

The President's Commission on Implementation of United States Space Exploration Policy
PUBLIC HEARING

Galileo Academy of Science and Technology
1150 Francisco Street, San Francisco, CA
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Pete Aldridge

Well, good afternoon. Welcome to the fourth public hearing of the President's Commission on Moon, Mars and Beyond. I'm Pete Aldridge. I'm the Chairman of the Commission. I'm especially pleased to be holding this hearing at the Galileo Academy of Science and Technology here in San Francisco.

And what an appropriate name, first of all, and the school's motto is "A new school under the stars." So I thought that was quite appropriate that we be here.

We would all like to thank Principal Margaret Chiu ... and Vice Principal Anthony Hailey, administrator Bettie Grinnell, and the students and parents of the Galileo Academy for allowing us to be here today.

The students are on the spring break, and although we know that the Galileo students are deeply interested in space, science, and technology, we also understand that spring break is spring break. Meanwhile, on the other side of the world, Principal Chiu, the school librarian Patrick Delaney, and other members of the faculty are in Shanghai participating in an educational exchange conference sponsored by Harvard University. Mrs. Chiu, we hope that you and your colleagues will see all these proceedings via the Moon to Mars website and know how grateful we are to be here at Galileo Academy.

Here today representing the San Francisco Unified School District is Assistant Superintendent Dr. Frank Tom. Dr. Tom, we wish you continued success in educating young people for careers in science and technology. Would you please stand so we can see you? You're out there somewhere. It's hard for to us see the audience with all of these bright lights in our face.

Now, I'd like to introduce the hardworking members of the Commission, starting at my far right and will be here shortly is Carly Fiorina. Carly serves as the chairwoman and chief executive officer of the Hewlett-Packard, which she joined in July of 1999. Her roots are deep in technology and she has served in senior executive leadership positions at AT&T and Lucent Technologies.

Michael Jackson is a Senior Vice President for E-Com Technology Corporation. He is a former U.S. Department of Transportation Deputy Secretary and was instrumental in the early formation of the Transportation Safety Administration.

Dr. Laurie Leshin is the Director of Arizona State University's Center for Meteorite Studies. She uses spacecraft and sophisticated laboratory instruments to trace the history of water and possibility of life in our solar system.

Les Lyles was in the Air Force for more than 35 years, rising from the Air Force ROTC program to become a four-star general and commander of Air Force Materiel Command. In that preretirement position, General Lyles was responsible for the U.S. Air Force research and development community.

Dr. Paul Spudis is a planetary scientist at the John Hopkins University at the Applied Physics Laboratory outside of Baltimore, Maryland. His specialty is in the geology of the Moon. He has also studied the geology of Mars, Mercury, and many other worlds.

Dr. Neil deGrasse Tyson is an astrophysicist and the Frederick P. Rose Director of the Hayden Planetarium in New York City. He served on the President's Aerospace Commission, which made recommendations to Congress and related government agencies on how to improve the health and future of this industry in the interest of the American economy and national security.

Retired Congressman Robert Walker is the chairman and chief executive officer of the Wexler and Walker Public Policy Associates—a firm specializing in telecommunications and technology issues. Bob served in the U.S. Congress from 1977 to 1997, representing his home state of Pennsylvania. While in Congress, he was Chairman of the House Science and Technology Committee, with NASA oversight. He, too, served on the recent Aerospace Commission as its Chair.

Dr. Maria Zuber is the E. A. Griswold Professor of Geophysics and planetary scientist at the Massachusetts Institute of Technology and leads the Department of Earth, Atmospheric and Planetary Sciences. Maria has been involved in more than half a dozen NASA planetary missions aimed at mapping the Moon, Mars, Mercury, and several asteroids.

Steve Schmidt, next to Maria, is our Commission's Executive Director. Steve is a Special Assistant to the NASA Administrator and our federally designated official for this advisory committee.

Before we begin today, I want to announce that today we are releasing information about responses to our website. So far, MoontoMars.org has received close to 4 million hits and over 5,000 written responses from 64 different countries. All of the responses have not been positive, but pro comments outnumber con comments seven to one. The opposition comments are mostly concerned with the budget and spending on anything that doesn't address terrestrial needs. Pro comments, with California in the lead, echo a strong belief that exploration is part of human nature, that space is the next frontier and that the Moon, Mars and Beyond initiative will reap benefits for all humanity, education, technology, and jobs. More details regarding the public findings are available on our website. That's www.MoontoMars.org. And I encourage you to read the press release there.

We will begin this hearing with a panel of experts on the entertainment aspects of space exploration. I don't need to tell anyone how many people get their information about space from novels, films and even videogames. Interesting, the creative technologies associated with new media are not unrelated to the high-tech of space.

Our first panelist literally needs no introduction. We are honored to have the accomplished and popular writer Ray Bradbury joining us via satellite from Los Angeles. Who knows? Perhaps the leap from publication of his *Martian Chronicles* to the first outpost on the Red Planet may not take

nearly as long as the progression from Jules Verne's *From the Earth to the Moon* to the Apollo launch. Mr. Bradbury, we welcome your perspective. We will hear from Mr. Bradbury first, and then after which, I will introduce our other panelists. Mr. Bradbury, are you on?

We're not getting any sound. Could we get somebody working on getting the sound? O.K., does Mr. Bradbury know he's not getting through?

Unidentified speaker

No.

Pete Aldridge

Okay.

Do you want to try it now?

Ray Bradbury

All right. Is this better?

Pete Aldridge

Yes.

Ray Bradbury

Can you hear me now?

Pete Aldridge

Yes, we can.

Ray Bradbury

Is it good and clear?

Pete Aldridge

It's clear, but it's—we still got a little background noise, but I think—why don't we go ahead and proceed?

Ray Bradbury

All right. Now I have always considered—I'm writing a new book called *Too Soon From the Cave, too Far From the Stars*, in other words, we're the in-between generation. We have been out of the cave about 10,000 years. We're on our way to Alpha Centauri with a way stop on the Moon and Mars. We know very little about the generation of life on Earth. We have tried to explain it to ourselves. It's very difficult. We have no answers.

I worked for the Smithsonian a few years ago creating a planetarium show about the universe, the Big Bang and what have you. And in doing that, I got to thinking about the generation of life on Earth and what we're doing here. There's not one of us who hasn't laid awake at night or stood up or laid out on a hill and looked at the universe and wondered, "What's it all about? Why are we here?" Well, my idea is this—that there's no use having a universe, billions of stars and all creation before us if there's no audience. So the universe, in mysterious ways, created life on Earth as an audience for this miraculous experience of being alive in the universe. We are the audience. We will witness and we will celebrate.

Now, if that is true, and I think it is, we are the audience that the universe needed to appreciate it. But now here we are on the threshold of space, running back to the Moon, which we should never have left, and going on to Mars. I would like to put this in a framework for you: 500 years ago, three Italians set out from various parts of Europe. Cristoforo Colombo—Columbus—set out representing Spain, and then England came along with Giovanni Caboti representing Henry VIII, and the third person, Verazzano, another Italian, set out for India. All three of them could not have guessed 500 years into the future. So, on the way to India, all three of them bumped into a huge obstruction, an obstruction that was empty, that was uncivilized, that was cold and rejected them. Cristoforo Colombo—Columbus—did not land on the main continent of this huge obstruction on his first trip. Giovanni Caboti examined the northern regions of this unknown continent. Only one man, Verazzano, landed. First of all, he's Italian on the shore somewhere near Kitty Hawk. Somewhere near Kitty Hawk—that's fascinating to think about it, isn't it? 400 years before Kitty Hawk an Italian lands on an empty shore, and 400 years later, the Wright brothers take off into the air above the Earth. Now, those people—and those kings and the whole population of Europe—could not possibly predict that these three Italians would found a nation of 300 million people that would become the center of civilization, the center of a new thing called democracy, and change the history of the world and become the most powerful power in the world.

But that's what happened. Nobody could predict the future 500 years ago.

Now we are called upon, in viewing the Moon and Mars, to guess ahead 500 years. That's almost an impossible task, but we must try to do it, try to imagine that the Moon is a base and Mars as a new landing place, and a creation for civilization will burgeon in the next 500 years, 1,000 years and 10,000 years, and become the center of a new frontier. It will move outward some day to Alpha Centauri.

Why? Because life wants to exist, wants to survive, and wants to be free of the conflicts of Earth even as America when it was created was free from the conflicts of Europe. So, we're going into

space to be free of the politics and conflicts of the various nations and to become one new nation on the planet Mars. I can think of nothing more exciting to all the children of the world and to their parents who are infected by the joy and the love of their children for space.

And looking at in a very practical way, we are spending roughly \$1 billion a day at this time for armaments, for war, for conflicts, for doubt and for hatred at times. If we would take one day each year and spend the money of that one day on space travel, we could do it. So, 364 days for armaments and one day for rockets for our destiny on the Moon and for our future civilization of freedom and a new democracy on Mars.

Pete Aldridge

Mr. Bradbury, thank you very much for your input. Question: obviously, the President's initiative has given us a vector for the future. One of the issues that this Commission has to worry about is to ensure that that program is sustainable during the decades that it's going to take us to begin this journey. Do you have any thoughts of how we continue to have—to sell this to the American taxpayer for it to be sustainable over this period of time?

Ray Bradbury

Just—just the way I have told it to you. If they see their destiny, if they see their children and their children's children in a new future that's brighter and better and more wonderful than this: it has to be sold on an aesthetic level, on a—on a level of relating ourselves to the universe and to the gift of life, which we wish to solve, and to preserve, that is the way you sell it. Don't try to speak of impossible gifts like gold, which Cortez talked about, or spices, which the kings of England and France spoke of, but the aesthetic things, the human things of the whole entire race of people on the Earth at this time, looking to the sky and saying, "Look what we've done."

Here is an antidote to war. Here is a release away from war. Here is something wonderful as against the bad news that we're getting almost every night from all over the world. At this very moment there are innumerable wars being fought all over the world in various locations. So, if we sell it on the basis of a new freedom, a new movement away from the politics and the horror and terror of Earth, I think people will recognize how true this is.

Pete Aldridge

I think you also pointed out the level of affordability. This is not a horrendously expensive task for us to do, if I read your words in the proper way. Is that ...

Ray Bradbury

The thing to do is for the people to ask their children—take a vote of the children. They will all look at the sky and say yes by the millions, by the billions. The children, knowing that their future is in space, will say to their parents, “Do it.”

Some years ago I wanted to put on a play about space travel, at Samuel Goldwyn’s studios. I went for a meeting with the executives. They seemed doubtful about my play and about the future in space. I said to the president of the studio, “Do you have children at home?”

And he said yes—a 14- and 15-year-old family.

I said, “Go ask them if they want to engage in space travel with me, if they want to move into the future.”

The next day the producer came back and said, “You’ve got it. Our children have just voted you in.”

So, that’s the answer to the problem now. The children of world will give us the answer if you get all the mothers and fathers in the world and the older politicians to look into the faces of their children and say, “Where do you want to go?”

And the children will point up and say, “There.”

Pete Aldridge

I’ll open it up for other Commissioners. Any questions? Anybody have any?

Yeah. Neil.

Neil Tyson

Thank you for that testimony, which appeals not only to the emotions of kids but I think to emotions of adults in this room as well. I’ve got a question, and it comes back to the idea that there is a credible rebuttal to the space program, which suggests quite independent of dreams of space that spending money on Earth to improve our life on Earth should be where any extra money might go, and the credibility of that is simply that we know we have problems on Earth. I worry sometimes that going into space we take our problems there. Why should we believe that if we go to Mars there wouldn’t still be wars? So, could you comment on that, just the role of space in our dreams of Shangri La versus the role of what we might do on Earth to fix it.

Ray Bradbury

Well, consider the social situation in England at the time that Henry VIII sent Giovanni Caboti. There were all sorts of problems that hadn’t been solved. The problem of a true democracy had not been solved in England. If they had stayed there and only worked on that, there would have been no

America. In France, in the time of Francis I when he sent Verazzano over, they had immense problems. They had not as yet had their revolution 200 or 300 years in the future.

They had problems that should have made them stay home. Why should Verazzano go anywhere? And in Spain, problems again, and in Italy, where Columbus came from, all over Europe, there were problems—there were plagues, there were all kinds of wars of countries invading one another—Italy being invaded by Austria, Sweden being invaded by Spain. All of these problems we look back on and say, “Thank God they didn’t try to solve those problems only, but they sent three voyagers out to invent America.”

So, there’s where you have the problem. We’re always going to have problems. We solve them. The role of medicine in America in the last 80 years is remarkable. When I was born in 1920, people died by the millions. By the time I was 30 years old, penicillin and sulfasalazine had been invented; nobody could have predicted that. But you don’t lag behind, you move ahead on all the fronts at once. You take the good things with you into space. We’re not going to take our problems with us.

We will refine ourselves along the way, and the first people that land there will be responsible citizens. They will be the first Martians, and then they will look back on Earth and call more people up. I do not believe we will take our problems with us. We will take representatives from every country in the world at some future time. I would like to send on the first manned expedition to Mars three Italians, if we can find any living relatives of Columbus and Caboti and Verazzano. Wouldn’t that be remarkable if we could send them on the first manned rocket to Mars?

Pete Aldridge

Paul.

Paul Spudis

Mr. Bradbury, you paint a very eloquent and compelling and idealistic picture. Let me offer a counterpoint to it, however. Americans tend to be very pragmatic people or very practical people. We embrace innovation, engineering, hard-headed facts, the bottom line. What you have outlined is a rationale based on aesthetic appreciation, which traditionally has never gathered much political support in this country. The problem we’ve got is we can appreciate the aesthetic aspects, but getting it to be a selling point is very difficult, because people expect practical results. So, given that background, I don’t—I don’t know if you agree with that premise or not, but—our problem is how do we appeal to that practical side of the American public? And I might suggest that one way is to say that space is a source of wealth. It’s a source of virtually unlimited wealth. And that seems to me something that would appeal to the American public much more than an aesthetic appreciation. Even though that would resonate, I think a practical approach would resonate with a much larger section of the population. Do you agree with that or not?

Ray Bradbury

Well, there's a scene in *Moby Dick* where Ahab is going after the white whale and Starbuck says to him, "Where is the profit in this?" and Ahab touches his heart and he says, "The profit is here, man, the profit is here." So, the ...

Paul Spudis

What happened to Ahab?

Ray Bradbury

The profit is not incredible wealth, but incredible wealth of love and well-being, a freedom to express joy instead of sorrow and melancholy. It has to be sold on the basis of a higher aesthetic, but an exciting one. Again, ask your children, and they will respond with shouts of joy.

They will not demand the gold or silver or all of the profits that we're speaking of on a practical level. They want the joy of going into space. I talked to all of the astronauts in Houston 30 years ago before we moved into space with the Apollo projects. I went down for *Life* magazine to do a series of articles about our plans to go to the Moon. I was in a room with 80 astronauts. They were all being very practical. All very practical. But it was announced from the front of the room by the *Life* editor that Ray Bradbury was sitting in the back of the room. Sixty astronauts jumped to their feet and rushed toward me. Why were they doing that? Because of the joy of knowing I cared about space, that I knew what it was to go up and look back for that first view of Earthrise. The joy of space. The joy of being on Mars, and the joy of finally moving to Alpha Centauri. It's on this higher level that children can give us that gift and we have to look to our children and not to the practical people who say, "Stay here and solve the problems before you move," because if you stay here, you will stay here forever, and Earth will be a mausoleum if we stay here for 10,000 years. We cannot do that. We've got to ask the children again and again, and the resounding answer will be yes.

Pete Aldridge

Maria.

Maria Zuber

Mr. Bradbury, in your book *The Martian Chronicles*, it took several tries for humans to get to Mars successfully and then start to form colonies. In the NASA culture now, it's very risk averse because we have had some failures. What would happen if in *The Martian Chronicles* played out—when we sent the first people to Mars and there were failures at the beginning? What would it take to tell America as it stands today and the rest of world, in fact, to keep on going?

Ray Bradbury

Well, when you think of the history of sea travel, thousands of people—thousands of people—had to die in order to come to America. Thousands of people had to die of various diseases on the coast of America. Millions of people finally sacrificed to make America what it is. So, the answer to all this is, no matter what, you can—we will prevail. You have to set yourself against this. We all have personal things that happen during our lives. In the last year, I have lost many of my friends. I've lost members of my family and what—you don't give up, do you? You just simply do not give up. That's the answer. You prevail, you move ahead, and you finally succeed. What we did here in America took millions of people working and tens of thousands of people dying. And we finally did it. And we are the beacon to the world because we wouldn't let ourselves be destroyed.

Pete Aldridge

Mr. Bradbury, we have run out of time and we really appreciate your input. I'm struck by the fact that one of the tasks that we've had is how do we sustain this program over decades in the future, and you reminded me that those decades will be lived by our children and we ought to listen to their vote. Thank you for being here today. We enjoyed your presentation.

Ray Bradbury

It's been a great pleasure. Thank you.

Pete Aldridge

I would now like to introduce the other panel members. First is an electronics story teller, John Bernardoni. Mr. Bernardoni is an executive producer of the Ancient Mariner Media, a multimedia production company that focuses on educational and entertaining programming about space exploration and the Internet.

The third panelist is what I could call a guru from the world of videogames. Lawrence Holland became an original game designer in 1984 with a space simulation game—Project Space Station. He then collaborated with Lucas Arts before launching his own company, Totally Games, in 1995. Gentlemen, we're eager to hear what you have to say. Mr. Bernardoni, would you start off?

John Bernardoni

Thank you. May I say, it's an honor to be asked to sit on this panel in front of the President's Commission on Moon, Mars and Beyond. We are all for you. We're backing you 100%. Carl Sagan said if you want to make an apple pie from scratch, you must first create the universe. And it seems to me a very appropriate thing. One other thing I would like to take total credit for, of course—

Mr. Bradbury talked about how Italians led the way and, being John Bernardoni, those are my people, and we're ready to do it again.

Pete Aldridge

Except they didn't really pay for the trips.

John Bernardoni

Do you know the Venetians? The word *genovezi* means "tight." I have some objectives for being here. First of all, I have had 30 years of experience as a producer in the live entertainment industry and some in film and television, producing some of the biggest names in the industry internationally, Broadway shows, major concert touring stars, comedians, you name them, and I have produced them in my life. I won't go into detail because of the limited time. I know their managers; I know their agents. We're friends. I'm credible with them and have a great reputation with them, and we talk all the time.

I believe—I'll get to this in a minute—that the entertainment industry will do the right thing when it comes time to stand up and back what's going on in a very personal way. They have always been very generous and they're incredibly patriotic. We are here to really basically re-ignite excitement about the human space program with children first, and the public second, and Congress, I'm not sure. That's probably your job, and all of the aerospace lobbyists and the President and yet hopefully Congress does listen to their constituency. Hopefully, they do listen to the children who are going to be leading the way. And absolutely, we are talking about the idea of the entertainment industry, media, and the advertising world coming together to back the President's space initiative in a very tangible way to reach millions—tens upon millions—of people both here and internationally. I believe that, frankly, having thought about this a lot on the plane out here, that you and the President and all of us are facing one of the greatest marketing challenges of our time. There are two generations of people who have no idea, really, what Mercury, Gemini, and Apollo were, what they meant, what they stood for. They do not know who Gus Grissom was and how he died and why he died and what he died for. And they don't really know why these people risked their lives when they have seen these tragedies occur. And that is something that we have to fix.

What inspired me as a child: I grew up, you know, my father was a GS-15 for the Kelly Air Force Base ... Logistics. He was fascinated with aviation. I was right there with him when the B-52's flew over our house and shook the girders of our house going into Kelly Air Force Base. That was a time during science fiction in Hollywood because we were part of the Atomic Age and we had great films coming out like *Forbidden Planet* and *It Came From Outer Space* and *The Day the Earth Stood Still* and *War of the Worlds*. It's so long ago, some of you may not remember. That fired the imagination. When I was 13, Alan Shepard came up. I remember they rolled a TV into the classroom at St. Margaret Mary's in 8th grade. Just the fact that a TV came into the classroom was a mind blower already. The fact that there was anything even on was even more impressive. I'm not sure we all grasped what happened that day, but it really did blow our minds. And, of course, as

time would go by, we would be able to repeat those opportunities with additional missions during Mercury, Gemini and Apollo.

The kids today haven't really had that shot. I don't think that they teach this in school, forgetting this school for the moment. And I find that to be tragic, because I believe that this is the greatest story of mankind, and the world: mankind leaving his planet for another world. Gene Cernan said that to me; that's not my idea, and I think he's dead-on right. He also told me it would be 50 more years before we fully grasped the significance of what that event meant. I didn't really know what he meant at the time. I thought about it a lot because I thought, "I do understand," but you know what? I think he's right and he's a very spiritual and intellectual human being, and very passionate, and I think he's talking about something that I still don't quite get, but I believe what he's saying. I don't think we fully grasp that, and these kids who are our future, the five-year-olds who may be in the Mars program, are the ones that have no concept of their history. And you cannot go into your future until you know your past. You cannot know who you are if you don't respect where you came from.

And I think that one of the jobs we have to do is to go back partially and say, "Here is what happened. Here is the story, and the voices, and the pictures and the video of those people who are still around who can tell you this story." And this is the only industry that I know of in the world where 95% of the participants who basically gave us the miracle of the 20th century are still here—articulate, passionate and can be talked to. Yet there is no national archive of their stories. I think that's something the kids need to hear along with all of the rest.

Spock said, "It is difficult to know the answer when one does not understand the question." It's a great line, from one of the Star Trek movies. And the question really is, What is the message we need to get out? Space exploration has forever changed life on Earth. Every man, woman and child on this planet, and probably animal life, has been positively affected by what we have generated through spaceflight, speaking to the practicality question.

The guy that was an Apollo administrator at one time, Jimmy Skags, told me that technology is project driven. It sounds incredibly simplistic, but boy, there is no project like mission Mercury, Gemini, Apollo, and Shuttle, Skylab, and what is to come. It can unify us as a people behind a quest that all people have in their D.N.A. and, as Mr. Bradbury said, boy, do we live in a time when we need a unifying symbol in this world. Space is something that everybody can relate to, no matter their religion, their economic position, their cultural background. It is something that we have had in our primal systems since time immemorial and, even more so than the ocean, I believe space is a great unifying symbol and can be a tremendous byproduct for the expansion of peace and goodwill in this world which we need desperately, particularly for our children.

What is the prime goal of the new space initiative and what is the President hoping to achieve? I have read it. I see it. It's very clear to me. But you always have to kind of, in the entertainment industry, you have to cut down to the kernel of something and we ought to talk about that during the question-and-answer part. Will the Congress and the public support the initiative over the long haul? This is a toughy. And, more importantly, how does it really affect me, how does it affect

them, will there be jobs, and will it make a difference, will it give hope and will there be tangible returns?

Let me just tell you a couple of quick ways that the entertainment industry can help in very tangible ways.

First of all, we have to make this cool for the kids. I was at a meeting—I have been to dozens of meetings in the last eight years as I have learned the space industry, NASA’s culture, the aerospace folks, I have met with scientists, engineers. I’m the only communication person ever in the room, so, I’m always kind of the black sheep. And a group of scientists were sitting around, and they were saying, basically, that they were kvetching or griping about why more kids weren’t signing up for aerospace. Now, this was three or four years ago.

I stood up and I said, “Why should they? There is no big audacious goal. Therefore, there are no missions. If there are no missions, there are no jobs. So, what’s the point?” I said, “You want to get kids pumped up, you got to have a vision, and I’m going to tell you how to get them pumped up. You get them pumped up through MTV. You get them pumped up through videogames. You get them pumped up through the Simpsons. You got to go where they live. You got to go to the music that they dig, what their peers are. That’s how you get to kids. You cannot get to kids through job fairs. And if you want to light a fire under the youth of America and the world, we’ll get U2 to do a song about going to Mars, and you’ll have 25 million zealots on your hands ready to sign up. That’s how you get to kids. Make it cool.”

Music industry: you get songs, video images at concerts, what you are doing major production now when you go to arenas.

Radio. I’m close to ClearChannel, which owns 1,200 radio stations in this country. By their mandate, they have to run public-service announcements, as does television and the stars of the music industry. I’m telling you, they will come forward both at their shows and to speak perhaps with Gene Cernan or with Buzz Aldrin, so you’ve got a kind of mixture of people that are talking.

Television and cable. Compelling major specials that are not boring, dry documentaries, that really get to the entertainment, edutainment part of this so that we are actually getting people wound up and excited about what is to come.

Advertisers. Hewlett-Packard and a lot of the Fortune 500 companies spend billions of dollars advertising, pushing their products during the year. The *Hallmark Hall of Fame*, back in the 60’s, along with Texaco and Kraft, were famous for being able to back brilliant programming for television. Some of the best programming that ever ran, and they did it in a subtle way by *The Hallmark Hall of Fame Presents*—whatever it might be. That connection and being able to wrap one’s arms around space, I think, is important.

Obviously, the film industry is terribly important.

Star Wars, George Lucas, Steven Spielberg, *Close Encounters*, *E.T.*, and even things that are fantasy space kind of interrelated, like *The Matrix*—those kind of things—again, kids love that. The general public loves that. You know, tens of millions of people see those kinds of films, and

we actually have one in the pipeline right now that is a feature film that's very compelling, which we can talk about later if there's time.

DVD's of course. Once you have got something in electronic form, we can manipulate the information into many kinds of things, some that are altruistic like a national archive of human space exploration and some that are more commercial, but once you get the images, you have got them.

Educational packages to schools. That sounds boring. I'm not talking about something boring. We're talking about creating out of these various programs something extremely compelling and exciting together with a website that will allow kids to go online and basically plan their own mission to Mars. The class will be split up into groups like "Your Propulsion," "Your Logistics," "Your Scheduling," "Your Food," "Your Radiation," and whatever—get them to think about these things, but not a scientific website, something that is very entertaining and yet gets across the message. You can be entertaining and convey an idea, and a message, you don't have to be dry about it. And that's been a problem all along with this whole process through this particular culture. And children's celebrities. Believe it or not, Marvin Martian, Shrek, Monsters Inc., the Teletubbies, Spongebob Squarepants, the Simpsons, Pixar. Pixar is brilliant. These kids, that's who they're watching. That's who they're listening to. And I'll bet that we can get them to perhaps focus again on this subject to back you up and to light a fire back under this country, and under Congress.

Sustainability is a definite concern. It's hard to keep a 15-year-old's attention for 30 minutes, much less 20 years. And I'm not sure, really, what the answer is to that one is, yet. Coming out with a big burst of power from the entertainment industry is not what you need. I'd like for that to happen because I really would like to see the entire country lit up right off the bat, but I think having talked to a lot of people that it's something that's going to have to be rolled out little by little by little by little, and more importantly, it can't be hell's-a-popping. Somebody's going to have to coordinate this. I just can't go to all of my contacts and producers and agents and managers and say, "Okay, look, this is your patriotic duty. We need to do this, this is important, this is our future, I need your people. I need the stars, I need the actors, writers, directors to come behind this, much like many years ago they did during the Library of Congress." I don't know if you remember 15 years ago after a compelling program, James Earl Jones would come on and say, "During the Revolutionary War, such and such happened, and such and such happened, and if you would like to know more, check out these books and visit your Library of Congress." Brilliant. I don't know if those were P.S.A.'s or somebody paid for those. That kind of thing is something that can be done again and needs to be done again.

We are on the—we are on the edge—I don't have to tell you, of losing our technological might to other countries. Somebody told me that China graduated 300,000 aerospace engineers to our 58,000. I don't know if that's true or not. I was at the National Space Symposium when I heard that and that Japan graduated something like 225,000. That's scary. You talk about outsourcing, it's going to make what's happening now look pretty silly. And if anybody really wants this to be an international effort, they're not going to have to worry about it, it will be an international effort, whether we like it or not, because that's where all these folks are going to come from.

Finally, I suppose I would like to tell you one thing that—quickly, and then I’m going to move this on so that my colleague to my right here can speak as well and we can talk during the Q & A further. There’s basically three things we need to do. We need to re-ignite excitement in the country and we need to use the entertainment industry to do that, and the Congress needs to deliver. It doesn’t do any good to go out and get people pumped up about something that doesn’t happen. We don’t need what happened in 1989 to occur again even though the public was barely aware of the fact that President Bush Sr. put his behind on the line, if you’ll forgive me, and stood out and said, “We are going to send a manned mission to Mars.” Why it never happened, frankly I don’t even know. I imagine it was a money issue. I imagine, you know, it got shot down in Congress. But he had the guts to stand up and say it just like the current president did, but we’ve got to deliver. This cannot be something that’s just a bunch of words.

And I think that I would like to ask that the Commission and NASA think about this timetable because we could lose an entire generation of expertise with kids because they’re not going to be able to hang on that long to this.

We can get out there for a year or two years, fan the fire. You know, get people pumped up, use all of the various mechanisms that I’m talking about in our industry. But at some point, you’ve got to deliver something. During Mercury, Gemini and Apollo, we had, what?—20 missions or something? There was something happening all the time. You know, it was very much concentrated over ten years. That’s not really what’s going to be happening in this new program. I’m not saying that I’m critical of the program, I’m not, but I’m concerned about the sustainability of it. We’re here to help you. We are behind you 100%, and—but it is the children, as Ray said, who are going to take us there. They’re the ones that are going to be going to Mars. We have to pave the way. Thank you very much.

Pete Aldridge

Thank you very much.

Mr. Holland?

Lawrence Holland

Good afternoon, ladies and gentlemen, the Commission and members of the audience.

I am in the games industry. I do not play games all day long. I do think about them and build them.

When I was 12 years old, I was one of the more than 600 million people around the world who witnessed something historic, something that brought strangers together, ever so briefly even thawed the Cold War. That event was the third week of July, 1969, and that event, of course, was the Apollo 11 Moon landing. To this day, I can’t hear those immortal words “The Eagle has landed, Tranquility Base” without getting a shiver of goosebumps all over me. I was in awe, I was excited, and I was of course relieved and I had a deep respect for the astronauts and the scientists and the engineers who through their courage and expertise made it all happen. And I felt a great sense of

pride and achievement. It was truly inspiring. Although I didn't pursue a career in the space program, I have been motivated to support space exploration ever since.

Now, over three decades later, more than half of the population of our country was not even alive when those first historic steps were taken. Many more don't even remember. That means that what I draw inspiration from isn't there for many others. So, when President Bush says, "Let's go back to space in a big way," I say, "Of course. Let's go. I'm ready. How can I help?"

But many others say, "Hold on a minute—what's it going to cost? Why should we do this? Why?"

Of course, that gets to the heart of our challenge, and it's already been talked about a little bit today. While there are plenty of scientific, technological, budgetary and organizational challenges to overcome to fulfill President Bush's directive, the greatest challenge of all is gaining broad public support for this endeavor that will last for decades. When NASA Administrator Sean O'Keefe said, "It is critical to NASA that we inspire the next generation of explorers," I wholeheartedly agreed. But I think this mandate needs to be broadened significantly. We need to be inspiring our entire nation to explore space as a first step. Meaning that we need to inspire the current generation as much as the next generation. So, how do we inspire our nation?

Well, we must tap into people's emotions very deeply. And how do we do that? Well, we must use the power and the drama of entertainment. In particular, I believe we must do the following:

We must use entertainment to get people fired up about the future space program, not just logically convince them. We must use entertainment to demonstrate the power of possibilities of space exploration, and finally we must create a personal connection for people to this enterprise, even though it's years in the future. When it comes to entertainment, I'm sure you can identify with the power of film to tell gripping stories of human achievements. Film that stirred passions about space travel and explorations through historical-based movies like *Apollo 13* and numerous documentaries. Certainly, even science fiction films have sparked our imagination, all these should and will continue to push us toward the heavens.

But I'm here to talk you to about a new form of entertainment, literally, the new game in town. This is the world of computer games and videogames. Simply put, games are hugely popular. Millions of people are playing them—of all ages.

In my 20 years in the industry, I have seen them grow from being on the back page of the business section now to be front and center in the entertainment section, right alongside recently released movies. In other words, they are now mainstream. In fact, by some estimates, the game industry is on par or even outstripped the movie industry in terms of revenue. A recent TV industry survey showed that the male population between the ages of 18 and 34 spends more time playing video games and surfing on the Internet than they do watching television. Clearly, a dramatic shift is under way and there's little doubt that games have already captured the imagination of our youth.

So, why are they so successful? That's because they do something totally new, totally fun, and totally involving. Their fundamental unique characteristic is that they are interactive. You're not just an observer as you are in a movie, but you're an active participant, usually the central figure in a drama driving the outcome. Games also immerse you in rich worlds of unlimited variety from

present-day circumstances to past historical situations or even futuristic or fantastical. When they immerse you, they create a suspension of disbelief so that you believe you are there. No longer are you watching a movie about D-Day, but you are on Omaha Beach struggling to survive and get off that beach alive. You must use your wits or your manual dexterity or a combination of the two to solve game challenges you are faced. Games are also incredibly deep. People are playing them following all kinds of time warps. They become so involved that hours go by. It's not uncommon for people to play 10 or 20 hours or more in a single game and sometimes in a single sitting. Good games engage you on multiple levels—both physically, intellectually, strongly emotionally and psychologically. There's a great diversity of games and a wide range of subject matters.

Some are rightly chastised for their meaningless violence, but there are many, many other types of games. They offer creative challenges like building and managing a city or designing an amusement park.

I have only scratched the surface here in describing what games are all about and the power of them. I haven't even mentioned that some games play out online where hundreds if not thousands of game players congregate to socialize and solve game problems together and to progress whether it's to slay a dragon or defeat the evil sorcerer. So why should we care about this phenomenon? Because I believe they're one of the keys to galvanizing public support for the space program as well as inspirational for inspiring our youth. They're a way of making the future space program here and now believable, alive and real. And through their own creative and personal achievement in these games, they can forge a bond with space exploration, and the women and men who make it so.

Imagine, if you will, a game that allowed you to build your own spacecraft, to explore the solar system. Imagine an Erector set where you could build and test rocket boosters, hundreds if not thousands of different ways, and test them to see if they make it into space or not.

Imagine again a game that allowed you to research advances in Earth sciences, human biology and even interplanetary propulsion technologies or to establish space station planetary bases as your technology allowed. The possibilities are really endless. But they can all involve facing real-life decisions and challenges with the economic and human safety tradeoffs that are real-life issues.

I am, and I hope to be bringing you games like these to a reality, ultimately showing people the power of possibilities in space exploration so that they can answer for themselves the perennial question of "Why space?"

How can this Commission help? Well, as part of outlining your meta-strategy or strategies for fulfilling President Bush's mandate, utilize entertainment and particularly games as a primary means for promoting space exploration. Much attention, rightly so, is devoted to marshalling the resources to expand our educational infrastructure so we have skilled people to realize this great endeavor.

I would not sacrifice any of these efforts. But I do believe games greatly add to the educational equation as they teach in a sly, fun way, by creating a challenging situation and forcing players to solve that through their own ingenuity, and by that very process, they learn.

In summary, in the near term, I think we have to be inspiring our entire nation towards space through active promotion, and the most powerful way to do that is through entertainment, and games can provide a unique and personal way of getting people inspired. So, it's really time to get in the game.

Pete Aldridge

Thank you very much. I look forward to playing some of those games. I can't wait. Let me ask both of you one of the things that we have heard during some of the hearings in prior cities is that in the past NASA has a restriction on their ability to market or advertise. That may be one of the problems that we are facing. Could we—would you mind commenting? Are you aware of this restriction, and would you mind commenting about it?

John Bernardoni

Thanks, Larry. Yeah, we ran into it right off the bat. I mean, like seven or eight years ago. You know, I worked at the Johnson Space Center more because I'm in Austin and they're in Houston and also because of what they do. And this whole subject came up very early on. I kept saying, "Well, you know, with all due respect, I know this is not your core competency, communicating, and marketing and promoting, but you're good at engineering and science and math and astrophysics, and you're doing what you should be doing, and let other people that are specialists in the business do it, and but—I'm curious to know why it's so flat and why it's so dry." And that's when I was told that basically there's some kind of a statute—I have never seen it—that says that NASA cannot promote itself, cannot advertise, cannot market, cannot recruit, and I'm glad you brought that up, because I missed it, and I could not find my third piece of paper. I think that that needs to be challenged. I'd like to know where that came from, frankly. I'd like to know where that came from and when it came, because apparently it's been around for a long time. I do think that NASA has as much right to recruit as the Department of Defense. What's the difference? I mean, is a soldier any more important than an astrophysicist? Not to me. So, yes, they do say there's a problem. I have never seen it. I think it should be repealed or changed greatly. And given some—take the handcuffs off. They should not be in the advertising business because they're not good at it, but they should be able to recruit and do some things that actually inspire the public beyond the website and also the miracle of the little rovers on Mars which are the only thing captivating the audience in space right now. Larry?

Lawrence Holland

Well, I'll be more blunt and less eloquent. It sounds very silly not to be able to promote the space program. It is certainly filled with real-life gizmos and sexy technology and great endeavors which our youth and our current generation would love to hear about and see. And when I see an advertisement on television about the Marines or the U.S. Army, you know, why aren't I seeing something about the space program?

Pete Aldridge

This commissioner would question the ability to sustain a program without some degree of promotion. This would be very hard.

Les?

Les Lyles

Yes, Mr. Bernardoni, sustainment is obviously a big, big factor in all this—sustaining the vision. We have talked about it, you have talked about it, and Mr. Holland talked about it. It's all very important. To turn the tables, how do you sustain the interests of the media, the entertainment industry, in helping us to carry this vision forward? And I'm coming from this from the experience of the last four years where the Air Force tried mightily, with some success, but tried mightily working with the entertainment industry in Chicago and New York and Hollywood to get them to help us to carry our message, in TV shows, in movies, in other activities, and what it really came down to were the Nielsen ratings and how important it was to get something that passes the sweeps in May.

How do you sustain the interest of the entertainment and media people to want to work this, and continue to do this when it may not be something that is the number one—it's not the *Friends*-type TV show or something.

John Bernardoni

Well, that's a good question, and I think that almost like the initiative, it's going to have to be rolled out little by little by little, and in order to sustain it. There's no reason to go and do a big spike and then have it fall off and in three months everybody forgets about it. And people forget very quickly.

This is something that I've struggled with and I really haven't gotten my thoughts fully formed on this, but I do think that—I think that the media right now is negative towards NASA, to be honest with you. Not toward J.P.L., the Jet Propulsion Laboratory, I think that they're the darlings of the industry, but I think the media is negative toward NASA. I think they take pot shots. That's the first problem that's going to have to be dealt with.

I'm not sure what the answer is to that except to get them together and say, "Okay, what's the problem? What's bugging you?" You know? Because obviously the Commission and NASA and the government have their hearts in the right place and are wanting to do the right thing for mankind and our children to get out there and do what our destiny is about.

So I think that you have got to have—it's like a marketing campaign, really. I mean, I'm a little surprised that in the defense arena that you were talking about with entertainment that you probably didn't get better ratings, because people do seem to be drawn—at least to my knowledge, people are drawn to a lot of games that—I know my son is, he is 15 and a half and he likes to smoke

people all over the place with various guns and things on computer games and video games. And he also plays the city-building games, thank God. But I'm surprised that you didn't fare better.

I think that we're going to have to hit a real chord in people's hearts that we have not hit yet as we roll out the idea of a campaign to back this initiative.

Ray is right. There is an aesthetic. Yes, it doesn't play out in Congress, maybe. But we have got to hit a chord in people's hearts that was hit with Apollo. That's where the sustainability starts. It's almost like a spiritual kind of a thing, if you will.

Secondarily, NASA and the aerospace industry have got to be providing us grist for the mill. They have got to have things coming out of the chute every so often. And when they come out of the chute, we need to have the right person, the right spokesperson, talking about it with the attending expert in that particular field so that we have got some meat on the bone coming down the pipeline.

