AMERICA'S VISION:

The Case *for* Space Exploration

Failure Is Not an Option

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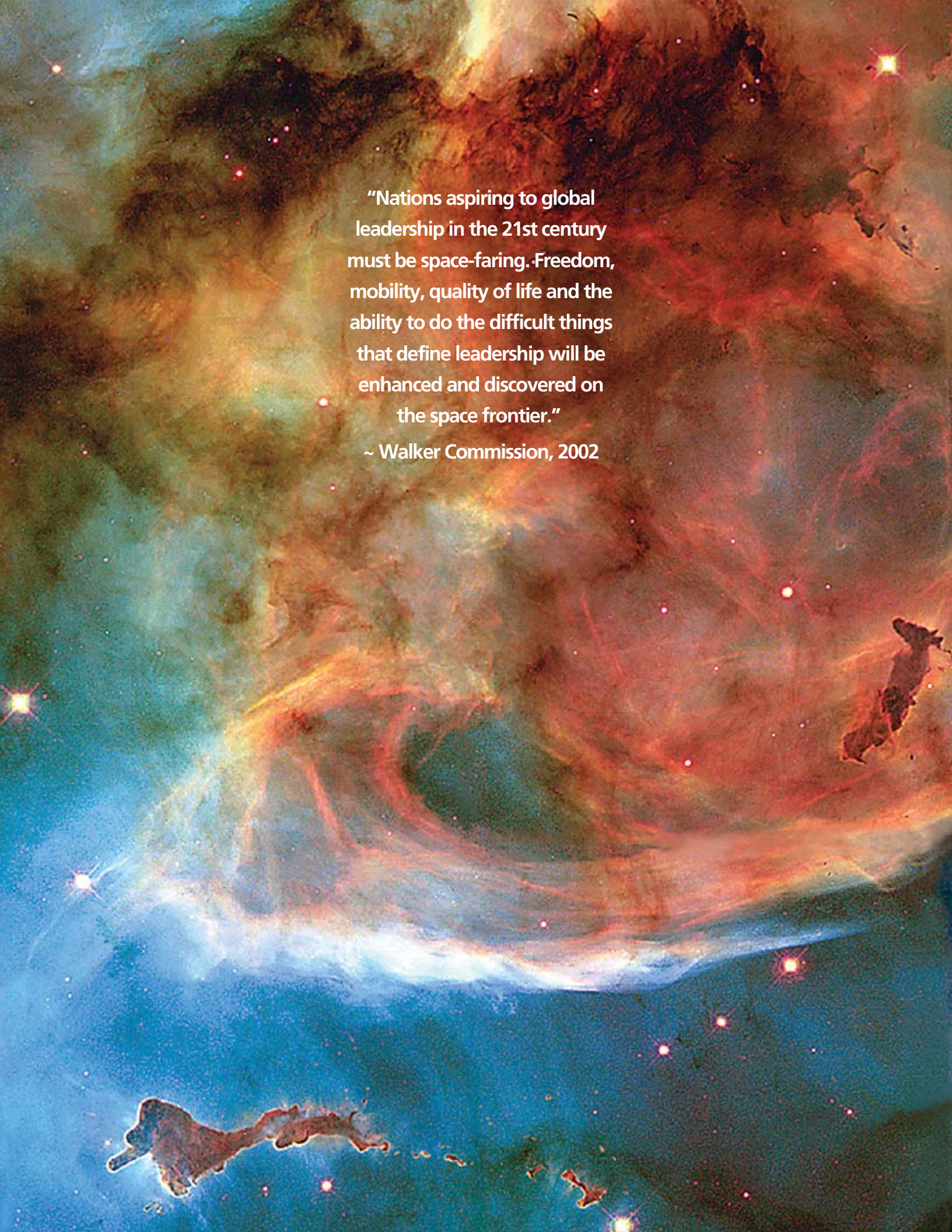

"Nations aspiring to global leadership in the 21st century must be space-faring. Freedom, mobility, quality of life and the ability to do the difficult things that define leadership will be enhanced and discovered on the space frontier."

~ Walker Commission, 2002

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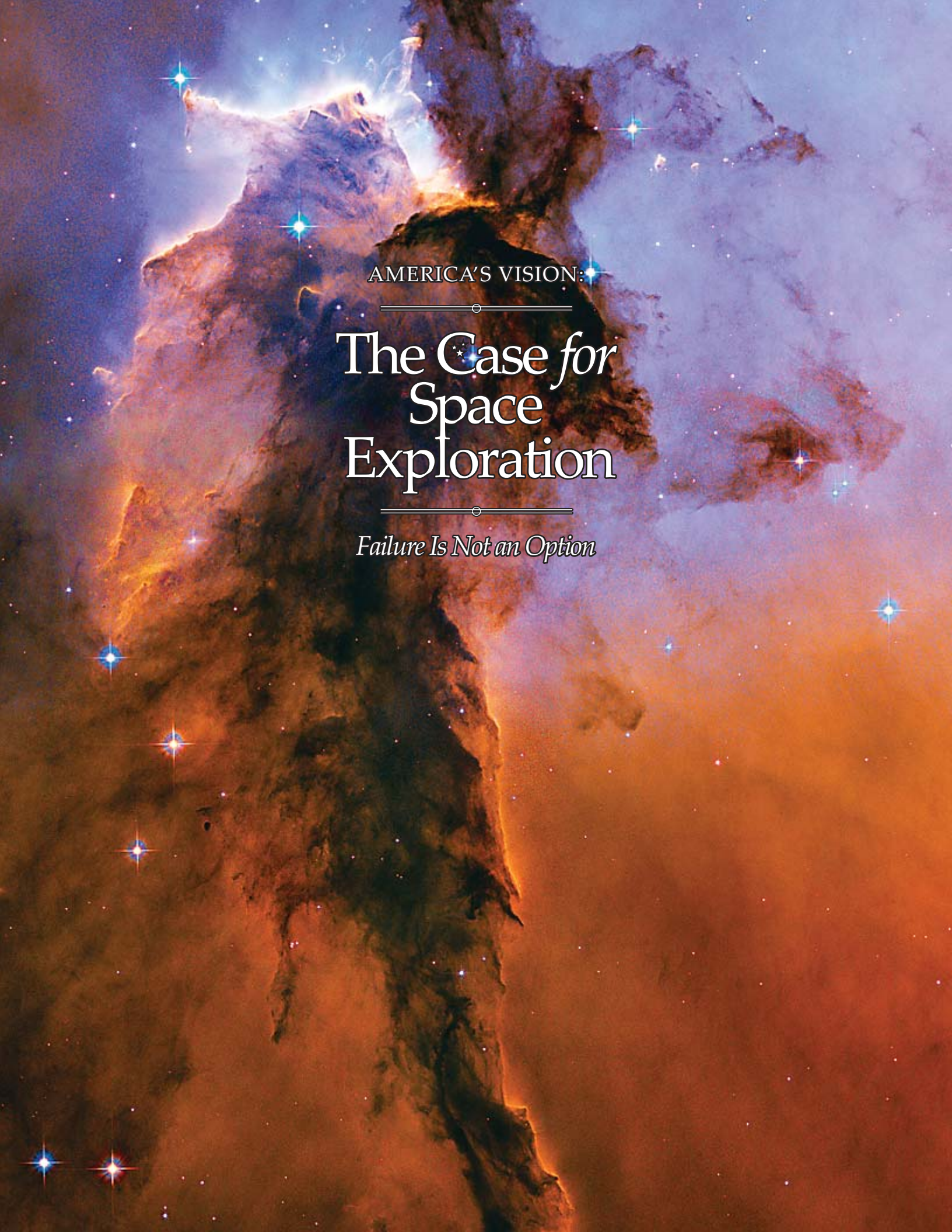

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Introduction

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With a mission "to vigorously advance civil, commercial and national security space endeavors and educational excellence," it will surprise no one that the Space Foundation strenuously supports the exploration and development of space, particularly the nation's new policy for NASA, the Vision for Space Exploration. What may surprise most readers — critics and supporters alike — is that the vast majority of Americans also support this vision. What, then, is the need for this publication?

In our view, the benefits of space exploration and development that permeate our daily lives have become so ubiquitous and transparent that most of us have forgotten where they originated. We take for granted that the United States has the most advanced technology and highest standard of living on the planet, without pausing to think about the history of investment in space research and development that has driven us forward for the past 40 years. The United States did not cement its position of world leadership by accident. It required thoughtful, and sometimes politically difficult, commitment to our national investment in the future — space exploration and development. Nor will the decades ahead naturally unfold in a manner that serendipitously assures the United States remains a leader among nations. Already, United States leadership is challenged by emerging space-faring nations around the globe. The time for a serious, renewed investment in our future is at hand.

Fortunately, the Case for Space Exploration is neither difficult to make nor to grasp. It is in that most rare category of endeavors that speaks both to our hearts and our minds. At an emotional level, every atom of every cell of every being on the planet came into existence in that one remote and ancient instant we call the Big Bang. We are the dust of the stars and the cosmos, and our yearning to understand the questions of our own existence pulls us inexorably toward the heavens. Exploration is the most sublime expression of what it is to be human, and space exploration is the ultimate expression of this humanity.

But the business of space exploration is hard, very hard. Thus, it demands the greatest effort we can put forward; the greatest minds, the greatest talents, the most inventive and innovative solutions to challenges — the stuff of which new knowledge, understanding, technology, and human capability is made. Here is where the economic and technology payoff is spawned. Our investments in conquering "the hard stuff" result in vast returns — the tools, knowledge, capabilities, and even new industries that ultimately benefit every human being on the home planet.

Whether you are a committed supporter of space exploration, a skeptic, or just someone who wants to understand better why more than 70 percent of the citizens of the United States support a more robust program of space exploration, this publication is for you. We hope that you will conclude, as we have, that the time to extend human presence throughout our entire solar system, as called for in the Vision for Space Exploration, is now.

Elliot G. Pulham
President and Chief Executive Officer
Space Foundation

James "Jay" DeFrank, Ph.D.
Executive Director, Research and Analysis
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Space Exploration: The Power of the Vision

Abstracted,… excerpted,… and adapted… from a keynote address by Astrophysicist ***Neil deGrasse Tyson, Ph.D.***

Editor's Note: *There is widespread belief that the space program is a good thing for our nation. But ask why and you'll get as many different types of answers as there are people. • According to astrophysicist Neil DeGrasse Tyson, the rationale for our space program has as much to do with national security and the economy as it does with the intangible, indefinable spirit of exploration that is written into our DNA. • The key point, Tyson argues, is that we can enjoy the many benefits of a robust space exploration program and afford to pay for it. In fact, we should probably spend a lot more on something that is so important to our culture but is all too often taken for granted. • In the following, Tyson explains why it is imperative we support the space program.*

True innovation requires a bold vision supported by audacious investments in human capital. Some will say, why rely on spinoffs for new products and technologies? Why not just invest in the product itself instead of waiting for it to happen as a spinoff of some larger effort?

Problem is, innovation just doesn't always work that way. For example, if you're the world's expert on thermodynamics, and I say, "Build me a better oven," you might invent a convection oven or one that's more insulated or one that's got better access to its contents. But no matter how much money I give you, you will not invent a microwave oven, because that comes from another place.

It came from investments in communications, in radar. The klystron in microwave ovens is traceable to the war effort, not to some oven expert.

As a scientist, I'm a bit outside of the traditional aerospace club. I've spent quality time within the space community, but, fundamentally, I'm an academic. This means I don't wield power over person, place, or thing. I don't command armies. I don't command labor unions. All I have is the power of thought.

So I knew the power of vision. While in graduate school, I was invited by Columbia Press to write a chapter for the *Columbia History of the 20th Century*. My chapter was called "Paths to Discovery," and I stumbled onto something that shocked me. My research began with this question: "How do cultures do great things? How did we go to the Moon? How do we go to Mars? How did they build the pyramids or the Great Wall? How do we accomplish these great, expensive, high-investment projects? How do cultures enable these periods of greatness?"

So I began to list all the "drivers" that had propelled people to do these great things throughout human history. I expected to compile a whole book of all the ways people found to justify doing these great things. But there wasn't a whole book's worth. There were just three. Three drivers. No more, no less.

We can list without much controversy the most expensive or audacious things people have ever done: the Apollo project, the Manhattan project, the pyramids, the Great Wall of China, the Taj Mahal, the great cathedrals of Europe. Make the list as long as we like, and every item on the list will have one of three things in common:

- National Security,
- Economics,
- The praise of deity or royalty.

I wasn't able to find a single case in human history that didn't fall into one of those three drivers. So, an inescapable conclusion was that if America wants to go to Mars or beyond, and if that's going to be expensive, if it doesn't satisfy one of these three criteria, then we're not going.

So there it was. I published it. And it got some limited attention in the media. But there I was, spring 2001, minding my own business, when the phone rings, and it's the White House. They said, "We'd like you to join a commission to study the health of the aerospace industry." I said,

"Are you sure you've got the right guy? I don't know how to fly airplanes." But someone there had read my writings. And, when I read up on on the subject, I learned that the aerospace industry had lost half a million jobs in the last 14 years. Something bad was going on. And so I agreed to serve, but more out of duty than out of passion. Our first meeting would be the end of September.

Then September 11 came. I live, then and now, four blocks from ground zero in lower Manhattan. I was home that morning. The first plane hit. Then the second. Then the Towers collapse in full view from my dining room window. I won't recount all the details. But at that point, any indifference I might have felt toward the aerospace commission had vanished. I was a changed person. "Yes!" I shouted, "I'm ready for this aerospace commission. Yes! I'm mad as hell!" Not only was the nation attacked, so too was my backyard.

This commission was loaded with strong, independent, powerful, and patriotic Americans, and we were mightily concerned about the state of America's aerospace industry and its vital importance to our national defense, to our economy, and to our mobility in this pivotal moment in history.

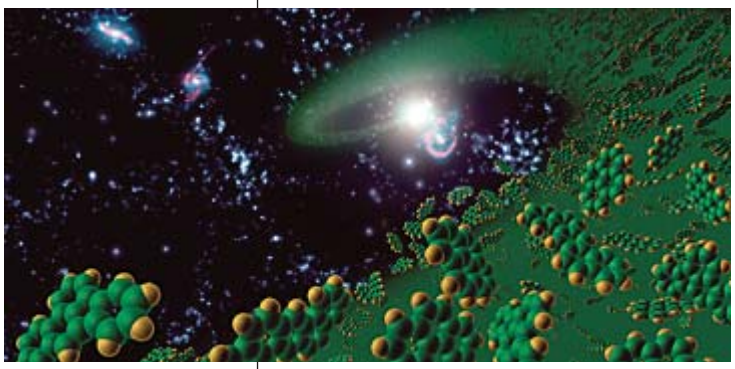
One of our research strategies as a commission was to explore the world aerospace climate because, clearly, what goes on in the world influences what goes on at home in America.

First stop, China — before they put a man in space. Like many Americans, I held the stereotypic view of China as a place where everybody is on bicycles in the big boulevards. Nope. We get to China, and everybody's driving Audis and Mercedes Benz and Volkswagens. Something's changed. Then we toured the Great Wall (driver: national security) and after looking far and wide and not seeing any evidence of technology at all, I pulled out my cell phone, called my mother in Westchester, and she said, "Oh, Neil, you're home so soon?" That's the best connection I've ever made with her with my cell phone. Nobody in China is yelling into his or her cell phone "Can you hear me now? Can you hear me now?" And when I got home, I peeked at the labels on things, only to learn that half of the stuff in my house was made in China.

So when China said, "We're going to put somebody in orbit," I knew it was going to happen. We all knew. China now says, "We're going to put somebody on the moon," and I have no doubts. If they say they intend to put somebody on Mars, I will have no doubts about that, either.

Of course we went to Star City, Russia, and other places you'd expect. But the visit that really made the hair rise on the back of my neck was in Brussels, with a group of European aerospace leaders. They had just released the European Union's multi-decade space vision, and they were moving ahead on their Galileo satellite navigation system — which will compete directly with America's GPS (Global Positioning System). We became worried. What if they finish their Galileo system, equip all their European airplanes with it, and then mandate that all airlines

must use this system to fly within European airspace? We have an ailing United States aerospace industry. So, we're trying to understand this, and they're sitting at the table very smug. That's when I became livid. Why? It was all clear to me as never before. We were at that table talking about aerospace products as though they were soybeans! What are the tariffs? What are your restrictions? Will you do this if we do that? All I could think was: something's wrong here! Aerospace is the leading edge of America's technological prowess. And if you're on the cutting edge of the frontier, you don't sit at a table negotiating usage rights!



