The President's Commission Implementation of United States Space Exploration Initiative

PUBLIC HEARING
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Pete Aldridge

Good afternoon. I'm Pete Aldridge. I'm the chairman of the President's Commission on the implementation of the U.S. Space Policy. As we have shortened it to say the President's Commission on the Moon, Mars, and Beyond. We're delighted to be here and it seems only appropriate that the Commission's first hearing outside of Washington would be held here in Dayton for the workshop for controlled power flight, move from a dream to reality. It seems fitting that we come here as we move forward to sustain the journey of the Wright Brothers that began more than 100 years ago now.

First let me introduce my fellow Commissioners. I began on the audience left. Carly Fiorina serves as the chairman and chief executive officer of Hewlett Packard, which she joined in July 1999. Her roots are deep in technology, having served as senior executive leadership positions in AT&T and Lucent Technologies.

Michael Jackson is a Senior Vice President for ACOM Technology Corporation. He is a former U.S. Department of Transportation Deputy Secretary.

Dr. Laurie Leshin. Laurie is the director of the Arizona State University Center for Meteorite studies and a professor Center for Meteorite Studies and the Professor of Geological Sciences at the university. No stranger to Dayton.

General Les Lyles. General 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.

Dr. Paul Spudis is the planetary scientist at the John Hopkins University, Applied Physics Laboratory. His specialty is geology of the moon. He has also studied the geology of mars, mercury and many other worlds.

Dr. Neil deGrasse Tyson. Dr. Tyson is an astrophysist and the director of the planetarium in New York City. His professional research interests include star formations, exploding stars, dwarf galaxies and the structure of the Milky Way.

Retired Congressman Bob Walker. Robert Walker is the chairman and chief executive officer of the Wexler and Walker Associates, a firm specializing in the telecommunications and technology issues. Mr. 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.

Dr. Maria Zuber. She's the E.A. Griswald Professor of Geophysics and Planetary Scientist at the Massachusetts Institute of Technology and leads the department of earth atmospheric and planetary sciences. Dr. Zuber has been involved in more than half a dozen NASA planetary missions aimed at mapping the news, mars mercury and several asteroids.

And our executive director, Mr. Steven Schmidt. Steve is the Special Assistant to the NASA administrator and is the federally designated official for this presidential advisory committee.

Now it is important I think to review the process of this Commission. We've been appointed by the President to make recommendations as to how to implement the space vision, which he set out on the 14th of January 2004. He has given us a firm direction and it's our job now to recommend to him the most important strategies or steps to accomplish this vision. This is a sustained journey. More than many, many presidential terms are covered by this plan. We are listening to experts and the public along with drawing upon our own expertise to generate this plan. I envision that we will select maybe 10 key strategies to recommend what we believe will lead to putting us back on the moon and on to mars and beyond. Certainly with yesterday's announcement of findings regarding the high likelihood that mars once had a good habitable environment, it encourages us to drive forward to put pioneers on the moon and explorers on mars. In addition to experts, we're listening to the American public, the ultimate customer for this vision. Through our website, we're accepting comments from people around the world who want to be heard on this subject. And lots of folks want to be heard.

We received more than 4,700 responses to our feedback opportunity on the web. Lots of folks are accessing the web pagement as of earlier this week, we received more than 1.8 million hits. I want you to know that every input is being read. We're listening. You may be interested to know that about 75% of those contacting us through the web are in favor of our sustained journey. Many of those who express their concerns about the process do so because of cost. As we approach this task of the Commission, we're looking at it through four themes or approaches. We see that we must make recommendations that are affordable, and therefore sustainable over several decades. I emphasize this is not a journey, -- this is a journey, not a race. So the management of such large projects and maintaining it's affordability are crucial elements of this endeavor. Also, we recognize a need to inspire a nation's young people and encourage literacy in science and math and engineering. We need those skills in our country to maintain our leadership position in the world. Also we've been chartered to layout the science agenda for the next several decades. What should we be pursuing? What makes the best use of our investment? And finally, we're looking at the strategies that will ensure our nation's competitiveness and maintain our prosperity. In addition to Dayton, the Commission plans to visit three more additional cities: Atlanta, San Francisco, and New York. Then we will write our report and give it to the NASA administrator or the

President. We have many distinguished Guests, some of whom have come to testify and we'll meet each of those in turn. On behalf of the Commission, I want to acknowledge the support and effort of many folks here in Dayton who have made it possible for us to be here today: the Air Force Materiel Command under General Gary Martin's leadership. Speedy martin, I don't know him from any other name than that. Our host: U.S. Air Force Space Museum. A terrific staff here. General Metcalf, formally with the U.S. Air Force Research Lab, the 88th Air Base Wing, the Aeronautical Systems Center and the Air Force Institute of Technology.

Also, we may have the first person on mars in this room here today. I would like for the students from the Hadley E. Watts middle school in Centerville, Ohio to stand up. Please stand up. Do you want to go to mars? Raise your hand.

Their science teacher, Melissa Layman, has brought them here today to observe our proceedings. They have been studying space exploration as part of their curriculum. We welcome you and hope that you're studying hard to be able to lead this great journey we're on. Commissioners, I call your attention to three student essays that are included in your reference material today. And thank you Mrs. Layman and we wish you the best in supporting the education of our future explorers. Thank you very much.

Our first witnesses today are indeed educators and among those we're counting on to guide the development of the next generation of space explorers.

With us this afternoon, we have Dr. Patricia Arnold who serves the U.S. space foundation in Colorado spring as Vice President of Education. Mrs. Margaret Finarelli, Vice President of the North American operations of the international space university in Strasbourg, France. Dr. June Scobee Rodgers, founding chairman of the challenger center for space science education, and Mr. Brett Williams, a teacher from Fredericksburg high school aeroscience program from Fredericksburg, Texas.

We welcome you and look forward to your testimony. Dr. Arnold, I believe you're going to be first. Please proceed.

Patricia Arnold

Chairman Aldridge and Commissioners, on behalf of the space foundation, I want to thank you for the opportunity to testify today on the importance of education and the Role that NASA and the United States space exploration plan might play in the renaissance of education. Now is the time to reignite the passionate interest in space and science education. However, the manner that we go about doing this is critical to success. We cannot be content with short-term solutions for ideas or thinking. Over the last 15 years, the number of American college students earning degrees in science, technology, engineering and math, hereafter referred to as stem, has continued to decrease. In 2000-2001, United States students earning engineering degrees was only a little over 58,000. That is compared to other countries such as India with 80,000, Japan with 200,000, and china with 800,000. If the United States is to retain our technology

leadership and our ability to compete in the global marketplace, it is imperative that the United States levels the playing field. America's new space exploration policy represents a journey over time. So does the reinvention of education. It must start with our very youngest students beginning in preschool and build through the graduate programs. NASA cannot be expected to solve all of education's problems. However, the agency will once again be embarked in programs that excite young people and in position to help our students develop a passion for learning and to turn dreams into reality. Because the space exploration vision will have such profound potential implications for future generations, in the written testimony, I have proposed both an approach and structure through which NASA can have the greatest impact on education in our country, as it refocuses its efforts to achieve the space exploration vision. The need to consolidate all NASA education-related activities into a lean and professional office of education outreach exists today and will become even more critical as the agency focuses on exploration. A significant difference exists between the current NASA education program and the new suggested office of education outreach. This difference is that the new office is small and highly focused, rather than a large department for bureaucracy. It is essential that the office serves as an effective liaison with education, educators and information multiplier organizations. Oversight and guidance to the office should be provided by a NASA-funded but independent and independently managed national board of advisors. The job of the advisory board is to recommend how best to deploy NASA resources through outside suppliers to excite and support educators and students in stem content proficiency and to best prepare the next generation for participation in space exploration. The advisory board must be autonomous from the agency and make recommendations to the office. Most importantly, it would recommend ideas for promoting a One NASA that is focused, lean, and efficient. NASA human resources should be used in assisting with developing the most valuable partnership and collaborations with museums, science center, and libraries in a non-bureaucratic way to better support student learning. The written testimony provided explains the essential responsibilities of the advisory board for creation and development of sequential scope and sequence, pre-K through 16 curriculum and an implementation plan for supporting space exploration. Additionally, it addresses the critical responsibility of the advisory board to suggest evaluation, rubrics, metrics, and a longevity study to determine student success in academic achievement and career paths. The most important anticipated outcome derived from the advisory board recommendations would be to ensure that generations to come, that American children are highly qualified and prepared in critical content areas and equipped to enter the work force. Again, written testimony outlines both the management and organization of the proposed office. However, I do wish to highlight a significant altered role for the project and contract managers. Managers must act as a support team for education programs, rather than being non-anticipates, isolated and unengaged in the project. They need to actively oversee the programs for education professional development and pre-k through 16 curriculums. At the strategic levels, these program and project managers must knowledgeable in sound pedagogy effective teaching strategies an methodology and current research and they must be willing to be an advocate for improved student learning, quality and qualified teachers and the benefits of early instruction for students in all content areas, including stem. In analyzing data from the 1999 TIMS report, the new U.S. state exploration vision can actually be a catalyst for teacher professional

development that tackles current United States deficiencies head on. We are at a cross roads for both space exploration and education. What better way to hook our children than with the United States space exploration plan. It has been some time since we have had this level of enthusiasm for the space program. We have to embrace it. We have to share the passion of space exploration with our youngsters and make sure they receive quality instruction about stem by exceptionally prepared teachers. A streamlined efficient and well-run NASA office of education outreach program can make that dream a reality. Thank you.

Pete Aldridge

Dr. Arnold, thank you very much. Procedure wise, we'll do is go through the testimony of each of the people on the panel and then we'll open it up for questions at the end. Peggy, glad to have you here and look forward to your testimony.

Margaret Finarelli

Mr. Aldridge and members of the Commission, I'm delighted to have been invited here today to talk about the special roles of the international space university might play in implementing the President's space exploration initiative. Not only do we have a unique academic

Pete Aldridge

Excuse me Peggy, could you pull the microphone a little closer?

Margaret Finarelli

Is that better?

Pete Aldridge

Yep.

Margaret Finarelli

Not only does ISU have a unique academic program for developing skills for working in international, intercultural environments, but we also, interestingly enough, produce some of the most enthusiastic, most passionate young people in the space business today. The skills of our graduates will help space agencies and aerospace companies in the U.S. and around the world as they implement this exciting initiative. And the energy of these young people can be tapped to create and maintain that broad public interest in space exploration. That's going to be so necessary to sustaining this initiative.

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ISU fills a special niche. If you're an astrophysist wanting to delve deep into discipline or an aerospace engineer wanting to hone those skills, ISU isn't the place for you. But ISU is the place for you if you want to learn how all of the pieces contribute to the successes of the space program, you want to learn the languages of the various disciplines comprising space activities, if want to learn to respect and take advantage of all of the members of the team putting a project together, the scientists, the engineers, the managers, the lawyers. In other words, if you seek to take leadership roles in future international space endeavors, ISU can help. I think our alums might be able to say this better than me. I'd like to give you a couple of quotes. One, "I went to ISU as a mechanical engineer and I came out with a much broader vision of the space industry. There are more than just technical issues driving designs and operations. Politics, money, law and even culture play a large part." And another, "to be effective as a future leader within NASA, I must understand the global issues of space endeavors and work effectively with diverse teams. The ISU curriculum gave me the foundations for doing precisely that."

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ISU is the only university completely devoted to space-related studies. The curriculum is an interdisciplinary graduate level one that addresses all aspects of space endeavors. We teach the students space science, space engineering, systems engineering, business and management, space policy, space law, space and society. And the curriculum also provides a variety of opportunities for the students to learn to work effectively and efficiently in international teams. The academic programs that do this are first, a two-month professional development summer program that rotates around the world, going to various universities and research centers. We've held sessions in Chile and Thailand. This summer we'll be in Adelaide, Australia. We also have two masters programs, a master of space studies and a more focused master of space management. The masters programs are conducted one-year long programs, they're conducted at our central campus in Strasbourg, France.

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A little reminiscent of the air and space museum, but quite a nice campus. The university was established in 1987 in the U.S., and moved to France in 1993 as a result of an international competition that was won by the city of Strasbourg in the region of Alsas.

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The intensity of the international experience at ISU peaks with student research projects, which are an integral part of both the summer program and the masters programs. The research projects address a complex project from an interdisciplinary perspective, and I've listed a couple of our recent research projects here because I thought they would be interesting to the Commission. Our masters' students have looked at human exploration of mars. Our summer students last year looked at lunar exploration missions utilizing international space station capabilities and our masters students in the current class are

right now looking at human missions to Titan and Europa, looking at the exploration challenges in the extreme, I would say. The impact of these projects transcends the report that the students produce. Again from an alum who worked at NASA Johnson on the International Space Station project, some meetings with our international partners were like what an ISU student experiences in the first couple of weeks. It is much better to make those same mistakes during an ISU design project before you are working on the billion-dollar project. After a month at ISU, you learn how to be much more productive as an international team.

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Each year our students come from 25-30 different countries. About 20% of them come from the United States. All toll, since the late 1980's, we've produced more than 2,000 alumni from 85 different countries.

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This is the secret of our success. I think the ISU network is one of the ISU's most important products. This network allows our alums to share communications and also to promote and facilitate international cooperation. One of our alums has told me personally that as he moves up the management chain at NASA, he increasingly finds himself across the negotiating table from ISU alumni who come from other countries. And needless to say, they can get right down to business. They've learned the tricks of the trade from these ISU projects and activities. This network also brings something else to the table that I think is important to the Commission. This is a network of young people who are absolutely passionate about space that's why they went to the International Space University in the first place and they're doing something to spread that enthusiasm. I would like to tell you about something called Yuri's night. Yuri's night is a global celebration of youth who are interested in space. This Yuri's night celebration is held annually on the anniversary of Yuri Gagarin's first flight into space. Last year, 10,000 people participated in Yuri's night celebrations that were held in 79 different locations around the world. About 15 of those were held in the United States alone. This global event was conceived as an ISU project by one of our then students and is still organized each year by an ISU alumna and she uses as a start, of course, the ISU network around the world and puts on these Yuri's night activities, as I said, impacting last year 10,000 people.

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In closing, ISU graduates have the capabilities for space leadership. They've got the skills to support space exploration activities. And here are two major points I would like to leave you with. These graduates have a growing network to facilitate international cooperation in exploration activities. And these graduates also have the drive and enthusiasm to help with the Commission's goal of sustaining public interest in exploration. Thank you very much.

Pete Aldridge

Thank you Peggy. June, you're next. Thanks for being here.

June Rodgers

Thank you Chairman Aldridge, to the Commission, and especially the children who are visiting us in Dayton here today. It's great to be back at Wright-Patterson and the Air Force Museum. I would like to begin by just getting you to imagine for a minute, imagine when a teacher says to her students, imagine, you're an engineer, an astronaut, a scientist. Next, she gives them specific challenges. Plot the correct navigation of a space probe that you've built so that it intercepts with a passing comet. Perform experiments to test for purity of water on a spacecraft bound for Mars. Use your robot arms to handle dangerous chemicals or collect leaves from plants at the remote center to conduct chromatography analysis. Perform experiments to test the purity of water on a spacecraft bound for mars. She watches as they complete hands-on activities, as they work collaboratively with team members. As they problem solve and find solutions. Her students no longer imagine they are scientists or engineers. They've actually become scientists. May I have the clip please?

This amazing transformation is taking place every day at each of the 52 challenger learning centers that are located in the United States, Canada, and England. Of each of those centers reach 200 to 300 schools. Now, I would like to give you a brief thought about where we're going beyond. Now we at the challenger center were truly over the moon with joy when President Bush announced his bold initiative to venture into the frontier of space and break the boundaries set by previous manned missions. He made a commitment to return to the moon by 2020, then mars and onto worlds beyond. It's ambitious, and I know you agree a thrilling goal. But for me, and millions of students, it's a familiar goal. For the past 17 years, students participating in a mission simulation at a challenger learning center have been voyaging to mars and returning to the moon many, many times over. These national standards-based missions, always relevant, have now become very timely. Talk about back to the future. But students today, fly to the moon or mars or a comet at our learning centers. Many of them here in Dayton at the Kaiser middle school, others at science centers in Peoria and the Owens Science Center across from Goddard, in Atlanta, some are located on university campuses, University of Lester in England, Florida State University, Purdue, University of Tennessee at Chattanooga, Cal State. Some are located at air museums, at Brooks Air Force Base at Merced and recently we found a contract to build one at Downey, California. Imagine a young girl or boy flying a mission today that someday in the future may be so inspired that they will go to one of Peggy's universities to learn to be a scientist or engineer and perhaps even an astronaut to fly to the moon or mars for that giant leap. We, the family members who lost our loved ones aboard challenger created challenger center to honor. To honor their memory. When Dick Scobee, my husband, flew on his first mission to space, flight 41C, it was a solar max repair flight and Goddard Space Science Center worked closely with that mission. When he returned, there were reporters and neighbors waiting at the door to

meet me and him to talk about his mission in space. He turned to me and said June, I want to take you away until you know first what it was about, what it was like.

We gathered at a dinner table in my favorite restaurant and he put out his hand to take photographs and the camera kept falling to the floor because only an hour before he was weightless in space. He kept stuffing his napkin under his dinner plate. The stars in his eyes that night shinned brighter than the stars in the skies. And I want to see those stars shine in children's eyes. But after a bit, I said to him, "Dick didn't it upset you, though that President Reagan mentioned everybody's name on that crew but forgot to mention your name?" He said, "no, June. What was important was the mission. We got the job done." So you see, when we lost 51L, how important the mission was to us.

We honor their legacy with the mission of challenger. Every time a child is touched by a challenger center program, when that first spark of curiosity is ignited, when exploration and discovery follow and possibilities literally extend through the universe. A few years ago, I received a letter from a young woman named Kristin Wentz. She said I participated in a voyage to mars mission simulation four years ago. It's still my favorite field trip. I think it was the beginning and basis of my love for space and science. I'm now pursuing my high school diploma and plan on going into some field related to space exploration, such as aerospace education engineering. Your organization has had such an amazing impact on my life so to the moon 2020, eight years PhD. Scientists, engineers, astronomers, high schools and middle schools and challenger center is here ready, waiting, inspiring middle school youngsters to take that path.

Challenger center is at the forefront of space science education for elementary and middle school students through our partnership with NASA, the Smithsonian Institution and Harvard University. Our programs are found in major urban areas and in rural communities with little access to science resources. Through our work in distance learning, children in even the most remote parts of Alaska are able to venture to distant planets. Students may leave from different locations, different backgrounds and different circumstances. They all arrive at the same place, same place of discovery and adventure. On a career path of excitement. Helping our nation. There's much more work to be done to fulfill the President's vision. And we at challenger center enthusiastically offer the resources and it's education programs as a critical first step to inspire and teach students science technology, engineering and mathematics.

The potential to explore distant worlds represents an amazing opportunity for our nation. What only recently seemed the realm of science fiction, now it's history. Because 200 years ago, another President, Jefferson, commissioned Lewis and Clark to map a terrestrial frontier that was in its time remote and unknown. 100 years ago, the Wright Brothers made their historic first flight at Kitty Hawk and took us farther into the frontier of knowledge and discovery. And today, we look to the future to those not yet named who will make their place in the history books of great American explorers. And with President Bush's plan to the moon and mars, together we can plot the course and navigate around the naysayers. And perhaps in 200 years from now, a youngster will open a textbook and study Lewis and Clark and they'll study President Bush's Commission and

your legacy. Perhaps a teacher standing in front of her class will say something like "imagine -- imagine you're living back on earth." Thank you all so much for this opportunity for me to share with you what challenger center wants to join with you in providing opportunities for our youngsters.

Pete Aldridge

Thank you, June. Very interesting. Ok. Mr. Brett Williams of Fredericksburg, Texas. Welcome.

Brett Williams

Thank you, Chairman Aldridge and members of the Commission. What you're about to witness is a brief introductory video capturing some highlights of my high school sub orbital aero science studies program. Everything you see is done entirely by the students. This is what high school students of today are capable of. And as you can see, these are not model rockets. Ladies and gentlemen, these are 500-pound hyper propelled sounding rockets, capable of achieving twice the speed of sound and lofting 35lb research packages to altitudes between 88,000 and 100,000 feet. Go ahead, please with the film.

That launch tower is a 60-foot tower on loan to us from the Air Force Research Lab through a partnership agreement. And that launch facility is through an educational agreement we have with the U.S. Army's White Sands Missile Range.

These are vehicles entirely designed by the students - nose cone and nozzle, each component. And the video continues, but I'm going to go ahead and stop it here. It's irrelevant to continue it. Go ahead and stop it. Go with the power point. Now I would like to tell you why there's a need for what we do, what it is we do and how well we do it, and our national destiny. The engineers of the past in the Apollo program are retiring and we're not replacing them with students interested in the science, technology, engineering and mathematics domains. Today's work force is changing with technology and changing fast.

Presently, if you're not increasing your abilities, you are being left behind by the job market. Therefore, we need to be teaching our students how to teach themselves. In public education today, there's a strong demand from documentation, accountability and financial management. Though understandable, it is leading to rote memorization and little more than knowledge-based development. Knowledge-based development is good, only if we teach applications of the knowledge. We cannot just give students tools. It is imperative that we show them how to use these tools.

Next slide, please. I'm sorry, actually that's the slide that should have been with that.

There you go Fredericksburg SAS program teaches the basics of physics and engineering through hands-on research design and development. The main foundation of the program is to develop research-capable vehicles to loft university research packages at a cost

difference of pennies to the dollar. Universities become involved in collaborative research projects with us thereby introducing our students to pathways from university's research to industry. In addition, the program develops life skills like critical thinking, problem solving, design and development, communication skills, team work, grant report writing, budgets and acquisition, industry specialties, like standard operating procedures, IDPS, CDRS, FRRS, and safety analysis. And we strongly develop life-long learners. Students are able to apply what they've learned, problem solve and learn to teach themselves. They become confident and capable of solving any problem or stress that arises in life or in work.

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Today, we are the only high school in the United States capable of putting a 35-pound package to research altitudes for universities. 80% of the students in the program go into engineering with about 10% to 20% of those going into aerospace specifically.

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We already have the Government's, military's and industry's support for our initiative. We have been talking with them for over four years about this program's potential. And understandably, they are all waiting to see success and infrastructure vehicles for management and dissemination of the program.

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Can you go back one slide? I'm sorry. These are a little different than what I sent. Let me get you lined up with what I've got. Go forward one more. One more. One more. This is some of our partnerships that we have presently in the industry and military. Go ahead one more.

Oh. And that slide should actually show a graphic where we're showing some successes. We have the successes and we can document them. Students are working in industries positions such as managing propulsion test facilities already, obtaining national security clearance as sophomores in college while working on their college careers hyper velocity project tiles, working on the shuttle's main test band and receiving awards for their work, receiving awards for co-ops for each co-op term they complete and being selected for many of our military academies, in fact, two this year alone. We have many more examples, on a larger scale which that slide would refer to, the data is showing the average student SAT score at Fredericksburg high school has increased by over 150 points since the start of this program.

Pete Aldridge

It's on the hand out, so we can see it.

Brett Williams

Good. If you refer to slide 7. Fredericksburg high school over the next two years is capable of producing close to 150 engineering students for universities to groom for industry. By becoming a state program in two years, we believe Texas has the ability to produce hundreds, if not thousands of engineers by the year 2010. Ladies and gentlemen, just imagine what the Fredericksburg high school sub orbital aero science studies program could do for the aerospace industry's workforce if it reaches potential at the national program. Our program can be replicated. The program already exists in Port Stockton as an alpha test and the very successful student launch initiative started at NASA's Marshall Space Flight Center four years ago by Art Stevenson and myself is the suborbital science program the first year. The program can also be disseminated. We need only the time to develop funding for the success. My recommendation for the moon to mars initiative, besides my program is to develop the needed aerospace work force. By supporting public education through the promotion of hands-on problem-based application of core curriculums to support relevant core classes. And I recommend you bring together high school academia and vocational courses to bring together project leaders and engineers you will need for this wonderful undertaking. Thank you for your time and truly best of luck with your endeavor as a commission.

Pete Aldridge

Thank you very much. I watched that rocket fire, I hope there was a quality control person somewhere close by.

Brett Williams

Absolutely. Everything you can imagine. It's a wonderful endeavor we do it annually. We have universities lined up right now at a frugal cost of interface with us. And there is a great deal of issues with safety. Procedures are analyzed with safety analysis, hazards are rewritten to take care of that. We have about five layers of safety when we do go to the pad for the prep and launch scenario.

Pete Aldridge

Very good. Let me start the questions, and I'll ask a general one then open it up to the other Commissioners. In fact, Dr. Arnold mentioned something about having an outreach program within NASA. One of the aspects of this particular program that we in the Commission have kind of begun to think about is that this really is not a NASA program. This is a national program. And that it's not only going to take NASA's participation, but we anticipate that other agencies, the National Science Foundation, certainly the Department of Defense maybe the Department of Energy, the Department of Education, people like that are all associated with this kind of a program. Is there some aspect of this that should take on a more national perspective as opposed to a NASA perspective? Any of the Commissioners? But I'll point it to you, Dr. Arnold.

Patricia Arnold

In conceptualizing this, I think the reason that we sort of have targeted NASA is because NASA already has some education outreach programs. And NASA would have the ability to partner with different federal departments and agencies, institutions, business. They already have somewhat of an infrastructure to do that. The kind of programs that we've heard about today are exemplary ones that need to be replicated. They need to be broadened and so they are of a national base. In the vision that we have, this particular office that would be aligned very closely with educators and education across the country would have the ability to do the kind of partnering that you discussed, you know? They can go to any businesses, any educational institutions, different, you know, DoE, DoD, whatever they needed to do in order to get the job done. There are so many good programs happening across the country, but unless you hear about them through a panel like this or some other way, what happens is they're noted but they're not replicated, they're not produced so it's constantly expanding. So what we're wanting to do, what we're suggesting is we need to be able to bring long more American children. There are some fabulous things going on at certain universities, certain high school, but we have got to start when these kids are 3 and 4 years old and we need to broaden that base. So that we have representation from all areas, all ethnicity. Giving students an opportunity. We do think that NASA has the capability of doing that. It does require a more intimate and attached kind of relationship, not a bureaucratic one that looks at the paperwork, but one that actually supports.

My experience as being a school administrator is you're going to get the most from your people, from your programs when you are actively engaged and you're a supporter and an advocate. For the programs to really soar and really take off, we need those kinds of project managers who are going to be the advocate. The person out there who ensures success of the program for students.

Pete Aldridge

Anybody else want to comment?

June Rodgers

I would love to. I would like to see the United States

Pete Aldridge

Could you pull the microphone closer?

June Rodgers

I would like to see the U.S. Department of Education very much involved; rather than, as now, mandating certain kinds of reading advantages, that they provide the leadership in inspiring professional development for teachers and exciting curriculum and lessons that

can be provided for the classroom. And that they work to influence textbook writers who now are cutting out a lot of the science laboratory work, the hands-on work, because the kids need to be able to read the information and take the test. You know, you can read a driver's manual and take the test but until you drive the car, you're not a driver. So that influence is hurting us in the science arena. I think that we can systemic change in our communities. Our learning center communities, 52 across the nation, will bring together parents and families for evenings to study the stars and work with youngsters and their different projects and the teachers and professional development. So there's a tremendous enthusiasm for activities like that. But we need this contagious spirit to carry over to the U.S. Department of Education.

Pete Aldridge

Peggy, sorry for taking over the Commission tier, but the International Space University actually started in the United States before it moved to France. Is there something about the model of the ISU that might be directly applicable to supporting this particular vision? University kind of dedicated to this kind of thing that be U.S.-only, is what we're getting to, since this is a Presidential initiative.

Margaret Finarelli

I think one of the great powers of education at ISU is the international dimension. I find it personally hard to imagine that this initiative would be implemented without international partners and good partnerships don't just happen. Good international agreements don't just get negotiated by accident. And even more important, the implementation of these projects on an international basis happens because people have the skills and the sensitivities. They have worked with people from other countries, from other cultures before. And so I don't think that it's necessary to replicate the ISU model U.S.-only. In fact, I think that would lose something. ISU isn't for everyone. We have 100 students in our summer program each year and about 50 in our masters' program. These are the people who are working on honing those skills to work on an international basis to lead these activities of international partners. So I think that the university as it stands is excellent, perhaps additional programs like this that promotes international activities. International interactions could also be good.

Pete Aldridge

What limits the size at ISU?

Margaret Finarelli

Probably the biggest limiter is the number of students that you can have so that they can all interact pretty effectively. In the summer program we find that's about 100 and we break the students down into two and more recently three design projects. Because it's in those design projects that they're having that really intense interaction. It would be marvelous to say that it's just a lovely thing for you get people together from 25 different

countries and they learn to share and talk to one another. It's hard. It's very hard for these students to go through this experience. That's what one of the students was saying in one of those quotes that I read. They learn a lot about how to listen to people from other cultures. And how to listen to what they're saying, what's the sub text in the message because we don't all communicate the same. So those are pretty much the limiters in the setup that we have now.

Pete Aldridge

Yes.

Les Lyles

First, let me thank all four of you for being here and the obvious interest and more importantly the passion that each of you feel for what you're doing and what this vision may mean for educating our young people here in the united states. Two questions. First, I'm curious. This reinforces what Dr. Arnold was saying, but I'm curious, is there any tie between your organizations today? I'm a big believer in leveraging what's already there and taking advantage of what's already there and tying things closer together that may have common missions, common veins, common passions, but are doing things separately. Has there been a tie between the Space Foundation and ISU and the Challenger Center and Mr. Williams, have you taken advantage of being a part of any of these activities? Is there a common thread there today?

Patricia Arnold

The Space Foundation and the Challenger Center partner. And we do a lot of things to reinforce and sustain and promote each other. And then in the bathroom this morning we had a discussion about we want to partner together so yes, those things are evolving.

Les Lyles

Ok so that's something that we need to build upon, but it's not far into what -- no pun intended, excuse me -- but not far into what you're trying to do in each one of these areas.

Margaret Finarelli

One of the powers of pulling together panels like this, is that you hear about one another's programs, you get to put faces with names. We've already percolated a couple of ideas that I think may have some impact down the road.

Les Lyles

That's great. Dr. Arnold, you talked about this outreach organization with NASA as sort of the nexus for it and a one-NASA. I'm curious if you're familiar with the one-NASA

program and current outreach activities and whether you see that as a step along the way of what you're recommending or are you recommending something radically different?

Patricia Arnold

I think it's more radically different, really. Because right now, and I think it's due to growth over time. NASA education has become so huge. There are so many different programs going on that even NASA doesn't always know. You know, there's something happening in one part of the country, and it would be nice to have this streamlined and funneled so that first of all, we know exactly what are the programs. Are they meeting the mission? Are they attaining the goals? And let's identify the gaps, because there are some gaps.

And I think the most critical point is the spiraling curriculum idea. One of the things when June was talking, I know from being in schools that unfortunately, and especially as the standards have progressed, space is taught maybe in third grade or fifth grade you know. It's hit upon at one time. Space can be a catalyst for learning in literacy, math, science. It should happen every single year from the time the kids are 3 years old until they're in post-graduate school. And it's a shame that that isn't occurring. I think by analyzing what's currently there, really holding on to the programs that are good, adding new programs that could reinforce that, and making sure that that curriculum is sequential. Because kids can't go into his high school class if they missed out in fifth or sixth grade. They don't have the skills set to do it. We're eliminating kids who could do a better job, kids who can have a future in this because we don't do the right things at the right levels.

Les Lyles

Thank you.

Pete Aldridge

Bob.

Bob Walker

Thank you Mr. Chairman. First of all, I'm delighted Dr. Arnold was able to participate on the panel, we take pride in the programs. Let me ask a question that goes beyond where some of your testimony was. Most of you testified in terms of the traditional models that we've had for education. Of educating young people up through graduate school and educating people to do things inside the space professions. But it's clear that when we compete on a global economy that we are probably going to have lifetime education in the future. And my question for those of you who are engaged in the education profession is, how would you see what we are attempting to do in the moon to mars and beyond mission contributing to the evolution of lifetime education that would

allow us to inspire interest in moving outside of traditional jobs into the higher tech jobs that this country wants to be competitive in for the future?

June Rodgers

When our youngsters fly aboard their challenger learning center simulators, they have to apply first for their jobs. And they are scientists or engineers, they're also technicians. And they begin to problem solve and see as they solve these problems as a team that you have to collaborate and work together. Better than any piece of information when you're working together. And they sometimes create solutions that even the teachers haven't thought of. So I understand what you're saying that as the need arises, you could have opportunities for new career paths with youngsters.

Bob Walker

Well, do you bring adults into the Challenger Learning Center? Can the Challenger Learning Center be used as a place to begin to build a knowledge base for adults who need to move out of jobs that are being lost overseas, for example? Where we need to get people interested in new kinds of professions? Is that something where the challenger center can make a contribution?

June Rodgers

Most definitely. Some of these youngsters of inner city and rural areas aren't even aware of the opportunities for a career.

Bob Walker

What if they're not youngsters? What if they're 50-year-olds?

Patricia Arnold

I can't tell you how many calls the space foundation has gotten since the President spoke. And we have a NASA educator resource center in our headquarters in Colorado Springs. And typically, it's for educators, but in the last month, we have had people who have no connection with education come in. We have a mars mania set up and people will come in and check out materials and they want to know more. And then another interesting thing, we do a space college career fair in connection with our space symposium and we typically have that for students just on the verge of going into careers. They're still in college. But this year, I've had people calling saying I'm mid life in my career, can I come to this career fair and learn more and hear more? So there definitely is an interest. People are wanting to make maybe a career change, and asking for help about what kind of support they can get to make those kinds of changes.

Pete Aldridge

Maria.

Maria Zuber

Let's start with Mr. Williams. I love your program and I hope you're encouraging your top students that come out of the program to apply at MIT. I find that the fact that you say that 80% of these student who go on to engineering means that even though they are in a hands-on laboratory experienced-based program, to indicate that they're really getting a good grasp of the fundamentals that are important to move on in the educational system. And I find that quite a contrast to the comment that Dr. Scobee-Rogers made about cutting back on lab based and hands-on activities to study and pass the test. So it seems to me the kind of things your students are doing are certainly conforming to educational standards. And so I wonder if you could just spend a couple of minutes talking about how math, chemistry and physics gets mixed into this curriculum so that these students are taught these things in a way that enables them to go on and apply to good engineering colleges and get in.

Brett Williams

Absolutely. This program really is going across the current right now when it comes to public education. I made a comment in my testimony that there is an issue right now concerning documentation, financial management, etc. And you're seeing it in the core classes where it's being stipulated what exactly needs to be taught in a certain amount of time. And there really is no opportunity to attempt unique endeavors with the students, to try to stimulate them in terms of finding a passion or developing an interest in any type of career pathway. And so when I came into education about eight years ago and I really do have an interest in trying to help with education, I saw where this was leading to really just stamping of educational certificates where we're just passing them through and I don't see that taking place in the workforce. I don't feel we're prepping them very well for getting out there and getting a job. So I put a great deal of emphasis on being able to teach themselves in the future, understanding research as a way to solve problems. And the program is a two-year program, but it brings in juniors and seniors and it's a cross section of the school. I have no prerequisites. They have to have a certain grade point average, etc. I made comment about academia and the vocational classes. You'll find even today, that even though we tried to prevent it, there's a dichotomy in education today, where you will have students that are very book smart. They know how to open the books and they know how to find the answers and they can talk a good book, but they aren't very good with hands-on tools, screwdriver, etc. Whereas over in the vocational building, you will find the students that don't really like getting into the books but are wonderful with their hands. In my classroom, what happens is they'll be teaming up on components and that academic youth will be teaching that one that's really good with the hands how to do this, whereas the one with the hands is showing that student how to use the tools. So you see this blending effect that takes place in the classroom that I think really leads these kids towards, what you could call a project management skill.

Understanding that there's two sides of the table in design and development and it's really working well. And the problem is it doesn't fit education right now in terms of what the U.S. education agency is wanting to see. It really is from the teacher's aspect.

There's a lot of facilitation and juggling and a lot of in and out approaches with the students. And so it is offset from the mainstream, I guess you could say. But I truly believe that when it comes to chemistry, physics, biology, etc., there is a need for these ancillary support classes such as this. Mine does very well with physic, chemistry and mathematics to help support what they're doing. Through my first half of the year as I'm teaching the curriculum, it lines up well with force vectors, etc, like this, with their classes scheduled. You can do forensics with biology and chemistry and English. I mean, there's no reason why these classes can't be there to support the core classes that hopefully stimulate the passion in the students towards those careers that they appreciate and they realize the need for understanding. Like with engineering, you find a lot of students who want to go into engineering but don't have much of an interest in mathematics. And they need to realize mathematics is the foundation of engineering. It's a window to the world. And they discover it when they start getting that hands on.

Pete Aldridge

Paul.

Paul Spudis

My question is for Dr. Rogers but I would like to hear some other opinions afterwards. As I understand, at the Challenger Center, your funding is largely private, is that correct?

June Rodgers

Private, yes. Some public.