You know, this is just like a distribution company in film. If you have one film and then there's no one else coming behind it, they won't pay you. Theaters won't pay you. And this is the same thing. It's got to be coming in the pipeline all the time.

And then, of course, thirdly, you know, I think that—I'm personally a little nervous about the 10, 15, 20 years issue. I'm not sure that anything is sustainable that long, other than religion. And so that I think we're going to have to be somewhat reasonable and realistic about what can be done. It may be something that ebbs and flows as we hit certain milestones.

But I will tell you this: the only thing that's going to really capture the world's imagination is sending men to Mars or finding life on another planet. It's going to take the big whopper to really get it to happen. The other things, I know, are necessary.

I'm not an aerospace engineer. I believe it when they say they need to go back to the Moon. I understand finishing the I.S.S. [International Space Station].

But it's going to need to be a campaign—well orchestrated, it cannot just be a hell's-a-popping that's thrown out there and the industry just goes wild on what it's going to do. Somebody's going to have to orchestrate what happens when. I think that it's possible to have good stories in the media over time, over a long period of time with realism, and then as we hit some good milestones that get people's attention and where something major happens or they're about to roll out a model of the next spacecraft or what have you, and when the Shuttles are going up, obviously that's going to get a lot of attention, I think it's possible, but I think it's only possible in a very realistic fashion with those occasional blips as we build toward the place we all want to go.

Les Lyles

Related to the Chairman's former question, perhaps NASA or the space entities need a media office in Chicago, in New York, in Hollywood the way DoD does to continuously get that message out? Maybe that might help.

John Bernardoni

The structure of it, I don't know yet, to be honest with you. The aerospace industry has a coalition that they formed to basically do something like what we are talking about, which is to back the initiative and get people excited. They have already raised a million and a quarter to do that. And they are very interested in me, and I know some of them, and ...

Pete Aldridge

Paul.

Paul Spudis

Yeah. Mr. Holland it's very interesting in your claim that games excite people. I think they do excite people. But I want to pick up on a point that Mr. Bernardoni just made, and that is this idea that you have a long program. It's long because the society is not willing to invest resources at more than a certain level. There's a certain level they'll tolerate and that's what paces the program. Is it not true that videogames or computer games in general play to our sense of instant gratification, that you have action? You finish a project quickly. You can start building something and you can finish it within the course of a couple of hours, whereas reality is different. In a videogame you can warp off to Saturn in 30 minutes, whereas in actual fact, it may take you eight years to get there and it may involve a complex sequence of events. How do you bridge that disconnect between reality and imaginative fiction where anything is possible, whereas in reality you are dealing with numerous real-world constraints?

Lawrence Holland

Well, that's a very interesting and actually deep question. Certainly, games by their very nature, like other media, try to cut out the boring parts. So they involve all kinds of, you know, time acceleration and ways to collapse time so that you don't have to sit and wait, you know—the six months it would take you to get to Mars. Let's hit the button so we can get there in a few—two minutes.

I think—I consider that a hugely positive thing since that what the goal of the game and many types of games is not so much to mimic reality, but to involve you in the complex and interesting choices that you have to make to overcome challenges.

And what games can do is it's they're not just a single path type of game. If you may think of an action game, you may think of, well, there's only one way to reach the end and then you're done. That could be a very short but many types of games—a term for it in our industry called God-games or life simulation games. I have referred to one that I've heard of called SimCity, which is about designing and building a city. And the wonderful thing about those types of games is they offer literally unlimited game play in terms of the way you can approach the game and play it, so

that one—one time you may want to play it one way and another completely different in terms of just how you want to try to solve the problem of building a city or multiple cities.

So, if you build a game based on the space program, a God-game would be a wonderful way to offer people that same sort of unlimited possibilities. So that, even though time is being accelerated, they're actually able to play these games many different ways. And when people play games, as I referred to in my presentation, they often play games, ones that they really enjoy, they play them for 50, 100 hours, and some of them even longer. Thousands of hours. Some of them multiplayer online games you literally play for—I mean, people play them for thousands of hours. And so, there's not really an end. There may be an interim end, but you can go back and play it a different way. So, I—I think that in our industry, we think a lot about replayability because we don't want the games to be just a two-hour experience.

Pete Aldridge

Bob.

Robert Walker

I tend to agree with your message, Mr. Bernardoni, that the single greatest achievement of the 20th century will turn out to be the landing on the Moon. It's certainly the only thing that 1,000 years from now that historians will be writing about from the 20th century. The question is, though, for you—and the reason why I think we have you all here—is the problem has been that this has been promoted by scientists and engineers who have no idea how to promote it. And it seems to me that if you are going to get sustainability in these programs, that ultimately, you have to have an individual connection with the American people. Again, I would disagree with you that it's only religion that survives over long periods of time. We have had several government programs that have survived over long periods of time, Social Security, H.U.D. Section 8. You know, there are—there are a number—there are a number of programs, and so on, that are not even in my mind even particularly meritorious that survive for a long time, but the fact is that the reason why they're there is either because they have a constituency that insists that they stay there, or because there is a large block of Americans who personally connect with what the government is doing in that regard or what's happening in society in that regard.

My question to you is, How does entertainment allow us to get that connection? Because if we rely simply on the fact that we are doing good things, and that there's a great opportunity here, we won't get there. Somehow we have got to establish that connection. And I think it's a belief of at least some of us here that entertainment may give us the opportunity to establish that connection that then will allow us to have the sustainability.

John Bernardoni

Well, you're right. People only line up behind a program, whatever it is, for a long period of time for two reasons: They either get money or there's something compelling about it that keeps them attached.

And I can tell you this, with complete candor, that the entire world is fixated on entertainment. It is a huge part of people's lives. And we have spent the last 20 years, the technology industry has, in developing a new pipeline to deliver content. We have a 50-inch-wide pipe with a trickle going through it at this moment. And so, therefore, it behooves the people in the entertainment industry to do more to create compelling entertainment that is intelligent and—I hope that's not an oxymoron—and provocative. But I would submit you to that the reason that the people will stay with this, if we can get through 30 years of relationships, a sense of almost like we had in World War II, that this is a national, patriotic duty and something that people should be honored to be a part of and want to be a part of. Then you will see, I think, a heightened involvement by the record industry, by the music industry, by the film industry, by the television industry and by specials, by the DVD people and all of the permutations where people get their entertainment—you will start to see a rise in the subject matter coming higher and higher, you know, above the fray of whatever other kinds of things they have been leaning on and I do believe that, again, people are connected to entertainment at the hip.

There's not a day that goes by that somebody is not paying—watching television, playing games, playing computer games, watching DVD's, going to the movies, going to Broadway and going to—people are fixated with entertainment. It's an out. It's an escape, which is why we got through the Depression. For a lot of people, you paid a dime to go to a movie. Even when they didn't have a dime, they needed to escape. And so you've got the connection. You've got the visceral kind of a connection you are talking about to the world of entertainment.

Now the question is “Can we marshal that world?” I really am not trying to overstate it. I mean literally marshal that world like we marshaled this country in World War II, during the bond drives, to say, “This is a biggy, this means something and here's why it means something.” And if we do a good job of answering the old three nagging questions—“Why did we do it?” “What did we get?” and “Why should we keep doing it?”—which frankly, I don't think the public has ever heard the answers to those questions, and if they don't hear the answers, this is not going to go forward, because we've got to sell the entertainment industry as well. We've got to have something to sell to them and whatever comes in the pipeline's got to back us up.

Pete Aldridge

Maria.

Maria T. Zuber

Okay. Video games are overwhelmingly played by boys. And action films are overwhelmingly watched by teenage boys. What is the entertainment doing to get girls more interested to the extent that the entertainment industry can help fuel this exploration vision?

Lawrence Holland

Well, there are computer games and videogames. Videogames are the—you know, the P.S.-2, X-box, games that you play in front of your TV with your controller. And you are quite right, that those are mostly played by boys. The types of games are highly action oriented, you know, running around, shooting things, but computer games, there's a lot greater diversity. They're played on computers sitting in front of monitors and using an input device like a mouse. Many types of games on—that are on computers are—appeal highly to women. Probably the most popular in the last several years was a series of games, unusually popular, by Electronic Arts, called the Sims. And that game is about taking care of people. About relationships. So, that component strongly appealed to women about 50-50, I believe—not exactly sure.

But I talked a little earlier about God-games. These games are about creating and building things. And those games traditionally also appealed highly to women. So that I think that already we're doing it, but we can certainly do more along those lines.

Pete Aldridge

Neil.

Neil Tyson

I think I might be missing something, and I want to have you help me clarify this.

Lawrence Holland

Sure.

Neil Tyson

If I understand correctly, you are both appealing to have more go on in the entertainment industry of what you already do, yet when I look at the—what has happened in these two fields, television, movies, as well as the game community, I already see a rather rich record of space-based games, space-based films.

Mr. Bernardoni, you commented that the next generation doesn't appreciate the legacies of the 1960's, yet *Apollo 13* as a film was a very successful production, as was *From Earth to the Moon* on HBO. We can't reason away that fact. And not a few years ago, two films within six months came out that dealt with asteroid threats. A year later, two films about missions to Mars. So, I don't see a dearth of this; I see it there at a rather healthy rate.

Are you saying that's not enough? Let me ask you—is there space—space! [laughing]—is there room for more of this in spite of the fact that there's quite—what I see as a healthy flux of it already happening these years?

John Bernardoni

Well, you're right. Truly, *Apollo 13* and *From the Earth to the Moon* were brilliantly done.

And I don't know what the demographics of who watched them was, but I would bet you it's probably older than younger. I would like to think that kids were watching them and *Apollo 13* in particular, I'm sure got a very broad audience. It did terrifically well. Candidly, when I'm talking about the entertainment industry from my point of view, I'm covering the whole gamut, television, film, radio, corporate advertising, print, the journalistic news, DVD's. I'm talking about the length and breadth of the whole business, not just film.

Yes, Hollywood has always been pretty good about rolling out, you know science fiction. Some of it stinks. The fact that the first two Mars movies came out, I was embarrassed. I thought, "My God, the first time out of the box and we're going to sit here and back up where everybody wants to go." They were rotten. I'm sorry, they were rotten. I'm sorry to the producers. It happens.

But we're talking about a campaign to—that's sustainable, that would exist in the form of public service announcements on radio, that would be designed for different audiences, something for five-year-olds, something for ten-year-olds, something for 20-year-olds, something for 40-year-olds. I mean, it wouldn't be just one P.S.A. They would all be done with different messages in their different ways because we're talking to maybe eight different audiences in reality.

So, yes, I do think that the industry can do more, but the film industry has done good work and there have been some good things that have come out.

I will tell you that one of my friends in the aerospace industry, in public affairs, one time told me that Hollywood was his worst enemy, and when he said that, I kind of went, "God!" But I get it. Because what they can do in the Industrial Light and Magic and George Lucas's place makes the Shuttle pale by comparison. There's no way that the reality of the true space program can match what can be done in a special effects lab. And that is a problem. Just like the gentleman earlier asking about the instant-gratification nature of our society. It's a problem. People want it now. They don't want to wait.

But, yes, I do think we can do more, and I'm talking about something very expansive that I think crosses across the entire media, and I believe that they can be brought to a point where they can get their mind right about what we're trying to do and what you are trying to do, as long as they believe

it's going to be delivered upon. I'm going to keep saying that: the worst thing that you can do in marketing is to out-hype a product. It's death. I don't know when is the right time for this to get started; obviously, this kind of thing takes planning like at least a year in advance of when you want it to hit the airwaves and what have you. But I do think that we can do more. Hollywood is going to do its thing, but again, if they see that this—that this subject matter is rising on the radar scope, of children in particular—and children, what have you, and young people and teen-agers who are the bulk of entertainment buyers, they're going to start addressing it more. Hopefully, it will be some reality-based movies, and not all aliens that eat you and things.

Pete Aldridge

Right.

Mr. Bernardoni and Mr. Holland, we appreciate it. We have run out of time. You have had a very significant input to our deliberation and we appreciate your time and for coming here today. Thank you very much.

Lawrence Holland

You're welcome.

Pete Aldridge

We're going to call the next panel up. It will take just a couple minutes to change the order.

Let's go ahead and get started. This is our education panel. The impact of education in youth is one of the four major themes this Commission is addressing as we explore the possibilities for making the new space vision a reality. I can think of no one more qualified to talk about gauging the level of space interest among young people than educator-astronaut Barbara Morgan. Ms. Morgan started out as a teacher, and after a dedicated career working with elementary school students, was selected by NASA as the first educator-astronaut. She is currently assigned to STS1-18, an assembly mission to the International Space Station scheduled in the year 2006.

We're likewise honored to have with us the executive director of the National Science Teachers Association, the largest organization in the world committed to promoting excellence and innovation in science teaching. Dr. Gerald Wheeler, Gerry, has a passion to discover how students learn. In the light of our national need to strengthen science curricula, we are looking forward to hearing what he has to say.

The other member of our Education Panel is James McMurtray, Executive Director of the National Alliance of State Science and Mathematic Coalitions, a former planetarium director and teacher of astronomy. I know Neil will have a few questions for him. He has been actively involved in reform efforts in science education over three decades.

Our last member is Dominic Farrar. He resides in Covina, California. He has a bachelor's and a master's degree in California. He is a teacher and athletic director at Royal Oak Intermediate since 1995 and co-founder of the program Odyssey, a recipient of Who's Who Among American Teachers Award and Los Angeles County Excellence in Teaching Award and ... Science.

I hope that each of us will educate us about how the best way the youth of our nation will make space science education more accessible. Barbara, I guess we'll start with you. Welcome.

Barbara Morgan

Thank you very much, Mr. Chairman and members of the Commission. Thank you very much for inviting me to testify today. I have enjoyed and appreciated the previous presentations to the Commission concerning the Moon-Mars initiative's connection to education. Those presentations offered a lot and I look forward to today's as well.

This bold new vision of exploration and discovery is the best thing to happen to education in a long, long time. It is marvelous in many, many ways. But what I'd like to do here today is to emphasize just one thing, the initiative's connection with America's classroom teachers. If the Moon-Mars initiative can engage classroom teachers, then it will reach and motivate America's students. If we are going back to the Moon and on to Mars, and beyond, then we must see teachers as our full partners. America teaches its children best through its teachers. During a school year, a classroom teacher might well spend more time with the child than the child's own parents do. So much depends on how the teacher chooses to teach and on how enthusiastic the teacher is about a subject.

A state can dictate curriculum, a test can influence what content will be taught, and even how it will be taught. Distance learning, educational software and the Internet can all bring subjects to a youngster virtually. But none of these can match the lifelong effects of a good classroom teacher who connects with students and who is teaching a subject for which he or she has a real passion.

You are all well educated: you have had many teachers. And those teachers who taught you best were the ones who communicated to you their passions for their subjects. They also gave you the skills you needed to pursue your own passions. You are on this Commission because of your own abilities to learn, which were fostered by your favorite teachers.

The Moon-Mars initiative offers us a tremendous opportunity to inspire and engage classroom teachers if we make sure from the very beginning that teachers see themselves as fully involved partners in this grand endeavor. Fortunately, the Moon-Mars initiative relates to teachers and to teaching wonderfully.

First, there is the adventure. Teachers love to give students adventures. Adventure grabs students' imaginations, especially the students who resist the more academic learning for learning's sake.

And now here we are, going back to the Moon and on to Mars. What could be more adventurous than that? It is bold, it is daring, it is physical. I'd like to repeat that. It is physical. With Moon-Mars, there will be real people going to real places where no other people have gone before.

Who knows what will happen, and who knows what they will find? This is a story to be told. This is history being made. This is history now, not in the past.

Consider how interested people are right now about Lewis and Clark. Well, that expedition pales in comparison to exploring the Moon and Mars. This undertaking is huge. It will attract many more students to science and engineering; further, those students who are not really engaged in school will be captivated by the adventure of exploration.

We often talk about the education pipeline providing America with future engineers and scientists, but we should also remember that we need the pipeline to produce an educated and involved citizenry, or else for whom will the engineers and scientists be working?

Still further, while we worry about the graying of NASA, let's not forget the challenge we have of getting people to go into the teaching profession. We are facing a shortage of teachers. And involving teachers as partners in this big adventure will definitely attract more good people into the profession.

A worthwhile adventure like the Moon and Mars also gives teachers a good perspective from which to teach risk. Teachers know all about risk. Some of our students are risking their futures every day, whether through risky behaviors or by missing opportunities to succeed. Many students are afraid to risk stating their opinions in class, or even to ask questions. But when children see astronauts rationally taking great risks—great risks—to explore and learn in obviously exciting ways, then the children can have something to compare their own life risks to, and they can take their own bold steps.

After adventure and risk, there is example, and teachers know that kids learn by example. They learn by watching what we adults do. Kids also pay attention to what adults decline to do. Going to the Moon and to Mars is a tremendous undertaking involving many things that we don't know how to do yet. But we know that we can learn how to do them, and students will watch us learn. They will learn that learning itself is valuable, and that we as a nation will always explore. The thrill of adventure and the lessons of example—these are enormous values to education. And I haven't even mentioned the cornucopia of subject knowledge our discoveries will bring to our classrooms.

I'm ready to discuss with you any questions you might have, but I do want to end here by repeating my main point, that America teaches its children best through their teachers. Make America's teachers our partners, and we'll get their students as well.

Thank you.

Pete Aldridge

Barbara. Dr. Wheeler.

Gerry Wheeler

Thank you very much.

We didn't compare notes ahead of time. The—and I'm going to use a PowerPoint presentation to speed me along rather than read from my notes.

I'm going to suggest six recommendations, eventually—I will start off with some other things—but then six recommendations that I think you ought to consider, the Commission ought to consider in terms of the vision that you are going to be presenting to the President.

First, the ... blatant advertisement that you already started to say. Go to the next slide.

I thought I was going to be the trigger man and I'm not. I have to say next.

As you mentioned, the largest science teachers group in the world, and we have science teachers, university professors, scientists, and even a couple astronauts that belong to our membership. And we have—next, please—through our journals, conventions, news releases, and Internet connection—incidentally, as a sidebar, I would be interested to hear the entertainment people talk about the Internet, too—our Internet connection: we directly reach over a quarter of a million teachers each month. We're in the face of science teachers.

A lot of times we use the phrase “teacher of science.” Because as Barbara would agree, a lot of elementary teachers don't see themselves as science teachers, but we're going to need to have them see themselves as teachers of science, so we have to worry about that. Next, please.

Our SciLinks initiative, which connects textbook pages, print pages, and NASA module pages to the Web actively, gets about ten million hits per month now. It's a very interesting interaction between the private sector (and in fact NASA helped get that off the ground), the public sector and a professional society. Next, please.

We believe that this education reform is crucial to the Moon, Mars and Beyond initiative and it's a perfect overlap. Next, please.

And that we need, then, and reform depends on, we think, three strategic issues that you will have to consider. Next.

That was a circle when I left D.C., I don't know why it's turned into a little bit more of an ellipse. We need to engage many, many more teachers of science. As I mentioned, NSTA is the biggest science teachers' group in the world. But our dirty little secret is there are 2.1 million teachers of science in this country and our membership pales compared to that number. My message later is going to talk about scale as you create a vision. We need to enhance professional development. We know a lot more about professional development now than we did 10 years ago. We need to move beyond the make-and-take and move to a more serious, coherent professional development. That has to be part of the vision. Next, please.

And finally, we need to increase the support for science, and I mean that beyond financial support. I mean the Lions Club, Rotary Club, the school board. At the local level, we need to have people know that science, technology, engineering and mathematics is crucial to their children. In fact, one of my bumper stickers is “Don't let your bias hold your child back.” Because so often the parents say, “Well, I wasn't very good at math, I wasn't very good at science.” The fact is their child needs to have that. Next, please.

I like Venn diagrams. So if you hit the middle, then you really hit home. And I think that the President's initiative in fact can hit the middle. It can engage many more teachers of science, it can change professional development and it can increase the support. Next, please.

Where are we now? Sadly, we have a long ways to go.

The TIMMS—and I'll do this very fast cause I don't want to burden us with a lot of bad news—but the TIMMS results says 8th graders are average and 12th graders are poor. I'm a nuclear physicist, and the rest of you that are physicists or had that in your background would probably be shocked that about one in five high school seniors who took physics could give one sentence explaining what the Doppler effect is. According to the NAEP results, in '96, less than one-third of U.S. students in grades 4, 8, and 12 performed above proficiency. I'm also a member of the National Science Committee for NAEP. Proficiency is not a high standard. Next, please.

In the 2000 NAEP, only 3% of black students achieved proficiency or above compared to 23% of white students, so we have a huge gap to deal with. Next, please.

And fewer than half of all the 2003 high school graduates took three or more years of science. Next.

So we have six recommendations for you to consider.

First, establish STEM [science, technology, engineering and mathematics] education as the core component of the President's vision for space exploration. Echoing what Barbara said and feeling the tension and challenge that you mentioned in the earlier panel, in order for this 40-year-type project to work, it's going to have to have STEM education as one of its core components. Next, please.

Develop a unifying vision to guide all education contributions for the exploration activities. We have many, many stakeholders from private sector to NASA to public teachers to the National Science Teachers Association all doing our own thing. The vision must have a unifying vision—excuse me, the statement must have a unifying vision. Next, please.

We significantly must increase the number of teachers and university faculty engaged in high-quality professional development through space exploration. We have an opportunity with this initiative, you have an opportunity with this initiative, to change the character, if you will, and the partnership, between higher ed and public school teachers. Next, please.

Enhance the content knowledge of educators through their intellectual engagement. The biggest hole in the dike, to be frank, is teacher content knowledge. We need to address the fact that you can't teach what you don't know. Next, please.

Create a compelling national understanding for the importance of STEM using the President's space vision. And you've already talked about it, and you already see that challenge, and I can talk for hours about my own opinion, but we need to have a sustained attitude, if you will, culture, if you will, that talks about the importance of STEM, and I think the President's space vision can do it.

And finally, and a little bit related to what Barbara said, explicitly include the science teaching workforce in all workforce considerations and discussions. I have been to literally hundreds of meetings in my nine years in D.C. where it's NASA or it's Intel or it's H.P.—talking about a very serious need: their need for the scientific engineering workforce. But very seldom does anybody acknowledge that we also need the science teachers, and right now industry, quite frankly, is so attractive to any young person that's oriented in that direction that if we're not careful we're going to eat our seed corn. We're not going to have the teachers that are going to produce the next set, and the next set meaning only five years down the pike, we're going to eat our seed corn if we don't explicitly mention science teachers every time we talk about the problems and challenges of the workforce.

I think that's it. If my paper made the same failures that my slide presentation did, and you probably don't have it, I will have to get it to you, there is a much longer presentation that should be in your briefing book.

Pete Aldridge

Dr. Wheeler, thank you very much. Mr. McMurtray.

Jim McMurtray

I thank the Chairman and the members of the President's Commission on the Moon, Mars and Beyond for the honor and opportunity to present this testimony. I'm James McMurtray, Executive Director of the National Alliance of State Science and Mathematics Coalitions: NASSMC is 38 state coalitions of business, education and public policy. We have an association with NASA through the Linking Leaders Program, which aligns, or works to align, NASA and state resources with state efforts to improve mathematics and science education.

A scientifically illiterate populace is an economic and social liability that no nation can afford. Full citizenship requires literacy, and scientific literacy must be part of that. To go back to the Moon and on to Mars will require a national resolve that cannot be borne entirely by a small group of science professionals. If science and mathematics are only for the few, then there is no shared national ownership of these missions of discovery and exploration, and unless they are supported by a literate electorate able to appreciate their value they will not happen.

Educating tomorrow's astronauts, then, argues for a bold enterprise. Our present system of teaching science to our citizens does not work for everybody because it is not designed to. The system reserves advanced science and mathematics for a small subset of the population. To bring relevant science to all students will require the most profound change in our thinking. It will require a different system.

There is a very long pipeline to a career in science and it narrows very quickly. Only a handful of students receive advanced instruction in mathematics and science. Those who do not continue in this pipeline are not diverted to some other path toward science literacy; they are simply removed.

Science and mathematics are no longer part of their education. They have been sorted out. Since they will not become scientists or engineers, they will have no more access to science beyond the satisfaction of their own curiosity.

Science education cannot be structured so that required basic science and mathematics instruction is limited to the first few courses and a long sequence that is designed to prepare scientists and engineers. If that is all our students get it will not be merely enough. It will be a foundation on which nothing is built.

Nearly three decades ago, the National Science Foundation and the National Research Council recommended fundamental systemic reform of American education. They defined this as fundamental, comprehensive and coordinated change in the policy, financing, governance, management, content and conduct of the system. Efforts were made but their impact on the system is hard to detect. Systemic reform has not happened.

Since its beginnings in the late 50's, NASA has designed and undertaken its missions and its programs through a technique involving the development of a critical path. Critical path planning does not begin by examining where we are and finding ways to make small incremental improvements, it begins with the desired outcome and some essential questions:

What are we trying to do?

What critical developments must happen along the way?

How will we know if we have succeeded?

Critical path is developed by thinking backward from the goal and designing a system that will produce exactly that result.

I propose that this strategy be applied to the design and development of a different education system. I believe this can be done with existing infrastructure and that it can be initiated while the current system continues to function. We need not dismantle what we already have, but we must immediately begin to design a replacement.

Simply improving the present system will serve only to make it do more efficiently what it already does. Systems are perfectly designed and operated to produce the results they get. To change a complex system it is necessary to change many things at once. Leave key elements unadjusted and the system will repair itself to its former condition.

Higher education is part of this system, and therefore, inextricably part of the problem. Our universities and colleges of education have to change.

But to a system, change is indistinguishable from damage. If we really did change lots of things in the system at once, if we changed many, many things in the system at once, that might cause the system to fail altogether. It would do irreparable damage. And what it might be replaced with is whatever could form in that vacuum.

Natural selection works, but it's not guaranteed that it will work for us. So let's not do that. Leaving this to chance is not in our interest.

The environment of all systems is other systems. A new design can be implemented to operate in tandem with the present system. Educators working alone cannot design a replacement system. This will require broad collaboration involving America's scientific and social institutions. This system will exist alongside the older system until it replaces it, and it will replace it when it shows that it works better. It will take all the creativity and wisdom that we can marshal, but it will be done. We face a teacher shortage, particularly in mathematics and science.

Our schools continue to fall short of our expectations. Our assessments define success as nonfailure. Females and minorities are underrepresented in science and mathematics courses. Perhaps this is because we have confined our thinking to a system in which it is held as self-evident that learning can only happen in groups, that such groups must necessarily be in a classroom, that classrooms must contain no more than a given number of students, that there must be 12 grades, and that each classroom must be presided over by a teacher trained in the very system we are trying to alter.

I am convinced that, within the present system, these problems have no solution. In a different kind of system, though, they might not exist at all.

What I propose is not a new experiment but a new design. We do not know what it will look like, but we know it will be very different because it will be designed to produce a different result. The system we have now was not designed. It just evolved.

Americans are capable of doing this. There are people in the country ready to take on this task. While we educate tomorrow's astronauts, we must also educate for a society, a culture and an economy in which the work of astronauts has value to the larger population.

We have done difficult things before. The two Voyager spacecraft gave us pictures of the outer planets, robots have shown us the surface of Mars, we've launched into space a telescope the size of a school bus and we repaired it in orbit. We can also build a system that shares our scientific legacy with our children and leaves none of them behind. They will not all become scientists, mathematicians, engineers or astronauts, but they can share the journey back to the Moon, to Mars, and beyond if it is also their journey.

Thank you very much.

Pete Aldridge

Thank you. Mr. Farrar.

Dominic Farrar

Good afternoon. On behalf of myself and my colleague Mr. Roger Lehigh, who is out in the audience, we're both cocreators of Odyssey, the program in Covina, Southern California, in the east San Gabriel Valley.

I guess what I represent is the advocacy of young people. I'm the one in the trenches. I currently have 140 kids that I have had since 6th grade and we're in 8th grade this year, so bear with me. Basically what I'm going to share with you today is maybe enlighten you on our experiment, so to speak, where we right now currently are in the process of middle school reform, and maybe some of these innovative ideas can kind of help impact or make a difference towards the future of our young people.

As American society continues to change and emerge into an increasingly accountable, challenging, competitive and demanding organizational climate, the human condition seems to deteriorate further from daily interpersonal connections necessary for healthy, productive lives with others.

It appears that education is the one major institution in the best position to counter the trend towards impersonal, bureaucratic campaigns. If our schools are to obtain the outcomes we desire, even as they grow in size, they must be reorganized in the forms that allow long-term, high-quality human relationships to thrive.

Currently, the design of many middle schools reflects the problem rather than the potential solution. For example, standardized testing, content standards, and teacher accountability has dictated the direction of the educational environment in many of today's classrooms. The answer for some teachers is become content experts and teach to a test. Often the student's perspective of what provides for the best learning environment is disregarded or neglected.

The vision and passion of Odyssey has been a turning point in the progression of our district and districts throughout our valley. At the beginning of our journey our title was appropriately labeled a pilot program as it was experimental in nature.

Through our own experience in Odyssey, results suggest that middle schools should consider alternative organizational structures. We would maintain a framework that focuses on a commitment to the whole child, and the key component to consider would be built around the organization and the management of time. The philosophy of our Odyssey program is drawn from the ideas contained in ideas in the epic poem the Odyssey, where Homer combined history and mythology to recount the trials and tribulations of a hero's journey to realize a dream. In order for Odysseus to succeed, he endured the challenges of finding his true sense of self, he recognized his strengths and weaknesses, addressed his thoughts and feelings, endured temptation and utilized his virtues to achieve his goal. May I have the first slide, please? As one of the creators of the Odyssey program, I recognize that the child also participates in a similar journey as they transition from childhood into adolescence. Odyssey's goal is to help each student develop a positive academic and social identity. Next slide, please.

The Odyssey program aspires to educate the whole child. In addition to the required grade-level English, math, science and social studies curriculum, we incorporated wide experiences, we have hands-on projects and character education known as teaching and practice of virtues.

One of our primary tasks is for each young adolescent to develop a positive perception of him or herself. Many of them are just beginning to search for those roles and choices that will bring definition to their turbulent, helter-skelter world. They're exploring and discovering answers by

identifying common traits among peers and focusing on their unique characteristics. Our goal is for them to emerge from the middle school with a healthy sense of self.

Odyssey provides positive moral teaching and training and guidance for young adolescents who are just beginning to develop a sense of identity. The foundation for our program centers on the introduction of the practice of virtues. In the short term, the function of virtues is to serve as classroom management in our program. Long term, the virtues are an intrinsic gift which children can empower within themselves and then share with others. The children continue to participate in ethical and moral excellence, which they then can apply to every aspect of their life. Next slide, please.

Another essential program component is looping. The practice of keeping the teacher and the students together for three years allows for meaningful relationships of adults and peers to develop during a critical time in young adolescent development. Looping also allows teachers to identify students' academic strengths and weaknesses and make any necessary accommodations or modifications to their scholastic progress.

Additionally, flexible scheduling is also a key factor for us. We utilize three primary types of time management within our program. We can do directed teaching as part of the traditional bell schedule within our program, we can do direct teaching, too, where we engage in block scheduling as necessary, but this allows for more depth and time spent on particular topics.

Blocking is one of our preferred methods of scheduling because it also permits teachers to team in an interdisciplinary classroom setting. Group scheduling and the availability to house the entire program student population in one location provides us with an environment conducive to applied learning activities and collaborative activities. Time is fundamental in order for successful implementation of our program. These variables are key factors to maximize our program's potential.

One of the most prominent educational philosophies we have adopted in Odyssey is the interdisciplinary team teaching. Now, an interdisciplinary teaching team usually involves two or more teachers who have specialized in different subject matter. This approach is most commonly applied with block scheduling. The primary objective is to draw content from two or more subjects and focus the material on a specific topic or theme. It also provides us greater flexibility in planning and implementing increased opportunities for tutoring and mentoring with the same students for a longer period of time.

Teachers and students have closer relationships, and as a result the students embrace the academic goals of the program. We work effectively with students who possess a wide range of learning abilities. Students also experience a greater sense of personal identity and enhanced ability to connect concepts across subject matter areas and increased opportunities to engage in cooperative learning activities.

We discovered that the interdisciplinary team teaching provides both the students and teachers benefits from a collaborative effort in planning, teaching, and assessing student learning. The relationships between colleagues are very positive and productive because everyone involved wants to contribute and participate in the development and progress of student mastery.

With a program of this magnitude, it is paramount that these quintessential components are implemented as a framework. At the core, these details are imperative in order for us to break the barriers of traditional norms. By intensifying the value of relationships, increasing the flexibility of time and instilling virtues into the character of our program, we are able to authenticate the intellectual, physical, social and emotional maturation of our learners.

By establishing these methodologies as our standard, the measurable and performance-based outcomes for Odyssey's learners have been extraordinary.

For example, data would demonstrate when scores have been disaggregated that Odyssey's A.P.I. (Academic Performance Index) scores have consistently been approximately 100 points greater than the general school population.

Furthermore, Odyssey learners in each of the subgroups—gender, language fluency, social economically disadvantaged and ethnicity—have achieved greater test scores than their peers. Performance-based assessments and activities provided unique challenges and opportunities for our learners to demonstrate their knowledge and comprehension of subject matter.

Often, this is in the forms of hands-on projects. Two of our major endeavors that utilize math and science skills are the creation of Rube Goldberg machines and the engineering and construction of a fully operational roller coaster. In each of these projects, concepts such as simple machines, algebraic equations and physics principles such as Newton's laws and other various applications become relevant to the learners as they create tangible products that bring the curriculum to life.

Today in our classroom are tomorrow's leaders. How do we discover the 21st-century Odysseus? The exploration and its future begins now. In my classroom children are virtuous. They strive to live by a higher standard, are challenged to exceed their expectations, have the courage to take risks, are creative in solving problems and have the desire, dedication and determination to make their dreams a reality.

Math, science, and technology are critical for the hope we have as a nation to realize history. However, the goal requires us to also recognize that we have an ethical and moral obligation to educate the whole child emotionally, intellectually, physically and socially. So, this slide right here, when we begin at 6th grade, you can see in the backdrop, this was actually what one of our first projects was. If you can go to the next slide, please.

What we did was we did the research and we actually recreated Odyssey, the movie. They wrote their own scripts, they built their own props and we integrated the curriculum across each of the grade levels.

You can see the math and the science components that had to be applied and it was a risk worth taking because at the foundation of virtues is what was empowered them to really accomplish what they did. Next slide, please.

Here is the archaeological dig. This was literally 6 feet deep and 30 feet long and they created their own cultures and they excavated the site. Powerful, powerful to see how excited they were but also to see that there was learning, there was growth and change going on. Next slide, please.

So then in 7th grade what we do, because we laid our curriculum right with the state standards, obviously, we start also to talk about their social self and their relationships, again trying to emphasize educating the whole child and so they built a Rube Goldberg machine. Next slide, please.

And there are some pictures of where they start, an ancient civilization, and there is a theme that's interconnected throughout to where they get right to before U.S. history which is the 8th-grade curriculum, and simple devices, they make one machine that's obviously contingent of each other and they are able to accomplish this with their math, with their science, with their character education and so on. Next slide, please.

And then 8th grade comes and they realize once they've discovered who they are and then they know how to have relationships with their selves and with their family unit and the communities, then we talk about the greatest gift that you can receive is the gift to give, and so they give back, and what we do is we do a computer literacy project and that's the engineering and construction of our roller coaster. Next slide, please.

There is the literacy project. We read to our five elementaries in our school, and those are our future Odysseans, and—next slide, please—and there is the roller coaster, and literally this is just an overwhelming experience, powerful like none other, and it's really not what the teachers have done, it's what the kids have been able to create. But it's magic. Because there is a spirit. Because there is a passion. They believe. Next slide, please.

And so there is just a few more pictures of each of our projects. And those are our virtues that are actually in a sequential order. So I appreciate again the opportunity to advocate for kids. Thank you.

Pete Aldridge

Mr. Farrar, thank you very much. Very encouraging.

Just a couple of real quick developments, and then I'll open it up for questions. Barbara, you talk about getting teaching of teachers. Are we doing enough?

Barbara Morgan

We're doing a lot, and I—just say we need to keep doing it and doing a lot more, and folks like Dominic, you have heard from other teachers, projects like these, we do have them all over the country, they are fabulous and if we just grab these folks and bring them in from the very beginning and continue to give them experiences where they can really get space on them it's going to make all the difference in the world.

Pete Aldridge

Dr. Wheeler, you talked about an integrating role, and I'm trying to understand that better. We've got a lot of projects. The Department of Defense has projects. NASA has projects. Industry has projects going on in this area.

Gerry Wheeler

I don't think I would call it integrating. That's a fuzzy word. It's not science education. More of a shared—the establishment of a shared common vision of where education does fit into this initiative, and that's the challenge, I think, the Commission has.

There are a huge number of stakeholders, making little modules, doing little things for teachers here, doing something there. We need to have a vision of what we need for this project in science education. What should we all be doing together?

It's great to celebrate some of the things we've seen here but if that stays there and it's not part of our coordinated whole, then as a country we're not going to move forward and I think that's the opportunity the Commission has right now, is to create that shared vision, that common vision of where education fits into this initiative and what has to be done, and then, whether it's an enterprise or NASA or an engineer at H-P or the science teachers in a particular school, they know how it all fits together and we can keep the march going, the beat going.

Pete Aldridge

I think what we've heard in many testimonies before is that our capability to pull off a mission as complex and long duration as this is declining because of the lack of a growing pipeline of people with the right talent to make this happen. And that it seems if this mission is to be achievable we've got to do something in the education field to make this happen.

So I don't think you will find any argument among us that education is clearly a part—in fact, it's in our charter. That we are encouraged to do this kind of thing. But it seems like somehow or another there has to be—I will use this term again, it's not a good one—an integrating function to make sure that where there are holes in our collective approach, we're filling them and we're not duplicating unnecessarily.

Gerry Wheeler

In that sense, yeah, I completely agree with you. The only thing I would add to what you said was that I think it's—I don't know if this is politically correct to say—but I think that education is sometimes a little bit like motherhood and apple pie and so we don't say it explicitly enough. I think you're completely correct.

If we don't solve the STEM reform effort in this country we're not going to succeed in the Moon, Mars and Beyond initiative, just plain and simple.

Pete Aldridge

I even think it probably goes beyond that. It's our whole industrial base.

Gerry Wheeler

Sure.

Pete Aldridge

I think we had testimony in another city, I don't remember exactly where it was, that technology creates wealth. That's a pretty simple statement. That's absolutely true.

Gerry Wheeler

A good bumper sticker.

Pete Aldridge

Right.

Mr. McMurtray, I'm intrigued by—you've got even a broader issue. The whole education system is broken because we're not achieving the results we want to achieve. Where do you start? How do you ... Do we form another commission? an Education Commission or something? Where do you start the process?

Jim McMurtray

I can't answer that question.

I'll answer another one that I know the answer to.

There are lots of people in the country who are concerned about this, particularly in business and higher education. They want to do something, and they are ready to do something.

I think that there is—I'm not the only person who feels that this system is too large, too big to fix. It can't be changed because it is so large and because systems resist change. It may happen at the state level, or it may happen at a national level and then be picked up by the states. It could happen in lots of different ways. So as to where we start, I don't know. We start somewhere.

Gerry Wheeler

May I weigh in?

Pete Aldridge

Yeah, sure, please.

Gerry Wheeler

We could look at a number, but one that occurs to me in the context of this Commission is that the private sector, in my experience, has been reticent about stepping to the plate, about talking about particular projects. I mean, I can't imagine H-P having one plant that's working very well and another plant that's not working very well and not dealing with that issue, and we have something like this young man's program and the industry in that community, industry has to help us at the local level gain the attention, the focus, the spotlight, saying. "This is good." In fact, we even see results in our hiring of these kinds of people.

