffic. Before making "a precipitous, total-immersion dive into the future . . . it would be shrewd to make sure first that we know how to swim," he argued. "Once begun, there is no way back."

The true believers would have none of this. They looked at the same evidence and reached different conclusions. Tischler likened the propulsion problems of the Shuttle to those of the SST, which was then being hotly debated in the U.S.: "If you fall short of design requirements, you have the option of flying part of your passengers all of the way or all of your passengers part of the way across the ocean."

Mueller looked at studies of the supersonic transport that predicted a market for 900 American SSTs in 1985, and extrapolated a market for 50 Space Shuttles. Obviously, something besides the data was driving perceptions of what to do next in space.

The skeptics' views were driven by experience. As they had learned in the Apollo program, development on the cutting edge of technology always runs afoul of the unexpected. It would be better, they believed, to move along incrementally and not let predictions outrun data.

Wernher von Braun likened this go-slow approach to life on a cruise ship, prompting Paine's injunction to swashbuckle. "Buccaneers," said a NASA memorandum, "stake out and create powerful outposts of stability, sanity, and real future value for mankind in the new uncharted seas of space and global technology."

The swashbucklers won out. Before Paine left NASA in 1970, the agency was leaning toward not just a Space Shuttle, but a Cadillac of Space Shuttles. A fully re-usable orbiter, about the size of a DC–9 airliner, would be launched atop a first stage that could also be flown back for re-use. A new engine producing 400,000 to 550,000 pounds of thrust would be developed for use on both vehicles. The orbiter would have a life of 100 missions with only minor refurbishment between flights, comparable to normal operations for commercial jets. It would carry a cargo weighing 65,000 pounds and measuring 15 feet in diameter and 60 feet in length. It would be able to land on a conventional runway and fly again in two weeks. The price tag was $10 billion to $14 billion for a vehicle to be ready in the mid-l970s.

The public attack on this plan sprang first from Capitol Hill. Senators Walter Mondale, William Proxmire, Clifford Case, and Jacob Javits warned their colleagues that the Shuttle was a cat's-paw for a "manned space extravaganza" that would cost between $20 billion and $25 billion. They cited distinguished space scientists like James Van Allen and Thomas Gold, who said the U.S. had no compelling need or use for such a vehicle, which they believed would drain money from other, worthier space activities.

Joseph Karth, chairman of the House subcommittee on space sciences and applications and a NASA supporter, wondered if the proposed Shuttle was technically feasible. "This is going to be more difficult than most people on the Hill suspect or NASA has led us to believe," he said. "And anyone who tells you this can be done for six or eight billion dollars is out of his mind."

These critics were drowned out by colleagues scrambling to get Shuttle business for their districts or states. While few congressmen grasped the technological complexity of the program, all of them readily understood its pork barrel potential.

The critics never had a chance, but they did wring some important commitments from NASA. Most had to do with cost, which soon became the program's overriding concern. During 1970, the agency brought the maximum price down from $14 billion to less than $10 billion, and promised that even this sum would be amortized within a decade by cheaper launches. In short, the Shuttle would pay for itself.

Still, it was left to the Office of Management and Budget to do most of the moderating of NASA's lavish planning. Few OMB officials believed the U.S. needed a Shuttle, and surely not the one NASA had in mind. But the key man at OMB, deputy director Caspar Weinberger, disagreed. He wanted to proceed with a Shuttle, but he let his staff negotiate NASA down to a cheaper model. In mid–1971 OMB informed NASA that its annual budgets during Shuttle development couldn't exceed the 1971 level of $3.2 billion. That allowed for a Chevy, and a stripped-down one at that.

But the Air Force refused to ride in a Chevy, and Air Force endorsement of the Shuttle carried great weight in Congress, in the White House, and at OMB. To keep that endorsement, NASA had to retain an expensive set of options, including the 65,000-pound payload capacity, an inertial upper stage for placing satellites in high earth orbit, and a cross-range capability of 1,100 miles. (This meant that the craft had to be able to fly 1,100 miles right or left of its space trajectory on re-entry, which would give it the ability to land from almost any orbit. Only a delta-winged vehicle could practically provide that flight characteristic. The simpler, straight-winged vehicle NASA preferred could not.) But while the Air Force insisted on these features, it refused to pay for them. NASA was caught in a cost squeeze from which there seemed no escape.

At the insistence of OMB, NASA turned to a think tank for help with its financial woes. It chose Mathematica, Inc., headed by Princeton economist Oskar Morgenstern. Using data provided by prospective Shuttle contractors, Mathematica concluded, just as NASA wanted, that the new vehicle would pay for itself—if it had a launch rate of more than 30 flights a year, a very conservative estimate in those heady times.

The Mathematica report strengthened NASA's hand, but it didn't carry the day. Critics at OMB and the White House still doubted that the Shuttle was worthwhile. In the closing months of 1971, Shuttle designs popped up and fell like ducks in a shooting gallery. This one was too expensive. That one would take too long to develop. The next one failed to meet the cross-range requirements of the Air Force. A climactic meeting was arranged with Weinberger and OMB director George Shultz. NASA Administrator James Fletcher came prepared to trade away the payload capacity that NASA and the Air Force wanted. He was amazed to learn that Nixon and his domestic policy adviser, John Ehrlichman, cognizant of both the upcoming 1972 election and the boost the Shuttle would give the slumping aerospace industry, had decided to approve the Shuttle with whatever payload bay NASA felt necessary.

From this war of wills emerged a Shuttle that no one had willed—except perhaps the Air Force. Congress, OMB, the Air Force, and NASA had all pulled in different directions: Congress toward cost recovery, OMB toward low development costs, the Air Force toward operational capabilities, and NASA toward a future of manned space flight. Instead of a horse, NASA got a camel—better than no transportation at all and indeed well suited for certain jobs, but hardly the steed it would have chosen.

Fletcher rushed off to San Clemente to join Nixon at a press conference announcing the decision to go ahead with the Shuttle and revealing its configuration. Nixon promised the American people that the Shuttle would "revolutionize space transportation" and "take the astronomical cost out of astronautics." Fletcher promised that "by the end of this decade the nation will have the means of getting men and equipment to and from space routinely, on a moment's notice, if necessary, and at a small fraction of today's cost." The two men posed for reporters with a model of the Shuttle. But it was the wrong Shuttle. Fletcher had taken with hun an earlier version, not the one that was eventually built. Plans called for a single-stage, only partly re-usable Shuttle, fed by an expendable external tank.

In a curious piece of technical inconsistency, NASA promised two different costs for orbiting payloads. Fletcher announced that the new Shuttle would put payloads in orbit for $100 a pound, but he also claimed a cost of less than $10 million dollars a flight, which yields a cost of something more than $150 a pound. Both figures were dependent on a launch rate of 60 flights a year by 1985 and a two-week turnaround time for refurbishing the orbiter. The first orbital test flight was projected for March 1, 1978. The total development cost was put at $5.5 billion, subsequently scaled down to $5.15 billion, with a 20 percent ceiling on overruns. This was about half the development cost NASA had estimated for its fully reusable Shuttle.

NASA had gotten out of its bind by trading operational costs for development costs. Except for a new engine, the launch vehicle would rely heavily on proved technologies. An expendable external tank and recoverable solid boosters would help keep development costs below the ceiling set by OMB, although they would raise the cost of each launch. But Mathematica had told NASA it would break even at 30 or more launches a year, and it was expecting 60 a year by 1985. There seemed to be plenty of cushion. So NASA promised all things to all men.

Then it developed a management technique to match. "Success-oriented management" is a euphemism for betting on the come. You assume everything will work as designed, so you test only at the end, when the entire machine is put together. This not only saves the time that would otherwise be spent on intermediary tests; it also creates an aura of confidence. No tests, no failures—and absence of failure is success.

A version of this technique had been used in the Apollo program. All-up testing, as it was called then, delayed the final check-out of the three stages of the Apollo launch vehicle until they were mated on the pad at Cape Canaveral. It succeeded largely because expensive redundancies were built into Apollo and problems were drowned in money. The Shuttle had no room for such luxuries.

For a while success-oriented management seemed to work. The first Shuttle orbiter, named Enterprise in deference to Star Trek enthusiasts, rolled out within a year of its scheduled completion date. No major shortcomings had come into public view, and between 1974 and 1977 NASA had even absorbed more than $300 million in OMB cut-backs in Shuttle funding.