Paul Spudis

Do you get some NASA money at all?

June Rodgers

Some small amount of NASA money. But I just have a request that I just made and I hope they respond positively.

Paul Spudis

What I'm getting at here, this model, mostly private, partly public might be a template that we want to use. But I would like your opinion on -- do you see any pitfalls in this arrangement? In other words, if you take public money, does that somehow dictate the agenda or torque you in a direction that you may not want to go? In other words, when

you take the government's dollar, they usually expect something in return. And I'm wondering, do you have any comments on possible problems with that arrangement?

June Rodgers

The biggest problem is not having enough money. But the -- I worked for several years for appropriations from congress and was able to get us a $1 million a year to work through our operations for national. And then each learning center has as $1 million or $2 million a year operating cost. No one has dictated to us what our curriculum must be. Aerospace industry, Lockheed Martin has worked with us. On space day Boeing gave us funding for our lessons for the teachers most recently. But no one has dictated what must be. They really allowed us to work along the lines of the national-base standards that we should qualify this material with.

Paul Spudis

Thank you.

Pete Aldridge

Neil.

Neil Tyson

I've got a question for Mr. Williams but I want to then have a reaction by Dr. Arnold on this. I'm going to accuse you of only underestimating the actual value of your own efforts and energies and initiatives in the success of your program. When any of us reflect on our life in school, I'm sure I'm not alone when I say I can only remember three or four teachers who ever really meant anything to me out of all the teachers that I had. And it's too bad those numbers aren't higher, but that's just sort of the facts of what's out there. I have no doubt that you would have been one of those handful of teachers for me, as I'm sure you are for your students.

Brett Williams

Thank you for the compliment.

Neil Tyson

So here we are about to talk about the possibility of cloning a program, when I wonder what matters more is whether we can clone you. So what I would like – my broader question is, you look back in the 1960's, I don't remember that decade as being full of educational outreach programs, yet there was still an intense interest in going into space, driven by the vision. So is the vision sufficient, or must we rely on these programs to get the pipeline filled? Is the vision sufficient, or do we have to actually clone star teachers such as yourself?

Brett Williams

I would like to make one comment quickly on that before it moves on. My major is in marine fishery. I don't have a degree in engineering or physics. When it comes to the teachers capable of replicating this program, I believe any one of them can do it. I think it would take one that has a strong interest in the future of their students. But beyond that, I don't think there's a need for cloning. I think it's totally capable and we're seeing that successfully in Alabama and western Texas. I think it really comes back to the horse being led to the water, the old adage that you can't make them drink. A lot of people have said feed it salt, but you're still getting it to open its mouth. I came into education thinking that you really had to show them a picture of a dead horse and that was the way to get them to understand. But I think out of the last eight years of teaching, I found that it's an issue of getting them to have the desire to run, create that thirst. And it's whether you're showing a greener field or another herd of horses that they want to run with, whatever it might be, it gets the job done. They'll come forward. I'm already seeing students talk about this initiative and looking at changing their career pathway.

Patricia Arnold

I would tend to agree with Brett. Over the last 20 years, the Space Foundation has actually trained over 30,000 teachers. And one of the things that we find is that teachers want to learn. Unfortunately, teachers through about seventh grade many of them have not had good training in science and math. They are lacking skill training, context knowledge. All you have to do provide that for them. We find that teachers get engaged, they get excited. They say I didn't know it would be that much fun I didn't know it would be this easy to do. And we've been able to help them so they can go back and do exactly what Brett is doing.

What happens though is that sometimes teachers are expected to do things that they don't have the capabilities of doing. And nobody is there to provide them that support. And I also agree with June. You know, teachers don't make much money and they have to pay, unlike businesses, you know, businesses will pay teachers to get masters degree. Teachers will pay for their own education. If they want to learn about something, they have to go pay for it. It would be nice if there was additional funding so teachers could get the training that they need and then they would do a better job in the classroom. I truly believe having worked with teachers all my life; I truly believe teachers want to do a good job. But you have to give them the skill sets, you have to give them the tools and you have to be their coaching. If those things happen, I think teachers will do a much better job. It's not hard to excite students. If you have a teacher who's knowledgeable and interesting, those kids are going to love it. We have to do that. We have poor kids in school who will never get that opportunity. It's a prerogative that we can no longer ignore. We've got to do it.

Pete Aldridge

Laurie.

Laurie Leshin

Thank you all for being here. It's really wonderfully inspiring to hear all the stories. This is really fantastic. I have a question largely for Peggy and Brett, I think. I believe very strongly about having a strong national space exploration program. It's key not only to inspiring kids to work for that space program but so that they can start following tracks that will eventually lead to populate the broadly-based high tech economy in the direction we're heading. I was wondering if you could talk about the students that have gone through your programs. They go on to engineering, but clearly they don't all go work for NASA.

Do you have statistics about where they've gone off? Maybe it hasn't been long enough for them to have the jobs. From the international space university, they don't all go work for NASA or space agencies or private space industries. What kinds of jobs do the student who go through your programs have? What kinds of ways are they contributing to the broader economy?

Margaret Finarelli

This is such an important point that you're making. In my years at NASA and working a variety of education programs, it always seemed to me that we're missing a bit. We come out of the space field and we say "ah", what we're really interested in is filling this pipeline with scientists and engineers. But in this increasingly complex society that we live in, everybody's got to have some level of technological literacy so that they can form opinions on the issues of the day, whether they're environmental issues or whether they're issues about supporting the space initiative, energy issues, etc.

And so what we are doing in making science and math more attainable by students in the K-12 arena is we're creating better citizens and more knowledgeable voters. I think that's extremely important. It's s as important, I believe, as this pipeline of scientists and engineers that we're creating. In fact, it's -- if you'll bear with me to share one more quote. After the President announced his initiative, I got an email message from one of our alums and she said to me, this was about the initiative itself. "This is something that will spur young people to be technically literate. Not just to go into science, but to be teacher, script writers, leaders and policy make who understand space and science." I think that's the kind of thing that we have an opportunity to impact broader society here. Not just the pipeline. As to ISU, just very quickly, because we recruit from all sectors interested in space, we got scientists and engineers, probably about 2/3 of our students come from those fields. But we have lawyers who are interested in space, we have people who want to go into public advocacy. We have journalists who are interested in science journalism careers. These are -- this type of interdisciplinary education as a way to have people understand the languages of all of these pieces so that they can go out and have these broader careers. That being said, most of our people stay in the space field because of that's their passion.

Laurie Leshin

I think it's probably your students who eventually when the statistics build up.

Brett Williams

I've got everything from ordinance officers on one of the newest commissioned vessels with the navy to taking the helm -- one of the first females taking the helm of a nuclear sub for us, private aerospace industry looking to get into the small satellite niche, NASA, we do we have a lot of interest. In fact, I've got two right now that look like they're heading to be the first astronauts out of the Fredericksburg area.

You started with the issue whether we could look at a national con consortium so to speak that's something I've spoken with Jim Pruett at the Marshall Space Flight Center. He heads up the educational division there. It is an issue that we've discussed for years, because there are a lot of interesting avenues and approaches and programs all over the country, Dave Krasaley out in California. I could go out and list a lot that we talk to. There is some concern with getting two together and issues of diluting curriculum and red tale and stuff like that, but at the same time, there is the need for some type of a national avenue or path stuff like that where it would be possible for people to find out what's in their area, what's available to them and careers that they're looking into and things like that, private or public or government. In Fredericksburg, we started an initiative there to reach more students horizontally and vertically and are trying to take reign on that. They're trying to develop a tech-training center there for training the trainers, teachers trying to get them started on this. And looking at it on the broader level of trying to gather all these groups that are randomly about the country. If it was an annual conference or something like that, where we could try to bring them in and find unique ways to make sure everybody knew what everybody was doing, and that's something we're looking in to in Fredericksburg. We are just getting started. We just finished our business plan and getting ready to present some local funding opportunities. So we're still a ways away from that, but we are cognizant of it.

Pete Aldridge

One last question. Neil?

Neil Tyson

Sorry to jump in with a second question and comment here. I did back of the envelope some arithmetic here from your photos of students here. I don't know if people saw the photos of your students crowded around the rocket, one or two dozen students. I think there's something like 30 million students in the country. If we did, in fact, clone your program and every group of 20 students made a rocket, that's a lot of launches from White Sands. How realistic is it to believe that such a program can influence an entire nation with the school population that we now have? And Dr. Rodgers, the challenger center also has this low through put issue when, for example, the New York City school

system has a million children. Maybe there is no good answer at the moment. But I want to at least put it in the record that perhaps not all programs are scaleable into the regimes we need and we need another level of creative thinking.

Brett Williams

Right. What we've been looking at with the Fredericksburg program, and it's three-tiered. It starts out with a single stability of rockets. It goes to transonic velocity. It looks at high altitude research, the plateau, whatever you might call it like we have at our school. It's understandable most schools won't care to go to that level. Alabama is holding it at the first year, stability and keeping it there. They're having great success with it. Not only that, we're looking at promoting it as a generic program as well, whether it be in microtechnology or biotechnology, whatever the flavor of the community might be, they might apply it that way.

As far as the launch facilities, I've been speaking with my congressman Lamar Smith for the last, oh gosh, four or five years about this issue and with the army, looking at where funding might be available and insurance and things like that. One of the best things we have going right now is the promotion of spaceport proposals from every state, in fact, we're working with Fort Stockton with helping them with a development of a work force for that proposed spaceport in Fort Stockton. They have several launches scheduled with the Air Force, I believe, within this next year. I'm not sure exactly how many states there are right now with proposed spaceports. It is enough I don't think it would be a problem in the near future. I think this is a problem you would be seeing in 20 or 30 years and by then, I think we could resolve it.

Pete Aldridge

I would like to thank the panel for coming, some very far distances, I guess. Peggy, you're probably the furthest from Strasbourg, France. We appreciate your contributions. We know you've given us some written materials that we will go over and a lot of interesting things to think about as this Commission completes its work. Again, thank you very much and we're going to take a 10-minute break while we change panels and we'll adjourn 10 minutes from now. Thank you.

Dan Curran

I'm a president of the nationally recognized doctoral level university with historic strengths in aerospace research, and technology commercialization. We are blessed to be located in Dayton, Ohio, a very technologically oriented community, known for innovation. We are proud to be a research partner with Wright-Patterson Air Force Base, a major science, technology and aerospace center. Among universities, the University of Dayton research institute is second in the nation in the amount of federally funded materials research performed annually, according to the National Science Foundation. Today we are developing nanomaterials that are especially applicable to space platforms, because they are strong, lightweight, and have high thermal conductivity. The University

of Dayton's research institute operates a -- as a premier private facility in the United States.

One of the emphasis is impact research, impact testing. Much of the lab's work is focused on what happens when debris in space hits a space vehicle, satellite or other equipment. Another research team is working on microgravity heat transfer experience on the NASA jet, with the goal of producing the next generation of cooling systems for aircraft. As NASA investigates replacement spacecraft for the shuttle, it will use a UD engineering professor's reliability models. We have also worked with the Air Force to improve spacecraft batteries. Two other examples of cutting edge research captures my imagination and illustrate the type and role that University of Dayton researchers have already played in supporting the nation's new vision for space exploration. Researchers are helping the Air Force research lab develop concepts for a rapidly reusable space vehicle.

Imagine a shuttle that gets used more like an airplane, virtually at will and on call. The UDRI is also working with the Air Force Research Lab on developing an automated system to assess the structural health of a spacecraft within hours after a mission, and recertifying it for flight. As you can see, the university of Dayton has a long history of working with NASA, the Air Force Research Lab, and other major aerospace companies in the areas of advanced materials and power, and propulsion research. Our track record in attracting federal research funding is strong, and growing stronger. The university of Dayton's research institute ranks first in Ohio, and 16th in the nation among non-profit institutions receiving department of defense research contracts and grants, according to the chronicle of higher education. The UDRI, the research institute employs 360 full-time researchers and support staff and a number of faculty are also supported by research grants and contracts. We provide many of the high-tech high-paying jobs that help boost the area's economy, which is closely tied to the strength of Wright-Patterson Air Force Base, and its aerospace and aeronautic research. That research is a major driving force behind the local economy. The university of Dayton's RAE search institute relies heavily on aeronautical and aerospace research of Air Force research lab. While scientific and educational communities strongly supports the President's proposed space policy, we do so with a reservation that we also want to maintain the current level of aeronautical research funding, and insure that Wright-Patterson Air Force Base is included in any renewed space exploration efforts. The Air Force Research Lab has enjoyed a long-standing successful partnership with NASA and aerospace research and space science and technology. The Air Force Research Lab personnel are stationed at key national -- NASA locations to carry out these partnerships to advance nasal's mission and the Air Force mission of national defense. These partnerships are productive and thriving for both organizations. Some examples of the successful partnership include integrated high payoff rocket propulsion technology program, a 15-year national program to double launch, mission, and spacecraft propulsion capacity, decrease cost, and increase reliability. The research lab scientists recently assisted with the Columbia accident investigation. In addition, the Air Force Research Lab developed microprocessors, lithium ion batteries for use in the mars -- on both mars planetary rovers. The Air Force and NASA needs a number -- needs a number of fundamental and common aeronautical

and space technologies, such as hypersonics, air and space vehicle structures, high temperature material, rocket propulsion, solar arrays, computer processes and the like. Future partnerships between the Air Force research lab and NASA include reusable metallic and ceramic propellant tankage, ground operations, rocket propulsion, thermal protection systems and power generation management and application. The Air Force considered these to be critical to the next generation of military and civil space operations.

Hypersonics is an area of strong interest to the Air Force, and the Air Force will benefit by continued NASA efforts in this as well. Thus, prosperity and continuing economic growth in Dayton are tied to continued support by NASA of these areas of research that are also very important to the Air Force. It is the hope of the community as the President implements his space initiatives that the partnerships between NASA and the Air Force will be increased in this area. The Dayton reaches has embarked on a strategy to build technological clusters in advanced materials, data management and aerospace.

These collaborations between government, academia, and industry will build strong world-class capacities in which we'll support future space exploration. It will also lead to thousands of high-paying science jobs and technology jobs in southwest Ohio. That is the kind of prosperity that we hope will result from an ambitious space program. We want the space program to go forward. A revitalized space program will fuel the growth of the high-tech jobs that are not only based in Ohio but across Ohio and the nation. The new technology that results from this investment has tremendous potential for commercialization both by the military and by the private sector. The University of Dayton and its regional partners have educational programs in place to support the education and training of the new workforce, required to respond to this direction, the new directions in space. With Wright-Patterson Air Force Base, the UDRI, and a wealth of other higher ED institutions, this region is home to some of the best scientists and engineers in the nation. We are poised to help the nation fulfill the promise of space. Thank you again for the opportunity to address you today and I look forward to your questions.

Pete Aldridge

Thank you, Dan. Mike.

Mike Cross

Mr. Chairman, members of the Commission, thank you for coming to Dayton and giving us the opportunity to present our ideas regarding the President's Commission on Moon, Mars, and Beyond and how that initiative, that policy, can bring economic growth to the Dayton area. It was interesting and fun seeing the students here today and recalling as a young man growing up being inspired and encouraged to pursue my interest in aviation and space, mathematics and the sciences due in part to the vision of America's space program during the 1960's. I am encouraged once again with the same sense of challenge with the President's policy statement a renewed spirit for discovery. Wright-Patterson

Air Force Base is pivotal to the technological infrastructure and the economic growth in the Dayton area. Much of the technological competitiveness within the Dayton area can be tied to the success, science, technology, research and development and acquisition enterprises located at Wright-Patterson Air Force Base. As a member of the department of defense contractor community in Dayton, I submit that the President's Moon, Mars and Beyond policy offers increased opportunities for growth in the areas of science, technology and research at Wright-Patterson Air Force Base. This policy will lead to innovation in the areas that aerospace currently works in such as materials, propulsion, sensors, information technologies, human effectiveness concepts and aerospace technologies, and will lead directly to the success of a renewed vision for space and lead to increased competitiveness and prosperity in the Dayton area.

The Ball-Dayton operation, which I manage here in Dayton, consists of about 230 high-tech positions. We support both the Air Force research laboratory and the national space and intelligence center. Many of the programs we work on involve the use of space data, space information and providing information to the operational community. One of the other areas of growth that our operation expects to find is in the area of information technologies modeling in simulation applications and collaborative enterprises. We as a company in Dayton offer very innovative tools that were derived from research with the information technology directorate for conducting modeling and simulation applications and for distributed decision support capabilities that can enhance requirements definition, system design, development, test and manufacturing of a distributed enterprise.

I anticipate that the space program will benefit from these technologies, and the concepts that we have used here at Wright-Patterson Air Force Base. In addition to fostering growth in the technologies that will support moon, mars and beyond policy, I anticipate many spin-off applications of technologies in the Dayton technology community. Very similar to the spinoff applications from investments in previous space programs. I am concerned, however, with possible reallocation of research funds from NASA’s earth and space science research programs and the Air Force’s aeronautical research. Such reallocations have the potential to have adverse impact on Wright-Patterson Air Force Base and the adjoining Dayton technology communities. As part of the Dayton Wright-Patterson Air Force Base contractor community, Ball stands ready to support the President's space initiatives. Let the journey begin.

Pete Aldridge

Thank you, mike. Mr. Omlor.

Richard Omlor

Thank you. Good afternoon. Mr. Chairman and members of the Commission, it's my pleasure to speak you to on behalf of the 350 employee-owner YSI, who have been making technological contributions to the aerospace industry for six decades. I hope our collective testimony today will verify what many of us already know, that here in the Dayton region and elsewhere, leaders in industry, academia, and the military fully

support a revitalized space program, because we witness the benefits to the economic development and quality of life as a result of the aerospace research and development. I have the unique opportunity to tell you that YSI. is already on the moon. We're already on mars, and we have already crossed the solar system. YSI 's technology is currently reporting temperature measurements from the moon, mars, space station, and from the pioneer 10 space probe launched in 1973, which did cross the boundary of the solar system last year. Our postcard from the edge reads, "wish you were here. It's a little cold, but the weather is fine." a bit of background on YSI --we are the global leader in precision temperature measurement; the most widely measured parameter in the universe, as far as we know. We became the parameter or leader in this parameter in large part because of our history with the country's space program. The educational tie is that we were founded in the basement of Antioch College here in nearby yellow springs by two students. They developed a temperature sensor that eventually went into every NASA space mission, setting the standard for temperature measurement. In the late 1960's, we worked with the Goddard Space Flight Center to establish the space qualified specification that describes high tolerance measurement devices. Today we are still the only company who is on the qualified parts list for the specification. In our 56 years, we have developed increased regulatory expertise, one-stop shopping for our customers, and perhaps most notably, our expert meteorology capability. In fact, we sell our projects to the NIST, the national institute of standard technology for the traceable standard. We have expanded our work in temperature and are currently executing or planning applications in fuel cell, research and development, power management, thermal protection, temperature compensation and personnel protection. The work in aerospace has yielded numerous discoveries and technological advances. These advances have helped us expand YSI into the medical technology and environmental science markets, where YSI continues to provide market-driven commercial applications for our technologies. Through this growth and expansion, I'm proud to report that YSI maintains 100% of its critical manufacturing in the U.S., providing jobs, revenue, but most importantly, a secure supply chain. Furthermore it's important to note that YSI 's unique advantage in higher reliability and accuracy have allowed us to provide critical products with the aerospace and clinical industries where not only the cost of failure is inordinate but lives depend on our reliability and precision. Moving forward, our experience suggests that the country's economy and quality of life would continue to improve directly and indirectly from a revitalized space program. Our story here is also about a collaboration in a region well known for innovation and invention. It is telling that the people gathered here today to testify here before you have all worked together, some of us for decades. Ball aerospace, mike's company, for example, provided the first arms for the space shuttle. We provided the temperature measurement devices for those arms. We currently have a long-standing relationship with the university of Dayton research institute and the Wright-Patterson Air Force Base both in temperature devices and environmental sciences. What would a renewed space program look like? In many ways, it would look like a collaboration that we enjoy today in the Dayton region, but I believe it would have to include a closer collaboration between NASA and the Air Force among others for an economic reasons as well as strategic purposes. That is a renewed program to identify specific goals, either technologies or outcomes that all interested parties can embrace, and in one net provides our nation with a competitive advantage. At

the outset, these goals should include not only how the achievement will advance the understanding and use of space, but also proactively how and where the goals can contribute to our life on earth. At YSI, our corporate directive is who is minding the planet. Which speaks to our ongoing commitment to making our life better. However, this takes its roots from an older and wiser mandate from Antioch's first college president and educator, Horace man. His quote from 1859 is painted on the side of our building, and it reads, "be ashamed to die until you have won some victory for humanity." this is a tall order but one we intend to pursue. We invite the Commission and many customers and partners to pursue in developing and launching a renewed national space program. Thank you again for your time with us, and on behalf of the employees at YSI, we thank you.

Pete Aldridge

Thank you very much. Vince. You're next.

Vincent Russo

Mr. Chairman, members of the Commission, thank you very much for this opportunity to address this prestigious and very, very important commission. My testimony today is based on a 41-year career in science, technology, and acquisition of aerospace systems. I have held many scientific and leadership positions and topics of materials propulsion, structures and their supporting technologies. I led the team that created the Air Force Research Laboratory. More recently, I spent five years as the executive director of the aeronautical systems center here at Wright-Patterson Air Force Base.

Incidentally, the aeronautical systems center manages on behalf of the Air Force, a $15 billion a year program and is responsible for the development and acquisition of all of the Air Force's aeronautical weapons systems. My testimony will cover three main points. First, how will we get off the earth's surface in order to explore moon, mars and beyond? Number two, should we have a national program that benefits both NASA and the Air Force, and three, where should the leadership of a national program be centered?

My first point -- how will we get off the earth's surface? I have been involved in several studies on how best to get to space. Most recently, about two years ago, I was a member of a general officer steering committee for a joint Air Force-NASA study on access to space. My personal, and I want to emphasize -- my personal frustration with that activity was that there did not seem to be a balanced look at the two major alternate ways to get to space. We can get there either with rockets, or we can get there with airplane-like two-stage systems. It was clear to me at that time that NASA and the Air Force's space elements preferred a rocket-based approach. I argued then, and I believe more so today, that the technology for a two-stage system is now at hand, and these technologies are the same ones the United States Air Force could use for a future strike system. For instance, the next generation bombers. Now, by airplane-like access to space, I am referring to a first stage of a two-stage system, that is highly reliable, has very short turn-around times, is launched on demand versus on schedule, is easily maintained, and can use multiple

existing runways. The staging speed would be around Mach 4, in order to allow the airframe to be constructed with conventional materials. A combined cycle engine that starts out as a conventional turbine engine and converts to a ram-scram jet would provide for a gradual speed increase from 0 to Mach 4. I believe we could build the system within a time frame of interest to this Commission. This concept not only is important to access to space, but it also embodies the same technologies that could allow the development of a future strike system. And -- and if you like to dream a little bit, how about this nation developing a single system that can use -- that can be used by NASA and others for access to space, and by the Air Force as a strike vehicle.

My second point -- should we have a national program that benefits both NASA and the Air Force? I believe our country cannot afford a parallel development of both a new access to space vehicle and a strong defense program aimed at future strike. Also, since the technologies for both applications are so similar and most likely identical, close cooperation is mandatory. Thus, I recommend we undertake a joint program with shared leadership by both NASA and the Air Force. It will not be an easy program to manage, since the requirements of both organizations may differ. But compromise will be required. But this is too critical for us not to make this a national effort. Plus, it may be the most affordable, the most affordable option we have today.

And my final point, where should the leadership of such a national program be centered? I believe that a thorough, well-balanced examination of the two alternate ways to get off the earth's surface will result in the conclusion that the benefits of airplane-like access to space and the relationship to future strike will make it an easy decision of which approach to pursue. Based on my knowledge of the national experience and capability to build such a system as I described, it is clear to me that we are now sitting in the region of the country where this work should be housed. At the home of the Wright Brothers, we are sitting where all of the military and many of the commercial innovations in aeronautics have occurred. All of the Air Force's airplane programs and high-speed programs from Dynasoar to the national aerospace plane were led from here. The people who have the detailed knowledge of how to do systems engineering, technology development, and technology transition are here. The people who know how to manage the complex systems development are here. The people who provide contracted-for technical and managerial support are here. The educational systems to continue developing the critical intellectual property, including the highly innovative Wright Brothers Institutes are here. The facilities and infrastructure are here. The community support is here, and of extreme importance and maybe more important, is the desire is here. This region of our country is truly the birthplace, the home, and the future of aerospace. Today a big part of the future is access to space, and future strike. Thank you very much for allowing me to provide my personal thoughts on one of the key issues facing your Commission.

Pete Aldridge

Vince, thank you very much. I'm sure the people in Dayton would not have any argument with your position here. Let me start off with a very broad question, and it gets related to

one of the tasks we have in this Commission, and that is to implement the President's vision, which has been laid out in a fairly clear manner, with goals set in mind and things of that nature. Our task is not to challenge that mission, because that debate has already occurred. The President made his decision. I believe we all support it very strongly. But one of the issues that we have in this Commission is to insure that this program is sustainable over a duration that goes tens or more presidents, and at least 20 or 30 congresses and sustainability and affordability is clearly one of those, but part of it in terms of sustainability is a sustainability of the American interest in this particular vision. So that they elect the future presidents and congress which supports the vision. I call this elevator speeches, but if you had an individual, a person that -- a taxpayer in an elevator, and you had two minutes to tell them why are we doing this program, what would -- what would your advice be? I'll start with you, Dan, to see if you would -- what is it that stimulates the American interest in this kind of activity?

Dan Curran

You know, having the opportunity to be at the University of Dayton, many of our students are already involved in research that is linked to the base, to Wright-Patterson Air Force Base. I think the excitement has to start early. We talk about grade school and we talk about high school. When you see a college student who is working in a nanomaterials lab, you really have to invest in the students. They are the future scientists. So, I would say look at the future. Look at the global economy. What type of jobs do we need? What type of student excitement do we need? So, again, the University of Dayton has had a very unique relationship with Wright-Patterson, and so have the other universities in the area, but how do you get the students to look to space, to look towards aerospace as a way to go and engineering, and other areas? I would point to that. The other thing I would talk about is the commercialization of technology. I think that's very important to get along to the public. I mean, people always talk about Tang, you know, that's -- Tang. That's nothing in comparison to the technology that was transferred in the 1960's and1970's. The same thing can happen again, and it's an issue of standard of living. So, I would point to education, tech transfer, and finally, I would talk also about the partnerships, and many people at this table have already discussed that, Richard and so on. The partnerships between aerospace, space, corporations, and higher ed really have to be pushed and see how that is --see how that synergy works for the nation.

Pete Aldridge

Mike, do you have any comments?

Mike Cross

I'll address it from the perspective of what it takes for me as the leader of the operations here in Dayton to inspire people -- my employees. One of the greatest inspirations that my employees get is innovation. The ability to innovate, the ability to create, to think outside the box, to come up with new ideas, and one of the elements of selling the program in this elevator presentation would be innovation. Our young people desire to

think -- to use their creative facilities to come up with new ways of looking at problems. New ways of implementing programs and this vision offers that kind of inspiration within people. The second one would be the level of spinoff technologies and spinoff systems and ideas that have impacted and have benefited our culture. We could point to the prior space programs and the spinoff kinds of things that have benefited not just the space programs, but the health programs and the automobile programs and those industries. So, those would be the two focus -- this whole idea of innovation and how this initiative could inspire that innovation, and then the spinoff of capabilities that come from that.

Pete Aldridge

Richard.

Richard Omlor

I think it's a great question because the public looks at the price tag, looks at the economy and says, I don't understand. I think in addition to what mike and Dan said is that number one, long term, it helps the economy because it makes -- gives us a sustainable competitive advantage globally. That story needs to be played out a little bit more. But I think the single biggest thing is that the technological advantages and how they will benefit mankind on the planet, new energy sources, cleaning up the environment, that is the real selling point. And keeping the communications flowing that as that moves along. This is a long term – you pointed out, it will cross a number of administrations. That's a critical piece. I think the third piece is to get the commercial partners to really play their -- their part is that as the jobs are created or technologies are created that that's communicated effectively, too. And we tried that a lot in our company, so I -- it's always exciting news when there's an event that keeps people interested in the program it's just a continual process.

Pete Aldridge

Vince.

Vincent Russo

Mr. Chairman, I have done a little studying on human behavior and what motivates people. And I'm a believer in the term bhags. I think some of you know what I mean when I use the word bhags. A big, hairy audacious goal. Well, the President laid one, out – a big, hairy, audacious goal that we are going to go to mars. I think the job your Commission has is to now specify what that means to the individual taxpayers in this country. I think my predecessor has said that I think that part is very clear to me. We are starting down the right path with a bhag a big goal in front of us. Its not going to be enough in my mind it's going to be enough to have a loose confederation of government agencies leading this thing. You need -- excuse me -- we as a nation need an ability of a single lead, a single point for this initiative. Somebody or some relatively small body needs to be in charge. It cannot be well, we're going to turn to the department of

education to handle this, and NASA to handle that and for the Air Force you do this part. Somebody else to do that part, and somebody else to do that part. Somebody or some organization has got to take the responsibility to make this happen. That's the main point that I would add to it, that has already been said.

Pete Aldridge
Ok, Dr. Tyson.

Neil Tyson

If I could direct this to Professor Curran. You as a university president sit at the nexus of many things, educational pipelines, spinoff to industries and the like. I'm guessing you're best qualified to respond to my next question.

Dan Curran

We'll see.

Neil Tyson

You made some very easy to agree with points about tech transfer and how investments in a space program can stoke an economy. And of course, there are two kinds of investments that can stoke an economy. One of them is simple money from the government, which then is tax based. The other kind is monies that come from a growth of an economic industry. You didn't specifically identify which of those you were counting on in this program. The reason why I ask is since America is a capitalist nation, it's -- ought to be easy to make a case that an investment leads to a return. If the return is greater than the investment, let's just do it and then we can stop the hearings and go on and have a beer. My problem is something is wrong because we still have people debating the cost of this mission. And the need to sustain that cost over the many years. The fact that's still a debated point tells me that either we really won't get a return on that investment, or if we do get a return on that investment, somebody's messages have been failing to reach the public, or congress, or nobody is trying as hard as they should to try to convey that message. So, could you respond to that, please?

Dan Curran

I think you're saying people have to know the return. And I joked earlier about tang. Well, that was a great marketing piece. You know this was up in space. How many people know what else happened in the 1960's and 1970's? A lot of the projects we have worked on at University of Dayton are transferred. We just signed an agreement to transfer our nanomaterials research to an Ohio-based company. I think there's been a failure to adequately articulate the commercialization opportunities that are there. So, one, I don't think people know the return. I don't think people are aware of the collaborations that take place, and certainly, in Dayton, one of the programs that was addressed earlier was the Wright Brothers Institute that was mentioned by someone. The

Wright Brothers Institute is a plan to establish approximately 20 endowed chairs from the region and the country to work in support of the Air Force research labs. Those chairs will be funded by corporate and private dollars. The research will move forward, so there will be federal research funds, but there will also be corporate funds. The expectation is that certainly it will serve the needs of the Air Force, and other agencies, but there will be a process of the technological transfer. I think that has to be emphasized. And it has to- the public has to be aware of that, because as someone said earlier, when you have all of the challenges that our country faces and you queue up the dollars, people question why. Well, I believe we have to get the return known. There's been a return in the past. We have to articulate what the future will bring. And again, I think Dayton is a prime example of that collaboration between corporations, in this case, the Air Force base, and academia. We know we have to have an outcome and the people have to know what that is.

Neil Tyson

There are many towns that are not high-tech and people have no idea. Somebody has got to be getting the message out.

Dan Curran

That's right.

Pete Aldridge

Paul.

Paul Spudis

I'm actually glad this came up, because my question is closely related. All of you mentioned the value of spinoff, technical innovation. And I certainly agree with that. There were studies done on the Apollo program, that for every dollar invested in Apollo, you got a seven dollar return. NASA has tried to use the spin-off argument for years and it's largely fallen flat and it usually happens on two grounds. First they trivialize it, they'll say oh, Tang or velcro, that's what we got for $40 billion. Or they will argue what you got from Apollo, would you have gotten through anyway, either through general technological advancement or some other effect. So you haven't really created anything. So, what I would like to ask anyone of you that would care to answer this is how do you break through that? How do you address the trivialization of that? Because I happen to believe – I agree with you that spinoff is a good thing. How would you address the two problems they have identified?

Mike Cross

I'll take a shot at that. Part of our parent organization, volume airspace technologies corporation in boulder is very involved in the space programs. We corrected the Hubble

optics, but we also put up one of the quick bird satellites, which has a sensor on it, that is one of the highest resolution sensors out there. All of that technology evolved again from a space program. The applications, though, -- that that information is being used for, we don't sell. We don't -- we don't publicize, we don't communicate well. For example, real estate, -- the real estate industry uses that information in very -- quite considerably, but we don't communicate that. Another example is the whole use of cell phones. So, it's a space-based kind of capability. It's generated and its genesis was from space. GPS. Okay. GPS was primarily for -- primarily for airplanes. It's a space-based kind of capability, but you can get in your car today and not get lost because GPS and I think what its communicating the -- the spinoffs that are near and dear to our culture that I think sometimes we fail to do. We talk about the things that are technological, but the utility part sometimes, I think, we might miss.

Vincent Russo

I think -- if I may answer that--

Pete Aldridge

Yes, go ahead.

Vincent Russo

We could learn a little lesson here from our commercial counterparts. Corporations like Hewlett-Packard and Intel and others never fail to put their imprimatur on a product that makes a difference in my life. I know who did what that led to make something better in my life. I don't see the federal government on these gigantic investments we've made ever ever doing that. So, we ought to think a little more commercially and just like a typical government organization that funded something and therefore it's natural. Let's do a little advertising.

Richard Omlor

If I could add to that, I think the -- if this program were to be launched, and the commercial partners were working on the contracts, I think that would -- there would be a missed opportunity. I think the -- what the Air Force has to offer, the military branches, the commercial partners and research in developing new technologies and new sensor technologies would be the next platforms for future growth. Simply taking existing technologies and moving them would be a tremendous loss for the whole country. We know the material work at Wright-Patterson Air Force Base. We are now starting to work with them. The materials sciences works in our commercial applications. Again there's a significant opportunity to pool that together and move that forward.

Pete Aldridge

Bob.

Bob Walker

The two of you have waded into things that I think are going to end up being controversies inside this Commission. And I would like to do a couple of things here. Vince, I think that you know well that you waded into the controversy when you suggest the airplane-like access to space, and clearly NASA in the past has developed some technologies that were antecedents supposedly for that, and ended up canceling them in large part because the shuttle community weighed in and said, no, we don't want the competition. The President has now decided that the shuttle is going to be retired. And the question is what does the next vehicle look like. You say it should be airplane-like. I have to tell you that your past experience of more rocket-like craft are – is probably the dominant thinking at NASA right now. In part because what I am told by people is they don't think they can do anything else. They don't think they can do what you suggest. Why do you think it can be done?

Vincent Russo

Sir, I -- have spent a lot of time in the last five years trying to answer that question. I would like to put new a car and take you about 50 miles south of here to the General Electric Company and let them show you the designs and the component tests already done that could build such an engine. It is only short of being put on test stands to prove it can work. I also say that this limit of Mach 4 is critical that we're talking about, because at that point, do you not need exotic, new materials of structural concepts. You do not need the fancy thermal protection systems that you need on other systems. You can build it out of today's conventional materials and today's structural concepts. So, the argument that this is a technology 10 to 15 or 20 years away, in my mind, is wrong. I think there's a lot of people that just don't have an opportunity to hear the story. It just doesn't get surfaced because of the interests and the bias, I think, towards rocket approaches. Because that's what we have always done.

Bob Walker

Can I follow up with just a question for Mr. Cross as well. Mr. Cross, you also waded into one that I would like your response on, and that is when you suggested that you have concerns that a possible reallocation of research funds could have an impact on this community. One of the charges of the President, to this Commission, is exactly that. Perhaps reallocating some of the monies inside of NASA to see to it that there is more focus on the moon to mars and beyond type program. If faced with that reality, that there might have to be a reallocation in order to have the new program, which is the more important, keep it in place as it is now or reallocating?

Mike Cross

Good question. With respect to the reallocation, what I would submit is that there is -- there is opportunity and there will be opportunity where aerospace and the technologists needed for this to implement this vision could be complemented. And that those

technologies could be leveraged from both aerospace and for implementation a of this vision. And Dr. Russo's perspective, for example, offers that very kind of position where the research is aerospace, where an air vehicle is used to get into space to used to implement or complement this initiative and that research would then not impact the area.

Pete Aldridge

Les.

Les Lyles

Vince, let me ask you, and I know that we've talked about this many times before and so I'm sort of –

Vincent Russo

Will you stand at attention when you address me?