If industry doesn't—for some reason industry has been reticent to do that. I mean, clearly the retail part of industry you can understand, they don't want to cause waves, but there is a lot else that I found a general reticence to step to the plate and be vocal in their own community about quality and demanding quality.

Pete Aldridge

Laurie?

Laurie Leshin

I thank you all for being here. It's a great pleasure to hear what you have to say.

I guess I'm following a bit on what Pete started off with: we really need to ask the question of how—you know, assuming that we are going to the Moon and Mars, how can we best leverage this great opportunity to help solve the enormous problem that you all have laid before us today? This issue of the future of science education, science and technology education in our country. And here we have laid before us a great challenge and opportunity of getting us to the Moon, Mars and beyond and we're being asked to do it within available resources, essentially, within the funding that we currently have.

NASA, now, does a lot in the education realm and my question for you is a specific one about, are there changes needed in the way that NASA is working with the education community within available resources? What can they be doing better? What can—what specific recommendations can we make to help them improve the quality, if you will? Or, are they pretty much on the right

track? You're the experts on this and I'm not, so that's sort of what I'm curious to hear your opinion about.

Jim McMurtray

I would like to take a stab at that. What NASA has been doing, and should continue to do—states control education, it's a state function. You cannot operate a national program that one size fits all. And to continue what they have been doing to work with, to try to help the states do whatever they're doing even if it's wrong, because that's the direction they're going. So to assist them in whatever they're trying to do to improve science and mathematics education, specifically to broaden it, to get it to populations that are not getting it, that is what NASA should continue to do, and perhaps even step up.

Laurie Leshin

In partnership with the states, you would say?

Jim McMurtray

Yes.

Dominic Farrar

I can testify, and I asked the kids, I said, "So what do you think about this opportunity for me to go and speak?" And when I used the word *NASA* they immediately gravitated and connected with the word and then the light went on. I think that closeness, that connection, where you get at their level and you speak their language, in this day and age, that assembly line Industrial Age kind of type of education is really not having the impact or making the difference, because kids have so many tangibles that they're so—that are so available to them, you have to find other means, other ways, of being able to stimulate them and motivate them, and where I was trying to advocate about educating the whole child, our kids in our program, and kids throughout the country, I think they're able, they're ready, they're willing.

I think they need the mentoring. I think they need the guidance system. Obviously the nuclear family has changed at home but a large part of it is "Seek us out, train us"—we need to teach teachers how to teach, so then teachers can teach kids how to prepare for the future.

Barbara Morgan

I would like to hear—I think I'm biased because I work for NASA—and I have to say, I think NASA is doing a really good job. Can we do more? We can always do more and I hope we will, but we are doing a really good job and we have for many, many years.

NASA has taken some really bold steps. They work in partnership with the National Science Teachers Association, with the National Council of Teachers of Math, with the International Technology Education Association, they work with the experts in the field—in the education field—and not to do NASA programs but to support the kinds of things that these organizations want to do.

And just for an example, with the National Council of Teachers of Math, several years ago NASA worked in partnership with them to use the NASA resources and the NASA enterprises not to teach NASA but to help teach the national math standards—to use the content that NASA has to offer. It's a wonderful partnership and that's going through another reform right now. It's going through its second generation. That's just one example.

Right now the newest NASA initiatives, the NASA Explorer Schools and the NASA Explorer Institutes, I think, is right on the money working in partnership with these schools.

We now have 100 schools who consider themselves as NASA Explorer Schools, and they have a long-term commitment—it could be longer, it's only three years but that's a great start—where they get professional development, resources, money from NASA to help get the kinds of things that they need in their schools, to help improve their math and science teaching and NASA is just now starting the NASA Explorer Institutes that will work with the informal education community, our science centers, Boy Scouts, Girl Scouts, organizations like that.

Also, if you think about it, bringing in—and I kind of alluded to this too—bringing teachers in from the very beginning so that they are the experts. You have folks all over the country like Dominic, who are fabulous teachers, who given the opportunity to have an experience they're going to grab it and they're going to take it back to their classrooms and they're going to fit it into what works best in their schools with their students in their community, and I can't think of—when you think about this, this is—in 40 years of human spaceflight, NASA has opened up its requirements for astronaut twice. The first time—and this is from test pilot days—the first time was to bring in scientists, and the second time was to bring in people who have experience and expertise in education, and I think that's a huge step.

Pete Aldridge

Bob?

Robert Walker

When the Aerospace Commission on which Neil and I served made its report, one of the things we said was that the educational reform needed to move in the direction of lifelong learning and individualized instruction.

Now, Mr. McMurtray and Mr. Farrar, it seems to me that both of you said something along the lines of individualized instruction, where we have to move the educational regime is toward more in the way of individualized instruction. I also think, though, that it's clear that the schools of

education in this country are not moving us in that direction, that at the university level, that those—they're sticking to the old system. They're still training people to teach folks to go out and participate in an industrial society when we've moved to an information society and there is a problem there—the long way of saying, my question is, Is there some way, when we start talking about a 20- or 30-year program to go back to the Moon and Mars that there is something that can be done inside there to bring about a change of how we teach teachers, so that, in fact, we can get the kind of enthusiasm in science, technology, engineering, mathematics, that we're going to have to have in order to sustain the program?

Jim McMurtray

The simple and the hard answer is a new system.

Dominic Farrar

And I think for us in our case what we have done is we have just been willing to take a risk and we're kind of trailblazers, so to speak, but it also stems from—again I want to re-emphasize what I was trying to say—we've got to teach teachers how to teach so they can teach kids, and by doing so that means that we have to first decide as a structure how we're going to reorganize how we go about the processes.

Because me, as a teacher, I'm passionate. I'll do whatever it takes in the best interests of a child, and if someone shows me how or allows me to be an active participant, that's where the implementation comes into play. That's where the change is created. And you do so by the communication, the collaboration, the teamwork.

If people would just, like what we're doing now, sit together and decide what's in the best interests of children, I think some change could occur, but again, it has to start at what level—there's got to be a mandate and then there's got to be the evidence of proof to support it with.

But I don't know, I wake up every day, and maybe I have lofty thoughts and I'm a dreamer, but I agree, some day at some point it's got to click at some level where what we have been doing for over 100 years is no longer going to be the norm.

And what we have to do is pool our resources together at every level and every entity throughout the country and say, "OK, what's it going to take?" and then go for it. Because our kids in our program, for instance, that's why they thrive, because it's not the norm. They know when they walk into our classroom that the experience is different. And so I would say, "Let's get together," you know what I mean, let's map it out, framework it and then I think like she said, it's the networking. It's everybody just kind of working together at every level.

Pete Aldridge

Neil?

I'm sorry, please go ahead, Gerry.

Gerry Wheeler

If I can give two quick answers.

Pete Aldridge

Yes.

Gerry Wheeler

I'll try to be quick. First of all, I don't work for NASA and I think NASA is probably—I'm going to get myself in trouble here—one of the best agencies in terms of having a coherent vision in terms of serving science teachers.

What we're missing is beyond NASA. So I appreciate that a lot of your message goes back to NASA, but what I was trying to say in my message was beyond NASA, and NASA really does have a fairly good strategic plan and a vision and has a long, rich history of working with groups like ourselves.

If I were to suggest something for them, and others, because NASA is the leader, is that we need to move beyond the individual very rich experience and think about scale. Too often, we bring 25 children to a particular enterprise and get them all excited. It's much more than 2.1 million kids out there. We've got to think about how we can use the new technologies (at the risk of sounding sophomoric)—Internet, etc.,—to bring that very rich experience, say at the Glenn enterprise, to more than just the class that visits to do one microgravity experiment. We've got to think scale.

If I go back to Congressman Walker's comment, as a physicist I would like to say that the physics department has failed just as badly as the schools of education.

The big problem in undergraduate education, in preparing the teachers to be teachers of science and math teachers, etc., is that the physics departments are using them as the cash cow. I taught classes of 200 people and I was teaching a thing that had nothing to do with that future 5th-grade teacher. I thought I did a very good job and I got good evaluations but very seldom that we talked to anybody in the School of Ed nor they to us.

One shining example I saw that you might consider in crafting your vision is NSF had a teacher collaborative program for a number of years that really did (you know, we follow the money, quite frankly) get the different departments working together and listening to each other, but the undergraduate preparation is probably the single biggest problem that I see in this country, that has changed the least in—while we have been wrestling with this challenge. It's a very serious problem. I'm making fun of my own departments, I'm sorry but—

Pete Aldridge

Neil.

Neil Tyson

I'll try to make this quick. First I want to just comment, Mr. Farrar, that if cloning humans ever becomes legal we'll make sure you're first so we can have more of you to do what you have been doing.

Gerry Wheeler

That's the way to go. That's going to scale.

Neil Tyson

I think—I can probably speak for all of us here even though I haven't interviewed you on the subject that in our entire lives we could probably only think of two, three, maybe four teachers that are as influential as Barbara Morgan had described a teacher can be. That's out of perhaps hundreds from K through 16. And so that's kind of depressing.

And I ask, "Well, what did those teachers have that others didn't?" And it wasn't so much that they gave a good exam or gave good homework, which so many teachers in ed schools are now learning to do, to become sort of professional pedagogues. They become experts in the process of teaching without carrying with them any enthusiasm for one particular subject or another, and that worries me deeply, because the teachers that influenced me most had a passion for a subject that had nothing to do with their formal training as a teacher.

And so what I want to ask is: There is all this talk about distance learning that separates the teacher from the student. What can we do to promote a future where you have enthusiastic teachers who are experts in a subject—people who are experts in a subject and enthusiastic, then you make them teachers as opposed to starting the teacher process from the beginning and then you get mired in how to write the perfect exam rather than how to inspire your students.

Gerry Wheeler

I still think that you are shooting at one section—everything you said is true, but it's a very symmetric system and I would argue that you could start it either way, and the person needs to be a complete person.

Good science teachers, the members of NSTA, have a passion for children, a passion for science, and that combination is what does it. It's not—I don't want a nuclear physicist going in and teaching fifth graders. I don't want a school of education person that doesn't know Newton's

second law going in and teaching seventh graders. It's not one or the other, it's the combination that we have to address.

Pete Aldridge

Yeah.

Mr. Farrar. Quickly. We're running out of time.

Dominic Farrar

I was just going to say, real quick, unfortunately, sometimes I think teaching is not as attractive for people when they get out of school. I would like someday to see the pendulum swing in our favor. But regardless, I guess my point is, we keep talking about math and science but this kid nowadays in society, we have to educate the whole child.

Part of it is because the nuclear family doesn't exist emotionally, spiritually, so to speak—I also have other trainings in other realms where I'm trying to—to build the kid socially, emotionally, because there is that neglect or that ignorance because that—that norm that used to exist when the kid just came to the classroom, you could lecture and he would take notes and he would be smart, you can't manufacture that anymore.

What you have to do is model it, introduce the practice, and reinforce it, so I think as far as teacher training is concerned we can't just look for the experts, we have to teach them how to—how to get through the kid with everything else that's going on in their life besides just math and science.

Pete Aldridge

Carly?

Carly Fiorina

Thank you all for coming this afternoon. One of you had a slide—perhaps it was you, Dr. Wheeler—and on the bottom of your slide, I think it was you, was a great quote about, in essence, the destination and the journey.

Gerry Wheeler

That was Dominic.

Carly Fiorina

Odyssey, yes, obviously. And I think our first panel was talking to us about how to make the goal, the end, exciting. Some of us, myself included, sit on this panel because of the journey the goal may cause us to take, and the journey that we're talking about is, I believe, if done right, the nation can take a journey where we will build both the capability and the character that is necessary for children to compete, and function, and live successfully in the 21st century, and that's very different capability and character than was required in the 20th.

My challenge to you all is this: We have talked a lot, today, about the sustainability of this mission. And the fact that sustainability requires commitment of a nation over a long period of time. One way of getting that commitment is to make it sexy, and fun, and entertaining. Another way of getting commitment is to connect it up to people's lives every day. And I think the education community, the teachers you represent, the parents that you interact with, the children that you guide, represent a grassroots community that could, should, and ultimately must stand up every day and say, "This is important. This mission is important because of the journey it will cause us to take."

My very direct question, which you don't have to answer necessarily today but I would like you to go back to your constituents and think about it, is, What would it take to have the communities that you interact with every day stand up, go to the Hill, go to their local Congress people, go to the assembly houses, and say, "This is important to do because of the journey we have to take, as a nation, as a people." It will take that.

Dominic Farrar

It will.

Jim McMurtray

A revolution.

Gerry Wheeler

That does take reflection. I won't attempt to try to answer it today.

Barbara Morgan

I will answer it, if you don't mind, in part, and that is again from our teaching—for our teachers to feel that they are truly partners and not just that they feel that everybody else sees them as partners. If you don't have the teachers helping with this, you're not going to have the folks to be able to do it, and so if all of us can recognize that—not that there are a bunch of folks who can't do it but that we have a bunch of folks who can do it, and who do do it every day and it is a very difficult and

challenging job and they are doing a good job and they want to do a better job given the opportunity.

So if we can really bring these folks on board from the very beginning, get them involved so that they are equal players, and equal—not players but participants—I think it’s going to make a huge difference. Then, you will have—you will have them speaking, and they don’t even have to speak. they will be showing rather than telling.

Gerry Wheeler

Actually, in good science, as you know, in science research it’s the joy—like the old Harry Chapin song, it’s the going, not the getting there that’s important, it’s the joy of discovery along the way, and doing good science teaching is going to instill, I think, that in children much more than the older way of kind of the memorization of facts.

Carly Fiorina

And let me be even more explicit about what I’m in essence asking you to think about.

When the inevitable—let’s say we get this thing launched—the inevitable pressures come along to shut it down. We have a failure. We have a budget issue. We have whatever it is. At that point, it has to be more than a Congressman who happens to have some jobs sitting around a particular location to stand up and say, “Protect the program.”

And making the connection, I think, between the mission and the journey that’s going to happen here on Earth will have to happen at a grassroots level, and you’re in a position, I think, to help make that happen.

Jim McMurtray

It’s a question of who owns it. And if it’s owned by a small group, then when those failures happen it will get shut down. If it’s owned by all of us, then it won’t be shut down.

The great library in Alexandria, the people inside thought it was a great thing. They were very pleased with it, thought it was a great library. The people outside didn’t know why they had it so they burned it down.

The ownership is what will sustain this. If it’s owned by one party or another party, then as soon as the balance shifts, it will go away, and if it’s owned by all of us then it will stay there.

Pete Aldridge

We have run out of time, but I think we went over our allotted time for this panel because this is probably one of the more important aspects of this mission, and probably one of the most important

aspects of the future of our nation as we look into the broader aspects of education. I would like to really thank the panel for their comments today. They have been really enlightening.

Dominic, keep it up. It's a very encouraging and motivating activity you're under way and I thank the rest of the panel for coming, and we'll adjourn for a 10-minute break and reconvene at 3:30. Thank you.

Well, first of all, we apologize for running a little behind schedule. but we will make sure that we try to make some of it up. And I have been informed that our satellite link drops out at 4:30, so at that point we will be finished by then.

Our final panel of the day is here thanks to the efforts of the National Industrial Base Workforce Coalition. The sustainability of the space exploration and commerce is a critical theme that must be addressed if we are to give legs to the space vision. The panelists here today represent workers at aerospace companies large and small, and they know the value of incremental, manageable steps in any business enterprise that is designed for the long haul.

Reecie Giesecke is president of U.A.W. Local 848, representing the workers at Vought and Lockheed Martin Missiles and Fire Control. As an ... he's been involved in almost every program using both old and new technologies to develop tooling and components, and he's held various leadership commissions over the last 30 years, including chairman of the U.A.W. Aerospace Skills Trades Council.

Dean Zvorak, president of U.A.W. Local 887, represents Rockwell International workers in Southern California. Rockwell was purchased by Boeing in 1996. Mr. Zvorak has also held many leadership positions, including trustee and bargaining and grievance chairman.

And our third panelist, David Goodreau, is chairman and co-founder of the Small Manufacturers Association of California. Mr. Goodreau has played a leading role in developing economic, educational and manufacturing programs and policies in California.

We welcome your comments about the economic strategies that are sustainable and manageable. Thank you for being here. I guess Mr. Giesecke is going to go first.

Reecie Giesecke

Good afternoon to the members of the President's Commission on Moon, Mars and Beyond. My name is Reecie Giesecke. I am president of U.A.W. Local 848 Aerospace Workers, Grand Prairie, Texas, and also vice president of the Texas AFL-CIO.

I come here today to speak on behalf of the employees of Vought Aircraft Industries as well as those at Lockheed Martin Missiles and Fire Control, who are major participants in the current Space Shuttle programs. Our membership has worked on projects such as the Space Station and military rocket systems also.

Jobs in America, the space program, require years of education, training and experience. When any program that encompasses all of the years of skill, training, comes to a close, the skill, training and experience of the workforce can easily be lost forever.

Today I want to give you one example of how the loss of skilled workers can affect the future of an industry. Our members also manufacture the leading-edge tiles for the Space Shuttle. We all know how important these tiles are to the safety of the Space Shuttle flight.

With the unexpected loss of the last Shuttle, we received an order to manufacture another ship set of these tiles. This takes almost two years to produce. The workers used to manufacture these processes and oversee them were either retired or working elsewhere in the aerospace industry. In fact, we had to find former employees who still possessed the required capabilities and were willing to return to the workforce to oversee, and train, new employees who were unfamiliar with these processes. We were lucky to find *one* of these older workers to help with the tile program.

This is not always the case. Whenever our capabilities vanish, any restoration process requires extreme diligence, attention, and the expertise to restore the skills to the workplace, lest it becomes extinct.

We support the President's space exploration initiative because we are moving toward the end of the Shuttle program. The vision of space exploration is worth supporting. And America's technological and skill workforce has earned its place at this table.

We recommend that the Commission, you, urge the Administration to lay out a clear framework and timetable for the President's initiative.

Secondly, we encourage your industry to stand at the forefront of advancing the new technologies needed for the space exploration program.

Third, we would like for you to educate the public and the members of Congress about the long-term positive benefits of having a robust space program.

Fourth, if the President, the nation, industry, and the American workers are united, we can rekindle the legendary American manufacturing base and maintain America's world leadership in space.

In conclusion, the employees I represent believe that the President's space exploration initiative is our passport to the future success of America's space program.

I thank the Commission members for their time and attention and will be happy to answer any questions.

Pete Aldridge

Thank you very much.

Mr. Zvorak.

Dean Zvorak

Good afternoon, ladies and gentlemen of the space panel. I am Dean Zvorak, president, U.A.W. Local 887, representing members at the Boeing Space Division with facilities in Downey, Seal Beach, Canoga Park, and Palmdale, California. I'm pleased to be invited here today to testify about

the space programs that employ our workforce and to confirm to you as Commissioners the impact that the President's space exploration initiative will have on current and next-generation American aerospace workers.

The United Automobile, Aerospace and Agricultural Implement Workers of America—the U.A.W.—is one of the largest and most diverse unions in northern America, with members in virtually every sector of the economy.

In the aerospace and defense industry, the U.A.W. represents workers at such major firms as General Dynamics, Boeing, Lockheed Martin, Honeywell, Raytheon, General Electric, Rolls-Royce Allison, Bell Helicopter and others. Our workforce produces rocket engines. Anything that is launched into space rides on rockets with our engines. It was our workforce that built the engines for the Saturn series of rockets used in the Apollo program. We built the Apollo Lunar Module that landed on the Moon. Our workers also built all the Space Shuttle orbiters as well as the engines for the Shuttle. The most important point I want to make for you today is to tell you what happened after the Apollo program.

During Apollo our union local had over 70,000 members with 30,000 members working directly on the program. Now our union is down to 1,200 members and the Downey facility was closed in the early 1990's. Closed facilities and laid-off aerospace workers are representative of what happened to our nation's space programs. Because of the continuous layoffs in space program work the jobs of American aerospace workers are vulnerable, especially those in California, where, since the 1990's, manufacturing is now almost nonexistent.

This leads me to the second major point I want to make: much of California's downturn in manufacturing is due to excessive environmental regulations and extremely high business taxes that have resulted in industry moving to business-friendly states. Because of the decrease in space program work, many dedicated, expert workers are leaving the NASA community and moving into commercial aerospace where there is greater job security.

A national space exploration program must have a continuous supply of eager, highly trained workers. Young workers, students, must be encouraged to obtain schooling in those professions and support our nation's space programs—programs that need not only scientists and engineers but highly skilled touch labor that supports these programs. And it is essential that current and future public policy include assurances there will be jobs for the next generation of workers in a national space exploration program.

In summary, as Commissioners charged with the task of making recommendations to the President on implementing the objectives of the United States space exploration policy, I recommend, first, the new space initiative should include a detailed study and review of the industries and workers whose skills will be required for the space exploration initiative to move forward.

Second, both current and future administrations should provide for sustainable, uninterrupted funding of the space exploration initiative in order to achieve a sustainable human robotic investigation of the universe.

Third, current and future members of the United States Congress must commit to a national space exploration initiative, no matter which political party is in charge, as to assure that America secures the first outpost on Moon, Mars and Beyond in the interests of our country's national security.

Fourth, there must be a national commitment to an education curriculum from kindergarten through college degree programs that support those studies which will educate and train our next generation of workers for space exploration positions.

And fifth, there must be more than recommendations. There must be action and commitment from the Administration, United States Congress, industry, American workers, and the U.S. citizens.

In closing, I would like to ask you, as Commissioners, to remember that American workers could be the greatest allies and defenders of the President's space exploration initiative. Use the strength of the American workforce and the excitement of new discoveries as the impetus for publicizing the need for continuing the space exploration initiative. Thank you for your time and consideration of my testimony.

Pete Aldridge

Thank you.

Mr. Goodreau?

David Goodreau

Thank you. This is a real honor to address such an incredibly terrific Commission. My name is David Goodreau. I'm chairman of the Small Manufacturers Association of California. We represent 1,000 small and mid-size firms throughout California. We also are one of the cofounders of the Small Manufacturers' Institute and we have done about \$2.7 million worth of grants, trying to help manufacturers in areas of education and economic development. Lastly I'm here with my good friends with the Industrial Coalition, whom we have had a partnership for over 12 years in trying to address issues such as this.

Now I guess in the next—what?—four and a half minutes I'm going to explain to you all the dynamic changes that have been going on in manufacturing, which is really revolutionizing the way we do business, and as you well know, manufacturing is in transition, and I put in my written testimony to the Commission what I described as the perfect storm, as you well—why manufacturing is never going to be the same again, so I would like to just do some bullet points here on how I think that applies to space and then maybe some of the recommendations that I outlined.

First is that there has been a severe decline in manufacturing infrastructural resources that serve the space infrastructure.

Secondly, that there are roadblocks within the science and technology career ladder that are keeping students from taking this career path. These blocks, really, are perpetuating a low

awareness of the manufacturing, science, and technology programs, and I think to a larger degree it's discriminating to a certain degree against those that have mechanical skills.

And lastly, that there is a real crisis in how society perceives manufacturing, science and technology careers.

Now, as far as those major points, how to address them, I took six out of the 11 to address you.

First is that we need to insist that we develop mechanical skills into the primary educational infrastructure.

Secondly, we need to help these programs integrate with the math and science theory so that it raises the perceived value of these programs and indeed those individuals that are taking the programs and that career path.

Thirdly, we need to create a modernization program for manufacturing, science and technology classrooms.

Fourth, we need to increase funding for high school and community-college programs that integrate the manufacturing, science and technology programs to where there is a continuum between high school, college, and indeed into the higher education.

Fifth, establish public-private teams at the regional level to support these school programs.

And lastly is to find a dedicated funding to encourage retired manufacturers to mentor youth and teachers in manufacturing, science, and technology programs.

In closing, I had an article that I provided to the Commission, and I don't know if you got it yet but it was written last week by Debra Saunders. It happened to be in the *San Francisco Chronicle*, so it kind of came to my attention. I really thought it was focused on what I was talking about where the perception of these careers that we're actually trying to develop a team to help this program. And it was entitled "Social Engineering 101" and it was defined where the San Francisco State University president had decided that they've got like a \$14 million shortfall so where do I cut? Well, one of the areas that he thought was essential to cut was, indeed, the school of engineering. And I just bring that to your attention, and, of course, I wrote a response to that from the standpoint that that really defines what we're talking about. Culture has changed how we view these programs and indeed, we've gone for so long, 20, 30 years, to where we now have people in leadership positions to where they really don't connect the value of science, technology, how it applies to space, and they don't relate to it where it fits into their schools and where it fits into the economy and how it helps students, for that matter. So I would just like to close by stating this is how I responded to that. I thought you might find it interesting. It says, "This proposal by San Francisco State University is an example of the cultural bias towards manufacturing. The fundamental creative skill and intellectual property behind any NASA program, and to a greater extent our national economic and defensive security. It is my view that any attempt to engage and align America's passion, resources, and vision towards a renewed vision of discovery will be futile unless we address the crisis in America's manufacturing infrastructure and the cultural bias that discriminates against those individuals with mechanical traits. America needs public and private leadership to instill awareness and pride into our culture as it applies to our industrial base and our educational

infrastructure that services the manufacturing community. We must stop dismantling the infrastructure that gives America an edge in the global economy. Instead, we need to reaffirm our pride in the blue-collar worker and the career ladders that lead to higher education and greater opportunities.”

Thank you.

Pete Aldridge

Thank you very much.

Make one comment and then a question. Obviously, the task of this Commission is to tell the President what we think he needs to do to make this a sustainable program and I think we’ve heard several times that part of the sustainability would become the ownership of this program by the American taxpayer, of which you represent a group of individuals that are certainly more directly affected by the success of this program than any other.

I know that, again, sustainability and ownership is key, and I just make a comment, I believe the labor unions could help us in that sustainability argument by getting on board, getting information from NASA, passing that on to their—to the members of the unions and their families and letting us—help us get this program going. That’s a comment.

The other part of it, Mr. Goodreau, is one of the complaints I have heard about is that when a small business organization goes in to NASA to talk about “How do I get more involved in the space program?” they’re kind of looked at as “Who are you?” and they don’t feel like they can get a role in. We have been looking at this issue and feel that there ought to be some way that small businesses can participate in a more aggressive manner, which also broadens the support base that we have for the program, and helps the economy and helps the competitiveness, because we know small business is very innovative and quick to react and so forth. So comment about that particular concern?

David Goodreau

NASA is a pretty unique government institution in that it indeed has its own supply chain, and I think many of you on the panel have probably been players in defining where the supply-chain management is going, and really what you are describing is simply that, and I think that there is going to be a next generation of that philosophy that’s going to—it’s going to mature, and I think that is that where the prime contractors, and I’ll put NASA in that situation, that it’s going to begin to understand its role in being a servant of those that are in its supply chain. It’s not a question of us versus them. It is, indeed, “How can we assure that those folks at the bottom of the ladder of our supply chain are going to be successful?” And I might even suggest that one thing that we don’t do is we don’t look at the schools as a part of that supply chain, and indeed it is, because that’s where the world-class employees are going to come from, so I think that trying to evaluate the way that you interact with these suppliers, trying to create a public policy with the legislators, awareness that

these people do exist and they're important to our mission because it is a team, that's what we're defining: a team.

Pete Aldridge

OK.

Neil.

Neil Tyson

Mr. Zvorak, I was intrigued by your bio, I have a mini-version of your bio in our notes, and I have a question regarding that. From what I glean from it, you went straight into the industry right after high school.

Dean Zvorak

Yes.

Neil Tyson

And what I want to know from you is, at that time, was that common for high school graduates? Or were you just—because I look at your career from that, and it—it looks extraordinary, actually, given that, and I'm just wondering, were you unusual? Or were others like you? Or is that possible today?

Dean Zvorak

It depends on who you talk to, I guess.

Neil Tyson

Can a high school graduate today do what you did today?

Dean Zvorak

No. No, because we look at wanting experience. When I got in there, what happened was I grew up in Simi Valley. They did engine testing. That always got my curiosity—I mean, the windows rattled on the house, you know, and Simi Valley was built by a lot of people that worked out at Rocketdyne, so that's where that connection came from. My dad actually worked out there, so I went and applied for a job because, hey, a good-paying job out there, it's close to the house and

that's what we did, and there were a lot of kids that graduated from the high schools that were able to get in there at that time.

Now, because of such downsizing, you've got to have five years' experience to get in, and it—you don't have the experience anymore. There is no more shops in the schools, metal shops, and things like that. Those are all gone away, so now, where do you find your experience before you get in there?

Neil Tyson

But to both of you, now, as a quick follow-up, if I may: given the rate that the frontier of technology advances, it will become increasingly more important for a workforce to be retrainable.

Dean Zvorak

Yes.

Neil Tyson

Does the union base have something—have that built in to enable workers to be able to track the moving frontier of the talent set that's needed for—as one generation moves into the next? Or does that have to come from outside?

David Goodreau

It has come from outside as of late, but it is something that we have been trying to work with, with the company also, to get that new technology and that training for those employees.

Pete Aldridge

OK.

Bob?

Robert Walker

Mr. Zvorak, I don't want it to look like we're picking on you, but I have a question for you coming out of your testimony, and that is that you say that we must have a commitment to a national space exploration initiative no matter which party is in charge.

Dean Zvorak

Yes.

Robert Walker

And I've got to tell you, I have been a fairly good partisan throughout all my political career. But I absolutely agree with that, and it goes to the questions—the Chairman's question of sustainability. If we don't have a bipartisan effort in this regard, we're going to have a—a problem sustaining this over a long period of time. Having said that, I know that the U.A.W. has endorsed John Kerry for president.

David Goodreau

Yes, they have. I just got that notice last week.

Robert Walker

But I'm wondering, I mean, is this an opportunity for the U.A.W. to, in fact, help make certain that presidential candidate Kerry does favorably speak about the idea of doing a Moon to Mars mission, you know, regardless of which administration may emerge in November?

David Goodreau

If he wants a lot of our voters' votes, members' votes, he will.

Robert Walker

Good. Well, I mean, that would be something I think would be very important in following up. That I think that's where a number of the unions could be very helpful in making certain that we build this kind of base in the future is, to take those opportunities to define this in a way that it becomes a bipartisan initiative so that we don't have to fight partisan battles both on Capitol Hill or inside administrations. So I thank you for that.

David Goodreau

Sure.

Pete Aldridge

Maria?

Maria Zuber

Yeah. I would like to follow up on the comment that Neil made that addressed retraining, but I would like to look at it from the point of view of pretraining, OK? When I was in high school, there were a lot of kids who didn't like to sit there and study and do homework but they were excellent with their hands and they loved to get into the shop and they loved to build things, but if you're going to work for the space program you need precise—precision, you know, machining that is going to require computer skills, OK? And—and you can't necessarily wait to be retrained and get those skills. You need those skills when you're, you know, starting at the middle school level and at the high school level. And even to be a machinist, now, you've got to be taking math and science all the way through. And is the word getting down from the union to the, you know, technical training schools where the kids are coming through the pipeline, the first time, that these skills are going to be necessary to enter that part of the workforce for the future?

Dean Zvorak

At the Rocketdyne facility that I came out of we had a program that invited kids from high schools in, and they sat with our machinists and watched what a machinist does, and saw the NC controllers that they had to work with. So they have to understand what it takes to get into this craft. And also working with some of the tech schools in the area. There are a few tech schools still left in the area but not as many. So that's why we started these programs of inviting kids in from the high school that aren't interested maybe in going to college but are interested, you know, in starting off with a skill and getting the job and becoming a machinist. That's what he wants to do. So we brought those kids in, and they would be in there for about two hours a day. So it worked out really well.

Pete Aldridge

Les.

Les Lyles

Mr. Goodreau, I was struck by your term the “cultural bias” against those with mechanical skills, technical skills and the blue-collar worker which is a term, by the way, I don't particularly like but it's one that's been used all the time, I think, in our country, and you mentioned one example of a way to try to address that is mentoring or teaching in schools. Do you have some specific examples, perhaps, that you have seen where that cultural bias has been addressed and perhaps overcome? Because it's one, I think, that can be a cancer, if you will, on all the things we're trying to do to succeed in our country, not the least of which is this very, very important space exploration vision.

David Goodreau

It is a cancer, and because—yes, and there are some outstanding models. One has been a part of what Dean was just saying from the standpoint we put into the San Fernando Valley, a region that's the largest aerospace base in the nation, they say. After Lockheed and everybody's pulled out to a large degree, with the exception of Rocketdyne, there still is these small mom-and-pop shops that are there, so we took a different approach. Instead of having a large corporation do the mentoring, which is kind of the typical model, whether it's Shell Oil or, you know, whatever business cluster you have, we put them in the small shops. Over about a five-year period, I'd say, we put—I'm going to say close to 200 students into mentorship positions. During a two-year period, when we actually had a grant, we took a high school that had a 50% dropout rate—they have a very—something like 98% minority population, in the residential population—very difficult region, and that school, over a two-year period, 30 students that started out, we only lost two students. Out of those 30 students, 15 of them ended up taking jobs with their employer. And it's tremendous—you can find these models, you know, whether it's in the Bay Area, Southern California, Washington, there are models.

The problem is models versus—you know, institutional change. And just the last point that's so important is taking away that stigmatism that it's either, you know, you're ready for work or you're ready for school. We have to blur that, and we have to find ways—and that's where these academies work terrific, mentoring, bringing the colleges in that work with the students. You show them the career path.

There is one student in San Bernardino right now, this lady is going to graduate from high school in June. She is going to graduate from college with her A.S. degree in August in machining, and she wanted to be a lawyer before she decided that she could make things—that she wanted to make things, and as a matter of fact I was going to have her come up, but incredible stories.

Pete Aldridge

Thank you.

Any other questions?

I would like to thank the panel for your testimony. You have given us a fairly rich set of recommendations here to act upon and I hope we can, but we also solicit your support in helping the President and this mission be accomplished over the decades to come. So thank you very much.

With that, we adjourn until tomorrow morning at 9:00 a.m. Thank you. Space Commission Hearing, 16 April 2004, San Francisco

Pete Aldridge

Well, good morning.

After an entertaining and enlightening day yesterday, we're ready to reconvene the fourth public hearing for the President's Commission on the Moon, Mars and Beyond. We're pleased to be holding this hearing at such an appropriately named location, the Galileo Academy of Science and technology.

Let me introduce our Commissioners.

On my far right, Carly Fiorina serves as the chairwoman and chief executive officer of Hewlett-Packard, which she joined in July 1999. Her roots are deep in technology, and she has served in senior executive leadership positions at AT&T and Lucent Technologies.

Michael Jackson is the senior vice president for E-com Technology Corporation. He is a former U.S. Department of Transportation Deputy Secretary and was instrumental in the early formation of the Transportation Safety Administration.

Dr. Laurie Leshin is the director of the Arizona State University Center for Meteorite Studies. She uses spacecraft and sophisticated instruments to trace the history of water and possibility of life in our solar system.

General Les Lyles was in the Air Force for more than 35 years, rising from the Air Force ROTC program to become a four-star general and commander of the Air Force Materiel Command. In that pre-retirement position, General Lyles was responsible for the U.S. Air Force research and development community.

Dr. Paul Spudis is a planetary scientist at the Johns Hopkins University Applied Physics Laboratory outside of Baltimore, Maryland. His specialty is in the geology of the Moon. He's also studied the geology of Mars, Mercury, and many other worlds.

Dr. Neil deGrasse Tyson is an astrophysicist and the Frederick P. Rose Director of the Hayden Planetarium in New York City. He recently served on the President's Aerospace Commission. He made recommendations to Congress and related government agencies on how to improve the health and future of this industry in the interest of the American economy and national security.

Retired Congressman Robert Walker is chairman and chief executive officer of the Wexler and Walker Public Policy Associates, a firm specializing in telecommunications and technology issues. Bob Walker served in the U.S. Congress from 1977 to 1997, representing his home state of Pennsylvania. While in Congress, he was the chairman of the House Science and Technology Committee with NASA oversight. He too served on the recent Aerospace Commission as its chair.

Dr. Maria Zuber is the E. A. Griswold Professor of geophysics and planetary sciences at the Massachusetts Institute of Technology and leads the Department of Earth, Atmospheric and Planetary Sciences. Maria has been involved in more than half a dozen NASA planetary missions aimed at mapping the Moon, Mars, Mercury, and several asteroids.

Steve Schmidt is our Commissioners' executive director. Steve is a special assistant to the NASA Administrator and is our federally designated official for this advisory committee.

We will launch the second day of testimony with a panel of propulsion experts. Without propulsion, we get nowhere, right?

Byron Wood has 40 years of experience in high-energy liquid rocket propulsion at Rocketdyne Propulsion and Power, a division of the Boeing Company. Mr. Wood was a development engineer for the Saturn Apollo J2 engine, taking U.S. astronauts to space and then to the Moon and was also in charge of the advanced architecture concepts resulting in the world's only reusable rocket engine, the SSME [Space Shuttle main engine].

Joining him is Michael F. Martin, president of Aerojet, a California-based company founded in 1942. Aerojet propulsion has been part of every major space mission the U.S. has ever flown. The company has provided propulsion systems for every spacecraft that has landed on Mars, and over 90% of all U.S. satellites in orbit rely on Aerojet propulsion.

Our third panelist is Jim Mosquera; he's a senior government executive with the Naval Reactors, a joint program with the Navy and the Department of Energy that is responsible for nuclear propulsion plants used in over 40% of U.S. combat ships. Mr. Mosquera was also a lead investigator for the assessment team on the Columbia Accident Investigation Board, and he has recently been assigned program management responsibilities associated with the development of a reactor model for the NASA Jupiter icy moons orbiter mission.

Gentlemen, we're eager to hear what you have to say.

Byron, I guess we'll start with you.

Byron Wood

Thank you. Good morning. Mr. Chairman, I thank you for the opportunity to speak to you and the Commission about propulsion's role in the national exploration vision for space, an issue I consider to be of national strategic concern. Please accept my written statement for the record.

I'm pleased we have a national exploration vision for space that defines the journey that will clearly benefit humankind. The technology needed for this vision will be vast, touching a myriad of disciplines and sciences, which will hopefully inspire and create a generation of scientists and engineers in this country.

The exploration vision will take us in space, farther and faster, allow us to stay longer at compelling destinations, and increase the magnitude of scientific data gathering and observation.

The long-overdue focus on what nuclear power will bring to bear is frankly astounding. If I could have my next chart, please.

In this figure, figure 1, I have tried to summarize the vision to illustrate the significant opportunities that working and moving in space will provide. The figure also tries to illustrate the role propulsion must assume in every phase of the vision to make it successful.

The goals of the exploration vision must depend on taking material necessary for the mission from Earth to space, either in a single launch as was done through Apollo or through multiple launches of large segments or many small segments joined in space.

Today operational global launch systems have an Earth-to-orbit capability of between 8 and 27 metric tons. This means it would take from 6 to 18 launches to put in orbit the equivalent payload a single Saturn V launch system delivered 40 years ago.

Referring to figure 2, the challenges to maximize mission success with payload capacity, then balance the risk of multiple missions with assembly in space versus the availability or affordability of propulsion systems to start the mission. Government and industry need to immediately and significantly team to move forward for spacelift capability to meet the requirements of the nation's exploration vision for unmanned, crude, and cargo delivery to space.

A launch system that we put in place must serve this nation for many years, after we retire the Space Shuttle. We must provide assured space access, with increased levels of safety that significantly improve loss of vehicle and, most importantly, loss of crew reliability.

So far we seem to be limiting ourselves out of fear for the cost of a new engine. I think we can address this challenge in cost-effective ways. For example, Boeing Rocketdyne recently completed development of the RS-68 engine using 21st-century processes for the Evolved Expendable Launch Vehicle program. Illustrated in figure 3 (next chart, please), we developed this new engine for \$500 million in less than 5 years. This engine now could be human rated and provide additional performance if needed and would be applicable to EELV [the evolved expendable launch vehicle] and Shuttle-derived solutions.