Our high-tech leadership is something we all took for granted for most of the 20th century. Every airplane that landed in your city was made in America. Every airline in the world wanted to fly American aircraft. Today, we only build half the new airplanes, and substantial parts of those "U.S." airplanes are built overseas and shipped to the United States for assembly. I started to get angry again. Not at the smug Europeans sitting across from me. I got angry at us. I got angry at America because we have stopped advancing. Keeping your lead is not just something you do incrementally. You want innovation that leads not to incremental but revolutionary advances. You want to be able to take a day trip to Tokyo — that's a 45-minute ride, if you do it right (you go suborbital, re-entering the atmosphere on the other side of the planet.) How come we're not doing that now? If we were, I wouldn't have been sitting at that table with the smug guys talking to me about their Galileo satellites — because we would have already developed some other navigation system, and we just wouldn't worry about other countries, because we'd be too far ahead.

So I'm angry that aerospace, the crown jewel that gives us our technological edge, has become a bargaining commodity.

And, of course, I'm an educator. When I stand in front of students, it is totally demoralizing if I say, "Become an aerospace engineer so you can build an airplane that's 20 percent more fuel efficient than the one your parents flew." Of course that has no hope of exciting them. But if I say, "Become an aerospace engineer so you can design the first piloted craft in the rarefied atmosphere of the planet Mars," the effect is totally different. "Become a biologist and help us look for life in the subsurface soils on Mars, or beneath the ice sheets on Europa, or elsewhere in the solar system. Become a chemist because we need to understand better the chemistry of the Saturnian astmosphere."

When you put that vision out there, it makes my job as an educator easy. With that kind of vision, all I have to do is point my students toward it, flames of ambition get lit, and a new generation of innovators rises up.

We have such a Vision for Space Exploration before us. There has been some controversy about how to implement it, but we all know it's fundamentally a sound vision. Unfortunately, not enough of our citizens know about or understand its details. Within the available resources, our

exploration of the local and distant universe will proceed at a stately pace, taking us back to the Moon, on to Mars, and beyond over the next 30 years. With some reshaping of NASA, this plan is entirely within reach.

But I have an idea. Let's get serious about putting America clearly in the lead again.

Let's double NASA's budget.

What would that take? It would take another $16 billion per year, making NASA a $32 billion per year enterprise capable of moving faster, farther, higher — inspiring the nation and driving innovation as it did 40 years ago. It would take NASA's budget from its current level of seven-tenths of one percent of the federal budget to 1.4 percent — still far below the Apollo heyday when NASA got four to five percent of the federal budget, but enough to get the nation moving again.

Double NASA's budget and what happens? The vision becomes big, and it becomes alive, and everyone at all levels of schooling and adulthood can taste it. This will attract generations of students into science and engineering professions, leading to spinoff inventions that will transform how we live.

We all know that emergent markets in the 21st century are going to be scientifically and technologically driven.

True innovation requires a bold vision supported by audacious investments in human capital.

~ Neil deGrasse Tyson

We all know that emergent markets in the 21st century are going to be scientifically and technologically driven. The sustenance of our economy will require it. But if we no longer innovate, what happens? Everybody catches up, and our jobs go overseas. And then we complain that "they're paying them less over there; the playing field is not level." Well, it's time to stop whining! It's time to reclaim the lead that we have all taken for granted these past 50 years.

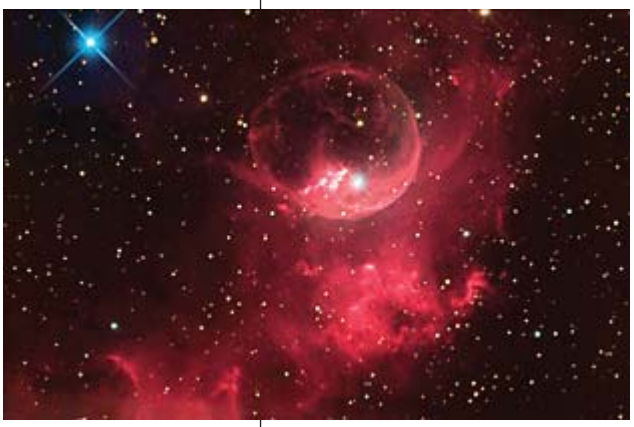
True innovation requires a bold vision supported by audacious investments in human capital. Some will ask, why we should rely on spinoff products and technologies when we could just invest in the product itself. The problem is, innovation doesn't always work that way. For example, if you're the world's expert on thermodynamics, and I say, "Build me a better oven," you might invent a convection oven or one that's more insulated or one that's got better access to its contents. But no matter how much money I give you, you will not invent a microwave oven, because that comes from another place. It came from investments in communications, in radar. The klystron in microwave ovens is traceable to the war effort, not to some oven expert.

And what about the Hubble telescope? When it was first launched, it had a bad mirror, remember? We still took fuzzy data, awaiting the repair mission. Better than nothing. But what were we going to do with the data? Then along came a computer science guy who wrote an algorithm that maximizes the information we can extract from the fuzzy Hubble pictures.

We used it for years. But then, somebody else said, "Hey, this is a good algorithm. We could use it for the early detection of breast cancer on mammograms." So right now, lives are being saved, simply because of the mistake in the Hubble mirror and the solution to try to minimize the consequences. We cannot neglect this fundamental way that invention and discovery take place every time we tackle the hard challenges laid before us by audacious visions.

Let me conclude with the following observation.

I claim that space is part of our culture. Many people within this industry complain that nobody knows the names of the astronauts, nobody gets excited by a space shuttle mission or by what's going on at the International Space Station — and so there's this lament that nobody cares anymore. I don't believe it for a minute. You know why? Because I have glow-in-the dark cosmic BAND-AIDS®. I have Hubble telescope refrigerator magnets. I have a can of Dole® pineapple slices that are prepared and sold as shapes of comets, moons, and stars. Four of the top ten grossing motion pictures of all time are about space. And when the announcement came that the Hubble might not be fixed, the loudest voices were not from NASA or the astrophysics community but from the public. The public took ownership of the Hubble telescope. When was the last time you heard of the public rallying behind a scientific instrument? That has never happened before. Ever.



America's culture? Well, consider this. If you go to a grocery store in Italy, one of the aisles will be completely lined with pasta. You can't help but notice it; they've got pasta we've never even seen over here. Do you think Italians notice that they have an entire aisle of pasta? Of course not. Go to the Far East. There's the rice aisle. We've never seen so many kinds of rice. Then go to an American supermarket. Nobody else in the world has an entire aisle of soda. But to us it's just the "soda aisle." Or look at the ready-to-eat breakfast cereal aisle. No other country has it. But we don't notice it. The fact that you don't notice it means it's a fully integrated part of your own culture.

Columbia gets launched. Nobody notices. Nobody can recite the names of the astronauts. Columbia breaks up on reentry, and the nation comes to a screeching halt. The nation mourns. The nation reaffirms its commitment to space exploration. This is not the behavior of a country that does not care. It's simply the behavior of a country that doesn't take special notice when it's there, but sure as hell takes notice when it's not there. That's the definition of culture.

Americans care deeply about space and not just in times of tragedy. This can be demonstrated in many ways, but allow me to share with you a brief story. I took a short taxi ride recently with a driver who was probably in his early twenties. He was one of those talkie drivers. In the five minutes I was in the cab, I learned that he's married and has a kid. And as we're chatting away, he stops and says, "Wait a minute, I think I recognize your voice. Are you an expert on the galaxy?" So I said, "Uh, yeah, I suppose." And he said, "Wow, I saw this program, and you were on it. It was the best, it was...." Blah, blah.

I recently received the following note via e-mail. "There are lots of things I have to do to become an astronaut. But first I have to go to kindergarten."
It was sent to me via the mother of a child who is fanatical about space.

But here's what's interesting. The driver was not interested in me as any kind of celebrity, that's a different kind of encounter. That's "where do you live, and what's your favorite color?" No. He started asking questions: "Tell me more about black holes. Tell me more about the galaxy. Tell me more about the search for life." We get to my destination, I'm ready to hand him the money, and he won't take it! This guy's got a kid. I mean, he's twenty-something years old with a kid at home, driving a taxi. I'm trying to pay him for the ride, and he won't take the money. That's how excited he is that he could learn about the universe.

If we double NASA's budget, whole legions of students will fill the pipeline. Even if they don't become aerospace engineers, we will have a new generation of scientifically literate people coming up through the ranks. People who will invent things that become the foundation of tomorrow's economy.

On the other side of this path, suppose the next terrorist attack invokes biological warfare. Who are you going to call? You want the best biologists in the world. Well, we're going to have them because they're working on the biology of life on Mars or Europa. We will have attracted that person because the space vision had been in place. Or maybe it's chemical warfare. We will want the best chemists in the world. Because of the vision, we know we'll have them. And they will not have left the path to become lawyers and investment bankers, as what happened in the '80s and '90s. And once this kind of intellectual capability takes its place in society, a $32 billion per year budget for NASA looks pretty cheap. It becomes an investment in tomorrow's economy and an investment in our national security. You start counting not just how many missiles are on alert, but how many scientists and engineers are there, too. This, by the way, makes the Vision for Space Exploration one of the most rare of great works — it fulfills not just one but two of the forces that drive nations to do great things: the national security driver and the economic driver.

I think we should marshal all of our resources to support this vision — to embrace it, and to cherish it, and to be champions for it. Our most precious asset is our enthusiasm for what we can do as a nation.

Going to Saturn on a Chapstick® budget

Americans expect great things out of their space program because the cultural connection runs deep. How deep does this go? It goes deep.

I was on the *Today Show*, July 1, 2005. The Cassini spacecraft had pulled into orbit around Saturn. There was nothing particularly scientific about it; it just pulled into orbit. But the *Today Show* figured that was newsworthy enough to put, not in their second hour with the recipes and shopping hints, but in the first 20 minutes of the first hour, among all the lead news stories.

So they call me in to the studio, and first they talk to the Cassini mission team — you know, the engineers — and they're jumping up and down and celebrating. Then they turn the cameras on me, offer congratulations, and ask what it all will mean. I replied that we're going to study Saturn, and execute large and targeted loops to study several of Saturn's many moons. But then Matt Lauer wanted to be hard-hitting, and he said something like, "But Dr. Tyson, this is a $3.2 billion mission. Given all the problems we have in the world today, how can you justify that expenditure?"

So I replied: "Pause. First of all, it's $3.2 billion divided by 12. It's a 12-year mission. So now we've got the real number, which is what? Less than $300 million per year." Then I said, "Three hundred million dollars. Americans spend more than that each year on lip balm."

When I uttered those words, the cameras shook and the lights flickered, and Matt had no reply. He practically stuttered and said, "Uh, over to you, Katie." And I realized in that instant that people just don't understand how inexpensive this space exploration really is, when you place it within the context of what we, as a nation, spend money on.

So I walked off the *Today Show* set and headed out to the street. On the *Today Show*, as you may know, bystanders gather in front of the studio, and watch through the glass. I did not know that they pipe the audio signal to them as well. So on my way out of the studio, from all the people hanging around outside the door, up came this spontaneous applause. And everyone held up their Chapstick® and said, "We want to go to Saturn!"

So I said, "Yes!" And deep down, I thought to myself that I should start the Chapstick® movement for space exploration.

The Vision for Space Exploration

Jim Banke, *Vice President, Florida Operations, Space Foundation*

Editor's Note: *The centerpiece of the nation's 21st century civilian space policy is the Vision for Space Exploration. • The vision directs NASA to finish its current space shuttle and International Space Station programs, return humans to the Moon and later send them on to Mars and beyond. This will be done on a step-by-step basis, spending only what is available each year. • Put another way: This isn't your father's space program anymore. It's better, it makes sense and, at less than one percent of the federal budget, it's affordable. • In the following, veteran aerospace writer Jim Banke, now with the Space Foundation at Cape Canaveral, explains the basic plan that is the Vision for Space Exploration.*

The vision is a stepping stone approach that is affordable and can be sustained through the years without significant additions to its budget or by sacrificing programs in science and aeronautics.

The vision is open ended and speaks to establishing a new transportation infrastructure that allows humans to continue moving out into the solar system and the stars.

The Vision for Space Exploration is a common sense plan for the nation's civilian space program that will allow human and robotic explorers to maintain a presence in low Earth orbit, return to the Moon, and continue on to Mars and points beyond.

Engaging the vision will ensure the United States remains a world superpower, provide the necessary resources to maintain our national security, and result in a significant economic return on our investment.

All of this will be accomplished by using a stepping stone approach that is affordable and can be sustained through the years to come by spending no more money than the nation otherwise would have spent on its space endeavors.

Space Policy Shift

The vision marks a significant shift in the way the nation previously approached spaceflight, particularly the early Mercury, Gemini, and Apollo programs of the 1960s.

Instead of a large-scale, crash program to realize a specific goal by a set deadline with almost no limit on the cost — which is what the original Moon race was — the vision calls for living within its means and taking the time needed to do it right and safely.

While goals will be stated and schedules determined, if there are technical problems or budget challenges in a particular year then the program will be stretched out. Of course, additional funding, if made available, would help to accelerate the program.

Another facet of the vision that separates it from programs such as Apollo is that it doesn't end at the next destination, such as the Moon or Mars, but will continue to push beyond.

The vision is open ended and speaks more to establishing a new transportation infrastructure that allows humans to continue moving out into the solar system and, one day, the stars.

What we do along the way in terms of science, engineering, national security, education, or commerce can be determined later, because we can't explore new horizons if we can't get there in the first place.

First Stop: Low Earth Orbit

The first major step in the vision took place on July 26, 2005, when Space Shuttle Discovery lifted off from the Kennedy Space Center on the first return to flight mission following the 2003 Columbia disaster.

NASA is to continue flying as many shuttle missions as it safely can until Sept. 30, 2010, when the fleet of winged spaceships will be permanently grounded and retired.

All but one of those missions will be dedicated to completing assembly of the International Space Station and meeting United States obligations to its international partners. The exact configuration of the station will depend on the number of shuttle missions flown.

A final shuttle mission to service the Hubble Space Telescope also remains under consideration.

Assembly missions to the station will be complemented by Russian Soyuz and Progress launches of humans and cargo, respectively. A new European cargo carrier launched on an Ariane 5 rocket will soon be available as well.

Aboard the station, crew members will live and work as normal but concentrating on learning how to operate and survive in space for long periods of time – skills that will be needed when establishing bases on the Moon or traveling to Mars.

Also, NASA will consider procuring cargo and crew delivery services from the commercial space sector as soon as a private company can demonstrate they have the ability to do so safely.

A New Spaceship

In the meantime, work is pressing ahead with the design and development of the new spacecraft and rockets that will replace the space shuttle after 2010.

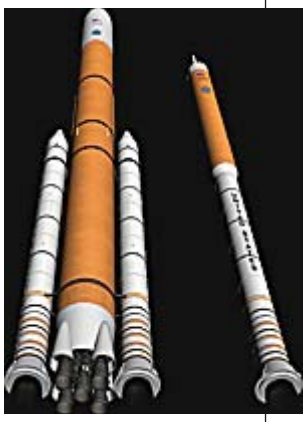
The centerpiece of the new transportation system will be the Crew Exploration Vehicle (CEV) in which astronauts fly to and from low Earth orbit. An unmanned cargo-only version will be built as well.

The CEV will be the same shape as the Apollo command module, only three times bigger. It will descend to Earth relying on a trio of parachutes, and be capable of landing on the water or the ground.

Each copy of the CEV is designed for reuse at least 10 times.

When in space, the CEV will have an attached cylindrical service module that will sport a pair of electricity-generating solar arrays and a propulsion system powered by liquid oxygen and liquid methane.

Crew safety and survivability is a major feature of the CEV. In addition to the capsule's having a heat shield, when the spacecraft is atop its launch vehicle an attached escape tower can safely pull the CEV away from an exploding rocket.



Heavy Lift Vehicle (left) and Crew Launch Vehicle (right)

By attaching other modules to the CEV, the reconfigurable spacecraft will be able to carry astronauts back to the Moon for the first time since 1972, and eventually serve as the backbone of a Mars-bound spacecraft.

There is a strong desire to minimize the time between the final shuttle mission in 2010 and the operational availability of the CEV. First flight of a crewed CEV could come as early as 2012, with a lunar landing targeted for 2018.