Les Lyles

No, not anymore. While I share your thoughts of two stage and an airplane-like vehicle as one of the initial stages or ways to address getting into space and getting back into space in a very aggressive manner, the reality is that there's probably no way that resources are going to support doing two types of programs. Both rocket programs and airplane-like program. My contention is, however, that maybe there's a way that these programs can be complementary to each other as a sort of a spiral development. Are you suggesting that we have one way or another? Or is the airplane-like program, or could it be, a spiral, a first spiral toward something more aggressive to eventually go to mars, which we're not going do to do in an airline?

Pete Aldridge

Short answer, Vince please. We're running out of time.

Vincent Russo

First I agree that it's going to be very hard to afford two programs. I think it's almost impossible. I think it depends on how you want to get to mars and beyond. Do you want to get there all with one big pushoff from the earth or is there a way to do little bits at a time? The disadvantage of aircraft is that you're not going to boost as much stuff at one event as you may want to and so you may have to compromise a little bit and have stages to get to where you really want to go. I still think there's need for the rockets, though, particularly in the second stage. And so that's why I keep arguing that these programs have to be really coupled closely because what you do on the second stage dictates what you do on the first stage. I don't think that you have enough money or resources or even

the skills in the country to build a brand-new rocket program and a brand-new single staged vehicle. I just don't think you do.

Carly Fiorina

I'd like to ask Mike and Richard to comment in particular on whether you think that this Commission ought to be considering potentially a different role for the private sector?

Pete Aldridge

Carly, can you speak up a little bit. I'm sorry.

Carly Fiorina

Potentially a different role for the private sector in this mission than in previous missions and I ask that question for two reasons. First, because Dr. Curran, to paraphrase your eloquent elevator speech, one of the things that you said was that the space program will require us to build the skills that we need to compete in the global economy across multiple industries. I ask it as well because I'm reminded of the fact that human flight was invented, not by government program, but two entrepreneurs and inventors. We as a Commission are concerned as our chairman indicated about the sustainability of this program. The sustainability over multiple presidents and multiple budget cycles and multiple congresses and it's in that setting that I ask about, how do you think about the role of the private sector this time as opposed to previous times?

Dan Curran

I think we deal with a number of the agencies, the Air Force, NASA. I think our part of our job would be lead collaborator initially on the technology. We are not afraid to share that technology and to leverage it. I think we have the unique perspective and position that we can do that without political boundaries that have not been tried, we're actually attempting a couple in that area right now. And I think that new technology, which we have it. I mean if we would all put the pieces together, as Vince said, they're here. It's not 15 years away, it's five months away, it's nine months away. So that is the first part. And the second part is setting that the expectation that this may not create jobs. That what it will probably do, we transition the workers from the standard manufacturing to the knowledge workers base and we need the educational backbone to make sure we can get there. And that is a concern of ours here because in the state of Ohio we are one of the chief exporters of college degrees, it's not just manufacturing jobs. So its two pieces and so we can take a leadership role as a commercial entity and the commercialization, but second is to make sure that we keep the transition workforce and keep the workforce here.

Pete Aldridge

Thank you very much. We have run out of time on the panel again. As usual, it's a very stimulating, and you've had a lot to say about the program. Again, thank you for coming. And we look forward to reading your testimony a little more -- more time to be given to what you've had to say. Thank you very much.

>>[applause]<<

Pete Aldridge

We have one more panel this afternoon and we'll wait until we clear this off and we'll proceed on.

Pete Aldridge

Our panel this afternoon is going speak to aerospace medicine, which is a very important part of this initiative for the exploration of the moon and mars and beyond. We're pleased to have two distinguished members of the Wright State University School of Aerospace Medicine here today. Dr. Stanley Mohler is the Professor of Medicine and Vice Chair of the Community Health at the university and Dr. Marianne Frey, Professor Emeritus School of Aerospace Medicine. Welcome you both and we're interested in your opinions as how human beings will fare as we journey into the solar system. You may proceed. Dr. Mohler you'll be first.

Stanley Mohler

Mr. Chairman, members of the Commission, it is a real honor to be invited here, along with my colleague, Dr. Frey. Our offices are across the hall from one another and we work together in teaching physicians and aerospace medicine. We started in 1978 and we have populated various centers. Johnson Space Center, Kennedy Space Center, the Civil Aerospace Medical Institute in Oklahoma City, the Air Force, the Navy, the Coast Guard. Various army activities and industries, airlines and over 20 nations have physicians who graduated from our program. Seven Japanese physicians in their JAXA space program have graduated. One of them is in our program currently. Our role is to look at is there a limit on what humans can expect to do in space? Will they die of radiation? Will they die of lack of gravity? Less gravity. And I just want to make a few comments on that and I won't read verbatim the submission. The bibliography listed in the references has three or four key data archive references that supply virtually all the information needed, and within those the references for successfully going to our moon. The moon, that's one thing we didn't pay for. And it doesn't cost anything to maintain it currently. And we don't have to boost it back up every now and then. And it's 72 hours away. And it should be a relatively straight forward -- I'm staying away from the economics aspect -- program of establishing 90-day rotations on a colony on the moon. There's plenty of regalith. We've seen the 12 humans who have walked on the moon kick up dust here and there. We have all the materials that we need. We can bring them up and we can do cargo

missions to supply the crews. What are some of the questions? Oxygen availability. That, there is technical capability of providing. Carbon dioxide balance and there is no atmosphere on the moon and so we'll have to be in compartments or pressure suits and we do have technical means of processing our exhaled carbon dioxide. There will be a balanced nutrition aspect. And Dr. Frey is going to cover the skeletal muscles and those aspects. A couple of the other items include the space pharmacy. Which will have over 200 different medications. And an onsite treatment facility where if a person's appendix acts up, they can bring it out. In addition, the trapped gas and evolved gas bubbles or bends that might occur on an extra habitation exploration afternoon sojourn will be there to put the person in. The every astronaut and cosmonaut, as we are proposing, joint missions and our graduates did help to support the mir space station operations and that provided a great deal of useful information. As you know, people have been up six months. Dr. Polyakov was up a year in total. And they're all active today, living normal lives. The radiation aspect of this solar cosmic rays, protons, some electrons. There are a lot of nutrinos, but we are told they are causing no problems. They are coming through us right now. The cosmic rays from galaxies, they have hardened aspects where they can protect from those to a certain extent. There will be a radiation hit. And that'll be known going in and that's always been the case for space flight. With respect to sleep-rest cycles, those are well known, the microbial contamination will be dealt with. Noise and vibration are going to be kept under control. Waste disposal. And with respect to the mars mission, the -- the longer term water requirement, and it's very fortunate. I just saw the jet propulsion lab announced they found evidence of past -- a lot of water on mars and it's probably in the north pole and the south pole and the tundra underlining the surface. And they had water on the moon that's been documented. So we're in good shape there. Toxicological changes are understood. They have sniffers that can detect it. The recreational aspects are fully understood and so that would also include communication with family and friends on earth. The mars mission they estimate will take about seven months. The 30-day stay initially, with seven months back is well within capability. The transit period is the highest risk for radiation but they have hardened devices that will protect in that respect. The international collaboration, and the different doctors that will come together, we feel will be a very significant interaction. So from the medical standpoint there is further research to be done, but we don't see any -- I don't like the word, but you
See it frequently -- show stoppers out there. To hit the astronauts and the cosmonauts. My last comment is on a late development mars habitation. You see the --

Pete Aldridge

Can you get close to the microphone, please.

Stanley Mohler

Sorry about that. You see the different cities. We'll have to have a Yuri Gagarin city of course -- we'll populate the surface. Now this is late-term, you understand, and not our initial activity. And Neil Armstrong and Edwin Aldrin city, and Harry Armstrong village who brought some of the famous doctors together for the first space medicine Air Force

facility at Randolph Field and he started right here in 1935 in Dayton. We'll project this as an evolutionary step that we can anticipate. And I think with that I'll conclude and turn it over to my partner, Dr. Frey.

Pete Aldridge

Ok. Mary, please.

Mary Frey

May I get a drink of water, please?

Pete Aldridge

Sure. And will you pull the microphone up close, because the sound in here is not working quite as good as it should.

Mary Frey

Chairman Aldridge and Commissioners

Pete Aldridge

You need to speak closer, much closer, inches away.

Mary Frey

Chairman Aldridge and Commissioners, our vision to send men and women to the moon and mars can be an inspiration and a unifier for the people of the United States of America and for the world. However, exploration has risks. And ethically before these brave pioneers embark, we must be able to minimize their risks. And maximize their well-being, their ability to perform successfully in space, and their chances to return to a normal life on earth. Next slide, please. The risks come from at least four sources. First, the reduced gravity environment. From almost zero to about 1/3 earth's gravity, which will cause fluid shifts in the body, loss of normal stress on the bones and muscles, and changes in stimuli to the nervous system. Second, the environment inside the vehicle or habitat poses threats from floating particles, which might be inspired. Toxic wastes, poor illumination, loud noise and poor thermal control. Third, the environment outside the vehicle or habitat poses threats, including radiation and meteorites or other debris. And fourth, the psychological and psychosocial stresses will be extreme. Next slide, please. Two risk factors that will rise to major importance for long distance, long-duration journeys are, first, the psychological and psychosocial challenges of these missions will be huge. Crewmembers will be isolated at great distances from earth with long lag times in communication. They'll be crowded into close quarters they will be in danger. And their sleep will be degraded. Interpersonal and group dynamics for intercultural and inter-gender groups must be understood and appropriate countermeasures developed. The

cosmic and solar radiation encountered outside of earth's protective magnetic field is unlike anything that we have here on earth. We must learn more about this radiation, about its effects on humans, including cancers and genetic problems and cataracts and how to provide effective shielding and other protective countermeasures. Next slide, please. Other risks of space flight, which were concerned in the short-duration missions of the past and the present will be much greater threats in the exploratory missions of the future. First the loss of bone mineral in space flight. About 1% per month. That's 10 times what people lose as they're aging. Cardiovascular changes, including arrhythmias and loss of exercise capacity and tendency to faint when hitting gravity on the moon, mars, or on earth. Muscle and strength loss. Neurological changes, including spatial disorientation, space motion sickness and neuromuscular changes. The immune system's reduced effectiveness in space and allergic responses. Inadequate nutrition and food supply. And the requirement for extensive extra vehicular activity, including risk of decompression sickness. Next slide, please. Excuse me. A related daunting challenge that is critical to astronaut health on a mission to mars is the necessity for advanced life support capability. This includes a closed system for oxygen, water and food. And effective waste management system. Accurate environmental monitoring, and user-friendly space suits and gloves to protect the astronauts and to
Enable them to do protective work and to do productive work on the surface of the moon and on mars. In this presentation, I've not addressed the very important challenge of providing medical care on exploration missions. Dr. Mohler mentioned it somewhat and that's a very important concern. Next slide, please. Potential countermeasures include exercise programs, both aerobic and resistive. Pharmacological interventions, nutrition and diet, light. Human factors design. Psychological testing and interventions. Selection criteria, including genetic screening and training. And probably a short-arm human centrifuge to provide artificial gravity as we see here. Next slide, please. The platforms for research and testing to allow us to meet these challenges will include the following. The international space station will be of major importance for testing counter measures and for some of the research required to understand the threats and to develop countermeasures. However, the ISS will not be a useful platform unless it has a crew of at least seven, allowing at least four to five crewmembers to be researchers and subjects. It must also have a necessary laboratory facilities. The moon could be a valuable laboratory for some research, and for some countermeasure testing for mars. Knowledge can be gained in living in less than one g environment the effects of transitions between g levels and radiation. And finally appropriate analogs on earth, such as human studies in bed rest or in the Antarctic, and animal research to learn about mechanisms of some of the medical and physiological stresses. Next slide, please. Meeting these challenges will require both NASA and the academic scientific community it will also benefit from international cooperation and interagency cooperation in the United States, including the national institutes of health, as well as other agencies. A much greater level of commitment and of funding for biomedical research and countermeasure research and development must be made than has ever existed before. But this commitment will payoff in space and on earth as we were talking about before. Space flight has been an inspiration for young people to study science and engineering. And furthermore, a spinoffs from space flight research and technology have made possible our lifestyle on

earth in every area, including health. Before I conclude, I'd like to mention something that has occurred to me actually while I have been here. And I'm not sure if the right Platform to mention this is here, but I believe that this Commission would benefit from at least two biomedical members. One, a medical expert, and the other an expert in biomedical research. Because, after all, we're talking about sending people to mars, human beings to mars. So, thank you.

Pete Aldridge

Thank you very much. It seems to me that this is a daunting task to solve these problems.

Mary Frey

I believe it is. I think we can do it.

Pete Aldridge

It's almost an enabling technology, unless we solve these problems we're not going to accomplish the vision that the President has set out for us, and the vision that is going to be accomplished by future presidents, as we've talked about. Are we doing enough now to address these problems? And when I -- you point out, we need seven member crews on the space station. And as far as we know we aren't planning anything close to that in the foreseeable future.

Mary Frey

Well, as the space station was planned we had always talked about seven member crews and that it would be a platform to doing research to go to mars, as well as for other things. And it was planned in the past that two members would keep the thing running and that the rest would be researchers and would be subjects for research. And that would be -- that would be the role of the space station. And if we're to get enough information to learn about these risks and develop countermeasures, we will need to do that kind of research on the space station.

Pete Aldridge

But are we doing enough in the other areas like closed cycle life support systems and radiation protection, and things of that nature?

Mary Frey

I believe NASA is doing something in all of those areas and they're developing a plan for what needs to be done. But the funding in life sciences is always been very minimal. It's never been a major concern. And I believe that's a very important thing that must be done if we're going to be able to do this.

Pete Aldridge

Well, since this is a critical task of this Commission for the implementation of this vision, if we're not doing something that we need to do, we would very much like to know that now. And if you have any input to the Commission, obviously, through our web page, we would be delighted if there's some deficiencies that we are -- that the program has in it now we would like to be able to address those deficiencies, to tell the President this is what you will have to do to make this program successful. And I sense that when you list all those things that we need to do, I just have a sense we aren't spending enough time on doing them all.

Mary Frey

No. I mean, we –

Pete Aldridge

We very much appreciate that.

Mary Frey

We have done some research on most of those things but there's so many questions still remaining before we even consider it.

Pete Aldridge

Maria.

Maria Zuber

This is a related question to the one that you asked Pete. The President's vision is tasked specifically to go to the moon as a stepping-stone for preparing for mars and a number of things that you mentioned in your presentation listed things that you could test while you were in orbit at the space station. And some thought really needs to go into what you can uniquely do on the moon that helps the human preparation for going to mars. There's going to be things that are gravity related, space suit design related, and have you given any thought to that? Or if you do give thought to it, could you please provide us with input. Because it's not clearly cost-effective to go to the moon to test things that you can do in your orbit.

Mary Frey

Well, there are things that can be done on the moon.

Pete Aldridge

Mary, microphone please.

Mary Frey

I must admit that I have not spent a lot of time thinking about this, but a little bit as I was preparing this and there are some things. The radiation environment on the moon would be more like the radiation environment on mars. Living for long time and doing a lot of EVA's will be done on the moon, which is something that we wouldn't be doing here in that particular environment. Making transitions from one g level to another, which must be done four times to go to the moon or back or to mars and back, at least. And so there are some questions that can be answered much better on the moon. Other questions, you know, it's important to find the appropriate and most cost-effective platform for each type of research. And the space station, I think, is best for some areas. Some things we can do on the ground.

Pete Aldridge

Laurie.

Laurie Leshin

Thank you for being here. This is a fascinating topic. This is probably -- people call this the century of biology and biomedicine and biotechnology. We are embarking on this incredible explosion in the biological sciences and we think a lot about the space program spining off technologies to industry and the public, but in fact I wonder if this is a case where NASA could be taking advantage of advances that are going on out in the biotech world today and I am curious about the level to which bioastronautical researchers such as yourselves are trying to partner with private industry to look at sort of the best new diagnostic sensors or the best osteoporosis treatments to be able to incorporate those into NASA's plans, rather than NASA trying to invent it all themselves.

Mary Frey

I cannot speak for everything that NASA is doing but I think there's a lot of working back and forth. There's been much development of sensors and sensor technology at the Ames Research Center. And I know that they do work with other groups. And I think that the more they do, the better it is. And I think that places can learn from NASA. I mean, I could give you lots and lots of the spinoffs in medicine that have come from what NASA has done, but they need to also learn from other agencies.

Laurie Leshin

It would be interesting to think about if there are some specific examples of places that we could look out, and things that are being done, not specifically for space flight, but then could be incorporated.

Mary Frey

When I was working at NASA and I was the program scientist for a neurolab space lab mission, we cooperated very closely with the national institutes of health, the national science foundation, and the office of naval research. As well as with all the international space agencies. And that pays off.

Pete Aldridge

Neil.

Neil Tyson

This list is impressive of things that we need to be thinking about in terms of the health and safety of the astronauts. I'm concerned because when I speak with my colleagues in the astrophysics community we are kind of preoccupied with the dangers of or the health effects of a solar flare going up while we are doing an EVA. And I'm just curious, given your collective confidence of the data that we've accumulated from how much time the astronauts have spent in orbit, in low earth orbit, I'm actually not worried about the rest of these things for which we have data. It's the ones that we don't have data. And I ask you, would you agree, given your expertise that the biggest problem here is going to be protection from these solar flares or cosmic rays and if so, do you see any research path that exists now, or must we recommend one to the President, that's going to lead toward a lightweight shielding necessary for these long trips?

Stanley Mohler

Well, I might observe that at Oakridge and the University of California, Livermore, and certain other centers, biological effects of ionizing radiation are continuing. And there is more to learn. And there is more to develop from the shielding standpoint. We in the U.S. and the Russians, particularly, they've been very much into orienting the travel vehicles between the takeoff and the destination to absorb a good deal of the radiation. There is an aspect of neutrons dislodged secondarily when primary solar flare protons strike various materials. But they do have anti- and countermeasures for absorbing those to keep the radiation level within acceptable bounds. So I think that the U.S., the Russians, Europeans, will have for the mars mission sufficient shielding. I don't think that the lunar mission, 72 hours there, every 11 years roughly the solar flares occur. And they can be partially predicted. But I don't think that will be a major problem because I mentioned the regalith that they can go inside and wait until the storm passes over. I would observe that our astronauts in international space station are partially shielded by

the earth's magnetic field since that does extend out of course beyond where the space station is orbiting. We do have a Russian and an American. They did, you may have noticed, exit the space station, left it on autopilot, which demonstrates the capabilities of the software and the related materials. They did come back in after a while because it appeared some moisture was collecting in one of the pressure suits and as a safety precaution. The things that Dr. Frey has presented are a tremendous archive of known data and questions for the future. And the mars mission there will be necessary some more research. Fortunately that's 30 years off more or less, and with the known evolution of technology along with a geometric progression, if you track it back, I am confident that information will be there to meet those matters. The primary aspect is identifying individual problems. I think that the moon is covered. That's going to be not a tremendous challenge. With respect to money, I think it's more of a political-global matter when the different nations share in a mission which has a secondary benefit of getting people together, I think it will be the will to cover the costs of the lunar mission. I think that for those who are astronomers, I think that the moon will prove to be the follow on to the Hubble telescope. And on the other side of the moon you can set up some of these telescopes that they have these interferometer telescopes where the farther the two telescopes are apart the more resolution can be achieved. That's your perfect telescope base is the other side of the moon.

Pete Aldridge

Dr. Mohler and Dr. Frey, we appreciate you're coming today and your testimony. We've reached the end of the scheduled hearing today. We will reconvene here tomorrow at 9:00 a.m. same location. And we look forward to a full day tomorrow of testimony from a variety of sources. Again, I thank the panel. Appreciate your input

Mary Frey

Thank you

Stanley Mohler

Thank you.

>>[applause]<<

Pete Aldridge

We're adjourned.

Pete Aldridge

Good morning, everyone. We are delighted to be back here in Dayton today. We had a very good meeting yesterday, and we expect more of the same today.

For those of you who do not know me, I'm Pete Aldridge, Chairman on the President's Commission of Implementation of U.S. Space Exploration Policy otherwise known as the President's Commission on Moon, Mars and Beyond. There's quite a buzz about mars these days and naturally, the discoveries announced earlier this week make going to mars an even more exciting opportunity. As I did yesterday, let me just briefly introduce my fellow Commissioners.

First is Carly Fiorina. Unfortunately Carly's not here right now. She'll be joining us later this morning. She serves as the Chairwoman and Chief Executive Officer of Hewlett-Packard. Her roots are deep in technology having served in senior executive leadership positions in AT&T and Lucent Technologies. And Carly, welcome, just in time.

Second—I'm going from my right to the left. Second is Michael Jackson, as the Senior Vice President of AECOM Technology Corporation, former U.S. Department of Transportation deputy secretary.

Dr. Laurie Leshin is the Director of Arizona State University Center for Meteorite Studies and the John Whiteman's Dean's extinguished professor of Geological science at the university.

No stranger to Dayton is General Les Lyles. General Lyles was in the U.S. Air Force more than 35 years rising from Air Force ROTC program to become a four-star general and commander of the Air Force Materiel Command here in Dayton.

Dr. Paul Spudis is a planetary scientist at Johns Hopkins University, applied physics laboratory. His specialty is geology of the moon. He's also studied the geology of Mars, Mercury and many other worlds.

Dr. Neil deGrasse Tyson. Neil Tyson is an astrophysicist and the Frederick P. Rose Director of the Hayden Planetarium in New York City. His professional research interests include exploding stars, dwarf galaxies and the structure of the Milky Way.

Retired congressman Bob Walker. Bob 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 Walker served in the U.S. Congress of 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.

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.

Lastly, our executive director, Mr. Steve Schmidt. Steve is a Special Assistant to the NASA Administrator and is the federally designated official for the President's Advisory Committee.

We are responsible for producing a report for the President with 120 days of our first meeting, which was February 9, 2004. So our homework is due in the first week in June. To produce that report, this Commission is conducting five hearings. We had one on the 11th of February in Washington, D.C. and then here in Dayton now. We're going to Atlanta on the 24th and 25th of March, San Francisco on April 15th and 16th, and New York City on May 3rd and 4th. At each of these locations, we take testimony from expert witnesses.

In addition, we are collecting feedback from Americans and other interested in space exploration on our website, which is www.moontomars.org. In fact, we've had more than 1.8 million hits to our website and nearly 4,300 written comments. I want to assure you that every comment will be read. Today we have a first in our process because we're going to open the floor for about 30 minutes of comments from the general public. We've arranged a lottery system for those of you who wish to speak. We will draw the names at 2:15 from a pool of those who do want to speak. You must be present at that time to secure your place. We will take as many speakers as time permits, and we ask that everyone adhere to about a two-minute time limit so that we can hear from as many members—as many people who want to speak as possible. We want to encourage anyone that wants to speak and doesn't have the opportunity today to use the feedback comments from our website.

Once our report is written, we'll deliver it to the NASA Administrator and then take it to the President. We tend to produce a report that has perhaps 10 or so key strategies that we believe are critical for accomplishing this vision. Let me remind you that this is a long-term vision, 40, 50 years or more. That's at least 10 presidential terms and many more congressional terms, and we are looking for the strategies that make our space journey sustainable and affordable. But the journey and the possibility to work on programs of space exploration will inspire our nation's youth and encourage greater math and science literacy.

Also, we've been charged with laying out a science and technology agenda where in what type of science and technology do we need to invest to make the journey possible. We're looking to the management skills and the techniques that make it possible to keep such a long-term program on track. And finally, we're looking at how this program can help keep the nation competitive in the world marketplace and enable all of us to continue to enjoy great prosperity. It is a tall order in the time we have. But I believe we can do it. Our first panel consists of many people from the Air Force. One of the great attractions in Dayton for this Commission was the exceptional work and talent that resides in the Air Force in this location.

It's probably important to remind our audience that this is a national vision. It belongs to all the people of the United States, and we're looking at—to all the resources and talent

that might be directed to this effort. So it gives me great pleasure to welcome from the Air Force several members.

First, General Greg Martin. Speedy Martin is the Commander of the Air Force Materiel Command here at Dayton. Lt. General Dan Newton who is the Vice Commander of the Air Force Space Command from Colorado Springs and General Paul Nielsen, Commander of the Air Force Research Laboratory. Gentlemen, welcome. We're glad to have you here. And I believe, Dan, are you going to be first?

Lt. Gen Newton

I'll defer to General Martin, chairman.

Pete Aldridge

Ok, Great.

Gen. Martin

Thank you, Mr. Chairman, and to the Commissioners, I want to thank this committee for taking time to spend with us here at Wright-Patterson Air Force Base and the of course, Dayton community as you gauge this nation's capability to point to moon, mars and beyond. Dayton is ground zero, as you know, for aviation. For aviation development from the days of the Wright Brothers, and between the base and the industry that we have here, and our community, it has been and we believe will continue to be a key player in our nation's space development. And we certainly appreciate the importance of this Committee's work to the future of our nation.

We, the United States Air Force, have had a longstanding partnership with NASA and the space community. As military's lead service for space, the Air Force has much to offer our nation and its leaders to implement this vision for space. I think both NASA and the Air Force are operating in the same medium, and we have and must continue to leverage each other's efforts and activities.

Next slide, please.

The Air Force has had a long history of involvement with NASA and other organizations who together have given us space capabilities that are second to none in this world. The boosters and rockets that were developed by the Air Force's western development division in the 1950s and early 1960s were the cornerstone of our space exploration efforts. In only seven years, from 1955 to 1962, General Bernard Schriever's group developed a workable atlas rocket, the titan, which would later serve as the booster for the Gemini missions, and the minuteman. These are rockets along with those developed by the army that carried our first astronauts into space and provided this nation with its initial intercontinental ballistic missile capability. The western development mission, which is the forerunner of today's space and missile center developed and launched our

nation's first satellites as well, and after NASA took over the space exploration mission in the late 1950s, we continued to leverage each other's efforts, and that partnership is a partnership that works.

Next slide, please.

This partnership, I believe you'll see, has helped us become the most dominant force in the world where we have—

Next slide, please—

Where we have one, as you can see on the slide, the last five—won the last five conflicts in a decisive fashion. Five wars in 13 years where air and space has played a decisive role. In fact, during Desert Storm, it's often referred to as our nation's first space war. But those contributions of space actually pale in comparison to operations Enduring Freedom and Operation Iraqi Freedom where space was truly integrated into every phase of the operations and pivotal to everything we accomplished.

Next slide, please.

We've drawn some key lessons out of those five conflicts that you can see on the slide before you. What's important here is not necessarily all of them—there are many more lessons, but if you'll go to the next slide, you'll see that there are three areas where space is absolutely pivotal.

Our communications network, which we often call the global information grid, our ability to achieve persistent theater-responsive intelligence, surveillance and reconnaissance and the need for being able to achieve discriminate effects in near real-time. In Desert Storm, a fraction or about 10% of the weapons used were precision-guided. In Operation Iraqi Freedom, the number is closer to 75%. Space delivered the means for us to provide near real-time effects and accuracy that we had never achieved before. Next slide, please.

Now, the Air Force has two major commands that are responsible for acquiring its systems. The Air Force Space Command, General Lord is the Commander and General Leaf as it's Vice Commander and of course the Air Force Materiel Command. Now the Air Force Space Command is really the Air Force lead organization for space acquisition, while the Air Force Materiel Command provides acquisition support not only there but also in our air armament command control and information systems. But AFMC also owns the Air Force Research Laboratory, which is responsible for all research, and technology that we use in our Air Force including our space activities.

Next slide, please.

It's actually at the Air Force Research Laboratory, as you see on this slide, where air and space superiority start. The Air Force Research Laboratory has 10 directorates and these technologies and the technologies developed here will play an important role in any

future space endeavor that our nation undertakes. We are conducting research across those directorates that will directly benefit any national vision for space exploration. From our work in propulsion to our work in space materials to more basic research in nanotechnology. Our research investments have increasingly moved from emphasis on air activity to an emphasis on space efforts.
Many of the technologies we developed in conjunction with industry and our national partners are dual use meaning that they can serve both civilian and military purposes, and it's important to point out that the Air Force is really only paying about half of the research laboratory's budget. It exists as a cooperative and available executing agent that can and does benefit other agencies. You'll hear more about the Air Force Research Laboratory in a few moments from Major General Paul Nielsen.

Next slide, please.

In addition to the Air Force Research Laboratory itself, we have two test facilities that are a part of this air and space nexus. These organizations can help to develop future space systems. For more than 50 years, the Air Force Test Flight Center at Edwards has been the home of the most major milestones in flight and in the development of rocket and booster vehicles. The Arnold engineering and development center in Tennessee is the most advanced and largest complex of flight simulation test facilities in the world and both of these test centers have infrastructure that has in the past and will continue to help improve rockets and boosters used to advance our national space capabilities.

Next slide.

I think there's a third point that should be made and that's that the Air Force will benefit from the national vision for space that challenges the imagination. It is the vision that kindles the flame, inspires the nation and provides focus. It's a vision that inspires the youth of this nation to pursue science, math and engineering degrees. That ability to be part of something big, something historic, so I think your work in establishing and in communicating this nation's space vision is absolutely critical. I'm delighted to be here. I look forward to your questions. At this time I'll turn the podium over to General Leaf, who will talk about the Space Command.

Pete Aldridge

Thank you, Speedy.

LtGen Leaf

Mr. Chairman, distinguished members of the Commission, I appear here today on behalf of my boss, General Lance Lord. He regrets he couldn't be here due to a family emergency, and I'm honored to serve as his messenger. This testimony was very important to both him and Air Force Space Command. As the chairman knows, I'm not a career space and missile professional. But I do bring a battlefield perspective that General Martin alluded to.

As a wing commander in Operation Allied Force, I had two pilots down in enemy territory. Their rescues were made possible in some measure by space capabilities. As an F-16 pilot, I changed how I employed the aircraft and its weapon systems because I knew I could rely and I learned in combat that I could rely on our space-based capabilities. In Operation Iraqi Freedom, serving with the land component commander, I saw firsthand how our forces were made both more effective and less destructive as they pursued victory. So I have a great appreciation for the national imperative to ensure that our space capabilities are protected the and enhanced and defended in an environment that affords NASA and our international community the opportunity to explore and maximize the space environment, not just for the nation, but for all mankind.

I'll concentrate my comments today around three areas, the historic partnership between the Air Force and NASA, our operational partnerships that are existing and working today, and how we'll work together for a bright future in space as envisioned by the President's initiative and vision.

Our historic partnership is a way that allows us to link the President's vision to the past. Air Force Space Command has remained a stalwart supporter of NASA and its predecessors as we have throughout 50 years of Air Force space and missiles. General Martin mentioned the western development division and the work of then Brigadier General Ben Schriever. In seven years, General Schriever and this brilliant organization created a missile industry able to provide the U.S. Air Force and nation with four complete missile systems of almost unimaginable complexity and capability. Space and missile system center is now our center of excellence, it's the successor to western development division, our center of excellence for space acquisition. Atlas, Titan, Thor and Minuteman formed the cornerstone of deterrence during the Cold War and became the basis for America's access to space. For the next four decades, and they did so from carrying Mercury and Gemini astronauts into orbit to interplanetary probes to the mars rover missions. Next slide.

Our long partnership in space lift continues as we transition our expendable fleet from our legacy boosters, which have served us so well to the evolved expendable launch vehicle. We continue to support both manned and unmanned space lift missions by operating our national launch ranges on both coasts. Modernization and sustainment of those ranges is ongoing to replace obsolete equipment and improve operations and ensure flight safety. Our current modernization program to be complete by the fiscal year 2008, includes approving range safety, increasing our responsiveness, flexibility, reliability and availability at the same time we reduce operations and maintenance costs and standardize and automate our processes wherever practical.

Next slide.

Partnerships are about people and Air Force astronauts are administratively assigned to Air Force Space Command. We're working to integrate them fully and work them into our leadership structure once their NASA tours are complete or in the interim and then

return them to NASA. We also provided support to NASA on the Columbia accident response and subsequent investigation.

Next slide.

As we look to the future, it is our duty and fundamental responsibility to gain and maintain space superiority and ensure the freedom to operate in space for all mankind. At Air Force Space Command, space superiority rolls off our tongues just as air superiority does throughout the rest of the Air Force. It's the first thought in all we do. Robust space situation awareness is the key to that mandate. Space situation awareness includes space intelligence, space surveillance, space reconnaissance and monitoring the space environment itself. We currently monitor over 13,500 objects in space that we catalog for collision avoidance based on over 180,000 observations a day. We track objects as small as a softball that could cause extensive damage to any manned or unmanned spacecraft. We continue to work very closely with NASA and other partners in the international community to minimize space debris and develop a debris mitigation guideline for space launches.

Next slide.

Our primary mechanism to formally coordinate between NASA and the department of defense is the partnership council. Since 1997, the partnership council has been instrumental in facilitating collaborative efforts to streamline operations, to cross utilize facilities and capabilities, to consolidate wherever possible our redundant facilities, to share support services, to leverage science and technology investments and simply to dialogue with our counterparts on other issues like the development of space professionals. General Lord is actively engaged as a participant and member of this council with Admiral Jim Ellis, the Commander of U.S. Strategic Command, the Honorable Sean O'Keefe and Undersecretary Peter B. Teets as well as Dr. Ron Sega. We continue our dialogue through additional leadership meetings, planning activities and participation of war games. Such as Schriever 2 which we developed for all our space mission partners to secure national security space well into the future.

Next slide.

Events like these not only highlight our true partnership. They continue to build a common space cadre that's essential to pursuing the President's vision. Developing space professionals remains our number one priority in Air Force Space Command. We will continue to develop well-educated, motivated and competent people who are skilled in the demands, the extraordinary demands of the space medium. Operationally and technically, through our space professional strategy, to sustain the U.S. as the world leader in space.

Next slide.

The men and women of Air Force Space Command will be ready for whatever the future brings by continuing to innovate, develop, design, launch and operate leading edge space and missile systems. With the help of the Air Force Research Laboratories, through Air Force Materiel Command and our industry partners, we are continuing to transform Air Force Space Command to ensure the medium of space remains a sea of peace to explore for the benefit of all mankind. We look back on our space and missile heritage with pride and eagerly anticipate the bright future that awaits us all. We stand ready, willing and able to support the President's vision.

Pete Aldridge

Thank you.

MGen. Nielsen

If you could bring up my title slide, please. Well, Mr. Chairman and Commission members, while they bring that up, first let me thank you for this great opportunity to talk to you about space, science and technology, something near and dear to my heart. I've submitted some written testimony that expands upon some of the comments I'm going to make because we want to leave some adequate time for questions and some discussion. I think all of you know that the Air Force Research Lab and its predecessor organizations have a long history of aeronautical and space science research and we've contributed already greatly to our nation's space capabilities. The honorable Peter Teets, the director of the national reconnaissance office and the Undersecretary of the Air Force has said the AFRL science and technology programs have historically been and continue to be a significant source of critical space technology for both the Air Force and the NRO. Other Air Force leaders have echoed those sentiments and we're real proud of that. Next slide, please.

This is a brief outline of what I'm going to talk to you about today. I'll provide a brief overview of the Air Force Research Lab and how we lead space science for the Air Force. I'll talk about the strong partnerships we have with all government agencies, especially NASA and then I'll talk about other concerns we have and share about the s & e workforce. Next slide, please.

On this slide I've highlighted the four directorates inside the research lab that will talk to you in this afternoon session. I want to highlight though while these are the four that will talk to you, all of our directorates are closely involved with space research. One of the great strengths of this integrated lab that we formed seven years ago, the Air Force Research Lab, is that we can bring expertise from all across the technology spectrum to any problem that the Air Force faces to any opportunity that the Air Force wants to take advantage of. Next slide, please.

Overall, AFRL has a team of about 5,200 people across the country, across the world really. We're the largest Air Force employer of scientists and engineers. We have a little over 3,000 scientists, engineers in the Air Force Research Lab and over 800 of them have

PhD's. We believe that the men and women of the Air Force Research Lab—defend America, by unleashing the power of innovative technology. This is not a passive role. We're not just supporters. We feel like we have an active role. Our people are at the front fighting the unknown, fighting time to make sure that we give our airmen the information superiority, technical superiority, precision lifeability survivability and a rich menu of effects. That's why we do the job that we do. We administer a little bit over $3 billion a year in science and technology funds, about half comes directly to us from the Air Force on Congressional appropriations. About half, what we call customer funds, from other agencies of the government, like NASA, like DARPA, other agencies like that give us funds to execute our program. Of our money, of this $3 billion that comes to us every year, over 80% of it goes to industry and academic institutions. We don't do this in-house. We reach out to the best and brightest our country has to offer. Next slide, please.

Now AFRL has been in a big strategic move over the last five years, moving more of our money into what we call space unique technologies. Back in 1999, my predecessor, General Dick Paul, noticed that we were spending about 13% of our S&T budget, science and technology budget, on space unique technologies and we pledge to double that over the next seven or eight years. Already we've gotten to 25% of our budget in space technologies. so the percent has gone up and the absolute dollars have gone up, which is also highlighted on that chart. Next slide, please.