Similarly, the Space Shuttle main engine, the most reliable engine in the world, can be modified as an expendable engine to reduce cost and be applicable to either the EELV or Shuttle-derived solution. We have also been developing an expendable upper-stage engine with company funding. It could be adapted with modest government support.

If an all-new engine is needed, then capitalize on that invested in recently cancelled NASA propulsion programs by redirecting them to highly reliable expendable configurations. In all these cases, some investment by the government will be required. But without some investment in a proper foundation for the new vision, I fear the vision will forever be handicapped or not achievable.

I'm continually reminded of a quote by Wernher von Braun: "Who will control the oceans of space?" Clearly, the United States exemplifies the need to go and lead in the space ocean. Superiority in space is a true strategic issue and will be determined by those who have the resolve to get there in the first place.

In my 40-year career, I've had the privilege to be an integral part of propulsion for Apollo, Space Shuttle, NASP [the National Aerospace Plane], X-33, and EELV. All of these programs affirmed and demonstrated the leadership role the United States seeks with regard to propulsion and going to space. But let's review some history.

In 1946, the U.S. propulsion industry was born out of transplanted technologies from Germany with a need to provide a Cold War launch deterrent. Referring to the skill of history for Rocketdyne in figure 4 (next chart), it took more than 10 years to develop a reliable capability to go to space, building a workforce of nearly 20,000 scientists and engineers to do it.

In 1958, with the birth of NASA, and in 1961 with President Kennedy's declaration of landing a man on the Moon and returning him safely to Earth by the end of the decade, we had a strong, robust industry to draw upon. That accomplishment, as we all know, was unprecedented. But the industry almost died in 1969 after the successful lunar mission program. Fortunately, the Space Shuttle program saved it, but it took another 12 years to revitalize the industry, leading to the first successful Shuttle flight back in 1981.

Today we again are at a crossroad. In the last 20 years, the government has started and stopped a dozen propulsion initiatives. In my June 2003 testimony before the Senate Subcommittee on Science, Technology and Space, I made a passionate plea to save this rapidly deteriorating national competency. In that testimony, I referred to the fact (figure 5, next chart) the U.S. is far behind the rest of the world in engines launched, barely 18%. Our estimates today indicate that more than 10,000 scientists and engineers are working in China and India to develop world-dominating propulsion systems and launch vehicles. Virtually all space-faring nations have or are developing space launch systems. The United States seems to be turning away from this critical capability, even resigned to turning it over to offshore countries.

The national exploration vision for space with projects like Prometheus and JiMo will use bold new advances in power and propulsion, multi-mission radio-isotope thermal generators, nuclear electric power conversion, and nuclear thermal propulsion. Industry eagerly stands ready to accept that challenge. However, any country that aspires to have a position of space superiority must have a robust spacelift capability. The exploration trip can't start unless we get out of the Earth-bound driveway. Derived, upgraded, or new propulsion systems will require four to seven years to develop, and that's if you have a skilled, experienced work force with facilities and process capabilities to do it.

How does this country expect to maintain the skill base and process excellence of a unique industry without work? If the U.S. capability to develop propulsion systems for spacelift is lost, can we afford the 10 to 12 years historically required to rebuild that capability, and at what cost?

In your evaluations, I ask that you seriously consider in your recommendations the following:

Get the propulsion industry significantly involved now.

Be sure propulsion is an asset, not a tail dragger.

With industry's help, define those tasks which are essential for any future propulsion alternative and get the workforce engaged now.

Using current assets, and even modified past assets, build a spiral development roadmap that will meet the vision's needs and keep engaged this great country's competencies vital to making it happen.

All studies I've seen clearly point to the need for a derived or new engine. Let's agree on what it is, sustain it, and reassert ourselves as number one in propulsion.

Thank you very much.

Pete Aldridge

Byron, thank you.

Michael?

Michael Martin

Mr. Chairman, members of the Commission, good morning. I'm very pleased to be part of the hearing today. Thank you for having us here.

Aerojet's products and technologies cover the entire propulsion spectrum: liquid, solid, gel, and electric systems for boost in space and missile defense and tactical applications. As Mr. Aldridge mentioned in his introductory remarks, we have a long and broad experience base and it's directly relevant to the discussion this morning.

Space exploration is obviously enabled by a strong domestic propulsion capability. Maintenance of that capability also has important implications for national security and commercial competitiveness. We know that the Commission is well aware of industrial base and demographic issues that we face in our business. So this morning, we're going to stay focused on our view of key propulsion technical and programmatic challenges that must be met to fulfill this new space exploration vision. Next chart, please.

This chart reflects our understanding of NASA's exploration roadmap. Phase one from now until roughly 2012 would see continued launches of various robotic trailblazers, paving the way for human exploration. In this phase, we'd also begin developing the basic crew exploration vehicle, or C.E.V., to carry humans on initial missions beyond low Earth orbit.

Phase two would continue robotic missions to the Moon, to Mars, and beyond and concurrently with experience learned from the basic C.E.V., we would begin spiral development improvements to accommodate orbit transfer modules and lunar landers required for returning humans to the Moon's surface. We would begin to look at the feasibility of onsite propellant processing and we would utilize nuclear power and propulsion to enable unprecedented exploration to Jupiter's icy moons and the outer planets. This phase would continue until at least 2020.

In phase three, we would combine additional C.E.V. development technologies with nuclear electric, possibly nuclear thermal, advances to support human exploration of Mars. In parallel, ambitious outer planetary exploration would continue, extending our presence to the edge of the solar system and beyond. Next chart, please.

This chart depicts the range of propulsion functions required for space exploration. We'd group them into two broad categories: launch vehicle propulsion for getting us to or beyond low Earth orbit and in-space propulsion to the actual journey in space—spacecraft-controlled orbit landing and return. Next chart, please.

NASA's final exploration architecture will drive propulsion requirements. Aerojet believes that near-term exploration activities can be accomplished with existing propulsion technologies and

hardware. However, it's going to be necessary to adapt them to mission-specific requirements. In the midterm, expendable vehicles will require human rating, and program plans will have to accommodate the intensive nature of testing and qualifying that hardware. The final architecture will also determine whether an upgraded launch vehicle with heavier lift and higher propulsion performance is necessary. We believe it's likely that technology breakthroughs are not required, but new engine developments or modifications must be considered significant program elements.

In the far term, nuclear propulsion may also play a role in launch vehicle upper stage and/or transfer stages. Ensuring the safety and operational viability of these systems will require us not only to use our existing knowledge base but to commit ourselves to a sustained advancement program. Next chart.

For in-space propulsion, again, existing technology and hardware can fulfill near-term requirements, both human and robotic near-Earth missions like those to the Moon.

Adaptations and qualifications, specific mission needs will be key elements. In the midterms, we explore the potential for using in-situ propellants. Engines would have to be developed to accommodate different chemical propellant combinations. Likewise, nuclear electric propulsion may become the propulsion of choice as we develop and gain operational experience with higher-power hull [?] and ion thrusters being developed for the Jupiter icy moons missions.

In addition, like launch boosters, the crude exploration vehicle propulsion systems will also require human rating. In the far term, the longer human missions requiring larger cargoes and reduced transit time may drive the need for nuclear thermal propulsion. This technology was developed in the 1960's, albeit under different circumstances. Since that time, there have been some 25 missions using nuclear power in space. So we do have some experience with the rigorous safety procedures, specialized knowledge, and disciplined culture that is necessary to do this work. Next chart.

This chart identifies some of the more obvious challenges common to both launch and in-space propulsion systems. We would probably add a fourth and another point of emphasis, and that would be particular to nuclear thermal propulsion. We need to assess the quality and the quantity of the historical documentation base that we have available to us and the human capital that's available to us. And once we have a good understanding of that, we need to create sustainable programs that ensure the successful rebuilding of an industrial base that has the necessary critical skills. Next chart, please.

In summary, Aerojet believes that from a propulsion perspective, the nation's new exploration vision is achievable and requires no new scientific inventions.

There will, however, be a significant commitment to the development and qualifications of various mission-specific propulsion elements. These commitments need to be realistic, they need to be sustained, they need to be consistent with available resources.

We also believe, in the mid to far term, that nuclear propulsion can provide substantial benefits for certain mission elements. We believe the majority of the technology is within our grasp. I'd also like to emphasize, I think we have so many obvious lessons from both civilian programs at NASA and from Defense programs from the Department of Defense. We can't emphasize enough the

importance of the timely and proper setting of requirements and the maintenance of those requirements baselines once they're put in place.

And secondarily, the ability to maintain predictable funding on an annual basis, because even well-planned programs can be disrupted, but by unexpected changes in funding levels. That concludes my remarks. We've provided more detail in a written statement.

In order to be responsive to your technical questions, I have two other Aerojet people with me today seated in the front row. Ms. Julie van Kleeck's area of expertise is chemical propulsion, and Mr. Joe Cassidy's area of expertise is nuclear and electric propulsion. Thank you again for letting us be here today. We'll do the best we can to answer your questions.

Pete Aldridge

Thank you, Mike.

Jim?

Jim Mosquera

Good morning. I'm here representing Admiral Skip Bowman, director of a joint Department of Energy and Navy program known as Naval Reactors. I'd like to thank the Commission for the opportunity to testify before you today. I will be discussing the specific topics of technical culture and safety from the vantage point of responsibility for nuclear fission reactor plants in Navy ships. But I would add that my discussion has a close parallel with points made to you by the sustainability panel yesterday afternoon because it speaks to the nature of the human and cultural and capital investment that must be made to initiate and sustain a measure of success and the difficult technical challenges that lie ahead in the President's vision.

At this point, I would like to note that I am submitting, for the Commission's record, Admiral Bowman's official statement before the House Committee on Science on 29 October 2003. His statement before the House Committee on Science was made in conjunction with their review of the Columbia Accident Investigation Board reports and provides some more detailed points that I will summarize here. Next slide.

First, some background so that you better appreciate my perspective. Through Presidential Executive Order and public law, Naval Reactors, also known as N.R., is responsible for cradle-to-grave direction and oversight of fission reactors used to generate propulsion and electric power for our Navy's nuclear-powered submarines and aircraft carriers. This includes 104 naval reactors, which compares in number to the 103 civilian reactors for production of commercial electric power. They are used in some 82 warships and one research submarine, comprising over 40% of our nation's major combatant ships, and we have more than 55 years of experience in the design, manufacturing, operation, maintenance, and disposal of practical reactor plant systems operated under a wartime footing and in a most unforgiving ocean environment. Over the years, our ships

have steamed for a cumulative total of over 130 million miles, and for a perspective, that's about 250 round trips or so, give or take, to the Moon and back.

Naval Reactors can also be assigned strictly civilian nuclear reactor projects under our Department of Energy responsibilities that are not associated with the Navy or any other Department of Defense program. For example, as indicated here, we developed the nation's first pressurized water reactor for the production of electric utility power in 1957. And most recently, at the express request of the administrator of NASA, the Secretary of Energy assigned to Naval Reactors direction and oversight responsibility for civilian space nuclear reactors associated with the NASA Jupiter icy moons orbiter mission. I will not, however, comment further, provide any details connected with this new assignment, because we've only just begun to organize and plan this work. Next slide.

Now some parallels between the Navy business and the space business. In some military and civilian applications, nuclear power provides compelling advantages. Nuclear fission reactors as applied to submarines have enabled persistent covert intelligence in the adversary's front yard, provides for defensive weapons strikes up close with no warning in preparing the battlespace for other war-fighters, and provides strategic deterrence for those who would threaten us with their weapons of mass destruction.

There is similar compelling justification for our nuclear-powered aircraft carriers in the area of speed, flexibility, and war-fighting capability. Nuclear-powered naval combatants were an important part of winning the Cold War, and their special capabilities are being exploited as they are asked to perform extra hard during this new war on terror, and as an example of an engineering challenge, one of our aircraft carriers, the U.S.S. *Abraham Lincoln*, returned last year from being deployed at sea for over 9 months; that is 50% longer than normal.

In the case of civilian space exploration, nuclear fission reactors offer the prospect of mission links, as a point of interest, measured in months and years, instead of days or weeks. More capable and efficient propulsion, such as ion thrusters, to establish stable orbits in complex gravitational situations. On the order of 50 times for payload by weight and 300 times more available electric power for science instruments and probes and on the order of 400 times the current data transmission rate so that more information can be more rapidly assimilated back here on Earth.

But despite the existence of such compelling arguments for certain applications, the decision to employ nuclear power brings its own challenges, both technical and political. Technical organizations and government and industry must sustain a culture that is up to the task of managing such a complex technology, to ensure safe, reliable, robust operations in the most unforgiving of environments, whether on the oceans of the Earth or in outer space, and you must perform the technical job consistently well in order to acquire and maintain political support. Next slide.

In testimony before the House Committee on Science in October, Admiral Bowman cited the concept of mainstreaming safety as a key aspect of this culture. On the surface, this seems rather obvious, because of course everyone is responsible for safety, but saying it and doing it effectively and consistently are entirely different things. Safety has to be ingrained in every action taken by every person at every level during the course of a normal day.

Admiral Bowman highlighted four core values in his testimony to the House Science Committee to exemplify the Naval Reactors approach to safety and specifically mainstreaming of that safety, and it involves people, formality and discipline, technical excellence, and competence and responsibility. These values and approaches were instilled from the inception of the N.R. program when it was founded by then-Captain H. E. Rickover long ago. Next slide.

At the center of this cultural discussion is people. As individuals, and collectively, they can and do make a difference, when and where it matters. You must first select young, technically competent individuals of high integrity. Then you must train them right and give them as much responsibility as they can handle.

Then you must keep only the ones who can walk the right cultural walk. And then you make opportunities for them to grow both professionally and in their personal life, and then you must even continue to keep them, because you must have people who will act with the understanding that they will have to live with the consequences of their own decisions, and they must be available to pass along crucial historical knowledge for the next generation. This is especially important for nuclear and other technical endeavors where hardware lifetimes can span a decade or more. Next slide.

There is no substitute for formality and discipline; for designers, builders, operators, and maintainers of hardware, there must be a strict adherence to approved methods, procedures, and other requirements, whether the action being taken is routine, occasional, or wholly out of the ordinary. But this level of rigor and formality and discipline is equally important for the supporting technical organizations. Hearsay, rumors, opinions, assumptions, and *ad hominem* arguments have no place in engineering decision making. E-mails, phone calls, face-to-face discussions—all occur, to be sure, but are not acceptable substitutes for formal recommendations and government actions that must be made based on high-quality technical work and documented in official correspondence under the signature of the responsible individual.

Some other examples of this formality and discipline come in the form of things like critical self-examination, taking the necessary corrective action, and making sure others learn from the experience. Or during the initial stages of a new project, taking the necessary steps to engage all of those who will touch the actual hardware throughout its entire life, including those who must bury it, or to ensure that those who are the doers and those who must oversee maintain a proper professional distance so that complete and independent technical recommendations and actions are taken. And finally, where there is an opportunity to cause and raise the acceptable standards for certain things, to do so. Next slide.

Technical competence is absolutely essential. There is no place for generalists who know how to manage but do not understand the technical details of what they're managing. It is necessary to understand the difference between facts, assumptions, and analysis. It is necessary to understand the technical merits of answers to hard questions like "How do you know?" "Where else could this be a problem?" "What is the worst that could happen?" "What is the best unconstrained technical answer?" and "Why isn't that the approach being taken?"

And then there is the need to recognize and deal with the seemingly small problems with a vengeance before they really get ugly. And finally, to encourage the minority report, the dissenting opinion, and the messenger of bad news and ensuring that it gets propagated promptly up the chain of command and dealt with appropriately. Next slide.

Responsibility, a simple word but too often misunderstood in the context of what is required to safely manage complex and unforgiving technologies, such as a nuclear power plant. And unfortunately, too often relegated to a separate oversight group.

To capture the essence of this concept, I will simply cite Admiral Rickover's views on this topic. He said, and I quote:

“Responsibility is a unique concept. It can only reside and inhere in a single individual. You may share it with others, but your portion is not diminished. You may delegate it, but it is still with you. Even if you do not recognize it or admit its presence, you cannot escape it. If responsibility is rightfully yours, no evasion or ignorance or passing the blame can shift the burden to someone else. Unless you can point your finger at the man who is responsible when something goes wrong, then you have never had anyone really responsible.” And last slide.

Let me summarize. On the more specific topic of safety, I hope you got the point across: with safety, consciousness is a passion, it's a way of life, it's a goal without equal that must be woven into the fabric of organizational business every day at every level, for those technology applications that possess great both opportunity and great risk. There is no special one-size-fits-all solution, management tool, or gimmick. And safety cannot be a responsibility delegated primarily to a safety department that attempts to impose oversight on the rest of the organization.

On the more general topic of human and cultural investment, let me end by citing two points raised by Mr. Norman Augustine as delivered in an address to the Armed Forces Communications and Electronics Association in June 1993, titled, “I'm Practicing Engineering.” He cautions us to remember the other words that President Kennedy uttered in his often-cited 1961 address before Congress, for a national goal to reach the Moon, specifically that, and I quote, “There is no sense agreeing to or desiring this goal unless we are prepared to do the work and bear the burdens to make it successful.” Mr. Augustine then goes on to warn that, again I quote, “We as a nation have forgotten that the way to achieve high-tech capabilities and high-tech rewards is only via a decidedly low-tech road. That low-tech road involves commitment to well-defined goals, assurance of adequate funding, acceptance of technical setbacks, persistence in the face of occasional tragedy, and an over all stick-to-it-ness that was once a part of our national character, but more frequently today is seen a character flaw.”

I would argue that my discussion here today is about some aspects of what is required to both bear the burden, persist, and stick to it, in the interest of getting a difficult job done in a safe manner for an unforgiving technology application. Thank you.

Pete Aldridge

Thank you very much.

It's pretty clear from the deliberations of this Commission that propulsion is the enabling technology, obviously, of getting to achieve this mission. And all of you have outlined various aspects of it from modification of existing vehicles in the near term and some upgrades for the heavy lifters for the midterm and it appears an enabling technology called nuclear propulsion for the far term is really part of it.

The question I have is, How do we manage a program so important to the success of the mission? Can it be done within the existing organizational structure of NASA or the government? Clearly, the role of the Navy and nuclear reactors is very strong and is a great success story of how it's been done, but how can we put together a program for the mission of Moon, Mars and Beyond, where propulsion is such a critical piece of the achievement of the mission? We've got to manage it right. Is there a suggestion as to how to manage it right?

Byron, do you want to start? Then maybe Mike and ...

Byron Wood

Well, that's a great question, Pete. You know, one that we think about a lot. Today I think it's clear that the way we'll make this a success is if we are able to combine all of the pieces, the government piece, the industry piece, academics as a part and we make it a total team, and maybe we have to create some new organization structure that oversees that or embodies it in some way, a national vision board of directors of some kind, perhaps, that will make that happen.

Today it's a situation that I think on the government side they feel the overall responsibility, commitment to make things happen and they kind of want to hold it close to the vest.

The industry, on the other hand, thinks it has its cards and being able to carry out the mission.

You know, as I said before, rocket science is easy, putting it into practice is another story, and I think it's going to take the combined resources of all of these elements, working together for a common goal, starting with what do we need and then enlisting the Congress and enlisting the public to get behind it, to make it sustainable. Because this kind of thing has got to be sustained more than just on four-year centers, which we tend today to feel afraid of.

Pete Aldridge

Mike, do you have a comment about that?

Michael Martin

Just briefly. I would second what Byron just said. I love the Admiral Rickover quote on responsibility. When I ran across it in Jim's material the other day, I cut it out and kept it on my desk.

I'm encouraged by the move to create a new code within NASA that will be responsible for this program, and I think clear lines of responsibility and communication are going to be the key, and we seem to be starting off in the right direction. I hope we stick with it.

Pete Aldridge

We had heard some previous testimony somewhere, I can't remember where it was, about creating a special projects office for propulsion, that integrates the needs of propulsion to the requirements that are being generated by the exploration system, but to really be the focal point for integration of all the industrial, government, integration of the Navy, support for the nuclear business, all being—does that sound wild?

Byron Wood

No.

Michael Martin

No.

Pete Aldridge

OK.

Well it seems like that there's some meat there that could be considered and certainly I would think expanding the role of the Navy in nuclear thermal propulsion, just beginning on the Jupiter icy moons project, it seems like there's—there could be a bigger role of the Navy in helping NASA in the nuclear propulsion. Jim, is that outside the box?

Jim Mosquera

Well, we're only ... Well, yeah, that's a little bit out of the box. The only thing we've been assigned right now is the Jupiter icy moons orbiter mission and for that the reactor really is not a propulsion device, it is meant to produce electricity.

My comment—I guess the only comment I would have on nuclear thermal propulsion is anecdotal—because I've not worked in that area directly—is that that is one of those areas where a lot of good scientific work has been done but when you ask the question, OK, have you actually delivered production hardware, is it out there flying today? I mean, I know in our business, we continue to be surprised on a daily basis by ships that are out there operating or by the ones that we're cutting apart to go say, "So how did they do?" and those are the devils you know. The devils you don't know in the nuclear thermal propulsion business, they require a lot more work.

Pete Aldridge

I just remember that Tom Stafford [?] since this group back in the 90's when they did their work, they commented about nuclear thermal propulsion was one of the enablers that reduced the cost of going to Mars by significant factors—2, 3, 4, something of that nature, and it may be that—we talked about this before—this is not only an enabling technology for the mission but it is also a way to keep it affordable within the budget that we currently have. Les?

Les Lyles

First, let me thank all three of you for being here. I think just, like our chairman said, this is a very, very important topic and one that we all realize is perhaps the long pole in the tent to some of the things we're trying to achieve in this space vision. I'm struck by—this is a similar question to one that Pete just asked. As I look back, I note that there's been for years an organization—loosely defined, organization—that looks at integrated high-performance rocket propulsion technology. It involves all the major companies, both big and large, that are involved in propulsion technologies, each one of the Services that have work involved in rocket technology, the laboratories, et cetera, and there's at least a framework for a roadmap or a spiral review or for the types of technologies that will be brought to bear to address enabling things that need to be accomplished to significantly improve in rocket propulsion. I have two questions: One, do you think this is working? It's been going on for many, many years, every company puts resources into this particular entity. And if it is working, is it a framework or at least a beginning for the sort of integrated propulsion office like that Pete described that can bring all these things together to address the needs here?

Byron Wood

Maybe I can try that one, general. You know, I think I believe you're referring to the IHPRPT [Integrated High Payoff Rocket Propulsion Technology] [?].

Les Lyles

It is IHPRPT [?]. I didn't want to use the acronym.

Byron Wood

I mean, don't ask me to explain it, the IHPRPT [?] program. But that has been an effective program and it's gone on for some time, but part of the reason it's gone on for such a long time is because it has always suffered from underfunding and redirection and repackaging—I'll just tell you that one IHPRPT program that we are working on, we've renegotiated seven times. It needs a bigger scope of where is all this going long term. Out of the IHPRPT program has come some exciting and breakthrough technologies in the propulsion world, and that's been a very good focus for those

programs, both in materials, operational complexities of rocket engines, advancing performance and capabilities and reusabilities and all these things, and those are all very important to moving ahead, but I think we're talking about the next level up, if I could refer to what Pete was talking about. I think IHPRPT serves a very important piece of that and has done some great work, but I think we're talking maybe the next step up.

Les Lyles

OK. And I agree with that. I'm wondering whether or not if there's at least a framework that you can build upon to take that next step, or do you need to do something more radical?

Byron Wood

I think, I really feel it would need something perhaps more radical than that. It's a good first step, but I don't think it goes anywhere near far enough.

Les Lyles

OK. Michael?

Michael Martin

I would agree. IHPRPT as it's conducted today is too diffuse and we would need somewhat of a different approach.

Pete Aldridge

Paul?

Paul Spudis

Yes, Mr. Martin and Mr. Mosquera, this question is sort of directed to you jointly.

You brought up first the value of N.T.R., and nuclear thermal rockets for long extended trips, like the Mars trips. I'm wondering, how would we go about setting up a program to develop and test this? One of the reasons we don't have a lot of practical experience in N.T.R. is that it's politically unacceptable; you can't really test it on Earth. It was tested on Earth in the 60's, but you couldn't do that today.

Do you have any thoughts on how to construct a program such that we can develop the kinds of nuclear propulsion technologies we need and at the same time get them validated and tested without having a lot of legal and political problems in doing so? Do you have any thoughts on that?

Michael Martin

I am going to ask our technical expert, Mr. Cassidy, to comment on that.

Pete Aldridge

Go ahead.

Joe Cassidy

I think the key thing that we have to look at first is the architecture studies that are going on before we even make a decision, if we want to make a commitment to nuclear thermal and in the event that the architecture studies lead us in that direction, there are plans in place, I know there's several studies that have been done looking at facilities, Earth facilities that could facilitate the testing with complete scrubbing of eflons [?] and things like that.

The problem you run into is that's a big facility investment, it's not a facility that we have in existence today without major modifications. So that's why I say, I think the first step is really, assess the architecture, determine if and when you need that technology, and how does it fit and play in with the nuclear electric piece that is already being developed under Prometheus.

Pete Aldridge

Michael?

Michael Jackson

Thank you, gentlemen, for coming today. I do believe this is a very crucial part of our work to understand what you're telling us today. I have two questions, really. The first one is for you, Jim. It's a simple question. You've laid out a very, very compelling and I think important set of guideposts for us to understand, that have to be embedded in a nuclear program, if a nuclear program is to have a component in the Moon to Mars mission that the President has laid out.

Some people might look at that and say this is a reason so daunting—it's a reason not to go this direction, not to seek nuclear propulsion. So I want to sort of—seat of the pants, it seems to me, and I just want to draw it out of you, that this is all something we have done, we know how to do this and we can take this discipline to the next frontier in space.

Do you feel that there's any impediment to doing that, if we do it with discipline, and skill, and focus like you've described?

Jim Mosquera

Well, I guess I would argue, it's a necessary but not necessarily sufficient condition. As the gentleman just stated down there, there are a number of things you have to think about when somebody asks you a question like that. The first is "What are the set of requirements and what are the various ways of meeting those requirements?" and you have to sit down with all the alternatives, nuclear being one of them, and decide if that's really the way you want to go. If the requirements can only be met by some form of nuclear power, then, yes, your statement that said, "Hey, that piece has been done before," that is, "What are the cultural underpinnings you need to make something happen correctly," yes, it can be done. As far as whether it's the right thing to go do ...

Michael Jackson

Absolutely, I understand that.

Jim Mosquera

The requirements or, whether it's technically quite feasible, you know, I'll tell you quite frankly, 15 years, which is the kind of mission time folks are talking about for the Jupiter icy moons orbiter or a reactor of any type, is a very tall order, so I can't tell you today whether at the stage we're at whether that is truly feasible or not at this point.

Pete Aldridge

Neil?

Michael Jackson

Pete, the second part of that question, I really wanted to ask, it was for the rest of the panel.

Pete Aldridge

Go ahead.

Michael Jackson

We have heard testimony that encourages us to write recommendations that create not a program but a space program, but a space industry and we're very, I think, focused on the importance of trying to create an industrial base that would sustain the Moon to Mars mission, but would also

allow us to embrace other missions which are purely commercial and have purely commercial motives and incentives.

So my question really is, how—do you have any particular recommendations about how to stimulate the development of such a space industry in the early stages of doing this Moon to Mars work, and on the propulsion? What type of procurement tools, incentives, business relationships, competition structures like we looked at in the Defense Department and other worlds would maximize the prospect of giving the best type of financial incentives to the private sector to develop the type of propulsion in particular that we need to meet this mission requirement?

If you could throw away the way we do business today and start from scratch, what would it look like?

Byron Wood

That's a good one. Can we do that?

Michael Jackson

Why not?

Byron Wood

I think, you know, that the mission—you know, I talked about how you get from the surface of the Earth to space and I think that's an issue we have to address first, and perhaps it can be addressed at the same time, but when we're talking about going to the Moon and then to Mars, and I really feel that the only way that we're ever going to make a firm commitment to go to Mars is if it is in the context of nuclear thermal, I mean, I don't know if we'll ever convince ourselves that we can send astronauts off for three years and never see them come back for three years and feel comfortable with that, whereas nuclear thermal can make some significant improvements in that, so— But that is a very complex proposition.

You know, Jim has taken on the Navy, he is *the* nuclear resource for this country. I think if we talk about going to Mars over the long haul, we've got to make this a U.S. initiative, not one that— where we compete and duke it out with each other. We need to clearly understand the requirements. This is to me is the next national commitment to do something, and it's fraught with hazard, as Jim's briefing very clearly put out.

We're dealing with devices here which, based on everything we can do to make them as safe as possible, there's still a mystique of safety about them, and if there were any kind of an incident or problem, political issues would immediately come to bear, so we've got to do this right. We can't afford to stumble when we put a nuclear device in space and, moreover, depend on that nuclear device to take astronauts to someplace that no one has ever been before, so I think we're talking about a whole new structure here, a national vision company, if you will, that is made up of

members of government, industry, and, you know, and that kind of goes against the grain perhaps of how procurement is done in this country, but I think we're beyond that for this mission. This is something that transcends the kinds of things that we thought about in the past.

These projects are too important and too big to be managed in the classical sense or we'll never get there, and I think that's what the last 20 years has shown us. We can't do this this way. It has to change.

Pete Aldridge

Michael, do you have anything to add?

Michael Martin

You know, we all hope and work for better, improved working relationships in government and industry, and I think many areas have come a long ways, we can do better there. I'd go back and repeat some things that we talked about earlier. I'd go back to setting requirements properly to begin with and then maybe not worrying so much about what is all this going to cost? Worrying more about what's affordable in the near term and make sure that we tailor a program that has clearly defined requirements, that allows us to have realistic budgets and realistic schedules and amounts that are affordable and achievable so we start to build a momentum of success early in the program.

Pete Aldridge

Neil?

Neil Tyson

Mr. Wood, I was intrigued by one of your diagrams that showed the run of employees in the propulsion—in Rocketdyne, I guess that was—running from 1945 to the present day. I have a very simple question. I don't know how easy the answer is. There was quite a ramp-up going into the Apollo-era generation over just a very short time interval and I'm just wondering, What was the background on that workforce brought in to this brand-new industry represented by NASA and not only that, the dropoff after the Apollo program going very low and just to the few thousands and then a ramp-up again—with that second ramp-up, the Shuttle base ramp-up—were those new people coming into that workforce or were you tapping some of the folks who were from the Apollo era, and if you get new people, what legacy are you losing? Could you just sort of react to this roller coaster?

Byron Wood

Thank you for asking the question. The phenomenon of that, the initial buildup of course was—it was a great inspiration to the technical workforce at that time. The engineers were looking—there were a lot of engineers were looking for employment in those days. The Cold War made it a very convenient place for them to go in a very exciting industry for them to get started on.

The buildup of the Apollo program kind of set the standard in engineering and science in those days, and the rest of the commercial and private and government industries all came along behind it, so that when the Apollo program ended, there were plenty of jobs for those people to go to and they went to them in droves. And what was left behind was a very small competency, so that when we built back up for the Shuttle program, we started all over again. Very few people came back. They were all satisfied that they had jobs that they liked, and so we built it again. And then as the Shuttle program has evolved, we're now in the next cycle. And as I look out into the industry today, as we build up again, we will largely have to build out of new people. And college grads are much more scarce these days.

Our workforce's availability in colleges is not as available as it used to be because by and large the content of foreign students has gone up and we are precluded from hiring foreign students, which I believe is a mistake in itself, so the next growth is going to be tougher, but it will have to be growth out of our college ranks and we'll have to pay the price in the time it takes to do it.

Paul Spudis

They can't be efficient, obviously, so—

Byron Wood

No—

Paul Spudis

Presumably you're looking for stable funding—

Byron Wood

Exactly.

Paul Spudis

As you testified already, stable funding, over this plan which obviously will need to go decades.

Byron Wood

Exactly.

Robert Walker

Byron, you made an eloquent plea, I thought, for the retaining of the American capability of in propulsion. But considering the fact that this has to be affordable, it has to be sustainable, it has to be credible, how far away are we from having a program that fits those parameters that can be done at the same cost as taking humans to orbit in a Russian Soyuz or taking goods to orbit in a Russian vehicle?

Byron Wood

Well, again, I think we have to come back and really look at the requirements and roadmap of what we want to do. I think in a lot of people's minds, that, Well, we're going to need a lot of mass in space, so here's what we'll do: We'll take all of our EELV's and we'll just keep stacking them together, put a rubber band around them and launch a big thing. Well—and that sounds good, but the problem with it is, is the more things you launch in one package, the less reliable it is.

We can't afford to be less reliable in this program. We're going to be putting nuclear payloads in orbit. We've got to go back and look at how can we do this program and make it reliable.

I think we can use a lot of the elements of what we have. For example, one kind of a vehicle that we've looked at would be taking one version of an EELV as a booster, marrying it with the other version EELV and putting a Shuttle main engine upper stage on it.

That kind of vehicle can approach 70 metric tons of capability. Two of those starts to approach a Saturn V, so we have the capability out there. What we need to do is look and see do we have the reliability and confidence in it that we're willing to commit a nuclear payload or humans to it. I don't think we're that far away.

Robert Walker

One of the reasons why we might look at reaching out to the international community is because there are a set of assets out there that can be bought at fairly inexpensive prices, to do some of the missions.

My real issue is, yeah, I think there's a lot of interesting stuff that we presently have or that could be developed in the relatively near term, that could be fit inside the program. The issue is, how do you do that in a way it's affordable? Are you telling us that you think that that integration can be done in a way which is affordable and competitive with that which is already available to us in the international regime?

Byron Wood

In the near term, Congressman, I think we can. You know, I think we've demonstrated an EELV program and we can make a low-cost propulsion. I think we've demonstrated we can develop it quickly and that we can make it reliable.

I think it's in the cards there, and I think we need to carefully consider the foreign capability and the price and cost of those assets. The thing we have to be very careful of from my point of view is that we've got to be careful that we don't put ourselves in a national security issue of having to rely on offshore resources over the near term or long term. So as long as we can play with those parameters, I think we can come up with concepts that will serve the needs of the vision near term and evolve those requirements and needs over the long term and make it affordable and make it fit the funding wedge if you would that this vision requires.

Pete Aldridge

Maria?

Maria Zuber

This is a follow-up on the topic that Neil raised about the workforce issues. Is our country training enough nuclear engineers and physicists for you to hire, and what sort of programs are we going to need assuming that the answer is no, which I can envision? Is there enough of a capability around now even to run the good internship programs that would be needed and other sorts of creative things to get with the engineering students to be going into this area, because it hasn't been a traditional growth area in technical universities?

Byron Wood

Well, the people that come to work in our industry are inspired by what they will work on. The people that come to our industry, as long as there is employment for them, they tend to stay with the industry. Our attrition rate is very low as long as there's work. But that's the Achilles' heel in it, is we tend to be very cyclical in terms to how to have programs that excite the people that come out of colleges. They want to be challenged. Many of the young students that we see coming out of colleges today are looking for the challenge first and the security second, which is kind of a reversal from the earlier days. I don't think we're training enough—anywhere near enough engineers and scientists, particularly in nuclear fields today, but on the other hand, if we were, we don't have the jobs for them to go to. So there's—we haven't completed the equation. We need the—you know, the equation has to have two sides to it to equal each other and today they don't.

Robert Walker

I think an analogy is that in our factories: we've learned that push systems are not necessarily effective and what you want are pull systems, and I applaud the discussions and the efforts being made on the educational front, but that's the push side of the equation, and I agree with Byron, what attracts people to our industry is the opportunity to work on exciting projects, and if we had more time I could tell you great anecdotes about 25- and 27-year-old people that I've seen in the last two years experience things that they never imagined they would be able to experience, and we own them. They'll be in this business for the rest of their working lives as long as we continue to have good projects for them to work on and reasonable job security.

Jim Mosquera

In our program, we do have programs to aggressively recruit all forms of engineers. It's a bit of a misnomer to think that being a nuclear engineering program, you probably don't have mostly nuclear engineers. You have to draw from all facets of engineering, but your question is well founded. There does need to be some more attention paid to nuclear engineering, and we're doing that. I'd like to add one additional clarifying point: all of you have referred to me at one point or another as part of the Navy—the Naval Reactors program—that's true, but I want to make sure you understand that our responsibilities for the JiMo mission are a D.o.E. responsibility, not a Navy or a D.o.D. activity.

Pete Aldridge

Les?

Les Lyles

Byron, you mentioned reliability a couple of times, and both in the context of safety for launching nuclear payloads and also [power plant sources?] and also man rating. I'm very familiar with the reliability and the robustness that we've built into the RS-68 and the [REL-10?] and today's generation engines. So when you talk about we're almost there in terms of reliability to get to what you consider to be the right level of man rating, are we talking hundreds of millions of dollars in years or in tens of millions of dollars in weeks or months to actually make that happen?

Byron Wood

Well, I think generally you have to balance the question of what the size of the mission, OK? If we talk about assembling things in space, I'm not sure we've done the complete analysis about what's the reliability of that.

Today I think we have some very reliable vehicles that could provide 8, 10 metric tons to orbit, but I fear that the kind of missions we're talking about are many multiples of that, which means multiple missions. You know, and so we need to balance how many missions do we want to have with the idea of some assembly in space versus how many times can we put it up and face the unreliability of the multiple times of putting it up, versus a bigger vehicle that can put out more that's less reliable than a smaller vehicle.

You know, and the only point I'm making is I think we have readily available to us the capability to put our arms around the near-term capability to do what I think the vision talks about. The vision doesn't say we're going to go to Mars tomorrow, OK?

I think we've got a pretty good roadmap, there's some pretty good building blocks to get where we need to go, but to make that ultimate leap in the end, to the Saturn V-class types of payloads, there's a lot of study that needs to be done with respect to the reliability of the launch vehicle and the reliability of what can we do in assembly in space. Certainly, the Space Station has demonstrated our capability to do precision large-structure, very successful assembly in space. Space Station is a marvelous example of that, and so we need to look at that experience and balance that, but I think the solution is there.

Les Lyles

Thank you.

Pete Aldridge

Neil?

Neil Tyson

Yeah, I've got a quick question. I think we all recognize that the nuclear frontier in propulsion would not be without political resistance. What I ask of you is, Is it not without political resistance because it is in fact not as safe as people say it is, or that it is as safe as people say it is, but the industry has failed to convey that fact? I don't mean to sound blunt, but we want to make sure this vision succeeds and we need to know every possible obstacle that could be in the way. If one them is the public is under-informed about the safety of this, then we would welcome advice on what needs to happen differently going forward.

Byron Wood

Well, in the work that we have done, in support of Prometheus and JiMo, there's a lot of things that need to be done to go back and reaffirm all of the lessons learned in terms of safety of nuclear payloads. I frankly think that we can and do have safe nuclear protection for launch to space. I don't think we have communicated that and made the public aware of it. I don't think at this point

in time we are dealing with, you know, something we don't want to talk about and that isn't safe. I believe it is safe. I believe we can make these things and have it perform as admirably as they do on aircraft carriers.

I think there's a lot of work that needs to be done before we make that commitment to go to space, but I think it's easily—not easily—but is achievable, and I think we need to be upfront with the public about that and make them aware of here's all the things that we are doing in the realm of safety.

For example, in the case of the JiMo program, we will launch with a passive deactivated nuclear device; it will not be active on the launch pad. Now, you still have nuclear material, but there are any number of safety measures that have been and are being and will be put in place for the JiMo program that I think everyone needs to be aware of.

Pete Aldridge

There's some who will argue that the nuclear reactor program in the Navy of course is operating in submarines in an environment that's much more severe than would be in space and has operated it for years and years in a very safe environment, safety record, so it's good. We've jumped from conventional to nuclear pretty quick. One last question: Is there some new technologies in propulsion coming along that might make that jump different? Is there something happening in the technology field that would be also useful for us to explore, maybe the giant leap forward in some area that we maybe ought to spend a little money on?