Shuttle-derived Spaceflights

Two new rockets are on NASA's drawing boards to support the CEV and the Vision for Space Exploration. Both will rely heavily on the use of the solid rocket booster, space shuttle main engine and external tank hardware designed for the space shuttle.

Using shuttle-derived hardware is expected to save money and make it possible to fly sooner than waiting for a new rocket or launch pad to be built. Existing factories, workforce, and launch facilities can still be used.

Targeted first to fly is the Crew Launch Vehicle (CLV). Its primary job will be to launch CEVs carrying crew or cargo into Earth orbit, and it will be a two-stage rocket with a CEV and attached escape tower on top.

The Crew Exploration Vehicle atop the CLV Launcher, from Kennedy Space Center

Called the "single stick" in some circles, the CLV first stage will be a single solid rocket booster made up of four segments like the booster currently used on the shuttle. A five-segment booster may be used to increase the lifting capability from 25 metric tons to 32 metric tons.

The CEV second stage will be powered by a single space shuttle main engine, which burns liquid oxygen and liquid hydrogen.

Initial test launches from Florida could begin as early as 2008. That would be in plenty of time to support deployment of the CEV, as soon as possible after the shuttle is retired in 2010, perhaps in the 2012 timeframe.

Heavy Lifter

When the time comes to return to the Moon, a heavy-lift rocket will be required to loft into orbit the hardware needed to make the trip,

including an Earth Departure Stage that will send a CEV beyond Earth orbit.

CEV arrives at the International Space Station

The massive rocket, capable of lifting between 106 and 125 metric tons to Earth orbit, will look something like a cross between a space shuttle and Apollo Saturn 5 rocket. Five shuttle main engines that are attached to the base of an external tank will power the first stage. Bolted to the external tank will be a pair of five-segment solid rocket boosters. An upper stage powered by J-2S engines originally used during Project Apollo will help complete the design and provide the boost needed to send a CEV or other cargo out of Earth orbit on its way to the Moon, and one day, Mars.

We expect that NASA will give this new rocket a more mythological name, but for now it is known by various acronyms, including HLLV for Heavy Lift Launch Vehicle, or SDLV for Shuttle Derived Launch Vehicle.

Other hardware, such as a new lunar module, need to be developed as part of the vision. And as new technology is invented and perfected, the rockets and spacecraft used for the vision will be modified.

CEV returns to Earth

Silver Lining

Announced by President George W. Bush on Jan. 14, 2004, the Vision for Space Exploration is a silver lining in the cloud that was the 2003 Shuttle Columbia disaster.

In addition to the technical failure that doomed the vehicle and its seven-member crew, investigators found that management was at fault, in part because the agency did not have a long-term goal for its spaceflight programs. Senior White House and NASA officials reacted to the Columbia Accident Investigation Board's recommendation for a long-term goal and created the Vision for Space Exploration as the missing direction for NASA and the entire aerospace industry.

CEV about to touchdown

Since the announcement, critical support for the nation's vision has continued to build. In Congress, lawmakers have twice passed appropriations bills providing full funding for the vision. Public support for the vision is growing, according to recent Gallup Polls.

No longer is the Vision for Space Exploration the President's goal alone. It has become the nation's goal.

The Global Space Economy

By the Space Foundation

Editor's Note: *When President Kennedy challenged America to land on the Moon before 1970, no one said, "If we do this, then in 40 years consumers will be able to purchase laptop computers, satellite radio receivers, and hand-held GPS devices from a neighborhood store." • But that's what happened. Solving the problems inherent in sending astronauts and satellites into space resulted in new products and capabilities that have transformed our culture and spawned a major segment of the global economy worth trillions of dollars. • So is it reasonable to expect that investing billions more in the Vision for Space Exploration will yield future economic benefits presently impossible to predict? • In the following, we look at the impact of the space program on the global economy and learn just how pervasive the influence of space is.*

As a direct result of the innovations, inventions, and discoveries that have enabled us to explore space, our daily lives on Earth have changed profoundly.

Many of the capabilities and technologies we have developed through space exploration probably would not have been developed in its absence, even with the same level of investment.

The quality-of-life benefits yielded by space goods and services are sweeping and significant, with tremendous value in time saved, injuries and casualties avoided, education enabled, and efficiencies realized.

Space exploration has advanced telecommunications, medical technology, weather forecasting, navigation, television, radio, computing, and many other industries. The nation's commitment to space exploration has engaged us in a unique type of problem-solving. As a direct result of the innovations, inventions, and discoveries that have enabled us to explore space, our daily lives on Earth have changed profoundly.

Space exploration requires experts in many different areas to work together to develop entirely new capabilities that operate reliably in a remote and hostile environment. Few other endeavors combine this interdisciplinary focus with the need to achieve not simply concepts or demonstrations, but also functional end-state results. No other endeavor addresses the same challenges as space exploration. Many of the capabilities and technologies we have developed through space exploration probably would not have been developed in its absence, even with the same level of investment.

Goods and services enabled through the use and exploration of space permeate our economy. Massive industries, with annual revenues of hundreds of billions to trillions of dollars, rely on space systems to provide key capabilities. From television to cell phones, from maps to weather forecasts, fundamental aspects of American life rely on an infrastructure of in-space systems in place today. Ma ny others — personal computers, compact discs, and cordless tools, among countless examples — derive in part from past investments in space technology.

Moreover, the impact of investment in space exploration extends far beyond the United States and the small number of other space-faring nations. Space capabilities shape life around the world.

Space Infrastructure

The global space economy is built on a space infrastructure consisting of manufacturers, service providers, and technologists in industry and government who deploy and operate launch vehicles, satellites, and space platforms such as the International Space Station. The cost of this space infrastructure is borne by commercial firms that sell satellite services; governments in many countries that use satellites to provide long-distance telephone, television, and Internet to their citizens; and the national space agencies (mainly those of the United States, Europe, Russia, Ukraine, China, Japan, and a few others). The cost of space infrastructure — launchers, in-space

systems and supporting ground operations, human activity in space, and the knowledge and technology base that supports the infrastructure — is about $60 billion each year. That includes every cent of NASA's budget, the budgets of all other international space agencies, the cost of military space activities, and nearly $13 billion of commercial expenditure on manufacturing and deploying commercial satellites and launchers.

This investment enables not only space exploration, with its extraordinarily rich legacy of science, inspiration, and human achievement, but also economic activity many times larger. Our spending on space delivers vast and growing improvements in quality of life, safety, security, health, and education in the United States and around the world.

Goods and Services that Use the Space Infrastructure

Goods and services relying on space infrastructure generate hundreds of billions of dollars in direct revenue, and in doing so enable important industries that are much larger. In fact, a defining feature of many space-related goods and services is that their cost is tiny compared to the convenience, efficiency, information, and other benefits they yield.

For example, most people would list direct-to-home television and satellite radio as space-related industries, and indeed, these services generate more than $50 billion in revenue each year, and provide access to television and radio to many new subscribers. Much more sweeping, however, is the use of space by broadcast and cable television. Broadcast and cable television providers rely on satellites to distribute nearly all content to cable head ends and broadcast affiliates and to transmit new feeds from location to studio.

Satellites also enable truly global Internet service. Satellites are not the primary mode of Internet communications, but they extend Internet content and access in ways that current terrestrial networks simply cannot accommodate. Satellites provide intercontinental capacity to augment fiber optic cable networks that underserve certain pathways, such as those between South America and Asia, or along many parts of the African coastline. Satellite connections have also allowed many Internet users to receive broadband service without waiting the years that it is taking in some areas to build high-speed landline connections.

Long-distance telephone service via satellite was the earliest widespread space application and delivered instant telephone access between United States and many other countries. Today, nearly all long-distance calls leaving the United States travel on fiber optic cables, but many nations that are not connected to cable networks due to expense or geography still depend on satellites.

Leasing satellite capacity for television, telephone, and Internet backbone around the world generates about $10 billion each year directly to satellite owners and operators. However, the true economic power of these applications of satellites is in the worldwide access to communication services, education, news, information, and entertainment provided to billions of people. In fact, they exemplify what is perhaps the most powerful statement to be made about space exploration and the global economy — that the concept of a global economy is difficult to imagine in the absence of global communications, and global communications exist because of space capabilities.

How much do we spend on NASA?

$16.2 billion in 2005, or 2/3 of 1% of the federal budget

The 2005 U.S. federal budget was about $2.4 trillion, of which NASA's portion was 0.68%.

About 15¢ per day, per person in the United States

This reflects NASA's budget divided by the U.S. population of about 300 million.

Less than the revenues of any Fortune 100 company

#1-ranked Wal-Mart has annual revenues of $288 billion. NASA's budget is about the same as revenues from The Gap, #130 on Fortune 500, with $16.2 billion in 2005.

About the amount spent to advertise cigarettes in the United States

In 1962 President John F. Kennedy commented that the NASA budget was "less than we pay for cigarettes and cigars every year." Today, tobacco companies spend nearly the amount of NASA's budget ($15 billion in 2003) on U.S. advertising and promotions alone.

More than we spend on space exploration

NASA's budget also includes about $1 billion for aeronautics. $1.5 billion for eath sciences, and additional amounts for other non-exploration activities.

Satellite navigation is another excellent example of the disproportionate benefits delivered by space goods and services. This global industry exists solely due to a service provided free to the world by the United States through the Global Positioning System (GPS) constellation of satellites. GPS satellite signals allow users on land, on the sea, and in the air with inexpensive GPS devices to determine their position and, aided by computer maps (most of which were developed in part using other satellite capabilities such as remote sensing), plot a course to their destination. GPS navigation has been so successful and valuable that that the European Space Agency is investing billions of dollars to develop its own GPS satellite constellation, Gallileo. GPS signals also provide precision timing for financial and cell phone networks.

Examples of Goods and Services Using Space Infrastructure

Example	Use of Space Infrastructure	Direct Revenues (2005)	Benefits and Related Revenues
Direct-to-home television and satellite radio	Broadcast of television content directly from satellite to consumer, providing access to television in rural locations and a choice of television providers to many consumers. Satellite radio delivers high-quality, large number of channels, available anywhere radio service; also, new emergency broadcast system function	$50 billion subscriber fees and advertising	$200 billion global television and radio industry
Broadcast and cable television	Content distribution to cable head ends and broadcast affiliates; news gathering; and communications infrastructure	$10 billion leasing of satellite transponders	
Long-distance telephone service	Communication backbone where terrestrial or undersea cables are not available, typically less-developed, remote, or difficult-to-access areas, or in areas where the Internet has created new traffic patterns		$75 billion international long distance market
Internet infrastructure			$1,000 billion (trillion dollar) global Internet economy, including $150 billion in rapidly growing global e-commerce
Broadband Internet	Last mile connections to the Internet, mainly using very small aperture terminals (VSATs). Provides quick set-up, reliable, consistent capability for broadband connections to the internet used by consumers and businesses of all sizes and types (purposes include credit card transactions, inventory data, digital signage in stores, Internet broadband connections to Internet cafes, many others)	$3 billion broadband service (including $2 billion global VSAT network revenues from business network users)	
Global mobile telephone service	Global telephone connectivity directly to and from low Earth orbit satellite systems Iridium and Globalstar	$2 billion subscriber revenues from satellite mobile telephone and data services	Emergency disaster communications. Global communication from remote areas
Asset tracking	Asset tracking using low Earth orbit satellites in combination with GPS providing information on the location of, for example, fleets, RFID-tagged packages, and physical inventory		$20 billion geospatial technologies industry. GPS and remote sensing data also result in time saved, improved safety, reduced costs, greater accuracy for Weather forecasts alone save many lives and hundreds of billions of dollars each year
GPS navigation, positioning, and timing	GPS satellite signal used by GPS chipset in automobiles, marine navigation, aviation equipment, asset tracking systems, mapping tools, and cell phones	$18 billion total revenues from equipment and related service	
Remote sensing	Remote sensing imagery (satellite images of Earth) helps monitor weather, create maps, track environmental impacts such as coastline erosion and pollution. Wide range of industries and applications — about one third of businesses in the economy are affected by remote sensing data	$<1 billion sale of commercial imagery remote sensing satellites	

Consumers increasingly rely on products and services such as On-Star, the General Motors GPS system that provides drivers with directions via the cell phone network and DVD navigation systems that integrate maps with automated voice directions. Industrial applications include trucking, aviation, and maritime services. Manufacture of GPS

navigation units and direct purchase of associated value-added products and services generates about $18 billion in revenue, with high annual growth. These dollar values do not, of course, reflect the time saved, improved safety, and reduced costs that users of these systems have realized.

There are many other examples. Almost $2 billion is paid each year for satellite images and basic processing, but analysis and use of the information they generate is a fundamental part of many massive industries. Satellite imaging is increasingly familiar to all of us, as we see satellite pictures of the Earth used for mapping, surveying, crop monitoring, assessing environmental health, evaluating traffic and land use impacts, military reconnaissance, and many other applications. As population has risen, demands on farmers, land developers, and transportation infrastructure to obtain the best possible use of property have risen, and the value of these geographic information programs and services is multiplied to the extent that they meet these needs.

Thousands of gas stations use inexpensive small satellite dishes (very small aperture terminals, or VSATS) to connect to dedicated communication networks that let them nearly instantly process credit cards at their outdoor pumps. Just about every adult in the United States has relished the convenience of these speedy transactions. Internet cafes in Europe connect to the Internet, chains receive data for "digital signage" in individual stores, and remote island regions establish telephone service using VSATS.

In summary, the quality-of-life benefits yielded by space goods and services are sweeping and significant, with tremendous value in time saved, injuries and casualties avoided, education enabled, and efficiencies realized. The table on page 14 summarizes goods and services of the space economy by quantifying the revenue they generate directly and that of the industries they enable or are related to, and describes just a few of the larger impacts they have on our economy and our lives.

Space Technologies Transforming Daily Life

Perhaps even more valuable than the goods and services that use space infrastructure are those that use technologies developed as part of space exploration. The impacts of these technologies are so ubiquitous that it is difficult to imagine life without them.

Just a few award-winning examples are illustrated here. However, even a complete list of specific spinoffs would understate the impact of work conducted by NASA and the companies, universities, and laboratories it has funded. Space exploration technology has had a profound impact on the full range of industries that define modern life, including computing, telecommunications, medicine, aviation, and many others.

For example, computing and digital data storage media such as compact discs rely on error correction code technologies pioneered by NASA to compensate for "noisy" signals from low power transmitters used to save weight and space in early launches.

Stereotactic Breast Biopsy Can Eliminate Need for Surgery
Hubble Telescope imaging technology with the ability to see faint objects, such as distant galaxies, is applied to imaging of suspicious tissue, delivering high resolution to see fine details, wide dynamic range and low light sensitivity to shorten exposure time and eliminate the need for invasive techniques such as biopsies.

Argonide Corporation

NanoCeram Superfilters Deliver Super-Clean Water
Thanks to cooperative efforts with NASA to develop advanced water recovery systems for long-duration space flights, NanoCeram® filters far exceed current filtration systems to satisfy the most difficult water treatment requirements. NanoCeram's filter system is composed of tiny tubes (with a radius of just one nanometer) that can filter 99.9999 percent of bacteria, viruses, and protozoa.

Humanitarian De-Mining Device Saves Lives
With guidance from the U.S. Navy, NASA contractor ATK Thiokol developed a low-cost, easy-to-use device to render land mines inoperable by burning the explosive they contain in the open atmosphere using space shuttle propellant.

Rear Admiral Harley D. Nygren, NOAA Corps. (Ret.)

Anti Corrosion Coating Protects the Statue of Liberty
NASA Goddard Space Flight Center developed a coating that provides long-lasting protection from corrosion for use on launch structures at Kennedy Space Center. The commercial variant of this nontoxic, water-based coating has been used to coat bridge girders, pipelines, oil rigs, military tanks, dock equipment, buoys, municipal water facilities, power stations, antennas, tractor-trailer frames, and marine products, and including the interior of the Statue of Liberty during its refurbishment.

Johns Hopkins University Applied Physics Laboratory

Programmable Implantable Medication Systems (PIMS) — Delivers Meds Automatically
Implanted PIMS devices deliver precisely-timed medication to diabetics and others. The PIMS is a direct spinoff of the Viking space probe laboratory that landed on Mars.

Video Image Stabilization and Registration
NASA researchers used their expertise and equipment for analyzing satellite video to create a new technology that dramatically improves crime scene videos.