We have broad investments in space that range from basic research to applied research to technical demonstrations. The technologies we developed support getting to space, situational awareness and operations in space, protecting our assets in space, which is becoming more and more important, and providing information back to users on the ground, because that's what space does, is provide information to people on the ground. Our contributions include space weather sensors, propulsion, lasers, microsatellites and materials in conjunction with NASA, AFRL has supported national efforts toward realizing the next generation of a space transportation system. We are also working in the hypersonic area and on turbine-based propulsion, on thermal protection systems, on guidance and navigation and control systems, power systems, secondary power on board the satellites, and high temperature materials, all of these needed for future launch systems and future missions in space. Next slide, please.

We're really proud that we have a long history of strong partnerships with many government agencies. You can see the alphabet soup up there almost. Obviously, these include NASA, the NRO, out friends in the Navy and Army, DARPA is very important to us. We work closely with Missile Defense Agency and others. The last comment up there, second to last, the space technology alliance is a novel approach where we bring all the players in the government together to make sure we coordinate, collaborate and plan our research efforts to the best effect for the nation. And then last bullet up there, we have some really innovative industry partnerships in many areas in the turbine engine area and rocket propulsion area where we plan our program collaboratively with industry to make sure all of us are spending our money to best avail. Next slide, please.

We not only have partnerships direct with NASA headquarters but with many of NASA's centers. This is too much to go into here, but I wanted to show you the breadth of the relationships that we have. Next slide.

To comment a little bit more on the space technology alliance, this is currently led by a joint leadership team from the Air Force Research Lab and the National Reconnaissance Office. It's a multiagency government consortium that we helped establish in 1997 to collaborate and plan technical road maps for the nation. This has become real important for us. Next slide.

You can see that there's a rich portfolio of space technologies that both the Air Force and NASA need. Some of these fundamental technologies include hypersonics, structures, high temperature materials we spoke about before, rocket propulsion, solar arrays, computer processors, and a whole bunch more. There are areas where we lead and NASA follows. There are areas where NASA leads and we follow and there are areas where we kind of lead together in very interactive ways because of our intense interest in each of these. Many of these technologies will apply to this new mission that the President has called us to. Next slide, please.

We have some existing partnerships with NASA that are at risk right now, and we do want to highlight those. We're obviously concerned that these technology investments may be terminated in exchange for some new technical investments. These are primarily focused on reusable space access and getting to space at an affordable cost. These include technologies such as reusable propellant tanks, ground operations, rocket propulsion, thermal protection, power generation management and application, we consider these to be critical to the next generation of both military and civil space operations. Hypersonics is another area where we would like NASA to continue their ongoing efforts due to the extreme talent of their men and women in this area. We do feel that good partnerships are nurtured by people fulfilling commitments. Next slide.

As General Martin mentioned, the Air Force scientists and engineer work force is an area of concern for us just as it is for the nation as a whole. In my written comment, I've provided more background on programs and characteristics of our workforce management, but in the interests of time, I'll just mention some of the key topics that are in that written testimony. First that our senior Air Force leaders are actively and deeply involved in this problem, addressing this problem. Second, that over 20% of our workforce of scientists and engineers are active military members, unique to the Air Force. Third, that we have an innovative personnel demonstration system that has kept our workforce fresh and vital. And finally that we have a robust science and engineering educational outreach program that complements the NASA program and spans k-12, undergraduate, graduate and postgraduate education. Next slide.

This is my final slide. Many of our space technology programs will help the nation achieve the President's new space vision. We're eager to work with NASA on these programs. AFRL looks forward to continuing our broad partnership with NASA. We're proud that AFRL technology, special batteries and computers are on the rover's spirit and

opportunity today on mars. To me this is the most exciting time in history to be a scientist or engineer. We've come through an amazing 20th century which saw the advent of flight, the invention of the transistor and integrated circuit, the development of quantum mechanics, atomic energy, relativity, the laser and tremendous advancements in the health sciences. Yet none of these advancements have stirred our hearts as much as the exploration of space. And what some have called the first space age. Now as we advance through the early years of the 21st century, I know we'll have accelerated advances across the whole range of technologies, but I myself look forward to the second space age and what will come from it. Thank you, Mr. Chairman, for this great opportunity.

Pete Aldridge

Thank you, Paul. Very interesting. We have emphasized in this Commission over and over again, and I guess we cannot emphasize it enough, that we do look upon the President's vision as a national vision. It's not a NASA vision. It really is national. And that we want to—by being national, we believe that all federal agencies should look to themselves as to how they best can contribute to this national vision.

For obvious reasons, the technology, the flow that comes from the various agencies and also the young people entering into the workforce that we all can benefit from, I think we were pretty much aware of a lot of the activities that go on between the Air Force and NASA, but I don't think it had, up until now, has this common vision of space exploration. The partnership council, your space technology alliance, all those things have been kind of ongoing.

Is there something different that we should be doing, given this new direction, that we're not doing, something the Commission could help stimulate a slightly different approach, if one is necessary? Is there something that you guys can suggest that we're doing differently?

Gen. Leaf

Well, I for one really believe that the strong partnerships that we forged in the past are a good path for the future. I think we can continue to work much more interactively and collaboratively as we go through this. I guess there always is a question when you set off a vision like this, do you do this through a confederation or do you do this through a single office that has leadership of a big program like this. And I think history has said generally this works better through strong leadership in a central office.

Pete Aldridge

Somebody's got to be in charge.

Gen. Leaf

Somebody's got to be in charge.

Pete Aldridge

Les.

Les Lyles

Let me thank all three of you for being here. Obviously, there are a lot of things that are going on in the Air Force today that very well play with this vision and the roles that NASA plays in other industry, consortiums and other groups and agencies play in this whole venture. I'm curious, though. I'd like—Paul, you talked about mutual technologies, NASA and Air Force technologies. the committee—Commission has been thinking of something called cluster technologies, key technology areas that need to be addressed. We have at least at one of our previous hearings or our first hearing; we gave some homework assignments to some of our witnesses. If you don't mind, I'd like to—Speedy, with your indulgence here with Paul, to leave a sort of homework assignment if you could get back to us.

We'd like your thoughts on the technologies you think that are very important for exploration in space, and we may even give you some ideas of what we think are those cluster technologies, how is the Air Force playing in mutual or common development of those technologies today but probably more importantly how could it play stronger in those technology areas in the future? I, for one, feel that there's a lot more that can be done and should be done, and we're just at the beginning stages, as you mentioned, Paul, of having that interaction, and there's room for growth, but we'd like your thoughts on which one of those areas, technology clusters, have the opportunity for growth or where there already may be strong interaction with NASA

MGen Nielsen

All right, sir. I understand this is a take-home assignment. Not an immediate answer.

Les Lyles

This is a take-home assignment.

MGen. Nielsen

Yes, sir, I've got it.

Lt. Gen. Newton

If I may, I'd like to offer homework to one of our folks in space command. I'd like Lieutenant General Brian Arnold in the space and missile system center to participate in that. We already have, as you know, a strong partnership, but he's our focal point for acquisition, systems development, and I think they can partner.

Les Lyles

My second question relates to that, if you will. I've always been very heartened over the years with the partnership council with the NRO, Pete Teets with his dual hat, Sean O'Keefe and Lance Lord. But there's something missing. Speedy, do you think this partnership council and particularly in light of our discussion about technology, could benefit fit from having Speedy as a member sitting at the table because of the technology areas that have to be addressed? Ron Sega is there from DoD but space technology, AFRL is the primary player from the department of defense. I'm just wondering if there would be some benefit of having from a technology perspective, Speedy, you sitting at the table with those other partners.

Gen. Martin

General Lyles, I certainly think so. We want to be careful that in this new structure that we have where the Air Force Space Command and the acquisition agent of the space and missile center, don't become separated from the air part of our Air Force, because we really believe that from a military perspective, it's a seamless medium. Now, there are different laws that apply. But in the end, the technologies that benefit both air and space need to be worked, I think, together in a partnered way and that we should join that partnership council, be a part of it as at level, not just the research laboratory level.

Pete Aldridge

Bob.

Bob Walker

Thank you, Mr. Chairman.

I have two areas, too. One of them might be a take-home assignment, unless somebody fells they have an answer. The question is if we as a nation had an adversary that ended up going to the moon and decided to use the moon for military purposes, is there any work that has been done to take a look at what this could potentially mean to our space-based assets and to our ability to operate from space in future conflicts? And as I say, that may be an area where there has been some work done that should be shared with us in a different medium, but if we could get some information along that line, I'd appreciate it.

Lt. Gen. Newton

Sir, I'd like to offer a partial answer and then take on the homework. Clearly, one of Air Force Space Command's key jobs is to anticipate possible adversary actions in, from and against our space capabilities and we don't always think worst case, but we try to look at every possible case. Whether or not there has been specific work done in that regard, we'll find out and get back with you.

Bob Walker

Thank you very much. And the second question I had dealt with—deals with a testimony that we had yesterday with regard to access to space. And in that testimony, we were told that there may be in the near term air breathing first-stage capability that would allow you to reduce the cost and put two-staged orbit kinds of vehicles in place. Do you think that such technology is really available to us in the relatively near term?

MGen. Nielsen

I think that comes to me. Everybody's looking at me.

Bob Walker

That would be my guess.

MGen. Nielsen

I think I disagree with that assessment a little bit. I think there's some great interesting concepts for how an air breathing first stage might change the economic equation and the operations of getting to space, but I don't think we're there yet. There's a fair amount of work that still needs to be done to develop hypersonic engines that would work in the air, and this actually has been something that has been pushed by the current DDR&E and Dr. Sega in his national air & space initiative. But I think to say that's near term is over promising at this point.

Pete Aldridge

Carly?

Carly Fiorina

Yes, good morning. Thank you all for coming. Obviously, the Air Force's leadership in space has been of huge benefit to our nation and to our world, and it is equally true that as we move forward here, we want to leverage the advancements, the knowledge and the capabilities. It is equally true, on the other hand, that military involvement in space causes some American citizens to be suspicious and may also make it problematic for us

to engage international partners. I'm sure you gentlemen have thought a lot about this. How would you advise the Commission to navigate our way through that?

Lt. Gen. Newton

I'd offer, if I may, that there's a good solid foundation and treaties and international agreements on what we do in and from space. And they will provide a framework for our continued participation with NASA. That's a pretty simple but pretty clear answer. There are many who express concern at the mere mention of military and space in the same sentence. I understand that. We'd like it to be a peaceful medium. We don't want to wage war in space, but others have already engaged our space capabilities terrestrially in the case of the Iraqis in trying to jam our GPS receivers. I see it as a bit of a foundation of peace, the military involvement in space.

I talked earlier about maintaining space superiority. If we were to lose our space capabilities in conflict, we would be necessarily less precise and more destructive. That's in nobody's interest. Not ours, not our adversaries. We would be less likely to deter conflict because we'd know less. There's a peaceful place for military participation in space. And taking that philosophy and the treaty structure, I think we can reassure our nation and our international partners that this partnership is a healthy one.

MGen. Martin

If I could add, the reality of the world is that competition and oftentimes competition turning into conflict occurs. I believe the United States' record of pursuing peaceful activities has been extraordinary. And oftentimes in retrospect is finally recognized where it perhaps at the moment is not. But our ability to maintain an edge and our ability to do as General Leaf has said, to use that capability to prevent mass destruction, has been very effective. Most wars prior to us using space systems took years and cost thousands and thousands and thousands of lives. These conflicts that I mentioned earlier have taken a matter of weeks and at most a couple of months, and have prevented what I would consider to be the significant loss of human and family activity. So in the end, although we would like space to be a peaceful medium, the fact of the matter is that the history says that it may not always be that way. We should be prepared for that, and what we have done so far, I think, has been very constructive to world security and peace.

Pete Aldridge

Maria.

Maria Zuber

The President's vision was rather specific for NASA in terms of the sort of parts of the scientific enterprises that are currently supported within NASA of what would be the main focus. Okay. That is not to say that other scientific areas supported by NASA are any less important. One of the things that we, especially the scientists on this

Commission, have been grappling with is that there are areas of science that are not mentioned within the vision that are very important, but what happens to these if they're not in the mainstream of the vision, and I'm thinking particularly of one area where the Air Force in particular might be able to help, and that's in the area of space physics is one area that has not been mentioned directly, but the Air Force Research Lab has a fabulously rich history. Has there been any thought going on within your circles about perhaps enhancing that activity to support the vision in the event that there are a focusing of the endeavor within NASA?

MGen. Nielsen

Well, we continue to support that area very strongly. You know, we have to balance all of our technology portfolio with all the needs of the Air Force. But this is an area which I think the Air Force has in some ways led the nation from the government side. Obviously, again, this involves a lot of people in the academic world and sometimes in industry. But we have created tools and continue to create some tremendous tools that help everybody that ventures out to space, and even helps us understand I think the net effect of space events on earth at times. So we continue to work that hard. That's primarily in the Hanscom area close to MIT actually.

Lt. Gen Newton

If I could follow up on that from a space command perspective and tie it to chairman Aldridge's first question as to do we need somebody in charge and are the partnerships enough, the very specific vision as provided will allow us to prioritize where the partnership has not always been able to because we've had so many things we must do. Given these clear goals, the prioritization will be more necessary and more readily achieved and I think that's going to be very helpful.

MGen Nielsen

I guess I'd just like to add, too, beneath a vision, there's a lot of enabling technologies. When you get down to technology, there's a lot of enabling things that have to be done that might not be first apparent in the vision. But just seeing the rovers on mars, you know, something as fundamental as having great batteries that had to be developed is very important. The solar cells that we continue to work to increase efficiency on are extremely important. Radiation hardened computers and electronics are ways to avoid having to have specific foundries for radiation hardened materials but design around that is important and we do research in all of those areas in the laboratory.

Pete Aldridge

Neil**.**

Neil Tyson

I think this question is for General Martin. In your presentation, which was quite thorough and a very nice review of the need and the value of our space-based assets, for almost every asset, either said explicitly or implicitly in your presentation, it is not much beyond either low earth orbit or geosynchronous orbit. In this Presidential mission, of course, the moon is the first target; Mars comes next and then beyond. It's not obvious to me that in the absence of what might be an obvious adversary taking post there that these would be viewed as important places for space-based military assets. And I wonder to the extent that there might not be an adversary with those same visions, does your interest wane the farther out this vision reaches, it being less and less relevant to our security here on earth?

Gen Martin

As a professional, it would appear that that interest would wane as we get more into exploratory versus the reality of security. But as a person and as an aviation and space enthusiast, it doesn't. But the reality is in terms of our budget and what our responsibilities are, we project usually out in the 20 to 30-year time frame, and if I could perhaps go back to a statement that a former chief of staff, General Mike Ryan made at a space symposium in LA about only five or six years ago, he said three things that he thinks about when he's thinking about space. First, that air and space are a seamless medium and that we should make sure that we don't separate them in the way we conduct and the way we construct our systems and construct our operations.

Second, what goes up comes down for the moment, and eventually what goes up will stay up, but what we do with space today in the U.S. military is focus on the terrestrial threats because that's where they are and that's where the conflict is and that's where we must pay attention from a national security perspective. But eventually and it will extend out further as years go on, eventually we will find that we must also be just as aware of the threats that could affect our operations either from space or in space, and as we do, to the moon and mars and beyond, then there will be a greater and greater military interest. If we look at the incredible enthusiasm that we saw in this nation for getting to the moon in the 1960s, it—I view it as two parallel actions.

We had a competition economically, I'd ideologically, militarily with the Soviet Union and a part of that competition involved space. So the actual exploration was able to ride side by side with our national security endeavors. In this case, I'm not sure the national security endeavors for beyond are quite as present and obvious as the exploration imperative. And so what we're doing now is trying to rekindle the spirit of exploration and the other things will be side by side, partnered and benefit from that effort.

Pete Aldridge

Michael?

Michael Jackson

Thank you, gentlemen. I agree that we need somebody in charge of the vision when it's implemented actually to put men and women in space and to go to the moon, go to mars. That is a cornerstone principle and I think that's right. Part of what this Commission is about is to look at the type of management structure, organization, procurement tools, budgeting and other issues that would make that organization successful. I also hear all of you saying that this is a vision that's shared by the country, by the nation and indeed by the world, because we would assume that the technology that exists around the globe will fuel the exploration mission.

So I've heard also that there is growing and closer coordination among U.S. governmental entities. Here's my question really. What lessons have you learned for us about how we can draw the private sector into this vision? Because it has to be something that is owned by the whole economy and has the whole country and indeed internationally, other nations thinking through the tough questions of technology and the issues that are associated with this mission. So what have you learned that will both protect the mission that you have in dealing with this objective of getting the private sector to be a strong partner? We have to have someone leading the band, in effect, but we also have to have a lot of creativity that's going to come from places other than the government. How do you manage that? What suggestions or advice do you have for us?

Lt Gen. Newton

I would offer the both most difficult and most important, to get industry involvement, commitment, progress, is a stable commitment to pursue the vision. As we look at every system that we've pursued militarily, every major acquisition project from my view as a requirements officer in the pentagon for 3 ½ years, the ebb and flow of interest in projects and the budget predictions that come with it are very destructive in industry commitment. That's difficult to avoid as we approach our budgeting, but a stable commitment to the vision that will give industry confidence that their investment won't be wasted I think is essential.

MGen Nielsen

And I think, Mr. Aldridge, you had said earlier this has to be a vision that survives presidencies and congresses. When you look at what happened in the Apollo program, that was a lot done by industry although led by NASA. There was this national commitment and the major companies and even the smaller companies of the country all contributed greatly to the Apollo mission in those few years from start to finish.

Michael Jackson

Yeah, but I want to push you a little bit on this one. The space shuttle and the Apollo mission was a government down spec, and it was handed to the private sector and said we want to buy component parts. And that was, in effect, requiring that you lodge the bulk

of the creativity and the directiveness in government agency that is going to then tell the private sector what things they need to make their vision work.

What I'm really trying to do is blow that up a little bit and say if you look at how we've done recent procurements in the military, coast guard and the DoD, we've talked about this, they've been integrated contracts where you had performance specification, not design specifications, and that has put much more of a stimulus into relying upon the creativity of the private sector to give us solution sets which then have to be judged by the government. But how do we take those lessons learned and convert them into this big vision of moon, mars and beyond?

Gen Martin

If we go back to the 1950s, the teams that were built had huge military and science, I think, collaboration. Today I don't know that for the actual development of the programs we have as much influence within the department of defense or within our organizations as we have on the outside. In other words, most of our missile systems that we're building today are being built by our contractors. Hopefully we will, from an acquisition perspective, give the vision and give the performance requirements, not the—if you know the old term of mil spec, where we tell them exactly how to design it. But to get to a way I thought your question was going, what's in it for industry besides the government contract, to be really captured as an industry, it would be useful for us to perhaps understand a bit more about what the opportunities are from an economic and business perspective for this exploration.

I would just use this sort of tongue-in-cheek example. It's kind of funny that in 1492, when Columbus discovered America, it took another 115 years before we had our first colony that was substantial. And I think Jamestown in 1607. Now there were many explorations that went on. There was some pillaging that occurred and there was some resource that came back to Europe, but they found America looking really for the Indies, as I recall, and found other things here and eventually established a colony. What is the equivalent in space?

We went to the moon 40 years ago. Haven't been back. I always thought that 115 years seemed like a long time. Here we are 40 years into it, and we're nowhere near having done anything economically, colony, and expansion. So human nature hasn't changed a whole deal. So where is the incentive to industry other than the government contract? Other than the government's vision? This has got to be a national vision and we got to believe there's something at the other end that will not only benefit the nation, perhaps benefit the world, perhaps benefit our way of doing, our way of living. And I haven't seen that discussed yet.

Michael Jackson

I don't want to monopolize. But you're dead right. We have to build in that thought process into this program.

Pete Aldridge

Let me follow up quickly. We have another few questions to go. Since we're passing out homework assignments, you have an expert in space systems acquisition sitting in El Segundo, California, in Brian Arnold.

MGen Nielsen

Yes, yes.

Pete Aldridge

One of the things you might ask brain to take a look at this vision for this national vision. It is system of systems. And it may take unique and new approaches to management of these kind of systems, and it may be nice to ask Brian that, okay, if he had to approach the management of a project of this magnitude and complexity and duration, how would he go about setting up the management scheme? He's the expert in this area and he should have a lot of ideas, a lot of lessons. He has a lot of scars that we all know about how not to do something. So I think the ideas from him would be particularly helpful to this commission to see his input, to see how he would best see that and his relationship between the government and industry and the systems engineering aspects of this, because it's going to be very critical that systems engineering be a very large part of this particular endeavor.

Lt Gen Newton

Mr. Chairman, I happily accept this homework on behalf of my good friend.

Pete Aldridge

And assign it to him. Brian's never going to talk to me again, I know. Okay, Laurie?

Laurie Leshin

Thank you. Thank you for being here. It's an extraordinarily impressive presentations and discussions. I want to actually pick up on the systems engineering question, because I—to me, that is one of the great challenges of all of this and the great even capital challenges, if you will, is the lack of solid systems engineers, engineering experience within the agencies. And I know that you have taken some steps, some concrete steps here to try and address it, but I don't know much about them, so I'm hoping that you can talk a little bit about what the challenges are from your organizations and that perspective and what you've done to try and address them. There's a systems engineering academy.

Les Lyles

Institute.

Laurie Leshin

I'd like to hear a little more about that, if I might.

Gen Martin

We—as we took a look over the past several years of some of our acquisition efforts and the number of programs that extended in terms of cost and time our original projections, I think we found that robust systems engineering up front had not been an area that we had worked as importantly as we should have. And this was not just a military problem. It was an overall acquisition systems development problem in all of our programs. I would say not all of programs, but in many of our programs.

We have rekindled that spirit. We have put much more emphasis in our Air Force institute technology which although here at Wright-Patterson does not work for the Air Force Materiel Command, it's part of our education and training command, and we are now beginning to recruit those kinds of people who will be systems engineers and who will both in industry and in our review of program plan and development, ensure that there is robust systems engineering across the different functions, if you will, of the program, of the total program that we're developing.

It will take us a while to get that expertise up, because saying systems engineering and doing systems engineering are two different things. We really have to understand the interconnectivity and heretofore, we sort of typical example was, we're all done with the software development except for the integration. And 80% of the work went into the integration. That's where the system engineers need to start at base level. And so we're making a very, very strong effort both in terms of developing our people and recruiting our people to focus on system engineering.

MGen Nielsen

But I think as General Martin said, it's not just an Air Force problem. It's not only system engineers but engineers. We have a need, a demand for more engineers than we're supplying right now. As Mr. Jackson brought out, I think one of the things that's a spin-off of a program like this that's good for industry is that we build the intellectual capital of the whole country through a program like this. And who knows where that leads. You build those engineers that go off to other things later in their life.

Laurie Leshin

That's actually one of the things I'm getting at. Do we need to have more of these kind of organizations that are doing this either through universities or through NASA and so to

see yours as a model, I would love to get some more information from you about how it works, what the training is like.

MGen Nielsen

I would also say General Arnold has done a great job out at Los Angeles spearheading that with some of the universities there. So it really has—it is coming together, but we're just now at the beginning of rebuilding that activity.

Laurie Leshin

That's a national need I think we need to address.

Pete Aldridge

Paul.

Paul Spudis

Yes, I have a follow-up question to the earlier point about the Air Force's interest dropping out further out. The discussion was sort of in the context of possible adversarial action, but there are other ways to look at the problem. For example, you can use the moon and its weak stability boundaries to position assets in various spots since its lunar space and that gives you a lot of advantages, particularly you can approach geo from the opposite direction, which is very interesting military. Secondly, has been there been any thought to given in Air Force to the possibility of using the moon as a logistics base? One of the unique things about the president's announcement was the specific mention of institute resources. I'm wondering if there are studies underway you guys are thinking about the possible use of logistics from the moon or other space assets?

Lt Gen Newton

I'm not aware of any specific studies on that finite topic. I'd just offer that we don't know the potential that will be delivered by this vision. And as we progress, as General Martin talked about the length of time it took to establish colonies in what are now the United States, we don't know what military potentials or requirements will be presented. As we progress, we'll learn, and as our imagination is fired by the capabilities, I'm convinced we'll find militarily relevant and necessary endeavors further and further beyond the planet itself.

If we look at the current application of space technology, whether it's from military to commercial or NASA exploratory efforts or in reverse, I suspect that on day one when the page was blank of each of those endeavors, we had no idea. We had no idea of the pervasive influence of the global positioning system would have on industry, civil life and military life. So I'm confident that our discoveries will lead to more opportunity, more interest and more requirement to invest.

Pete Aldridge

Neil.

Neil Tyson

Perhaps one of the most important words in the Commission's moniker there is the word "beyond." Mars is not a destination where we end. Its enroute to the further exploration of the solar system which I'd like to believe one day we would all think of as our backyard. But that exploration includes some very real objects out there that have not only scientific interest but also put our security at risk, namely those are asteroids that whose orbits cross earth's orbit. What I wondering to the extent that we do receive testimony from scientists in this regard, do you see the protection of earth from asteroids that might have our name on it as something that NASA should do, or do you see this as part of your portfolio of defense as we go forward? Because that might ultimately influence the distribution of funding as it takes place within the NASA execution of this vision versus what else among other agencies and the nation, specifically the Air Force, might contribute.

Lt Gen Newton

I'd just respond by saying that that's a key example of the need for the partnership. NASA has the expertise and does the exploration and are more likely, therefore, to lead the discovery of such a threat, finding that asteroid with our name on it. And then clearly our responsibility for the defense of the nation as, in that case, some planetary, global implications and it will require a partnership and perhaps a primary responsibility moving to the department of defense.

Neil Tyson
Okay.

Pete Aldridge

Well, thank you very much. Speedy, appreciate you being here. Dan, glad you came from Colorado Springs. Hope the weather is nice there. Paul, it's been a terrific panel. We thank you for your testimony. And for your contributions. And the—I think—I know all the Commissioners appreciate what you've presented here. Thank you very much. We'll now set up for the next panel.

Pete Aldridge

Could we take our seats, please? We are quite honored to have with us today another high school group from Greenon high school. Teacher Kathy Estep. Would you all stand up if you're back in the back, please? Let's show who you are. You're doing government studies, right? They're here watching public policy be made. Thank you for coming. It's an honor to have you here. Our second panel this morning is focused on the

science of exploration and pioneering of the moon and other heavenly bodies. We welcome them here this morning.

First is Dr. Roger Angel, Professor of Astronomy and Optical Science at the University of Arizona. And there's an Arizona State and Arizona rivalry here I know. Dr. Michael Duke, director of space combustion center at the Colorado School of Mines, and we have a third guest, who is running a little late who got stuck in Chicago, Dr. Andy Cheng, who is a senior staff and supervisor of the planetary exploration group for Johns Hopkins Applied Physics Laboratory. Dr. Cheng's specialty is asteroids. And hopefully he will be here by the end of the panel. He's at the airport and we're trying to get him here as quickly as possible. And we'll start off with Dr. Roger Angel. Thank you.

Roger Angel

Mr. Chairman, distinguished Commissioners, it's a pleasure to be here available to talk to you.

Pete Aldridge

Roger, would you move the microphone just a little closer?

Roger Angel

A little bit closer, okay.

Pete Aldridge

Thank you.

Roger Angel

Let's see. I have given some written testimony which I hope has made its way to you, and it's a little longer than I can say in five minutes, so I'll just try and summarize what's in there. I've come to the moon sort of lately as a user really, so I'm looking at it with I hope a fairly cold eye to see what the moon can do and what it can't do for astronomy, and I think in thinking about it, it's led me in some directions which perhaps tell us more generally what will make exploration I think really work on the moon. I think what I've been looking at is the moon as a site for big telescopes and following the Hubble telescope and there's a new James Webb telescope, six meters, to go to L-2 on the next decade. But even beyond that, there are fantastic things to do in astronomy.
There's kind of a seed change where after hundreds of years of speculation, we know that there are planets, big planets around the stars, and almost certainly there are earth-like planets, but just as it was 400 years ago, our telescopes are not powerful enough to see those planets yet. But we're on the verge of doing that.

So you think in the next 50 years, if that's in our vision, we can hope that to build telescopes that will see planets like earth and by looking at their spectra, we can see if

they have life on them. So this is a huge new evolution for big telescopes for astronomy and it will need telescopes bigger than the Webb, maybe 20 meters across, and in particular it will need telescopes that are cold, close to absolute zero, and this is something we can't do in near-earth orbit. When we're looking for this generation of telescopes, we have to look to the Lagrange points like L-2 or to the moon and particularly the poles of the moon, because there the sun is always on the horizon. It's easy to shield, and you can make a big telescope very cold.

Now, the model that we would like to follow, and it's particularly true for very big telescopes, is the Hubble model. Hubble's outstanding success has been because it could be refurbished, rejuvenated by the visits of astronauts, and this has been so crucial and frankly it's so sad that that wonderful activity of astronauts is now going to be terminated, a lot of us believe prematurely. Telescopes last a long time. The physics of the optics of telescopes doesn't change. If you build a really big one in space, you want to keep it going. On the ground, they go for a hundred years, the Mount Wilson telescope.
The same will be true in space. You have to keep upgrading the instruments as the science and the technology changes, but the big piece of glass up there that's collecting the light never becomes obsolete. So we would like with the big telescope to have astronauts to refurbish it perhaps every decade. They don't have to keep going back, but you would like that longevity, and would you like also for them to help in building such a thing, because if it's 20 meters, having it all come out like remotely is pretty difficult. That's what our needs are, a place that's far from earth, cold, where astronauts can help build a telescope, and where they're going to be around hopefully on a scale of decades, not just a quick in and out. And we're particularly sensitive to that after Hubble. Having got a telescope that could keep going forever and now it isn't going to because the astronauts won't be there. So is it better we can go to a free orbit like the Lagrange L-2 which is a million miles from earth, opposite the earth away from the sun, or we can go to the south pole of the moon.

I have to tell you that when I talk to my friends in astronomy and at NASA about telescopes on the moon, they're pretty darn skeptical. And one of the reasons is they think, well, is this going to last? If we plan for that sort of telescope to go, who knows if in 10 or 12 years it's going to go away. So this issue of stability that we heard about earlier is crucial.

The other thing that I really want to hit on, because having thought about telescopes and thought more generally toward the moon, unless there's some real advantage to going to the moon like there are going to be people there who are going to stick around who can help you, it's a lousy place to go because it takes about as much energy from the earth to get to L-2 or to lunar orbit, but in order to get anything down to the surface of the moon, it costs you about a factor of three more mass, because you have to take a rocket and its fuel and you have to break to get down there. So unless you have a particular reason to put your stuff on the surface of the moon, it's crazy, costs you more effort. But if the people are there, I mean, we can say we're going to put our telescopes at L-2, astronauts please come and fix it when it busts, and that's a million miles away and maybe they

don't want to go there. So we should think hard if there are going to be people on the moon, it's a very good place to put telescopes so that would be a compensating point. Now, what this thinking has led me to is what is it that we do beyond Apollo, beyond space station when we go to the moon, and if we can somehow get rid of this mass penalty and land stuff on the moon that doesn't cost us that factor, that would be enabling not only for astronomy but I believe for a whole lot of exploration on the moon.

And there's one way to do it. The telescopes want to go to the South Pole, and when you read about it, you find that there's very likely ice in the dark craters at the South Pole. All the evidence is pointing that way. We haven't had the robotic missions that actually landed and scooped it up and said, yes, here's ice, but it looks as though it will be there. So the vision that I would see, that I would urge you to think hard about for the moon, is can we pass this break point where we send folks there and reckon to get the capability to get the ice, to use solar electric power to turn it into oxygen and hydrogen, store that in the cold craters, and then to run a ferry, a reusable ferry from the moon, which will go up to lunar orbit, collect stuff, and come down again.

This to me is the break point, because that would mean then that we can start to put telescopes and anything else on the moon without this penalty. There have been things since Apollo; another thing that's very interesting that you must follow is the smart one, which is using solar electric to get from Leo to the moon. So, if you combine solar electric to get to the lunar orbit and then a reusable ferry to get to the ground, then your mass capability is increased by an order of magnitude to take stuff to the moon —then that's a very interesting point. I mean, for Apollo, the liftoff mass from the earth was 400 times the mass of what was delivered to the surface. If you use these new technologies, solar electric and ice on the moon, you could change that ratio to 40. And at that point, putting telescopes, starting to think about resource exploitation on the moon stops being pie in the sky and starts to be possibly real.

So I guess one of the things I hope—it's been looking in the literature about the moon. You find there was a huge energy until about 15 years ago when NASA turned off the spigot. And there's been a little bit since then. There have been one or two key missions like Clementine and Lunar Prospect and SMART. But we desperately need to do these remote sensing things to understand the resources, and I believe in the mix of what we want to see happen now is a vigorous effort—we talked about industry, military effort.

I hope that you will try and make sure that the smartest people in the universities get turned on to think about these problems. I would like to see a challenge, which is, okay, this business of using the ice and making a ferry sounds interesting. Can we do that ultimately for an operating cost that might be, say, 20% of our space budget, because then you could keep this thing going for a long time, and then it would become very interesting scientifically. So I would challenge people to think are there new technologies and new ways to open this kind of thing on the moon. So I urge you to think not about sort of general enabling things, but specific things that we want to do, specific challenges.

I think that could be enormously helpful. I'll stop. I haven't said anything about telescopes, but it's in my write-up. You can do fabulous things. One of the things you can see, the very first stars, the universe was completely dark for several hundred million years after the big bang, and then the first stars lit up, and this telescope staring endlessly at one point of sky on the axis of the moon could see those very first stars, and if we could also see life on nearby planets, these are fantastic goals. But we need this infrastructure.

Pete Aldridge

Thank you very much. Dr. Duke?

Michael Duke

Mr. Chairman and members of the Commission, I'm honored to be able to appear with you today. I am a lunar scientist, and I look forward to amazing science accomplishments that will follow from the President's vision. However, my topic today is what Dr. Angel just referred to, and that is the use of lunar resources. and as he said, this may be—seem to be a rather narrow technology, but it is of truly strategic importance. The moon's resources consist of the minerals and glasses in its rocks and soil which are concentrations of metals, silicon, oxygen, small amounts of solar wind, carbon, hydrogen, nitrogen that are trapped in the soil. As he said, recently, we've become to believe that there may be larger concentrations of hydrogen, perhaps carbon compounds and other things trapped in the permanently shadowed craters near the lunar poles.

In addition, solar energy is abundant on the moon. We can put all of those together to make a system that can do some of the things that Roger was discussing. These resources will not be free, but they are surely far less expensive to develop than taking things from the earth, and as he said, a source of propellant in space can qualitively change our space transportation system. When a vehicle is launched from the moon, about half of its mass is propellant.

If there had been a gas station waiting for the Apollo lunar excursion module on the surface to refuel it, half of the mass that we sent up from earth would have been—would not have been necessary. We would have needed a half-sized saturn five vehicle to do that mission.
If we can, in fact, bring propellant to space to an earth-moon, Lagrangian point, for example, we could actually reduce that launch vehicle requirement from earth by ¾ compared to what we used during Apollo. But there's an additional benefit. In addition to reducing the size of launch vehicles from earth, having propellants in space allows us to really consider reusable space transportation systems. If we can refuel vehicles in space, why not use them again and again and drastically reduce the number of vehicles that we have to build for a long-term exploration program? If you have a propellant depot in space, you can also fuel spacecraft that are bound for mars and could change the entire way we operate in earth-moon space.

The advantage is that the energy required to send propellant from the moon to lower orbit is about 1/20 of that is required to send it from earth to lower earth orbit. There is a tremendous energy advantage. Lunar propellant might be used—lunar propellant might be used for lower satellites, uses such as that could actually become commercial opportunities. Ok.

So, how do we get propellant? Oxygen is a major component of rocket fuel. Oxygen can be extracted from lunar soils and volcanic gasses, such as the orange glass that we found at the Apollo 11 -- at the Apollo 17 site. An early robotic mission should be designed to demonstrate oxygen production. This would establish the reality of lunar resource extraction while significantly reducing potentially the transportation costs associated with subsequent misses. Hydrogen is also a key element in the production of rocket fuel. The Clementine and Lunar Prospect are findings related to existence of hydrogen on the moon, at the poles raise an exciting possibility. But we need more exploration of those resources to understand what it is, in what form the hydrogen is. Perhaps it's in water, perhaps not.

We need to know its concentration, we need to know its extractability so there is an intervening step between where we are now and when we can design the systems that will actually extract and use it. If we find that there are extractable water concentrations near the poles, it's likely that we would set our first human outpost there. If it's not there, perhaps there are other places that we should consider to establish a human outpost.

There are other lunar resources metals, ceramics, gasses that can open new opportunities, both on the moon and in space. Materials are there on the moon from which we can build silicon photovoltaic solar cell systems to generate electricity or thermal concentrators to concentrate solar energy. Lunar soil can provide radiation shielding for—for activities on the moon. We could develop thermal insulation or radiators based on lunar materials. There surely will be problems to overcome.

The, in particular, we need to develop systems that can operate for long periods of time and we need to take into account how to do that in the lunar environment, particular we need to understand how to control the effects of lunar dust on mechanical equipment. In conclusion, I want to return to the strategic importance of lunar resource development. It would be unfortunate if our current opportunity to explore the moon and mars were to be interpreted as just a set of missions that respond to a limited goal, for example, getting the first people to mars. We need to ensure that we improve both the technological and the programmatic, that is the cost capabilities, that allow us to progress beyond the steps that we can take now. The establishment of a reusable and expandable space infrastructure that's based on lunar resources can be a key to the future viability of space exploration. Thank you.