Byron Wood

Well, I read a lot. I have many of my top scientists at my company forever probing the academic community and wherever they can, where are there ideas out there, you know, the first person to come forward with a real valid antigravity approach will be embraced by all of us—

Unidentified speaker

Yes.

Unidentified speaker

And make a lot of money.

Byron Wood

And make a lot of money.

I think there's a lot of embryonic work going on out there in those kinds of things. Unfortunately, they worked well in the laboratory, but they worked well in the laboratory because they have a room like this auditorium full of equipment to make them work, which means that they aren't going to go very far. But over time, I'm hopeful that we will come up—you know, mother nature has been unkind to us over all these years and requiring that we have a thrust-to-weight ratio of more than one if we want to go anywhere, and I fear that that will be the case for some time, but I don't want to make anyone think that the possibility isn't out there somewhere and we should look for those nuggets and, you know, put some effort behind them.

Pete Aldridge

Mike, have you got any IR&D [independent research and development] going in this area?

Michael Martin

My concise answer would be no, but maybe we'll see if Julie or Joe has any thoughts that—

Pete Aldridge

Yeah, Julie, go ahead.

Julie van Kleeck

It's possible that some of the advances in chemical propulsion, we're looking at advanced materials, also some of the computing tools and advanced processes we're putting in place now will probably help us bridge the gap a little better than we might have been able to do in the 60's, You know, even though we've been in leaner times, probably over the last several decades in propulsion, there have been specific advances that take advantage of modern computing tools and the capabilities there that will probably reap some benefit when you go try to bridge that gap.

Pete Aldridge

Thank you. Well, we've run out of time again. I would like to thank the panel for coming and sharing with us your thoughts. It's been very enlightening, and we thank you for it. Thank you very much.

While we change the panel and the name tags, we'll take about a 10-minute break.

Pete Aldridge

“The Prospects for Space Prosperity” is the title of our next panel. The whole subject of prosperity and competitiveness is one of the major themes this Commission is addressing. And we’re pleased to have two distinguished panelists to present information related to that theme.

Dr. Stan Rosen is the director of strategic development and integration for Boeing Satellite Systems and Chairman of the California Space Authority board of directors. Dr. Rosen has also led the Hughes Electronics Aerospace and Missile Defense System Planning and was a strategic planning director for Hughes Defense Systems.

James Benson is the founder and chairman and CEO of SpaceDev. He brings 30 years of successful hands-on high-tech entrepreneurial and management experience to SpaceDev and also has brought experience working with global resource issues and economics energy policy, advanced technology assessment, and governmental policy, and what did you do in your spare time?

James Benson

Made money.

Pete Aldridge

Good for you. I believe we’ve got a lot to learn from Dr. Rosen and Mr. Benson, so, Stan, we’ll ...

Robert Walker

Mr. Chairman.

Pete Aldridge

Yes, Bob?

Robert Walker

Since I serve on the SpaceDev board, I am going to recuse myself from any activities with regard to Mr. Benson.

Pete Aldridge

I understand.

James Benson

You can shoot at me. It's OK.

Pete Aldridge

And probably will. Stan?

Stan Rosen

Mr. Aldridge, good morning, again, members of the commission. You know, Byron Wood on the last panel was here from Boeing and although I work for Boeing and, coincidentally, in light of yesterday's presentation, I should mention, was also involved in bringing Space Camp to southern California and in a public space-oriented exposition for California, I'm not here to represent any of those entities. I'm here to represent CSA [the California Space Authority].

I want to of course thank you for the opportunity to present the views of CSA. If I could have the first chart. We will talk about who CSA is. And it's a statewide, nonprofit organization, and we're here to talk to you about the space exploration initiative that was announced by the President. And we feel it's very appropriate that CSA have the opportunity to share our perspectives with the Commission, since this, the California Space Enterprise writ large, which has long been a leader in the U.S. space program, will likely play a significant role in the achievement of the goals and objectives set forward by the President.

If I could have the next slide, please. Summarizes the fact that the California Space Enterprise community, our industry, our academia and workforce is a large portion of this nation's, and the world's, space capabilities, and CSA was created to provide a coordinated voice for this enterprise, and of course, we, on behalf of California Space Enterprise, welcome this Commission to California.

Let me first state that the California Space Authority supports the initiative very strongly, including all of its goals and objectives, which you know what they are explicitly, I won't elaborate them here. Furthermore, we believe, having looked at it, that a reasonable set of programs with meaningful and timely milestones can be executed within affordable budgets. We recognize that there are many challenges on the path of all of those who will implement this initiative, including the establishment of the proper management structure, developing appropriate technology, consideration of the effects on youth and education, and the overall sustainability of our civilization's expansion into space. We're going to have comments regarding each of these topics in the broader overall context that you've set up for this panel of the initiatives, implications, for competitiveness, and prosperity.

For reasons that I will soon hopefully make clear in the presentation, it's probably appropriate—and we recommend—that a new name be adopted as we discuss this initiative—a name not associated with a past administration's program or even with the current president, a name that

could be more easily understood by the public and is not limited to exploration. Therefore, along with others who will appear before you hopefully in the future, CSA is recommending that this initiative be referred to as Moon, Mars and Beyond as opposed to a space exploration initiative. The California Space Authority believes that the challenges of the Moon, Mars and Beyond initiative can successfully be met by addressing and consistently emphasizing four major themes regardless of who occupies the White House or who controls Congress. These themes should be tailored and communicated to different audiences, including government leaders at the federal, state, and local levels, as well as to the general public.

Next slide, please. Perhaps the most important factor in addressing the issues facing this Commission is that, in the longer term, the course that you're contemplating—and the course that's being laid out—is not limited to exploration at all. In fact, it's about opening up a new frontier for human development. And it's been well demonstrated that space technology and space capabilities can in fact provide many benefits for our civilization. And in my testimony, written testimony, I go into what those are a little bit, and you're very familiar with them.

But now it's time for the next step. And we believe that human operations on the Moon, for example, can have as significant an impact for life on Earth as has been obtained from operations in geosynchronous orbit. The Moon has many unique, unexploited characteristics, which we can discuss in the Q & A if you want, and constructing large, distributed facilities on the lunar surface is a job which is uniquely suited to humans. If you ask, "What is the role of humans in space?" that's one that they are uniquely suited for. From the lunar surface, use of recently emerging technologies for such functions as power production—we talked about nuclear and solar power production—information collection and processing, especially with distributed apertures, high-data-rate communications, power beaming, propulsion, and space transportation, innovations in all these areas can potentially revolutionize operations in Earth orbit and elsewhere in the Earth's neighborhood. The initiative that you're contemplating will open the path to these and many other capabilities. CSA and its partner companies and organizations have started preliminary studies of these unexplored potentials of use of the lunar surface. We believe that only by explaining and pursuing the revolutionary potential of such expansion of civilization will this initiative receive the long-term support it desires. The capabilities I've alluded to have significance not only for science but also for civil, commercial, and potentially national security applications. And longer-term operations such as supplying transportation, power, communications, and other utilities in the Earth-Moon system are roles that can eventually be assumed by the private sector.

Because these implications are truly multifunctional and cross sectors, a proper management structure must coordinate and represent multiple government and private interests. For this reason, among others, we recommend reconstitution of the National Space Council within the White House and strengthening the space caucuses within Congress. Moreover, the infrastructure and technology developed for the initiative should keep the long-range operational prospects I have alluded to in mind. The technologies all tie together. Identifying and understanding these longer-term potentials is an important and critical near-term and continuing activity which may not be receiving enough emphasis.

My second point: We want to emphasize, as have many others, that the inspirational quality of such a long-term vision and the opportunity to develop new ideas that have not been explored, will excite students and professionals alike to develop the skills needed to take these next significant steps. And more importantly, in doing so, they will create the capabilities for future national and international well-being in areas well beyond space technology. We need skilled engineers and technologists, and this initiative since its announcement has already demonstrated its ability for inspiration.

Space exploration and development will continue to inspire students to study math, science, and technology and will create a new generation of skilled systems engineers, which is something that you all know we need badly. This inspiration can and should be supplemented by opportunities for students to participate hands on in ongoing space exploration activities. Following the example of JPL with the Mars rovers. Moreover, we strongly recommend that young people be intimately involved in laying out the plans and strategies for this initiative, including looking for ways to capitalize on our lunar operations capabilities. But, I must say, on the other hand, we must not drop the ball and disappoint the innovators of the future by failing to continue to progress outward into space.

My third point: Space exploration and development will help the United States to continue its role as a world leader. The United States is the only country ever to land astronauts on another body, and when it did, it was a time of great national pride. The citizens of the United States will certainly take pride when the nation's flag is again accompanied by our citizens on the Moon, and added for the first time to the surface of Mars and other planets. And the capabilities that I've talked about which were derived from six lunar operations will certainly provoke future national strength in all the domains I've mentioned.

Final point: Lastly, space exploration can improve the United States' relationships with other countries, by providing opportunities for international participation in this very bold and endless venture. The likelihood of other countries' participation we feel was significantly enhanced by President Bush's decision to complete the International Space Station. CSA believes that outward expansion can and should remain a strong, unifying global theme.

So it's the view of the California Space Authority that understanding the implications of these four themes will help to strengthen the Moon, Mars and Beyond initiative throughout its lifespan. It should now be clear it's our view that the initiative is a national imperative, critical to the continuation of the United States' quality of life, and global competitiveness, through the creation of new jobs, new technologies, and new operational capabilities.

Final slide. So once again, I thank you for the opportunity to present the views of the California Space Authority on the Moon, Mars, and Beyond initiative. CSA will continue to be a strong voice in support of this activity. In fact, we've already been vocal supporters of this initiative in Washington and in Sacramento. And we're currently promoting a resolution, which was drafted in the California Assembly, in support of these activities and programs. And we'll submit that for the record. Andrea Seastrand, who is the executive director of CSA, is here, and she and I look forward to the opportunity to answer any questions you may have about this statement. Thanks very much.

Pete Aldridge

Thank you, Stan. Mr. Benson?

James Benson

Thank you very much for inviting me. I'm very happy to come here and shed some—give you some new ideas. I think you probably will not have heard some of the ideas that I'm going to be describing to you. I know a few of you on the panel, I hope maybe over the years to get to know some of you better, and in addition to Andrea out in the audience I would also like to acknowledge Rusty Schweickart, one of our Apollo astronauts, Steve Durst of Lunar Enterprises, and Scott Hubbard, who is head of NASA Ames research. So we have a good audience here.

First slide, please. One of the things that I'd like to spend just a minute or two on: describing my background and why I think I'm here. I spent about 30 years in the computer field from the introduction of the IBM mainframes in the 60's, the IBM 360s and I helped design and develop the world's largest time-sharing operating system on the CDC 6000s.

Do we have my slides?

Great. OK.

Pete Aldridge

Somebody's probably working on it now

James Benson

If they have a PC I have it on a Memory Stick here. I thought I was told last night that this was up and running. All right. I'll assume they're working on it. I spent about 30 years in the computer field in and out. I invented full-text indexing, searching and retrieval in 1984. Before then you could not search for a word or a phrase. I built my company, Compusearch, for 11 years and sold it in 1995 for millions and retired at 50, only to become bored at 50 and a half. And I looked around for some challenge to wake up to in the morning and after about a year and a half of research, I realized that space is just like the computer industry was about 20 years ago: it's bloated, bogged down, and basically lives and breathes by the mainframe mentality, that bigger is better. We have large corporations who are afraid of innovation and only fly technology if it's already flown before, and it's like the old IBM FUD factor of fear, uncertainty, and doubt. Whoever got fired by going with an IBM because it was the risk-free thing to do? That's the mentality that we have in the space field today, and I decided to come in as a geologist who had made money in the computer field to try to introduce modern commercial business practices based on the microcomputer way of thinking, that you can do things with industry standards and hardware-software interfaces and by

bringing modern, low-cost, high-performance technology to the space industry, where that simply hasn't been done before. And my slide show, which is supposed to be up here, has a variety and ...

Pete Aldridge

We have it in our book here.

James Benson

I wish I had a copy. Then I could address it as I went along. The—it's important because each one of the slides shows technology that SpaceDev has already developed and the successes that we have already had in the space field. We spent 1997 getting organized on paper, '98 getting organized from a corporate point of view, and in 1999, we started winning our first contracts. So the successes that I'm going to talk about—thank you very much—the successes I'm going to talk about have really only come—have only taken place since the year 2000.

You can see on the vision page, SpaceDev is a publicly traded corporation, and we have decided to build a private space program. One step at a time, starting small. I don't have time to tell you why originally I started SpaceDev, but it had to do with NASA and I ran into a brick wall, wasted two years and \$2 million, and backed up and said, "Okay, we're just going to have to build a program from scratch, one small technology at a time." So our goal is to make space happen. And if I were going to change the title, I would change the title to the Moon, Asteroids, Mars and Beyond to the Stars. So let's have a real challenge here. So a SpaceDev goal was to help create self-sufficient human settlements on the Moon, near-Earth asteroids, Mars and beyond to the stars.

Today's problem: 20 years ago the computer industry was bogged down and dominated by large bureaucratic mainframe computers that believe bigger is better. Today the space industry is bogged down and dominated by large, bureaucratic mainframe-like companies that believe bigger is better. Revolutionary methods are needed. The computer industry was revolutionized and the global economy stimulated by smaller innovative companies that implemented the microcomputer way of thinking that small is beautiful. No one took Apple computers being built in a garage by Steve Wozniak and Steve Jobs as very interesting and even looked down on them, yet within 20 years, all the companies that I worked with—Burrows, Honeywell, Sperry, Univac, CDC—are gone, and only IBM remains, yet Hewlett-Packard, Compaq, and now Gateway and Dell and those companies have really dominated and the entire global economy has been changed simply because of doing things smaller, quicker, and with more modern technology. So SpaceDev believes in and is successfully implementing the microcomputer way of thinking in the space industry in order to stimulate the economy and insist humanity explore and develop the almost unlimited natural resources in space.

Now, if you take a look at our technology roadmap, you can see what our vision is. On the lower axis along the bottom, our launch vehicle half and on the upper side, you can see more things related to unmanned planetary landers, resource utilization, and so forth. In the lower left-hand corner, those green shaded boxes, we've already accomplished. And the ones in the yellow, we are

already under contract working on, so within our 20-year plan, we pretty much accomplished everything within that first five years. We have the world's first orbiting Internet node in place now—that's a NASA mission called CHIPSat that we launched about 15 months ago, it's 60 kilograms, it's the size of a suitcase, it's the world's first orbiting node on the Internet, it's the world's first satellite whose mission control and operation center is a laptop computer anywhere in the world with a dial tone.

And some of you probably know that, yes, there are new things happening in propulsion. In fact, our hybrid rocket motors have propelled people toward space twice; once was on the 100th anniversary of the Wright brothers' powered flight December 17th, when a SpaceDev hybrid rocket motor powered a pilot to Mach 1.2 in 15 seconds almost straight up on Burt Rutan's Spaceship One. That rocket motor was developed by us in less than one year for less than \$1 million. It's the world's largest of its kind and we don't have to man-rate it. It's already human rated because it burns rubber and laughing gas. There's nothing safer than hybrid rocket motors, and you'll see that we're working on a microsat launch vehicle with the Air Force Research Lab, we're working on orbital maneuvering and transfer vehicles, and while CHIPSat originally started off as a \$5 million fixed-price contract after NASA lost two faster-better-cheaper missions—and, by the way, faster-better-cheaper became a joke within the industry by the big guys: Which two out of three do you want? SpaceDev is showing that you can have all three. You can have faster and better and cheaper. We did that satellite from scratch—developing all the subsystems, all the software, nothing had ever flown before—for \$7.5 million in three years, and now we've gotten a contract for \$42 million for six more satellites for \$7 million and, like the computer industry, they're going to be twice as powerful as the previous satellite at the same cost, so we really are bringing the microcomputer way of thinking, and our technology roadmap relies on water propulsion systems. Water is the most abundant substance in the universe and if you want long-term propulsion in space, solar thermal water is the way to go. The water is already in space. We need to simply go get it from the near-Earth asteroids that are dormant comets and start using solar-thermal and water as a propulsion.

SpaceDev's small sat success—you can see on the slide how small that satellite is, with some of the proud team. That satellite was developed by six people; one of them was a 24-year-old Harvard EE who developed all the hardware and software by himself. And that's all on orbit right now, still working, still ticking, after surviving some of the worst recorded solar storms in history. The next slide, propulsion successes: you can see the photograph of Spaceship One on its first historic flight being piloted almost straight up, powered by the rocket motor on the bottom. That was developed by three engineers and two technicians in less than a year for less than a million dollars. It's already safe, as I said, because it simply burns rubber and nitrous oxide.

There's my PowerPoint projection up there.

We'll just continue this way. Low-cost Moon and Mars missions. In 1999, SpaceDev developed mission and spacecraft designs for JPL called Mars micro-missions. We teamed with Boeing to bid on it, but when NASA came out with an RFP that stated all the highest evaluation points would go to all those companies that had successfully flown Mars operations (namely Lockheed), Boeing bowed out, we bowed out, and Boeing paid us then to design a lunar orbiter, a high-definition TV

live-streaming video orbiter, whose estimated cost was less than \$25 million, As were the Mars micro-mission data relay orbiters, less than \$25 million.

On the right-hand side, last year, we designed and developed a lunar dish observatory for Lunar Enterprise Corporation. We believe that we can land a small dish on the south pole of the Moon for less than \$35 million. The next slide: human spaceflight. This is just a chart; I think I neglected to say that these are my own personal opinions—while I'm talking about SpaceDev and our accomplishments, any projections or opinions that I'm giving are mine. We're a publicly traded company. I have to be careful how I frame things.

So, on the human spaceflight slide, please notice that we put the Shuttle in there as a size example. On the left-hand side are common core boosters that we're developing for our small launch vehicle under an Air Force contract, and by putting an existing airframe onto the side of those, we believe we can put three people on orbit for 1/10 or 1/5 the cost of a Shuttle and probably more safely because again they're hybrid rocket motors. So we're already doing suborbital flights with those motors, and there's no reason why they can't be scaled up. Large hybrid rocket motors have already been done of that size.

Missions beyond Earth orbit: We believe that there are a wide variety of scientifically and economically attractive missions to the Moon, near-Earth asteroids, and Mars are now possible and affordable if conducted by smaller companies, with the right stuff. Not just companies that say they can, but companies that have started small and have made accomplishments, one after one, in a stepping-stone fashion as SpaceDev has done.

Finally, my recommendations: I recommend that the current and future administrations, Congress and NASA administrators who have the right stuff work together cooperatively and aggressively to stop treating NASA, its centers and its activities as pork barrel job-maintenance programs. Yeah, I'm sorry, but it has to be said, we all know it's true, there's a lot of that going on, and it's just the nature of our economy. This is the greatest economy in the world, it's the greatest country in the world, but let's face it: there's a lot of politics involved in how budgets work and supporting these centers.

Number two, stop treating big-company programs as entitlements. I've worked with these big companies and they need multibillion-dollar programs to keep all their jobs going, but they're not doing the innovative risk-taking stuff that we are, and they are not entitled to that money. They are not entitled to those billions. Staff NASA from the top down with A-team players who have successful private-sector startup track records and who have excelled in the development of lower-cost, smaller, innovative, microcomputer-like technologies. And finally recognize and reward the small, innovative companies that give NASA successes by delivering smaller, lower-cost, higher-performance systems and missions.

That's about all I have to say for right now. I wish I had a couple of hours and I could get into some substance, but I want to leave you with the feeling that a lot of what you're hearing is business as usual, and please be aware that there are companies and people out there who are doing things in a smaller, more aggressive and innovative way, and NASA really needs to start embracing that and not treating those as anomalies. Thank you.

Pete Aldridge

Thank you very much.

It sounds like, Mr. Benson, that you're requesting a kind of a cultural change in NASA. Am I interpreting that correctly?

James Benson

Yes, very much so, that's exactly what I'm after. Donald Rumsfeld has been talking a lot about transformational technologies. Back in the 60's and 70's, we called those paradigm shifts, but this technology is here today and it can be implemented, and that's the biggest problem that we have, is the space priesthood that NASA has gathered around its stuff that sort of intimates that nobody can do space but NASA and that's simply not the case. NASA really needs to embrace commercial business practices, and with this administration in particular, you would think that there would be strong encouragement for innovative, job-creating companies, which we all know is where jobs are created, in the smaller startup, innovative companies, so, yes, corporate change is definitely needed and it's very difficult to do.

Pete Aldridge

Stan, you laid out a couple of themes for the—for how we proceed. Is it your perception that we are organized and structured within the current organization to accomplish those themes?

Stan Rosen

The short answer is no. The two main points that we made about organization had to do with the way that the government is structured to integrate across sectors, namely the Space Council and congressional caucuses. There are other management artifacts we could discuss as well—the point being that if it's treated as a NASA initiative alone, in the long term, and with NASA's implications in mind, exploration and science primarily, you come up with one set of conclusions and one management structure. If it's looked at in the broader context, you'll come up with other organizational and management approaches. I couldn't tell you what they are.

Pete Aldridge

One other question, which has been related to the sustainability of this mission over decades and multiple administrations, has to do with affordability, has to do with prosperity and the contribution it makes back to the economy and for the competitiveness of the nation, and there have been a lot of comments made about this is going to cost \$500 billion or \$400 billion or a trillion dollars. Have you guys done any analysis of the return on investment in the space business? OK, you put a billion

dollars into this particular area and it returns back? I know we used to do analysis like that, \$3 billion back to the community.

Stan Rosen

I think, Mr. Aldridge, you're aware if you say, "You guys," CSA has not independently charted those kind of studies, but the community—we all together—have, as you're probably aware. There's been a lot of investigation of both direct and indirect benefits. The direct benefits are the ones that I hear the least about, by the way, and that is, what does it mean to have a communications satellite industry, what does it mean to have weather monitoring from space, what does it mean to have GPS? Those are the direct benefits, and they're extraordinary.

The secondary benefits, the indirect benefits—the technology spinoffs and ancillary industries and all that—are probably even larger, and there's been an effort throughout the years for NASA, as you know, to track spinoffs and tell those stories because they're under-appreciated. And then maybe the third level of benefits is all the jobs that come out of these and how jobs then ripple into the society, not just the jobs that derive directly from working on space and from space services etc., etc., but from the communities that benefit when those folks go home and buy groceries, etc. So those large-scale implications are not something that CSA has quantified, but I think the industry has.

Pete Aldridge

We had testimony someplace, again, I can't remember, that said, well every dollar spent for space is spent on Earth, so it does make a big difference in that area.

James Benson

May I comment on that, please?

Pete Aldridge

Sure, please.

James Benson

A few decades ago writer and scientist Robert Heinlein said that when we get to Earth orbit we're half way to anywhere. And what he meant was the amount of energy that it takes to get to Earth orbit is about equal to the amount of energy it takes to get from Earth orbit to anywhere in the solar system. Yet for the last few decades, by the time we get to Earth orbit, we're running on empty, and we've just been going around in circles. Between Earth and Mars is a minor asteroid belt, which is believed to be about 5% made up of 5% dormant comets. That's a lot of water. Water is H₂O.

That's rocket fuel. Water is the most abundant substance in the universe and in the solar system, and it's right out there waiting for us to go get it. It's the white gold of space, so with the Bush Administration's family ties to oil, black gold, you know, why aren't we looking at white gold in space? So, if we could refill on orbit, then we can go anywhere we want to go, and simply extracting water from a frozen block of ice shouldn't be that difficult, and then we'll be creating jobs beyond the Earth orbit and creating an economy that expands and isn't just left to the cradle of humanity.

Pete Aldridge

Les?

Les Lyles

Mr. Benson, you made some compelling comments, and I think that some of us would resonate with, and—but then you also mention the term “smaller companies with the right stuff.” How would you define or how would we or a future or even a current administrator of NASA define which companies have the right stuff? What does that really mean, and sorting that out from companies that don't have the right stuff, that can be a throwaway term, but it could be very important so that the right choices are made as to who gets involved in this.

James Benson

That's a really good question. In 1996, after about a year of research in what I wanted to do next after I retired, I started reading—I became interested in entrepreneurial space activities and I attended a conference and obtained about half a dozen different business plans from people starting up—Pioneer Rocket Plane from Pete Conrad and Universal Space Lines and so forth, and the thing that struck me about all of these business plans were three things in common: None of them had any management experience or successful track record. Secondly, none of them had ever actually designed or built anything, and the worst was, every one of them required at least one piece of nonexistent technology and, in the case of rotary rockets, at least six.

So I decided not to invest in those enterprises but to invest in myself because I had the belief—I had faith in my own track record, so I think to answer your question, you need to look with companies that are headed by people who have a successful track record and who are willing to start small. I had big ideas when I started SpaceDev and I made some mistakes and I'll be the first to admit it, but once I realized what I was up against, we fell back and we started taking little contracts, but we had a vision and we're working on that vision as you saw and therein step by step we're doing it successfully. We've now had \$20 million worth of contracts, we've flown the country's smallest, highest-performance, low-cost satellite, we're propelling humans toward space, and all of this is since 2000, so we want to keep graduating from one step to the next and there are other small companies out there who are developing successful track records, and you really need

to steer clear of the wishful thinkers and the daydreamers, the blue smoke-and-mirrors guys. And success breeds success and I think it needs to be rewarded too.

Pete Aldridge

Paul.

Paul Spudis

Yes, I have sort of two questions, totally unrelated, one for each of you. I'll go with Dr. Rosen first. You mentioned in your testimony about the key role of the Moon and specifically the key role of the Moon in helping to establish space infrastructure. I would like you to elaborate on that a little bit. How do you see that developing, and what do you think the key technologies and programmatic needs are to get us on that path? What would you go after first?

Stan Rosen

You know, when we started thinking about this problem and looked around for the state of thought on that, we were surprised to find that most of the discussion about what you do when you go to the Moon and why you want to be there was limited to a very narrow channel of thoughts, helium-3 perhaps, look for water, which is not a bad idea obviously, science, maybe some backside astronomy and, in the context of the charter of this Commission, prepare to go outward. We said, "You know there are some attributes of the Moon that are much more attractive to do things looking back toward the Earth," such as the fact that it represents a large stable Earth basing and space basing surface, has access to vast amounts of energy, has very little atmosphere, if any at all, and has some opportunities to be able to create infrastructure there that you can influence Earth orbit operations, for example, by creating power supplies on the Moon that could be used to beam energy back to satellites in Earth orbit or satellites on their way to Mars. Other opportunities for information collection, large distributed antenna systems, to look back toward the Earth system and understand what's happening in the Earth's environment or to look out toward Earth-crossing objects to find them at an earlier time.

So just by simple thinking it through, we said, "You know, there are some potential things that could be done from the Moon that have not probably been explored." So the message is not that I or CSA or anybody in the community fully knows whether these are practical or desirable or when they should be done, but that there's a potential there to explore many new ideas that are exciting and that, in fact, once they've been demonstrated to having the potential for influencing commercial, security, and scientific operations, as well as other civil applications on the Earth, much more opportunity to contribute to the sustainability of the prospect for going back to the Moon than if it's only looked at as a way station to go onto Mars and other places. So specifically do I know the answer to your question? No. We're recommending we think about that a lot harder.

Paul Spudis

So, you would undertake this as a research project in conjunction with the lunar initiative. In terms of going to the Moon, you would conduct various activities to explore possible paybacks.

Stan Rosen

And in fact the infrastructure that's developed to go back to the Moon probably needs to be developed with those longer-term paybacks in mind. Because depending on what size crews you think you'd eventually need, what kind of sustainability is important, what kind of power system is going to be on the Moon, what kind of information-processing architectures you want to have on the Moon, or whether you want to use laser communications or not, in the longer term would influence the near-term investment in the architecture that we want to develop as a nation and as a world. So our recommendation was to start early and begin thinking real hard now about how you would operate from the Moon in support of these other opportunities.

Pete Aldridge

Carly?

Carly Fiorina

Thank you. Paul?

Paul Spudis

I'll just ask this quickly to Jim. You mentioned earlier the possibility of innovative ways of doing small missions, let's say robotic missions. How would you implement that in a programmatic sense as part of this initiative? Would you advocate that NASA do data purchase offers? Do you have any particularly good ideas on ways to implement doing missions like this?

James Benson

Well, Paul, I've got a couple of ideas. One is data purchases. I would like to see—let me give you a couple of quick examples. Lunar Prospector was a great mission. It was \$100 million, the lowest-cost mission beyond Earth orbit; it had five instruments on it. So basically did about five. It created five new datasets for human knowledge at a cost of an average of about \$20 million apiece. NASA's near-Earth asteroid rendezvous mission—NEAR—cost about \$250 million, had about five instruments on it also. That's \$50 million per dataset that the taxpayers were willing to pay. So that's \$50 million per dataset for asteroids, \$20 million for the Moon. I would like to see NASA, the National Science Foundation, and the National Academy of Sciences get together and come up

with a list of science datasets that they would like and put historical prices that they paid in the past and simply offer those up on a COD basis that whoever delivers that scientific data at that cost or less will be paid upon delivery, and there is no risk to the taxpayer until it's actually provided. And if I had \$20 million apiece to go after datasets I would be bringing in a lot of data and making a lot of money.

Secondly, I like doing things as products. That's where I made my money on earlier was selling to the government products. As long as we're stuck in this anti-American idea of cost-plus contracting, we're going to be stuck with costs that keep going up and up because people would like to have 8% of a billion rather than 8% of 100 million. So, cost-plus contracting is really a bad idea. I would like to see missions offered up as fixed-price products. We would like to deliver missions as products. You want a Mars data relay orbiter? Put a price on it and we'll deliver it as a product. And don't ask us how much it costs. Let us have some profit.

Pete Aldridge

OK, Carly.

Carly Fiorina

Thanks, Pete. And thank you both for coming this morning. As promised, Mr. Benson, you have been provocative and I think many members of the Commission are excited about the possibility of involving small businesses and startup businesses differently in this space mission than we have in the past. And on a personal note, I must say as an employee of Hewlett-Packard, I like your description of mainframe companies. But, having said all that, your history of the PC industry, which certainly began in a garage, left out, I think, that part of the success of that industry was the requirement for scope and scale and volume to drive prices down and capabilities up. And so I would like you to comment, if you would, on your thinking about the role of scope, scale, volume in undertaking a mission of this type, recognizing the very important role that small firms can play. The second thing I would like you to comment on is, as a publicly traded company, as a company attracting capital, how is that going? And how might it go better?

James Benson

I'll try to answer quickly. I'm going to have to give a two-part answer to the first one. We did one satellite for NASA—CHIPSat—and I think a lot of people felt that maybe that was an anomaly. But then we got into a quarter-of-a-million-dollar study with the Missile Defense Agency, educating them about microsats, and they liked it so much they gave us \$800,000 to do a conceptual design for three out of a proposed constellation of 400. So, we developed a conceptual design for three satellites. They liked that so much they recently gave us a \$43 million contract for the first six, as I mentioned before, at about the same price as CHIPSat, except they'll be maybe 50% more capable and we're hoping that that will be another step on the road toward scale, to large

quantity, so we can keep the price down. We ought to be able to deliver these satellites for one or two million dollars in quantities. And we've got Ted Wait and Gateway right around the corner from us in Poway, California. Yeah, I'd like to go over there and set up a little assembly line and just crank out four satellites in a few months. There is no reason why that can't be done. It's a little bit more difficult when you scale up to larger things like people to Mars. That's a huge step and its one that's going to take a while, but I think by doing it incrementally with small steps using higher technology and innovative ideas we can probably get there sooner and for less money and less risk than putting all of our eggs into the nuclear basket and trying to launch everything all at once. I mean, that's a 20- or 30-year proposition. Take the numbers they're giving and triple them. In both time and money, that's probably what we're looking at for that kind of a development. But if we do it incrementally, I think we can do it faster, cheaper, and with lower risk.

Publicly traded company, it's great on the one hand but this Oxly stuff is killing us. We don't know if we can stay in business as a publicly traded company two or three years from now when all the requirements have really come down on us. So we're fighting the good fight and I'm glad we're publicly traded because it gives people an opportunity to go out and buy a share of space development and exploration for a buck fifty.

Carly Fiorina

Thank you.

Pete Aldridge

Well, we've run out of time—

OK, Bob?

Robert Walker

Just one question for Dr. Rosen. I would like to go to something that we talked about with some folks in Atlanta, the whole idea of prizes. I would just like to throw a proposition out to you: If, in fact, we were to institute a billion-dollar prize for someone to go to the Moon, establish a permanent station there, and keep people in that permanent station for, say, a couple of years—with your experience with a lot of rather entrepreneurial industry in California, do you think that there would be people who would take us up on that?

Stan Rosen

Unquestionably. Whether they would be successful or not is another question, but you'd have a lot of innovation coming out of something like that.

Robert Walker

I mean, isn't that the case that even if nobody succeeded there would be a lot of innovative work done on the way to trying to do it that would in fact benefit the entire industry?

Stan Rosen

I think the X-Prize is demonstrating that, and other historical prizes have demonstrated that. There are people like Mr. Benson who are very entrepreneurial who want to get out there and try to make something new and different happen, and with an incentive like that I think they'll find a way to—

Robert Walker

May I add one more element to it? What if as a part of that prize then you added one more thing: that if someone won the prize they would get ten years of tax-free status afterwards?

James Benson

I'll take the billion ...

Robert Walker

Would that, in fact, attract some of the big guys?

Stan Rosen

It's hard to say. When you say, "The big guys," obviously the larger companies have a different calculation in terms of which activities they undertake, and I wouldn't want to speak for all of them as to whether that particular incentive would be attractive to them. I would imagine that there are some companies out there, given the vastness of California Space Enterprise, that that would make a strong difference to, yes, sir.

James Benson

Can I make a quick comment, please?

Pete Aldridge

You can make the comment to the chair, rather than back to Bob.

James Benson

Mr. Chairman, the X-Prize for \$10 million is appropriately sized. The Orteig prize that Lindbergh won for flying across the Atlantic was only \$25,000. That was a lot then, but it wasn't enough to pay for the effort. The \$10 million X-Prize isn't enough to pay for the effort that we're involved in on the propulsion side, but it's good enough. And, I would suggest that, instead of a single billion-dollar prize, map out what you want to do one step at a time. Let's start with a lunar dish observatory, then let's go on a maintenance mission for that and then back again and build it up step-wise up to the billion-dollar prize but add some \$10 million, \$25 million, \$50 million, because one company can't go out and get financing to do a billion-dollar thing. Nobody would believe them. It's too much.

Pete Aldridge

Well, again, we've run out of time. Thank you very much, Dr. Rosen, Mr. Benson. We appreciate your testimony. You've stimulated us once again. And we appreciate your time in coming to the Commission.

James Benson

Thank you.

Stan Rosen

Thank you.

Pete Aldridge

Okay. We're going to change panels to a science and technology panel. We will wait just a minute till we get the names changed.

To address the theme of science and technology, we now welcome a panel of experts who will tell us about asteroids, Mars, and planetary science for the "beyond" portion of a new space vision.

David Morrison is the senior scientist at the NASA astrobiology institute, where he participates in a variety of research programs in astrobiology: the study of the living universe. Internationally known for his research on small bodies in the solar system, Dr. Morrison is the author of more than 135 technical papers, has published a dozen books, and asteroid 2410 Morrison is named in his honor.

Dr. Michael Carr is an astrogeologist in with the U.S. Geological Survey in Menlo Park, California. He earned his doctorate in geology from Yale University and his bachelor of science degree in geology at the University of London. His specialty is Mars, which he has studied for over 30 years.

Dr. Carr is, quote, A strong advocate for further robotic exploration on Mars. Not, however, an advocate of human exploration, end quote.

Rounding out this perhaps provocative panel is Dr. Jonathan I. Lunine, professor of planetary science and physics and the chair of the theoretical astrophysics program at the University of Arizona. Dr. Lunine is also a distinguished visiting scientist at NASA's jet propulsion laboratory and an interdisciplinary scientist on the Cassini mission to Saturn and on the James Webb next-generation telescope. Gentlemen, welcome, and we look forward to your testimony.

David Morrison

Thank you. It's a pleasure to be here. I appreciate the opportunity. I am a NASA civil service scientist and proud of it, but I want to make clear right at the beginning that I am not speaking for NASA. I'm here as an individual scientist giving my own opinion. I'm going to talk about two things: first, astrobiology and how it relates to Mars, and secondly, asteroids.

I've had a varied career. I started as an astronomer, worked most of my career as a planetary scientist, and about eight years ago was one of the founders of astrobiology, which you already described as the study of the origin, evolution, distribution, and destiny of life in the universe—a big order. But astrobiology does allow us to focus on some elements of Moon, Mars and Beyond and especially directs our attention to Mars.

Astrobiology deals with the big questions. The three that we like to use as what you would summarize astrobiology in an elevator in 30 seconds is that it's the study of how life begins and evolves (that is, where did we come from?). Does life exist elsewhere in the universe (are we alone)? And third, what is life's future on Earth and beyond (where are we going in space)? These are the defining terms for astrobiology, but you'll notice they also appear in other forms in the NASA vision and mission statements.

In terms of astrobiology we're naturally directed toward the planet Mars. It is the most likely abode of life elsewhere in the solar system and is also the only planet that I can imagine humans establishing a permanent presence within the 21st century. While it's hostile by Earth standards, the gravity, atmosphere, temperatures, diurnal cycle, resources like water on Mars make it a uniquely attractive target for human exploration. I would like to emphasize that Mars is equally attractive because of the possibility of finding evidence for life, past or perhaps present—probably microbial life, but that is really no less interesting to the biologist. We will need to search carefully for evidence of life on Mars and do so before we send astronauts. I'd like to point out that there are profound implications of almost anything we learn about life on that planet.

If there is no life on Mars today or if Mars—if life once existed there but has perished, then clearly we want to understand what went wrong with Mars and to draw lessons for the stewardship of our own planet. Secondly, if we find life, and it's genetically related to Earth life with DNA and RNA, then we will probably have established that microbial life forms can be exchanged between worlds, hitchhikers on meteorites, and we will have the opportunity to study how our cousins have evolved for four billion years in a completely independent and alien environment on Mars. Third, if

there's life there and it's not related to us, does not use the same sort of genetic system we do, then we will truly have discovered independent origin, a second genesis for life within the solar system. And that discovery will infinitely enrich our understanding of the fundamentals of life and also encourage us to look for other inhabited worlds. Any of these three discoveries would surely rank among the most important scientific results of this or any other century.

Clearly, once we send humans, we will have carried a vast load of terrestrial microbes at the same time to Mars. So, I would like to stress the importance of carrying out a careful robotic search for evidence of life before we land humans. This is not to delay sending humans to Mars but to argue for a robust robotic system over the next 25 years. Secondly, I'd like to speak a little bit about asteroids. Asteroids is one of the places where astrobiology really, really counts because the astropart—the asteroids—can collide with planets and have profound effects on biological evolution. The near-Earth asteroids come closer to us than any other objects in space and sometimes collide with our planet. They should be a part, I think, of any long-term plan for the future.

Asteroids are important for three reasons: They're leftover building blocks of the planets, which makes them of great interest to scientists. As a potential resource, as mentioned by Jim Benson, they could provide important material such as iron and water in space. And third, since they do occasionally collide with the Earth, we may someday need to defend our planet against such an impact. It's only in the last 15 years that we recognized this asteroid impact hazard is serious. We know in particular that the impact 65 million years ago did away with the dinosaurs and, incidentally, with most mammals and most other life forms on Earth at the same time. That could happen again. It is improbable. That is to say, impacts don't happen very often. But without a better knowledge, we cannot be sure that our generation won't be the one to experience such a threat.