Behind the scenes, however, normal development snags were taking their toll, and NASA's reduced budget meant there was no money to prevent these snags from becoming big problems. Inevitably, the weight of the launch vehicle rose. Something had to go. Two escape rockets on the orbiter were jettisoned, leaving the astronauts locked onto the launch vehicle during lift-off. The auxiliary jet engines and their fuel tank were scrapped, meaning that the Shuttle would have no fly-around capability. A number of other features went by the boards, and with each deletion NASA moved farther away from the spacecraft it had envisioned.

The public and Congress knew little of this. About the only public controversy was stirred by an April 1977 report by the House Committee on Appropriations. Among other things, it criticized NASA and the Rocketdyne Company for deciding to proceed with production of the Space Shuttle main engine (SSME), a decision the committee felt might have been influenced "more on contract scheduling and costs than the maturity of the design." Indeed, during 1977, the SSME began to experience an ominous series of turbopump failures.

But in August of that year, the public watched Enterprises's first test flight largely unaware of the problems mounting behind the scenes. The orbiter lifted off its 747 carrier with grace and conviction at 20,000 feet and glided down to a flawless landing at Edwards Air Force Base. It looked like another virtuoso performance by NASA, just what the public had come to expect from the folks that had given it Apollo.

Then came 1978 and more engine failures. New rocket engines routinely have taken more time and money to develop than expected and have been full of bugs. But they usually end up delivering more power than specified. The development of a new engine was a curious risk for NASA, and it was probably taken mainly to give the Marshall Space Flight Center something to do. NASA compounded the risk by betting that its new engine would deliver 109 percent of its rated capacity. In a bargain-basement development program this gamble never had a chance. When the Shuttle engines first went on the test stand, they couldn't deliver even 100 percent of their rated capacity, but weight growth in the Shuttle demanded the full 109 percent if the craft was to perform its mission.

The engine was simply too advanced to work to full capacity the first time around. In 1978, NASA couldn't get one to survive so much as a run-up on the test stand. In five tests, four different engines and one turbopump were damaged, resulting in four months of down time and $21 million in repairs and modifications. By the end of the year, the illusion of NASA's infallibility was in tatters.

But its troubles were just beginning. Earlier manned spacecraft had solved the problem of re-entry heating with ablative thermal surfaces, materials that eroded during re-entry and carried the heat with them. Obviously this wouldn't do for a craft that was to fly 100 missions. NASA turned to re-usable ceramic tiles, for which it set breathtaking performance standards. The insulation not only had to weigh just 1.7 pounds per square foot—the highly advanced Apollo shielding had been 3.9 pounds per square foot—but also had to fit the irregular contour of the Shuttle body, withstand temperatures ranging up to 2,750 degrees, and be cheap.

Tiles made of rigidized silica fibers with borosilicate glass coating met all these specifications. Some 31,000 of them, in black high-temperature and white low-temperature versions, were ordered to cover the Shuttle fuselage save the areas of highest and lowest re-entry heat. The difficulties arose not with the insulating material but with placing the tiles on the spacecraft. Each one had to be individually designed, molded, machined, and applied to ensure that it met the exacting tolerances set by NASA: for example, the gaps between tiles had to range from 0.025 to 0.075 of an inch.

NASA and Rockwell International, the contractor tiling the Shuttle, badly misjudged the task. Putting the tiles on *Columbia*, the first orbiter scheduled to fly in space, ended up taking roughly 670,000 hours, or about 335 man-years. The craft still lacked 10,000 tiles when Rockwell shipped it to Cape Canaveral in March 1979. The missing tiles were air-shipped to Florida, where a motley team of Rockwell employees installed them at the rate of less than two tiles per man per week. At various times, college students, a few tomato pickers, hippies, and assorted smokers of God-knows-what answered the Rockwell call for labor. Despite NASA's disclaimers, it seems few had any incentive to work well or quickly. Some wanted the job to go on indefinitely—and it almost did.

Then NASA concluded that the glue holding the tiles in place provided "negative margins of safety." So 25,000 of them were "densified"—that is, removed and reglued with a "densified bonding surface." What wasn't known was that the waterproofing material applied overall was quietly dissolving the glue beneath the tiles that weren't densified.

While public and congressional attention shifted between the comic opera of tile installation and the Chinese fire drill of failing engines, still another critical—although less noticed—shortcoming precluded launch of the first Shuttle in 1979, or even 1980. Kenneth Cox, who was in charge of navigation, guidance, and control for the Shuttle, says he couldn't have approved the Shuttle for flight in those years "without significant risk." He simply didn't trust the data he was getting from computerized flight simulations. This would be the first spacecraft to carry a crew on its maiden voyage. The astronauts' safety would depend heavily on the reliability of computer models and wind tunnel experiments. But computers are only as good as the data and assumptions that go into them, and no wind tunnel in the world was capable of duplicating the flight regime of the Shuttle. This craft had to go from re-entry at 25 times the speed of sound to landing, one hour later, at about 200 m.p.h. Separate wind tunnels could re-create segments of that descent, but the tunnels had different characteristics and functioned at different Reynolds numbers. In other words, you could find a slow wind tunnel to test a full-scale orbiter, and you could find a fast tunnel to test a very small model of the Shuttle, but until the Shuttle itself flew you could never be sure that the test results were exactly comparable.

The Shuttle was known around NASA as the Flying Brickyard; it was Cox's job to ensure that he had anticipated and built into the flight control system all the characteristics of a brickyard traveling at Mach 25. And he had to program the five on-board computers to check each other, identify mistakes, and overrule errant commands. "If the computer fails," said Cox, "you've bought the farm." All this took time. A lot of time.

Development dragged on past the original launch date of March 1, 1978 and into 1979. Congress began to ask embarrassing questions. Talk was heard in Washington of abandoning the Shuttle altogether, although most observers agreed that it had really proceeded too far for that. Besides, whatever doubts there were about the floundering project were obscured by a coating of SALT. The Air Force would soon be dependent on the Shuttle to launch its space missions. The most important—and the most secrecy-shrouded—of these involved the orbiting of reconnaissance satellites. If Shuttle operations were delayed further, the Air Force faced a hiatus between the use of its last expendable launch vehicles and the availability of the Shuttle. The Air Force, and indeed the entire intelligence community, dreaded this prospect. Perhaps more important, so did Jimmy Carter, who in the spring of 1979 was concluding the SALT II treaty. He would have to convince a skeptical Congress that the U.S. had the reconnaissance capability to verify Soviet compliance. There could be no gap in launch vehicle availability.

The administration asked for more money for NASA in 1979, and Carter made it clear that he wanted the Shuttle to get whatever funding was necessary in the coming years to put it back on schedule. Congress went along because it had already poured more than $10 billion into the project and because the military implications were so serious. In 1979, General Lew Allen, the Air Force Chief of Staff, said, "Whatever else the Shuttle does and whatever other purposes it will have, the priority, the emphasis, and the driving momentum now has to be those satellite systems which are important to national security." For the first time since 1971, cost was no longer the main determinant in Shuttle development.

NASA paid a price for this reversal of fortunes: the myth that the U.S. had an independent civilian space program was irretrievably shattered. In Fiscal Year 1980 the military budget for space activities exceeded NASA's for the first time since the beginning of the Apollo program. With the Pentagon now piping the tune on Shuttle development, some observers wondered aloud if an independent civilian space agency could survive.

The infusion of money nevertheless had the desired effect. The first Shuttle flew on April 12, 1981, somewhat reviving NASA's reputation and quieting public criticism. Since that first launch, some three years late, the operational record of the Shuttle has been improving steadily, if slowly. After four successful test missions, the first operational flight went up on Nov. 11, 1982, and was followed by four missions in 1983 and four in 1984. Eight flights are scheduled for this year—of which six had taken place when DISCOVER went to press—and 14 next. On the basis of this record, NASA has sought and won Ronald Reagan's approval to begin development of the Space Station, the orbiting outpost the Shuttle was designed to serve.

The record of the Shuttle so far is decidedly mixed. The bad news is that it's not up to specifications. The solid rocket boosters came in over their design power, but the troublesome main engines have yet to achieve the 109 percent of thrust NASA anticipated. This shortfall, combined with weight growth on the launch vehicles, has restricted payload capacity to 47,000 pounds instead of the specified 65,000. NASA is developing a liquid boost module to add thrust on lift-off.