Pete Aldridge

Thank you very much. Let me address kind of a general question. How hard is it going to be to extract resources? I mean, are we talking about, you know, 1/10 of 1% of the material process is really going to produce something important or is it 10%? I mean, what type of—

Michael Duke

If you are talking about the grade of the orbit on the moon, we don't quite know for the lunar ice deposits. They may consist of 1% of ice mixed with the dirt. But there may be places where there is 10% water mixed with the soil. We need to find those places. At 1% because ice is relatively easy to extract, you just heat -- gently heat the material up. You can produce probably economic systems if the concentration is 1% and surely if the concentration is 10%. From typical lunar glasses, you can extract 4% oxygen in a pass of the process.

So, the—the resources are not highly concentrated as they are on earth, but a guess at the cost of taking a kilogram from the earth to the moon at this point in time is about $100,000. $100,000 a kilogram to get something to the moon. So you can develop a lot of processes within that --

Pete Aldridge

That's true. But what I was getting to also is that the process of extraction on the lunar surface, if it takes five years to generate enough fuel to be able do a launch, then it says, well, I'm not sure—

Michael Duke

We have constructed at the Colorado School of Mines, we have constructed scenarios and others have, too, and a typical plant should be able to produce at least 10 times its mass of material in a year. And there are a number of concepts that would do that, and for the lunar polar ice, it may be 20 times its mass in a year.

Pete Aldridge

Ok. Dr. Angel, one of the thing you mentioned was this solar electric propulsion. That seemed to be kind of an enabling technology. Is NASA spending enough effort on developing such a technology?

Roger Angel

I don't know. I do know that the European smart one is on its way and it's already worked its way up a good way out of lower earth orbit. If NASA isn't spending on it, they jolly well should be.

Pete Aldridge

Ok. Laurie, do you want to comment?

Laurie Leshin

Well, and Maria probably knows this is better than I do. We're flying a mission on dawn. It's been demonstrated.

Maria Zuber

Yeah. Actually, I wanted to ask a question about that.

Pete Aldridge

Go ahead.

Laurie Leshin

Are you up first?

Pete Aldridge

No. Go ahead.

Maria Zuber

Yeah. I wanted to maybe explore a little bit the comment that you made about saving the mass penalty as you go to the moon. I assumed you were talking about solar electric there, get you to the moon?

Roger Angel

That is one—that is really a separate thing. That's a way of further cutting the mass you have to launch from earth. But to get rid of the mass penalty of landing on the moon, that would involve locally generating the fuel and then running a reusable rocket from the surface of the moon up to lunar orbit.

Maria Zuber

But it's still costing—you don't really get rid of the full mass penalty because once you get into the lunar gravitational well, you're still you can't land on the moon; you need fuel to land on the moon.

Roger Angel

No, the solar electric gets you to lunar orbit and then the up and down there has to use real fuel. But that is oxygen and hydrogen that you get from the ice. So you would load up with enough local hydrogen and oxygen, get the lunar orbit, pick up the load and then come down again.

Maria Zuber

Ok. I see. I've kind --

Pete Aldridge

Go ahead.

Maria Zuber

Can I ask another question? It is a little bit related. For those in the audience who aren't familiar, the—when there is a discussion about whether or not this ice is in the form of water, the other possibility, of course, is implantation from the solar wind. And if there isn't really—if it's ultimately determined, and I think we need to determine it, that you don't really have significant water ice in the shadowed craters, is it really viable to have a lunar—a long-term lunar base?

Roger Angel

Well, we need to look at that. But hydrogen in the form of water is about as tightly bound as it can be. We know that hydrogen there, in some form. So, if it is bound in another form, maybe we can think how to get that out, too.

Maria Zuber

I think the concentration of the hydrogen and if it is, in fact, concentrated in limited areas like the cold traps, whatever its form, it will be useful. As Roger said, if you have water to make—to make propellant, you have to split the water and get the hydrogen and oxygen out.

Pete Aldridge

Neil.

Neil Tyson

In a related issue, I'm concerned about the total energy budget here because most of the discussion we've had about rocket fuel, we could just write the equation on the back of an envelope, but it doesn't say—perhaps it ought to—but when we write that equation, it doesn't say build a factory here to make this happen. And so to simply say separate the hydrogen from the oxygen to get rocket fuel, I haven't heard people talk about how to

actually do that on the moon because that takes as much energy to accomplish as the energy you recover from bringing the hydrogen and oxygen back together again. So could you comment on where you get all the energy to actually manufacture the energy that you're going to use to supply rockets and other energy you need to sustain a colony?

Roger Angel

Well, it would be voltaic energy and at the south pole, you needs your panels on a rotating axis so that they're always pointing square on to the sun, which is shining pretty much all the time on the high points of the south pole. So, I don't want to confuse again with solar electric, but if you get the lunar orbit with solar electric propulsion, that means you have a lot of solar cells on that package that came from the earth. So, what you then bring down to the moon is the payload and also all the solar cells and you set them up more and more. So, the space station is already some fraction—what was it, 100,000 watts or something? So, we would just keep on bringing—every time you bring a loads from earth, you bring down all the solar cells. I think it is within these calculations and separation, that's allowed that you have to bring the solar cells and then pretty soon they generate more than their mass in terms of their rocket fuel.

Pete Aldridge

Ok. Laurie?

Laurie Leshin

Ok. I want to ask about—thank you, by the way, for those of us traveling to be here today. Given that part of our charge is to think about this whole program of, moon, mars, and beyond, especially thinking about astronauts on mars trying to sustain themselves for a long mission. I'm curious about if you can start to draw for us the board part of this. Just my limited knowledge of how mars resources would be proposed to be utilized, it has to do with using co2 from the atmosphere and processing that and it has to do with ice in the Martian surface, which is at 50% to 80% levels in the first meter, not 1% levels and not in permanently shade regions, but in regions of sunlight. I'm concerned, I'm curious about how, you know, if learning to utilize the lunar resources is really what we need to learn to learn how to utilize things on mars. I'd like you to try and help me on that connection.

Michael Duke

There may be some differences. There might be some similarities. As I understand, the gamma—gamma ray spectrometer results, there might be a lot of water closes to the surface in equatorial -- regions and that might be the first resource that we go after, which would be quite similar probably in extraction technology what-to-what we would use on the moon. But I think the real crux of the matter of using space resources is to have a demonstration of their use anywhere. Because what you have to do is you have to overcome the resistance of the project managers, who say, well, that's a new and untested

technology that we can't safely introduce into our system. And we will never use resources on mars without such demonstrations. We can—we can demonstrate that on the moon and sort of start the mind set thinking about it.

Roger Angel

Can I try a slightly different cut to this one? I see this business of running this ferry on the moon as probably the most useful step we can take towards mars exploration. And the reason is that what it takes, there's a threshold there what you need to make this work. You have to do the mining, you have to do the separation and the hydrogen-oxygen, you have to store its and then you have to run a spacecraft, a reusable spacecraft on the moon. it has to go up, come down, you got to refuel it, service it. so, there's a level of activity that you would have to get going on the moon, which is if you can make it go, it will tell you a tremendous amount about what you need to do for mars. Because you are not going to go to mars like Apollo and stay a few days and come back. you have to do something, probably generate the fuel there. These skills, this kind of human resourcefulness on another planet demonstrated on the moon and this process, I think is absolutely crucial.

Pete Aldridge

Bob.

Bob Walker

Just a follow-up to Neil's question, would solar dynamic play any role, do you think, in doing factories on the moon to make fuel?

Roger Angel

I'm sorry. I missed the first—

Bob Walker

Solar dynamic, as a way of powering factories?

Michael Duke

If they can produce at the same sort of mass fraction as solar voltaic, surely when you set up models, you're looking at what is the system that produces the most electricity for the least mass delivered to the moon for the longest period of time. So, if they are competitive in that way, that they could be used.

Bob Walker

Doctor Angel, I was interested in your testimony in which you talked about the fact that the telescopes that you take to space, if you service them every once in a while, the bulk of them remain for a long, long time. Would that seem to indicate that if, in fact, we find that it is not in our best interest to use the shuttle to service the Hubble in the future and, thereby, abandon its mission, would we be better off as a nation boosting it into an orbit where it could be kept and be used again in the future rather than deorbiting it?

Roger Angel

Yeah. That's what I would like to see happen to it. If we're going to send up a rocket, for god's sakes to go crash it, send up a rocket that will go park it, put it into mothball mode and wait for 10 years or whatever. It will still be useful at the end of that time. So I—that would be a much better outcome, I believe. Better still would be do what we were going to do and use up one shuttle to do that.

Pete Aldridge

Les.

Les Lyles

Thank you. if I could stay on the telescope doctor, you may have stated and I may have missed it, what size of the optics would we needs on a telescope on the south pole of the moon?

Roger Angel

I think the size that would take us to what we want to do with planets and so on and get beyond the Webb telescope would be 20 meters.

Les Lyles

Webb, about seven or eight meters?

Roger Angel

Webb is six.

Les Lyles

That obviously portends a huge mass that we would have to get up there with a 20-meter telescope. Are you satisfied that the right technologies will being addressed to reduce the size and weight of optics to manage the level for launch and launch capabilities today?

Roger Angel

Not today. In fact, I've initiated, I hope, a national academy study that will be joined with the Air Force and NRO and NASA to actually look collectively at how we can bring this mass down. I have to say there is a great trick on the moon for the survey telescope, which is to make a mirror out of spinning liquid, which can be very simple and very low mass. It's unique to the moon because you need gravity. That's another way to do it.

Pete Aldridge

Ok. Let's interrupt the questions just for a second. Dr. Cheng, Welcome.

Andy Cheng

Good morning.

Pete Aldridge

Flying through Chicago is tough, I know.

Andy Cheng

I know.

Pete Aldridge
We've introduced you. So, we have a few more, about 10 minutes left in the panel. We'd like to have your presentation and then we'll open up for questions again.

Andy Cheng

Ok. yeah. My testimony is about the asteroids as an exploration destination. And I summarize it as in the following—there's great science because the asteroids tell us about the early solar system, tell us about how earth-like planets formed. There are great resources on asteroids because there's material you find there that cannot be found anymore on the surfaces of planets like earth that have differentiated. And, finally, the role of humans in exploring asteroids is something that we should not ignore because humans can respond to unexpected discoveries.

One of things we found when we studied an asteroid up close for the first time, this was Eros with the NEAR mission, we found that the asteroid did not look at all like we thought it would and that if we had astronauts there, I'm sure they would have responded, they would have looked at the features, thing like these ponded deposits that we saw, things like tectonic features, the bridges, the grooves, the liniment things that were not expected. The astronauts would have said, hey, we've got to get a better look at that.

We better do something. On a robotic mission, NEAR was a great mission, but we had to plan everything in advance. We had to plan the landing years in advance. We were not allowed to talk about it, but we had to plan it years in advance. Everything else in the mission was planned weeks or months in advance. But if we had astronauts there, they would have gone—they would have seen these features and said, hey, we need to look at it more.

And the other reason we need to study asteroids is that there is a great natural hazard associated with asteroid impact that every few hundred thousand years you can expect an impact that would have a destructive energy, something like global nuclear war. Simultaneous detonation of all the nuclear weapons on earth. We don't know when the next one of these impacts will occur. We had NASA already trying to find, discover at least 90% of the asteroids large enough to do that kind of devastation by 2008. But the point I wanted to make is that even after we find them, there is more that we need to know. Suppose you find something and you think I don't like the orbit it's in, I want to change that orbit. How would you do that?

Well, we're not really sure. The only thing I know is that if we're going to try anything like that, blowing it up, deflecting it, whatever, that we don't want to do something that would make the problem worse. That would be bad. Right now, we do not know enough about how these asteroids are put together, what kind of materials are in there, how strong they are, whether they're single rocks or they've been fractured, how they were made. We don't know enough about them to be able to say this is what you've got to do to solve the problem.

So, there is an exploration challenge there as well, which is not only to understand the record of the early solar system that is contained in the materials to be found in asteroids. Also, there is a problem of understanding the present day asteroids, their structures to know how to deal with one if we find that we got to change a little bit because it's too dangerous. So, the final thing is that I'm interested in the asteroids as well. I think all of us should be because they've really played a central role in the development of life on earth.

The strange thing is that the earth and the moon are known to have undergone a tremendous early massive bombardment. These bombardments that are far bigger—the impacts that we're talking about are so-called basic forming impacts, far bigger than we've talked about so far. Nothing like that has happened in the last billions of years on earth. But up to about 3.9 billion years ago, the moon and the earth were plastered with these huge, terrible impacts. There's no question that life could not have sustained itself before these impacts ended. But the strange thing is, truly strange thing is that as soon as that massive bombardment ended, basically life did start on earth. That when the earliest known evidence of life on earth dates essentially to the end of the massive early bombardment.

Now the question is, is that a coincidence? We're not sure. A lot of people think its' not a coincident. So, what is the relationship between the bombardment of the earth and the

moon by these asteroids and the development of life? The one ended, other began. Is it because these asteroids established the conditions favorable for life? Okay, that's another thing we'd like to know. Thank you. I guess I have only a few minutes left. I'd like to leave time for questions and whatever. Ok?

Pete Aldridge

Thank you very much and glad you made it. Questions? Yes, Neil.

Neil Tyson

Thank you for that very concise review of what we all need to know about asteroids. You mentioned what an astronaut might do on the spot. Are they floating alongside the asteroid with a conjoined orbit with the asteroid? What do you imagine that is in practice? Are astronauts landing on the asteroids, digging, pitching tent? Could you offer a comment on how you combined the presence of an astronaut with activities on an asteroid?

Andy Cheng

Ok. Yeah. The asteroid is, depending on its size, would have very low gravity. A near-earth asteroids, most of them, we're talking about objects a few miles across or smaller, those have very little gravity almost like being near the space station. You would be practically weigh less nearby. You think of it more like operating an EVA, let's say, by the space station than on the moon. Now on a larger asteroid, something the size of Eros, there is enough gravity you can imagine walking or hopping, you can imagine actually pitching some kind of structure or putting a flag into the surface. That kind of thing you could imagine doing on larger asteroids and also an asteroid as large as Eros you can go into orbit around. Very tiny asteroid, the one kilometer and smaller, they're so small, you probably cannot even go into orbit around it. So, it is really more like station keeping. It's more like extravehicular activities around the space station. So, it is different from what you would do on mars. That's surely true.

But that would not be the purpose of doing human exploration of asteroids. You would do that because you are interested in the asteroids, because you're interested in maybe in the resources that could be found on asteroids, and you'd also be interested in proving out the manned exploration, manned expeditions and may want to go somewhere that, for example, you might want to spend a few months at. If you had to come back in a hurry, you could do it because it isn't that far away from earth. That would be the purpose.

Pete Aldridge

Questions?

Neil Tyson

One more. Dr. Angel, as you are surely aware, not everyone in the astronomical community agrees that it's still expedious you to put—expedious telescopes on the moon. one of our challenges in this Commission will be to ensure, or at least guides the vision in such a way, that whatever happens on the moon has utility for continuing on to mars and then beyond.

So, what I could glean from your telescope building is that it can give us practice doing things on another planet's surface. But the actual act of producing a functioning telescope, which would then require some kind of service, even if it's only once in a decade, on first hearing feels slightly afield of this vision. And I'm curious. Could you comment on that? And what do you tell us to put in our report with regards to building telescopes verses engaging in activities that are directly related to going on to mars?

Roger Angel

What I think we need is telescopes and I think there is no way now that you could plan that this is something you definitely want to do. What we have to do is understand this potential for overcoming the mass penalty. That's really crucial. And whether we envisage this kind of long-term presence on the moon, if that isn't driven by astronomy, but if that is something that comes out of what our goal for exploration will be, then I don't think you'll have any trouble convincing the astronomy community that they would want to put telescope there is because it would be a huge asset at that point. I think it is a useful exercise in looking at our thinking of what we should be doing and what our plans for exploration would be. But I think the same goals that would lead to making very interesting for astronomy would also be enormously enabling for taking the next step to go to mars. I don't think they're far apart at all.

Neil Tyson

Yes.

Maria Zuber

Yes. Andy, it sounds like what you're saying, most of the asteroids that would be accessible to us would be the very small asteroids so the encounters with them would be more like an EVA than it would be walking on the moon or any planetary source.

Andy Cheng

That's right.

Maria Zuber

So, have you given any thought to where asteroid exploration would fit in a very general timeline of this vision so it would seem like there is some value—there is a value of exploring asteroids in their own rite for scientific purposes, but it sounds to me like you're not seeing you wouldn't be developing any sort of human capabilities that would directly help you go to mars. Is this a post-mars or pre-mars?

Andy Cheng

I would say it was pre-mars. It's a way of testing crew support—life support equipment and vehicles and so on. You know, that would need to survive years long journeys through interplanetary space. I don't think you'd want to send it near an asteroid. But it would stay there and use it to support astronaut exploration of asteroids.

I probably should also emphasize that you have resources on asteroids that you probably don't have on either moon or mars and there might well someday be economically viable reasons for wanting to go out to an asteroid and use some of those things. So, there's resource utilization experiments that I think you want to do on asteroids that would be independent. You wouldn't be testing exactly the same thing that you would put on either the moon or mars, but there are things you want to do on asteroids and resource utilization.

Maria Zuber

Thank you.

Neil Tyson

You didn't mention—you didn't mention the fact that it costs you nothing in fuel to approach and get very close to an asteroid. Do you not see that as a great savings?

Andy Cheng

That is a tremendous savings, yes.

Neil Tyson

Ok. I wanted to confirm that for the record.

Pete Aldridge

Ok. Well, I'd like to thank the panel for coming today. It's been some stimulating discussion. Andy, glad you made it. We did get something useful and your presence here was quite valuable. For the rest of the panel, thank you very much. We'll take a 10-minute break and before the next panel. Thank you very much.

>>[applause]<<

Pete Aldridge

Could we take our seats, please? Seems I've lost control of the Commission. They're coming down as we speak. Well, it takes me great pleasure today to welcome what I would call a national hero. Senator John Glenn to these proceedings. Senator Glenn, thank you for coming and taking the time to share your thoughts on this important mission.

As the first American to orbit the earth in Friendship VII in February 1962, completing his mission in just under five hours, he was a very patient man, and the second flight opportunity which came in 1998 as a mission specialist where he flew on the shuttle discovery. He supports a variety of research payloads, including the deployment of the Spartan Solar Observing Orbiting Spacecraft and investigations on the aging process. Senator Glenn, you are indeed a wise man from your beloved Ohio and we look forward to hearing what you have to say. Welcome.

Senator Glenn

Your introduction is too kind, Mr. Chairman. I appreciate it. And you're in good hands with the General Lyles. If you want to know how to get into trouble or how to get out of it around here, he's the guy. He is the go-to man.

Les Lyles

Thank you.

Pete Aldridge

We all know that very well.

Senator Glenn

First question, I guess, that you want to address is why go into space at all? Good threshold question and that's been a question I think since the early days. There are two answers to that and I'll get to that in a minute. Perhaps I have a little unique perspective, since I'm the only one here, I believe, who's been around, involved with the space program since clear back in those days in 1959.

I was just looking in the vehicle back here and it still has the cockpit laid out just like it was back then. So, if anyone wants to see what it was like back in those days, that's it, except they didn't have that nice big hole in the side, I can tell you that.

>>[laughter]<<

Very short chronology. Man program was born in the cold war. Soviet claims of technical superiority, they were taking their students from all over the world, tens of thousands of them to Moscow and educating them, sending them back home, communism was on the march and we were worried. They were proving their claims of technical superiority. They were orbiting vehicles when ours were still blowing up on the launch pad back in those days and Mercury was announced in the spring of 1959, went on to Gemini, Apollo, Neil Armstrong landed on the moon, of course, in 1969 and that sort of put the damper on the Soviet claims of technical superiority. They have had a program and abandoned their program at that time. But even in those days, there were two purposes in addition to just the Soviets spur of communist danger. Two purposes in additions to that.

The first was one you're involved in right now. Pure exploration, the first time humans could move above the atmosphere of our home planet. And our American history is one of exploring. We were explorers, we wanted to go and America, John Kennedy announced we're going to go for it, go to the moon and that was it. It was exciting.

As we talk about today, national pride's involved; our research truly was better in the long haul. I can still remember some of those national days of exaltation and celebration after Al Shepherds' first suborbital flight, my orbital flight in 1962, Ed White's spacewalk, Frank Borman's memorable cruise around the moon on that Christmas Eve that you may all remember in the beginning, and it was a very, very moving thing at that time. And then Neil Armstrong, of course, that incredible first step that anyone has ever taken on any place other than earth. So, it was a national spirit. It was exhilarating, it's pride and the President has talked about this. Back in those days, we all shared in it. And it is important because it deals with how we view ourselves and how the world views us. And that was the start of human space flight exploration. Now our first moves into microgravity, though, and zero-g brought on a whole new existence with its problems of working in a weightless environment, but also a tremendous opportunity. An opportunity to basic fundamental research without the effect of gravity, something scientists could only dream of 100 years ago.

Now the second purpose of putting people in space was to do basic research and that was understood by everyone and we tried to gets everything we could on to every flight back in those days. Basic research. We had science experiments on almost every flight. On Friendship VII, even on that first orbital flight, I had instruments to do spectrographic measurements, ultraviolet measurements, sun measurements, spectrographic film and each flight after that had some research on it and we were limited to what we could do, obviously. These were things that were add ons to each flight. Skylab was up for a little bit longer, of course, and did more research. But we didn't have a spacecraft specifically designed to do laboratory work.

The space station was conceived as the first permanently orbiting laboratory and the first step toward that was to build the shuttle that could fly and be a small laboratory of its own and do 14-day limited research and go ahead and build the station with its capability to take all the pieces up there and put them together. And that then was going to give us

long-term research. At the same time, we invited other nations, now 15 partners, cooperating to get ISS operational and fully manned. It's the largest international cooperative engineering project ever attempted. It's gone very, very well. Scientists not only our own, but those all over the world, responded with hundreds and hundreds of experiments and devoted millions and millions of dollars to projects that are lined up today to go up there. And just as an example, on Discovery and you mentioned by going up in 1998, on discovery, we had 83 projects. 83. We had a seven-man crew and seven-person crew; rather, we had a woman from Japan. So, a seven-person crew, up nine days and we were very, very busy to do all those projects, to administer all of those things and those were called from hundreds of other projects that were the ones that were worthy of being put up there. Columbia had 90 projects on board. a lot of their information wasn't all lost. Some of it was telemetered back on to ground, came in on telemetry. Anyway the point being that e had a big reaction from scientists on this. And a high percentage of this is oriented to improve life right here on earth. Medicines, pharmaceuticals, bio-reactor cell studies, may have application to cancer, plant studies on rice, Japanese scientists were excited about some of the things on our particular flight, it maybe gives them a way to maybe have some rice that has a higher production of grain than anything they have now. Excited about that.

Combustion experiments. Lowest fuel-air ratio for combustion that anybody's ever had. Didn't think it could be that low. I think your automobile runs on like 70% fuel-air. This goes to 8%. The lowest ratios ever, ever discovered. I was doing studies on aging, frailties of old age here on earth. Protein turned over into muscle, osteoporosis, immune system. I had a project there that was insulation development could only be done up there because the stuff is so light. If we get a way to stabilize it, its new insulation capabilities would save tremendous amounts of energy right here on earth. I won't go through all those because there are long lists of them. I'm sure you already have them available to you. But just to summarize them, NASA has broken these down into five different basic areas. Biotechnological, combustion, fluid physic, fundamental physics and material sciences.

The biotech is an exciting area that merges biological science, engineering and biochemistry to improve human health. The microgravity environment of the station offers a unique environment for research on the growth of cells, tissues, biological materials. Such research can provide new strategies for probing disease processes, developing medical counter measures for space travel and advancing our knowledge of cellular processes. Combustion. I mentioned that a moment ago. And then fluids physic, involves physics engineering science, fluid dynamics and etc. And then fundamental basic physics, basic breakthrough-type civics, and not to be left out on this are the getaway packages as they're called of some of the students have put together and they're put up there. If you've ever seen an ant colony in orbit, they have all kinds of things that the kids come up with and you meet with these kids after the missions that their projects have been on and it is exhilarating to go and talk to the kids. They're really fired up about these things.

These things have brought new business efficiencies and so on along with them along the way and NASA's estimates on the economic benefit of projects like this are about a 7 to 1 economic benefit and this has been studied by several different studies. That, to me, is rather amazing. These kinds of experiments are value to people right here on earth and the potential hasn't even been scratched yet because we haven't even gotten the shuttle to get—I mean to the station to get it complete. It's only about two-thirds complete.

It's manned by only two people instead of the planned crew of six up there to do hundreds of projects and indeed we have projects that are planned and in the cue now, projects that people—academics and laboratories and companies have spent millions of dollars to get ready for this. Our scientists and world scientists have been depending on us. And it's—now under this concept we have now, though, the new vision concept, we're saying that the only research that the U.S. can do up there must be directly applicable to the moon, mars, or the project is canceled. that's it.

The NASA literature and their Q&A's and their question and my discussions—discussion at NASA headquarters, that's exactly what they mean. Unless it's applicable to going to the moon or mars, all this other research is going to be cut. No matter how long in preparation or how important and to save comparable—comparatively small dollars. And to me, I think that end of this thing is wrong because that pulls the rug out from under our scientists who place their faith in NASA and the scientists with NASA who devoted years and years of their work and international scientists also. And somewhat I talked to one of our—I won't give any names—but one of our international partner of scientists from one of our countries. I think they're left scratching their head wondering why they put their faith in us and what happens next is that serious because they put a lot of effort in this and now they see this thing is beg scrubbed. I personally visited some of those scientists when I was in the senate and tried to encourage them to be cooperative with NASA.

Now one of the aspects mentioned in the Congress. When I was in the senate, year in and year out for, I don't know, 12 or 15 years, whatever it was, I handled the debate on the station and the NASA budget when it was on the floor of the senate. And we'd always list the values that would benefit people right here on earth and that was basically the way the space program was sold through the years. You can go back and look up the congressional testimony and see some of the debates that we had at that time. And was pride a factor? Was exhilaration about exploration a factor? Certainly it was.

But it was also the biggest selling point in the Congress was the results here, as Congress would like to have them, have some benefit to their people back home and their own constituencies. And that's basically how the program was sold, through these years. Now we learned many things just by going. You have to invent new me totals and control systems and things like that, they have spin-offs and so on. I'm not indicating that we've lacked a lot of scientific breakthrough by the way we've gone. We have. We've had a lot of scientific breakthrough and the program envisioned now that you are talking about, moon, mars and beyond will also fill in a lot of blanks like that. There will be a lot of things invented just by the fact of doing it.

But I just don't think that we're going to maximize our research return that we should and that Congress has depended on all these years about what's in it for our people here now. That is there for our grasp and not to be knocked out for lack of comparatively few dollars. I know billions are lots of dollars. But when we're talking about a $521 billion deficit of what $2 trillion national budget or whatever it is and we're talking about $2 or $3 billion, a lack of that is going to knock out all the research that these people have placed their trust in us to do.

Let me be philosophical for just a moment, too. I think the U.S. became great because of two things. We put more effort into education for our people and we put more into basic fundamental research. We learned the new things first, we put them to work, the investors, the entrepreneurs took over and we invented jobs and industry and businesses and the rest of the world followed in our wake. Now with globalization, we're finding others outdoing in the U.S. in education and I can give you a chapter and verse on that. We won't have time on that this morning, but I headed up a commission that Dick Riley, Secretary of Education, asked me to head up several years back and what's happening to our math and science education in this country and it's in dismal shape. 20-second summary of it is that our kids—the third international math and science study that was done with 41 nations over three years showed that our kids, up to about the fourth grade, are top drawer. They're in the top two or three nations in the world. By the time our kids get out of high school, they are two or three from the bottom. Other nations are out competing us.

All this movement of jobs and business and industry overseas isn't all because—it's not all because it is low-cost labor. They're beginning to educate their people above the level of our people coming out of our own high schools and that's something we have to reverse. so I think those two things -- education and research. We learn the new thing, we put them to work and in this globalization, we're beginning to be out done. I think we're voluntarily stopping some of the most unique cutting-edge research in the history of the whole world that we built and now we're going to let other nations do it and they get the benefit from it? I don't think that's right. I think that is a mistake and to cut out that part of NASA that we have built the station for, deliberately, spent $32 billion on it spend so far, probably another $15 billion or so to get the thing complete and get the core complete and I'm sure you're familiar with all the terms of core complete and assembly complete so on for us and the other countries, and then use it for just this very limited purpose when for a few bucks, we could continue this research that I think is so valuable and I used to convince people to vote for this on the senate floor for year after year after year and now to pull out from under this I think is a major mistake.

And then use our investment in it for you, for a limited purpose. Well, there are some other areas that I hope we can discuss also. The Hubble. I was heard the discussion here earlier. I was listening to that discussion earlier. I hope we could find a way to do that other mission, to Hubble. The only reason it was knocked out and I understand the equipment, the improvements to Hubble have already been made. They're ready to go, as I understand it. The only thing is that devoting a mission to that. The requirement that we have a safety launch ready on the ground in case they get in trouble up there because

they can't get to the station from where they are, if they go to the Hubble, I don't think that is going to be on future of the whole program. If we have to make launches sometime, but in case we get in trouble, if we are not going near the station, we have to have somebody on the ground with another launch ready to go in is that our policy for the future? I can't believe that's the way we're really going to go on this. But that is apparently the way we're going right now. The Hubble, I'm sure most of you saw the Sunday's lead editorial in the "New York Times," premature death for Hubble in which they came out with a very good discussion of that, if you haven't seen that one. They support going back to Hubble and think we should be doing that. It was termed by some—one of the astronomy groups as the greatest advance in astronomy since Galileo. And to not do everything we can to get every year's value out of that thing requires one more launch, I would hope we certainly could do that and help keep that online just as long as we can.

It's been spectacular. Moon to mars or a question I would ask is it earth orbit direct to mars? I think that's one you have to come up with an answer to in some of your recommendations. Some of the discussions a while ago here were very, very interesting. If you think about what the President said that we were going to launch from the moon because we could save money by doing that. I think that's a very debatable point as to whether we really save money by launching from the moon. If you figure going to mars requires a very large vehicle of some kind, it's going to have to last for a couple of years out there and back with current technology unless we can get some of the ion engines going to the point where they can speed things up and cut it down to three or four months' transit time each way but it's still going to be a year-long mission. And you get up to 17,500 miles an hour in earth orbit with all of this tonnage.
I don't know what the estimates are of the tonnage that's going to have to eventually go to mars. But you're up to 17,500. Now we're talking about going out about slowing down as you get out toward the moon, then coasting in after you get by that equigravisphere point then into lunar orbit. And no atmosphere to break there. So you have to then use whatever the speed is at that point. I guess it is 5,000 to 6,000 miles an hour once you're in lunar orbit. I don't remember what that figure is. Then you're talking about having to use fuel that you carried with you to break all that and set it down and then start assembling all these things that people talk about for manufacturing fuel and all in a vacuum, in a vacuum, and put it all together out there somehow. And then launch. In other words, you're taking your refinery with you, I guess, on however you're going to do this thing out there. And you're setting it down again.

And then you're trying to in effect making a Cape Canaveral out on the moon. It would be a smaller one, I'm sure. But it's enormously complex and to take all this tonnage up when the escape velocity you need to go to the moon's about -- I think we use about 25,000 miles an hour before, something like that. To go to mars, I suppose we are what 35,000 to 45,000 miles per hour. You have half of that speed, half of that inertia that you want already built up in earth orbit. You're ready to go. To propel out of earth and go straight to mars then with whatever your equipment is all tested here on earth. All tested here, not put together in a vacuum with fuel sources or whatever you would try to develop on the moon, it just seems to me the direct to mars is the best way to go. Now,

there's one—if we want to go to the moon and set up a base there—if our eventual objective—and I haven't heard this spelled out exactly, is to put a permanent base on mars, if that's our objective, then maybe going to the moon first, which is a little nearer earth, of course, and testing out some of these things. But even at that testing them out on the moon I sort of question because unless we're just going to the moon for research on the moon's sake, and I would support that.

But to do it in a step as a launch pad to mars, I think you have to look at that very, very carefully about the expense of the dozens and dozens of trips back and forth to the moon that are going to be required to take all of this equipment up there and get it operational and supply everyone up there with the food, the water, all the consumables you're going to need to do for this crew up there all the time. So that's a balance out that you're going to have to make. I would question very seriously whether it's cheaper. I just don't—I have trouble believing that that's the case. But if you think about the physics of going up there and trying to use the energy to do everything you have to do, then going to the moon first becomes very, very debatable. To save these few dollars, too, the only way to look at it, I believe, to save the dollars that we're talking about, we're breaking promises to our own scientists who put their faith in NASA and the companies that is put their faith in NASA to do the research that they were designing equipment to do. I think we're breaking our promises to the 15 nations, our partners who—it just questions our credibility when we don't, as I understand it the words were used when it was asked whether they were consulted, it was said they were informed before the announcement was made. That's a big difference when you're dealing with 15 partners that have worked together like this for so long, credibility of what we've been able to build up over the last 20 years. The scientific community was coming around and infused with projects to go on the station, things they wanted to do. If the scientific community gets down on this whole thing, I think we will have longer term trouble also.

In effect what we're saying is science is not as important to the U.S. As that very tiny amount on the budget. It's just a matter of seeing how far we can go and all the exhilaration of going into space deeper. And I support that and support it fully. But I really question some of this other area. The costs, you have to look at these costs very carefully. You can't do a monumental program like this on the cheap. It's worth doing right. You got to do it right. We can't cut any corners in this. I don't know what your estimates are on how much it's going to cost to do this. I know in the chart that I'm sure you're all familiar with, the affordability chart here, I was told that dark blue area we're working toward on the dark blue part is put all together some $170 billion, I guess. I'm not too sure what all goes into that.

But all the other things go down to nothing, of course. The station is phased out there before we—by about 2017. And everything else goes to zero in support of that crew exploration vehicle and the human robotic technology along with the exploration mission, part of that particular chart.

Since the early space days, I have thought always that there was going to be two—that these things of exploration and research went hand in hand and I believe we should be

doing both. I don't think you can cut out one to do the other. I think they're both valuable. They both benefit us eventually. Instead of seeing how we can terminate the shuttle and station, I'd like to see them being stretched out so we can use them again.

Why go into space? To explore, certainly. But also to do research of benefit right here on earth. It's not a stunt. It's a solid science and the scientific community has backed that. To finally have the opportunity to have the station completed, which we're within—we can see the light at the end of the tunnel here as the shuttles get going again. We're going to be able to complete the station. But then not to use it to its maximum advantage for people right here on earth, I think is penny-wise and pound foolish. I think we can do both. I support the long-term goals. I thought that was excellent to lay out some long-term goals, but not at the expense of benefits for people here on earth and for a comparatively small budget. I think we can do both. It's the first time in human history we can go up there and do exploration way on out, whether we make moon the first stepping stone or not, I don't know. But it's the first time we are developing the capability to do this. It's the first time in human history that we can do this kind of research on the station and we're cutting it out. I just don't think—I have pride in exploration. That's the macro exploration. I also have pride in basic research that's micro exploration too. I think they go hand in hand. I guess we'd have to ask about are we enough concerned about earth and obviously if I had my way your slogan would be earth, moon, and mars and beyond. I think we owe it to the people who are going to pay the bills to get the max research return benefit to them here on earth. Thank you.

Pete Aldridge

Senator, thank you very much. Obviously we're struggling with an issue here of once we develop program that is sustainable over multiple administrations and congresses. Part of our goal is to try to put together a very strong rationale that can sustain a long period of decades of support by the American people. You've hint at several of the areas about inspiration and research, and we've talked it among ourselves about the elevator speech that we make to the American people, you know, the two minutes you have, why are we doing all of this, can you kind of summarize how you would do the elevator speech for us?

Senator Glenn

I'm not sure which elevator speech you mean.

Pete Aldridge

Well, the two-minute sound byte you have that says, ok, in two minutes what would you—how would you explain to the American people and the taxpayers who have to sustain this program over 40 or 50 years, why are we doing it?

Senator Glenn

It would be a dual program. I've always thought at each step along the way as we go into space, the earth orbit, beyond, moon or whatever, each step along the way, we should maximize the research return that's a value to people here on earth. And there are lots of projects for that. I mentioned just a few of them a moment ago here. The human benefits. The telemetry that's been developed.

Cochlear ear implant that is 60,000 people have now. This finite element analysis. Software now being used for almost everything being designed these days that NASA developed. These are all things that is come out of program of research like this. Every bit of progress made in all human history is made because somebody is curious and learned something new. Somebody had to wonder, let's go a different direction or whatever and that's what is at the base of every bit of progress.