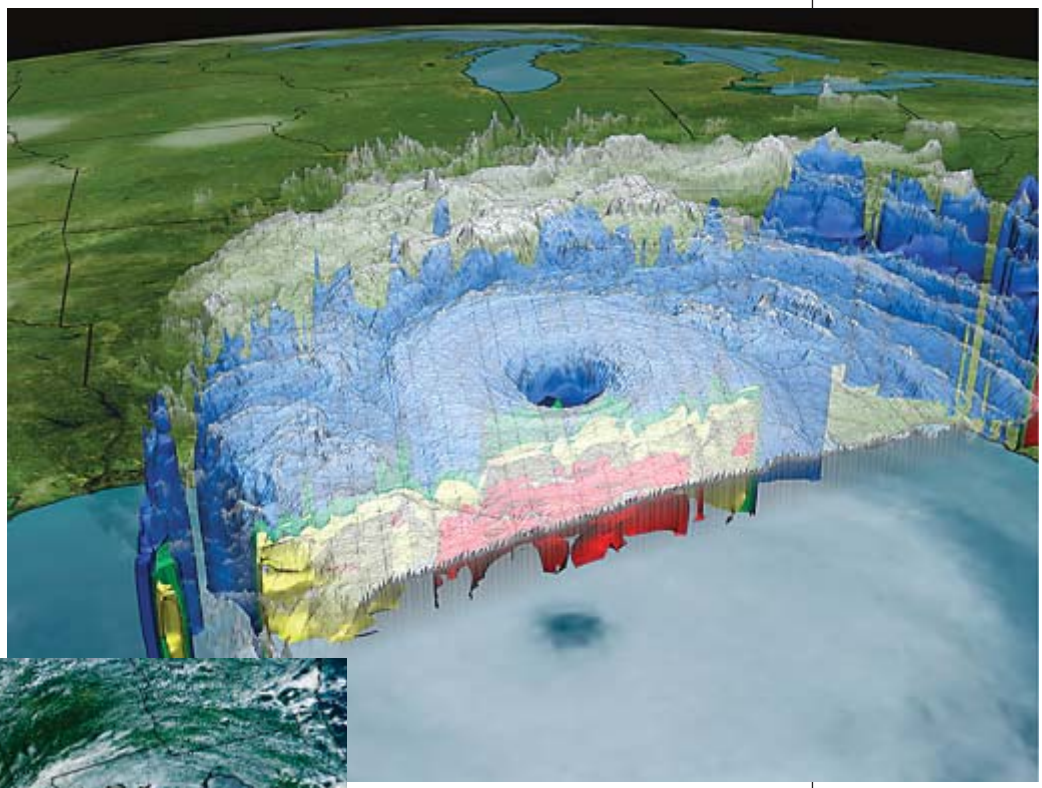
Television and telephone signals are compressed so massive amounts of information can be carried using limited bandwidth and small devices, drawing on decades of research on wireless communications in space. Surgeons and doctors rely on imaging technologies such as magnetic resonance imaging, precision miniaturized surgical instruments, laser devices, and advanced materials that have their origins with astronauts and space hardware. Flight simulation systems, advanced avionics, automated instrumentation, and other features of commercial airliners derive from NASA aeronautics and aerospace research.

The pathways taken by these capabilities often meander in and out of NASA's programs, as technologies are transferred from NASA field centers and contractors to operational space programs. They are reused, adapted, and enhanced by other organizations in industry, the military, or academia, and then sometimes reinserted in NASA's technology stream or perhaps combined with commercial research and development projects. While these complex interactions make it more difficult to map the precise pedigree of space-derived products or to compile a complete listing, the interplay among disciplines, organizations, and users makes the legacy of space exploration technology richer.

What the Future Holds

We can state with certainty that the unique problems and powerful problem-solving environment of space exploration will continue to enrich our economy and our lives. While we can make some guesses about what new capabilities, goods and services will result (environmentally useful water and agriculture techniques, new sources of power for tiny mobile devices, ultra-high precision products manufactured in space, or even public space travel on short suborbital flights), we can state with equal certainty that we don't know for sure. The process of space exploration is that of conquering the unknown, and its true economic value lies in the power of transformation inherent in that very uncertainty.

Satellites generate 90% of the weather forecasting data used in the United States.



Geospatial Operational Environmental Satellite (GEOS) image of Hurricane Katrina before landfall. Upgrades to the GEOS will improve the detail of imagery, increase atmospheric sounding capabilities (which helps accuracy of forecasts), and provide better relay abilities so data and images get to users faster.

Space based radar data from the U.S./Japanese Tropical Rainfall Measurement Mission (TRMM), as with this Hurricane Katrina image, are helping to solve questions of hurricane intensity, a critical issue for decisions on evacuations.

A Day Without Space

Elliot G. Pulham, *President and Chief Executive Officer, Space Foundation*

Editor's Note: *Technological advances and spinoffs resulting from America's space program have transformed our lives and culture so totally that it is all but impossible to imagine life without them. • But these innovations often are so totally integrated into our everyday existence that we frequently lose sight of just where they came from — or that they are even there at all. • Consider the story of the person who said weather satellites were a waste of money because all they had to do to get the forecast was turn on the Weather Channel. • In the following, Space Foundation CEO Elliot Pulham highlights some of the many ways that space enhances the daily life of an average American.*

In today's world, "A Day Without Space" is simply unthinkable.

Although every person's life and story is different, each of us relies on space technology numerous times every day.

Life in our world today would look nothing at all like it does without the technologies that have flowed from our investment in the exploration and development of space.

We are living off the investments made a generation ago.

The benefits of America's investment in space touch every aspect of life in the United States. Our standard of living — one of the highest in the world — would look nothing like it does without these strategic investments. However, the impact of these investments is all but invisible because they are so ingrained in our culture that space is an inseparable part of the fabric of our daily lives.

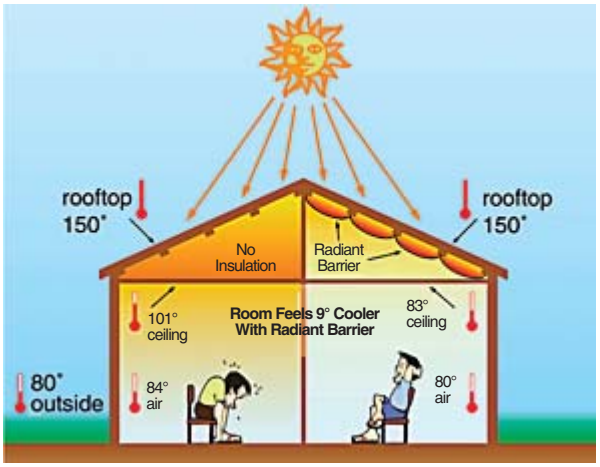
With the tremendous demands upon the United States federal budget, our nation faces a daunting challenge in articulating the value of renewed investment in space exploration. While predictions can be made, there are no guarantees.

But if the past is prologue, even a cursory look at life in America today vividly illustrates the significance of the returns on our investment in space.

In today's world, "A Day Without Space" is simply unthinkable.

To better illustrate this point, consider a few hours of a typical day for "Amanda," a 34-year-old mother living in Anytown, U.S.A.

As her alarm sounds, Amanda awakes refreshed and ready to face her busy day after sleeping snugly in a home insulated with radiant barrier technology developed by NASA, with a central heating system that keeps the indoor atmosphere clean with filtration technology developed for the space shuttle. Amanda also runs an EcoQuest™ air cleaner in her home, which uses filtration and ultra-violet sterilization technology developed for the International Space Station to help reduce exposure to harmful allergens.



State of Hawaii; Department of Business, Economic Development and Tourism; Energy, Resources and Technology Division

Amanda's comfortable sleep was also enhanced by her mattress of viscoelastic foam developed by NASA to cushion astronauts from G forces. Additionally, her bedding is made of temperature-regulating fabrics originally developed to shield astronauts from extreme temperatures in space, based on fabrics licensed by Outlast Technologies. Of course Amanda and her son have also felt safe as they slept because their home is equipped with smoke detectors that emerged from the Apollo program and anti-intrusion alarm that employs infrared sensors developed for Air Force satellite programs.

Tempur-Pedic®

As she gets out of bed, Amanda slips on her glasses made of strong and lightweight lenses created for astronauts, with optical coating treatments developed for space shuttle windshields. Starting her day with coffee and a peek at the day's news, space continues to have an impact. Both the news in her newspaper and the live reports on radio and television have been transmitted via satellite — either directly to a home system like DIRECTV® or XM® Satellite Radio, or indirectly in the form of satellite feeds to her local newspaper or cable TV operator. Her weather information is gathered through a network of civil and military weather satellites. It's going to be a chilly day with light rain, so Amanda dresses her son in comfortable school clothing made of fireproof fabrics and athletic shoes that trace their origins to NASA research and development.

Amanda and her son Todd then head to school in the family car — a veritable treasure trove of space-derived technologies. Anti-lock brakes developed for jetliners and the space shuttle are an important safety feature, as is the thermal firewall between the passenger compartment and engine. Protective airbags rely on tiny sensor/triggers called accelerometers, originally developed for rockets and missiles. The anti-glare windshield employs optical coatings developed for the space shuttle cockpit. Vehicle aerodynamics and fuel efficiency have been designed into the car through the use of computational fluid dynamics software developed for spacecraft wind-tunnel testing. The impact resistant unibody automobile was welded by robots — the precision and function of which were improved through aerospace research. Further, some of the advanced welding technology they use was developed to meet the complex welding requirements for the International Space Station.

Amanda's car also includes a United States Air Force Global Positioning System (GPS) satellite navigation system, and OnStar satellite positioning and communication systems. And their in-car entertainment is provided by a satellite radio with commercial free programming otherwise unavailable in her local marketplace.

On the highway, Amanda enjoys improved traction in the light rain thanks to highway safety grooving developed by NASA to improve runway safety for commercial jetliners. Without their even knowing, their journey takes Amanda and Todd over a bridge built of anti-corrosive metals, also developed by NASA. After dropping Todd at school, Amanda rests secure in the knowledge that his teachers can reach her in an instant by cellular phone if needed. Her cellular phone runs on a network that depends upon GPS satellites for precise timing signals that enable the entire network to function. Her phone itself depends upon a monolithic microwave integrated circuit (MMIC) chip, developed by Air Force researchers for satellite telecommunication systems.

Safety Grooving

NASA developed ways to channel water on wet runways into grooves to prevent space shuttle wheels from uncontrollably slipping, or hydroplaning. The same safety grooving techniques have dramatically reduced accidents — by as much as 85% — since their widespread application to roadways.

On her way to work, Amanda then stops at a service station where she uses her ATM card to pump gas. The service station's bank "talks" to Amanda's bank — a transaction requiring both terrestrial and cellular phone networks that, again, rely on GPS satellites to assure the precise timing required for clear communication and accurate financial transactions. Information about the gasoline sale is beamed via satellite from a VSAT terminal on the service station roof to the fuel distributor, who uses the information to track product distribution and plan deliveries in the most cost-effective manner possible.

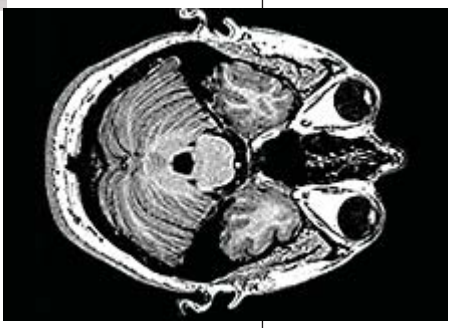
It's only 8:30 a.m., and space technology has already touched Amanda 27 times.

Although every person's life and story is different, each of us relies upon space technology numerous times every day. Carpenters rely upon cordless tools originally developed for Apollo astronauts. Doctors rely upon medical imaging devices, microscopic surgical instruments, remote medical monitoring devices, defibrillators, oxygen monitors, LADARVISION® lasik surgery tools and scores of other medical instruments and technologies that have emerged from the Apollo program. City planners use remote sensing satellites, farmers use remote sensing satellites and GPS-controlled machinery.

The list of space "spinoff" technologies is estimated to exceed 40,000. The industries these technologies have created employ tens of millions of Americans, and generate hundreds of billions of dollars in economic activity.

Life in our world today would look nothing at all like it does without the technologies that have flowed from our investment in the exploration and development of space.


LADARVision®



Medical and Scientific Imaging

Digital imaging was developed in the mid-1960s to explore the lunar surface. The Jet Propulsion Laboratory pioneered digital image processing to enhance electron microscope, X-ray, and light microscope images, enabling many medical applications, including CAT scanning, diagnostic radiography, brain and cardiac angiography, ultrasounds, surgery monitoring, and nuclear magnetic resonance.

But we are living off the investments made a generation ago. Whether we leave our children and grandchildren a better America will depend upon the choices we make today about renewing our commitment to the exploration and development of space. The home of the future, the car of the future, the industries of the future, and our life in the future — all will be shaped by the vigor or timidity with which we approach the exploration of space.

The economy is global. Our competitors are on the move. It is once again time to do what America has always done — look forward, dare greatly, and seize the future. America's Vision for Space Exploration provides the framework to do exactly that.

Technology Trends in Space: Meeting the Challenges of Space and Exploration

John Mankins, *President, Artemis Innovation Management Solutions, LLC*

Editor's Note: *Extending the limits of human space travel and operating for long durations on the Moon, Mars and beyond poses many challenges that will have to be overcome. As we saw with the Mercury, Gemini, Apollo, and subsequent programs, devising technologies to meet the challenges encountered in those programs provided unanticipated benefits that have radically affected our lives and culture. • Pushing the limits of human space exploration will again require a new level of technological innovation that will undoubtedly provide applications we can barely anticipate. • Noted space technology expert, John Mankins, in the article that follows, looks at some of the possibilities as we expand the frontiers of human capabilities and knowledge.*

In case after historical case, space programs have focused our innovations and created a rich heritage of new capabilities and new technologies that have then benefited the quality of life here on Earth. Solving the tough challenges today to enable an affordable and ambitious space program will leave a similar legacy of innovation and benefits for the future.

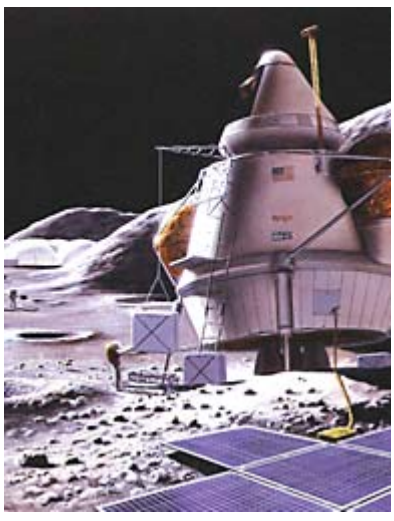
Laboratory advances during the past decade suggest that an entirely new paradigm may be at hand—one in which groups of modular robots self-assemble into different shapes as required by individual mission objectives.

New materials, coatings and lubricants will be needed for long duration stays on surfaces characterized by dust, wide temperature swings, and vacuum or near vacuum. These emerging solutions may well find use in a range of terrestrial settings — anywhere from the dry cold of the Antarctic, to the heat and dust of the Sahara, to the unique and difficult environments in factories worldwide.

Many challenges must be solved to enable human space exploration. The most important of these challenges are providing air, water, and food, and protecting astronauts from hazards like exposure to dangerous natural radiation and deterioration of bones, muscles, and organs caused by spending a long time in a low gravity environment.

Solutions to these problems will require the development of robust, portable, and self-sustaining life support systems that can operate in a range of environments and extremes of temperature. Not only will these solutions ensure safe, affordable, and effective operations in space, they will be a platform for innovations that will benefit people and industries on earth.

Ambitious missions to the Moon or Mars, and the in-space technologies required to get there, will require robots of all types. These future robotic systems may independently assemble, maintain, and service systems in space, as well as assist astronauts in difficult operations, including scouting hazardous terrain on the Moon and Mars. Many future robotic systems will not look like classical "robots"—anymore than an automated vacuum cleaner does. Laboratory advances during the past decade suggest that an entirely new paradigm may be at hand—one in which groups of modular robots self-assemble into different shapes as required by individual mission objectives. These self-reconfigurable, dexterous robotic manipulators may be originally designed to acquire planetary samples but could easily find manufacturing, medical, emergency response, and other applications terrestrially.



New capabilities will be needed to work on and explore the airless and remote planetary surfaces of the Moon and Mars.