The turn-around time between the first and second Shuttle launches was four months. The gap is now down to about two months, but the two weeks originally projected seems impossible. Most Shuttle flights have landed at Edwards Air Force Base, where the dry lake bed provides a cushion against the erratic behavior of the landing gear. There are no plans to land on commercial runways; they are simply too short. The shock and vibration of launch are taking a far higher toll on the main engines than anticipated; it seems unlikely that any of them will survive NASA's goal of 50 launches.

The first flights of *Columbia, Challenger,* and *Discovery* were late; *Atlantis* was to be launched in early October. Many follow-on missions have been late as well; five have been scrubbed altogether. Some satellites launched from the Shuttle have been either lost entirely or placed in erroneous orbits, requiring depletion of their limited fuel supplies to set them right. These mishaps weren't the fault of the Shuttle, but the complete space transportation system has yet to achieve the reliability of the expendable launch vehicles it replaced.

The good news is similarly compelling. Most of the shortcomings are under control and getting better. The orbiter and the external tank are getting lighter. Launches are more regular. Turn-around time is decreasing. The bugs that always infest new technology are disappearing.

Even with the bugs, the Shuttle is the most sophisticated spacecraft ever flown, a generation ahead of the rest of the world and the envy of all spacefaring nations. Its main engines have the highest thrust-to-weight ratio of any ever developed; its thermal protection is the lightest and most efficient ever flown. The Shuttle has retrieved satellites. It has served as a platform for astronauts repairing satellites in place. It has provided capacity for scientific experiments on a scale that dwarfs the capabilities of Apollo and the Soviet Soyuz. The Shuttle has more versatility and potential than any other spacecraft ever flown, and it has also delivered on the promise to routinize space flight.

Have the taxpayers, then, gotten their money's worth? Ah, that's another question. One answer is undoubtedly no. Another is surely yes. The choice between them is philosophical and political more than it is technical.

Cost has driven the Shuttle from the outset. Cost dictated the shape and pace of its development. Cost remains its only compelling raison d'être. And cost is the principal criterion by which it should be judged.

Judged on cost, the Shuttle is a turkey. The problem isn't that it cost too much to develop, as OMB had feared, but that it costs too much to fly, which no one seems to have anticipated. The Shuttle cost something like $14 billion (in 1985 dollars) to develop, well within the budget and the 20 percent fudge factor predicted by NASA in 1972.

But NASA also promised then to amortize the Shuttle's development costs, whatever the total. That notion was abandoned years ago, and with it went the Shuttle's main initial selling point. By the time NASA went back to Congress for more money in 1978, it had ceased to claim that the investment in the Shuttle's development would ever pay off. The Shuttle simply can't fly cheaply enough to turn a profit. No one knows exactly how much a flight costs, but it's nothing like the $10 million that Fletcher predicted in 1972. Nor does payload fly at $100 per pound. In 1985 dollars, these predictions convert into $25.8 million per launch and $258 per pound. Earlier this year the Congressional Budget Office suggested five ways to compute the costs of a Shuttle flight, and they ranged from one and a half to six times these predictions.

Accounting Meth.	Cost per Launch	Cost per Pound*
Short-run marginal cost	$42 million	$646/$893
Long-run marginal cost	$76 million	$1,169/$1,617
Average full operational cost	$84 million	$1,292/$1,787
Average full cost less development	$108 million	$1,662/$2,298
Average full cost	$150 million	$2,308/$3,191

*65,000 pound payload/47,000 pound payload

In 1972 Fletcher pegged the cost per pound of payload on a Saturn rocket at $1,677 (in 1985 dollars). So if and when the Shuttle gets up to its rated payload capacity of 65,000 pounds it will cost, under the most reasonable accounting method (average full cost less development), about the same per pound as an Apollo launch 13 years ago.

Bad as it is that the American taxpayer won't be reimbursed for Shuttle development, it's worse still that more development money is being poured into the Shuttle to bring it tip to specs. Worst of all, even when these investments are written off, every Shuttle flight in 1986 will cost the American taxpayer a minimum of $50 million. NASA Administrator James Beggs reported earlier this year that NASA was budgeted on average $121 million for each of the 14 flights scheduled in 1986, four and a half times the amount predicted by Fletcher in 1972. Since the commercial rate to hire a completely dedicated Shuttle payload is $71 million, the American taxpayer would subsidize Shuttle operations next year to the tune of $700 million if all 14 flights were made and each earned its full commercial rate. In fact, fewer than half the flights will earn the full commercial rate. Americans can look forward to subsidizing all Shuttle missions—including foreign, commercial, and Air Force flights—for the foreseeable future. Like old John Henry, each Shuttle flight hauls as many as 24 tons and what does it get? Another day older and deeper in debt.

Why not raise Shuttle fees? Simple. Ariane. While the U.S. was abandoning expendable vehicles and developing the Shuttle, the European Space Agency went about developing its own launch vehicle. Now Ariane is operational and luring customers away from the U.S. The Shuttle and Ariane are both heavily subsidized, launching spacecraft for all corners at losses amounting, in the U.S. at least, to hundreds of millions of dollars annually. (Ariane has no fixed pricing policy, so outsiders can't be sure just what it charges for any given flight or how much it loses.)

Ariane handcuffs the U.S. If America continues to subsidize flights, it increases the loss to the taxpayer. If it raises prices, it will lose business—even U.S. business—to Ariane, which already includes among its customers GTE and Satellite Business Systems, which is jointly owned by IBM and Aetna Life & Casualty. This would reduce the number of Shuttle flights, which would increase the cost of each flight, which would also increase the net loss to the taxpayer. In 1973 NASA envisioned 60 Shuttle flights a year by the sixth year of operation. Mathematica pegged the break-even point at more than 30 flights a year. Now NASA hopes to have 24 flights a year by the end of this decade—but don't bet on it.

In short, the Shuttle is an economic bust, with no prospect of making money. It's the SST of space, a remarkable piece of technology that costs more than it's worth in the marketplace.

But cost, say Shuttle supporters, isn't the best criterion for judging the spacecraft. In fact, they contend, the cost constraints that have crippled the program from the outset account in large measure for the Shuttle's development problems and disappointing operations. Retired NASA engineer James Nolan goes so far as to say that "the American people got the Shuttle they deserved." Others are more circumspect. New technology, they argue, always entails the fits and starts that the Shuttle has experienced, but the development must be done. The Europeans, the Japanese, even the Chinese—not to mention the Soviets—are moving aggressively into space, and if the U.S. wants to remain competitive it must invest in the future.

Furthermore, supporters contend, new uses for the Shuttle are just around the corner. It has unique capabilities that may be very important in the commercialization of space. Orbital manufacturing of crystals, pharmaceuticals, and space structures can take advantage of near-zero gravity to achieve results impossible on earth. Even tourism in space is now within reach; the Hyatt chain already has a commercial featuring a future hotel in orbit. The prospects, say the Shuttle faithful, are limited only by our imagination. Mueller claimed in 1969 that "the Space Shuttle, by its very existence and economics, may generate the traffic it requires to make it economical."

That kind of logic tends to get circular and metaphysical. You would only build a Shuttle if you had some reason for sending men into space, but you can't know all the masons until they get there. Christopher Columbus is the classic example of this phenomenon. According to this line of thinking, you simply must bet on the unknown occasionally, for even when predictions are wrong, the unexpected may prove a greater blessing.

To date the Shuttle has found no gold in orbit. Nor is it likely to. A second-generation Shuttle may be necessary for the space transportation system to become truly economical, but that's not to be the next step in space. When the Shuttle went operational in 1982, NASA began to argue that the orbiter opened the way to development of the Space Station. The purpose of the Shuttle in the first place had been to reduce the prohibitive costs of resupplying the Space Station. Of course, it hasn't done that, nor does it have any prospects of doing that. The real cost of putting a pound of payload in orbit is at the same prohibitive level as 16 years ago. But rather than make good on its promise, rather than develop a second-generation Shuttle that might prove profitable, NASA is pressing on with the Space Station.

Does Shuttle development, then, have anything to teach the U.S. as it embarks on the development of a space station? It surely can't tell Americans what will happen, but it can offer a handful of cautionary thoughts. First, as Tischler warned in 1969, "the desire of the aerospace industry, which includes members of government agencies, to build exquisite and innovative equipment does not of itself justify spending the taxpayers' money." Second, beware of civil servants, however well intentioned, who propose to swashbuckle with the public purse. Third, high technology designed to cost will end up costing. And finally, progress is in the eye of the beholder.