That's why we have the standard of living we have now. Here we are with the very first time we've been able to go up above the atmosphere and cruise around up there and do things in this unique environment and it's of value to people right here whether it's cancer studies in the bio-reactor or whatever. And we're just in the infancy of it. We just have a toe in the door. I want to see us maximize that. I think it's of value for everyone here on earth.

That was my argument in the years when I was in the senate. We used to carry every year the station would receive about 2/3 of the vote in the senate. About 1/3 of the senators were very opposed to it. We had some very lively, to put it mildly, debates on the senate floor. You may have seen some of these in years passed and some were pretty good. But the station was supported. It was always supported with the idea that it was going to give research return of value to people right here on earth. The Congress bought that and believed it and they still do. You knock all that out and go to Congress; I think you're liable to get a—well, not as warm a reception as you might want. Put it that way.

Pete Aldridge

Neil.

Neil Tyson

Senator Glenn, I found your testimony especially refreshing in its candor and I want to thank you for that. Even for the tone. I found it quite refreshing. Let me ask you, in one of our briefings we saw a chart of the run of NASA funding from 1959 right up to present day. If you do sort of a running average on that funding, put it in constant dollars, 2004 dollars, it was about the same from back then to today. And you say, ok, that means we have about as much money to go to mars, as we had to go to the moon back in the 1960s. But there's another—there's an important difference between these two eras. Back then that amount of money represented 2% of the federal budget. Right now it's about .7% of the federal budget. So I ask you—

Senator Glenn

That's for the total NASA program, I believe.

Neil Tyson

That's correct. So I ask you, we could solve all of your concerns by saying let's just make NASA a bigger percent of the federal budget. One of our directives, however, is to accomplish this mission within available—is it available? What's the word? Available resources?

Pete Aldridge

It's affordable.

Neil Tyson

Affordable resources. So the natural thing is to see where to cut. But I, like you, would just rather have—would rather do it all. Do you believe that's possible? Is it possible in the floor of the senate today to say we want to do it all and, you committed 2% in the 1960s, commit 2% again today. But the problem is in the 1960s, we were in the cold war and there's not such an obvious adversary today to scare people into making those same kinds of investments. So could you comment on what is the obvious desire to engage in it all, but the obvious barriers against upping the budget to what we all want it to be to accomplish.

Senator Glenn

What this does, in the current budget it cuts things out. It's the—what we're talking about is a grand total of I think about $2.9 billion to keep the research going and start the new missions as they had thought they are going to start and now are going to be canceled. That is not a huge amount of money when we're talking about a $2 trillion—I don't know what the exact budget is this year, but I think it's around $2 trillion, something a little over that. When you think of that amount we're spending and the potential of this for trade, globalization, the outcome of this, us leading the world in research, I think you could sell that. And I think you're going to --
If we go off—if the attitude of the Congress is going to be that we're going to cut things that are—that we could be doing that are of benefit right here on earth, then I think you're going to lack support. I don't know whether that answers your question or not.

Neil Tyson

Well, we want the support. So why don't we just say top off the budget. Will that fly in congress? Top it off. By the way, that—Bob just called to my attention, of course, this $3 billion of reallocated money is only 1/5 of even the total NASA budget. So, you're

right, it is pocket change in the big picture. If it is pocket change, why wouldn't congress just say, well, top off NASA'S budget so you can continue it, meanwhile, let's follow on to mars.

Senator Glenn

I'd be happy to see somebody fight for that. We have people go in and fight for things far less worthy than this in the Congress and get them. And I think this is so crucial for the future that I'd be happy to see the NASA budget increase by that amount or stretch the whole thing out some way. I don't know. But I think when we have built over all these years and built this specifically to do basic research and now we're going to cut it out and say only if it applies to going to the moon or mars, can't do anything else. I disagree with that.

Pete Aldridge

Bob.

Bob Walker

A couple of questions for you, John. First of all, you have kind of a unique experience in this that I'd like to throw a hypothesis up with you. The President has really said that what he wants us to do is prepare to go to the moon. I'm wondering from your perspective whether or not if we are going to recommend the mission that gets that done, whether or not the astronauts who would go to the moon at some time in the beginning of the next decade should be appointed now so that they could be a part of the planning and the work that NASA does toward that mission for the next 10 years as we do it, at least show a pool of astronauts be appointed now from whom the actual moon travelers would be chosen?

Senator Glenn

I think as far as ahead—as far ahead you can probably appoint people like that, why the better off it is. I think anyone in that whole crew down at Houston now, which is great bunch of people, I think any of those people would be eligible and would be good. They're very carefully selected.

I think any of them could probably do it. I don't know if they would have to be. If we're talking about going to the moon, by when, 2015 or sometime after 2015, would they have to be appointed now, I wouldn't think they would have to be now. But when you get into designs and when you get into all the details of things and how the timelines are going to work out for each crew member and things like that, then the earlier you get the astronauts involved, the better off you are.

Bob Walker

But isn't there some value in having the original Mercury VII astronauts who were personalities, who were real people, who the American people could focus on as being clearly the national heroes who were going take us into space, didn't that have some value in the early stages of the program?

Senator Glenn

I suppose. Although we went through that whole selection program, we never knew whether they appointed the good ones or the bad ones. Some of that selection was done right here at Wright-Pat, as a matter of fact. We went through some bad days here on some of those tests. But I think the earlier you can get all that planned—I don't think—you don't want to let people away from—you don't want to isolate them and say, ok, we'll call you at the appropriate time when we're getting ready to go, we'll send it off and let the engineers design this thing. You want to cut them in on this as early as you possibly can so they can tell you out of their own experience what will work and what won't work from their viewpoint because that's going to be very valid input.

Bob Walker

Just one other area that I'd like to pursue with you based upon our mutual congressional experience. I take your point very well about the fact that we are not looking like reliable partners with regard to the science community if in fact we begin to eliminate missions in order to do this. On the other hand, it would be my contention that one of the problems with NASA on capitol hill is it's become extremely unfocused in recent years, that part of the problems that it faces on capitol hill are that all of those things that people wanted on capitol hill and they have put into the budget has resulted in an agency that doesn't have very much of a focus in their mission and that as a result there's a lot of complaining about the amount of money that's being spent and that by focusing the mission you can in fact convince congress that the amount of money that we are now going to spend over the next 20 or 30 years will at least produce real results because it will be inside a focused frame work. I just appreciate your comment.

Senator Glenn

Yeah. I've always thought NASA was reasonably focused. I didn't agree with the Gehman Commission. Their accident analysis was first rate. But I thought some of the things about NASA and the organization and reorganizing people in the different boxes, they're going to make the same decisions anyway probably, just a different organization, I thought some of those were—maybe I didn't agree completely with them. I've always thought there was a pretty good focus. We came along. We did the lunar landing. We came out of that, we started the station. The station's been a long time getting put into place. I thought that was what we were going to do. We were going to get research from that. Very productive. American people would support going out deeper into space. Maybe back to the moon. Maybe straight out on into space. My view is going to the

moon, if we are—projects are worthwhile doing on the moon even if mars weren't there, then we ought to go to the moon. But the use the moon as a steppingstone, as I said a little while ago, I have serious questions about that.

Bob Walker

I was on a chairman of a committee, though, where the committee was pretty much populated with people who has centers in their districts who spent all their time trying to figure out missions from those centers getting into the authorization bills or appropriation bills whether it had anything to do with the overall mission of NASA at all. That's the problem I think NASA has begun to suffer from in terms of the legislative process and in terms of this administration.

Senator Glenn

One of the biggest problems is something like this is going to be management of the whole project. It's going to be enormous if it goes through as it's outlined. Enormous. I'd submit if we can't manage a station right here near earth and get the best return out of it, I don't know what this says about our ability to go on out into deeper space which is going to make the near earth look like child's play in comparison.

Pete Aldridge

Les

Les Lyles

Senator, again, thank you very much for joining us today and thank you staff out in Ohio state, they were very courteous when we were trying to set this up.

Senator Glenn

Thank you.

Les Lyles

My question is related to what we just talked about. Part of our charge in this Commission is to look at the organizational structure and management structure to make this mission and this vision a reality. I'd be interested in your thoughts. You may have commented just a second ago. Perhaps this is something you could provide us later. Your thoughts on whether or not we have the right organizational structure either within NASA or NASA in conjunction with other agencies to manage a venture like this and whether or not there are other ways we can look at the whole organizational structure of NASA in general.

Senator Glenn

I sort of have to take a pass on that, I think. Because NASA is doing -- they're reorganizing right now even we're here. They are working on reorganizing for this thing. I don't think we know the results of that yet. I have to trust that's been well thought out and they're going in the right direction with their organizing to support this. Anything like this, I think you obviously have to think of the end product out here, what you want and where you want to go. Then you start working back from it, not the other way around, setting up a headquarters that's going to do wondrous things here. You start with a product here and work back and I think that's what they're doing. So I think we'll have to wait and see how the organization shapes up.

Les Lyles

A related question. This is also piggybacks off of what Bob just talked about, focus. We sort of toyed about this idea as we look at the vision and other things that NASA is doing, perhaps the first "a" in NASA, aeronautics, should be looked at again, whether or not the focus of the organization and agency should be all strictly just space activities. As an accomplished and distinguished airman, I'd be interested in your thoughts in whether or not the first "a" part of NASA is one that in a zero sum games needs to be examined in terms of tradeoffs.

Senator Glenn

For many years the aeronautic industry, Pete, you were very much involved in the aeronautical industry. It was the biggest single factor outside agriculture in

International trade, economics, did more from this country than anything else. Where did it come from? It didn't come because a couple of guys got together and built an airplane. It came basically from NACA, NASA'S predecessor. NACA became NASA. It's the aeronautics and space administration – you've got to remember that and out of all that research back then on aerodynamics and all of the things that you're more of an expert in than I am, all of those things are what let led us to have the kind of industry we have.

It's a good example of the kind of thing we're talking about here. Basic research, some guy in a laboratory down in someplace running a tiny wind tunnel down there somewhere and drawn out lift over drag tables never thought that maybe his work was being used to found an industry that was the leader of the whole world and was one of the biggest factors in the U.S. economy. That's the reason why I keep coming back to the basic research I think is so important. In the chart that I referred to a while ago here based on long-term affordability, the gray at the bottom is aeronautics and other science activities. I'm sure you're all familiar with the same chart. It goes up slightly throughout the years. I think at this time when we're under more competition globally, Airbus, all of the things we've used as examples of this, I think it's time we put—I'd like to see more money in that aeronautics area also. I know we can't fund everything that we'd like to fund. But some of these things are key toward developments for the future that are going to be of

worldwide importance for U.S. business and industry. If we're going to lead the world in those areas, you don't do it just by waiting. You do it by doing the research that's going to make you a leader this those areas. Seems to me aeronautics is one of those that has a track record we should be doing more in that area too.

Pete Aldridge

Carly.

Carly Fiorina

Good morning Senator Glenn. Thank you for joining us. I was interested in your comments about the—repairing the Hubble or servicing the Hubble and in particular your rejection of the notion that we should have a standby rocket ready to rescue astronauts if they got into trouble. Obviously when we are talking about sending people into space, having grave concern for their safety is paramount and clearly the tragedies that we saw recently with the shuttle has heightened our concern in this regard. But one of the things that I personally worry about is for this vision to be sustainable, for it truly to become a national priority, which I believe it must, the nation also has to have a realistic view of the risks required and the investments required. You have spoken a bit about the investment you believe is required.

I wonder if you could talk a bit about the risks and how you would advise this Commission to talk candidly with the American people about the risks that are required to accomplish these kinds of objectives.

Senator Glenn

The old saying in aviation was if you want 100% safety you put all the airplanes in the hangar and don't ever set them out. That gives you no crashes. Anytime you are involved with the speeds and complexities with the heat of the re-entry and things like that that are still fairly new in human history there are going to be problems once in a while. Our track record so far, we've had—every crash record so far is one per 56 flights or something like that is the average or 54. That's something that we have to work on every day. I would point out one thing, though.

We've had three fatal accidents in space, involved in the space program. When Gus, Ned and Roger Chaffe were killed on a launch pad fire down at the cape, then the challenger, then columbia each one of those, in my view, it wasn't the science, it wasn't the research, it wasn't the engineering, there were waivers given on each one of those that should never have been given. They had paper in the launch pad fire when we were still using in those days 100% oxygen environment. You remember in high school, when you had a thing of oxygen and took a glowing piece of metal wire, you put it in and the thing burned just like that and that's what happened in that thing. They had a spark of some kind, ignited the paper and they were killed.

On the challenger, we knew that there were problems with the foam. I believe it's on every mission we've had indications of foam problems. It got to be where that wasn't looked at as any problem. But it was a waiver. On some flights there are as many as 1,400 or 1,500 waivers. Some are tiny little things that didn't make any difference. But on anyone like that where it's not working as designed, where it's not working as engineers have tested it and when you give a waiver where something doesn't work right, that's where we've gotten in trouble in the past. On the challenger, there was some indication of burning around that o-ring around it on previous flights. Well, it didn't blow up then, it must be all right so it's a little thing that doesn't make that much difference. But it did. So the waivers on design and engineering effort that NASA and the contractors have put forward basically has been very, very good. I think that area of granting waivers when something isn't working as advertised is something we have to look at very, very carefully. You can't do that anymore.

Pete Aldridge

Maria

Maria Zuber

Senator, I want to go back to this issue that you mentioned about it being a good idea to go to the moon for the sake of scientific research but not necessarily as a stepping stone to mars. It's been a long time since we've had people walking on another planetary surface that had a significant gravity field and we need a lot of development associated with EVA suits on another planet and such. So are you saying that from that stand-point that it's a better use of resources to go straight to mars and, you know, go to the moon strictly just for research purposes rather than preparatory human factors?

Senator Glenn

That's a difficult question. I guess I think you're going to have to cost out how much it's going to cost to go and set up a lunar base. I haven't seen any cost figure estimates on that yet. I would think the $170 billion estimate here given on that chart in the solid blue area in the chart, if that's to be for the total program, if we could guarantee it could be had for that price and you get a fixed-price contract for it right now, you better take it. That's the best bargain you're going to get. I'm sure that's the low ball figure on this thing. If not—I think we all know realistically—

Pete Aldridge

Somebody has to sign the other part of that contract.

Senator Glenn

That's right. A big bond behind it there too. I think that the—I lost my whole train of thought there. Anyway, I think the—oh, going to the moon, if we can learn a lot on the

moon, yes, we just had the samples back. That's all we've done. Had people experience the hours they've had, about 300 and some hours I think on the moon. If we can learn a lot there and that's the scientific judgment, then maybe we should do it. But that's going to be so expensive that I'm not sure you're going to have money enough to mount a mars mission right behind that and have it be acceptable to the people who have to pay the bills. Plus, to me it makes it more complex. If you have half your speed of going to mars, here you are all in earth orbit, why would you go up and sit down on the moon and start all over again and try and make a—and do it all in a vacuum and with new things up there to build fuel, a refinery, a mining operation. I don't know what you're going to have. But once you're in orbit and you have it all set and your vehicle is going, it would seem to me it would be better go that direction. Can we learn a lot on the moon? Fine. But I hope we don't chew up all the money on the moon and never get to mars.

Pete Aldridge

Laurie.

Laurie Leshin

Thank you, sir. It's a real honor to have you here. Thank you so much for coming. I want to change the subject a little bit and talk a little bit about education and youth. In my view, one of the purposes of venturing out and exploring the unknown is to inspire the youth of today to encourage in their education in such a way that they will be prepared to invent the future as we need them to do.
I was happy to hear that you served on a science and math education commission and I would be very interested to get a copy of the report and have a look at it.

Senator Glenn

I got it here.

Laurie Leshin

Thank you, sir. I'm wondering if you can give us some suggestions because this is also a part of our charter about how NASA or, you know, this national exploration effort can really help engage with some of the issues that you laid out there to help solve them.

Senator Glenn

NASA has had a pretty good -- I think a very good outreach program to schools. They provide a lot of material. They're on the e-net. They have lesson plans, all sorts of things like that. They have recognized for a long time the importance of NASA as a—not an example, but as a move to get these kids more interested in math and science. They've had some good effects from that.

We have the space day every year in Washington that occurs in whatever the day is this year in May and so we go down there and they have kids in from all over. They're just starry-eyed going there. They're just great.

I think NASA'S done a pretty good job in that particular area and continues to. There was a lot of question whether a teacher should go into space. That was solved at one time. We had the terrible accident with the challenger and it set that back. But we were set to move ahead on that now in these days. I think in that area they're doing pretty good.

I'm very concerned about this math and science thing. I think unless we get a handle on that for our kids, we're going to get outdone in the future and it's unnecessary. In the back of this, I was the chairman of this thing, what we did, calling on my own background, in the back of this you might want to look. We put all the stake holders in the education system from the school board and superintendent team, the principals, teachers, the parents, state leadership, higher education institutions, business, gave them each a checklist. A checklist of what we thought they could do if we want to reverse this trend and get us going again. Not the least thing we found, though, the problem with this thing was teachers. Teachers themselves. And that we have -- 25% of the math teachers in this country are teaching out of field. They never had any training themselves in college and math themselves and here they are teaching math. The same thing in science - 20%. 30% of the teachers leave the math and science profession within three years. 50% are gone within five years. It's a big churning mess of teachers coming and going. That's not the case in most foreign countries. They have more stability. Teachers have more honor, better pay. We give a checklist in here. If you want, I can get a copy of this sent to all of you.

Laurie Leshin

A checklist for NASA.

Pete Aldridge

Senator, we appreciate your time.

Senator Glenn

Thank you.

Pete Aldridge

We took more than we scheduled you for. But I know this is very interesting. We appreciate you coming and sharing your views with us. You can be assured we heard you. Ok?

Senator Glenn

Thank you very much.

>>[applause]<<

Pete Aldridge

We are not finished yet. We have a pop-up witness and I'd like to spend just five minutes. We'll delay the start of the session later this afternoon. Frank Samuels, who is—works for Governor Bob Taft here in Ohio. Frank is the aerospace development executive for the governor and he'd like to make a few words, a few comments to us this morning. Frank, the floor is yours.

Frank Samuels

Thank you very much, Mr. Chairman, General, Congressman Walker it's great to have you back in Ohio. Members of the Commission. Thanks for the opportunity to appear briefly on behalf of Governor Taft we join in welcoming you to Ohio. Aerospace is front and center in many of his concerns, support for the NASA vision. I'd like to spend just a couple of minutes giving you some examples of how Ohio may be able to help you reach your mission of advising on affordable and successful space exploration. The key to that is clearly teams of productive people creating a host of new products and systems through collaborations. Collaboration is very much a theme on the governor's mind. He's been discussing NASA Glen Wright Pat collaborations for example with General Martin and with top NASA officials recently in Washington.
We think in Ohio we are creating some of the new models of collaboration that are relevant to your achieving your mission. You heard yesterday from the Dayton community about the Wright Brothers Institute, an initiative which I think Dayton and Ohio can be proud. One example I want to talk about briefly this morning is the Ohio Center for Advanced Power and Propulsion.

This center is a newly designated center. It is a part of the governor's third frontier project which he announced two years ago, a 10-year project to build intellectual capital to create jobs and economic growth. Advanced power and propulsion is one of the five key areas in this vision. Collaborations are the key here. Public, private, business, university, multiinstitutional. We have since the governor announced the program made $200 million in state awards for centers. We have used the National Research Council the National Academy of Sciences to manage the proposal evaluation process to assure the highest level of science and commercial promise. The Ohio Center for Advanced Power and Propulsion, one of our major investments, intends to be the primary research and development enterprise in the world.

It is a public-private institute partnership with five Ohio institutions, Wright-Patterson, the Glenn Research Center, GE aircraft engines and other defense contractors and to me interestingly, the American Electric Power Company (AEEP), the largest generator of

electrical power in the country that has an interest for earth benefits, to use Senator Glenn's phrase. A variety of work is going to be conducted at these various institutions all aided by computational modeling.

Here it's worth pointing out that Ohio is now installing our third frontier network, 1,600 miles of broadband internet connectivity, among 17 research institutions including Wright-Patterson and the Glenn Research Center. It will be operational this fall, not just in the planning stages. We have bought the dark fiber. We have bought the equipment. It's in the test racks now. It will be installed this summer and we will have the network connecting all of these institutions up and running in the fall.

We think this will make the connect researchers and make the collaboration I've talked about even more productive than it would appear similar pli on paper. Obviously we're not talking just about things, not just about technology or not just about products, we're talking about people. I was very interested in Dr. Leshin's to Senator Glenn about the work force issues, really and clearly that is a major objective to build a skilled work force interested in science, engineering, technology invasion and product development.

Ohio is engaging this issue right now. We have some challenges and we need to create and we have now a commission advising on how to create more qualified high school graduates in science and math, more qualified college graduates in science, math, and engineering, how to build bigger research base and a more productive technology enterprise. My conclusion is that simply collaboration among these various elements is key. We think in Ohio we have some examples and you'll doubtless find them in other states you'll be visiting. I think basically it comes down to some very simple propositions. Insist on excellent science. Pay attention to the work force issues, and encourage, force if necessary, collaborations among institutions and across sectors and dare I say it, maybe across state boundaries. Thank you for the opportunity to be here this morning.

Pete Aldridge

Thank you very much. We are running pretty late. Does anybody have a burning quick question?

Frank Samuels

I hope not.

Pete Aldridge

One quick question.

Neil Tyson

Frank, as you know, and sadly for those of us who supported the third frontier initiative, the bond levy did not pass last year.

Frank Samuels

Yes.

Les Lyles

Which implied perhaps a lack of understanding of the population about the benefits of science and technology. Are there some lessons learned from that that perhaps might benefit us as we look at how to sell - both in terms of sustainability and growth in future things like this vision for mars? Is there something you learned from that?

Frank Samuels

Yes. Just by way of a little bit of additional background the governor's third frontier proposal included as one of the elements a Ohio constitutional amendment to provide us the authority to issue bonds. That was defeated by 46,000-vote margin on a 7.5 million votes cast. A very narrow margin. I don't know how it is in your respective states, but when school levies go up, they can get defeated by even greater margins and frankly we don't give up on school—K-12 education just because in one case there's a defeatable levy. No more are we giving up here. I think the lesson to be learned, -- however, is that there has to be substantial grass roots activity.

I think in the case of the issue one ballot informed by focus groups and all the things you do when you have the big marketing campaign, we struck themes that are correct but they weren't translated adequately to personal, grass roots understanding. I think that would be what I would suggest to you here. Some of the thing that Senator Glenn was talking about in terms of real-world benefit should be the things you should focus on. I would not, however, give up. On denigrate the aspirational aspects of what you're trying to do here. I think the aspirational aspects do motivate the young, the young students, motivate many of us still even though we could but I in no way I think that—I think the aspirational elements of it in terms of motivating the younger generations and the people that you want to engage maybe for the first time as well as providing a sense of grass-root benefit, melding those two things, is what I would suggest we've learned from our own experience here in Ohio.

Pete Aldridge

Frank, thank you very much.

Frank Samuels

Thank you, Mr. Chairman.

Pete Aldridge

For your comments. We will adjourn now and reconvene at 12:45. Okay. Thank you.

Pete Aldridge

Well, good afternoon. We're running a little bit behind schedule today, but given the witnesses and the importance of the topics, I guess it's expected that we'd be running a little bit behind schedule. This afternoon we'll be focusing on a science and technology panel. We're delighted to welcome some additional members from the U.S. Air Force technology development team to talk to us this afternoon. This next panel is investigating science and technology, as I mentioned, and we welcome from the Air Force Research Lab and I guess across various parts of the country Colonel Joseph Boyle, associate director of the propulsion directorate, Dr. Charles Browning, director of materials and manufacturing, Colonel Mike Leahy, director of air vehicles, Colonel William McCasland, director of space vehicles. I don't know recall exactly what the order is. Dr. Browning, we'll start off with you. Welcome.

Charles Browning

Thank you, Mr. Chairman. It's our pleasure to get this started this afternoon, and good afternoon to everyone. We hope you didn't have too big of a lunch today. It's my pleasure to be here representing the men and women of the materials and manufacturing directorate. It seems like we're all bringing with us today some key take-aways.

I brought three with me. The first is to make you aware of the pervasive enabling nature of materials, secondly is to illustrate for you some of the exciting R&D that is been done in space materials that's currently ongoing and that is on and perhaps in some cases over the horizon. Lastly, to give you a flavor for the collaborative nature of virtually everything we do. Many of the points you heard from our boss this morning.

If I could have the next slide.

This is a brief look at our directorate. Most of the people are located here at Wright-Patterson Air Force Base where we have a unique facility designed specifically to carry out world-class R&D. About 1/8 of our total workforce is located at Tindall Air Force Base in Florida. Their facility designed for air based technologies R&D. As you can see on the map, we have several offices and sites across the nation.

The next chart.

As I said earlier, one important message that I wanted to deliver to you today is the importance of materials which are fundamentally enabling to virtually all of our systems. You can see on this chart a glimpse into the breadth and depth of some of the work that's taking place in space materials technologies throughout the years. Several major areas shown in the blue box from structures to propulsion to sensors and so forth have been impacted. An interesting characteristic of materials, which we also feel is a major strength, is that early in their development cycle, many can be very pervasive as far as their applications and in selected applications can even exhibit multifunctional characteristics.

There are many examples of enabling technologies that originated here over the years, many of which we take for granted today, such as mercury, cadmium telluride, rare earth magnets that go in tremendous amount of electronic applications and carbon-carbon composites. Focusing on carbon-carbon a minute, work on carbon-carbon started in the early 1960s and has found numerous applications in a variety of areas from being a current standard for all aircraft brakes today to use in heat exchangers to nose tips, heat shields and leading edges such as those of the space shuttle. To reiterate one of my points while I'm on this chart, the activity shown here as well as in subsequent charts involves strong teaming between the Air Force, other services, industry and academia throughout the whole program.

If I could have the next slide.

This next chart illustrates some of the more recent focus areas for applications to spacecraft. Once again, as you see, they span many areas from propulsion to structures and assemblies. One specific technical theme that I want to focus just briefly on is thermal management. This is an area that has been and will continue to be a major technical challenge for the materials as well as the systems communities.
This includes the spectrum of managing heat generated internally from onboard systems to managing the extreme thermal environment of re-entry. In the case of spacecraft, thermal control coatings, thermal planes and radiator materials will be crucial to controlling spacecraft temperatures. Once again, carbon-carbon which started back in the 1960s has found itself to be a versatile material that offers a viable route to heat pipes, thermal planes and radiators.

If I could have the next slide, please.

In addition to spacecraft, responsive access to space is another key application area for us. Several key applications being addressed are noted on the slide from structures to the cryotanks that hold the fuel to vehicle health monitoring. In keeping with my thermal management challenges, TPS or thermal protection systems will be crucial. We're looking at materials for hybrid cooled leading edges which can involve totally new combination of materials such as carbon with ceramics, metals, foams, and even phase-change materials all the way down, as you see on the chart, to high temperature ceramics for control surfaces. To achieve a goal of near aircraft-like operations which is quite a challenge, built-in health monitoring diagnostics will be another very important area.

You'll hear about several of these application areas I've shown on all my charts from my fellow speakers to the right who happen to be customers of virtually all the materials technologies you'll see on these charts. If I could have the next slide, please.

I would be remiss if I didn't mention revolutionary technologies and my next chart is my last chart. That I'll conclude just as I started materials have been and will continue to be enabling for space applications. There have been many key accomplishments from the materials community to date and we are very excited about the dramatic revolutionary opportunities that will allow us to meet the challenges of the future. Many of our things are outside the security area on the displays and we hope you get a chance to visit them today. Thank you very much. Colonel Boyle is going to speak next.

Pete Aldridge

Colonel Boyle.

Col Boyle

Thank you. Mr. Chairman, members of the Commission, I'm Colonel Joe Boyle and on behalf of the men and women of the propulsion directorate I want to thank you for this opportunity to present to you our capabilities and our science and technology program. Unfortunately with the short time, I won't be able to address all of our portfolio programs, rather I'll focus on those programs that are specifically applicable to the moon, mars mission.

Next chart please.

We have a long history of collaboration with NASA dating back to the development of the F-1 engine that powered the Saturn-5 moon rocket. This collaboration has continued to today where we are coordinating our efforts through both the National Rocket Propulsion Test Alliance known as NRPTA which coordinates test infrastructure across the country and schedule and the integrated high payoff rocket technology propulsion program known as IPRT whose goal is to double performance, reliability, performance, and cost effectiveness of rocket propulsion systems today. Today, I will focus on only 4 areas of the propulsion directorate program. You can ask me questions on the rest of it later. That would be great. The first is a unique set of test experimental facilities that have dotted layman's ridge at Edwards AFB since the 1950s.

Second, I will address the technology efforts and plans for advanced reusable booster engines that are currently undergoing. I will then explore the applicability of electric propulsion, specifically how effect thrusters which meet the orbit transfer mission and finally, I will discuss the pervasive power program and how it applies to space mission.

Next slide please.

We need to all be careful not to lose sight of the many exciting opportunities that are emerging and perhaps yet to emerge, revolutionary technologies offer. These are the things that will be providing us with transformational capabilities, many of which we likely even haven't thought about as of yet over the next several years and I've illustrated two on this chart. Biomimetics is the mimicking of materials and processes that nature does very well. Has potential to produce revolutionary advances such as room temperature IR Detectors. Nanomaterials technologies has great potential for delivering dramatic improvements in areas such as electrically conducted plastics and embedded sensors for vehicle health monitoring.

If I could have the next chart.

As I mentioned earlier, collaborations are key to delivering these improved capabilities. And we have several noteworthy ones in space materials on the chart. I've highlighted two of them that I'll speak to. We co-sponsor an annual symposium on space and missile materials which has become the pre-eminent event for setting a national agenda on critical space materials technologies, and you can see some of the collaborators in the middle. We're also conducting as we speak a materials on the international space station experiment which we fondly know as Missy to obtain actual space data on many materials.

This is an excellent educational outreach tool. We extend the participation to school students from the surrounding area, and we have over 21 student experiments in the first Missy payload. As I mentioned in the beginning our collaboration with NASA on the original on the original moon mission began with the F-1 engine development. During that timeframe, six separate test stands were constructed at Edwards Air Force Base for the development and production and acceptance testing. Three of these stands have recently been modernized and modified. They are capable of testing locks hydro locks hydrocarbon engines up to 1.5 million pounds of thrusts. One of these stands was most recently used to develop the RF-68 engine which you see on the right, which powers the Delta IV evolved expendable launch vehicle.

The other motorized stand is a high-pressure component stand recently activated on 14 January 2004, coincidently the same day as the President made his speech. Let me not forget the capability also exists to test large solid rocket motors at this site which we do continuously and regularly. I invite the Commission to visit our site for up closer and personal exposure to our facilities if they like.

Next slide, please.

Now shift gears from our facilities to describe the current science and technology program applicable to the moon, mars mission. Let me start with reusable booster engine technology. The main programs in this area are called the integrated powerhead demonstration or IPD and the hydrocarbon boost demonstration. Both of these programs included the new engine cycle called the full-flow stage—combustion cycle, which is critical enabler for the mission extension life that we look for on these engines – up to

100 mission life, this amounts to a factor of 10 increase in engine life over the current space shuttle main engine.

The critical technologies involved are oxidizer rich combustion environment, hydrostatic bearings and advanced cooling design and manufacturing.. Recently, as you can see in the pictures above, the integrated power head program demonstrated these technologies in turbopump tests at NASA Stennis.

The full engine system demonstration is in build-up and is planned to start later this year and will complete by the end of fiscal year 05. The hydrocarbon boost program has completed vehicle level trade studies to determine the best fuel combination which turned out to be liquid oxygen & methane. The final area I would like to talk about is in reuseable engines is the development of sensors and control concepts to meet system level needs for integrated vehicle health management. This will also be extremely beneficial not only to reusable engines, but also expendable system to ensure high reliability launch processing operations.

Next slide please.

The next mission is orbit transfer electric propulsion more specifically how it affects thrusters is a leading candidate for orbit transfer applications. The flexibility of hall thrusters makes it an excellent choice for most all spacecraft measuring requirements from LEO to GEO all the way down to simple station keeping. We are currently developing technology for 20 kilowatt hall thruster as a building block for orbiter transfer applications. By leveraging precision work in hall effect cluster thrusting we can develop a modular and scalable propulsion system capable of meeting propulsion needs of multiple spacecraft missions. Our electric propulsion guys is coordinating their efforts under the impnpt program. Integrated high payoff rocket propulsion technology with the NASA Glenn Research Center on this hall effects work.

Next slide please.

Of course, getting to space and operating there requires more than just propulsion in our directorate we also work on power. Power technology's most applicable to moon mars mission are based on the more electric aircraft initiative. These technologies are not developed specifically for launch vehicles but are highly relevant based on the pervasive nature of power technologies. This initiative enhanced the concept of using electrical power for driving aircraft subsystems typically driven by hybrid systems of pneumatics, hydraulics mechanism and electrical system. The use of only an electric power optimized the aircraft's war fighting capability and reduces life cycle cost. It will also reduce the life cycle cost using the vehicle. Technology include power generation used in turbo generators for mars, auxiliary and energy power as well as both conventional and high temperature super conduit systems. Work is ongoing in developing the regenerative hydrogen oxygen fuel cells. Power distribution is meeting the challenge of increased operation temperatures for power management with variable speed drives. Energy storage is looking at provides batteries through improved batteries through electro

chemistry and packaging to increase energy density, reliability and life while reducing size, weight and environmental impact.

A stellar example of this application of this technology is the lithium battery which is currently powered both mars rovers. Thermal management is critical to future space platforms which will require aggressive cooling concepts to deal with significant waste of thermal energy.

Next slide please.

In summary, the propulsion directorate has some of the most modern test stands for rockets propulsion demonstration and development. The technology, being demonstrated for reusable booster engines, will provide the bedrock for enhanced performance while handling longer life, higher reliability and lower cost engines. All of which are important characteristics of reusable as well as expendable rockets. The dawning of electrical propulsion hall thruster provides an excellent candidate for a wide variety operation orbit transfer mission critical to the moon mars mission.

Finally, to get into space and operate the power is a critical need. Again, the technology derived from the more electric aircraft initiatives supplies an array of technology options that can enable to moon mars mission. Members of the Commission, I thank you again for this opportunity to boast about the world class capabilities of the propulsion directorate. And I'll turn it over to Colonel Leahy.

Col Leahy

Thank you, Mr. Chairman, ladies & gentlemen.

Next slide please.

One up from that if we could. There we go. Along with our traditional role of pushing back atmospheric flight the vehicle directorate science and technology program directly support space access. More significantly, a significant portion of our research is focused on making operationally responsive space lift system a reality before 2020.

Next chart please.

The return of investing expendable launch vehicles a nearing the flat part of the curve while expendables will remain the answer for very heavy payloads the greater number of small and medium payloads do support a reusable space access paradigm. In those instances, we want to operate more like a traditional air breathing platform that a space faring one. We need turn time in hours and not weeks and launch cost is single not double digit millions. This new capability will enable a wide range of Air Force and NASA space missions. We will not get there tomorrow, but the first spiral in that revolution is only a flight demonstration away.

Next chart please.

So how do we get to an airplane-like operations by maturing and integrating 3 major technology thrusts. Colonel Boyle discussed the advances in propulsion and power are those are clearly a key player. Another key is leveraging over 50 years of researching and experience in designing, building and operating responsive aircraft. The final key ingredient is converting Dr. Browning's new materials into advanced thermal protection systems for TPS. Continued investment along those 3 major fronts will permit an integrated microscale flight demo within the decade. Spiral technology development, build a little test a little, fly a little will pave the way for the first acquisition spiral.

Next please.

Thermal protection system are the focus for our space research because the shuttle experience shows us the drive turn times and therefore cause a responsiveness. Operationally responsive space lift mandates TPS which can reduce the damage from impacts, in other words, it's durable, can be replaced fast when damaged, can mechanically attach it, is an integral part of a vehicle heart monitoring system. So we can find the damage fast and use of airplane-like design principles to build configurations which minimize the impact of TPS repair and replacement in the first place. Thermal protection systems have come a long way since the shuttle was designed. We will take a representative look of the state-of-the-art using those four critical TPS characteristics in turn.

Next chart, please.

This slide highlights recent demonstrated advances in durable TPS. The black bar on the left represents the performance of the new not yet existing shuttle tiles. The far right green bar is a similar tile wrapped in our ceramic matrix composite alternative. The test data validates an order of magnitude improvement in damage tolerance when we use the composite wraps. The increase in weight for the item protection is minimal. There is a sample here we will ask to be passed out of the composite wrapped tiles and we have other advance TPS that in the exhibit area.

Next chart, please.

While we can increase the damage tolerance it is impractical to try to eliminate it completely therefore we need to quickly need to be able to remove and replace damaged TPS. Adhesive technologies in use today are much too labor and time intensive to meet a rapid turn goals the solution is mechanical attachment and these images are from our most recent generation of thermal blankets. The attachment mechanism is magnetic. Here we blend our experience quick released access panels from stealth aircraft for a structural research for a innovative affordable solution. Component level tests of validated the ability to repair and replace the mechanically attached tiles up to 500 times faster than the current shuttle adhesive approach. We have tested the samples to 2,000 degrees and 165 decibels of acoustic loading.