Today, NASA, with support from the Air Force and many individuals, is carrying out the Spaceguard survey to find asteroids and chart their orbits before they hit the Earth to provide decades of warning. And that is going very well. Probably as studies that are under way come to fruition, we will extend that survey to smaller objects and ultimately should be able to predict the next impact. Whether it's a large object that could kill us all or a small one that would simply obliterate a city that we are talking about there. These are intrinsically unlikely events. We're not in the business of calculating the probabilities of impact any more. We're looking at asteroids one at a time and determining are there any out there that will hit in our lifetime or our children's or grandchildren's lifetime. And the final note is that in addition to searching for asteroids, I think it's only prudent that we begin to develop the technology for defending ourselves. This is the one natural hazard that we can defend ourselves from. An incoming asteroid, given decades of warning, can be deflected so it will miss the planet entirely. We understand that in principle. It's probably reasonable that we should start to develop that technology. One particular proposal that intrigues me is to use one of the three Prometheus missions to do a demonstration, to go to a small asteroid, use the electric propulsion and deflect it a tiny bit, make a measurable change in its orbit so we can stand up to the people of the world and say, "We're not only searching for potential threats from asteroids, we're beginning to develop the technology that ultimately could defend our planet from this sort of threat from space." Thank you.

Pete Aldridge

Thank you very much Dr. Carr.

Michael Carr

David has covered much of what I was going to say, but let me just start by saying I am a strong advocate for robotic exploration of Mars. I am also an advocate for the human exploration of Mars, but in the future after this robotic exploration has been—has fulfilled certain requirements. Let me just talk a little about human exploration and why I think—I think it is inevitable that we will ultimately go to Mars. And I have sat in many workshops where the rationale for human exploration has been discussed. We've talked about stimulating the economy. We've talked about national pride. We've talked about the effect on education. And I don't think any of those reasons are the real reasons that we will ultimately go to Mars. I think we go to Mars because it is—it inspires us. It fills us with awe and pride and it's—it lifts us above the humdrum everyday concerns of food and shelter. And I think this driving, this spiritual driving force will ultimately take us to Mars. Having said that, I think there is a lot that we must do before we go—we ultimately go to Mars. Let me just elaborate some on what David has said. The main interest in going to Mars is the potential—the possibility that life may have started there and may—and there may still be extant life there on the planet. The reason for that hinges on the story of water on Mars. In 1971, we first—the Mariner 9 mission—returned pictures and we were astonished to see evidence of large floods, of erosion by dry river valleys all over the planet. And the reason we were so surprised is at that time we knew that conditions on Mars were very harsh—that it was too cold for liquid water to be there, much, much too cold. Something had to have happened in the past, we thought, that had changed, and that conditions had changed and the planet had evolved from an Earth-like place to the dry, cold desert that we know today.

And much of the last 30 years has been spent trying to understand better the evidence for water and understand better the reasons or mechanisms whereby the planet may have changed. And we're still in a quandary over those things. We still don't know how one can change the climate of Mars. Atmospheric modelers have tried various tricks and with no success. We simply don't know how it might have happened. So the whole question of liquid water on the planet—on the surface of the planet—has been questioned. People have questioned the formation, the mode of formation of those valleys. People have questioned whether there really were large floods, whether they were caused by water. Recently, of course, with the Mars rovers we have just acquired a very strong, almost totally compelling evidence that, in fact, there are—there were in the past bodies of water there. What we have found at the *Opportunity* site is a thick sequence of evaporites. These are salts that form when lakes or seas evaporate and leave behind these beds of evaporites. The evidence is unambiguous. This is extraordinarily stimulating because, indeed, we now have absolute firm evidence that habitats, that on Mars there were places in which life could flourish. Prior to the discovery of these evaporites, people have thought, “Well, perhaps the water is only underground and seeps out in local places.” And there is contrary evidence of warm conditions on the path from mineralogy and so forth. But what this latest discovery confirms unambiguously is that there were

lakes and seas on Mars. So that has enormous potential for exobiology. In this sense, Mars is a biological treasure: something to be exploited but something to be carefully taken care of. And we have to understand this planet. Understand whether, indeed, biology did start on Mars and whether biology is present today—any biology is present today before we contaminate the planet with terrestrial organisms and so confuse the signal and perhaps destroy the evidence that is there. And that’s why I say we need a very strong aggressive robotic program before we send people to Mars.

And what should that program consist of? It should consist of rovers just like we have on Mars today—well-instrumented rovers, instrumented not only with geologic instruments, as the present rovers are, but with biological instruments and with instruments to determine organic chemistry. But we also need sample returns. And sample returns are extraordinarily important, because with samples in hand on Earth, we can utilize the full analytical capability of all terrestrial laboratories on Earth to analyze the samples. We can also adapt the analytical strategy to the results as they come in. And we can also develop instruments to attack problems that the samples present, problems that we didn’t anticipate. I think the availability of the lunar samples or the acquisition of the lunar samples demonstrates this potential for samples well.

The combination of mobility, being able to get around the planet with rovers, and the sample return, is very important. And it has been demonstrated by this recent *Opportunity*. For example, *Opportunity* landed in a small crater. Out of reach was an outcrop. And this outcrop is the—is where this—these evaporites are found. Had we landed there just with an arm and reached out and dug up the soil we would have totally missed the exciting materials that are just a few meters away. So we have to have sample returns that are combined with mobility—that is, Mars rover sample returns. And we’ve been working on these kinds of missions for 30 years—ever since *Viking*. And we still have not had a Mars rover sample return. And I believe a number of Mars rover sample returns are essential before we send people there, before we jeopardize the evidence that might be there of former life and prebiotic chemistry. Thank you.

Pete Aldridge

Dr. Lunine.

Jonathan Lunine

Thank you, Chairman Aldridge, and members. I am very pleased to be here this morning. I was told that my purpose here is to address the “beyond” element in the President’s initiative and that’s the “way beyond” element, apparently. I’m supposed to skip over the entire solar system and go directly to the search for Earths around other stars. And so I’ll begin with a recurring dream that I had as a child growing up in the middle of New York City. And in this dream I was standing in an open field, night was falling, the stars came out in incredible brilliance. You don’t see that in New York City except at the Hayden Planetarium. And the planets of our own solar system were there with unreal clarity. Suddenly, in this dream, I was moving through this cosmos seeing the stars that

passed me, wondering what strange worlds awaited me at the other end of this journey. Now, of course, I never got to the other end before waking up.

And that's actually an appropriate metaphor for the human aspiration of finding other Earths around other stars. For four centuries before that, there were millennia of wondering and speculation and philosophy. Four centuries after the start of the Copernican revolution we still don't know whether a planet like the Earth exists in an appropriate orbit around another star. The elements are very good. We know of 100, actually 120 now, planets around other stars that are the size of Jupiter and Saturn, and those planets are abundant enough to tell us that the universe makes planets in abundance. It's an easy process. Part of the star formation process. And most importantly the technology for detecting Earth-sized planets is rapidly maturing, and that's what I want to talk about this morning.

We as a nation do know how to detect Earths around the nearest stars in the sky, the nearest stars to our own solar system, and therefore how to begin to implement the "beyond" part of the President's vision. It doesn't require astronauts; it does require putting into space potentially two different kinds of telescopic systems—one that works at optical wavelengths (and this is the electromagnetic spectrum)—here's optical wavelengths, and the other at infrared wavelengths. Our eyes work in the optical. The infrared we think of as heat radiation, but it is simply light of longer wavelengths than what our eyes can see.

So what are the advantages of both the optical and the infrared? Well, these contain different clues to the nature of a planet—the composition of its atmosphere, its temperature variation, the presence of clouds. The infrared is better at determining temperature and the abundance of certain gases that we think of as part of a habitable planet. The optical part of the spectrum is better at looking for variability, looking for clouds. In the optical part of the spectrum, we can actually do this with a single telescope in space that's equipped with a device called a coronagraph that masks the light of the parent star. And so in this little simulation here, the sun has been blotted out, Jupiter is very, very large. This would be a solar system like our own and one can see an Earth-like planet closer to that star—not as bright as Jupiter but still visible. The telescope would have to be something that would have a diameter at least six meters long; it could be shorter in width if need be, and it's within the capability of space-borne systems today. The other system would be an interferometer, which would work in the infrared. Coronagraphs don't work as well in the infrared; interferometers work somewhat better in the infrared. And here one would have several telescopes along a beam that would combine the light in a very precise way so that the star that one is looking at is blocked out completely, and that allows planets potentially to be detected from under the glare of that parent star.

So in this little simulation, the star is here, there is what is called an interference pattern due to the combining of light from several mirrors in this telescope system, and you can see, then, an Earth that is about a billion times less bright, 100 million times less bright than the parent star. This device could be mirrors arrayed along a girder, or it could be free-flying spacecraft that are precisely aligned with each other. Its technology is less mature than the coronagraphic technology, and so the coronagraph is likely to fly first. But with these two concepts, which are both called

Terrestrial Planet Finder, we have the solid foundation for a program that would discover and characterize habitable planets around other stars before humans return to the Moon in force.

Go to the next slide, please. The coronagraph could fly in 2013 or 2014, perhaps, after a period of time here in 2007 to '11 when some precursor missions that are already on the books such as Kepler, Simm and next-generation space telescopes look for giant planets and also for Earths in close orbits around stars. The interferometer might fly in 2018. Now, I'm not advocating a plan that in total excludes astronauts, because really TPF [Terrestrial Planet Finder], which is embodied by these two missions, is the gateway to something much grander, something that might require the intervention of astronauts in space or on the Moon. If Earth-like planets are discovered around nearby stars, we'll want to know many things about them. Do they have continents and oceans? Is there plant life that's generating energy by photosynthesis? We can't answer these questions with the TPF design shown here. What this requires is a follow-on, a much larger device, which I'll call Life Finder, which has a large enough system, is a large enough system that the light can be so finely divided that one could find the telltale signature of chlorophyll or other similar pigments associated with photosynthesis on this planet, and conceivably one could resolve this planet, perhaps seeing details on the scale of half the size or a third of the size of the planet itself. I don't know what that type of system would look like. It's a long way off, two decades or more. And for that reason I'm coming to tell you that the Commission should not recommend jumping directly to this very large Life Finder mission, which is a human-tended observatory on the Moon or somewhere in space for detecting and making the initial characterization of Earths around other stars. This can be done with TPF, and to try to do it with Life Finder would set the search back by a decade or more.

TPF could provide an incredible boost in interest in going to the Moon or sending astronauts to places like the stable Lagrange Two point if in fact TPF discovers that there is an Earth around a nearby star and there is then a strong desire to find out what the nature of that planet really is. And so what I'm recommending is that over the coming decade the search for other Earths and the return of humans to destinations beyond Earth orbit take separate paths with the intent that they meet again after both having seen their initial successes separately and not before. So I want to close by briefly sketching two versions of a story that takes place in 2014.

A scientist takes her kids camping, and in version one NASA has not flown TPF because it's tied the search for other Earths to the establishment of a lunar base, and so nothing has flown yet. In the second version, TPF flies in 2014 and very quickly discovers, let's say, two Earth-sized planets around separate, nearby stars. In version one of the story, the family is sitting around the campfire; the kids ask their mother whether there are aliens in space and she replies that nobody knows. But she also says that there might be planets like our Earth spinning around some of the stars in the sky. So the family all looks up and the conversation ends as it always has through history in ambiguity, because no one ever knows if there are other Earths beyond our solar system. In version 2 of this story, after TPF is flown, the same question is asked by the kids. But now the scientist walks their kids away from the campfire out into an open field and points to a certain set of constellations in the sky, and she points to two stars in particular and says, "Do you see these two stars? Each of them we know has an Earth orbiting around it, much like our own Earth orbits our sun. We know

that there is air and there are clouds around that particular planet, the one around that star, and so there are plans are to look more closely at it to see if there are signs of life.” And then she concludes, “Maybe some day when your children’s children’s children are alive, they will go to that distant world to touch its soil and meet whoever or whatever is there.” No other generation before us in the whole history of humanity could lay claim to the second scenario. But we possibly can within a decade. Thank you.

Pete Aldridge

Thank you very much. Questions? Maria.

Maria Zuber

Yeah. First of all, thank you all for coming. Each one of you, without being asked specifically, commented on life, OK? There has been a lot of discussion on the Commission whether or not the search for life should be a central scientific—the central scientific tenet for exploration with obviously the other reasons that you articulated for doing so, but then the other reasons for, there’s a lot of interesting things to explore that don’t involve life and, you know, suppose we go, we look more closely at Mars, we don’t find life, does that cut off planetary exploration? So what I would like to ask is for each of the three of you to comment on how the search for life just fits into a broader scheme of exploration and whether or not there should be a specific—whether or not that search should be the driving factor in the scientific aspect of the exploration.

David Morrison

My own belief is that life is the most important organizing principle although not the only one. But I said life, not just the search for life. It really takes two elements. For the scientist and indeed for the public also, finding evidence of life on another world and comparing that with the life on our own is basic. But the other basic thing is the moving of our life from its home planet to other worlds. The expansion of terrestrial life into the solar system. And I think that’s equally important.

Michael Carr

With respect to Mars, I do believe that life is what is driving and what should drive the program in its early years. I am not a biologist, I’m a geologist. I’m interested in how different planets work. I’m interested in the planet’s interior and the planet’s geological history, but I just don’t see that as strong a rationale as the life issue, which is very real for Mars.

Jonathan Lunine

From my point of view, if you look at human cultures throughout history, every human culture has a set of stories that essentially addresses the question of their role and humans' role in the cosmos. And so I would see life as an organizing factor, or an organizing motivator, I should say, in exploration. But in the broader sense, I think that David hinted at, we all want to know what our place is in the universe, how the universe came to be, and how planets came to be, and then how life came to be. And by natural extension, whether we are something that is extraordinarily rare or unique, an intelligent species on a habitable planet, or whether we are a very common outcome of the evolution of the universe. And so it isn't just the search for other life on a planet in our solar system or another planet that is like the Earth orbiting around another star. It is the understanding of our place within the universe and whether we represent a singular or a common phenomenon.

Pete Aldridge

Paul.

Paul Spudis

Yeah, my question is for both Dave and Mike. You both alluded to the fact that you envision a robot series or robotic missions over the next 20 years, and that in fact is part of the President's vision. But you also mentioned that we needed multiple sample returns. I want to ask a hypothetical question. But before I do, I want to make one point for us and then I'll make the hypothetical question. About the contamination, the human contamination of Mars. One thing that we have found out in the past 20 years of exploration is that the surface of Mars is a sterilizing environment. There is UV there, there's a very oxidizing surface, so I'm not so much worried about the contamination of the surface. And it seems to me if you're going to look for extant life it is going to be at depth in the planet somewhere because it can't exist on the surface. But aside from that, let's assume that we do have a robotic program and we do have a series of sample returns, and let's further assume, for the moment, for the sake of argument, that each one is negative. You don't find life in each sample return. How many of those do you require before you declare that Mars does not have life and never has?

Michael Carr

Of course, we can't answer that question. We've got to sample different environments and we've got to ensure that we understand the planet well enough that we know the range of environments that are there. For example, you say it's unlikely that there is life on—near the surface today. We don't know whether the hydrothermal systems, active hydrothermal systems are present, in which you could have life almost at the surface. We don't know how deep below the surface one would have to go to have—to find conditions where life—terrestrial life—could survive. Until we—until

we explore globally more of it, the planet, and go to some of these places where we're suspicious that terrestrial life could survive, I think we should defer sending people there.

Paul Spudis

Let me follow that up—

Michael Carr

I don't know what the number is.

Paul Spudis

Let me follow that up a minute. And the reason that I'm pressing on the number is, you sort of set it up as a predicate, that in order to assure that we're not contaminating our answer that we need to address this question first. And what I'm asking is, if you can't define the criteria by which you're willing to make that call, essentially you're saying, "Never go with people."

Michael Carr

I'm—I am not really saying that. But I'm saying that, basically, you should do—given the range of environments on Mars, you should sample as many as could probably sustain life and then be—and seeing what you find there, make some sort of prudent judgment that perhaps that in effect the chance of finding life right at the surface is pretty close to zero. You'll never get—prove that there's no life there. And I don't know what that number is. The NRC had a panel and they came up with ten sample returns. What is it? It could be 100. I doubt it's 100. But I think it's closer to 10.

Paul Spudis

So, essentially, it's a non-falsifiable hypothesis.

David Morrison

The problem is initially, as you say, on the surface. The surface is a pretty unpleasant place for terrestrial life. And so it may be possible to go there without risking a contamination of the subsurface. In that case, all you have to do is establish that there's no Mars life at the surface and you can defer till later the question of probing down perhaps kilometers below the surface to an aquifer. But it's a dynamic question. I don't think you can set requirements now for what we'll be doing 25 years from now.

Pete Aldridge

Laurie.

Laurie Leshin

Thanks, gentlemen, for being here. It's good to see you all here. I want to—I have a specific question and a whole bunch of other ones, too, but we'll see how far we get. But I have a specific question about the Moon, which we haven't talked about much here with you all. There has been—and along the lines of the subject of astrobiology, that is, understanding the origin of life on our planet, the Moon has a very important role to play there. David, and I know you've been involved in some discussions of this, and I wonder if any of you have comments on sort of how the science we can do on the Moon can help us in this quest to understand where we came from and where we're going, what role the Moon can play there, because that's where we're going first with humans, and I think it's—should be an important part of this.

David Morrison

The Moon is very exciting, as you know, in many ways, to geologists. But to biologists it's of interest also because it's a—the place we go to find out what the first billion years of history of Earth and Mars were like. And I know that my astrobiologists are interested in defining the conditions under which the planets formed, the early bombardment, the time scale for those events that were crucial at the time life was forming on Earth. So it's a very interesting place to study habitability, but perhaps not to study life itself.

Laurie Leshin

So we need to understand—in order to understand the time, the snapshot in time, when life was emerging on our planet, which is not well preserved on our planet, we don't have a good rock record of that, the Moon is a great way to go to explore that. Is that fair to summarize what you just said? Jonathan, do you want to say anything about that one?

Jonathan Lunine

Well, I was also going to say, and you articulated it already, that the first half billion years of the Earth's history is lost to us in the geologic record, and it's there on the Moon. And so that's a crucially important object from that point of view. It could very easily have been that we would not have had the Moon. It was the result of a particular large impact at a particular angle and in a way we lucked out, I suppose. And that, too, is important because those large impacts that build terrestrial planets also brought in the water and the organics that were the raw material for life, and the leftover from that large impact is orbiting a quarter million miles away from us. And so

understanding its composition tells us something about the things that were hitting the Earth at the time and supplying these materials. So it's important as well from that point of view.

Laurie Leshin

So it is your view that the Moon is a very natural component of this exploration strategy that has as one of its pillars understanding the history and future of life in the universe, OK. I have another one but I can wait if you ...

Pete Aldridge

Let's go with Neil and we'll come back.

Neil Tyson

I just have a comment. Jonathan, you noted you had this dream of a perfect night sky even being a city person. Perhaps were you not a city person, you could not have dreamed it because it would be out there every night. So, in the city where there is no night sky, that's the place where you dream about a night sky. So I'm wondering if that was part of it. Just a comment.

Jonathan Lunine

Well, it helped that I live four blocks from the Hayden Planetarium.

Neil Tyson

But, David, thank you for your comments earlier. I just had a quick comment and then a broader question. I think you made an assumption, reasonable, but still a very big assumption, that if we find life on Mars and we find that life to be DNA-based, you assume, then, that we would then be related to Martians, but is there any way to test for whether life might have no trouble making DNA wherever life forms, so that DNA itself might be what's inevitable in wherever you would find life?

David Morrison

Well, that's a good question, and I admittedly went through that too fast. We know all life is related on Earth. We can do the analysis of the genomes and can see the amount of divergence between one microbe and another, which is related to the time since their last common ancestor—if we found a group of microbes on Mars that fit that pattern, but with a deep divergence billions of years ago—so it's not just “Do DNA and RNA exist?” but are the patterns put together in ways that there is some resemblance to the common ancestry we have here? Then I think we would come to that

conclusion. If it was totally different, we'd say this was an independent origin of life and there probably is a whole spectrum of interesting possibilities in between.

Neil Tyson

My broader question was the issue of sample returns. How much of that incentive to return samples from Mars or anywhere else is because people are not thinking more robotically about such an exercise? In this vision we are charged with thinking about how to use *in situ* resources, how to go far beyond what even we do today in terms of robotics, telerobotics, and the like. Why is it so hard to imagine setting up a remote lab so that you don't actually have to bring the rock back to Earth to put it in your Earth lab? Can you imagine a remote lab that does all the same things?

David Morrison

Well, Michael spoke to that and he should speak again. But the quick answer is no, not today. Whatever capability we have to build a lab on Mars, surely our labs back at Earth will be decades ahead of that. So by bringing it back you always have access to the best technology.

Michael Carr

There's a geologist at JSC who calculated the total—the total mass of all the instruments that are currently working on the lunar samples. And it was a staggeringly large number. And it is not just the mass but the sophistication of the instruments and the sample preparation and so forth that are needed to prepare samples for analysis. It's—I find it almost impossible to imagine a remote lab on the Moon or on Mars doing what we can do with samples returned here to the Earth.

Pete Aldridge

Laurie.

Laurie Leshin

Thanks. I'm not going to spend time arguing with Mike about whether or not we should send humans to Mars. But I will make one comment about that, which is what we're really talking about is intelligent sampling. You made the comment of if *Opportunity* hadn't had wheels and just was able to reach out, that really wouldn't have been very intelligent sampling. And so since it can drive over it can be more intelligent. Well, humans would be the ultimate in intelligent sampling. At least we hope we would train them well and would have geologists in the bunch.

Michael Carr

I've just spent three months helping drive these rovers around Mars. And I think we're doing fieldwork pretty well. And we are intelligently—we did intelligently look at that outcrop and sample it. We got microscopic imaging of it, we got analysis of it, we got mineralogy. We have a very limited set of instruments, and we were doing fieldwork, you know, right there at JPL.

Laurie Leshin

In any case, this is a long and interesting argument, but I have a broader question. When the President announced the vision, I think he stated very well that the goal essentially is to advance the economic security and scientific interest of the nation, and so science is an important leg of that stool, if you will. It's one of the legs that holds up the exploration vision, and to me it's so compelling to hear you talk about how we—our toes are on the precipice, we stand on the precipice of being able to make some of these discoveries that would truly change our view of ourselves and truly fundamentally change people here on this planet. And I just wanted to get you all to talk a little bit more about that—what you think it would mean to actually really be enabled to go off and aggressively pursue and make these incredible discoveries. You can talk about how the public responds to what you do, what you've observed in your careers in terms of how people engage with this idea of the quest for understanding how we fit in. I'm pushing you to take the science hat off and speak from the heart a little bit.

Michael Carr

I've been working on Mars for 30 years and I continue to be amazed at how interested the public is in what we're doing on Mars. I give public talks and the place is jammed. There are people standing around the walls and there are people lying on the floor in front; they give—our website for the Mars rovers had more hits than any website in the history of the Internet. There were more hits than there are people on Earth. The interest is just astonishing. And I think it does reflect back to this—what I talked about at the beginning of my talk, this feeling of awe about the universe and the pride in we have the capability and we are doing this. We are going out there and exploring and I think it's—I think it resonates enormously with the public and I think the response is indicative of that.

David Morrison

We have all had that sort of experience. This week at Ames Research Center we had open house, and more than 700 people came to hear about Mars and specifically to talk about the search for life on Mars. It included the mayor of one of the local towns, CEOs, little kids, everybody. That seems to be an interesting thing to everyone as well as to scientists. And I remind you of the great interest that was aroused and the publicity a little less than ten years ago with the Mars rock—LHA4001—that had the President holding a press conference, it had all of this coverage for the possible

discovery of fossil microbes. Think how much more it would be if we actually found real life and were able to analyze it the way we do the genomics on our own life and make comparisons. I think we would all be blown away.

Jonathan Lunine

I would add two things. I do from time to time read the foreign press, in particular Italian newspapers. And about the only non-jaundiced coverage of the United States is the coverage of science and space exploration. Actually mostly space exploration, because on the biological side there's the whole issue of human embryos and so on. And so it brings home to me again the point that this kind of activity of exploration and discovery is an activity of humankind that we are doing as leaders of this effort because of our technology and wealth. But it is something that brings everybody along. And there are very few activities, I think, that this nation is engaged in today where we can say that. I also would add that Dr. Tyson's point about the lack of ability to see the sky is not a trivial issue. Fewer and fewer—in terms of percentages—fewer and fewer people are able to actually look up at the sky and commune with the universe the way humans have done for presumably tens of thousands of years. And so we're drawing a curtain across that sky, and space exploration is the only way that we can punch through that curtain now. The fact that the World Wide Web exists means that these enormous numbers of people are sharing in that. But in some ways it's a race against time, because we will eventually close off to ourselves the heavens, and it won't be a part of our experience at night anymore. And I wonder what that will do to our thirst for exploration as—in total, speaking of humankind in total.

David Morrison

I would like to just add—we haven't talked about it—but the other issue that I mentioned, defending our planet from asteroids, is something else that the public very much resonates with. Our impact hazard website at Ames is the most popular website that Ames maintains. And there are people who think that it's a reasonable thing for us as the one superpower, the leading technical nation on Earth to do, is to assume some responsibility for protecting us against a catastrophe that could be avoided.

Pete Aldridge

Maria?

Maria Zuber

Yeah, actually, that was a good lead-in to my next question. You mentioned a possible nuclear propulsion mission and the Prometheus project as one way of testing the technology for asteroid deflection. But we've been charged by the President to think about how humans and robots could

work together in space, and when it might be appropriate. Has any thought been given to how humans could contribute to the asteroid deflection problem, and if not, should they be?

David Morrison

I think a couple of Hollywood movies were made along those lines.

Maria Zuber

That's not what I'm talking about. [Laughter]

David Morrison

You never see—a robot is not an independent thing. It is run by people, it is built by people, it is controlled by people. So humans are very much involved, as you know, Maria, in all of what we call robotic exploration. This afternoon, I believe, Rusty Schweickart, an Apollo astronaut who's been involved with looking at this Prometheus option, will be talking to us about that, and I should probably defer to him. But I think right now we are talking about the ability to give a first demonstration of controlled moving an asteroid robotically relatively inexpensively and we don't for that purpose need asteroids, we need humans, although we may later.

Pete Aldridge

Let me butt in here for just a minute. It does seem, though, that the mission, the vision, for the Moon, Mars and Beyond would be developing technologies that are directly applicable that if we found some potential dangers, could be used for the purpose of asteroid defense.

David Morrison

Indeed. This leads to a robust infrastructure in space. If we become a true space-faring civilization and a multi-planet species, then probably, if there were an asteroid threat a century or two in the future, you would just contract out to someone like Jim Benson and say, "Go take care of it." The structure would be there.

Pete Aldridge

I know in the press conference the President did mention the fact that while national security was a different path, the technologies that are associated with it do contribute to national security, and I would guess defense of asteroids is very much related to national security as anything we know about. So, that's—I could see that case. Maria, are you through?

Maria Zuber

No. I think Carly has more. I'm through.

Pete Aldridge

Carly.

Carly Fiorina

Unless—are you finished?

Maria Zuber

I'm done. Yeah.

Carly Fiorina

OK. Thank you all for coming, and each of you have been both eloquent and spellbinding not only in terms of the science but also in terms of the human and emotional appeal of what you do every day. And I'm struck always, when I listen to people like you describe the enthusiasm of the public and watch each of us get spellbound all over again. I'm always struck by the difference between that reaction and the cynicism and pessimism that any discussion of a NASA mission always elicits. And, in fact, when the President announced this mission, there was the inevitable discussion of "Why go? It's not affordable." From a political point of view we rapidly spiral down into all the reasons it's a bad idea and it can't be done. And I wonder if you have a view on why that is.

Jonathan Lunine

Well, let me take the first crack. There are several issues. One issue is that I think there is a general misperception in the public as to how much we actually spend on space endeavors, and very often if this comes up in class or I'm giving a public talk, I'll ask people how much they think this nation spends on space exploration. And usually no one answers because people confuse millions and billions and so on, and then I say, "OK, let's have a federal dollar. Let's take out a dollar bill and this is a federal tax dollar, and how much of this dollar bill is spent on NASA?" And they usually come back with a gross overestimate: Twenty cents, forty cents, fifteen cents. And I tell them it's a penny and they don't believe it. So I think some of the cynicism and mistrust really has to do with the fact that people somehow believe that we are spending a very large fraction of our national wealth on space exploration and we're not.

Pete Aldridge

In fact, it's less than a penny.

Jonathan Lunine

It's now less than a penny. It's half a penny.

Pete Aldridge

Point seven [0.7].

Jonathan Lunine

It's almost a half percent.

Pete Aldridge

Do you have comments?

Michael Carr

Well, I'm a little surprised at the question. Because as far as the scientific exploration of the solar system, the missions like *Voyager* and *Viking* and the present Mars rovers, and so on, I find nothing but enthusiasm. And I think there is enthusiasm for true exploration. Going to places that people have not seen before. And I think the cynicism with respect to NASA has—with respect to the agency—has come from another source. I think it's come from long-term problems with Shuttle and Space Station, that truly were and have been extremely costly and promises that were made that were not fulfilled. And I think that's where the cynicism has come. I think one of the—one redeeming aspect of the agency is its continual exploration of building things like Hubble and on the science side. And the science side continues to be inspirational. I don't encounter much cynicism associated with that aspect of the agency.

Pete Aldridge

Dave, you want to comment on that?

David Morrison

I'm a NASA employee. I'm enthusiastic. The people I work with are enthusiastic, the public I speak to is enthusiastic. That's all I can say. And it is centered on the science and exploration, which is what I know something about.

Pete Aldridge

It is interesting to note that if you ask people who are—about the space program, nobody would really argue against the robotic missions or the scientific missions and some of the things that NASA is doing. Seems like the criticism comes when the human spaceflight element is where the question and the controversy surrounds it. I know that that's only about a third of the NASA budget. The rest of it is other things.

Robert Walker

Mr. Chairman, I would point out that I remember, though, in the Hubble mission that some of us who were supporters of the Hubble mission in its earliest days and helped come up with the funding for it took a lot of public hits when it ended up having a flawed mirror in the earliest days. There was not universal enthusiasm for some of that. And as somebody who has fought for about 20 or 25 years now to see to it that *Gravity Probe B* ultimately flies, I can assure you that there are some science missions that have a lot of critics and concerns about them. So, you know, it is not—

Pete Aldridge

Unfortunately.

Robert Walker

It's not a totally bleak picture.

Pete Aldridge

Real quick. Real quick.

Neil deGrasse Tyson

Just real quickly—the three of you spoke about public interest in talks you've given and website hits and the like. I wonder, could you—I should direct this to keep it clean—about—Dr. Carr, could you comment on—could you foresee that same level of public interest in this vision if life were a lesser part of that vision and it became more of sort of a planetary geology exercise rather than a

“life in the universe” exercise? Because in my personal experience I don’t see the public enthusiasm with rocks, if the rocks are not specifically tied to the search for life. And could you—in your own experience, what have you seen in this regard?

Michael Carr

Well, I do think—I do think the potential for life is a grabber. But I also think that just exploration, irrespective of the prospects for life, resonates with the public and that when we go to Io or Europa or whatever, people are interested.

Neil Tyson

New places.

Michael Carr

Other places where really there isn’t a life issue—well, there is with Europa, but not with Io. And yet people are interested—people are really interested in what’s out there.

Neil Tyson

So milestones of this vision ought to be, not to put words in your mouth, but let me suggest, then, that to maintain public support and to have checkpoints on progress, you might then suggest that we install milestones of new places to go, to see new ridges to climb over, so that there is a new thing people can look forward to that they haven’t seen before.

Michael Carr

A new place to go could be a different planet but it could also be just going over the horizon.

Jonathan Lunine

But I have to say, just if I can add one thing, that ultimately people are interested in these worlds in the context of whether either they do have life or whether someday people are going to be climbing over those ridges, and so there is always the connection in some way between the rocks and biology—either our own or some strange biology we haven’t discovered yet.

David Morrison

Let's recall Ray Bradbury's statement. If there is no life on Mars now, there still can be in the future, and we will be the Martians. We are in that transition from being citizens of planet Earth to being citizens of the solar system.

Pete Aldridge

Gentlemen, thank you very much. This has been another stimulating panel. I notice, that Dr. Lunine, in Arizona I guess you can see the stars in the skies in Arizona.

Jonathan Lunine

Very well. Yes, at least, for now.

Pete Aldridge

Dr. Carr, Dr. Morrison, thank you very much for your time, and we appreciate you being here. Thank you.

Pete Aldridge

We're going to adjourn now and we'll resume at 1:00 p.m. Thank you.

Pete Aldridge

We'll get started for this afternoon. This gives me special pleasure to welcome our next witness. William "Red" Whittaker is widely known for his many achievements in the robotics community. Currently Dr. Whitaker is the Fredkin Professor of Robotics, the Director of Field Robotics Center, and founder of the National Robotics Engineering Consortium, all at Carnegie Mellon University. He's also the chief scientist of RedZone Robotics. Red, we're delighted you're here and you can enlighten us how robots can help reach our mission goals. The floor is open to you.

William Whitaker

Great. So, I will, in fact, speak about robots, although the presentation is deviously titled "Going for the Poles." It's great to see the Moon and beyond mixed into the agenda, besides that central focus on Mars. Next slide, please.

I'm using this polar opportunity just as a context to introduce the impact of some great robot capabilities that are existing and on the horizon. But the poles are also interesting in that they

haven't been explored on the surface and offer some incredible resources like volatiles. I've titled a new feature Magellan Routes, which I'll say a few things about. And the idea is that these are routes that encircle some part of a planet and that are navigable by robot with the idea that the sun would never set—it would never encounter the dark. So, you want to think about it as orbiting a planet, but on the surface, and keeping up with the sun. It's kind of an alien concept for us since we're here on Earth and you'd have to have a very fast jet for that. But let's just get right into it. Next slide, please.

This is—I'll use a pointer to actually point at a pole, which is a fixed point. And the sun clocks around. This one is the Moon. If we were looking at Mercury, for example, it would take half an Earth year for the sun to get around. And since the Mars poles are tilted, you don't have to move at all in order to get long periods of persistent light.

Now instead of holding the fixed point on the pole, I'll now come down a few degrees off the pole and stay in the light all the time. And so the idea here is that although there's no point that's always illuminated, if for whatever reason you're on the move, there are actually infinite routes that are traversable, that are continuously in sunlight. So this is something you might call a power scenario as opposed to a power source. Of course, I won't give you a patent for a perpetual motion machine, but it's a way to just keep going all the time. Next slide, please.

So there's no point, but there are routes, and that there are seasonal opportunities on Mars.

Next slide? And that for robots to follow these, they actually follow daylight. And right at the terminator, they can actually choose their temperate zone. So, you think of these bodies as being either cryogenic cold or blazingly hot. And the reality is that, near the terminator you just choose your temperature. And could do it in search [?]. And it is those violent hot-cold cycles that are the bane of equipment on the surface. So this beats so much of that technology. And so you can go around a little feature, go around the pole, go around the whole region.

Next? This just repeats the advantages, and some of the way you get away with it is that you can actually go travel maybe 10 or 12 times faster on the Moon than you might here on Earth, in part because there's the gravity advantage—and you pay energy for that—and the solar advantage, by not having the atmosphere. Next.

So how fast do you have to go? Actually, not very fast at all. It is creeping speed. And of course, it gets—you choose your speed because the closer you are to a pole, the slower you have to go, and the further off the pole that you come, you'd say, well, it's a little quicker that you have to go, but in fact these are speeds easily achieved for robots, including allotted dwell time and navigation time. And you get that for the energetic advantages. By the way, if for whatever reason you chose, in the “beyond” scenarios, something like Mercury, the energetics are such that the speeds needed to clock the equator are almost imperceptible motion. Next.

So the real topic is robots, and I just put it out there to say, “What do you need to track those kind of bold scenarios?” Because it's real clear that robots will be the first circumnavigators, and the first to the top of the great volcanoes, and maybe first to the poles. Whatever explorations we know about on Earth, will be by robots first on these planets. So, these are typical of the evolutions of robots. These are the first of my 30. I'll show you number 66 today. But that's irrelevant. These

institutions all have 100. And the community is now a family of thousands. And each of them then have these tributary technologies. And I'll start with things like persistent desert travel, self-contained intelligence, circumnavigation. This literally clocked a piece of our arctic pole just to show the idea of 9 km in one command. And then on to the planets.

Next? So at the time of *Sojourner*, this was clocking the Atacama Desert, and you may recall an era when the model was to be a robot slave to the lander? And of course, the breakthrough is to traverse afar and to be self-reliant. So in the first outing this one did 200 kilometers and since then has clocked about 1,000 kilometers. And some say that those ranges are not even really interesting at the scale of planets, meaning that you certainly wouldn't buy a family car that was good for 1,000 kilometers. Next please.

So although it seems quite odd, this is actually a speed that would do just fine for circumnavigation. It's also the kind of speed that just does fine in sustained travel for doing regional exploration. But it's interesting that this one, even though it put in the distance, didn't cross the mountains and didn't get over to the next valleys. And the kinds of terrains that are presented actually far exceed the difficulties of the kinds of things we do today, even though those terrains are traversable by many robotic means. I think for the sake of moving along, we'll maybe go to the next slide.

One of the things about watching these robots is that when they are at work, it's actually a little boring, because, you know, when they're traversing day after day, kilometers after kilometers, valleys after valleys, it's—even though they have purposes, watching them just doesn't enchant like it used to. So this one had two points to it. The first is that it is a thinking machine and it's thinking not about navigation. Right now there's too much navigation on the brain, getting from A to B. And not so much what is the purpose of the machine when it's doing that. This one had the purpose of seeking meteorites and, in fact, discerned five of them. Which was actually, as you know, if we put 100 pseudo meteorites on the table and three or four good ones, it would be very difficult for a human to discern what's the genuine article. And the other is this isotope analog, and the idea that new power sources break open a lot of good things. Next?

So, you know, at first it just looks like it's driving around. In fact, it's on the search. And the Antarctic is where we seek our meteorites now. And one of the things that this does is to classify geology and determine what's uniquely different and that's the kind of thing that comes from the sky. So you wouldn't figure it out, but right there is a meteorite that it ultimately finds. And again, it probably makes sense to shorten the movies just because in order to find a good one, you might have to look at 1,000. Next slide?

So then, on to the sun synchrony. The first thing you want to think about it is that the solar rays are vertical like a billboard or a shark fin. We're accustomed to seeing solar at the equator where there's a sunrise and a sunset, but if there's never a sunset, then what you need is a square-rigged sail. And you can put it transverse or you can put it longitudinal and the machine will figure out what phase it has to be in to catch the sun. But this is one that wandered, sought the sun, powered itself up. At no point in its nine-kilometer traverse was it ever behind the power curve. Next.

One of the advantages here is you get three times the productivity, just because we hibernate now every night. And then spend time to activate and deactivate. And when it's not cyclical like that, you just go all the time. So next?

The next is this kind of autonomy business. The terrestrial standard is now something like a command per kilometer. And what you want to get is that it is always appropriate for the terrestrial ambitions to exceed what we fly by an order of magnitude or so, because, as you know, it takes a while to harden and deploy. The other notion is this science on the fly, which is the controversial notion of imparting to the robot the capacity to make decisions. Still kind of a cultural thing. Next?

And then, lastly, I wanted to put this example in for a couple of reasons. I'm aware that the Commission will at least take a look at grand challenges. This is one from last month. And that the next thing I wanted to say is that the kind of performance that achieves is far beyond the computing and sensing required for these scenarios, and what we're about to look at was actually done by a student team. So could we go to the next, please?

And you say, "Well, you know, that's a little hot for planetary work," but on Mercury, you can actually achieve these energetics even though you don't need them. That's in part because you're so close to the sun that you get the juice. And whether or not you're there, all this very simplified kind of navigation performs well and is of great utility. Again, let's cut it there. These things get boring. Next.