Senator BROWNBACK. Good statements by all.

Let's run the clock at 7 minutes and then we can bounce back and forth and probably go a couple of rounds here.

Ms. Smith, do we know what the cost per Shuttle flight is now?

Ms. SMITH. That's not an easy question to answer. It depends on how you look at it. There are two ways that those costs are usually described. One is called "average costs," and the other is called "marginal costs." The average costs essentially take the annual Shuttle budget and divide it by however many flights there were that year. So five flights or six flights, whatever, you just do the math; it comes out to $400 million, $500 million a year.

Senator BROWNBACK. $400 to $500 million——

Ms. SMITH. $400 to $500 million per flight, I'm sorry.

Senator BROWNBACK.—per flight.

Ms. SMITH. Yes.

The marginal costs are the additive costs of flying an additional Shuttle mission in a given year, or the costs that you would save if you did not fly a particular Shuttle mission. So it doesn't account for the infrastructure cost, basically, of the Shuttle program.

NASA currently calculates the marginal costs of a Shuttle flight at $115 million a year. That's in full cost accounting.

Senator BROWNBACK. Okay.

Mr. Chase, what should the vision be as to why we are going to space? If you were to articulate that in a way that the American people would identify with, what would that vision be as to why we should be going to space?

Mr. CHASE. I think the traditional reasons that have been put forward—spin-offs and the valued education and the value for international cooperation—those are all benefits, but those aren't the overall rationale for going to space. I don't think any one of those can justify the expenditures and the programs.

I think there's something much bigger at stake here, and that is, if you look historically, societies that have expanded their frontiers are the ones that have prospered, the ones that have the energy and the drive within that society to do other things, whether it's economically or other areas of success within that society. And I think that as soon as the society begins to or stops exploring and stops opening that frontier, they begin to risk some long-term detrimental effects. That's not something you'll see in 5 or maybe even 10 years, but you have a long-term detrimental effect that will impact society. So I think that that's one of the motivating factors, that that is a hallmark of societies that are successful and are leaders in their world. So I think that's an important reason.

Clearly, there are a lot of outstanding benefits to the motivation aspect in terms of motivating the next generation of explorers, the next generation of scientists and engineers, and, frankly, for that matter, the next generation of business leaders and lawyers and anyone else who may be engaged in that business or aspire to a higher calling.

So there's a lot of reasons to go. I don't think there's any single reason that is a——

Senator BROWNBACK. But how would you articulate it to the American people? If we continue forward, this is billions of dollars annually, how would you articulate it?

Mr. CHASE. I think you would articulate it by saying that this is important to the future of our—not just our society, but even in some ways our civilization, to continue being a leader in the world. And it's important for their kids to have opportunities that they see a hope for the future.

You know, there's not a lot that we look at that says, "Here's the vision for 10 years down the road. There's something hopeful that you may be able to step foot on another planet or another planetary body and have the chance to experience something that no human has experienced before, to have experiences that nobody's ever had before." I think that can be a very motivating factor for a child or even for someone today who is interested in that field.

Senator BROWNBACK. So it's to open space for the vision of humanity as always pressing forward?

Mr. CHASE. It really is. There are economic reasons, there are social reasons, but it's a continuous expansion of our frontiers and of our understanding of society and then obviously the benefits through technology that accrue to the society that's used to do that.

Senator BROWNBACK. Dr. Roland, how would you answer that question? What's the vision for why we should be pursuing space?

Dr. ROLAND. There are two things. I think it is important to do exploration in space. But it's my very strong belief that any exploration that you want to do in space with our current technology, you will achieve far more with automated spacecraft than you will with people. Any mission you do in space costs ten times as much if you send people along. So if you want to go to Mars and explore, you can send 10 unmanned missions for the price of one manned mission. And the main purpose of the manned mission becomes simply returning the humans.

I'm not saying that's an unimportant national goal. It is inspirational and exciting, but it's kind of a feel-good space program. And right now I don't feel very good about our space program.

I think we get much more sustained payoff, and we have consistently over the last 40 years, from our automated spacecraft. We've spent two-thirds of our budget on manned space flight, and we're doing basically what we were doing 40 years ago. We send astronauts up into low-earth orbit and they float around and come back. And it's our unmanned spacecraft—the communications satellites, the applications satellites, the reconnaissance satellites, the deep-space probes—they're the ones that have given us all the payoff.

So I think if we want to tell the American people that the space program is good for them, that's where we should be making our investment.

Senator BROWNBACK. If you based it on scientific discovery of what's taking place, you would stand by your previous comment——

Dr. ROLAND. Absolutely.

Senator BROWNBACK.—and can you quantify that?

Dr. ROLAND. Yes. I recommend to you an exercise. I tried a short time ago to find any scientific results from Shuttle or Space Station research that was written up in refereed scientific journals. It doesn't appear there, because it isn't important science. All the science that NASA gets published in the best journals is coming from the automated spacecraft.

Now, the one exception to that is there are some human physiology experiments that are written up, but that's—again, it's sort of a circular argument. We're going to send people in space so they can learn to survive in space in case we ever find anything for them to do in space.

Senator BROWNBACK. Ms. Smith, what would your comment be about the scientific information that we're getting? Does it come more from the manned or from the unmanned launches?

Ms. SMITH. There is scientific information that comes from both human and robotic spaceflight. I do have to agree with Dr. Roland that it is difficult to point to some breakthrough scientific discovery that can be directly traced to the presence of humans in space. There have been many space stations, both on the American side and on the Russian side, and Shuttle flights and all sorts of other flights. They do gather a great deal of data about biology, which is useful if you are going to continue launching humans into space. They also learn things that can be applied here on Earth. So there are medical advances that other scientists say have developed because of the space program.

But critics of the space program argue that those advances would have been made anyway, even if you had not been launching humans into space, and they might have been made sooner if you had not devoted the sums of money to the space program and you had devoted them to earth-based research instead.

But there is scientific data that comes back from the human space flights, and there's a lot of data that comes back from the robotic flights.

Senator BROWNBACK. Mr. Chase, your response? And then I want to go to Senator Breaux.

Mr. CHASE. Well, I think the debate between humans versus robots is actually a little bit of a false argument. I think that any space program is a balanced approach. You have both human exploration and you have robotic exploration. There's no doubt that there are destinations in our solar system that a human will probably never, ever be able to set foot, and robots are going to be a critical role in that exploration.

But there's also things that robots will never be able to do with current technology or even technology in the mid- to long-term future that humans will have to fulfill. There's a certain amount of interaction with the environment, the mobility, the dexterity, the response time that a human possesses. A robot can be sitting on the surface of a planet and not know what's sitting behind it unless it's turned that direction by an operator; and, even then, they may not know exactly what it is. It takes a human to get down there and interact with that object or that environment to understand what's going on.

Now, the other thing that I think puts this in perspective is, I would proffer an exercise as well. I would challenge any earth-based scientist that does work in a laboratory and ask them, "Would you be willing to substitute a robot for the work you're doing in your laboratory?" And I dare say the answer is no, they would not be willing to do that, because they know they can achieve more with humans in that loop and in that capacity.

Today we have the technology to replace humans to go to Antarctica with probes and robotic measuring systems. We don't do that. We could send probes to the bottom of the ocean, but we don't do that. We send humans. So there's a reason that scientists in the scientific arena have humans in the loop, per se, in those discoveries.

Senator BROWNBACK. Senator Breaux?

Senator BREAUX. Thank you, Mr. Chairman. I thank the panel for their testimony.

Dr. Roland, are you saying that this particular Space Shuttle is defective, or do you think that any reusable Space Shuttle that is manned is not the proper approach? I mean, is this one uniquely defective in what you think, or do you think that if we did a VentureStar or a type of program which was a different type of reusable vehicle, that that could be okay, it could be a better way of doing it? Or do you just fundamentally think that the reusable manned space vehicle is not the right way to go?

Dr. ROLAND. I think this one is uniquely defective, and I think it's conceivable that the reusable idea could still work. And I think NASA was fully justified in pursuing it. It seemed like a good idea at the time. What we underestimated was the wear and tear on the spacecraft that requires such an extensive amount of maintenance and wears out the spacecraft faster than we thought. That economic model doesn't work.