In other words the simulated mission environment; a real vehicle will be covered with hundreds of these blankets and similarly attached tiles. It is time to move on to large scale tests.

Next, please.

Again leveraging our airplane knowledge base we are adapting the integrated vehicle health monitoring techniques developed for the F-35 and UCAV mentioned in the previous two talks to provide the ability to quickly determine which tiles are damaged. Component level tests have produced very promising results and we are almost ready to conduct large scale test article integration.

Putting together a locks tank surrounding aerostructure and embedded health monitoring. Another example of our NASA partnership the next generation of launch technology program demonstrated the tank technology vital to this structural test. The test article will be subject to realistic thermal acoustic and mechanical loads in order to validate our structural design tools and finer estimates of weight, cost and turn times. This integrated ground demo will by definition work the configuration issues (that 4th integrated feature of TPS) that are needed to refine the flight demonstration program.

Next chart, please.

Flight demonstrations are the only way to open the space medium to the kind of affordable and reliable access that exists routinely in the aviation world. With our industrial partners we have conducted the systems engineering analysis and trade studies for the operational concepts to the point where we can identify the sweet spot for initial advanced technology demonstrator. While this microscale demo will have no operational residual value it will allow us to very affordably mature the critical integrated technology suite, demonstrate the critical operational responsive characteristics in a way no ground test could ever provide direct scalability and traceability to full-size hybrid ELV and two staged orbit design. Nothing focuses the mind like flight test. The time has come to bring that intensity to the responsive space lift challenge.

Next, please.

Continued advances in thermal protection systems. Combined with advanced propulsion and power and modern airplane design principles and practices will allow the air vehicle directorate to give the Air Force the wings it needs to remain the greatest air and space force in the world. In so doing we will lower the cost for space access for going to the moon, mars and beyond. Thank you. I will turn it over to control to Colonel McCasland.

Pete Aldridge

Thank you Colonel Leach, Col.

Col McCasland

Good afternoon Secretary Aldridge, Commissioners. It is a treat to represent the scientists and engineers in the space vehicles directorate. We work mostly at Kirtland Air Force Base in New Mexico and a third of us are scientists in Hanscomb AFB in Massachusetts.

Next slide please.

The important technology needs for Air Force space capabilities are sketched in this slide. I will touch on what we are doing to advance the state in each of these areas. These might be candidates for the kinds of technology clusters that General Lyles asked about in this morning's session. They are engineering issues that matter to us in the Air Force and that is why we're investing in advancing the state of the art there but they are pervasive technologies applicable to almost any kind of space payload. All of these need to be underwritten by a solid foundation of scientific knowledge in the space operating environment.

Next slide please.

And I will start with that. The Air Force has been a leading sponsor of astrophysics research starting before the space age. We built the national solar observatory in Sunspot, New Mexico, for instance, which we now operate in partnership with the National Science Foundation. We need to be experts in space weather because of the effects it has on spacecraft themselves and on radio propagation through the ionosphere and what that means to military users especially for GPS and UHF stations. Space weather starts with the sun and new solar research is stemming from applying Air Force sponsored adaptive optics to solar telescope that will result in an over order of magnitude increase in resolution and this coupled with new predictive models opens the door to predicting solar storms.

We have launched new instruments to track the transport of coronal mass ejection between the sun and the earth and have an active research partnership with NASA and their solar century program. Scientists in my directorate created and maintained the engineering codes this characterize how charged particles effect spacecraft. We invent and prototype space-based instrumentation and translate the scientific results into actionable information that we disseminate to military users worldwide. An exciting new result in the series is emerging ability to predict up to about a four-day horizon the effects of solar storms for space operators and users of space systems.

Next slide, please.

Spacecraft are primarily electronic machines and Air Force spacecraft have to operate in a severe radiation environment both from natural and man made causes our directorate has a long established person to build rad hard versions of popular electronic piece parts. An example of the 35 mips machine that we call the rad 600 that you have in your hands

there, now operating on the mars rover is a as a result of over 10 years of collaboration between AFRL and BA Systems an industry. But computational needs have grown substantially and may grow a million fold over the next 15 years as we look ahead; the total market for rad hard electronics is relatively flat.

That is what is plotted in the graph on the lower left of the capital investment needed to keep rad hard parts just two or three generations behind commercial technology ran around 250 million in 2003 and we think it will be three times that to recapitalize them to catch up to today's feature sizes. So, our newest research has been directed at a strategy we call design hardening. We exploit unusual designs in circuit laydown coupled with evolution of IC protection to produce rad hard parts. And the latest collaboration with industry the rad 750 which is also on that card is the first rad hard microprocessor that did not require a special foundry. This 300 mips machine closes the gap with commercial technology to about a generation as well as marking the beginning of an end of our need to capitalize an unprofitable production capability.

Next slide, please.

Air Force spacecraft—space capability needs project an electrical power demand on the magnitude of higher than the current commercial comsat which are about 18 kilowatts. We have, for the past 15 years, been investing and improving crystal and solar cell efficiency underwritten every major advance and approaching the theoretical efficiency of 39% first for crystalline cells. 95% of all U.S. systems and 90% of Europe spacecraft operate with solar cells that were developed in AFRL. This work was inducted in the space foundation hall of fame this year in recognition of its significance.

But our research is shifting from solid crystalline to thin film organic substrates and nanoengineered chemistry and that is what I'm handing down the line with that small piece of foil. Even with the loss of the area specific efficiency from today's crystalline cells down to 7% or 11% for today's thin film efficiency, we still see factors of five reductions in the cost per factors of 10 reduction in the weight per power and 10 time reduction in the power per stowed volume for thin film based solar rays. This combination of like structures and thin film cells opens the door to practical hundred kilowatt solar powered spacecraft for today's launch vehicles.

Next slide please.

Antennas and optical aperture are also fundamental to space based communications, radar and optical based surveillance systems. The parametric relations on the left side of the chart display the strong dependence of key radar performance measures on antenna array length. An example of the state of the art in commercial comsat antennas, Boeing's Thoriah which unfurled is 12 times larger than stowed size. Our research and tests are aimed at demonstrating the structure's support technology suitable for space based radar with a stowage ratio of 25-to1 and we are partnered with DARPA for a flight demonstration of a 100-to-1 stowage rate. The success here would open the door to high altitude space based radars. We are also advancing the state of the art in deployable

optical telescope structures, an area in which we forged strong partnerships with NASA. Engineers in my directorate assembled the first flight weight flight representable deployable telescope. An instrument that opens to Hubble's aperture get stows to fit within a Pegasus launch shroud.

Next slide please.

When military operators talk about speed and getting inside an adversary's decision making timelines one of the key technologies underpinning that is flexible globally deployed communications network. We learned from deploying into distance threats we must bring the phone company with us and global connectivity calls for space basing much of this infrastructure. Our vision is for transformation from a circuit based architecture to internet based network protocol coupled with bandwidth growth of several orders of magnitude.

Effortless attacking several the key technological risks of this vision specifically whole earth-wide field of view multiple lines of sight laser com terminals and associated network controls switching and routing technologies. The combination of precision pointing optical terminals, high efficiency laser devices and commercial single mode fiber all add up to a viable means to simultaneously shrink the footprint of user sat come terminals by an order of magnitude and free throw the bandwidth by two orders of magnitude.

Next slide, please.

Well, in this afternoon's session here we have briefly highlighted current AFRL research motivated by making space capabilities more flexible, affordable and operational responsive to our services needs we are working on game changing technologies for driving down the cost to accessing space and share NASA'S vision that some kind of reusability is right the way to drive down launch costs.

We are aggressively advancing the state-of-the-art in all key technologies needing to making the payload mass that we do launch accomplish more than it ever could. We have a long history of collaborating with NASA and we expect the relationship to grow. We share NASA'S concern with stimulating the call to study hard science and engineering and the picture in the lower right shows my directorate's space scholars class of '03 program for advanced under graduate and graduate study interns in our laboratory. We sponsor other educational outreach programs running through elementary through high school and my directorate's program aren't unique. They are representative others all that general Nielsen mentioned this morning. Personally, I'm excited with this initiative will generate the intellectual fire for science and engineering study for the next generation that the first generations of space exploration did for me and my generation.

Pete Aldridge

We use the word participation and collaboration and several others. I can't remember what they were especially with NASA. What does that mean? Does it mean that we meet every three or four months and talk about what we're doing? Do it mean that there are NASA representatives in your offices? Does that mean that the Air Force is represented in NASA offices? What is this level of collaboration we are talking on?

Col Boyle

I can give you a few examples of that. The first that I'll talk about is the IMPRP program. It's the integrated high payoff rocket propulsion program. We meet twice a year in conference where we review even other's work but that's not it. We are constantly meeting. We actually have joint programs, the IDP program up until 2 years ago was Air Force program. It is now a joint program with NASA. The deputy program manager, though he doesn't sit in out office, he's named the deputy program manager for the IPD.

There are three of the five engineering directorates under the IPD program are NASA program managers, two of which are Air Force programs so is the integrated joint program so we do those. We cover the gambit of meeting a couple of times a year to review everybody's programs and roadmaps to all the way down to actually having joint demonstration programs.

Pete Aldridge

Is that true for the other offices?

Col Leahy

I will give a different example we also have that kind of relationship. Right now in our new test facility where we can the only place in the world you can do mechanical, thermal, and acoustical loading at the same time, the first test panel in there is the second generation TPS system designed and built by NASA. So we are collaborating where we have facilities they don't, and vice versa, in other parts of it we will be doing testing for the X-37, similar testing, different pieces later this year. Other places are we have more cooperative efforts.

Charles Browning

In the case of materials which is a subset of the program Joe mentioned there's an integrated materials working group and industry is big part of that collaboration. So everybody gets together and jointly manages and works the program.

Pete Aldridge

So NASA that is bringing people and resources to this and the same for the Air Force.

Charles Browning

Obviously.

Pete Aldridge

Les.

Les Lyles

I was going to ask a similar question as the chairman. To be more specific I have always been frustrated in the past occasionally when asking your guys about the cooperative efforts and you told me about meetings that you had as opposed to real joint efforts so it is good to see when there is joint collaboration going on and teamwork and leadership on some of these.

Joe, I would be very interested, it might be very helpful to the Commission if you could provide us as a homework assignment some information on how IMPRP has actually progressed. It's been going on for several years, is the collaboration with the Air Force, NASA and industry. We have watched this collaboration with the goal of doubling the isp and propulsion systems.

What I would be very interesting to see how the collaboration of this nature, a collaboration of this nature really works and are we really making progress and are people actually contributing to that. If you could provide that to us, I think that might be very helpful.

Col Boyle

I can do that. I will also like to answer that a little bit today. The IMPRP program is set up in three phases, five years at a time. We are currently in the second phase. The first phase we have demonstrated significant improvement in specific impulse, thrust capability and not only solid rocket motors, that was the big thing we did but also in the electric propulsion area. We have had significant advances.

We have not gotten to two times yet but that is a lofty goal and challenging one and that is what we think we need to go after as part of the Air Force Research Lab and making the challenges in technology really push us. But I will get you full report on that.

Les Lyles

If I could ask Charlie just question, a odd question but I think you will understand the context and our part of our charge in looking at education I think you will definitely understand this. As you and I know you sort are the model in command in the laboratories for your work of the historical black colleges and universities. Have you thought or are there ways that you can think of that part of the inclusiveness that this vision could be one we share with all of the institutions including HBCU'S and a way we can address that?

Charles Browning

Well, I think there is an unlimited amount of opportunities there. You are very family with our initiative and it—if you look at what it takes, it takes an infusion of money but not a lot. It takes sustainment. Once you jump in to this thing someone has to keep it going. And there's lots of opportunity at all sectors. HBCU'S is a good example that impacts a lot of things. A lot of photonic things going on.

So there are tremendous amounts of opportunity you could start a similar initiative on space materials and you could get variety of folks from all levels of the institutions involved. I think if you infused dollars and infused leadership, you get the students excited, you get the faculty excited, then you are on a roll. So, it will work.

Les Lyles

Thank you.

Pete Aldridge

Bob.

Bob Walker

I must admit that I scanned the list of your materials development to see where my next generation of my golf clubs were going to come from, but --

Charles Browning

You would have thought that gone fiber would have been the leading golf club material in the 1960s.

Bob Walker

I was interested in the fact that so much of the research that you talked about was in the reusable area. The Air Force has been seen in the past as being pretty resistant to reusable spacecraft. Is this something that is coming out of your partnership with NASA,

or is it because there's been a change of direction in terms of what the Air Force thinks its needs will be for the future?

Col Leahy

One key—maybe all of the above is the first part of the answer. The other key part is that the space command has stepped up and recently finished an analysis of alternatives which looked at the different requirements they had to perform missions in space. That analysis is pointing us toward a degree and amount of launches for small and medium payloads that really cannot be metaphorably unless we move toward a reusable and responsive reusable kind of paradigm. That is the most recent driver for us is the acknowledgement that is where we need to go to meet the requirements of the user.

Bob Walker

The question for this Commission is what kind of time frame do you see these kinds of developments coming in? As we look towards the technologies that are going to be necessary on our time line, how far out do we need to be looking in terms of ability to get more bang for the buck from reuseables?

Col Leahy

We are targeting to be able, again, to support the analysis of alternatives saved, to have something we could put into initial operational capability in a 2018, 2020 timeframe, this would be for a smaller or 1000 pound LEO to a hybrid ELV kind of approach directly move towards larger two-staged orbit kind of things. But we have the component technologies well enough understood right now, and one of the next key steps we have to make is to do the integration, address some of the systems issues. You can't address responsiveness at a small component level. We totally have to create that at a larger level and have plans to do so in the future.

Col Boyle

I have a little more on that. As far as the propulsion units are concerned, which is what I specifically know about. Our rule of thumb normally is that from the time we actually demonstrate like what we are talking about in the IPD program that will end in 2005, it takes between 5 to 10 years to actually get an operational kind of engine. So that would give you the timeframe. So that if we actually demonstrated something in 2005, then it would go to development and it probably be around 2015 at the earliest or maybe between 2010 or 2015. Those are the kind of timeframes that we talk about in the propulsion area.

Pete Aldridge

Maria.

Maria Zuber

Let me start by saying a number of investigations I have flown into space have benefited directly from technology you have shown here today, keep up the good work in that regard. My question is there a fairly nonbureaucratic and transparent way to, say, share test facilities and infrastructures? Because in the coming implementation of this vision, you know, I could see some of the assets that you people have being available, and I'm thinking of like test facilities as well as like ground stations for communications.

Col McCasland

I could think of one tool we called a cooperative research and development agreement, a CRADA, that's the way for a research partnership to be cast where contributions in kind—could be labor, could be facilities—are outlined.

And then all of us as tech directors have authority to commit Air Force resources to that agreement because we decide and can recognize that there's pay-off to the Air Force. That's what collaboration is all about, we can accomplish more with the resources if we form a partnership than we could going it alone. We do that on a routine basis, absolutely.

Col Boyle

I will also add that the test facilities you saw at the beginning are open to anybody. We have commercial test agreements with industry that comes up and the RS68 was a good example where we are using the NASA Stennis facility. We work with a number of folks to get test facilities used across the board.

Col McCasland

My directorate, the three little spacecraft called the university nanosets went through their environmental qualification in our facility in Kirtland and are currently manifested for launch on an Air Force rocket this July.

Charles Browning

I was going to add building on General Lyles question, and we use things called educational partnership agreements, E.P.A.'s, easy to do instruments which allow universities, lots of folks to come in, we share facilities, equipment, share bodies. There are a lot of opportunities out there to do sharing.

Neil Tyson

I have a comment and a question. I, too, was impressed by the list of materials and technological advances you shared. But if I can pick one as an example, you mentioned

lithium ion batteries, lithium, I think I use one for my laptop computer and it gets me across the country without having to restore it.

So that's impressive, but then on another side, it's not impressive because it's still sort of a chemical battery. So it's more an evolutionary, on the concept of a battery, rather than revolutionary on the concept of a battery. And I'm curious, how –um- what is the nature of your investments in this effort? Is it to try to increment what you are doing, or do you allow yourself the ability to fail, so that one day you will have a truly remarkable breakthrough? So really the question is, what percentage of your experiments fail? And should it be higher?
>> [laughter]<<

Col Boyle

I don't think any of us want to answer that question at this point.

>> [laughter]<<

What I will say, however, is that we set our goals, make them really difficult to achieve, specifically in the IMPRP program that I mentioned earlier. But one of the people that's not here today that was originally on the list, Air Force Office of Scientific Research where most of our basic six-one research is done, that's where those folks do revolutionary kinds of things that they hand off to some of us folks to move along a little bit further. The earlier you start research, the more failures there are, and you probably learn more from failures than successes. We have had our share but I won't give you a number today.

Neil Tyson

A quick follow-up. Many of the testimonies we've received, this one seemed to have the most number of items in it that would have commercial applications. So going forward, since there's some interest in this panel, and indeed in our directive, to try to stimulate the free market to participate in this effort, how competitive can you expect to be if some percentage of that becomes a free market exercise? Because they know that, while it will help us get to mars, they will also help some other activity that goes on in everyday life, like golf clubs.

Col McCasland

I think that's something we look for too because we recognize that, if we're trying to carry the freight on research investments, strictly on government-appropriated funds, it will go so far. But if there's commercial spin-off and the opportunity for private capitalization and a return on investment, then that's a whole capital market to tap. So we're open minded by policy to permit those who contract with us to seek commercial exploitation.

Col Leahy

And I believe each of us has an office that's purpose is to do tech transition and seek out those kinds of opportunities, and we have example frameworks, CRADA's and others, and it really allows us then to take more our resource if somebody else picked that up and focus on Air Force-unique problems.

Col McCasland

We may ask for unrestricted intellectual property rights because of our investment with defense applications, but those are negotiation we have in any particular partnership agreement.

Pete Aldridge

Thank you for the panel discussions. Before we leave, the Air Force promotion system does recognize scientists and engineers, and Neil McCasland has been selected for promotion to Brigadier General, and we congratulate you on that.

>> [applause]<<

Col McCasland

Mr. Secretary, it is a real treat to hear that from you because as many of you know the officer who is responsible for my promotion, General Lyles, is on the panel. But I will bet you don't recall that my first performance appraisal that earned me my first early selection had your signature on it, so thank you.

Pete Aldridge

We do good things every once in a while. Again, thanks to the panel. It's been very enlightening and sounds like there's a lot of collaboration and partnership going on. Keep it up and I think we got a vision statement that can, in fact, we can do better by getting closer together and using a lot of the talent and capability that exists in the Air Force to support this new national vision, not just the Presidential vision, and it's not just the NASA vision. It is a national vision, and we think it's something that is very important.

Thank you very much for coming. Thanks.

>> [applause]<<

Well, we don't have a panel, but we do have an individual with us this afternoon. The Commission welcomes Lennard Fisk, who brings us a report from one of the council's workshops which was entitled "Issues and Opportunities Regarding the U.S. Space Program", sounds like a very opportune and timely subject. This workshop was held

earlier this year, certainly before the President's announcement, and sounds like again it was quite appropriate and could support some of the deliberation of this Commission. So Leonard? Have at it.

Lennard Fisk

Thank you very much. I hope you don't mind. I'm just going to talk.

Pete Aldridge

Lennard, would you get the microphone a little closer?

Lennard Fisk

How is that?

Pete Aldridge

That's good. Thank you.

Lennard Fisk

Let me talk if I may, is that all right?

Pete Aldridge

Yeah.

Lennard Fisk

Good. Thank you for having me here and it's also kind of you to hold this just south of Michigan where I live, and it's easy to come and see you. As you mentioned, I would like to tell you today about this workshop that the National Research Council held, and it was last November, under the sponsorship of the Space Studies Board, of which I am the chair, and also the Aeronautics and Space Engineering Board.

As you mentioned, the purpose was to discuss national space policy. We simply asked, what should be the essential features, and how should it be implemented. As I'm going to tell you, there are many aspects of the highlights of the workshop that are well embodied in the President's vision for space exploration. We also had some views on implementation, exploration. We also had some views on implementation, which you may wish to consider.

But there were also some serious departures from what the participants at our workshop thought the correct approach should be, and I'd like to call those to your attention. Now, I've provided, with the testimony that I submitted, a list of the participants of the work

shop and a copy of the report, which I hope you have. As you can see from the list of participants, it represented quite a broad range of experiences in the space program.

The participants that participated in leadership positions in NASA, in industry, in the military, as well as in the science community. The discussions were very informed and lively, and perhaps what impressed me most was the extent to which we agreed on the key issues, and let me share some of these points with you now. We took it as a given that the space and earth science program of NASA were productive and progressing steadily, and were of continuing importance. This is a point I want to return to.

The space policy issue, then, was not with space science, but it was rather with human space flight, which lacked direction and purpose. And we also observed that there were certain factors that have contributed to the success of the science program that should be noted by the human space flight program. There is a large external to NASA constituency in the science program which has an ownership of the program and enjoys a constructive tension with NASA, as to how the program should be executed, and this encourages the program to excel. There are very clear goals for the science program, which are established by the science community.

There's an extensive process of strategic planning and perhaps most significant for thinking about the exploration initiative, the science program is conducted through a sequence of successes. There are a series of individual steps that accumulate success; from which progress can be measured and then momentum sustained. We argued that the goal for human space flight, which at that time was lacking, should be exploration.

Exploration is acquisition of new knowledge—knowledge of space as a place for human activity, knowledge of our solar system knowledge of the universe beyond our solar system. Exploration is a basic human desire perhaps innate in our genetic code, and human space flight can be the modern realization of that basic trait. We were specifically concerned with the dichotomy that has existed between space science and human space flight over most of NASA'S existence. We argued, and this is a point that I felt was one of the highlights of the workshop—it did not have to be the case. An exploration program properly conducted in which humans and robots play their appropriate role, would result in synergy between the robotic science of NASA and the human space flight in a way that has not existed in a long time.

We recognized that exploration of our solar system is a long-term endeavor which needs to be accomplished with a series of incremental steps. This necessary incremental approach holds the promise of sustaining public and political support for decades. You can have robotic missions to the moon and mars laying the foundation human exploration and a series of regular series of test flights, launch capabilities—all will create the appearance and the reality of progress, and sustain interest and support. We noted that with a clear goal for NASA, it's possible to make the near-term decisions—Phasing out the shuttle, purpose of the space station, and we agreed the purpose of the space station should emphasize preparation of humans to live and work in space.

We worried about the ability of NASA to accomplish an ambitious exploration program. The infrastructure of NASA was formed and sized to support Apollo, and many unfortunately previous goals were set to support the infrastructure, rather than the reverse. So the question is, is the current infrastructure properly configured for a bold initiative? The work force of NASA is aging, the attitude seems risk adverse process seems more important than ingenuity. Can this mind set be changed? There's also an aging work force and infrastructure in the space science community, and we asked, who are the bold new minds that will lead us into the future? Now, clearly, there are many aspects of the President's exploration initiative that are consistent with what our participants thought should occur.

The main goal is exploration. Humans and robots optimally exploring the solar system, incremental steps, shuttle phased out, space station primarily devoted to preparing humans for space and it is my hope that your Commission is worrying about how to structure NASA and the program to succeed, and of course all this would make our participants cheer. But there were serious inconsistencies too, which I want to point out to you. As I'm sure you know, the President's 2005 budget for NASA which begins the exploration initiative has resulted in major collateral damage to certain of NASA'S science disciplines.

In a sense, the science disciplines have been divided into those which are perceived as essential for exploration and those which are not, and the latters have suffered serious reductions, particularly in the out years. And I would like to question the location of that demarcation and indeed its wisdom of that demonstration in the science program. The center of connections program at NASA which has as its goal to understand the sun and its influence on the space environment of the solar system has seen serious cuts to the programs on which it depends—explorer program of small missions, solar terrestrial probe which are missions, dedicated to fundamental processes of the sun-earth system.

It is frankly inconceivable to me that we would consider sending humans forth into the solar system or sophisticated spacecraft out without developing an understanding of and ability to predict the space environment through which we fly it would be like embarking on an ocean voyage of exploration without an adequate marine weather forecast.

The sun-earth connections programs should be charged with and provided resources needed for developing a predictive understanding of the sun and the space environment it controls. The definition of exploration in the President's initiative seems remarkably narrow to me. The planets and the moons of the solar system are worthy of exploration, but the sun is not. The origins program of NASA, which looks for conditions that would support and perhaps even reveal the existence of life elsewhere in the universe, is in, but the structure and evolution of the universe program is out. It's as if we have divided the exploration program by wave-length.

Infrared and visible light astronomy which can reveal inhabitable sites is in, but x-ray and gamma ray which reveal the more violent parts of the universe is out, and this makes no sense. Then, of course, there's earth science, which has been badly cut. NASA has

actually a responsibility under the space act and its amendments to use its capabilities to understand our home planet and predict its future. There's a difference perhaps between priorities and responsibilities.

We may now have a priority to explore, but we still have a responsibility to deliver to the policymakers and the public a sufficient knowledge of how to be good stewards of our home planet. As many of you know, I ran the NASA science program in the late 1980s and early 1990s, and I, like my predecessors and my successors until this new initiative, strived to pursue all the relevant science disciplines of NASA equally. We recognized each for the fundamental importance to explore, understand and utilize space.

The proposed exploration initiative has resulted in a fundamental departure from that balanced approach, and so I encourage you, as you plan the President's exploration initiative, to recognize, first, all the science disciplines that you will need for success, that true exploration is a broader concept than is currently being did he find, and that NASA has responsibilities beyond exploration on which it should not falter. Thank you very much.

Pete Aldridge

Thank you. Question on—in looking at the—at this priority versus—or priority versus, I guess you would call it responsibility or obligation, clearly we can't do everything for everybody with the certain amount of funds that are available to NASA. I noticed there's a lot of question about the earth science and the solar. What about the other activities of NASA?

We talk about, of course, the first "a" being aeronautics, and there's a lot of things going on in the aeronautics field that one might claim are a little out of the lane of NASA, such as air traffic control and aircraft safety, which one might look upon the responsibility of the industry to be focused on that. Are there other areas like those in NASA that they might, if we had to spend more money on those things which have been—which are out, could we reallocate funds from some other location to put them back in, without having—the NASA budget. You.

Lennard Fisk

Help me out with your question here. I'm reluctant to say too much about aeronautics, about which I know so very little. But I think the issue that we are all facing into, as you point out, is that the NASA budget is limited and the number of things we are supposed to do is limited. The sad part of about the NASA budget is of course is limited because it is allowed to decline in the 1990s and when we look at budget we all thought NASA would have in that timeframe, even in keeping up with inflation, and in times of budget surpluses, we nonetheless managed to lose a significant piece of what NASA's programs should cost. And so, with NASA if the budget had simply been allowed to keep up with inflation, we would have probably be not having this debate at the moment. We would be able to have the exploration initiative as it is being defined and we not do the collateral

damage to all other things. And I think that maybe one of our goals in life should try and restore the level of support that the federal government has put into NASA to historically in a position that you simply don't have the money that's the issue. Then you end up making these priority calls. The difficulty, I think, on the science part you know that I tried to give you this sort of three things to think about. One is you got science disciplines that you better support because you need them. I mean if you're gonna to do exploration -- you're not gonna do. NASA's responsibility, no one is doing the earth science the way that NASA . . . Think about the program that earth science had envisioned coming in to the 1990s. Mission to planet earth, spacecraft producing extensive observations of the earth, modeling activities, interdisciplinary science, actually developing a real understanding of the global climates system – global change. The program today is a shadow of that even before the president's initiative and unfortunately it is not something that you can easily pick up elsewhere in the government. All it does is -- there is a close cooperation that frankly as a citizen of the planet I get concerned that we are not using our capabilities in space to understand the planet we are going to depend on. We may send some folks to mars but there won't be a lot of us and the rest of us would like to know how the home planet is going to survive.

Aldridge

You raise the point, which is probably going to be a politically sensitive one. You said that programs support the infrastructure rather than the other way around. That implies that we need to think about what infrastructure is required and be prepared to make decisions regarding changes to the infrastructure that will be more rational. That's going to be hard but . . .

Fisk

But don't you think that's necessary.

Aldridge

Yes, I was just going to say that. It's something I think we most recognize among this commission and that in order that it is affordable, we can't afford to waste money on the things, which are not contributing to the direction of where we want to go.

Fisk

As you well know, I mean NASA was created to, you know, to do the Apollo program. The Houston center was Johnson and was established and other NASA centers were expanded at existing facilities. I mean, it's sort of – maybe it's an interesting intellectual exercise to say if this is the initiative and you had a clean sheet of paper – what would you do?

Aldridge

One of the questions that I'll ask and then I'll turn it over to the commissioners, that we've all had is and I don't know whether your report addresses it, is why are we doing all of this? Inspiration and exploration – it's all fun and for those of us in the techno field think that it is great that we are doing this kind of thing. But how do you explain it to the American taxpayer what are we doing this all for?

Fisk

Well, I think and there is many answers and I'm most comfortable not with the ones that say like inventing Tang and other things like that.

Aldridge

I don't think it's true that tang was associated with the space program. As a matter of fact, it's one of those

Fisk

Urban myths?

Aldridge

Velcro was, but I'm not sure tang was.

Fisk

But the way I sort of view this is I try and imagine, you know, what the world would be like say a hundred years from now, or five hundred years from now, and I find it inconceivable that we would not push this civilization into space on those kinds of timeframes. And so, therefore, with both people and you know, evermore capable machines and then you simply say to yourself, well, shouldn't we be about it? You know. Shouldn't this country, which has the resources to do it, be the people that are leading us out there? You have to think on very long horizons that when in you think in terms of, you know, using the solar system and inhabiting the solar system. We'd all be better off if we could remind the American public of what a small portion of the national budget goes to this activity. I know that 15 billion dollars sounds like a lot of money. It does to me too but not as a percentage of which this country spends on many different things and therefore this investment and really what is the long-term future is perhaps the wisest one to make.

Aldridge

The question I have is really something that we have among the commissioners discussed, is what is the real mission. Is the real mission to send humans to mars? Or is

the real mission to inspire young people to enter science and engineering to have the technology spin-offs that really provide a better life for humans on earth? You know, how you approach doing the mission may have changed your answer.

Fisk

Well.

Aldridge

How do you see that?

Fisk

Well, I would argue that the real mission is to learn to use space, to go forth into space, in the optimum way. Now one of the things that has appealed to me about the initiative, as I understand it, as opposed to say Apollo, where we simply -- the idea was to go to the moon, plant the flag, say that we did it and oh, by the way, let's put a little science along the way to see what, you know, to justify why we are there. Um, let's do this one systemically that the idea that we are extending this civilization into the solar system and therefore let's choose the means to do it to the optimum means. If robots can accomplish this thing, let's do it with robots. If humans assisting the robots makes it better, then do that. But we shouldn't get, I hope, into the point of saying, you know, that the whole idea is to put a human on mars and plant the flag. That's not sustainable. But what is sustainable is the sense that we are pushing the civilization in space by using all means of technology whether it's using humans, robots, or all this and go forth. That's inspirational to people that follow and the mission is to get out there and get going.

Aldridge

A little anecdote here, about the 15 billion dollars that, I don't know if any of you drink Snapple, and I'm not making an advertisement, when you take the top off and there's a little quote inside there. One I saw the other day is the American people; just the Americans spend $650 million dollars a day. Per year, on golf balls. Most of that is spent by friends of mine by the way but . . .

>> [laughter]<<

Pete Aldridge

Laurie.

Laurie Leshin

Thanks for being here, Len, and I want to compliment you on your report. Great to see the synergy between that and many parts what have the President proposed. I wanted to

ask you about something you didn't mention in it to comment on the role of international participation for enabling this adventure. It's something the Commission is charged with commenting on, and I was wondering if you would share your distributions on that—Deliberations.

Lennard Fisk

Thank you for reminding me, we have talked on that and I should have included. It would be wonderful to have an international participation in this. I think, you know, we need to—This comes down to Pete's question about how the—how we do the—you know, why are we doing this. I presume we are not doing this to demonstrate U.S. technological prowess as we did in the Apollo program, because we have many other ways to do that these days, anywhere from our military to our technologies, consumer goods, what have you.

But it would be very worthwhile if we did this together with other nations, and then there's a sort of a caution. We need to do it not on behalf of human kind, because that will be perceived as another form of U.S. arrogance. We should do it, rather, together with humankind and using other nations to participate in this. And I think if we do that, it becomes a demonstration, not of U.S. technological prowess or even of U.S. arrogance, but of U.S. goodwill.

I think there's an opportunity to demonstrate to the world that—I think there's an opportunity to demonstrate to the world that we have humankind's interest at heart in here in the sense of going into space on behalf of humankind, but more importantly together with humankind.

Laurie Leshin

And from your experience at NASA, you might be able to comment on how to best actually go about creating those partnerships that are successful and real partnerships. I mean, engaging people early—what characteristics?

Lennard Fisk

It's clearly—the engaging people early is a very important issue there. We—you probably, as you would imagine, hit the most resistance if you say; I've got this wonderful plan. It's all designed and, of course, the worst thing to say is I can't really pay for it so maybe you should come, you, international partner, you ought to come and contribute something to this. That does not work very well, as you would imagine.

It is, of course, tricky because the organizations of other nations ' space programs are very different from the U.S., and they are—you have to be overly sensitive and concerned about how you fit into their planning processes, among other things. I mean, Europeans have a consortium of nations, the European Space Agency, the Japanese have another structure, the Russians and so on. And so it takes a while to align yourself with

their interests and priorities as well. It is certainly worthwhile if you can do so. I presume this will always be U.S. led. There's no other space program that matches what we can do. So it's a U.S.-led, International participants, makes it—but a lot of sensitivity for their national interests and concerns is always the important issue.

Bob Walker

Len, you gave a paragraph in your statement that the Chairman already referred to, which I think is one of the more important though we heard in the testimony, when you said we worry about the ability of NASA to accomplish ambitious exploration in the future and that the infrastructure was formed in size to support Apollo. Just a couple comments for your reaction.

My guess is you look back at the Apollo era, and very little of the science done then did not support the Apollo program. There was extreme focus during that time while they are building that infrastructure. Secondly, some of the problems we have accrued since have not been just the budgetary problems of the 1990s when the budget was held relatively stable, but also during that same period that operations budgets began to eat NASA alive and that detracted from our ability to do the bold initiatives. So my comment is, you know, is that where you think some of the problems are, and what were recognized in your report, and secondly, wouldn't more focus be a welcome way of being able to use the budgets more effectively?

Lennard Fisk

Yeah, focus is, again—focus is okay but if there are casualties in the focus, you have to decide whether those casualties are acceptable to you, and as we talked earlier about the sciences. I just wanted to make sure I understood one thing you said. During the Apollo program, space science as a whole flourished. I mean, it was not the—it was a very enlightened policy that NASA started.

Homer Newel was the associate administrator or whatever it was called back then, and you look at the kinds of science that was done at Goddard and JPL and so on, NASA looked out and said we want a space science, more than an Apollo program, we want a science program it lifted the entire enterprise. There were many other features of Apollo. The whole university community did not exist in space science prior to Apollo. NASA went out and essentially bought itself a university community.

They built buildings, most of us are at universities that actually have facilities that were built by NASA in order to encourage the university to create a space science enterprise in its activities. And, of course, it—that whole activity built the national infrastructure to do space more than just NASA. I think one of the things that—the only other comment I have, be sure when you think infrastructure, don't think bricks and mortar. This is people and I think what worries me a lot is the aging work force of both NASA and its centers, and the broader science community. This gray hair is not unusual at many of the

meetings that I go to. And you wonder—I mean, it was such a wonderful event, most of us—many of you my age are sputnik kids.

We were inspired to go into space because of the early space program and so on, inspired to go into science. If you can achieve that again, that may be wonderful, but that may be hard to do these days. It's not that big an event. And yet, but you have to ask yourself, who are the people who will do this for you? Where is the work force going to come from? Are the best and brightest going to go into this? Not so clear.

Neil Tyson

One of the more fascinating ways I managed to convince the public that NASA budget is not really all that large, of course, it's a dollar per American per week if that. It's less money than what Americans spend on cosmetics and beauty products. To put it in that context, people tend to be a little more warm to the mission. But what worries me, when you look back at, for example, the Wright Brothers, two guys in a garage and out comes an airplane.

In 1969, Neil and Buzz, again two guys, on a moon. And behind them was the mandate of an assassinated beloved President and 10,000 scientists and engineers and $50 billion of budget. And so to say, well, mars is next and maybe we want more money to do all the science that NASA has done so well, one of our concerns as a Commission is the mandate that would enable that, in Congress and other funding sources.

And my reading of history tells me that science alone has never been a sufficient driver to dislodge the amount of money required to do large projects. The space science period you referred to involved missions whose costs were basically below the radar in terms of funding debates in congress. It would kiss the fringes of it, but basically a billion-dollar mission here or there could go through without much problem. What I'm trying to get from there then, we all agree that science is a noble enough cause in this regard. Is it noble and convincing enough to the public to say to the public, the NASA budget, we need you to top it up so we don't lose the science initiatives it worked so hard to sustain. In your experience, where do you think this will play out?