And then what does it take? Well, the point of this certainly isn't to—the approach is anytime there's a new ambition, is typically to orbit and then land and then traverse, sometimes sample return. And in many of these venues we've already done some of that. So no matter what the venue, there is an argument for some boldness and ambition. Next?

So—on the Moon, tremendous agenda, particularly around the poles and these unique prospects for volatiles. But beyond that, the resource, utilization, and experiments call for working machines, and there are entire scenarios for habitation that are built around these regions. Next?

On Mars, again the poles with the icecaps and the prospect of volatiles. But these technologies, these robot machines, are going to be universal. They're good for anything. And that particularly, the high-end capabilities have a great deal of utility in fulfilling bolder scenarios. And then beyond, since you ask, an interesting mission might be to spiral the surface of Mercury. So imagine that you land somewhere, anywhere, maybe near the pole, and you traverse and since you've gone around once, traverse again. And again and again and that there is that capacity then to cross the equator and keep on going. So you get that kind of full coverage. Now, that's a little dreamy, obviously, but it kind of casts the bold vision of where do you learn your basics and where do you exercise them and what do you use them for and how they are, in fact, useful in a lot of places. Next.

So these robots are quite capable of offering us the poles and many other venues. And then the Moon is a great place to start, in part because of its accessibility and great energetics. And that some advocacy to actually go for these polar scenarios. But really from robotics, the real story in robotics is that its growth and its technical capability is outpacing Moore's Law. And that's with or without the space enterprise. And the second is that it is so broadly capable that it is, of course, in this exploration context, it's these driving missions mostly. But in the terrestrial commerce, it's

everything from subsea operations to maintenance, agriculture, mining, subterranean operations, infrastructure, toys, tools. And that is a movement that is one that serves us all. So those are comments. And I'm not sure of the format, but thank you.

Pete Aldridge

Thank you very much. Laurie? No, I'll turn it over to you. You're first.

Laurie Leshin

OK, thank you. Thanks, Dr. Whittaker to be here. It's great to meet you, actually, and because I know a lot about your robots. And having searched for meteorites in Antarctica myself, I can tell you that it's exciting to think about again the human-robotic connections there. I have a question that's a little bit different than what you've been talking to us about, which is about the students that work with you and about the experience of building these machines and going out and having to make them work. And it seems to me that one of the greatest challenges we face in making this vision successful is to train systems engineers better and to overcome barriers between science and engineering. And I'm wondering if you can talk a little bit about the experience—that's about the—how students interact with you on these projects. And whether there are scientists involved in them at all. For example with the meteorites.

William Whitaker

Sure.

Laurie Leshin

So are there now a bunch of engineers running around that know something about meteorites as a result of having built this?

William Whitaker

Right.

Laurie Leshin

Are they getting jobs at NASA? Is this a model program that we can use to help address some of these workforce issues?

William Whitaker

There's a vernacular in the trade that some of the space robot program is the house that CMU built. I think that's pretentious, but that clearly that students who engage in this matter have the experience of their lifetimes and that many of them may have three, four, or five of what you just saw before the age of 22. That this last initiative was exclusively students, in part because it disallowed contracts and there were a core of 50 that grew to 250 strong, that besides the leap of technology, the relationships with companies and taking the work to the world, one of the critical agendas is building these leaders. And that is a very nonlinear scale, since the excellence and the vision and the capacity for implementation is great. That one can reflect on—you take a student who comes off the pipeline with robotics experience on both poles, three continents and the Atacama desert by the time you get them, and you couldn't buy it. It takes 10 years to build them and a second to lose them. And one of the things that the space initiative better do is grab them and grab them big. Because they are—it's like a pro football draft and the world is tearing their arms off with great opportunities. Many of them live the vision and move from these kinds of training grounds directly into missions. One of the things I would suggest is that we give some of them their—give some of them those bold initiatives early. If all were known, the robots that we fly now could exhibit very quickly all their capability if we let some of this great creativity and youth run with it. Something else?

Pete Aldridge

Les.

Les Lyles

Dr. Whittaker, again, thank you for being with us here this afternoon. I liked your analogy of Moore's Law applied to robotics, robotics technology. I think it's appropriate, but I have to tell you, I was a little bit surprised last month that the DARPA initiative down in the desert and the lack of success that the teams had involved in that, I was wondering if there was something unique about that particular challenge? Or does it portend that perhaps there's still a lot of technology maturation, engineering, that still needs to be done in robotics that that particular scenario pointed out that perhaps others have not?

William Whitaker

Well, let's see. First, let's think about that a little bit. It's interesting you label it a failure.

Les Lyles

Lack of success.

William Whitaker

Try this one: A children's crusade of seven months' duration that averaged 24 kilometers per hour and hit 54 kilometers per hour and sustained that in circuitous mountain roads for 12 kilometers, and glitched on one hairpin. Now, consider that the oldest technologist in the batch was maybe 21. And consider that that's a completely pickup outfit, right? It does not have the kind of systemic maturity. And just an aside, same kids a few days later would just let things loose and traverse maybe 119 kilometers without the eyes of the world. That the same kids in the particular team that I led patented last week with seven claims, and that you'll see a broad literature out of it. And a new field probably in the arena of high-speed navigation of unrehearsed irregular terrain. And so, you know, one of the things to get is that—it's an interesting thing, and actually, it's kind of an agency mindset that comes in hard with harpoons and arrows. And that my 2 cents is that the great accomplishments don't come cheap. They don't happen first time around in seven months and come easy. The ones worth doing are actually worth digging in to go get it again. It's so interesting that if the kids ran the show, they wouldn't have the same story that might be—by the way, it's no secret that they shared the center of *Scientific American* with the Mars space venture. And pulled down the—and held eminence, if you will, right with what we say is going on in space. And by the way, in terms of inspiring a generation, don't kid yourself. Hundreds of thousands of people enrolled, not a dollar of government money spent, and people from high schools to pickup shops to garages to universities that are burning strong right now out there to do it. Something else?

Pete Aldridge

Neil?

Neil Tyson

Thank you. You referenced Moore's Law as something that it beats in terms of its rate of achievements. What is the actual metric that's being used to compare with Moore's Law?

William Whitaker

I call it Red's Law.

Neil Tyson

Red's Law?

William Whitaker

Yeah. It's a composite. I actually quantify it. And it has metrics in it, like these combined speed and distance accomplishments that are normalized by computing that gets it done. So-called meters per second. And then another is—another part of it tracks the economic growth, which are the metrics on the robotics industry that are other than the fixed manufacture. And then a third is the composite of the technologies and components that go into it, because robotics is a lot more than the computers. So one of the stories going on is that those enabling technologies, which are everything from actuation to sensing to pose estimation techniques and the like are also in high growth, and that's one of the reasons that it outpaces the computing.

Neil Tyson

The reason why I ask is, it just never occurred to me to think of the speed of a robot as an important measure of the value of the robot to exploration. So it just never occurred to me to think that way. When I think of this vision, I think of robots that might have to sort of build a minifactory that will manufacture rocket fuel or extract water from the soils that an astronaut would then later drink. And so—or have a robot recreate itself in the famous test of whether robots can propagate through the solar system. So are any of these on your horizon as a robot pioneer?

William Whitaker

Absolutely. So, be clear that, first, two things. I think it's a magnificent topic that we engage in in this moment, which is to look at, like what might those metrics be as the *Guinness Book of Records* will be posing language to look at what happened last month, it actually will have to be in a whole new realm. Is it distance? Is it speed? Is it that it's thoroughly unrehearsed, is it that there is no human interaction or engagement? Certainly not by the meter or by the kilometer or this kind of thing. Single command. So they've got a lot to look at. Getting back to the point of this question, to be quite honest with you, what we show today is not at all my primary identity. I am really committed to robots that work, and my robots of record are tools, not toys. The early identity were the machines in operations to clean up Three Mile Island, and the commercial fortunes are things as pedestrian as rebuilding underground sewers, directing agricultural machines and mining operations. And that if all were known, this is a sea change. This is a major shift that has to occur in the thinking of space-faring enterprise—to go from machines that wander and see and infer and reason into machines that work. And to be quite honest with you, the only metric of what those are is what they accomplish.

Pete Aldridge

Maria?

Maria Zuber

Yeah, OK, tell me if I'm wrong. I would contend that if you wanted to send a robotic rover to the poles of the Moon or Mars that you would need nuclear power. I mean, if you want to go to the poles of the Moon and really do something there, I mean, you've got to go into the areas that are permanently shadowed, not the areas that are permanently light. So from a standpoint of scientific exploration and wanting to try to see if there's hydrogen or a form of water ice on the Moon, you want to go where it's dark, not where it's light. And on Mars, once you get up to polar latitudes, I know we were planning to put a lander near the South Pole several years ago, and it was terribly underpowered. And you could barely—you could either collect data or you could downlink data, but you couldn't do both at the same time because there wasn't enough battery power to do it, even with solar cells. So how close—first of all, am I correct about that? And second of all, how far are we from implementing that sort of technology?

William Whitaker

Well, it's very humbling of me to even answer this kind of a question in the presence of Paul Spudis, but here's a little of what goes on. In fact, that magnificent treasure of the eternal cold traps are in many cases immediately adjacent to the regions of near-persistent sun. And the way that works is that, to get a cold trap, you can think of the cup that I'm holding. What you need is that it's shadowed. And in order for that to occur, that it has to be in the presence of grazing sun. And so, in fact, these sunlit regions come to near proximity or near directness to the deep cold traps. The second part that's of interest, I mentioned the idea of circumnavigating features. So some of the features of interest near the poles are things like knolls or hill mountain tops that are, in fact, nearly persistent sun and where circumnavigation of those, which would take speeds that are almost imperceptible, get these machines directly into line of sight with the cold trap. So there are in fact scenarios from there of energetics that are beamed in, kinetic devices that are projected in, and other means of exploration. So the short of it is, you know, not only get right where you want to go without going in, and that you get to see great options or lots of opportunities for that. And then about some of the poles, like Mars, there's no question that I am an advocate of isotope power for those purposes. And what it is, is a great gift. The message that we have right here is that what you really get done is power. Or energy, depending on how you look at it. And that when you begin this transition or the space community begins the transition from exploration to work, then, of course, work is the expenditure of power and we're into a whole new realm of how to get it done. I have simply pointed out some great—a combination of scenarios and, as you pointed out, power sources that can change everything.

Pete Aldridge

Red, we're of course running out of time again, but one of the tasks of this committee, this Commission, is to write a report to the President about how to implement the Moon, Mars and

Beyond vision. If you had to write something in the report to tell the President to do something about the robotics area, what would you say?

William Whitaker

Well, let's see. The first bullet that caught my eye in looking at that policy were very near-term objectives for robots. Like robots to the Moon by 2008. And as a practitioner of the trade, that there's actually a—that's very possible, but that is not implemented in—without getting right after it. With those ambitions, 2004 is the time for those mission studies, element designs and that's the right leverage, because that is the chief investment. And so immediately, cast that vision by locking in those studies. The next is to embrace this sense of robotic ambition and boldness. These machines are capable, competent. These technologies will rise to these scenarios. The third is to leverage extensively on the tremendous power that the private sector brings to bear, particularly when it's time to get after this. One of the reasons that last experience went so well is the magnanimity and true partnership of industry that jumped right in there, enabled, led systems and brought the maturity to the trade. And then the, my sense is that, if—it's kind of a Grant's Tomb question. Because on any of the bullets which have to do with an exploration to or a robot on the surface of, that's what it means. And there's nothing to the doing but the doing of it. So get right after it.

Pete Aldridge

Red, thank you very much. It's been very helpful and stimulating. Appreciate your time coming here.

Pete Aldridge

I would guess that we would call this a pop-up guest. Rusty, welcome. Rusty Schweickart was the lunar module pilot on Apollo 9, has devoted his life to sharing space with others. Among his many organizations which he's active, Rusty is also one of the founding members of the Association of Space Explorers, an international organization of space flyers. Rusty is with us today as the Chairman of the Board of the B612 Foundation. This organization is developing space systems to protect Earth from future asteroids. Welcome, Rusty. We look forward to your comments.

Rusty Schweickart

Thank you very much, Mr. Chairman and members of the Commission. Before I start, I would like to just make a personal statement that I believe that this group of people before me has a tremendous responsibility for the future of humans in space. We have been presented in a fairly amorphous way with a wonderful vision of Moon, Mars and beyond by the President. It's clear that this is the new direction. But it is still, at this point in the public mind and in the mind of even

NASA watchers or space geeks or whatever, it's still pretty amorphous. And your Commission is being looked at by many, many people to provide the—the specific exciting, inspiring reality to make that something people can really endorse, buy into, and become part of. So I'm extremely happy to be here today to address you. I don't know whether I envy your work or not, but it's certainly a very important task. And I say that in all sincerity.

I have had a great history in both public service in the government, not only flying on Apollo 9, but at NASA headquarters for many years, in state government here in California—I was the chairman of the California Energy Commission for many years. I've also held positions, not only in the nonprofit world but also as a CEO of startup companies several times. So my experience in that sense is very broad. Today, I am coming before you specifically wearing a hat, that of the Chairman of the B612 Foundation. Let me say that our specific interests—well, let me say first who we are. We're a group of astronauts (both former and current), astronomers, engineers, and a few others from the venture community, for example, who have come together knowing the situation with near-Earth asteroids in terms of our discovery of near-Earth asteroids and understanding the history of near-Earth asteroids and the potential for collision with the planet and destruction of life here on Earth. We came together about three and a half years ago to essentially take the other side of that coin which was not being addressed. That is, we know these things are out there. Thank heaven we're now cataloging them and putting them in the inventory so we know what to expect. At some point we'll know what to expect.

But what about doing something about it? What do we do? And we got together to say, “Can something be done about it? What can be done about it? And how do we get it done?” We concluded very rapidly that, in fact, with the technologies which are being developed today in NASA, particularly as it turned out, about a year after we started, when the Prometheus program was announced, in terms of high-performance propulsion and power systems, that in fact we—the technology is available to actually do something about this, that is, to take responsibility to see that these asteroids do not in the future collide with the Earth. How to go about that was a real challenge. And our conclusion, given that NASA developed the Prometheus program or announced the Prometheus program after we got started, was recognizing that this technology could handle the task was to then convince, if you will, NASA that this is something which they should place into the program, that is, not just going out to the Jupiter icy moons and looking around, or out to Saturn or whatever else. But that they should also go to near-Earth asteroids with the intent of exploring, developing capabilities to operate in and around near-Earth asteroids. Out of that capability, we would come to the point where we would be able to assume the responsibility of assuring that the Earth was no longer impacted by these very large and powerful bodies in the future. Now, I'm not really here today to convince you of that or argue that particular point, although there are many of the questions which you asked this morning—for example, the public acceptance of nuclear energy in space is extremely important for any activity of a routine nature beyond low Earth orbit. And this is one of the most important projects in my mind.

If you will, this is the world's largest ever environmental initiative, and it requires nuclear reactors in order to do it. That's a very interesting juxtaposition, if you will. I've met, for example, with environmental groups to try and bring them into rational dialogue in how do we address this great

challenge. But the reason I'm here this morning, or this afternoon as it turns out, is really to go beyond the particular basis on which the B612 Foundation was formed. By the way, B612 I know is a little mysterious to people, but if you go back to when you were a child, you might have read Saint Exupery's story about the little prince. Well, the little prince and his rose were housed on asteroid B612. B612 was their home. And so we decided the little prince is our hero. He was there first, so we're the B612 Foundation.

Now, I'm here because as we worked our way through in very serious detail the questions of "Is it possible, is it feasible, for humanity to assume this responsibility of ensuring that we don't get wiped out by an asteroid impact?"—in looking at that, and addressing it, we concluded from a technological point of view, the answer is yes, we can do this. Or, let me say, within 10 or 15 years, we can do this. So we established a very Kennedy-esque goal within the foundation. Our B612 foundation goal is "to alter the orbit of an asteroid in a controlled manner by 2015." And we believe that, in fact, that is a reasonable goal. The way we accomplish it is to convince NASA to identify this as one of the Prometheus objectives in their Prometheus program. And we testified last week. Ed Lu, who's just come down recently from the Space Station, is the president of the Foundation. I'm the chairman of the board. We testified before Senator Brownback's committee in the Senate last week on this subject, in addition to meeting with Admiral Slidell, by the way. But when you look seriously at not just the technical issues of how do you do this, but is there such a thing as a program or building an operational capability to deflect asteroids, the answer is, in all likelihood, no—for the simple reason that the likelihood that we will have to deflect an asteroid occurs about once every several hundred years. And it's impossible to conceive of an operational system that's standing by for 100 years before it gets used. So in wrestling with this question, we come to the dilemma of how do you then responsibly protect the future of life on this planet from this particular threat?

Well, what you realize when you look at it is that near-Earth asteroids are, in fact, not primarily a threat. They are primarily an opportunity. And my goal in being here today is to extract from that third word, that is, from *beyond*, I want to pull near-Earth asteroids out of the beyond and move it back up in my view where it belongs, which is the asteroids, Moon, Mars and beyond. Now, the reason I say that is because the asteroids, near-Earth asteroids in particular, and let me say that in general, while the asteroid belt itself, the main belt of asteroids, is a huge resource, without question, they're much harder to get to. They number in the millions, in the hundreds of millions. But near-Earth asteroids are in fact, quite easy to get to, some of them. In fact, they're easier to get to in terms of energy than it is to land on the Moon and to come back. And at the same time, they are tremendous resources. They're resources from the science point of view. I won't go into that in any great length, but they are the primitive materials out of which the Earth was formed, out of which the solar system was formed, and in particular, the inner solar system. So that there is a wealth of scientific information, scientific data, and understanding that can be gained from ventures to near-Earth asteroids.

But the most important aspect, given your charter, is the resources implicit in these asteroids. People talk about and look at Moon, Mars and Beyond, and one of the statements about the Moon is "a steppingstone to Mars." A steppingstone in what way? Many people have talked about the

potential utilization of resources on the Moon in order to reduce the costs of getting to Mars. Well, if one looks at the near-Earth asteroids, the near-Earth asteroids, which as I say are easier to get to than Mars—than the Moon, excuse me, have a much higher quality of resource materials that are available for conversion into oxygen fuel, silicon, metals, whatever. They're far richer in these materials, because unlike the Moon, they were not blasted out by a huge impact years ago, and only the lighter elements comprise the Moon. And it's clearly a very desiccated environment in which we're sort of desperately trying to find a few traces of water at the poles, perhaps. The near-Earth asteroids, many of them, are rich in water. The carbonaceous chondrites? 17%, 18% water. They're rich in metals. Some of them very: a little too rich, in some sense. But there is a tremendous resource extant in the near-Earth asteroids. You're looking at hundreds of thousands of these bodies. Not just a few. Not a thousand. We're talking hundreds of thousands of near-Earth asteroids, the surface area of which is equal to or greater than that of the Moon. I didn't quite work that out before I came up here for the panel, but I'll guarantee you with hundreds of thousands of them, in fact, the surface area is comparable with at least the surface area of the entire Moon.

So we have a tremendous resource there which we should not in any way bypass by allowing it to simply exist in the "beyond" portion of the President's space vision. Now, I would suggest that, in fact, if one is looking at opening up deep space to human activity on a routine basis in the future, that these resources will become the most favored seed for private commercial development of space. Private companies, if there were a buyer for the products and services that would be available from near-Earth asteroids, would attract investment capital without question. Just think for a moment, if there is, in fact, human enterprise extending out beyond low Earth orbit into the deeper solar system, these resources will provide not only fuel and oxygen and that sort of thing for the exploration activity itself, but derivation of solar cells from *in situ* materials in space can change the economics, which basically torpedoed the space solar-powered satellites 15 to 20 years ago, for lack of cost-effectiveness. The economic equations change dramatically as soon as you have an enterprise going on there, which provides a whole series of—opens up a whole series of products and services to be provided. So there are industry potentials that are very cost-effective in the long run, provided NASA takes that role of an enabler.

And it is my firm belief that as we move into space, if NASA or the government or governments of the Earth assume this role of an enabler, that private enterprise will flourish in this new environment. And when that day comes, then the other element, not the greed or the curiosity, but the fear element, is also addressed in a routine way. That is, the Ace Moving and Mining—space moving and mining company simply gets contracted to go over to asteroid so-and-so and give it a gentle nudge so that it doesn't impact the Earth in 38 years. And it's a routine matter to do that without ever setting up some kind of a standalone space defense system, which is not practical. So my personal feeling is that from the B612 hat, the way we're going to protect the Earth in the future, is by private initiative having an additional job, which is going over there and nudging that. And at the same time, providing jobs in space for young people, manufacturing, etc., and, fundamentally, enabling human activity routinely beyond low Earth orbit. So that is the principal issue which I come before you to discuss. I'm happy to answer questions or to opine on any of the other myriad questions that you're facing as a Commission. Thank you, sir.

Pete Aldridge

Any questions? Go ahead.

Paul Spudis

You know, it's—I agree with your assessment that asteroids are potentially very resource rich. However, we have a lot of ignorance about them, any of us, and particularly your statement that they're particularly volatile rich and the Moon is volatile poor—well the [bulk of the?] Moon is volatile poor, but the polar areas are not. In fact, the real issue is not the volatile content but how accessible are they? So what I would suggest—and I agree that certainly it's a valuable resource that needs to be investigated—is before you commit to getting most of your resources from the near-Earth objects or any asteroid that you do a bunch of near survey missions—you need a variety of robotic probes to actually assess what's there and assess how accessible it is. And we need to do that in any event, regardless of whether we mine the Moon or not, you need to know what your resources are. So that I would submit that's probably the first step you want to do.

Rusty Schweickart

I have absolutely no debate on that whatsoever. And in fact, our basic proposition to NASA is exactly that: that one of the Prometheus missions be assigned to begin the exploration of near-Earth asteroids. There are scientific—immediate scientific questions, there are resource questions, there are structural questions about the asteroids, because they are, as you're well aware, characterized as rubble piles, at least the larger ones. So there's a great deal that we have to understand about them. At the same time, we already know from meteorite samples all over Earth, and spectral surveys, etc., that they are also resource rich.

Paul Spudis

I'm just curious: is there any particular reason why you want this to be a Prometheus mission?

Rusty Schweickart

Yes. There are a couple of reasons. Number one, before Prometheus was actually announced, we had already analyzed what would be required in order to actually provide enough Δv to one of these near-Earth asteroids in order to cause it to miss the Earth. When we looked at that, we sized the ion, if you will, the ion or plasma engine that would have to be utilized. We sized the nuclear power which would be required to provide the electricity to power that engine, and, lo and behold, Prometheus announced, "Here we are." So it fit perfectly.

Paul Spudis

Right, I understand, it was more for the collision mitigation. But I was talking about resource prospecting as a separate thing. You could—I'm just wondering, I'm afraid to commit—a Prometheus-class mission is going to cost billions of dollars, no matter how you cut it. And if you want to make an assessment of what the resources are and build all the various classes and get a really good analysis of what's really there, it might be cheaper to send smaller robotic—chemical robotic probes—several of them, than to invest in one big Prometheus-class mission, but you would have to do that if you got to the point where you wanted to mitigate a collision. But to just do the prospecting you don't need that, correct?

Rusty Schweickart

I suspect that that is correct. At the same time, Prometheus, while it's not fully funded, it's certainly an accepted program and is receiving funding. Our feeling is that the Prometheus mission, the near-Earth asteroid mission, if you will, is a perfect testbed for Prometheus. It is far less challenging than the Jupiter icy moons orbiter mission to which it is already assigned. In other words, the near-Earth asteroid mission would actually be a steppingstone to the current Jupiter icy moons orbiter mission. In addition, by simply going to a near-Earth asteroid and landing on it, you would certainly bring along a science package which would analyze—or provide either sample return, which, by the way, Admiral Slidell found quite an interesting concept—that is, not just going to land on one, putting off a package, but also returning samples. So in other words, since the Prometheus program exists and has this capability, my question is, given all of the valuable contribution which could be made by going to near-Earth asteroids in terms of opening up deep space through resources, etc., why should we go out to Saturn, fly around Saturn for no particularly good reason other than curiosity? When we go to the near-Earth asteroids, we satisfy curiosity, greed, or commercial development, let's say, and fear. So in other words, we have all three major motivating factors, which are addressed. And the Prometheus missions are there. So let's simply pick this as one of several targets for the program. But I totally agree that other missions might be cheaper if they're only designed to begin exploring the issue of resource development.

Pete Aldridge

Carly?

Carly Fiorina

Thanks, Rusty, very much for coming this afternoon. As you may know, this Commission is spending a fair amount of time thinking about how to get private industry deeply engaged in this mission, both large companies, small companies, venture capital, traditional sources of capital. And you've obviously thought a lot about that as well. Could you talk a little bit about what you think it

will take to achieve the vision you just laid out, where you have private enterprise working in space, and also perhaps accomplishing some other objectives at the same time?

Rusty Schweickart

We have thought about it. I have not done a great deal of what would be called legitimate analysis. You know, cost-benefit equations, etc.

Carly Fiorina

Neither have we yet, so it's okay.

Rusty Schweickart

But from a conceptual point of view, which, as you and I both know, 80% of the right answer is at that level, from the conceptual point of view, it seems to me quite clear that as long as major space activity, whatever it is, remains in the hand of government, it will always be a painful process in the sense that while taxpayer money may be available for opening up potential, whenever something goes wrong, there's hell to pay. Neil Tyson knows that in spades from the recent CAIB [Columbia Accident Investigation Board] that he sat on. All of us are very painfully aware of what happens when something goes wrong and you're spending taxpayer money.

My personal feeling is that part of the government responsibility, when there is large—really large—potential for the human future involved, is to enable, to be the first there, perhaps, but then to enable industry to follow. How do we do that? We do that by being an anchor customer, for one. I mean, clearly there will be government operations in space, for many different reasons. If fuel *in situ* is to be made available, why should the government produce it, put out a contract, an announcement of opportunity for oxygen, for water, for fuel, whatever, to be made available in space, rather than dragging it up from the ground. That clearly is key to opening up deep space activity. So I think the government has a great opportunity for being an enabler, becoming a customer for products and services, which then will enable, if there is a reliable customer, private investment to benefit from it. I'll give you one very specific example. Opening up the West in this country. Well, we had a witness earlier in the day from the U.S. Geological Survey—mapping is an extremely important subject in terms of territory of any kind. Well, the near-Earth asteroids are a very unusual territory, because they come in little chunks and they're in all kinds of orbits, but in a sense, the near-Earth asteroids are territory in space. Tremendous surface area. Today, in a way, although we don't talk about it that way, the near-Earth asteroid detection program is the very beginning of a territorial mapping program, but if we're going to talk about private industry eventually mining and providing—you know, manipulating materials in space for products and services, it would be very helpful for the government to provide the maps, and not only maps—say, the size and the orbit—but also the spin rate and the composition of the asteroids, etc. So there's an enabling type of thing that the government could do.

Pete Aldridge

Rusty, we've run out of time again. I appreciate your coming forth today and telling us about this interesting concept, because I think it does fit the mold that we have been talking about. As Carly's pointed out, more private-sector involvement. So again, we appreciate your time. Thank you for coming.

Rusty Schweickart

Thank you.

Pete Aldridge

We're going to take a 15-minute break and we'll be back at 2:15.

Pete Aldridge

OK, if we can get started, I guess? Could we get started, please? Could we get started, please? For our final testimony of the day, and in keeping with our emphasis on education and youth here at the Galileo Academy, we're pleased to welcome M.R.C. Greenwood, the Provost of the University of California. We have saved the best for last. [laughter]

M.R.C. Greenwood

Well, thank you very much. First of all, thank you all for inviting me to testify here this afternoon. I'm looking forward to doing it, and I hope I can help you with your deliberations, and I want to thank you on behalf of the nation for taking the time out of what I know are very busy schedules and careers and other activities to serve the President in this way, and we're looking forward to hearing about your deliberations in the near future.

The goal that the President has set for space exploration—Moon, Mars, and beyond—is indeed an ambitious goal, and in order to accomplish these goals, we're going to need a lot of partnerships. We're going to need sustainable assets, we're going to need intellectual brain trusts, we're going to need the ability to integrate and sustain business, university, and government relations, and you're going to need both incremental opportunities and transformative opportunities and partners that can make those things happen, and so I'd like to talk to you a little bit about the role that the University of California thinks that it might be able to play in this ambitious program. Now, by way of background, for those of you who don't know the University of California, we have nine, soon to be ten, campuses that are home to more than 200,000 students, more than 50,000 faculty, and a lot of other academic personnel. Six of our undergraduate campuses are part of the prestigious American Association of Universities (AAU). And you probably already know that our faculty have many Nobel Prize winners, about 45 right now, 48 National Medals of Science winners, a

number of National Technology winners, and huge numbers of members of the National Academy of Sciences, Institute of Medicine, National Academy of Engineering. We are the nation's leader in federal R&D [research and development] expenditures, in the development of patented inventions, and in the awarding of Ph.D. degrees.

So, as the state's public designated public research university, in the state of California, the University of California makes a major contribution, not only to the advancement of worldwide knowledge but to the economic growth of the state. You know, many research universities across the nation make huge contributions to the economic development of the states that they're in. California is slightly different in that we have this large research university, which is the dominant research partner in the state of California, although there are a number of other distinguished research universities that play a very important part. But just to give you an example, the annual economic impact of UC in California alone is about \$14 billion. And it's been projected in a recent economic study that the university did that we would create almost 100,000 new jobs in California over the next decade. And just—you know, just to give you an idea of the kind of partner that we might be able to be as you move forward with this vision and the connection between the university, the intellectual brain trust, and technology transfer, the concentration of businesses that fine universities bring into the triad that's necessary to advance such huge objectives, the University of California makes the claim that one in three biotech companies in the—in California were started by one of our—one of our alums, one in six IT, and it's pretty dominant also on a national picture. I say this not so much to brag about the University of California, which any good provost would do for you, but to point out that if as you progress forward, the intellectual brain trust you will need will have to be multidecadal. So you're going to have to have partners in the American research universities, and we would hope that the University of California will be one of them that can sustain the continual output of new ideas, building on ideas, taking ideas up to proof of concept and also that has the educational trailing that reaches back into the schools and up into the Ph.D.s and beyond. So maybe it's the sort of intellectual model of Moon, Mars, and Beyond.

So I want to talk about a few down-to-Earth benefits that flow from expanding the frontiers of human knowledge and overcoming the limitations that are imposed by existing technology, which you are facing in your deliberations. Historically, space exploration has driven our nation to break a lot of critical new ground in extremely powerful and productive and beneficial ways. Indeed, one could argue today that your Commission is not only about Moon, Mars, and beyond, but about the structures and the partnerships that are important for the nation's future economic security, and in a time when we're talking a lot about national security, there are those among us, and it would be those in the universities as well, that are very concerned that if we don't maintain and if we don't have the intellectual brain trust for the future, national security will be endangered in a very real way, not in the very timely way that it is right now but in a very long sense.

So to accomplish, as you've heard most of the day, I gather, the technological challenges to your panel, I'd like to talk a little bit about new leaps in technology that are going to be absolutely necessary, and let me talk for a few moments about nanotechnology and the convergence of bioinfo and nanotechnology that will allow us to create products that are smaller and stronger and more efficient for use both in robotics and in human space exploration missions. It's not just a question

of miniaturization. It's also about synthesizing from nano-scale building blocks to take advantage of the unique chemical and physical properties that exist at the nano scale. Now nano-scale-derived materials will likely be harnessed for use in future space exploration, and whose systems, we hope, will be embedded with machine knowledge, potentially allowing them to operate almost as if they were living systems. Now nanotechnology, like biotechnology and its precedent, the emerging field of molecular biology, is a young industry, but by the time some of the objectives of your Commission need to be realized, we hope that it will be a developed industry or a developed set of industries, and some of you on this panel are probably more capable than I am to talk about the economic prospects, but a recent study that I read indicated that this could be a trillion-dollar industry. So not only could we accomplish some of the goals of this mission, but it is very likely that this will stimulate the nanotechnology-infotechnology fusion.

The UC system has been a major participant over the years in NASA research programs. This year alone we've had over 70 millions of new contract and grant awards. Recently, the campus that I was recently the chancellor of, the University of California at Santa Cruz, was named the best university in the space science area. So we believe that, along with our own universities here in California, but also in partnership with those who would join us, that we could provide an incredible future asset to be developed, sustained for the future. Now I want to focus for a moment on the San Francisco–San Jose–Oakland area because it's a critical regional component of the national strategy that you might be looking at. This region of the country enjoys the highest concentration of information technology capability, based on its longstanding leadership in microelectronics, semiconductors, computer hardware and software. It also has one of the most powerful and dynamic concentrations of the fast-growing biotech and biomedical firms, driven in large measure by the use of information technologies to develop new products that are based on exciting discoveries that are coming out of the human genomic mapping, which is a recent and probably critical milestone for the future understanding of what constitutes the origin of life as we move into more understanding of what might sustain life on other planets. In no small part, the successes of these regions have been driven by the contributions of the university, and I mentioned that before, but we also have, as part of the university's circle, the federal and national laboratories with whom we collaborate, and that would include the UC Berkeley, Lawrence Berkeley National Lab, the Lawrence Livermore National Lab, the UC San Francisco, UC Santa Cruz, Stanford, and SLAC [Stanford Linear Accelerator Center?]²—all have added major intercampus, interuniversity centers which also interface with industry and have, in fact, generated industries in the area. I'm sure that Carly Fiorina could tell you in more detail than I can what the connections between universities and industry can be and some of the challenges to making them the most effective and efficient that they could be for the future objectives.

We have pursued, the University of California has pursued, new partnership opportunities with NASA, and we are an important player in the new NASA research park, which is planned just down the road from here. It's a world-class shared-use R&D campus. The university has been expanding our presence in the region to become more of a focal point, not that we aren't already a pretty big focal point, but a focal point for research and education throughout Silicon Valley, and we want to focus on developing the next-generation technologies that will enable the nation's space

exploration while providing these business opportunities and return to investment. You may know that in the state of California we have four institutes for innovation that were established just a few years ago that are cross campus, and they are partnerships with industry. These centers were established with the understanding that for every dollar the state invested, there would be \$2 invested from other partners—business partners or faculty members who are able to obtain federal grants or other types of resource assets, and in most cases these institutes matched the contribution of the state by an almost \$3 to \$4 for every dollar invested. So we have some experience in pulling together the kinds of organizations necessary to establish new models of doing business and that could—are potentially sustainable over decades.

As an example of the sort of relationship that can be built between the federal government and universities and provide a kind of portal access to the intellectual assets of an organization as large as the University of California with its partners, I would cite for you, and probably some of you know this, the first of the NASA university affiliated research centers, the so-called UARC, which was established just last year with the University of California, with Santa Cruz as the lead campus, the university received a 10-year, \$330-million contract to operate the UARC in the NASA research park starting in September of 2003, and the primary objective of the research to be conducted under this agreement and through the UARC was the provision of new technologies derived from bioinfo and nano. We are now involved in developing a partnership at the NASA site to establish the creation of a bioinfo-nanoresearch and development institute through a partnership of government, academia, and industry which it's intended to couple the extensive research development and expertise of the entire UC system, NASA, and then prominent industrial partners in this so-called BIN (bio-info-nano) fusion science to the goals of the new space exploration vision. So it's a way for the NASA organization to have a portal into a very powerful intellectual brain trust that has experience with trying to develop mission-directed but very early-stage and basic research opportunities or products that can be used in the—in the very challenging proposal and goals that have been set forward.

Now you asked about education, so let me tell you that one of the things that we have been spending some time on, and this has involved the NASA folks as well, is working with San Jose State University in the Foothill–De Anza Community College District to try to establish a new approach, at least a new local approach to science, technology, and engineering and math career goals and a return to preeminence of these areas in our schools and our students. In the state of California, we have what is referred to as the master plan, which means that every segment of higher education has a specific set of missions and we try to connect with the new master plan from our K-12 objectives with the community colleges and the comprehensive state university and the research university to try to provide a very powerful pipeline. One of the tools that the university of California and the California state universities have is that by studying our admission requirements, the so-called “A through G” requirements, we determine, in many ways, the curriculum of the state of California, which makes us unique among research universities, because many other fine research universities can change their admission requirements, but it would not affect the state's high school requirements necessarily. For example, if Harvard were to change its admissions requirements it would not change the high school requirements in the state of Massachusetts, just to

give an example. They might influence them, but they wouldn't change them. So we are hoping, and very enthusiastic about, the opportunity to start moving the University of California to try to really change the way science and math education is working in the state of California, and we're hoping to have strong business partners in this operation in order to provide this Commission and those who would work with us with the kind of a state approach to science and math education that will ensure that there is a strong and evolving workforce to sustain the technologies, the partnerships, and the new discoveries that will be necessary to help you move this forward. So those are my remarks. I've tried to touch on a few of the things that I think would be important to your objectives, and I would be more than happy to answer any questions that you have. Thank you.

Pete Aldridge

Thank you very much. It's very good. Yesterday we heard some discussion about teachers. And I guess a viewpoint that, obviously, if you have a very motivated young kid in science but you have a very unmotivated teacher, that doesn't work—you have to have the motivated teacher with a motivated student, and there was some discussion about our role in teaching the teachers, and especially teaching a science teacher.

M.R.C. Greenwood

Correct.

Pete Aldridge

Do you have a program—having a teacher, sometimes you get into the department of education and you teach the teacher, but they may not have the skills in physics and mathematics and things to be a science teacher. How do you handle that type of a problem?

M.R.C. Greenwood

Well, I won't kid you, the national shortage of qualified science and math teachers is one that we all need to be very concerned about, but the University of California is working now to try to develop a new program that would help us to build—first of all, strengthen the teaching skills of those teachers who are already in the schools, and then to inspire and develop new teachers of science and math. Our biggest problems in the state of California are in the math and physical sciences area, not that we don't have problems in other areas as well, but the number of individuals who are becoming credentialed in math and in physical sciences is very low compared to the projected hires over the next period of time that we have. And I know this is an interest of the—of the administration in California right now, but we're just in the process now I think of defining exactly how to do this. Now, having said that, the use of technology in providing new materials and

new understandings in compelling ways for us to keep particularly the students who are more advanced in science and math involved in going on to something that NASA has always had a role in, and in fact many of the NASA websites are among the most popular for teachers and students to visit, and which help them hook them on science, if you will. The complication is integrating those materials with the California and/or other state standards in the curriculum. And that is an issue that has been very difficult for many individuals, for many school districts to deal with. And now the President's "No Child Left Behind" has tried to address this, but if you don't start preparing the teachers differently, then it's hard to change the school environments. And I'm afraid, in many ways, we've come to think of science and math in some areas as very much rote learning and not nearly enough getting the students excited and hooked and getting them to use their own very high-quality minds to think about what they could learn that's new. But it's harder. It's much harder to engage students that way than to just tell them what is.

Pete Aldridge

What would you do different?

M.R.C. Greenwood

What would I do differently?

Pete Aldridge

Yeah.

M.R.C. Greenwood

In terms of inspiring teachers?

Pete Aldridge

Yeah.

M.R.C. Greenwood

I would start with the—right at the high school level, with trying to inspire young people to think about what it would mean to teach in, you know—to teach young people and open their minds to the really exciting questions and opportunities, not to mention job opportunities that they would have. So I would start trying to identify students in the high school who have the potential for becoming good science and math students and maybe would like to go back to teaching. In the universities where we do have the responsibility for training students to get their credentials, I

would concentrate in the areas in which students are currently trained—that is, at the major level, and try to work with both the education and science folks to try to create an environment where very bright young people wanted to become teachers in our schools. Probably the most successful thing that the University of California—well, one of the successful things that the University of California could offer in this respect is that we have a program called the New Teachers Center, in which—it's a program where teachers entering the profession are put into a more professional environment and mentored. The national statistics are that—of new teachers who enter in any field, about 50% of them will be gone within five years. Using the program that we've developed, which has now become a bit of a national model, about 90% of those teachers are still teaching, teaching five years later, and many of them have become mentor teachers themselves. Now, we haven't focused that on science and math, and that might be one approach that would be a useful way to go.