Also, at the time, NASA was basing all its projections on an unrealistic economic model of how many flights there would be. And those two things together make this particular reusable not workable.

And I think we just don't know if we can design and operate a robust reusable that will have a lifetime that will really make it worthwhile. It might be that there's some combination of the two where our orbiter is reusable but it launches on an expendable, and that the cost balance might show up there.

I'm just encouraging them to take the experience we've gained from the Shuttle, which is not trivial, and design a better launch vehicle.

Senator BREAUX. How much of your concerns with this particular Shuttle are because of the way it is launched through the rocket type of launch as opposed to like a regular airplane, which would be a suborbital type of operation?

Dr. ROLAND. Right, I think if we could build a small orbiter that could be launched from an airplane, at least theoretically that sounds much more appealing. Of course the whole problem is that when any launch vehicle lifts off the ground, it has to carry all the fuel it needs to get into orbit, so the enormous cost is in the first 100 feet and then it starts going down rapidly after that. So if we can develop another launch vehicle that'll get the orbiter up to a level where it's only a hop into space, then we have an entirely different technological model.

Senator BREAUX. Is it your understanding that NASA, at this point, really doesn't have any plans to look at an alternative type of vehicle and they're now planning to use this one through the year 2020?

Dr. ROLAND. That's what they told us in the fall. We were waiting to see what they were going to do about the Shuttle fleet. And their solution was to try and prolong its life and defer, essentially, development of a replacement launch vehicle. And I think that's the great problem. I'm not opposed to the program they've designed in general or manned space flight in general. It's just that this is not the vehicle that's going to achieve our objectives for us.

Senator BREAUX. From your knowledge, what type of vehicle— would be an option, and what would that option look like?

Dr. ROLAND. I tend to think that we ought to separate cargo and people, and that we need a small orbiter to take people into and out of space. That's the vehicle in which we should invest all the safety and life-support systems, and we just make it as safe as we possibly can, but make it smaller, just to carry the people. Then we have separate automated launch vehicles; they can be either expendable or reusable launch vehicles, the heavy-lift vehicles, the trucks that carry the material up there. The astronauts meet them in orbit and do their business and then the astronauts come back safely. And then you have a vehicle that's not only a launch vehicle for the astronauts and much safer, but it's an emergency crew return vehicle, as well, and you solve two problems at once.

Senator BREAUX. So you're not really saying that we just shouldn't do manned space flights at all. You're just separating the vehicle that takes humans up from a separate vehicle that perhaps would be used for heavier payloads and would not necessarily have to have the extreme human safety precautions maintained.

Dr. ROLAND. Yes, this is what we do with our expendable launch vehicles. This is what the Air Force does. You accept a certain amount, a certain probability of failure. In other words, if you get up to 95, 96, 97 percent success rate, it's economically infeasible to try and get that any higher, and so you accept an occasional loss of one of those launch vehicles. But we can't do that with people. And so we ought to separate those two functions have a much higher safety standard for the smaller and lighter vehicle just to get the people and down.

Senator BREAUX. Mr. Chase and Ms. Smith, can you comment on that? Mr. Chase, you were talking about how you need humans in space, but it seems like what Dr. Roland is really suggesting is that you would still have humans in space; you would just have a different vehicle for getting there and then you'd have a different vehicle for the heavier payloads that would be necessarily utilized in space. Do you have any comments on that?

Mr. CHASE. Yes, sir. Although I don't agree with Mr. Roland's contention on some of the lack of the value of the Shuttle at this present time, I think that we actually have a lot of areas of agreement in terms of where this ought to go. And some of the items that I outlined in my testimony are a three-stage approach that NASA is planning for their future space transportation needs. What NASA has finally realized, and the space community has realized, is that we can't take this jump in one bite, so to speak, in one step. We can't go just straight from the old system to a brand new system that is a single-stage to orbit that incorporates all the latest technology.

What we've realized is that we have to do an evolutionary approach. And the evolutionary approach is we continue to use the Shuttle for the duration needed to finish the Space Station. The next step is, you do exactly what Mr. Roland mentioned, which is put a crew transfer system in place that can take the burden off of the Shuttle to transfer a crew to and from the Space Station and be used for future missions. And then the next stage is that crew transfer system could become part of a next-generation launch technology. So you have a three-pronged approach to this problem. And I do——

Senator BREAUX. Of course, the problem, at least in my information from NASA, is they're not thinking in that terms right now. We're talking about until year 2020 using the Space Shuttle as both a human delivery system as well as a cargo delivery system. And there's not a lot on the books right now, from the standpoint of looking at the next generation. It's just not even being started yet.

Mr. CHASE. They did have a restructuring of their Space Launch Initiative program, which was to address the next-generation system. And out of that program is the orbital space plane and what they're calling next-generation launch technology, which is being done in conjunction with the Department of Defense.

I think I mentioned in my oral testimony that that's an important relationship to develop, and I think it's important for this reason. The DoD has a very strong track record in developing X vehicles and test vehicles for their eventual systems. And I think that's important element that has been missing in some of NASA's efforts. We try to go too quickly to an operational system, or just do one X vehicle and all the technology is thrown into that one system. And I think a multiple approach, where we test technology on a variety of X vehicles and have the experience from DoD in doing that, will go a long way to solving that problem.

Senator BREAUX. Okay, those are good suggestions.

Thank you very much, both of you.

Senator BROWNBACK. Let me ask you—you've got some good thoughts, but I want to hear—We hear a number of different schools of thought. There's been, I think, a beautiful public debate that's taken place since this last Shuttle disaster about doing more space probes. Everybody agrees we should be in space. Should we be doing more unmanned? More manned? Should we be going back to the moon and colonizing the moon? Should we be going to Mars and beyond? Great debate, and the sort of thing we really ought to be talking about in broad scale, and I'm delighted we're having that sort of discussion.

Ms. Smith what is the rationale? If we were to say to the people that are most supportive of this, we need to go to the moon and establish a long-term presence, an exploration presence, on the moon, what's the major reason for us to do that?

Ms. SMITH. Well, there are advocates of returning humans to the moon that would say that you could use the lunar surface as a place for scientific observatories, you could put telescopes on the far side of the moon, you could mine the moon for helium-3 and bring it back to earth and use it for fusion reactors.

Senator BROWNBACK. I'm sorry, for what?

Ms. SMITH. Helium-3 and use it for fusion reactors. There are others who would like to put solar power systems on the moon and beam the energy back to earth. So there are a number of concepts out there for practical utilization of the lunar surface. And if you also wanted to commit to sending humans to Mars someday, then you might set up fuel production sites on the moon using the lunar materials to produce the fuel that you would need to go to Mars. So the visionaries in the space field lay out a number of scenarios as to why it is that you might want to go back to the moon.

There are others, however, who feel that we've been to the moon—"Been there, done that," don't need to go back again. That we really need is a commitment to going to Mars. In fact, some of the Apollo astronauts who have been to the moon have that point of view. They see going out to other places in the solar system as part of this destiny to explore, and they feel that we need to move on from what we did in the 1960s and start a new quest to send humans to Mars.

Senator BROWNBACK. What's the purpose of going to Mars?

Ms. SMITH. Exploration. To set up settlements there. Again, to do scientific research, to do a lot of geological research. They make the argument that Mr. Chase was making earlier, that if you have humans on site, that they're much better at doing science than robots because they're adaptable. When you send a robotic probe to some distant destination, if you haven't programmed it with the information it needs, then it's not going to be able to adapt to changing circumstances, whereas people can.

So those who argue in favor of sending people to Mars want the people there on site, because the feeling is that they can do better scientific exploration there. They can look at the geological sites and decide which rocks are the most important, as former Senator Schmitt did when he was on the moon in Apollo 17, because he was a geologist and he was trained to do that. So people see that as, sort of, the added value of having people there, that you can get more bang for your buck even though the bucks are so much greater when you're including humans.

Senator BROWNBACK. The cost of doing an unmanned mission to Mars versus a manned mission to Mars, do we have any idea of what factor we're looking at?

Ms. SMITH. There are a number of ranges of cost estimates for sending people to Mars. There's a gentleman who's very enthusiastic about this, Bob Zubrin, who has very low cost estimates. I believe it's in the $10 billion range. And when NASA was last asked the question back when President Bush gave his speech in 1989, they came up with a program that was about $400 billion.