The deep dust on the Moon and Mars present challenges for both human and robotic missions. On the Moon, the dust grains are small and jagged, and may pose a hazard to astronauts' lungs during long stays. On Mars, remarkably fine and chemically active dust may damage electrical equipment and contaminate life support systems. New materials, coatings and lubricants will be needed for long duration stays on surfaces characterized by dust, wide temperature swings, and vacuum or near vacuum. These emerging solutions may well find use in a range of terrestrial settings — anywhere from the dry cold of the Antarctic, to the heat and dust of the Sahara, to the unique and difficult environments in factories worldwide.

Another difficult technical area is generating power for surface operations. Lunar and Martian missions will typically encompass many activities, and will require reliable and long-lived power supplies. These power sources will range from large-scale power plants, to novel, long-lived rechargeable batteries and fuel cells, to miniaturized "power management on a chip." Power plants will service permanent structures and habitats. Portable, affordable energy will be essential for landers, rovers, shelters, and science experiments. Miniature sources will power hand-held electronic devices, life support systems, space suits, and robots. The unending demand for smaller, better batteries for wireless consumer devices could be met in the future with solutions developed for exploring Mars.

Government space exploration programs have enabled not only terrestrial technologies and applications, but also have provided the foundation of knowledge and technology for innovative private space flight efforts. During the summer of 2004, when SpaceShipOne won the "X-Prize," it achieved a milestone in human spaceflight that was believed to be unthinkable less than a decade ago: a fully private, non-government journey to the edge of space, 100 kilometers above the Earth. SpaceShipOne demonstrated several novel capabilities. The body of the ship was built entirely of composite materials (largely carbon fiber). The ship's engine was the first new human-rated rocket engine since the space shuttle main engine in the 1970s, and the first ever human-rated "hybrid" engine (using both solid and liquid fuels). One of the most innovative of its features was its use of "morphing vehicle systems." This ship, uniquely, could change shape into one of three configurations during the course of the flight. It was thus able to fly in the low atmosphere, in the upper atmosphere, and in space.

Truly novel technologies are at hand to achieve transformational future space capabilities—and the benefits of doing so. Exciting new discoveries are constantly emerging from university, industry, and government laboratories in the United States and internationally. Hosts of promising new directions in technology point toward where future space capabilities may journey. However, no program can follow all possible paths, and whether for space or for more mundane applications, it takes time and investment to translate today's discovery into tomorrow's technology. In case after historical case, space programs have focused our innovations and created a rich heritage of new capabilities and new technologies that have then benefited the quality of life here on Earth. Solving the tough challenges today to enable an affordable and ambitious space program will leave a similar legacy of innovation and benefits for the future.

Educating Tomorrow's Workforce

Patricia Arnold, Ph.D., *Vice President, Education and Workforce Development, Space Foundation*

Editor's Note: *To realize the Vision for Space Exploration the United States will need the best scientists, technicians, engineers, and mathematicians it can produce. • But there is trouble in our halls of higher education. The number of United States students graduating with these advanced degrees is shrinking each year, while nations like China and Japan are ahead of us by light years. • We've been there before. Then Sputnik woke us up and you couldn't keep enough slide rules and pocket protectors on the shelves of college bookstores. With proper motivation we quickly educated the workforce necessary to beat the Soviet Union to the Moon. • In the following, Space Foundation educator Patricia Arnold explains how the Vision for Space Exploration can inspire and motivate a new generation — and thus benefit the nation's economy and security.*

The National Defense Education Act of 1958 and associated research, helped motivate, inspire and educate a generation of scientists and engineers who took our nation to the Moon, cementing a technological leadership that became the envy of the world and delivered an unprecedented level of economic dominance.

The United States has now fallen from third in the world to 15th in producing scientists and engineers.

A recent survey reveals that more than 5,000 science and engineering positions in defense-related fields are unfilled.

Executing the Vision for Space Exploration — exploring the Moon, Mars and beyond — has the unique capacity to inspire and motivate a new generation to tackle the tough academic subjects required not just to achieve the vision, but to secure our future as well.

As a country, we cannot wait for the brain drain to occur and then react. The new vision can guide a renewed interest and readiness in science, technology, engineering, and math for America's youth.

As the United States moves toward implementing the Vision for Space Exploration, we face serious barriers. We are losing the scientists and engineers who not only propelled us to the Moon in the past, but who have also been the foundation of the very way of life we enjoy today. We have two distinct issues that together create a fundamental threat to our national security — a security that is more than national defense, but economic security as well. The first threat we face is that an entire generation of scientists and engineers is retiring now, and the second threat is that we are not replenishing them. Growing evidence attests to a looming crisis in the United States: a shortage of scientists, engineers and high-technology personnel. As a nation whose global leadership position is built, to a large extent, on a foundation of technological innovation, this impending shortage of scientists and engineers must be reversed. Executing the Vision for Space Exploration can play a decisive role in addressing these threats and reversing the erosion of our technological leadership.

Much of the leadership in technology and economics we enjoy today is built on equity gained from the very successful National Defense Education Act of 1958 that appropriated money for education in math and science. Spurred by Cold War concerns about Sputnik and the "Space Race," this Act, and associated research, helped motivate, inspire and educate a generation of scientists and engineers who took our nation to the moon, cementing a technological leadership that became the envy of the world and delivered an unprecedented level of economic dominance.

For the last fifteen years, the number of American college students earning science, technology, engineering, and math (STEM) degrees has continued to decrease. The United States has fallen from third in the world to 15th in producing scientists and engineers; the problem is compounded because many of the graduating scientists and engineers are internationals who return to work in their home countries. According to the 2002 report of the National Center for Education Statistics in 2000-2001, the United States graduated 58,098 students with engineering degrees, from both public and private colleges and universities. Annually, India graduates 80,000, Japan 200,000, and China 800,000 students (Xinhua News Agency, Dec. 21, 2002). Indications include a decline in the number of native-born science and engineering graduates entering the workforce, increasing global competition for science and engineering talent. The number of newly declared computer science majors

decreased 39 percent from fall 2000 to fall 2004 (Computing Research Association). From 1990 to 2004, the number of bachelor's degrees awarded in engineering dropped by eight percent (National Science Board).

Once again, we should be hearing the wake up call for lack of preparedness felt years ago during the Space Age. Students have drifted away from pursuing scientific fields of study. A recent survey reveals that more than 5,000 science and engineering positions in defense-related fields are unfilled. Competition will grow even fiercer in coming years as the Department of Defense (DoD) must compete with private industry for the limited number of qualified candidates.

By 2010, it is projected the national demand for STEM employees will rise by 10 percent. According to a 2004 National Science Board report, *An Emerging and Critical Problem of the Science and Engineering Labor Force,* "We could reach 2020 and find that the ability of U.S. research and education institutions to regenerate has been damaged and that their preeminence has been lost to other areas of the world."

The huge number of DoD lab scientists and those in the civilian labor pool nearing retirement age and not being replenished with new American scientists could interfere gravely with our ability to ensure our technological leadership and national security. This impending shortage presents the United States with the challenge to recruit, retain, educate, and graduate new generations of scientists, technicians, engineers, and mathematicians. The challenge is a daunting one. Prospective students for these fields are not enrolling at four-year colleges and universities in the numbers needed. It is imperative to implement both short and long range solutions. Short term, the Department of Defense SMART Act, NASA Science and Technology Scholarship Program, and internship and mentoring programs targeting the collegiate level are helpful for the immediate future.

However, inspiring elementary and secondary students to seek STEM post-secondary education and careers is vital if the United States is to address the shortage. Unfortunately, underserved pre-kindergarten through 12th grade students are particularly absent from these disciplines. Executing the Vision for Space Exploration — exploring the Moon, Mars and beyond — has the unique capacity to inspire and motivate a new generation to tackle the tough academic subjects required not just to achieve the vision, but to secure our future as well.

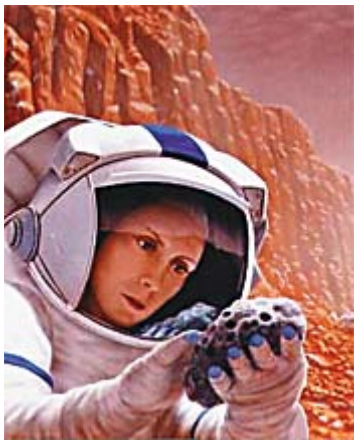
Inspiring elementary and secondary students to seek science, technology, engineering, and math post-secondary education and careers is vital if the United States is to address the shortage.

To be ready to explore the Moon, Mars, and beyond requires the intellectual capacity to achieve the extraordinary and expand the limits of human capabilities. America's new space exploration policy represents a journey over time and so are the educational challenges associated with it. It must start with our youngest students and build through graduate programs. The Vision for Space Exploration gives our country a new opportunity to improve education and our competitive standing in the world. As a country, we cannot wait for the brain drain to occur and then react. The new vision can guide a renewed interest and readiness in STEM for America's youth. If we act now to devise strategies to address future demands proactively, we can still maintain our competitive edge.

A Consistent Theme: Support for Space Exploration

John M. Logsdon, Ph.D., *Director, Space Policy Institute, Elliott School of International Affairs, George Washington University*

Editor's Note: *Experts have gathered time and again to discuss what the future direction of the space program should be. Although the details are sometimes different, each report has reached similar conclusions. • Like the Vision for Space Exploration, these studies say that a robust human and robotic space exploration program is unquestionably in the long-term best interest of our nation. • In the following, George Washington University space policy expert John Logsdon reviews the details of several studies that provide the foundation for the vision.*



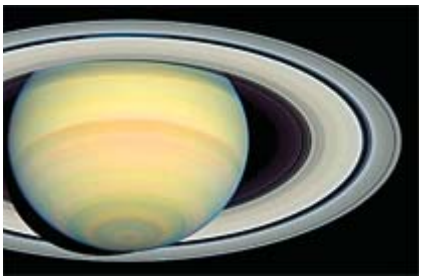
In its August 2003 report, the Columbia Accident Investigation Board noted that in the aftermath of the Apollo 11 landing on the Moon in 1969, "President Richard Nixon rejected NASA's sweeping vision for a post-Apollo effort that involved full development of low-Earth orbit, permanent outposts on the Moon, and initial journeys to Mars." With this rejection, the result was a "lack, over the past three decades, of any national mandate providing NASA a compelling mission requiring human presence in space." Absent such a mandate, NASA became "an organization straining to do too much with too little."

1986 Commission on Space:
We must lead the exploration and development of the space frontier, advancing science, technology, and enterprise that make accessible vast new resources and support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars.

On Jan. 14, 2004, President George W. Bush, reacting to what the Columbia Board characterized as "a failure of national leadership," proposed to the American society a Vision for Space Exploration that was intended to reverse this 35 year "lack of a national vision for space." What he proposed echoed in large part the objectives that NASA first proposed in 1969 and that, as noted by the Columbia Board, "have reappeared as central elements" in the many proposals over the past two decades emerging from blue-ribbon groups who have given careful attention to America's future in space.

1986—National Commission on Space

The 1986 report of the National Commission on Space noted that the commission had been charged by the Congress and appointed by the President "to formulate a bold agenda to carry America's civilian space enterprise into the 21st century." The commission spent "the better part of a year" in an intense nationwide effort to obtain input from experts and the general public, taking into consideration America's "heritage, its likely future goals, and its potential impact on world history." It recommended as "a pioneering mission for 21st century America": "to lead the exploration and development of the space frontier, advancing science, technology, and enterprise, and building institutions and systems that make accessible vast new resources and support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars."



In order to achieve this vision, the commission recommended a NASA budget substantially increased from the levels of the 1975-1985 period, but less than half of the share of the United States gross national product (GNP) spent on civilian space at the peak of the Apollo program. With such a modest investment, it suggested, space exploration would remain an activity characteristic of a "21st century America" that would be a "vigorous, expansive society, its citizens inquisitive and adventurous, eager for new challenges in the forefront of humanity."

1988—Committee on Space Policy, National Academies of Sciences and Engineering

The recommendations of the national commission were submitted to President Ronald Reagan shortly after the January 1986 Space Shuttle Challenger disaster. As the country focused on recovery from that tragedy, there was little chance that they would be adopted. In late 1988, the National Academies of Sciences and Engineering chartered a Committee on Space Policy in recognition that "long-term, durable, and widely accepted goals for the nation in space are essential," and had been missing for the preceding two decades. In its recommendations to President-elect George H. W. Bush, the committee noted that while "the appropriate long-term reason for putting humans into space remains an area of continuing controversy[. . .] it is difficult to deny that some men and women will eventually live and work on other celestial bodies." The committee recognized that "humanity's aspiration to explore other worlds, and perhaps eventually to expand human presence and activity beyond the immediate vicinity of Earth, provides a vision that gives meaning to current activities involving humans in space." Given this, "the question becomes what role, if any, the United States wishes to play in humanity's quest to become a multi-planet species."

1988 Commission on Space Policy:

"Long-term, durable, and widely accepted goals for the nation in space are essential," and had been missing for the preceding two decades.

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Moon-based Inferometer Telescope

This report was one of the influences that led President Bush on July 20, 1989 to propose what came to be called the Space Exploration Initiative, which included a return to the Moon, "this time to stay," and then "a journey into tomorrow — a journey to another planet — a manned mission to Mars." The president asked "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."

1990 –Advisory Committee on the Future of the U.S. Space Program

For a variety of reasons, the Congress and the American public in 1989 were not ready to commit to supporting such an expansive vision. For one thing, there was a perception that NASA was not ready to take on such a bold task. To assess NASA's problems, President Bush in 1990 appointed an Advisory Committee on the Future of the U.S. Space Program, chaired by Norman Augustine, a widely-respected aerospace industry executive.

1990 Committee on the Future of the U.S. Space Program:

Most Americans do support a viable space program for the nation — but no two individuals seem able to agree upon what that space program should be.

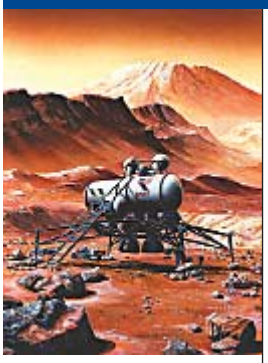
While most of the committee's deliberations and report were devoted to NASA's shorter-term problems, the group also had much to say about the broader context within which NASA was operating. It deplored "the lack of a national consensus as to what the goals of the civil space program are" and observed that "most Americans do support a viable space program for the nation — but no two individuals seem able to agree upon what that space program should be." The committee recommended a balanced space effort, including what it characterized as

"Mission from Planet Earth," human travel beyond Earth orbit. The committee observed that a focus for NASA's human spaceflight program was badly needed, "if it is not merely to drift through the decade ahead."

It suggested that this focus should be "the human exploration of Mars." Such an endeavor, it judged, "must be justified on the basis of intangibles — the desire to explore, to learn about one's surroundings, to challenge the unknown and to find what is to be found." A program of human exploration could be "tailored to respond to the availability of funding, rather than adhering to a rigid schedule." One reason for such a focus was that "any large organization, such as NASA, generally works best when it has an overarching and challenging objective to guide its long-term future."

2002 Walker Commission:

"The challenge we face on the space frontier is to build from dreams and concepts to new technologies and destinations, to the political will to move forward. For nearly two decades, we have been satisfied to limit our dreams, rely upon proven technologies and invest little in building public or political support for space initiatives. But the potential to do great new things has never been clearer."



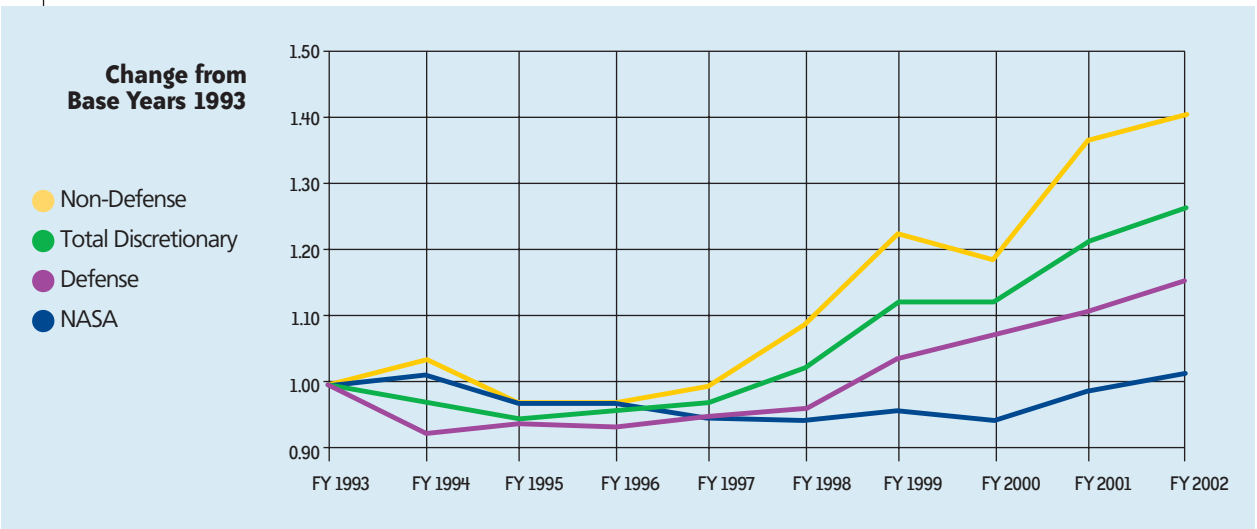
The committee based its recommendations on a budget that "will grow by approximately 10 percent per year in real dollars" for the succeeding decade. Such budget growth, it suggested, would bring the NASA budget by 2000, as a share of the United States GNP, to approximately one-half of its Apollo-era level, and thereby "enable a strong space program." During the 1990s, however, the NASA budget actually decreased in constant dollars as other parts of the federal budget increased (Figure 1); this reality led to NASA's "straining to do too much with too little."