Pete Aldridge

One of the other things we've heard is the declining students, graduating engineers, scientists, and I assume the University of California is experiencing the same statistics, the declining number?

M.R.C. Greenwood

We've actually had graduate growth across the university in the last few years. We have seen—we've actually built our engineering programs, both at the undergraduate level and at the graduate level over the last few years, although we have seen recent declines in students going into those fields. We were—the state focused on this about four years ago and started providing additional money to the university to build our engineering programs, and we had a goal of raising our engineering enrollment by a—I think—I'm not sure of the exact percent right now, but the short version is we doubled it.

Pete Aldridge

Were most of those foreign students?

M.R.C. Greenwood

No. Actually, in the university of California, many of our students are not international students. Part of that has to do with the way in which the University of California is funded, which doesn't make it that easy for us to fund international students at some points, so we have lots of domestic students. We do have a lot of very talented international students at the graduate level, but probably fewer than you would see in your typical research university.

Pete Aldridge

Yeah, Neil?

Neil Tyson

California is unusual among the states. California plus a handful of other states distinguish themselves in some important ways. For example, you have the whole sort of equation of the economic, technological funding model built in. You've got a prestigious university, you've got high-tech industries, you have a NASA presence in your state, so—

M.R.C. Greenwood

At both ends?

Neil Tyson

So given this combination, it seems to me that the whole vision is sort of an easy sell in California, but I don't know that most of the country can say that about their own state. They might have a university but no NASA presence. Or they might have a tech corridor but no great universities to look at the causes and effects of these investments. What advice would you give us when we prepare our report to try to convince those that don't already know the equation that they should still support this vision? Because we're going to need support from places far beyond Florida and California to keep this going for 30 years and beyond.

M.R.C. Greenwood

Well, I think that would be—that would be the challenge for the partnering in how you identify both your outcome objectives and some of your political objectives. And there certainly is a long history when universities are asked to partner with other partners across the country. There are some good models for that. The National Partnership for Information Technology is one way that that's been done. But I would say that you need to think hard about this and you need to get the university and industry partners thinking about a sustainable 20- or 30-year partnership that could build pockets of excellence in other parts of the country attached to the main focal points where you've already got, if you will, the seed core and the assets and the base that you would need to move it forward. So—

Neil Tyson

Might this include virtual centers where people can plug in without having to then invest in the infrastructure—

M.R.C. Greenwood

Well, NASA has had some experience with virtual centers and some of it has been extremely successful. So that would be one way to do it. On some of these—on some of the projects—some of the scientific projects you would need to do, some virtual centers would work very well. In other cases, you would have to have project-oriented teams that can meet virtually but probably would have to be in one place or another to finish a prototype, for example.

Pete Aldridge

Laurie?

M.R.C. Greenwood

But I'm not a space scientist. I'm a biologist. Although I did, in fact have—

Neil Tyson

We need biologists now.

M.R.C. Greenwood

I know. I know. You certainly do—

Neil Tyson

When the life crawls out of the cave, you know, we're going to need you to check it out.

M.R.C. Greenwood

No, no. You're going to need us well before it crawls out of the cage. You're going to need it to identify it long before it ever got in the cave. No, actually I'm a biologist, and I have, and disclose that I was funded by NASA many years ago for some work on human exploration.

Pete Aldridge

Laurie.

Laurie Leshin

Thank you. Thanks, Dr. Greenwood, this is fascinating. This is a particularly interesting topic to me coming from a research university myself, and I'm really struck in this entire thing how necessary, interesting and innovative partnerships with universities and, you know, the intellectual agility and enthusiastic young workforce and, you know, great assets that universities can bring to all of this.

M.R.C. Greenwood

Constantly coming in, rejuvenating us.

Laurie Leshin

Yes. Self-rejuvenating in many ways. So I'm interested in the UARC that you discussed.

M.R.C. Greenwood

Sure.

Laurie Leshin

And I'm interested in that pretty substantial investment that it sounds like NASA has made in that and I'm curious about what the procedure is for the exploration endeavor to take advantage of the work that's going to be funded and done by that. How does that UARC interact with NASA to help propel this exploration vision forward, and is that a good model, do you think? Should we be doing more things like that?

M.R.C. Greenwood

Well, I can tell you whether it's a good model, you know, in the future, because it's only about six months old, but it's innovative.

Laurie Leshin

We've got to go now.

M.R.C. Greenwood

It's innovative and the reason that it's unique is that it is—it's a partnership that's based around a working relationship with NASA. Where NASA brings to the table tasks that it needs to get done, and the university then works to form the work team that will do that, and it might not be university

people, it might be business people. I mean, it might be industry people and in several cases it most assuredly will be, but the university keeps it coordinated, responds to the tasks, does the management of it, and the beauty of it is that it can come out as a task when that task is done, you can go on to something else, you can tap into the entire University of California and find the scientists, investigators who are interested in doing this work, and it doesn't preclude a joint partnership, and the work—most of the work that's being done right now is actually being done at NASA. And, of course, there, depending upon the work you're doing, there are complicated and necessary arrangements that have to be done to deal with some of the FAR clauses and issues that have to do with ITAR and things of that sort, but we so far have managed to find a successful route, but we've just started the process of doing this work and so at the moment I think we're—I think both partners are satisfied that we have enthusiastic folks that want to work on this, we have a mechanism for doing it, and it is more flexible for NASA than some other arrangements that they might have had. It was a long and arduous competition, I would tell you.

Laurie Leshin

Can you give an example of one or two of the projects that they've asked you to look at? Or is that—I'm sorry if this is a little bit—

M.R.C. Greenwood

You know, I have to tell you, I probably— I could be more specific—

Laurie Leshin

I would love to see more information.

M.R.C. Greenwood

But I would be happy to give you some specific information. I've only been doing the provost job for two weeks, and even though Santa Cruz started this, I can't reel them off the top of my head. There is someone in the audience, however, who could answer that question. Dr. Berry is here from the UARC and I'm sure he can tell you in detail.

Laurie Leshin

OK. Well, we can talk afterwards. That would be great.

Pete Aldridge

Carly.

Carly Fiorina

Thanks for being here. I want to follow up on Laurie's question because I was also intrigued by the nature of the partnership that you described, and I would like to ask you specifically what didn't go well, what hasn't worked well? You've had the experience of being funded by NASA as a biologist and you now have the experience of trying to put together a relationship. What would you change, if this were going to become more—a more routine way of NASA to operate?

M.R.C. Greenwood

I think it's the time issue. The time invested in getting the contract to the point where you can actually agree on it. These are not easy bureaucracies to mesh. And in the business world—well, I don't know, you know more about joint ventures than I do, but it would have taken a very long time to sort of work through some of these issues but it's a new venture for NASA to do one of these particular kinds of arrangements and it was a very new thing for the University of California.

What didn't go right? Well, probably it's a culture clash, you know, what the university is expecting. They're used to the sort of grants and contract world, much less interested—much less used to the federal acquisition, except in the national labs where we know quite a lot about it but, you know, having the campuses involved in this, that took working out. I don't know at this point I'd be prepared to say anything didn't work, because the good news is we successfully concluded the negotiations, we are friendly partners—I mean, we're getting along just fine. We're not having any further problems now that it's established, and we're getting the task orders and moving forward. So in a year, I might be able to answer that question but right now I don't think that we've got any major complaints.

Pete Aldridge

Les.

Les Lyles

A quick comment about that subject on UARC. Should be very interesting for us to go back and take a look to see if there's any difference, lessons learned in approach between NASA's UARC structure and the Department of Defense UARC structure which has been going on for some time now.

M.R.C. Greenwood

They are different but I can't tell you exactly how, General.

Les Lyles

There could be some lessons learned both ways, positive or negative, in that regard. My question is, obviously we're all very concerned about the decline in science and math and engineering amongst students, both at the university level and obviously before that, as a lead-in, but one particular area is interest in science and math amongst minorities.

M.R.C. Greenwood

Right.

Les Lyles

Are you aware of anything or is the University of California, do you know of things that either we should be doing or things that might be successful to try to reach out to minorities and stimulate the interest in the technical skills, a lot more in that particular area, whether it's in historical black colleges and universities or historical Hispanic colleges and universities, this is a major area that—of concern, and we're not quite sure what the right things are to do.

M.R.C. Greenwood

Well, as you undoubtedly know, California is the most diverse state in the nation, and we've had quite a lot of experience with trying to bring science and math education into schools that have traditionally been what we call under-performing schools. And the University of California, in the wake of Proposition 209, has focused a lot of its efforts on developing the students in the under-performing schools and the lower what we call API quintiles and one of the things we've done is develop a program called the University of California College Prep Online Program that brings to rural schools, urban areas where they don't have advanced placement courses, where they don't have the science and math teachers that would be necessary, where students, if they don't get an opportunity at the class the first time it comes around, they won't get another opportunity because if there's one physics teacher, there's one class—this program delivers online the advanced-placement courses in physics, math, biology, and it also delivers free to any student in the state of California SAT prep online and ACT prep online, which 20,000 students took advantage of just last year alone. Right now we have about 6,000 students enrolled in some of the advanced-placement courses and they're in 57 of the 58 counties. So we've used this technological tool, and this program just started a couple of years ago. We use this technological matrix to get into 57 of the 58 county superintendence areas and provide this material, and then how we do that depends on the school—in some cases it's straight online, in some cases there's supplementary coaching, sometimes there is a science teacher there or a math teacher who uses these materials. So to get to your question, how do you get to minorities here?

Well, first of all, you've got to be sure they've got access to the materials, and many minorities are in schools where if there is an advanced math course, there's only one or there are very few, so the other approach we've taken, and we're doing this in the Imperial County area, that's Southern California, and up in the area where I was, in Santa Cruz and in San Jose, we're targeting what we consider critical path points. For example, algebra: trying to really focus on getting students and their families to understand why they need to pass algebra, that it is a blocking move with respect to college going, if you don't take algebra, trying to get more students to take it. Our programs show that you can shift the performance of those students pretty quickly with certain types of intervention. We have summer algebra courses. We have a program calls Cosmos, which is targeted towards students who are interested in and good at science. And they come and they spend six weeks on four of our college campuses and they're deeply immersed in programs with our scientists and our graduate students and a high school teacher, and one of those programs at Santa Cruz was astronomy and astrophysics, so and those programs, the high-performing students, those programs are equally diverse as the state. It's not—we're identifying plenty of smart, young minority students. The question is, Where are we losing them? And so, yes, we have tools. Could we do better? You bet.

Les Lyles

Thank you very much.

Pete Aldridge

Maria.

Maria Zuber

Yes. Doctor Greenwood, I wanted to go back to a comment you made before, that when you saw your engineering enrollment going down, that you took steps to increase it. What precisely did you do?

M.R.C. Greenwood

Well, first of all, the business community said, "The state of California is a net importer, it needs to be producing more engineers," and at the time the state had some funding that could go in that direction and that was a priority of then Governor Davis, and so we were able to—we were able to utilize that funding to help us build our enrollment. In fact, in the institution I recently was Chancellor of, UC Santa Cruz, we were just starting an engineering school, and it has enormously increased its enrollment in a very short period of time.

Maria Zuber

But did you use those funds to increase the recruiting or to—yeah, I know the University of California is an excellent school system, so you get far more qualified applicants than you can accept. Did you target engineers in the admissions process? You know, you made comments before about changing, you know, the admissions standards.

M.R.C. Greenwood

Well, we certainly talked about the quality of the University of California engineering programs and the fact that we were enlarging them, and that in itself was enough to draw a lot of students into applying. We also focused some of that funding on areas of engineering that were critical to the California economy. So mostly the new, what I would call new 21st-century, engineering programs and that was a very successful move, and the students who came in were quite excellent, and many of them, even in a down economy, many of them have been recruited into businesses in California and elsewhere.

Pete Aldridge

Bob.

Robert Walker

The University of California has a rather unique role in its work to manage the national energy labs. Can you give us some idea as to why that type of role and having the University of California do that is better than, say, the Department of Energy just running the labs themselves?

M.R.C. Greenwood

Well, I would go back to—first of all, I'm surprised you asked that question. I think the way I would like to answer that question is that the university of California considers managing the laboratories a public service to the nation. But, as a secondary consequence, what we can provide is a constant stream of new young people that are interested in working in the research areas related to the national labs and the Department of Energy's objectives. The way in which that has played out for the university is that many of the technologies that were necessary for national security have been developed out of basic research discoveries that started in the university and got transferred. Not just in the University of California, other universities have contributed, but a large number of University of California individuals have provided a lot of basic knowledge. So there's—has been a lot of—I mean, the Department of Energy managing the laboratories themselves, I have always felt and I've put a hat on that I wore once before in front of your committee, and say that there are great

difficulties in having the government manage the bureaucracy necessary to run those laboratories, in my view.

Robert Walker

Thank you very much.

M.R.C. Greenwood

And I think most people agree with that, but maybe not you.

Pete Aldridge

Dr. Greenwood, there have been some discussions raised throughout the—our sessions, the last month or so, about the very long-term nature of this effort and the fact that it may be something that we may have to take a much more bolder step into the education process, and there's been a suggestion of some type of space academy that would be a place to bring in students, maybe paying their tuition, to increase the number of experts in the space community as a feeder into both industry and in government. Does that sound like a wild idea?

M.R.C. Greenwood

Are you thinking about this at the K-12 level or at the university level?

Pete Aldridge

At the university level.

M.R.C. Greenwood

Well, since I haven't heard the idea until just now, I don't know exactly what you have in mind. I think you could do it one of two ways. You could establish a separate institution with all of the—both assets and problems associated with establishing an institution and trying to run it and keeping it fresh, et cetera, or you could connect it to some of the programs in the universities and then run special types of, if you will, academy programs. You know, bringing them together for a semester, you know, doing a semester or two in the course of their four-year education for some common course work and that could be done, I would guess, over the next 20 years. It could be done both virtually and in person.

Pete Aldridge

The virtual approach was more the concept. Not—although there had been some discussion at creating an academy much like the military academies where you do bring in space cadets, so to speak, although we don't like to use those words, but—

M.R.C. Greenwood

Well, whether or not you see that as a good direction to go depends a lot on whether or not you think you can create an environment where the people you hire to do this job will have enough new input to be able to keep the group inspired. I mean, it's a staleness issue. It's a staleness issue with graying faculty sometimes and it's a staleness issue sometimes in the government labs that it's hard—people get used to doing something one way and they don't see the next wave. Now this is why I personally believe we need business and we need the sort of innovation that the—the entrepreneurs, the people who start startup companies would bring because they have a different way of looking at how you take risk and what you are going to do to try to be sure that you get the best idea, not just the next idea. And ...

Pete Aldridge

Dr. Greenwood, thank you for your time. It's been very helpful.

M.R.C. Greenwood

It's been a pleasure. Thank you for inviting me.

Pete Aldridge

Thank you for being here.

It is now time to open up the discussion to the audience for them to make comments—they're not here to ask questions, they're here to make comments. And I'm getting more—and I'm going to start picking out a couple of names at random. I'll call one name, come up. Ken Winans The next person to be behind him would be Michael Ayala? Ken, you're first.

Ken Winans

Thank you. Good afternoon ladies and gentleman, and my name again is Ken Winans. I come here on behalf of the W Foundation, which is a space education foundation founded by my wife and myself. I'm also here as a representative of the Chabot Space and Science Center, which for those of you that are not familiar with it is the Smithsonian affiliate of the West Coast. First off I want to—I know you've been hearing a lot of things from a lot of different people, and I would like to

try to give you some additional new thoughts that I hope you will take back and convey to the President. First off, I'm struck by the historical note that here we are in the state that was the birthplace of the X-planes, the Apollo command module, and the Shuttle. Yet, today, we have a new challenge in the space horizon better known as China. I find that very interesting, because spend so much time talking about why we should go. Maybe the good old-fashioned reason why we went before. So one thing there ...

Pete Aldridge

We only have two minutes now.

Ken Winans

OK, I'm going to get going here. What are we doing locally? You have another area of education that you need to move on, which is the involvement of museums. Chabot Space and Science Center, Smithsonian affiliate. You have a problem today. Ask me how many artifacts from the Smithsonian Chabot has. Zero. The Smithsonian has a horde of collectibles in their warehouses that have never seen the light of day. They will not lend them out to local museums. Now what am I? I'm a collector. I have been lending my items to museums to help beef up not only the history of the space program and its role but how important it is to get kids involved in the history and how important it is. I will tell you after 9/11, it was amazing how kids were down, distraught, and, you know, confused. And to go to talk to these kids and to tell them, "Look, I want you to remember one thing—there are six American flags on the Moon. No other nation has done it. You come from a special nation. Don't ever forget it." Six months later those seventh- and eighth-graders will still talk about it and say, "We want to be Americans; we want to be astronauts." So I do not believe it is a hard push for you folks to get the public involved. But, if you do not get the museums for them to go to, you're losing a tremendous advantage. Final comment, and I want to bring this up. That you have—you know, we all remember Dr. Von Braun's very famous phrase when a panel such as yourselves asked him what will we find on the Moon? He said Russians. Let's modify that comment to say what could we find on Mars? Chinese. And so I think it is very important for us to take this serious. It's not just our decision. We have another nation that's funded by a military. And they're moving very quick and they're serious. Thank you for your time.

Pete Aldridge

Thank you, Ken.

Pete Aldridge

Michael? And while Michael is coming up, Katie Snyder? Go ahead, Mike.

Michael Ayala

Yes, my name is Michael Ayala. I'm a student at City College of San Francisco and I will be transferring to San Francisco State in another semester. My area I'm studying is mathematics, physics, and clown study.

Group question

Clown study?

Michael Ayala

There's a—yeah, it's a long story. There are four points I like to bring up. The first point—I think that incorporating international cooperation into this program would be an excellent point, and within the past few years we've been noticing that the United States has been interacting with other countries more in a reactive sort of way and usually under areas of distress. This program offers an excellent opportunity to have the United States interact with the other country in a more proactive and more positive way. Point two, I would like to bring up in education is that students I've been noticing—excuse me—that you've been asking questions about getting students involved with the educational program. That, too, I think is an excellent opportunity, but not only having the students interact with other students within the local schools, but also interact with other schools and also interact in an international way. So that too in a kind of educational way doing what the adults are doing in the International Space Station and the Moon and Mars program. Third point I'd like to bring up is that this program offers an excellent opportunity for getting the United States to adopt the—getting the United States to get into the metric system, which is slowing for some reason, America is the last country, I don't know if it's because of some type of inertia, gravity well, or drag coefficient or escape velocity, you name it. My fourth and final point—when we go to Mars and space and other things, if we could all remember to at least once a day laugh—at least once a day. That's all I ask. And if you're going to publish this—your findings and give it to the President, I would suggest to print it on metric paper, that's A-4 paper and that's all I have to say.

Pete Aldridge

Michael, thank you very much.

[applause] Katie Snyder. Katie, before you—Jim Spellman will be next, OK.

Katie Snyder

Commissioners, I—can you hear me? I'm the mother of a college-bound high school senior who has consistently wanted to be an astronaut since she was two and a half. We have some suggestions for you based on our family's experience, and my daughter has some advice which I will convey on

her behalf. I don't remember what captured her attention at two and a half, but at 8, she took an intensive three-hours-a-day three-week class all about space called Blastoff in a local summer school program where she got to do fun things like eat astronaut food. This kind of program is probably a good bet for enticing younger kids but it's the only one of its kind I've ever heard of. I can put you in touch with the educator in charge of the summer school if you wish. At 9 she wanted to know if I would miss her if she was living on Mars. In fifth grade, she attended the one-week summer space camp at the NASA center at Ames. We would not have let her go so young if it had been father away because we would not have been able to afford the cost of air fare, nor would we have allowed her to fly alone at that age. You have only three such camps across the country. But you couldn't ask for better advertising. Start more of them. In seventh grade, after being told that we would not pay for her to go to NASA space academy in Huntsville, Alabama, she applied for and won a merit-based limited one-per-lifetime scholarship to go. So we did, after all, put our then 12-year-old on an airplane by herself and hold our breath until she arrived safely. You have only two NASA locations which offer space academy. Make more. Don't make all of us parents remind ourselves quite so early that it will be worse and will be when our kids are flying off to Mars.

Here is where we started running into trouble helping our daughter pursue her dream. I'm a psychologist; my husband is a graphic designer. We support her but we can't guide her in how to prepare herself appropriately to be an astronaut. She's checked online, so she knows which colleges produce the most astronauts but she doesn't know which kinds of professional preparation give her the best chance of being selected. When my husband and I were young, NASA needed pilots. But what will NASA need five years from now? She's been zigging and zagging all through high school trying to figure it out. Anyone with less determination would have given up. She started with astrobiology. She spent three weeks after ninth grade counting slime cells at an astrobiology lab at Ames, and although she loved the scientists, she disliked the work so much she was completely beside herself for the next semester. Then, she decided that designing space habitats for the Moon or Mars might get her there, but she said there were so many crackpots online discussing that topic that it seemed a dangerous path to follow and she didn't know how to contact anyone at NASA that could seriously advise her.

If even a national merit scholar planning a double degree in biology and biomedical engineering doesn't have a place to turn, you guys are seriously undercutting yourselves in drumming up enthusiasm among less dedicated citizens. Here is Molly's advice—first, create a specific office to mentor kids who want to be astronauts. You need real people, not just a website with generic “Do well in school” advice. Kids need to be paired with dedicated advisors, though each advisor could be mentoring many kids and the advice should be age specific. Molly needs to know right now if her college major is one that will help her reach her goal. Second, and I am quoting here, she said, “All kids want to be astronauts, the problem is getting adults to fund it. You should be aiming your publicity at taxpayers over 18 and be sure to stress all of the advances that have already occurred thanks to the space program and all of the advantages to us on Earth of the presence in space.” When asked about the idea of promulgating space exploration through video games, which we read about in the newspaper, she was in favor of using the complex and realistic ones she played at space academy but not unrealistic commercial ones. As an aside: on the seventh-grade field trip to

the Exploratorium here, I couldn't pull her off the computerized Shuttle docking simulator. One last idea: if you want to appeal to kids, ask them for ideas. Ask them to send in essays with their suggestions to a website and then select the 20 kids with the most creative ideas to form a brainstorming panel.

Our daughter's pursuit of this goal has involved our whole family in following developments in space exploration with bated breath. Thank God I got to talk today. I didn't know if I would get to, and I don't know if half an hour is enough. You may be missing some really great ideas. There are other people you won't get a chance to hear today. We hope you find our ideas helpful. Thank you very much.

Pete Aldridge

Thank you.

Katie, I'm glad we had a chance to talk too. And please get that letter to one of our people down here. See Susan? We'll—we'll take it personally. That was very, very good. And best of luck to your—your daughter. Jim Spellman. And while Jim is coming up, John Reid is next.

Jim Spellman

Good afternoon, ladies and gentlemen. I'm Jim Spellman. I am here today before you as a representative of the National Space Society, one of many pro-space organizations. I am also a child of the space age. I was essentially born a few days after the creation of NASA. I have seen its triumphs, its tragedies, its setbacks, and its greatest achievements. I'm encouraged, and yet I'm also discouraged at this Commission. I'm encouraged that we have a present administration that has finally decided to look at space and make it a—an agenda item. It's only taken them three years and seven lives. I'm discouraged because if the camera who's pointed right at me can pull back and show this audience, this auditorium seats about 1200 people. And I think we can count maybe about 40, 50 if we're generous. Now, I know Susan Flowers. She's an excellent PAO. I know she's done her job. But if the gatekeepers in the media don't consider this an interesting issue, it's not going to make the front page of the *San Francisco Chronicle*, despite good reporters like Kay Davidson right here. We do not have the Walter Cronkites anymore. Thank God he's still alive. But we do not have the Jules Bergmans, we do not have the Roy Neals. We do not have the reporters, the scribes the historians that are out there that are able to make it interesting for the American public.

Carly made a comment earlier today about the cynicism. And I think that is partial because the American public don't see themselves as a stakeholder. After all, they are the ones that are footing the bill. They need to be told why this is important. We have the honorable Mr. Walker up here, who yesterday talked about other government programs that have survived longer, such as Social Security. I dare say that the space program is more important than Social Security. I dare say that the space program is more important than Social Security. Social Security is only good for giving somebody a paycheck for existing for one more month, whereas with the space program, we're

actually giving ourselves a hopeful humanity. So I call upon you to look at your history, particularly the Space Task Group Report of 1969, the National Commission on Space Report of 1986, the Ride report of 1987, the Augustine Report of 1989; those who fail to remember our history are condemned to relive it again once again in the future, and that's what we're doing with this Commission. I'm fearful that this report will be treated like all the other reports that have a common thread. They might get one new cycle and then it's going to be shelved and buried. And I'm very concerned that we've got to get beyond the paper rockets or in the day of Silicon Valley here, CGI computer-generated imagery and we need to actually start doing things that all these various reports plus this one that this Commission is now working on is going to recommend to the President. The leadership must not only come from the top down, it must come from the bottom up, thank you.

Pete Aldridge

Thank you very much.

[applause]

John, as you're coming up, the next speaker will be Roger Gilbertson.

John Reid

Good afternoon, Mr. Chairman, and commissioners, and audience. Taking a look at the enormous task you have. You guys can't fail. I'm a past president in the National Space Society, local chapter. I had attended President Reagan's National Commission on Space in '86. It must have been about 50 times more people in the audience. So this—at least we've got a core group here. I've helped the National Space Society in the past in their marketing techniques. I basically did screen printing of banners, billboards—I had a billboard campaign. But I did banners, t-shirts, bumper stickers. So I know a little bit about leveraging ideas and trying to help an organization recruit people, get the message out that, yes, we want a space-faring nation. You guys might actually have to create a congressional amendment, not just a House bill or Senate bill, but actually an amendment to the Constitution if you want something to survive 30, 40 years and pull it off. My hat's off to you. Right now, I work for a company, it's called Magnet Enterprises, we build electromagnets for particle accelerators, plasma containment. You know, take a look at what's happened with the superconducting supercollider project. You guys don't want to go the way of the dodo, that did. And right now America's fusion program is in danger of pulling the plug on it. The Tokamak Fusion Test Reactor at Princeton. I tried to help Professor Bruno Coppi at MIT with his burning plasma experiment. Right now, the—the international thermonuclear experimental reactor, the engineering design that's been completed 11 years ago, it's still not being built. The U.S. doesn't want to sign it. So you guys have a huge project ahead, to try to make this thing come alive and live. And I certainly hope you can pull it off. I think you're going to have to network with all of the universities, but all of the science centers, all the planetariums, all of the national museums, the Smithsonian. And that they're all hooked together with Internet getting the material out. I think

you're going to have to get public input from sports, celebrities. When you have a Super Bowl, you have the Olympics that you've got people coming out saying not just support the United Way, but support the President's Commission on Space. This is why—have film clips. Have more traveling exhibits like NASA has traveling exhibits so that it's not just a piece of paper that people are reading or looking at, they can actually feel and touch examples of the technology that will have to be created for us to go out and live the mission. So that's about it.

Pete Aldridge

John, thank you.

Roger? While Roger is coming up, Bruce Pittman is next.

Roger Gilbertson

Hello, my name is Roger Gilbertson. I'm from Mondotronics, robotstore.com, where we are bringing robotics education to the next generation of our future. I would like to thank the Commission for your work and for giving the public an opportunity to both attend and express our views. I'm of the Apollo generation, that lucky group of kids old enough to experience the Moon landings but young enough to not be distracted by the issues of the adult world. When I was nine years old, Neil and Buzz first walked on the Moon. And I could not get enough of it. I would stay up, perhaps for the first time in my life, past midnight to watch every frame that was transmitted from the Moon. My parents would find me 2:00 a.m., 3:00 a.m.: "Please, go to bed. "No," I'd plead. "They're about to deploy the Allsat package" or some other excuse and they'd let me stay up. And when the coverage ended, and we returned from the Moon for the final time, the boost that the Moon mission gave to me personally kept me going, sent me to aerospace engineering, robotics, inventing and entrepreneurship.

150 years ago if President Lincoln had formed this Commission, you may have been called the Commission on Iowa, Colorado, and Beyond. You would have faced many of the same questions. Can we afford to explore the West? Isn't it dangerous out there? Shouldn't we solve the problems of the East Coast first? And maybe they would have asked, "Is there life in California?" But 150 years ago we could have gathered at this very same spot on a grassy hillside, looked across the sparkling San Francisco Bay, and we would have seen scores of schooners and clipper ships pouring through the Golden Gate, no bridge in place—and on the docks we could have met the disembarking hordes, the prospectors, the fortune seekers, the entrepreneurs like Levi Strauss. The risk takers, of course, the scoundrels that would create the Barbary Coast and the wild, wild West. Some would strike it rich, some would fail, others went home but many stayed to carve out a new world. And we now know that there is indeed life in California. The testimony that we've heard these days and I'm sure that you've heard through all of your sessions clearly tells us that the space frontier would be just the same. So my one urgent request for you, this august and respectable board, is that you not let your work go to the world only as an august and respectable document that will ultimately gather dust. You've got to give us more. You've got to distill the spirit and the

energy and all the ideas that were presented here to its quintessence. You've got to give us jazz and rap and rock and roll. You need to make an MTV video, an X-Box game, you need to get Madison Avenue on it. You need to have visuals of humans and robots giving high five on the Martian surface. You've got to ask James Cameron or Steven Spielberg to give your report for you to the American people. Madison Avenue will do it pro bono. Because, like me, they're of the Apollo generation now as well. And we'll do it if you ask. Give us your results in a form powerful enough to keep a nation of 9-year-olds awake at night. Knock our socks off. Thank you.

Pete Aldridge

Thank you.

Bruce, while you're walking up, Dave Bengel will be next.

Bruce Pittman

Yeah, my name is Bruce Pittman, I am a systems engineer and an entrepreneur. I'm also one of those Apollo generation people and a graduate of the University of California system. I started at Ames in 1974 as a co-op student. Well, first, I started the year before that as an experimental subject, Spam in a can, right before Skylab, so I spent 105 days in an 11-by-17 room with no doors or windows for 57 cents an hour because I too wanted to be an astronaut. That's dedication. OK. That's stupidity, but that's also dedication. I wanted to say four things—one is that you guys have an awesome responsibility in helping to influence the architecture of this new mission. As a system engineer, you find that that has an enormous power. So what I would say to you is "Don't be too specific." Try to keep the options open because there's a lot of things that could happen between now and then. Along those same lines, the second piece of advice would be allow for the insertion of new technology. We have the tendency in the aerospace business to want to lock things in and— and specify things. We like to, what I call, dive for the weeds. And in some cases, it's useful. In this case, I think you need to let things be fuzzy for a while. I know that that's uncomfortable and people want certainty, but I think in this case, you need to let things be fuzzy for a while. The third thing is—and I started some—some weird and wonderful things, when in—when NASA was going to turn off the *Viking* lander, we started the thing called the Viking fund. And kids sent in their milk money to keep the *Viking* lander on Mars. And I mean, they were—they were incredible letters that these kids sent in with the money to support it. We gave NASA \$100,000 collected from all of these kids to be able to do this and shamed NASA in coming up with the \$17 million it was going to take to keep the *Viking* lander alive. So, what I would say is, Keep those—the door open for the general public to participate in this. If you want to create enthusiasm for this, let one seat on the vehicle that goes to Mars be to somebody from the general public. You, know, don't throw that Dennis Tito kind of enthusiasm away again. Embrace that. And finally, if you really want the entrepreneurship of America to do, consider coming up with a totally new alternative, and that's take the centennial prize and put it on steroids. Offer \$10 billion to the first company that puts a

man on Mars and successfully returns him to Earth. There you will see American entrepreneurship rise. Thank you.

Pete Aldridge

Thank you, Bruce.

John Patterson will be next.

Dave Bengel

Good afternoon. Thank you very much for this opportunity. My name is Dave Bengel, Bengel and Associates, I'm an independent consultant inventor. I've been working in a variety of areas including composites manufacturing, launch vehicle design, robotics, and I've just developed some new concepts for launch vehicles. It so happens it's related to an earlier effort. In the late 70's, NASA, somebody brought in gifted high school students. One of the ideas they came up with was to tether fixed-wing aircraft like control on model airplanes like high school students do. And by using a tethered rotor, you could do a high-altitude launch. I learned of that after I had come up with the concept independently. I'm in the process of developing in the various places in DOD. What that's led me to is if you launch from high altitude, you have much less problems with wind buffeting. The launch vehicle can be much more delicate and I've developed some new technologies for the tank that will enable remanufacturing the tank in orbit in two different configurations, including space stations, equipment for mining, anything you need. So the tank becomes part of the payload. It's going to make access to space much less expensive. Excuse me. I haven't practiced this.

One of the things that is going to be needed to remanufacturing in orbit is robotics, in order to wind up accomplishing that. And I'll have very detailed proposals for how to carry that out. It so happens that the same robotics technology needed to remanufacture in orbit can also be used on Earth, of course, for personal assistance, personal protection, and not to forget to mention that they should be usable, they're going to be able to jump at 100 mile-per-hour, take people's weapons away. They'll be able to deal with conflict resolution without hurting people. There's an opportunity to replace all lethal weapons with nonlethal robotics means.

Now, in closing, let me mention something that I heard on public radio a couple of years ago, somebody did a study on how to motivate people to come up with more creative solutions. You just heard a person here talking about, you got to keep it freed up. You don't want to have it too over-determined. What this particular individual found was that if people are motivated by reward, by money, in the first place, that they generally rush to a solution, and the solutions they got were not as creative as people who are motivated by personal satisfaction and accomplishment. So I would say that that's the thing to emphasize in terms of getting people involved and so on and so forth. I've also got some proposals that I've been putting forward about how to restructure to incentive communications and cooperation in people in the U.S. Government and various other corporations is you've got to specifically reward communications. That is to say, proactive communications and

proactive cooperation have to be tracked, and then they have to be used to guide people's career paths. And I'll be coming up with a much more detailed proposal on that too that I'll be sending into your website. This stuff will probably also be posted on space.com. And if anybody is interested, please e-mail me at bengelcomposites@yahoo.com. I say that a lot.

Pete Aldridge

Thank you very much. John Paterson is up. The next person is Phil Lane.

John Paterson

Thank you, Mr. Aldridge, and the Commission. My name is John Paterson. I'm a senior systems test engineer with Lockheed Martin. Prior to that, I was with NASA Ames for eight years. Back in September when I knew this was coming, that Bush was going to make a pitch, I wrote a white paper for our management. I took out what I considered the proprietary parts and forwarded it to your Commission. I hope that you'll have a chance—it's a worthwhile read. It will only take you five minutes. It will put the whole thing in perspective, I hope. My areas of expertise while I was at Ames were in surface mobility and *in situ* resource utilization. I was one of the members of a team that worked on the first SEI, so I can speak with a little bit of experience. Since then, I've been working with large-scale integrated test systems, mostly on satellites. I'm currently a senior test director with the airborne laser program down at Edwards.

One of the things that I've learned within systems engineering is if we need to make a change or something goes wrong, and we need to add a test or we need to change a part, there's a form that we fill out, and one of the lines on this form is "Consequences if work not performed." The worst consequence, being something in the order of "high probability of mission failure." The least consequence being something in the order of "operator inconvenience." For this nation not to pursue this program, I think we're going to backslide severely. And I don't think that's a good thing. During Apollo, it's commonly known that the monetary spinoff was something like \$4 for every dollar spent. At the same time, this nation enjoyed the highest level of master's degree and post-docs per capita that we've ever seen. I don't think anybody can argue with these results. I've got this in conference paper form. It was written by Hum Mandell from Johnson Space Center. And I don't think those data points can be argued with. And I think it can happen again. Not only would this effort be excellent for the country, the nation, not only from an economical and technological standpoint, but also in the rewards of quality of life. Not just for us, but internationally. I would like to give you an example of Third World nations seeing food grown on Mars and we would, during a 600-day stay, at least partially. It's going to definitely alter their perception of quality of life, especially if they're going without food. They're suddenly going to question their paradigm, their governments. I know that sounds very highfalutin', but in reality, I think that's one of the consequences of performing this. And I think that's a good thing. I think it will be providing change for the better. To put this in perspective, if you get a chance to read one chapter of Gerard O'Neill's book, *The High Frontier*, he calls this going towards a steady-state theory. It's worth the

reading. I think it's important that the U.S. lead this effort under the guise of democracy. It will promote healthier governments, healthier standards of living worldwide. I had a question, but I'm not allowed to ask, but one of the data points that I would like to give you is three weeks ago, I received notice from the Mars society, of which I'm a founder, that there's some new evidence of methane on Mars, which pretty much points to that there is life there. It's not a guarantee, but if you haven't heard that yet, it hasn't been in the public realm, but it's bound to be in the next couple of months here.

Pete Aldridge

John, can you wrap up now?

John Paterson

Thank you. We had a false start at this effort in the early 90's and I would like to see a successful one this time around and I hope that's what you take with you to DC. Thank you.

Pete Aldridge

Thanks, John. I was hoping that there weren't viewgraphs.

Phil Lane

No, no, no, no, no—Hi, my name is Phil Lane. I'm trained as a physician and microbiologist, and I worked for about 10 years down at Ames in the space life sciences payload's office. So I've been involved with the space program since I was age 14 and watched the first Apollo landing.

Just a couple of general comments for y'all. The space program is a delicate balance of human activity, astronaut activity, which then yields, you know, an incredibly important inspirational role for society and for young people. And a science yield which, from my perspective as a scientist is what is, of course, most important, and also development of enabling technologies and opening up areas of commercial activity which—and it's a complex balance—which NASA has sometimes gotten right and sometimes gotten wrong. Got it right, I think in the lunar program, which was, of course, to beat the Russians there, but what we ended up with was about 500 pounds of lunar rocks and a bunch of data from the surface which entirely reoriented our understanding of the formation of the Earth-Moon system. And so there's a fundamental science reorientation that came out of that activity. The commercial activities that have been beneficial from NASA activities and others have really been sort of relatively limited to weather satellites, GPS, and communications satellites. On the other hand, if you step back, you can say, well, the benefit from weather satellites alone has probably paid for the entire space program. But getting that balance right is really hard. And in the last 10 or 20 years, I think we've not gotten that balance terribly right. We've devoted an awful lot of resources to the Shuttle and to the International Space Station. And the science yield has been

relatively minimal. And I hate to say that, because I worked for 10 years doing that. But at the funding levels of NASA, which is—currently it's around \$15 billion, I believe—for a long time it was about at the level of the NIH. Yet, the science yield and the benefits to people in general that were coming out of the NIH funding were a lot higher. So putting that together and trying to redirect the way NASA does business, which is the Commission's charge—I'm getting lost here, sorry I'm not used to public speaking. I wish you the best in this, but I want you to try and figure out ways where you can meld the human activity with the robotic activity to sort of maximize the yield. Another good example of that is that the human expeditions to fix the Hubble. Some of the—that's some of the premier activities that NASA has ever done.

Pete Aldridge

Could you wrap it up?

Phil Lane

Time to go? For the Moon and Mars, I just wanted to recommend—a Moon base is a terrific idea both for resources and for science. Sending humans to Mars right now is way too expensive. Let's stay on with the robotic missions. With the ultimate goal but not the near-term goal of putting people there. Thanks.

Pete Aldridge

Thanks, Phil. That wraps up the formal Commission meeting. We did get a chance to have everyone who asked to speak to speak tonight. So that was very good. And with that, we'll adjourn. There will be a press conference at 3:45—no? Wonderful. We have a chance to—to adjourn and proceed with other matters. Thank you very much for coming. It's been a pleasure to be here in San Francisco. And certainly at the—at this great institution. And we thank you for your patience and hopefully you have gotten the word in to us and we will take the appropriate actions. Thank you.