The robotic probes—how expensive they are depends on how focused they are in their missions. But they're probably, you know, $100 million, something like that. It's a vast difference.

Senator BROWNBACK. Dr. Roland, give me your perspective on why we should or shouldn't go back to the moon or to Mars.

Dr. ROLAND. If the moon were paved in diamonds, it would cost more to go get them than they're worth here on Earth. One of the reasons we haven't gone back to the moon is that we discovered nothing there worth going back for. It is true that you could do some science there and you could do some experiments, but nothing where the payoff is anywhere near the cost. And I think the same thing is true in Mars.

This notion that humans, in situ, do better research than machines, I think is simply not true. I don't know of any particular activity that a human is going to do on Mars that a machine can't do. Remember, our machines are controlled from earth. We send them out, and we tell them what to do. We don't have to pre-program. We direct them around. We have them get samples.

Twenty-five years ago, NASA could have sent an automated probe to Mars to take soil samples and bring them back. We could have it down in the Air and Space Museum now. And we haven't done those automated missions that we ought to be doing.

I have no doubt that someday humans will go to Mars, and we'll probably go back to the moon, and we'll probably colonize the moon or Mars or some other place in space, but not with the technology that we have now. What we have now is a technology that allows us to do an enormous amount of scientific exploration, and that's being cut off while we float astronauts around in near-earth orbit. It's just an imbalance of our priorities.

I agree that the space program has to have some balance of priorities, but throughout NASA's history it's been spending two-thirds of its money on manned space flight and we get very little payoff from that.

Senator BROWNBACK. Mr. Chase, I want to give you a chance to respond to any of those comments, please.

Mr. CHASE. I think that there's another avenue of this discussion that's worth having, as well, because I think that you can make the case that there are reasons to go back to the moon and go to Mars, and I also believe that we will be doing that at some point down the road. However, I think there's another consideration, which is it may be better for NASA to build capabilities that allow us to make decisions when we're ready to make those choices.

For example, low-cost access to space is a critical part of whatever sort of mission you're planning, whether it's to launch a probe to do an environmental study of the earth, whether it's a military satellite, whether it's a mission to the Space Station, whether it's a mission to the moon or to Mars. And so low-cost access to space is a major part of any sort of an element of future space exploration.

Another good example is, NASA has begun a look at nuclear propulsion and power, Project Prometheus, that is in the Fiscal Year 2004 budget proposal. That is a capability that is critical to both human and robotic probes. That is a capability that will allow us to go places in the solar system we just can't go with chemical rockets. And that's a capability that can be built for a number of applications, and then when we decide and make a decision about where to go, we can apply those capabilities to those missions.

Now, there is somewhat of a danger in establishing a single destination for the program. Obviously, that gives you the ability to rally behind that destination, and there's a lot of very attractive reasons to do that, and that's probably the direction most people think of today is saying let's go back to a single place. But if you apply all of your resources and all of your technology behind a single destination and you either never get that mission going or it has a failure en route, you're left with nothing in the inventory for you to do next. So that's why there's a rationale and a growing sense, even at NASA by Administrator O'Keefe, that we need to build capabilities to do a number of missions, and then as those missions come about, assemble those capabilities into the spacecraft that can achieve that mission.

Senator BROWNBACK. In my discussions with the Administrator and with other people that have thought about the space program, a number of them will identify that we will need to build the capacity to travel in space and that's what our objective should be. We need to build the capacity that we could get to and from Mars in a relative period of time so that humans could take it, and have the capacity to do it. We don't necessarily need to say right now that our objective is to go back to the moon or to Mars, but we need to be able to build the capacity. We'd probably test that technology and use it through the unmanned to build up the capacity where we could do it in a manned capacity. But our objective isn't to go to the moon or to Mars. It's to open up space for human exploration for humanity, how do you react to that?

Dr. ROLAND. It seems to me that there is a tendency to associate our current space age with the age of Columbus, and I think it's the wrong analogy. We're in the age of Leif Ericsson. We have managed to get to the moon, but we don't have a robust technology and a robust infrastructure which will allow us to stay there and exploit and create a permanent presence there. Our effort ought to be invested in developing that capability and infrastructure, not in trying to demonstrate that we can do a technological feat.

I think it was very important, in the context of the Cold War, to send humans to the moon as a demonstration of our technological prowess. But I don't think we have to prove anything anymore. I think we have to have a rational space program that builds up the infrastructure that will allow us to do all of these things in space, and we're not doing it now. We're spending our money flying astronauts around and not developing the launch vehicles we need for the future.

Ms. SMITH. Mr. Chairman, I can't resist bringing to your attention a study that was done in 1985 to 1986, with which I was associated, from the National Commission on Space, called "Pioneering the Space Frontier." And the overarching theme of that report was that we should open up the solar system for science, exploration, and development. And the space transportation system laid out in there, which was called the Bridge Between Worlds, was, in fact, a series of spacecraft that went on interlocking orbits so that you could access Mars and the areas around Mars basically anytime you wanted to.

So there are folks who have thought about these things for a lot of years. The problem has always been money. They're very expensive to do, and the Nation has other priorities.

And what many people who are proponents of human space flight have been searching for has been that catalyzing effect that would make it imperative for America, or for planet Earth, to go out there and do it again. We had that compelling reason to go to the moon. And, as Dr. Roland said, it's hard to find that compelling reason to send humans to Mars because of the expense involved in it.

So I think on various bookshelves around town and around the country you'd find a lot of studies that came out with ideas of how you could accomplish this.

One of the concerns of the Commission on Space was that they didn't want to do another Apollo program, which was a dead-ended program. You went there, you picked up a rock, you came home, and it was done with. They wanted to establish that infrastructure so that you could go, not once, but repeatedly, over and over again, that you had that infrastructure in place. The problem has always been the funding for it.

Senator BROWNBACK. You're talking about a catalyzing event. Are we coming upon one if the Chinese launch into space? We've had testimony in this Committee that they will shortly thereafter announce that they are going to the moon and to stay.

Dr. ROLAND. I can remember debating with former NASA Administrator Dan Goldin, who was making the same argument ten years ago, threatening that if we gave up our lead in human exploitation of space, the Japanese were going to move ahead of us and that they had a manned space program.

It is a bad way to make our national policy to think that these symbolic programs are the best way to proceed into the future. We have 40 years of experience in space now. We really know what works and doesn't work, and we don't have to put on demonstration programs to prove we're better than other people. We just have to develop a rational program that will achieve our goals.

My historical explanation for why we're in this dilemma now is what I call "the barnstorming era" of space flight. We are now in the era of space flight which is analogous to barnstorming in the 1920s. We've learned how to fly, but we didn't have any idea what to do with the capability. So we would go out to the annual picnic and take Aunt Emma up for a trip. Right now we are just showing off in space that we know how to fly. It was in the 1930s, when the airplane turned into a commercially useful tool and a militarily useful tool. Then it started to develop its own technological trajectory. We don't have such a trajectory now for manned spaceflight.

Senator BROWNBACK. But would we, Dr. Roland—if we, though, continued to go out for the Aunt Emma picnic——

Dr. ROLAND. Right, uh-huh.

Senator BROWNBACK.—and watch the launch and come back——

Dr. ROLAND. Right.

Senator BROWNBACK.—won't we learn as we go along? Then we'll be able to get to a point that we find, a very good logistical, military, commercial reasons for us to be up on the moon on a permanent basis. If we're up there knocking around and exploring, will we find things that we hadn't thought of previously? Isn't that actually even the truth of most of human discovery? Is you go not because you particularly know why you're going, or what you're going to get, but once you get there, you find out that what you come back with, the reasoning is far different, but very important?

Dr. ROLAND. Senator, I agree completely, and we've been doing this for 40 years, and we've found out what works: unmanned communications satellites, unmanned reconnaissance satellites, earth resources satellites, scientific probes. We have a whole repertoire of space activity that works and is of proven productivity and usefulness. It hasn't happened with people yet.

Now, I'm not saying that we should stop sending people, but we haven't had that catalytic event where people have demonstrated that they're indispensable to some very useful activity in space. I think one of the reasons is that we don't have the right infrastructure.

If we could put people in space for free, there would be lots of things for them to do up there which would be worth the cost. If it costs a billion dollars to put them in space, there aren't very many things up there that are worth the cost.