In the decade following the December 1990 publication of the report of the Advisory Committee on the Future of the United States Space Program, there were no major external reviews of the civilian space effort as NASA focused its efforts on regular flights of the space shuttle and, beginning in 1998, assembly of the International Space Station.

2002—Commission on the Future of the United States Aerospace Industry

Then, in 2000, Congress directed the White House to create a Commission on the Future of the United States Aerospace Industry (Walker Commission), with one of its areas of emphasis being the United States space program. The commission began work in the second half of 2001; its report was issued in November 2002.

Figure 1. NASA Budget in the 1990s



The commission observed that "nations aspiring to global leadership in the 21st century must be space-faring. Freedom, mobility, quality of life and the ability to do the difficult things that define leadership will be enhanced and discovered on the space frontier." It lamented the fact that "a sense of lethargy has infected the space industry and community" and noted that Japan, China, Russia, India, and France, to name a few, see space as a strategic and economic frontier that should be aggressively pursued."

> ***"So should we," concluded the commission. "The challenge we face on the space frontier is to build from dreams and concepts, to new technologies and destinations, to the political will to move forward. For nearly two decades, we have been satisfied to limit our dreams, rely upon proven technologies and invest little in building public or political support for space initiatives. But the potential to do great new things has never been clearer."***

The commission recommended that "the United States create a space imperative" which, among other elements, would "accelerate the exploration of the near and the distant universe with both human and robotic missions." It characterized government funding for long-term research and infrastructure as "insufficient and unfocused" and called upon the federal government to "significantly increase its investment in basic aerospace research."

2004—President's Commission on Implementation of United States Space Exploration Policy.

At the same time he announced his new Vision for Space Exploration in January 2004, President George W. Bush created the President's Commission on Implementation of United States Space Exploration Policy. This nine-member commission concluded in its June 2004 report that "the long-term, ambitious space agenda advanced by the President [. . .] will significantly help the United States protect its technological leadership, economic vitality, and security." The commission unanimously endorsed the "ambitious yet thoroughly achievable goal of space exploration."

2004 Commission on Implementation of the Vision:

The long-term, ambitious space agenda advanced by the President will significantly help the United States protect its technological leadership, economic vitality, and security.

The American nation has an opportunity to ensure space leadership for decades to come, and that leadership opportunity can reap multiple benefits for this country, if the political will and consequent resources to seize it can be sustained.

This brief review of two decades of recommendations on the future of the United States space program shows remarkable consensus on one basic theme: **that a strong and valuable U.S. space effort must include a challenging long-range goal, and that among possible goals the preferred one is human and robotic exploration beyond Earth orbit.** In addition, most groups who have examined the ongoing space effort have concluded that investing increased budget resources is needed for that effort to succeed in providing maximum payoffs to the nation.

In its final report, The Columbia Accident Investigation Board noted that "the absence of a strategic vision [for space] in itself has reflected a policy decision, since there have been many opportunities for national leaders to agree on ambitious goals for space, and none have done so." That policy decision has now been reversed. The American nation has before it an opportunity to ensure space leadership for decades to come, and that leadership opportunity can reap multiple benefits for this country, if the political will and consequent resources to seize it can be sustained.

Public Strongly Endorses Space Exploration — A Gallup Poll

Commissioned by the Space Foundation, on behalf of the Coalition for Space Exploration

Editor's Note: *Americans are enthusiastic about their space program. And they support it by overwhelming majorities. Those who work in the space program know this in their hearts. • Proof comes at obscure times, such as when a NASA manager from Florida visits relatives in Minnesota and someone in the grocery store line asks about the shuttle mission patch on her jacket. • Proof also comes in the form of scientific surveys, with questions carefully worded to avoid any appearance of bias, and conducted by one of the most prestigious names in the polling business. • In the following, the results of a 2005 Gallup Poll are presented and the support it uncovers is both profound and pervasive.*

Extent of Support for 2004 Plan for Space Exploration

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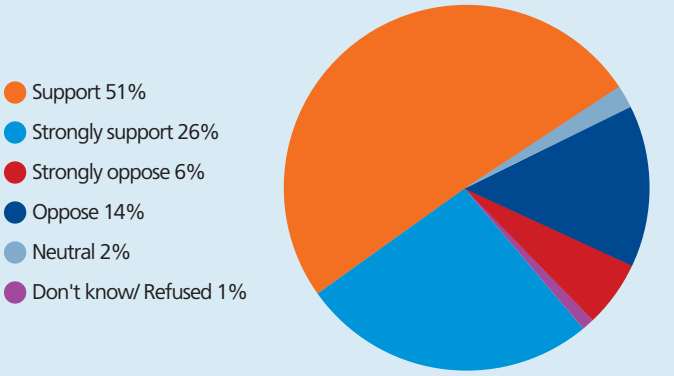

Americans continue to show strong support for NASA's plans to explore, discover and understand our universe by implementing the nation's Vision for Space Exploration.

That's one of the conclusions of a new Gallup survey on public attitudes about our nation's space program that was coordinated by the Space Foundation and sponsored by the Coalition for Space Exploration.

More than three-fourths (**77%**) of the American public say they support a new plan for space exploration that would include a stepping-stone approach to return the space shuttle to flight, complete assembly of the International Space Station, build a replacement for the shuttle, go back to the Moon, and then on to Mars and beyond.

With funding for such a program expected not to exceed one percent of the federal budget, **51%** of adults surveyed say they support the program and **26%** strongly support it. Of note is that a majority of both Republicans (**84%**) and Democrats (**77%**) support such an exploration plan.

The results to this particular question are higher than measured by Gallup in 2004 when the same question was asked. In 2004, **68%** of Americans supported or strongly supported the exploration plan.

Agreement with Statement:
"America's space program helps give America the scientific and technological edge it needs to compete with other nations in the international marketplace."

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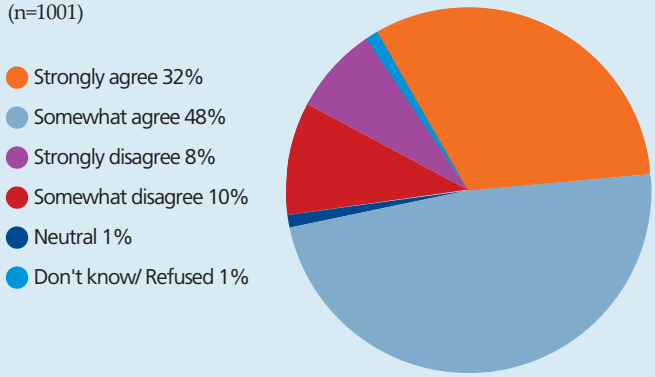

When it comes to NASA's budget, almost three-fourths (**73%**) of American adults surveyed think NASA's budget should remain at its present level (**36%**) or be increased (**37%**). **NASA's current share of the total federal budget is seven-tenths of one percent, or about $58 per year for the average citizen**. During the height of Project Apollo, NASA's share of the budget was about four percent.

Among The Gallup Survey's Other Findings

- Seven in ten adults (**71%**) say they are somewhat interested (**49%**) or very interested (**22%**) in America's space program.
- Of nine possible answers, most (**26%**) said the most popular reason America continues to explore space is because it is human nature to do so. Almost one-fourth (**24%**) said it is to conduct science experiments.
- Eight in ten adults (**80%**) say they somewhat agree (**48%**) or strongly agree (**32%**) that America's space program helps give America the scientific and technological edge it needs to compete with other nations in the international marketplace.

Agreement with Statement:
"America's space program benefits the nation's economy by inspiring students to pursue careers in technical fields."

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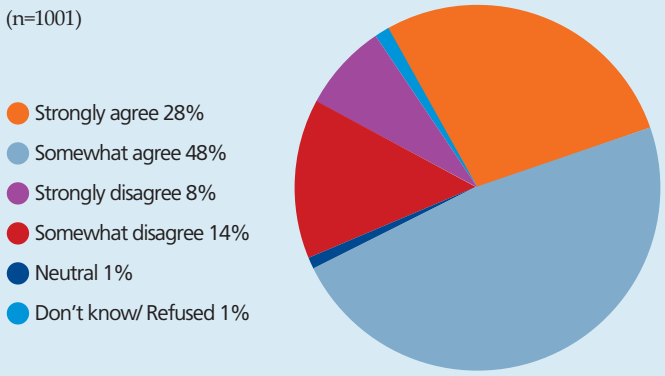

- More than three-fourths (**76%**) of adults somewhat agree (**48%**) or strongly agree (**28%**) that America's space program benefits the nation's economy by inspiring students to pursue careers in technical fields.

Survey Methodology

The survey results are based on a nationally representative sample of 1001 telephone interviews with a general population sample of adult men and women age 18 and over residing in telephone households. The Gallup Organization's full-time interviewing staff conducted the survey during the period of June 9–July 1, 2005.

The survey was commissioned by the Space Foundation in an effort to understand better the extent of support and public attitudes toward America's space program.

For results based on samples of this size, one can say with 95% confidence that the error attributable to sampling and other random effects could be plus or minus three percentage points. In addition to sampling error, question wording and practical difficulties in conducting surveys can introduce error or bias in the findings of opinion polls.

The complete Gallup survey report and supporting data is posted on the web at: www.spacecoalition.com

Opinion Regarding the Funding of the Space Program

	2005 %
At this current level	36
At a slightly increased level	25
At a significantly increased level	12
At a slightly decreased level	12
At a significantly decreased level	4
Not fund at all	8
Don't know/Refused	3
Total	100
Number of Interviews	(1001)

American Strategic Leadership and Manned Spaceflight

Joan Johnson-Freese, Ph.D.,
Chair of the National Security Decision Making Department at the Naval War College Newport, Rhode Island

Editor's Note: *To be a leader in the world, a nation must be a leader in space. • Other nations have learned this and even now we are engaged in what an increasing number of people see as a second space race. While they have a long way to go, these nations are making progress. • While we are working with a number of partners on the International Space Station, America can ensure its role as a leader in space and in the world by maintaining a robust space program as outlined in the Vision for Space Exploration. • In the following, space policy expert Joan Johnson-Freese describes how the vision will help America uphold its leadership in the world despite the pressures of being the world's only remaining superpower.*

Neil Armstrong demonstrated to people everywhere that no dream was too big and thereby dared them to dream as well.

The United States went to the Moon because it could. It dares to do the hard things that other nations do not, an integral part of what makes America a leader.

The United States needs to again recognize and embrace the leadership opportunity offered by human space exploration…based on cooperation, not competition.

Participating in a space program does more than help …create technology and industries; it builds dreams and generates pride.

When American astronauts walked on the Moon, a new "us-them" was inherently created, "us" being the people of Earth…and if you believe that space is too big a place to have only one populated planet, a "them" is potentially still to be found. No other person will ever have the same role in history as Neil Armstrong. He was the first person from Earth to step onto another celestial body. He, an American, led the way for all humanity. He demonstrated to people everywhere that no dream was too big and, thereby, dared them to dream as well.

Global leadership has characterized America's role in space and, technologically, the United States is far ahead of any other country in space capabilities. Consequent to two Chinese manned launches since 2003, however, the perception has emerged that China is catapulting ahead of the United States. While patently untrue, a space race has been created that is destined to be won largely by image. With China willing to play the tortoise to the U.S. hare, there is the very real chance that the United States could be perceived as bested based on consistency rather than capabilities.

Since Apollo, the United States manned space program has been plagued by lack of political will, with the manned program carried forward by (weak) inertia rather than real motive. Unfortunately, much of the American public views space largely as an interesting museum exhibit, and space is largely ignored by Congress unless their constituents' jobs are at stake. In reality, space has become an integral part of everyday life not just for Americans but for individuals all over the world. The Global Positioning Satellite (GPS) system is a global utility. It is important to the extent that people will not be denied — or, as the advent of the European Galileo program illustrates, even take the risk of being denied — the services these navigation satellites provide. GPS is an American program — another example of America leading the way into space, just as it did with Apollo. While the impact of Apollo on everyday lives was less explicit, it was, nevertheless, just as powerful.

Global leadership is a role that has been thrust onto the United States and, thankfully, one to which it is eminently qualified to respond. The United States not only has the military might to lead, it has been viewed, as former President Ronald Reagan put it, as the "shining city on the hill" that others want to emulate. The United States went to the Moon because it could. It dares to do the hard things that other nations do not, part of what makes America a leader. Now,

however, lack of political will and a perceived lack of a strategic purpose could result in the United States tacitly ceding manned spaceflight leadership. Make no mistake, doing so will cost the United States its global leadership role.

Global leadership is part and parcel of America as the "shining city on the hill." Foregoing that leadership dims the lights in the city at a time when America's place in the world must be more pronounced and more positive than ever before. Fighting the global war on terror and shaping the world into a more stable place where human security needs are provided for all requires both American leadership and global cooperation.

Can America's global leadership image stand a little polishing? While it is sometimes more important to be feared than loved by certain countries, it appears that the United States might be precariously close to overdoing it. A Pew Research Center Poll taken in April and May 2005, for example, showed China, a communist dictatorship, was viewed more favorably than the United States in 11 of the 16 countries surveyed, including Britain, France, Germany, Spain, the Netherlands, Russia, Turkey, Pakistan, Lebanon, Jordan, and Indonesia. India and Poland saw the United States in a more favorable light than China, and Canada was about evenly split. The United States is having trouble conveying its message.

While to a degree it may be normal for other countries to view the only remaining superpower with angst, if not outright hostility, these poll numbers indicate negative feelings toward the United States beyond what is normal, and certainly not desirable. Tanks, planes and lasers will not stop the spread of feelings or ideology. And, whether we like it or not, a poor image clouds positive, progressive messages that America seeks to convey. For America to lead in the longterm, it must have willing followers.

In the 1960s, leadership was the motivation that took America to the Moon, wanting to show itself leading in a technological competition against the Soviets: a techno-nationalist show of prowess. Today, post 9/11 and equally, or more importantly, with the on-going war in Iraq, the United States needs to recognize again and embrace the leadership opportunity offered by manned space exploration. But this time it should be based on cooperation, not competition. Leading an international, inclusive expedition off planet Earth offers the United States a strategic alternative to counter both the militaristic image of the United States that has prevailed since the Iraq War and from concerns regarding the potential weaponization of space by the United States. It offers an alternative that would go a long way toward rebuilding America's soft power, the power to shape the others' preferences in line with those of the United States by inducement and attraction, rather than force. Participating in a space program does more than help countries construct technology and create industries; it builds dreams and generates pride.

America has demonstrated its military ability to make others bend to its will. Now we must work at not needing to use that ability. Soft power is essential for building a stable, peaceful world where the human security needs of all are met. Cooperative manned spaceflight creates leadership opportunities that build soft power.

The material for this article is drawn from the author's new book Heavenly Ambitions, forthcoming from Columbia University Press. The views expressed in this article are the author's alone and do not represent the official position of the Department of the Navy, the Department of Defense, or the U.S. government.