And, with all due respect to Marcia, I would maintain that $1 billion is a much better estimate of what a Shuttle flight really costs, including the total overhead. I can give you a citation on that. And that's $1 billion a flight if you don't include amortization of the development costs.

When NASA proposed the Shuttle, it said it was going to be so cheap that it was going to amortize its development costs in the first 12 years. Of course, it never did. So you should, actually, be putting amortization of development costs into the cost of a Shuttle flight. And if you do that, the number is $1.7 billion a flight. But I think $1 billion is a good rough figure for what it's really costing.

So it's a very expensive proposition to be putting people up there. As a matter of fact, the space telescope is my favorite example. It's used as an exemplar of how useful manned space flight is. Well, we could have had two or three space telescopes for the price of the program we have, because we're spending all that money every time we go up to repair it. We'd be much better off having several automated space telescopes. They'd be in a more useful orbit, they'd be of a more practical design, and we wouldn't be tied down to the Shuttle as we are now.

Senator BROWNBACK. Some observers have suggested that NASA should explore developing a replacement for the Space Shuttle instead of trying to extend the existing program and complementing it with an orbital space plane. What are the challenges to this approach? And do you support going that way?

Mr. Chase?

Mr. CHASE. I believe that the Shuttle has inherent capabilities that need to be maintained to complete the Space Station, first and foremost. The remaining components of the Space Station are in—most of them are at the Kennedy Space Center in Florida waiting for launch, and those can only be launched on the Space Shuttle. You can argue that that was a design flaw, that we should have allowed those components to be flown in other systems, but the bottom line is if we intend to complete the Space Station, we have to have the Shuttle to do that. And there are a lot of things that have been neglected in the investments that need to be made in the Shuttle infrastructure, both the vehicles themselves and the infrastructure at the Kennedy Space Center and other NASA centers that support the Shuttle.

And that's been done to some degree, because there's been a sense of an either/or proposition, that if you're going to fund the

Shuttle, you can't do next-generation launch investment; or if you're going to do next-generation launch investment, you have to starve the Shuttle. And that is not the case. You can do both.

And, in fact, there are a lot of ways to integrate the Shuttle program into next-generation systems and research. For example, the Shuttle can be used as a test bed for some of the new technologies that are being looked at for next-generation systems.

So I think you have to have a period where you're flying the Shuttle, you're also flying an orbital space plane, which is kept as simple as possible, to do the crew transfer, and then you're also doing investment in the next-generation systems.

The key is I believe that NASA has matured its thinking of the point to know that we do have to have that balanced parallel approach, rather than simply embarking on a single replacement system and then when that fails we not only have not upgraded the Shuttle, but we don't have a replacement system to replace it.

Going back, as well, to the exploration discussion, I think that there has been a maturing of the thinking that we can't have a mission simply to go there, that we have to have to build the infrastructure and build the capability that lets us do missions long-term, not just a flags and footprint type program, which is what a lot of people describe Apollo as being.

So I think we have a phased approach that involves multiple systems being brought online.

Senator BROWNBACK. We've been joined by a person with personal experience, Mr. Nelson, Senator Nelson of Florida. The floor is yours to ask questions.

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Thank you, Mr. Chairman.

Dr. Roland, I did not see you, because I was looking straight at a TV camera. Were you the Dr. Roland that was on a CBS program with me?

Dr. ROLAND. Yes, sir.

Senator NELSON. I guess I don't remember—2 months ago, or so.

Dr. ROLAND. Yes, something like that. That's right.

Senator NELSON. You made a statement, and I heard it through my earpiece, that the Rogers Commission had recommended that the Space Shuttle be terminated.

Dr. ROLAND. I believe what I said—what I meant to say and what I said in my prepared testimony here—was that the Rogers Commission said, "Do not make the Shuttle the mainstay of your launch capability." In other words, they were encouraging NASA, not to stop flying, but to get on with developing a stable of launch vehicles where you could choose the vehicle best adapted for any particular mission.

Senator NELSON. And that was clearly the conclusion as a result of the Challenger tragedy——

Dr. ROLAND. Yes, sir.

Senator NELSON.—17 years ago, was that instead of the Space Shuttle being the space transportation system which it was thought to be, that you would use the Space Shuttle primarily where you needed the human in the loop, and you would use expendable rockets to put up other payloads that you did not need the human in the loop. That was the final result.

Dr. ROLAND. I went back and looked at the Rogers Commission report, last night, in fact, and that isn't exactly what they said. They took their charge very seriously, and it was only to advise NASA on what to do about the Shuttle program. So they were very cautious about what this other stable of launch vehicles should be. I am quite sure that in their press discussions surrounding the release of the report, they did say that they thought there should be another stable of launch vehicles. And I don't think they limited manned space flight to the Shuttle. I think they were anticipating a follow-on manned launch vehicle.

Senator NELSON. And 17 years later, here we are.

Dr. ROLAND. Here we are, that's right. Yes, sir.

Senator NELSON. And we don't have one.

Dr. ROLAND. Yes, sir.

Senator NELSON. I would hope that we would accelerate those technologies, and I've been kind of nipping at the heels of the Administration to try to get them to do that and not to look to NASA as the sole source of the funding for developing new technologies since, in fact, other agencies clearly have an interest in this, as well.

Dr. ROLAND. I agree completely.

Senator NELSON. Other agencies, I might say, that are a lot more flush with cash than is NASA.

Dr. ROLAND. Yes, sir.

Senator NELSON. Well, as you look from the experience of what we learned 17 years ago and some of the mistakes—now, Mr. Chairman, you might want to rein me in, because I might be getting far afield. You're talking basically about the future of manned space flight, so I will ask questions that are directly related to that—NASA learned a number of lessons—and I would address this to each of the three—17 years ago, NASA learned a number of lessons, and it wasn't only about cold weather stiffening rubberized gaskets, but it was also about mistakes in human communication, where communication is like water; it's really easy to flow from the top down, but it's not necessarily as easy to flow from the bottom up. Do you think that NASA learned those lessons and practiced those learned lessons on into this experience?

Dr. ROLAND. I think they learned them and then forgot them again. I think the Columbia accident was very similar to the Challenger accident in the sense that it was a systemic flaw within the system. It was a stressed system in which the operators were proceeding with inadequate resources for what they were trying to do. They performed heroically, but they had more problems in the system than they had resources to fix, and that meant looking the other way when a lot of problems arose. And when problems arose, stick your head in the sand and hope for the best. That's what happened on Challenger, and that's what happened on Columbia.

Senator NELSON. What do you think, Ms. Smith?

Ms. SMITH. Well, I don't mean to put you off, Senator, but I think that until the Columbia Accident Investigation Board determines exactly what went wrong, we aren't going to know the answer to that question.

Senator NELSON. Mr. Chase?

Mr. CHASE. I have to agree with Marcia that we won't know the answers until the investigation is finished. I can certainly offer some preliminary assessments that I believe to be the case.

I've had the privilege of working at the Johnson Space Center, I've worked for a NASA contractor, I've lived in the community around Kennedy Space Center, and so I've observed NASA from a variety of angles, both from within the agency and outside.

I think with Challenger, and certainly as your experience with the agency would probably concur, there were a series of severe endemic problems within the agency that resulted in the Challenger disaster. There was a problem of suppression of information from the top, an active suppression of information.

I think in Columbia, to date, we have not seen that there has been an active suppression of the information. You can debate whether or not certain pieces of information were elevated properly from within management and engineering, it seems, but I have not seen evidence, to date, that indicates that there was an active effort to squelch that discussion.

The what-if-ing scenarios of what happens to a vehicle and what happens to systems goes on on every single mission. I had the opportunity to work console for three different Shuttle missions while I worked for the Space Station Program, and that's part of what you do, is you understand the details of what happens to that vehicle and what happens to those systems, and you go the absolute worst-case scenarios, and you talk about those. It just happens that e-mail now puts that down on paper, and some of that is now transmitted and can be taken out context.

So I think that's a difference in those two areas. I'm sure that we'll find areas that need to be improved, and those improvements certainly need to be made. But I think that is a very dramatic difference between the two incidents.

Senator NELSON. The question of photographs, Ms. Smith, what do you think? Looks like NASA is going to be taking photographs, if such an occurrence should occur in the future. What do you think about whether or not they should have taken photographs this time?