Amazing True Tales of Space Exploration

James Cameron, *Filmmaker; edited text, from an address February 3, 2005, first Space Exploration Conference, Orlando, Florida.*

Editor's Note: *Spaceflight is accomplished by the hard work of people who have great stories to tell. • And now with the Vision for Space Exploration, NASA has a new and incredibly exciting tale to share as astronauts, flight controllers, mission managers, and others put together this program that could see us back on the Moon by 2018. • Along the way, according to legendary Hollywood director James Cameron, by fully involving the public at every step, the vision will survive changes in the economy, leadership in Congress and presidential administrations. • In the following, Cameron offers his insight into what makes a good yarn and why the space program may be among the greatest stories ever told.*

Only by seeing the passion of those who practice space exploration can the average person feel the sense of participation and excitement. There are six billion of us here on the ground who are not going to get to go and a handful of us who will. Those who go become the avatars for the rest — the eyes and ears, the hearts and spirits for the rest of humanity.

When we set foot on the planet Mars with our eyes fixed on other moons and beyond, we'll be telling the greatest story of the 21st century. And when the first man or woman creates those historic footprints, every human being will stand vicariously in those boots at that moment. We will all be uplifted and ennobled as one. We will be energized by the greatest accomplishment of all.

This is your space program. You are a participant. The public wants and should have ownership. They want to be included. They want empowerment and participation.

In the Apollo days, it was all NASA's public affairs office could do to keep the ravenous press at bay. In recent decades the roles have reversed and it's harder now for NASA to get into the public eye.

I've been asked lots of times by folks at all levels of NASA, what can we do better to reach out to the public? Well, two things. One, tell the story better. Two, have a better story to tell. Now for the first time in a while, we have a better story to tell, so the job just got a whole lot easier.

Now we can talk about the challenges of sustainable mission architectures for the Moon and Mars, and we can tell the story of actually, really, no kidding planning to send people to Mars. Not some vaporous someday, but when these other specific and defined tasks are completed.

That's big.

But telling the story better in the meantime is also critical. How do you sustain interest over the next decade while all this groundwork is laid?

NASA and the space community need to find better ways to involve the public through education and media.

We need to think of one of its key products as the story, not just the science and technology. Telling the story involves putting a premium on the images, both in capturing them and getting them out there. It means embracing the concept that human exploration of space is a story of people, not of agencies and systems. We need to take a cue from the tawdry world of reality TV and make our characters interesting. Astronauts and the many who support them on the ground need to be free to be seen as human beings with hopes and fears; people who make

mistakes, who have dreams, who work hard and care about what they do — three-dimensional, living, breathing people.

Only by seeing the passion of those who practice space exploration can the average person feel the sense of participation and excitement. There are six billion of us here on the ground who are not going to get to go and a handful of us who will. Those who go become the avatars for the rest — the eyes and ears, the hearts and spirits for the rest of humanity.

On my recent ocean expeditions I brought along a number of young scientists and, in the IMAX film that resulted from the expeditions, it's the heart and passion of these young researchers that conveys the importance of the task of doing science, and not the actual content of the information.

Audiences are responding remarkably well to what is basically a science documentary, because they see people on the screen who care about what they're doing.

The key to telling the story of humans in space is humans. People. This is how we communicate as a species. We perceive events through the experience of others.

To aid in the task of telling the story, NASA also needs to allocate resources for better imaging and better live streaming of those images. The images are your most important product. It's already getting better.

I'm actually lucky enough to be a co-investigator on the proposal for the mastcam, which was selected for the '09 Mars lander. The team will be developing a stereoscopic high definition camera with zoom lenses and motion video capability. It will literally capture the first moving images on another planet.

As a moviemaker, I think that's pretty cool.

Now, there are good science and engineering justifications for having these images, but to the public, seeing our machines moving and working on another planet will have tremendous impact. This is a great example of telling the story better. And when we set foot on the planet Mars with our eyes fixed on other moons and beyond, we'll be telling the greatest story of the 21st century. And when the first man or woman creates those historic footprints, every human being will stand vicariously in those boots at that moment.

We will all be uplifted and ennobled as one. We will be energized by the exhilaration of accomplishment. We will be energized by the greatest accomplishment of all.

So what are we waiting for? Let's go!

An Advocate for the Next Giant Leap for Mankind

Neil Armstrong, *Astronaut, first man on the moon*

Editor's Note: *Only 12 men have walked on the Moon — so far. • As commander of Apollo 11 in July of 1969, Neil Armstrong was the first, exploring the Sea of Tranquility for more than two hours along with lunar module pilot Buzz Aldrin. • Their position is unique in history, but maybe not for long. Soon humans will return to the Moon and, a few years later, land for the first time on Mars. • Speaking in Houston on March 11, 2004, just two months after the Vision for Space Exploration was announced, Armstrong gave a professorial lecture on the history of the Space Age, from Sputnik 1 to that first giant leap for mankind. • In the following, Armstrong recalls those glory days of Apollo and endorses a bold new vision for sending explorers beyond Earth orbit for the first time since 1972.*

Apollo proved that humans were not forever a prisoner of Earth's gravity. We could leave our own planet and go to other celestial destinations, and Americans were no longer second best.

Our economy can certainly afford an effort of this magnitude, but the public must believe that the benefits to society deserve the investment.

Noting the advancement of knowledge, the rate of progress is proportional to the risk encountered. The public at large may well be more risk-adverse than the individuals in our business, but to limit the progress in the name of eliminating risk is no virtue.

It was a great shock to most Americans when, in October of 1957, Sputnik sailed across the night sky, and people could actually watch it.

The space age had begun, and we weren't a part of it. Americans were embarrassed, and for the first time ever, people began talking seriously about people going into space. The competing configurations (for the spacecraft) were a highly swept delta wing, a flat-topped lifting body, and a flat-bottomed lifting body.

Max Faget and Paul Purser of Langley argued that if we were to get a man into orbit soon, the only choice, the only reasonable choice, was a ballistic shape lifted by an ICBM booster. The Soviets had reached the same conclusion.

One obvious configuration was the sphere. It had no instability problems at any Mach number, and its aerodynamic characteristics were very predictable. But depending on its entry angle into the atmosphere, it might produce deceleration forces which are beyond human tolerance.

Russians went the spherical route, and the Americans, using the work of Harvey Allen and Al Eggers at Ames, developed modified warhead shapes. And so it happened that the Vostock on the A1 booster and the Mercury on an Atlas, were created and launched, and human beings found themselves circling the Earth high above the atmosphere.

Soviets were soon flying multiple crews, and we wanted to also. We wanted the ability to do more. The Gemini added onboard rocket propulsion so we could maneuver in space, and it had an onboard digital computer. Digital computers weren't so highly regarded in those days. They could be accurate, but they were interminably slow. This one didn't have any gigs or any megs; it had 4K of memory. No screen, just one seven-digit register for input and output. But Gemini crews could navigate.

And, for the first time, knew how to get to a destination without asking for directions. Using all this computing power, they took great pride in controlling their entry into the atmosphere, the trajectory, and landing precisely close to the ship that was awaiting them. I landed (Gemini 8) near Okinawa, but my intended target had been the Caribbean. I doubt the record will ever be broken.

Apollo had a crew of three and more propulsion and more computing power. Apollo proved that humans were not forever a prisoner of Earth's gravity. We could leave our own planet and go to other celestial destinations, and Americans were no longer second best.

Space stations emerged in the 70s with Skylab and Salyut, and Apollo and Soyuz rendezvoused and docked in the 70s, paving the way for international participation in later stations, and here on the ISS.

After Apollo, NASA conjured a grand plan to expand human presence in space and include one or more permanent terminals in Earth orbit, craft to depart from and after return to the terminal from various places in the solar system, and reusable craft to service the entire enterprise by shuttling back and forth between Earth orbit and the Earth's surface.

Advocates were unable to persuade the establishment that that was all doable with the resources available, and only the last piece, the shuttle orbiter, was funded. The shuttle has now been operating for a couple of decades, with occasional time-outs for good reason. And, although it never came close to reaching the original planned flight rate, and, consequently, the economies of scale, it has done a remarkable job of performing a very wide range of mission types.

From time to time, new grand plans have been announced, only to decay and dissolve from an inadequate level of public support, as interpreted by their elected officials. Now our president has introduced a new initiative with renewed emphasis on exploration of our solar system and expansion of the human frontiers. This proposal has substantial merit and promise.

The success of that endeavor will be dependent on overcoming principle concerns of cost and risk. Our economy can certainly afford an effort of this magnitude, but the public must believe that the benefits to society deserve the investment. Noting the advancement of knowledge, the rate of progress is proportional to the risk encountered. The public at large may well be more risk-adverse than the individuals in our business, but to limit the progress in the name of eliminating risk is no virtue.

The success of the endeavor will also be dependent on the degree to which the aerospace community, all of us — government, industry, and academia — can coalesce their forces and converge on a common goal.

So that's a retrospective of the beginning of the Space Age. And the remarkable thing, to me, is that we happen to be living in a time when we could watch the entire process occur — and be involved in a substantial part of it.

Risk is Our Business

Col Steven W. Lindsey, *NASA Astronaut*

Editor's Note: *It takes thousands of people to prepare a space shuttle mission for launch, but ultimately it is a small crew of astronauts who will climb aboard and put their lives on the line in the name of science and exploration. • This special set of human beings knows more than any other why it is so important to have a space program. They have examined the risk of being hurled into space. They know the goals of their mission. And they find the whole thing worthy. • Just ask Steve Lindsey, commander of the second shuttle mission to be flown following the Columbia accident. He lost his friends in that disaster, yet there's no hesitation on his part to fly. There's no sense he's playing a daredevil, either. • In the following, Lindsey reports first-hand why the Vision for Space Exploration is worth the risk.*

The next time a space shuttle lifts off from the Kennedy Space Center, I will be strapped into the commander's seat on Discovery's flight deck, beginning my fourth spaceflight.

Thanks to my training and the confidence I have in the teams of people who manage the space shuttle program and prepare the vehicle for launch, I won't be dwelling on the risks that are inherent in making this voyage — a journey I know 14 of my colleagues aboard Challenger and Columbia did not complete.

As I prepare this column, it is the holiday season of 2005. Launch of STS-121, as my next spaceflight is called, is still months away. There's much training that needs to be done, but already I know we will be prepared to fly when the time comes.

I have a great crew for this test mission, which will include a visit to the International Space Station. Flying with me will be pilot, Mark Kelly, and mission specialists, Mike Fossum, Lisa Nowak, Stephanie Wilson, Piers Sellers, and Thomas Reiter.

The spirit of exploration is something that lies deep within all of us. It's an important thing to do. The value — both tangible and not — of what we learn from spaceflight is worth so much more to humanity than the risks involved that I am personally willing to put my life on the line and take those risks.

You can't take those risks to zero. Not ever. Exploring space — doing things that have never been done before — is going to be a high-risk operation for a long time to come

If it were 100 percent safe, we'd never fly. If it were easy, we'd never advance — and never learn.

We have a long and complex set of tasks to do on this mission, many of them a continuation and expansion of the test flight work done during the STS-114 mission flown in July 2005. We'll also be re-supplying the space station and taking care of a few assembly tasks as well.

Assuming all goes well, when Discovery lands and we walk off the Orbiter, we'll be able to say that we accomplished our goals and have taken the next step in the Vision for Space Exploration.

For me, that's the reason I'm willing to take the risk.

The spirit of exploration is something that lies deep within all of us. It is an important thing to do. The value — both tangible and not — of what we learn from spaceflight is worth so much more to humanity than the risks involved that I am personally willing to put my life on the line and take those risks.

It is important, however, to note that at NASA, when we discuss risk, it is always about minimizing the chance something could go wrong to the maximum extent possible. We build redundancy into our systems, learn how to make repairs in-flight and train ourselves to handle technical failures in a way that gives us the best possible chance to not only come home safely, but to complete the mission as well.

When I climb aboard Discovery on launch day, I know that the NASA team will have done everything they can to make things as safe as possible. If the NASA team didn't believe that, they wouldn't launch us. And if I didn't believe that, I wouldn't fly.

That's the promise I've made to my family.

However, things still go wrong. You can't take those risks to zero. Not ever. Exploring space — doing things that have never been done before — is going to be a high-risk operation for a long time to come, and as history has shown us, sometimes it is impossible to cheat death.

Astronauts know that, yet still we continue to look for ways to make spaceflight safer while reaching for what's just beyond our grasp. If it were 100 percent safe, we'd never fly. If it were easy, we'd never advance — and never learn.

It is our destiny to explore, and I am proud to have a small part in it.

Recommendations

By the Space Foundation

Because the case for space exploration is so compelling, the Space Foundation makes the following recommendations for implementing the nation's Vision for Space Exploration:

The future of the nation is at stake. United States leadership in space cannot be expected to continue unless we create again the conditions to develop the world's greatest minds, tools, and talents.

The next 50 years depend upon the investments we make today. A vigorous, ambitious, aggressive, and well-funded space exploration program must be a national priority.

The journey must be undertaken with a greater sense of urgency.

United States accomplishments in space, if untimely and overshadowed by the achievements of others, will weaken our ability to lead — whether in competition or collaboration with other nations (and both are desirable).

A PRIORITY:

The Vision for Space Exploration must be seen as a top priority for the Nation. Fund it.

Since it was unveiled, the Vision for Space Exploration has been embraced more as a post-Columbia prescription for NASA. Instead, it should be seen as an urgent priority for the nation. As persuasively argued throughout this report, the future of the nation is at stake. United States leadership in space cannot be expected to continue unless we create again the conditions to develop the world's greatest minds, tools, and talents. United States national security depends upon having the intellectual capacity to respond tomorrow to crises we cannot define today. It depends upon economic strength rooted in unsurpassed technology. It depends upon an industrial base capable of delivering whatever national means are required.

For five decades, the United States' technological leadership has come from our investment in space exploration and the research, development, academic foundation, and industrial capacity it drives. The next 50 years depend upon the investments we make today. A vigorous, ambitious, aggressive, and well-funded space exploration program must be a national priority. If it is only a tool for bringing management focus to a small government agency, we will fail.

A SENSE OF URGENCY:

This epic, inevitable journey must be undertaken with a great sense of urgency. Now — not later.

The vision has been framed as a journey, not a race. If so, the journey must be undertaken with a greater sense of urgency. The United States is not the only nation making this journey. Credible space exploration programs exist in other nations. United States accomplishments in space, if untimely and overshadowed by the achievements of others, will weaken our ability to lead — whether in competition or collaboration with other nations (and both are desirable).

The present political "go as you pay" assumption places a higher priority on static levels of NASA funding than on high levels of national achievement. If not the race, at least the pace must be re-examined. The United States must proceed with a sense of urgency and a commitment to funding success.

EMBRACE THE DIFFICULT CHALLENGES:

We must choose the difficult path of invention and discovery or others will define the future for us.

One of John F. Kennedy's most quoted statements about the Apollo program is, "We choose to go the Moon [. . .] not because it is easy, but because it is hard." Kennedy was right. The vast cornucopia of intellectual, technical, scientific, academic, industrial, and other benefits that have come from our space programs were the result of invention and innovation required to do what had never been done before. If the United States is to benefit from this Vision for Space Exploration going forward, it must choose the difficult path of invention and discovery — not the easy path of recycling its current capabilities. While proven systems and off-the-shelf products can provide a quick start to this bold new endeavor, a balanced approach that demands new capabilities is also essential. We can reconfigure our current inventory in a variety of ways to serve the vision, but, by inventing new systems, technologies and capabilities, we will better serve the nation.

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OUR NATION'S SPACE PROGRAM:

We must demand a long-term program that extends human presence across the solar system — because the future of the nation and of generations to come is at stake.

Because the future of the nation is at stake, the exploration of our solar system must be the nation's program and not just NASA's. From the point of view of our leaders who oversee the space agency, only a strong national imperative can justify significant additional financial outlays. And make no mistake — if the United States is to proceed with the urgency required, significant new outlays will be needed. From NASA's point of view, leading an urgent national imperative is a different proposition than managing the bureaucracy to achieve flat budgets and avoid controversy. The nation must demand a long-term program that extends human presence across the solar system while assuring continued United States leadership and the political, social, technical, scientific, academic, military, economic, and other benefits that accompany such leadership.

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The nation must demand a long-term program that extends human presence across the solar system while assuring continued United States leadership and the political, social, technical, scientific, academic, military, economic, and other benefits that accompany such leadership.

Biographies of Authors

Patricia J. Arnold, Ph.D.
Vice President, Education and Workforce Development, Space Foundation

As vice president of education and workforce development, Dr. Patricia Arnold leads the Space Foundation's education mission and all education programs. Arnold recently facilitated a collaborative effort between the Space Foundation, the University of Colorado at Colorado Springs (UCCS), and Regis University to jointly offer a Master's Degree with a Space Studies emphasis. Arnold's educational experience spans 36 years, including serving as dean of the School of Arts and Science at the University of Southern Colorado, Pueblo; principal of elementary, junior high, and high schools; and teacher of all levels. Arnold earned both a Master's Degree and Doctorate in Educational Leadership and Innovation from the University of Colorado.

Neil Armstrong
Astronaut, first man on the moon

Neil Armstrong served as a naval aviator from 1949 to 1952 and flew 78 combat missions over Korea. He joined the National Advisory Committee for Aeronautics (NACA) in 1955. His first assignment was with the NACA Lewis Research Center in Cleveland, Ohio. For the next 17 years, he was an engineer, test pilot, astronaut, and administrator for NACA and its successor agency, the National Aeronautics and Space Administration (NASA). As a research pilot at NASA's Flight Research Center, Edwards, Calif., Armstrong was a project pilot on many pioneering high-speed aircraft, including the (4000-mph) X-15. He has flown over 200 different models of aircraft, including jets, rockets, helicopters, and gliders. Armstrong transferred to astronaut status in 1962. He was assigned as command pilot for the Gemini 8 mission, which launched on March 16, 1966, and Armstrong performed the first successful docking of two vehicles in space. As spacecraft commander for Apollo 11, the first manned lunar landing mission, Armstrong gained the distinction of being the first man to land a craft on the moon and first to step on its surface.

Armstrong subsequently held the position of Deputy Associate Administrator for Aeronautics, NASA Headquarters, Washington, D.C., where he was responsible for the coordination and management of overall NASA research and technology work related to aeronautics. He was Professor of Aerospace Engineering at the University of Cincinnati between 1971-1979. During the years 1982-1992, Armstrong was chairman of Computing Technologies for Aviation, Inc., Charlottesville, Va.

He received a Bachelor of Science Degree in Aeronautical Engineering from Purdue University and a Master of Science in Aerospace Engineering from the University of Southern California. He holds honorary doctorates from a number of universities. Armstrong is a Fellow of the Society of Experimental Test Pilots and the Royal Aeronautical Society; Honorary Fellow of the American Institute of Aeronautics and Astronautics, and the International Astronautics Federation. He served as a member of the National Commission on Space (1985-1986), and as Vice-Chairman of the Presidential Commission on the Space Shuttle Challenger Accident (1986), His authorized biography, *First Man: The Life of Neil A. Armstrong,* was written by former NASA historian James Hansen and published in 2005.

Jim Banke
Vice President, Florida Operations, Space Foundation

Jim Banke is vice president of Florida Operations for the Space Foundation and was recently appointed by Florida Governor Jeb Bush to serve on the Commission on the Future of Space and Aeronautics in Florida. Banke also directs the Coalition for Space Exploration, where he is responsible for the Space Foundation's support of a collaborative industry effort whose mission is to ensure the United States will remain a leader in space, science and technology. He is a veteran aerospace journalist with 20 years of experience covering the world's space programs with an emphasis on launch and mission operations. Banke earned a Bachelor of Science Degree in Aviation Business Administration from Embry-Riddle Aeronautical University, Daytona Beach, FL.

James Francis Cameron
Filmmaker, Academy award-winning director

James Cameron is a Canadian film director noted for his American action/science fiction. Thematically, James Cameron's films generally explore the relationship between man and technology. Cameron went from set builder to art director, in film *Escape from New York,* to film director. Cameron directed Arnold Schwarzenegger in 1984's *The Terminator* and its sequel sever years later, *Terminator 2: Judgment Day.* Cameron also directed Signorney Weaver in *Aliens* and Ed Harris in *The Abyss.* In 1998, his film, *Titanic,* broke box office records winning eleven Oscars, including Best Picture and Best Director. James Cameron enthusiastically promotes exploration of our world and offers exciting viewpoints, both mirroring and influencing the audiences he reaches.

Jay DeFrank, Ph.D.
Executive Director, Research and Analysis and Vice President, Washington Operations, Space Foundation

Dr. Jay DeFrank is the executive director, Research and Analysis and vice president, Washington Operations, for the Space Foundation. DeFrank leads the Space Foundation's effort to assess the state of the space industry, research and analyze key issues affecting the civil, commercial, and national security uses of space, and develop products to inform the public and aid decision makers in the formulation of policy. He also serves as the public spokesperson for the Space Foundation in Washington, D.C. Previously, he was deputy director, public affairs for the U.S. Air Force and director of media relations for the Department of Defense. DeFrank earned a Bachelor of Science Degree in Journalism, Magna Cum Laude, from Southern Connecticut University; a Master of Science Degree in Communication, with distinction, from the Annenberg School of Communication, University of Southern California; and a Doctorate in Communication/ Media Studies from the University of Colorado at Boulder.

Jim Jannette

Chief of Staff, Space Foundation

In 2003, Jim Jannette was appointed chief of staff, responsible for directing the day-to-day business operations of the Space Foundation, providing leadership in establishing policies and procedures, and acting for the president and chief executive officer in his absence. Jannette joined the Foundation as vice president of marketing and communications after relocating from Florida, where he was president of Watermark Strategic Communications. Jannette also served in the United States Air Force, as a White House appointee under President Ronald Reagan, and as the assistant administrator for public affairs for the Federal Aviation Administration. He earned a Bachelor of Science Degree in Education, graduating Phi Beta Kappa, and a Master's Degree in English, Summa Cum Laude, both from Ohio University. He also earned national accreditation as a Public Relations Counselor (APR).

Joan Johnson-Freese, Ph.D.

Chair of the National Security Decision Making Department at the Naval War College Newport, Rhode Island

Dr. Joan Johnson-Freese has served as Chair, Department of National Security Studies, at the Naval War College since August 2002. Previously, she was on the faculty at the Asia Pacific Center for Security Studies in Honolulu, Hawaii; at the Air War College in Montgomery, Alabama; and the Director of the Center for Space Policy & Law at the University of Central Florida.

Within the realm of international and national security studies, Dr. Johnson-Freese has focused her research and writing on technology programs and policies generally, and space programs and policies specifically, including issues relating to technology transfer and export, missile defense, transparency, space and regional development, transformation, and globalization.

Dr. Johnson-Freese's next book is entitled *Heavenly Ambition: Will America Dominate Space?* for Columbia University Press, due out in 2006. Prior book publications include: *The Chinese Space Program: A Mystery Within a Maze* (Krieger Publishing, 1998); *Space: The Dormant Frontier, Changing the Space Paradigm for the 21st Century,* (Praeger Publishers, 1997); *The Prestige Trap: A Comparative Study of the US, European and Japanese Space Programs, with Roger Handberg,* (Kendall-Hunt, 1994); *Over the Pacific: Japanese Space Policy Into the 21st Century,* (Kendall-Hunt, 1993); and *Changing Patterns of International Cooperation in Space,* (Krieger Publishing, 1990). She has also published over 70 journal articles relating to international space cooperation and competition issues.

Col Steven W. Lindsey, USAF

NASA Astronaut, Commander, STS-121

An Air Force Academy graduate and experienced test pilot who has logged more than 5,000 hours of flying time in more than 50 different types of aircraft. Lindsey became an astronaut in May 1996 and is a veteran of three Space Shuttle missions, including one trip to the International Space Station (ISS). A native of California, Lindsey is assigned to command the crew of STS-121, a return-to-flight test mission and ISS assembly flight targeted for launch in 2006.

John M. Logsdon, Ph.D.

Director, Space Policy Institute, Elliott School of International Affairs, George Washington University

John M. Logsdon is Director of the Space Policy Institute at George Washington University's Elliott School of International Affairs, where he is also Professor of International Affairs. He holds a B.S. in Physics from Xavier University (1960) and a Ph.D. in Political Science from New York University (1970). Dr. Logsdon's research interests focus on the policy and historical aspects of U.S. and international space activities.

Dr. Logsdon is the author of *The Decision to Go to the Moon: Project Apollo and the National Interest* and is general editor of the eight-volume series *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program.* He has written numerous articles and reports on space policy and history. He is frequently consulted by the electronic and print media for his views on space issues.

Dr. Logsdon is a member of the NASA Advisory Council and of the Commercial Space Transportation Advisory Committee of the Department of Transportation. In 2003, he served as a member of the Columbia Accident Investigation Board. He is a recipient of the NASA Distinguished Public Service and Public Service Medals and the 2005 John F. Kennedy Award from the American Astronautical Society, and a Fellow of the American Institute of Aeronautics and Astronautics and of the American Association for the Advancement of Science. He is a member of the International Academy of Astronautics.

Biographies of Authors

John C. Mankins

President, ARTEMIS Innovation Management Solutions LLC

John C. Mankins is the President of ARTEMIS Innovation Management Solutions LLC, a management consulting, research and development start-up focusing on solving tough innovation challenges for government, industry and not-for-profit clients. Mr. Mankins is an internationally recognized leader in space systems and technology innovation, and as a highly effective manager of large-scale technology R&D programs. His 25-year career at NASA ranged from flight projects and space mission operations, to systems-level innovation and advanced technology research & development management. He is also well known as an innovator in R&D management, and was one of the creators of the widely used "technology readiness level" (TRL) scale for technology assessment.

Before leaving NASA, Mr. Mankins was the manager of Exploration Systems Research and Technology within the Exploration Systems Mission Directorate with responsibility for an $800M annual budget, involving more than 100 individual projects and over 3,000 personnel. For 10 years, he was the manager of Advanced Concepts Studies at NASA, and was the lead for critical studies of space solar power, highly reusable space transportation, affordable human exploration approaches, and other topics. He was the creator or co-creator of numerous novel concepts, including the "MagLifter' electromagnetic launch assist system, the Internet-based NASA "Virtual Research Center" the "Solar Clipper" interplanetary transport vehicle, the "SunTower" space solar power system, the "Hybrid Propellant Module" for in-space refueling, the "HabBot" mobile planetary outpost architecture, the Advanced Technology Life cycle Analysis System (ATLAS), and others. In recognition of his accomplishments, he has received numerous awards and honors, including the prestigious NASA Exceptional Technology Achievement Medal (of which he was the first recipient).

He holds undergraduate (Harvey Mudd College) and graduate (UCLA) degrees in Physics and an MBA in Public Policy Analysis (The Drucker School at Claremont Graduate University). Mr. Mankins is a member of the International Academy of Astronautics (IAA), the International Astronautical Federation (IAF), the American Institute of Aeronautics and Astronautics (AIAA), and the Sigma Xi Research Society.

Mr. Mankins is an accomplished communicator, including political, programmatic, technical and lay audiences. He has authored or co-authored more than 70 published papers, reports and other technical documents, and has testified before Congress on several occasions, and has been consulted on R&D management and space issues with organizations in the U.S. and internationally.

Elliot G. Pulham

President and Chief Executive Officer, Space Foundation

Elliot G. Pulham is president and chief executive officer of the Space Foundation, leading this globally respected nonprofit organization headquartered in Colorado Springs, Colo., in the pursuit of its mission: to vigorously advance civil, commercial and national security space endeavors and educational excellence. Pulham leads a team of space and education professionals providing services to educators and the space industry around the world and is widely quoted by national, international and trade media in their coverage of space and space-related issues. He previously served as the Foundation's executive vice president. Pulham brings national award-winning experience in public affairs to a Foundation focused on creating public awareness and support for space endeavors, and on using the excitement of space to inspire academic achievement. For a decade prior to joining the Space Foundation, he was senior manager of public relations, employee communication and advertising for all space programs of The Boeing Company. Pulham's experience spans more than 25 years since his undergraduate studies at the University of Hawaii's school of Journalism.

Neil deGrasse Tyson, Ph.D.

Astrophysicist, American Museum of Natural History; Director, Hayden Planetarium; Member, Commission on the Future of the U.S. Aerospace Industry

Neil deGrasse Tyson, Ph.D., is the Frederick P. Rose Director of New York City's Hayden Planetarium. He serves on the board of directors of the Space Foundation and was a Presidential Appointee to the Commission on the Future of the U.S. Aerospace Industry and to the Commission on Moon, Mars and Beyond. Tyson is the on-camera host, narrator and executive editor of the PBS-NOVA mini-series *Origins.* He is the author of seven books, including the acclaimed *Just Visiting This Planet* (1998) and a memoir *The Sky is Not the Limit: Adventures of an Urban Astrophysicist (2004).* His newest book, *Death By Black Holes and Other Cosmic Quandaries,* is scheduled for publication in 2006. He has been voted by the editors of *Crain's Magazine* to be among the 100 most powerful minority business Leaders in New York.

Dr. Tyson continues to work as both an educator teacher and astrophysics research scientist at the American Museum of Natural History, where he also directs the programs and operations of the Hayden Planetarium and serves as an expert commentator for virtually all major national television news networks. His remarks for this report were excerpted from his keynote address to the 2005 Goddard Memorial Dinner in Washington, D.C.

Editorial assistance also provided by Space Foundation interns, Margaret "Ashley" Whelan, a graduate student studying space policy at George Washington University's Elliot School of International Affairs; and Josh Kaushansky, an undergraduate student at American University.

The Space Foundation is a national nonprofit organization that vigorously advances civil, commercial, and national security space endeavors and educational excellence. Headquartered in Colorado Springs, the Space Foundation has offices in Washington, D.C. and Cape Canaveral, Florida.

In 1983 a small group of visionary leaders in Colorado Springs saw a need to establish an organization that could, in a non-partisan, objective and fair manner, bring together the various sectors of America's developing space community and serve as a credible source of information for a broad audience — from space professionals to the general public. The Space Foundation was founded March 21, 1983, as an IRS 501 (c)(3) organization "to foster, develop and promote, among the citizens of the United States of America and among other people of the world a greater understanding and awareness of the practical and theoretical utilization of space for the benefit of civilization and the fostering of a peaceful and prosperous world."

In the years since its founding, the Space Foundation has become one of the world's premier nonprofit organizations supporting space activities, space professionals, and education. Its education programs — accredited through 17 universities and colleges — have touched teachers in 49 of the 50 U.S. states.

As the global space community has evolved, so has the Space Foundation — embracing all facets of space — commercial (including telecommunications and other satellite-based services), civil, and national security. In fact, the Foundation is one of few "ecumenical" space-related organizations that embraces the totality of this community rather than focusing on a narrowly defined niche.

The Space Foundation annually conducts, along with its partnering organizations, the National Space Symposium (The Broadmoor, Colorado Springs), Inside Aerospace (Washington, D.C.), Florida Space (changing venues in Florida), and Strategic Space (Omaha).

For more information, visit **www.SpaceFoundation.org.**

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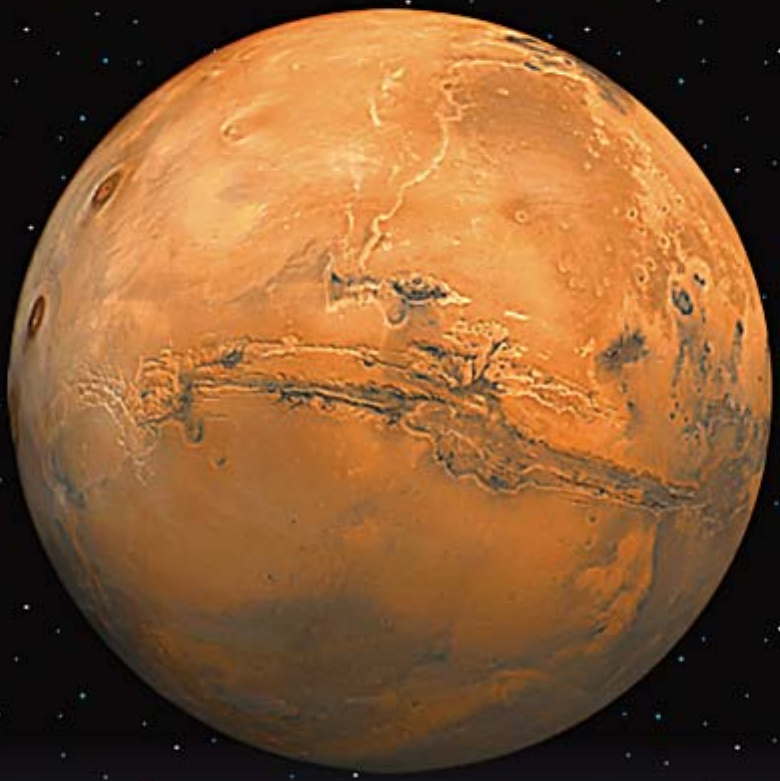

"Man must rise above Earth
to the top of the atmosphere
and beyond,
for only then will he
fully understand the world
in which he lives."

~ Socrates,

sometime around 400 B.C.

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