Ms. SMITH. Well, again, Senator, not to put you off, but I don't think CRS would take a position one way or the other. I think NASA has explained itself. It said that it had gotten photographs in the past and had not found them particularly helpful in trying to determine whether or not there had been missing tiles on previous flights, and so they felt that they would not be particularly helpful in this case. So they've explained why they chose not do that, and it would be up to Admiral Gehman and his team to decide whether or not that was a good management choice.

Senator NELSON. So you don't have a personal opinion about that?

Ms. SMITH. No, sir.

Senator NELSON. Go ahead, Mr. Chairman. I've got several other questions, but——

Senator BROWNBACK. I've had my chance. I was just getting ready to close the panel down when you came in.

Senator NELSON. Do you have another panel coming?

Senator BROWNBACK. No, this is it. So if you have another couple of questions, go ahead and ask them and then we'll finish up.

Senator NELSON. May I have more than a couple?

[Laughter.]

Senator BROWNBACK. All right. We may bounce back and forth a little bit here. I may give you the gavel and go on. Go ahead.

Senator NELSON. I'd love that, Mr. Chairman.

[Laughter.]

Senator NELSON. The last time I had the gavel in this Subcommittee, we went for 5 hours.

[Laughter.]

Senator BROWNBACK. Oh, well, I couldn't handle that.

Senator NELSON. As we look at some of the things that are happening, do you have any technical suggestions for this Committee about buying some more time if you've got a damaged area of an orbiter and you want to buy some more time—I'm not suggesting there was anything that could be done to save this particular mission and crew—such as cold soaking or a higher angle of attack or keeping the crew in space longer to rescue them—if you're damaged area is your left wing, keeping your left wing up instead of the roll reversal taking it back into a left wing down? Any suggestions?

Dr. ROLAND. Senator, I don't have the technical competence to answer that specifically, but I do have a suggestion that I think's in the same realm. I think in the future, until we either have a clearer idea and clearer prospects of a new and safer Shuttle, that all Shuttle missions in the future should go to the Space Station and should involve an inspection of the Shuttle before it returns.

And, additionally, we might want to consider—we've been speaking earlier about developing a small astronaut orbiter which would be only to transport people to and from orbit—we might want to consider using the Shuttle unmanned as a heavy-lift vehicle. It can fly up and it can fly back without the astronauts onboard. This would not hold down the costs, but it surely holds down the risk to human life of a technology that I think is becoming more fragile as time goes on.

Senator NELSON. Any other comments?

Mr. CHASE. No, I don't have the technical background or the currency with the programs to make the recommendations.

Senator NELSON. The future of human space flight. Where, in your opinions, would you like to see us go as we get back into flying with the Space Shuttle? What would you like to see the program evolve into?

Mr. CHASE. Senator, one of the discussions that we've been having is this notion of a destination-driven program versus building capabilities that let us go multiple destinations, and I think that's a very good debate to have. I'm not sure that that debate has been decided, but clearly NASA is moving towards this notion of building capabilities to do a number of things. Rather than simply building a vehicle that goes to Mars or just goes to the moon, why not build capabilities that let us do a number of things in space that can be applied to robotic missions, to human missions, and anything else that we may want to do.

One of the recommendations put forward in the Commission on the Future of the Aerospace Industry, chaired by Congressman Robert Walker, was just that notion, that you need to develop the capabilities to do a number of missions. And, in a lot of ways, that's more exciting, to understand that you have the capability through developing nuclear propulsion and power options for in-space transportation, but you can then take that and apply it to a number of missions, to send a robotic probe to Europa, to send a human mission to Mars. That, I think, opens up your possibilities. You have some challenges in perhaps how you motivate that team that develops the systems, because they may not know exactly what they're driving towards. But it does open up your possibilities, and that's where I think we should go.

The most important element in all of that is the access to space. Getting low-cost access to space is critical. The capabilities of the Shuttle are critical for the short- and near-term. Then as you develop and phase in the next-generation systems, that's what enables you to drop the costs. And I was encouraged by your comments earlier and your comments in the past related to the role that the Department of Defense can play in future space access, both in developing next-generation RLVs and perhaps how the fleet of the evolved expendable launch vehicles, EELVs, can play in our space transportation needs. Those are very robust and very new systems that are much simpler, much more efficient than their predecessors. I think there's a major role for them to play in future access.

Ms. SMITH. Well, Senator, I'm not allowed to take positions or have opinions, so about all I can offer in this context is that it——

Senator NELSON. But you're one of the great experts on space.

[Laughter.]

Ms. SMITH. But it may be useful to have the context set for where it is that NASA and America expect to go in the long-term in human exploration. Most of NASA's programs have this long-term view. The planetary program does, the astronomy program does. But when you get to human space flight, the Space Station is basically it. Because it's taken so many more years than people expected for it to become operational, and it's still not there yet, people have sort of given up looking at what is beyond space station. In fact, NASA, I don't think even has a cutoff for when the Space Station is going to stop operations or transition to something else.

And so in terms of trying to develop an architecture for the future and decide what your options are and what kind of launch vehicles you need and whether you want to have one vehicle for human space flight and another vehicle for cargo, you really need to know where it is down the road all of this is going to be taking you.

And I know that there are a few people at NASA who have been looking at this over these past few years, but because of the funding situation at NASA, I think there aren't a lot of people there who feel that they can stand up and say, "Oh, yeah, this is the way it's going to be." And so I think that, you know, even after all these years and after all the studies that have been done on future space goals, that here we are in 2003 and it's still not clear what direction this is all leading in. And I think that's an important component of then backtracking and saying, "So what kind of launch vehicles do I need?"

Dr. ROLAND. I don't think, with our current technology, there are any missions for people in space that are worth the cost and the risk, but that does not mean that there's not a value for human missions in space—conceivably on a space station, conceivably going to the moon, going to Mars. And the question is, when will the cost come down enough that the value of having people there, which is now so much more expensive, intersects with that cost? I think the space program should be focused on making that happen sooner rather than later, and that means launch vehicle development. I think Mr. Chase and I agree that access to space is the big issue, and that's where we should be concentrating our research and development.

Senator NELSON. Mr. Chairman, I'll conclude my comments just by responding to Dr. Roland.

In one sense, I agree with you, and that is that the risks for human space flight are not accurately projected. Indeed, in a flight that I participated in 17 years ago, at the time it was generally thought to be catastrophic one in 100. It ended up being one in 25. And now we know, it's two in 113. And that's why I have been unrelenting in my advocacy for the safety upgrades on the Space Shuttle and have been unforgiving, Mr. Chairman, to a NASA that has not pressed with those safety upgrades as a first priority of business; instead, stealing money from the Space Shuttle, which would have gone into safety upgrades and other things, and putting it in other things in NASA. So in that regard, I think you're right.

Where I would disagree with you—and this is my concluding comment, Mr. Chairman, because I know you want to shut down—and that is that Americans are, by nature, explorers. We're about to celebrate the 200th anniversary of Lewis and Clark. And that was a big deal in the day. That was like an Apollo project in their day. And that reaped enormous benefits for us. And I think that we need, as a country, not only the development of the technologies and all of those spinoffs to the value of our society here on the planet, but fulfilling that part of our nature as explorers.

For example, one of my crew mates, Dr. Franklin Chang Diaz, has been developing over the last 30 years a plasma rocket that he's just about ready to test if NASA will keep giving him the money. He's got a 30-university consortium, he's got a test model, and this thing would ultimately take us to Mars in 39 days instead of 10 months, which is conventional technology, would solve the problem of gravity, because it would accelerate half the way and decelerate the remaining half way, and would create a magnetic field around the rocket, which would help us repel the solar flares.

And so these are the kind of things that I think we've got to be visionary in. And I'm so grateful to you, Mr. Chairman, because you are a visionary, and I'm glad that you're the Chairman of this Committee.

Senator BROWNBACK. Thank you very much, Senator Nelson, Astronaut Nelson.

I want to thank the panelists, as well. This is the start of a lengthy process. It's been going on for some period of time. But we do want to fulfill the dreams of us as explorers, and I don't think anybody on the panel disagrees with that. It's just how we do that and how we proceed forward.

I want to thank all of you, individually, for your expertise and your continued support and enthusiasm for how America proceeds forward into space.

Thank you very much. The hearing is adjourned.

[Whereupon, at 3:55 p.m., the hearing was adjourned.]

○