Lennard Fisk

It's a complex answer, complex question. So I will give you a complex answer to that. I think most of us in the science program of NASA recognize that, without a healthy NASA doing a large program, the science program of NASA is not going to survive and not prosper. For all the times that the—For much of the history of the space program, depending how you did the accounting, the science budget of NASA was about 20% of the total NASA budget. And the science budget went up when the NASA budget went up.

In recent years the science has done better than the agency as a whole because of the spectacular things it's done. So today it may be higher, but throughout the history of the

program, 20% held. If you think about it, the space science program of NASA, taken together—earth, space, life science, is about equal to the national science foundation, which is all science, outside of NIH. And so the idea of an aggressive science program in NASA standing on its own is not probably going to happen.

But let me play the card in reverse to you. If you were granted the kind of money that went with Apollo to do the moon-mars mission, and you could sort of ignore the science program and go forth and build launch vehicles and go back to the moon and do all those good things. You have a problem that you want to sustain this program through multiple administrations on a relatively low budget, and therefore the variable is really time that you do it this over. If the content is the same, we are eventually going to go moon-mars, and the budget is fixed, then the only other variable is the time, and you know, this may stretch and not go as fast as people would like and so on and so forth. You need the science program in that context, and you need a healthy science program, because the science program produces results for NASA, visible, active results that people love to see in that context. The mars is having a wonderful time, moon can have a good time. But the broader science program as well is what creates in people's minds the sense that things are happening in NASA that are good things. If you wait for 30 years for it to end up on the moon, you know, no one may notice.

Pete Aldridge

Len, we have run out of time. Thank you for coming and sharing your views and the report with us. You can be assured that it will be one of the key reference documents for our deliberations. And again, thanks for coming down from Michigan, and hope the weather's good up there. Thank you. We're going to take a 10-minute break, and we will be back here at 2:35.

Thank you.

>> [applause]<<

Pete Aldridge

Ok. Could we please get started. Before we start the panel, we will before we start the panel, we will have a lottery, and here in this basket in front of me are names of the people that have been—that are going to win in order to be able to make a statement for two minutes. If they run over two minutes, we have this high-powered laser gun we're going to shoot them with. But I'm going to pick 10 people now, and if we, at the end of the session if we have any more time than that, we will pick out some additional names, if we have additional time. We will pick the top 10, and let me go down and do that right now, quickly.

Steven Solch, and we would like for you to come over here so when we are prepared, we can go right into it. Ray Zimansky, Shamansky. This is a question, but it's by Danny Cooper. We will let Danny come up and ask the question.

John Livingston.
James Brown.
John—I can't pronounce—Berenach, or e.
Do you know who you are? You got it?
Allen Thompson.
Three more.
Gerald Szkotnicki.
Lyle Kelly.
And the last one for now, Monica Ice. And that will with it for the time being.
We have some time, if you take less than your two minutes, we will have some time for additional people.

I'd like to welcome three individuals who represent the three large, probably the largest aerospace contractors, who create the hardware, software and people that operate many of our aerospace system today. I'd like to welcome Mike Mott, Vice President and General Manager NASA systems from Boeing, Jeff Harris, Vice President Strategic Management from Lockheed Martin's Information Systems and Solutions and Craig Staresinich, Northrop Grumman.

Gentlemen, welcome. We welcome you to the Commission meeting and look forward to your comments and before we get started and its just a public discloser I do sit on the board of Lockheed Martin and I'm therefore going to recuse myself from the discussions surrounding Lockheed Martin, and I believe one other member, Bob Walker—

Bob Walker

I'm a consultant with Lockheed and I will recuse myself.

Pete Aldridge

The way we'll handle this there won't be any issue in terms of programmatics here, I will point to each of the Commissioners who will ask the questions and the discussion will be between them and the participants. Mike, thank you for coming. You are up first.

Michael Mott

Ok. Good to be here. Thank you Mr. Chairman, and members of the Commission. It's my pleasure to join with my industry colleagues and be here to testimony. As I understand it we have a very specific homework assignment from the Commission to discuss the challenges of managing a layer program that will have a large program with a 40-year road map that will maximize long-term multiple system and receive intense public and technical scrutiny. The challenge is you have asked each of us to do that in five minutes.

If you think about it in May of 1961, when President Kennedy committed our nation to go to the moon, John Glenn had not even orbited the earth, yet within a decade our world

was changed forever. President Bush's announcement had a profound effect on all of us, not just as Americans, but also as industry, collective enterprise, avocation of advancing aeronautics and space technology. This national vision will offer direction, purpose, rejuvenate our sense of challenge and national pride, this vision has the capacity to inspire people and cause them to find the very best they have to offer. More importantly, the new national vision offers an affordable and sustainable path to demonstrate America's commitment to the exploration of space, however the vision is only the start of the journey. The President has the privilege of only doing the first viewgraph if you will.

We've got a lot of work to do to meet this challenge to do all the back-up required for that. The issue you have asked us to address is not so much a matter of vision, but a matter of execution, and that is the challenge of both management and leadership. The complexity of developing, integrating and operating the dozens if not hundreds of robotic, human and telerobotic systems to launch, assemble, transfer and land and build permanent human habitats on the moon and mars far exceeds anything we have attempted to do in space before.

We have been building the vehicles in space for a fairly long time. We know how to do that part of it. We have been integrating complex, adaptable complex systems and know how to do that as well. Can we function as integrated and diverse teams and can we cooperate on an international scale? Look at the international space station. When completed, it will have taken 88 missions to space to assemble an outfit, launching 100 major components on NASA space shuttle and Russian vehicles, that is truly a global project involving the science and technical resources of 16 countries and efforts of more than 100,000 people throughout the history in the largest peace time effort ever. Think about it.

On our first assembly mission, we took flight hardware that had never been closer than 10,000 miles on this planet, rendezvoused, docked and assembled it, 250 miles on orbit, traveling at 5 miles a second, turned on the light switch and everything worked. That's a real credit to the leadership of NASA, the international partners and the contractors working on this historic program.

There's no question in to my mind, we can do this, we can step up and execute the President's challenge. A little over 10 years ago a group was assembled. A very senior space program managers group was assembled to discuss lessons learned from managing very large program. General Tom Stafford, who let that effort, presented many of the legacies to the commission in earlier testimony. I would like to call your attention to just four of these lessons as a precursor to guidelines we think will have application in the future.

First, clean lines of management, authority and responsibility for all elements of the program. Ensure that one organization or prime contractor is clearly in charge. We have learned this the hard way on the international space station. I think we have the roles and responsibilities sorted out now on the international space station, but that was not always the case. I think the NASA administrator, Mr. O'Keefe, should be really commended for

putting this piece necessary together and making all the management, discipline and tools to make it actually happen. Number two, establish realistic program milestones providing clear entry and exit criteria for the decision process and create useful capabilities at each step. I think you had it about right when you asked us to think about 40 years programs.

I personally think we should be thinking in longer terms but the point is the same. We will have to have many clear performance-based requirements and milestones. And as soon as we know that we won't be able to meet the requirements, it is the design, not the requirements that must change. I know the Admiral Steidel, who is heading up the office of exploration systems, now at NASA strongly agrees on this point.

In the past, we have had it exactly backwards, changing the requirements to meet the design. This approach has historically gotten us in trouble. An executable plan always starts with a stable requirement, but no one is smart enough ever to get it 100 % right the first time and, in fact, situations do change, so there must be a mechanism to adjust. This mechanism just needs to be at a high level and it needs to be very painful. I also believe we need to set milestones that provide demonstratable success roughly every two years. This program must be able to show the American taxpayers that we are making progress toward our goals or it will lose the attention and support of the American people.

Third, I'm sure that the administration and the congress clearly understand the technical and programmatic and realistic cost of the program. It is a program that they know must last beyond 40 years and it's likely impossible to estimate the total life cycle cost with any degree of certainty. However, I know you have seen the charts of the NASA administrator displayed that shows something between $150 and $170 billion for exploration systems. Now I am not quite bold enough to sign up for a fixed-price contract but I am pretty confident think we can get to the moon and probably pretty close to mars $150 - $170 billion. As we settle on architecture, we can certainly estimate the cost of the near term projects over the next 10 years with enough certainty to let the American taxpayers and their elected representatives make an informed decision.

We in industry, NASA and even DoD have historically accepted overly optimistic cost and schedule numbers. DoD has recognized this problem and established the cost analysis improvement group (ga16) to act as an independent cost assessment team. A recent and very distinguished senior acquisition executive relied heavily on this group to provide the reality checks necessary to the estimates generated by the program managers and contractors and then insisted that the services or agencies fund programs to CAIG level. This is an important step in the right direction. NASA should consider something like the CAIG.

Mandate simple interfaces between elements is number four. Here we have a principle that applies directly to what we refer to now as the system of systems approach. We must work to create open architecture that allows us to bring in new systems and technologies as they are developed in an endeavor which will last many decades, we cannot lock in to any single system or technology. The open architecture approach can only be achieved

by focusing on clean interfaces and nonproprietary standards. So, where does that take us? One of the most significant changes in the aerospace business in recent years has been in the complexity of the work being managed.

We are engaging in programs with enormous levels of complexity and technical independence that far exceeds what we have done in the recent past. Programs like missile defense, future imagery architecture, future combat systems and the international space station involve a level of systems interdependency and requirements for timeliness and precision that most would have been unmanageable is program in the past. The key to all of the programs of system to systems is the systems integrator. The decision on how the system integration will occur across this complex of systems of systems that will be necessary for system enterprise must be made sooner, rather than later. As government and industry developed the lead system integrator function, it's in reality more of a mind set or mode of operation than a particular organizational structure so let me address some of the keys to the success of this lead systems integration.

First, the lead system integrator must own the system architecture and have the tools for enforcing requirements. One of the early lessons again from the international space station, without the contractual tools necessary to enforce the requirements, the LSI was just ineffective. By similar token having some reside in one NASA center while others reside in another is a recipe for disaster. Once requirements are set the LSI must be ruthless about the enforcement. The second key is collaboration. Ronald Reagan once said it's amazing what you can accomplish when you don't care who gets the credit. This needs to be the attitude of all of us.

The LSI must bring together the best of NASA and national labs, DARPA, and other government agencies industry and academia, and as a former marine, it bugs me but we got to bring in the United States Air Force as well big time. All working together in a badgeless environment for what is best to do the nation. The team must be able to draw from the best of industry, government and academia and integrate these technologies and systems seamlessly into single systems of system.

The third concept of operation is interdependence. The LSI must maintain an arm's length independence from actual hardware production. While we will have certainly have hardware producers represented in the LSI, but the function of the team is one of architecture and systems integration, not the hardware.

The fourth principle is developing of systems of systems engineering tools, the most important developments in the revolution in military affairs occurred in modeling and simulation and other systems of systems engineering tools. We understand the interoperability of these systems well enough before we begin the first mission, the first piece of hardware development. The LSI must continually remodel the architecture as new technologies and capabilities come together.

The fifth principle is open architecture. There is just no one that I know of can imagine that when humans land on mars or perhaps even Europa, there will be the technologies

we have in hand today. In order to assure that technologies can be used, the architecture must be open. We must be able to ensure spiral development. I have no doubt that the program managers that we are training will be up to the task of managing the incredible complexity and uncertainty of this endeavor that the Commission is evaluating.

There's a drawing at NASA headquarters from a third grader of a rocket exploring the solar system, on it she had written the caption, "we will never know unless we go." How does that saying go, ". . . And the children will lead them." America's successful goal-focused initiatives have produced a spectacular record of success which have benefited all humanity. I know that we won't let that third grader down that 50 years from now will be reminiscing about the first landing on mars and the challenges that are yet to come.

This is all about making a difference for the future and our children's future. Throughout history, America has been blessed with many things, and one thing that always seems to me is that we have the right people at the right place at the right time. As I travel around the country, I am pleased to see that it's still in such very capable hands. Thank you very much.

Pete Aldridge

Thank you, Mike.

Jeff Harris

Thank you, Mr. Chairman, Commissioners. We are pleased to be here today. Mike, thank you for the good setup. I have spent my whole career in government and Lockheed Martin, putting together complex systems that had to be system of systems.

To begin today, I recall a story following one of the great DoD success stories, where a foreign minister went into the secretary of defense's office and congratulated the secretary on the military victory. and said, but I have just one question, how did you get it to all work together so well? And it was clear as the secretary answered the question; it is the people, processes and the ingenuity that cause us to get to a system of systems environment. As my title slide says, system of systems for the challenges that we have here is one of the more important things that you will do, and as many of you on the Commission know it's easier said than done.

My second slide, as Mr. Chairman, you mentioned, mission success must be paramount when you do something this hard and it is clear that everyone on the team understands that they are on the same mission, and their working towards the same goals. The easiest programs I have worked on in my career is when everyone wakes up every morning with a clear idea of what the criteria for success is. And when they focus energies against that mission success, the job becomes easier. Doing it right the first time isn't necessarily how you begin the job. It is that clear focus on what needs to be done so you can anneal

the process to get to the desired outcome that will require the leveraging of many different organizations and infrastructure.

And what's important in this point is, you are leveraging the expertise, not the whole organization, not the whole kit and caboodle. Pulling the pieces together to form the new team together for the collaborative sense as testimony has pointed out today. Every program manager knows there's a milk stool that balances cost, schedule and performance. And in this particular system, it will be the milk stool across many different systems and platforms, and each one of those have to be carefully traded, so if the organization does not allow the decision process to get their arms around early on, the trades between these, one of the elements will become a run-away element and the system won't close.

In a system that spans several decades like this, it is not enough to control the three legs of the milk stool; you must control the fourth element, which is time. As you are developing through different time elements or epics, the spirals and the sub-spirals have to be controlled, so you understand how they are interrelated. Having two people come together with the interface works but they're in the wrong spot in time does not work. When it is an aggressive reach, you have to manage risks. The risks have to be traded and you look to your system engineers to sort out what is real, what is fake, what is the path forward.

So systems integration, systems engineering, integration and test, see it, you must do it early, you must do it often, you must do it continuously. We describe this as a thick integration capability where the bench strength has the experience and resources in order to allow the process to move forward smoothly.

My next slide.

This is really the recipe. The take-away box on the bottom, the program manager is really the CEO. Of the enterprise, setting the vision, the mission and allowing everyone to know where it's going. To see it function is the eyes, ears and muscle of the program manager. Again, that thick integrator is the muscle, it is the open architecture, it is the definition, it is understanding via parametric analysis, how to determine the requirements, trade the requirements and allocate them out to the important subsystems and software or operations. What many people learn too late in a program of this complexity is that more requirements come through the interfaces than come through specifications. So everybody says, if I have gotten through the a-speck right, I can release everybody off.

And what we have determined over decades of scar tissue, is that when the interfaces come in and bring more complex requirements to the table, if they are not treated with even the same emphasis, if not more emphasis, the system will have some lack of control that can spiral. That leads me into right the passion for configuration management. It is a process. It is where someone is driving timely decision making, so that the configuration is always understood across several hundred thousand people and numerous organizations conducting the program. Where you are managing risk, you're managing

margin of that risk, all the TBD'S and TBR'S. What needs to be determined and resolved must be done in a process to easily flow into the test verification. This cadence for program execution is how you measure. You cannot manage if you do not measure.

My next slide.

When you are looking at cost schedule across cross program synergy, it is the see it function, system engineering, integration and test, begins first in a program, executes throughout the program life cycle, watching out for the program manager to make sure you are closing around the mission, the mission that everyone understands. You require the best people. The people have to have scar tissue and have to have this consistency of purpose that I have mentioned several times. Everybody says you have to break the program down into small bite-sized pieces to execute. They call them IPT'S. Many don't recognize is "I" stands for integrated, not independent.

The fear of independent program teams or independent project teams each running off and getting their job done but not being able to come into the middle is something that you must guard against very carefully. All of these complex programs if they don't have a process to make timely decisions and communicate those decisions to the far reaches of the program; you are wounded before you even begin.

On my final chart there are several models to take a look at systems of systems integration. I put only two up here. Reflecting on what mike said, starting from the bottom bullet. The organizational conflict of interest is important. You architects and your system engineers ought to be separated away from the industry teams that are doing the hardware and the software so you have the natural tension that we recognize at the national level, at the program level. The industry and government has to be equally engaged, government must, must, must do the job that they are chartered to do and must reach out to the breadth and expertise of the industrial team in order to accomplish programs that are this complex. As you can see no single person can do it. On the case of the left, the national teams is a function to get a lot of good ideas on the table quickly, to understand the breadth and depth of a national missile defense capability. On the right where we're honing several decades of experience with the transformational communicational architecture, the see it brings the specific skills of many companies together in order to go accomplish the transformation of the department of defense with a global information infrastructure. The full spectrum of mission support is required. The see-it team is the muscle of the program manager to go accomplish the objectives. Thank you.

Pete Aldridge

Thanks, Jeff. Greg?

Craig Staresinich

Good afternoon and thank you for the opportunity to speak today.

As a matter of further introduction, I spent the first 14 years of my career in space industry with Johnson Space Center at NASA and mission control on Apollo, Skylab and space shuttle missions, so this is extraordinarily exciting to me personally.

Next chart please.

This chart shows that Northrop Grumman had a 45-year partnership with NASA in mission success ranging all the way from Pioneer I in the late 1950s to the programs that you see on the upper right-hand part of this chart, Chandra X-ray observatory, the earth observance system space informatory mission and James telescope. I would like to focus on the third from the top. The national polar orbiting operation environmental, space satellite system or impose.

Next chart please.

I'd like to focus on this because it's really a good example of systems of systems. This program is made up of, if you replaced the word segment with systems, the space system, command, control communication system, launch support system, data processing system and field terminal systems. It's a good example of a typical program that has systems within systems.

In designing systems for moon and mars, NASA will lead the integration of a similar set of system elements, manned and unmanned space vehicles, communication, and routing systems beginning with today's infrastructure and heavy lift challenge, and also a set of users including scientists, academia and researchers who have diverse expectations and priorities on how the exploration data and artifacts should be made available to them.

Can I have the next chart, please?

On this chart, you will see the complex system elements I just talked about in right hand column of this chart. If you back up to the center column, the element of overall systems management whether they're led by NASA or a contractor, they are listed here. Including management of overall integration and acquisitions, operations leadership including conops. Oversight of technology, developments, definition of expected business models and ensuring adequate funding for the overall system. In the far left, you'll see the infrastructure that enables sufficient user input from systems conception to completion of the system concept.

I would like to suggest there are six management factors that are key to effective systems of systems management. First in a system initiative as comprehensive as the space exploration initiative, it's critical that responsible visionaries articulate the overarching system objectives that will govern the system in the way it will be implemented, likely emanate from the center management column. One visionary path might include surveying all available and applicable knowledge and proceeding through a road map of missions which incrementally enables progress to the moon, mars and then beyond. An alternative concept could start with the final objective of mars and work backwards to

identify the highest leverage risk reduction initiatives and associated expenditures to accomplish the final objective, this suggest minimizing dollars spent on technology and developments that do not substantially support the mars objective.

Secondly as indicated by the far left hand side of this chart, our experience base suggests that systems of systems management begins and ends with the users. For NASA, these are the scientists, experts in universities and national labs and academies and international partners. Our experience with system of systems initiatives suggests user interface management is not about a one time input to systems definition, it requires a substantial government-led infrastructure to cull requirement inputs and manage the inevitable requirement creep that enters into these systems as an ongoing process.

Third, regardless of the acquisition approaches and user interface selected, system to systems management on large scale requires that key responsible authorities take their leadership role in managing across and beyond not just to the interfaces. Our engineering managers at Northrop Grumman are expected to understand both sides of an interface and we actively nurture a culture that supports this attitude. Effectively, working beyond interfaces and systems management requires active customer support.

In our defense programs we find that open communications during the acquisition process, appropriate incentives and planning phases conducted in a cooperative environment with customers and users are crucial for the requirement of long-term contracts. Another element of work and beyond begins with modeling and simulations. This was discussed earlier. These capabilities can promote mission success for large systems in several ways when performed at system level at early phases during the early phases they provide valuable input before committing to a design. Simulations that emulate the system and model interactions as well as the effects of failures must necessarily incorporate interface knowledge early in the developmental cycle.

The interactions necessary to create simulation are key to organizational learning and simulation capabilities maintained over the life of the program enable us to test new technologies and interfaces without putting live operational systems at risk.

May I have the next chart, please?

I want to talk about organization process and threads. On a large scale integration effort we actually work hard to ensure that all individuals contributing to the system understand their role and understand how it affects the rest of the system of systems. We place strong emphasis on organization, teamwork and collaboration. We actively seek individuals who are trained to think in threads. Threads across the organizational boundaries. We use technology to tie geographically diverse elements together. We integrate customers and users into our IPT's rather than reporting to them separately.

Process management becomes a common denominator and we negotiate process assumptions between organizations and teammates for everything from software plans to requirement flow down to verification databases. The larger the integration effort, the

more critical the management of systems organizational cultures, processes and threads becomes.

Fifth, talk about technology. During the design and development phases as well as throughout the life cycle of a moon-mars mission, technology is clearly a factor. We pride ourselves in managing technology and are strong advocates of development gates for system of systems. Gate discipline ensures that we don't move out faster than technology is available. We also use it as a way to eliminate losing technologies. And sixth and finally, systems management on a large scale requires broad system level thinkers trained to think in threads.

NASA'S vision for space exploration will inspire a whole new generation of youth. We at Northrop Grumman are beginning to see more of a system of systems and mission systems engineering, emphasis in college curricula and this should support NASA's future. These broad thinkers will oversee the whole development of lunar missions, new applications and robotics, new laser communication applications and mission planning involving a number of space vehicles. They will learn the skills of broad thinking through educational and practical experience. These six points are really only a sampling of the kind of factors that contribute to the culture, processes and initiatives inherent in large system management capabilities. Thank you.

Pete Aldridge

Thank you, Craig. Questions?

Les Lyles

Yeah.

Pete Aldridge

Les.

Les Lyles

Jeff, I'll address a first question to you. You bring an interesting perspective and a varied one to this particular topic. Having run the NRO, running a small space company, space imaging activities and now being part of a larger aerospace company, I would like your thoughts on the subject of private sector interests and involvement and stimulating interest in this particular vision since you have done that in a couple of venues now. Any ideas on things that this Commission might want to make comments on or NASA might want to address as we try to make sure we have that part of the equation looked at?

Jeff Harris

General, an excellent question. I would answer it with the focus on people. In my experience in government, it was building small teams of dedicated people that, again, know what the mission is and give them the resources to go get the job done.

In that construct, that team immediately went to industry so that in the first program office I worked in, 60 or 80 engineers would leverage 80,000-100,000 people in the private sector reaching through the systems engineering integration function I talked about. In the private sector, it's important for them to have jobs that are important, and that they have a customer that pays attention to what they're doing, because they want to be part of a team. It's a buyer-supplier relationship but in getting these hard technical jobs done, there were simple tests.

If you asked a private-sector team to work overtime to get a job done and have it faxed in that night, if the private sector noticed that you weren't in the office to receive it when they sent it in, that did more to disincentivize the team than anything you could do contractually so it was that sharedness that went to do it. My experience with a small company was very interested because small companies have an amazing agility and ability to get the job done because we try not to smother the process.

Watching a small company develop its ISO certification was interesting because they took that agility—I can call the ISO certifier coming in and saying I never had a company pass this easily the first time as a commercial company. I said have you ever certified a space company before? He said "no." "but you guys are even more attention to detail than the pharmaceutical companies." And I said, "pharmaceutical companies only kill people. We kill satellites."

But it was the sense that there was only one satellite and we had to take care of that in a process that was good, and she went on to say "you had a procedure for making sure the refrigerator got cleaned out every Saturday" but it was that attention to detail but again it was forming the team up. In each one of those it was a focus on process and people that was inclusive.

Pete Aldridge

Carly?

Carly Fiorina

Forgive me in advance if the wind-up to this question is a little long because I want to explore something with you. One of the things we have talked a lot about with other panelists is the elevator speech of why we would undertake this mission. And I think one of the more compelling elevator speeches we heard, and something that I believe virtually all of us on this panel believe is one of the most compelling reasons to undertake this mission is because it will create the skills and capabilities that we need as a nation to

compete and prosper in the years ahead. That implies that this mission is more than building a vehicle that can go to mars.

That in fact, this is about creating a national priority that involves many, many aspects of society—indeed, many aspects of the global community, not simply private industry, not simply NASA or DoD but the education community, the university community, et cetera, et cetera.

The management tools and techniques that you have described, which are clearly very effective in accomplishing a specific mission where very clear set of accountabilities is required—it works. I would certainly agree with you that systems-level thinking is required, and that is a different kind of thinking than others, and it's a skill we need to develop as a nation. My question would be, as we think more broadly about this mission, a mission that involves lots of different constituencies, in this nation and around the world, that involves more than getting a vehicle on mars, for example, are there lessons that we can learn from the systems thinking that industry has developed? Are there lessons that we can learn from a program-management approach that could apply more broadly?

Jeff Harris

I think it's a very good point and absolutely. We've used the word amongst all of us in previous panelists about collaboration. One of the messages in collaboration is getting to a shared set of values. System engineers are a very useful glue in a program to get you to share values. Early on, when I was just understanding what worked and didn't work as a young system engineer, I would watch a decision get made at 10:00 in the morning and I would test at the end of the day if it had flown to the end of the system, because it's a time is money and had we actually gotten it out there without much delay? If you think about national priorities, Rosie the Riveter is my hero.

It was clear that the country had a priority, and everybody knew what their role is when we were producing aircraft in order to go win something that's really important. The race to the moon was the same place. People understood why it was a race. I was interviewing in my office when I was in the pentagon the designer of the soviet booster, and he was describing each of the failures.

And after the fourth failure he described, I said, "what happened next?" And in his broken English at the time, he said, "Americans landed on the moon. Program over." And it was clear how the race -- this was after the wall had come down—how important the race was to them to develop the technology, to focus on the goal and to get the job done. As we reach out to the youth of America, it's important that we get them excited.

I adopted a grade school near the National Reconnaissance Offense and I have—office and I was doing the opening ceremony and I was ill prepared for talking to third graders. I reached in my pocket as I ran out the door a little model of the rocket, and I'm

explaining the robotics versus manned space flight, and I held up a model about this size, and I said to the next generation of leaders, "does anybody know what this is?"

A little hand goes up in the back and says, "it's a Titan IV" and of all the answers a child could have given, "you're hired. Come right here." I just couldn't imagine. But here was a work force that's in the Washington area that has their parents engaged, and so when the President sets an agenda and everybody gets behind it, it really does work. So this is exciting.

Michael Mott

I think Jim Webb, when he was the administrator that did the Apollo program, I think one of the things that he took away from it that he actually tried to talk about in the future was the fact that we, in fact, did it, from may of 1961 and we landed in July of 1968, that's pretty darned impressive, of the program undertaking they did in fact have 4% of the federal budget, but the reality that they could manage something that complex is dazzling. And I think that one of the great things that would come from this, the mere fact that we would have almost the audacity to go do it and then we would generate the skills, I think Senator Glenn pointed out early it's the same kind of challenge, not only the research challenge, the scientific challenge but the no-kidding engineering and management challenge to put a program of this complexity and actually make it work. And I think the lessons that we would learn from that, that we would be able to share in a systems-like thing, regardless of what the system is would have enormous positive impact for industry, American industry and for the world, for that matter.

Pete Aldridge

Michael.

Michael Jackson

I would like to ask you a couple of questions about how you can take lessons learned from successful system of systems projects that we've seen in the government, the most successful system of systems work, and think for us a little bit about the structure of the governmental entity that has to run this, NASA? Is it up to the job? Is it structured right? Does it have the right type of assets?

Does it have assets that are going to be an impediment? Think a little bit about lessons learned from success stories and then try to do an analysis against what you see at NASA. This is not about throwing rocks at NASA. This is about saying how do we think through the organization that will sustain such a broad-based program over so many years with the type of skill sets that are necessary for success?

Craig Staresinich

Let me take a shot at that. This goes to the earlier question about lessons learned in generally. I think the larger system you manage the more imperative it is to establish good communication ties. Communication becomes a more critical issue. I think it's also incumbent on the leadership of this initiative to make sure that they get everyone involved and be able to hear what the people are saying at the lowest levels of the organization.

That's a lesson we've learned in several of our aspects. To answer your question, sir, I can only comment on a program that I managed called the Chandra X-ray observatory for Marshall Space Flight Center. The thing I thought that made the program most successful was the almost badgeless interaction between the government and industry. We had their engineers sitting side by side with our engineers, working issues as they came up. There was no communication gap because you were side by side with them. And I think that's a lesson that if we can instill, and the larger the system the more important it is that all parts are well integrated to close the communication gaps.

Jeff Harris

I had a meeting with Admiral Ellis, the Commander of Strategic Command a few month ago and he was reflecting on operation Iraqi Freedom, and he said a lesson learned is not learned when you just write it down, so I think it's understanding that and continually communicating and training so that people respond. When we tend to do when we see a problem we don't like we call out the uh-oh squad and everybody points out the problem and makes uh-oh sounds but you're not taking the necessary steps to get your arms around it and quickly move on to the solution.

Pete Aldridge

Neil.

Craig Staresinich

We're becoming a much more process-oriented organization, and I used to think the same way that lessons learned are important and you've got to write them down. I agree with you, Jeff. You've got to incorporate them in your processes so that everybody uses them. Don't just write them down.

Michael Jackson

That was a very polite answer but you didn't really answer my question so I'm going to give you a chance to take a homework assignment, as we have said.

Craig Staresinich

Ok.

Michael Jackson

I mean, honestly, do they have the right people, resources, organization, structure, assets? Are there impediments in the assets that are there? How do you take the centers and harness them to a single big mission? What sort of procurement technologies and tools have they used? And do those need to be changed?

There is a huge fulcrum of success around organizing NASA and managing NASA in the right way to make this work. You can have the greatest team of support mechanisms from teachers to—you know, big system integrators, but if you don't have the home-base organized right you lose, so that's really what I'm asking you to thinking about and help us think through.

Craig Staresinich

Ok.

Pete Aldridge

Neil?

Neil Tyson

I have a question that probably doesn't need more than one of you to address but is certainly applies to all three of you. This third grader who knew that it was a Titan IV, I don't suppose the third grader also knew that your industry has undergone considerably consolidation over the past 15 years and having lost the half a million jobs at some last count that I took, so there seems to be a disconnect between the message that we're going to have to try to put out in our report to attract fresh talent into the aerospace, engineering, scientific pipeline and the reality that exists in your industry today. Could you comment on the—What your—what the aerospace industry looks like today for such a vision versus what it looked like 20 years ago with the breadth and depth of activity that went on given the number of companies represented as competing forces towards a vision?

Jeff Harris

I'll take a quick answer since I started with the anecdote. My purpose when we adopted the grade school was when I recognized we were losing young women from math and science before sixth grade and we had to stem that loss prior to—I read the article and said, "let's go get a grade school." By adopting the science fairs and getting them to interact with our people all the time, and then grow up and be able to do interns within

the organization, I think the chasm between their school experience and coming into industry was somewhat reduced. The other end of the spectrum speaking from Lockheed Martin of the 130,000 employees that we have given that the age of the work force, given the way the last couple of decades have treated this industry, we're hiring some 50,000-60,000 people over the next couple of years as we readjust to get to the right age groupings so I think we can talk to these groups and say there is a great opportunity, so given an exciting job and a great opportunity, we're back to making it a career.

Michael Mott

Neil, when we were out talking to universities prior to January the 14th, it was very much like Jeff said. "why in the world would I come to work for big aerospace? Your all's track record is humble on a good day." Since January 14th, now they're excited. They believe in this.

This has never been a question in most of our mind of when, it's—or a question of if it's just a question of when and now we know when. And so the excitement that we're seeing, or certainly that I'm seeing in my travels at the university level, and certainly at the grade school level is just—is awesome, and in fact, you start looking at the time line on this, it's going to be these grade school youngsters that are going to be the ones doing this mission not the—not the folks who look like me, so we've totally changed an excitement level literally since the 14th of January.

Pete Aldridge

Carly, do you want to follow up?

Carly Fiorina

Back to this systems of systems and can we apply it to even a broader system, a little bit consistent with Neil's question, at the same time that we have developed through a system of systems approach in many cases, the most effective military capability in the history of the world, the science, engineering and mathematics capabilities of our nation are the most imperiled on a relative basis that they have been, so clearly, we're not solving, yet, one of the fundamental issues that I think faces us with the—with this mission, so perhaps as a homework assignment I think one of the things we're really struggling with as a panel is this will require to your point collaboration, communication, alignment of goals and objectives, and a systems-level thinking applied to an incomprehensibly complex and -- to an incredibly complex and diverse set of constituencies over a multi-decade period. That is a system of systems opportunity that I would argue is more complex, and more encompassing, than anything we've yet accomplished. So the question is can we leverage what we have today into that even broader and more complex realm?

And if so, how might we do that? I think that's one of the things we're struggling with.

Michael Mott

I think in a lot of ways, we are doing that and we're managing a lot of different systems that we haven't managed before. I think the international space station, when we started down that path a lot of years ago has changed dramatically, and again actually doing that and doing it on orbit is very impressive. Each of our companies, and there are certainly a lot more examples out there if you look at what's going on in things like missile defense, and all of these kinds of things, being able to—to put all of that system complexity together, and when you look at—it's much more than the lessons learned, it's understanding what are the best practices and making darned sure that they get implemented, and I'm—I don't know how my colleagues do it, but we have a no kidding, honest to gosh formal process in program management for any of these large-scale programs, and it's a grade sheet that we ensure that they're implemented.

And as you—and as the programs get more complicated in the integration across—we talked about the integration across the boundaries which is always the real tricky part, is more complex. I love Jeff's comment about it's not independent, it's integrated and a lot of IPT'S, they don't understand that, and it's trying to make sure that they work together and that their piece that they're going off to fix is able to do that, but this is not—as Jeff said, it's a lot easier said than done but I think, again, in industry, we have demonstrated that we can do it.

A colleague of mine once commented aerospace was a lot more fun when you didn't have to make money at it. We launch a rocket, stick it in the water, and go "nice try, we'll get the next one." That's not the case anymore. So the industry focus on how to do go these things is much more process oriented. It's just an entirely different game, and we do have a lot of scar tissue over the last eight years to show for it.

Pete Aldridge

Unfortunately, we've run out of time. I would like to thank the panel for sharing your views. If you do have any comments as we've asked you for homework assignments, we have the website, and you could send it in any way you like but we would be interested in the overall management approach of how we manage this systems of systems in a better way than perhaps we otherwise would have done.
Craig, Jeff, Mike, thank you very much. Ok.

We now have the opportunity to hear from the audience. I picked out the names, and I will not call them in that order. I will just kind of randomly call the names as they come about, ok? Pick—what—the timer, and that's the laser beam fires at two minutes? Ok. I'm going to—I didn't put them in the right order. Lyle Kelly.
Lyle, would you come up and --

Lyle Kelly

Thank you.

Pete Aldridge

Is the speaker on?

Lyle Kelly

I think it is. my name is Lyle Kelly. I'm a Procter & Gamble engineering retiree from Cincinnati currently with the mars society. And I have three thoughts on sustainability I wanted to leave with you. Three things, I think, will help with sustainability are, one, the attention of the public. We have to keep the taxpayers plugged in and I think we can do that by having simple goals that they can understand and hang on to. I would see those goals as mars by 2020.

That goals—those goals need to be articulated well and frequently. We have a short attention span here in the public. Also, milestones that can be achieved and touted that give a sense of pace will also help keep the attention of the public. The second factor is low cost. If we're going to sustain this across administrations and sessions of congress, we have to be below the radar screen of the cost-cutters. So I would contribute two items that will help us with low cost. One is a simplified architecture, both the hardware and the whole mission architecture. And secondly, building off existing technology rather than having a huge R&D investment will keep costs down. And the third factor is private enterprise. Here, I have in mind the kind of enterprise that involves the public, like space tourism. I haven't heard anybody mention the X prize these last two days.

To get tourists into suborbit will involve more of the public. The more we can do to get the public physically engaged, personally, in space the better off we'll be and the more they will be willing to contribute to that sustainability.

Pete Aldridge

Lyle, thank you very much.

Gerald Zakniki. From the Wallace Kettering Science Institute.

Gerald Zakniki

Thank you very much, members of the committee.

Pete Aldridge

Put the microphone closer.

Gerald Zakniki

I just have a few comments to make. I think it's a wonderful opportunity for everyone to learn about this exciting project and I think what many people are approaching is what new things can we see? What are the gains that the civilian can predict out of this

project? And it's clearly they can't be predicted so it's hard to get your arms around what eventually this project will lead to, but one Comment I would like to make is many observations regarding collaboration. In that I think the more diverse a group that collaborates on a project the more innovative the approach is and the more surprising the results we have.

Working in the neurosciences, we look at some of the research that's being done, we have scientists and physicians, neurologists and neurosurgeons who work on process, an interdisciplinary team we think about approaches that otherwise a single unit of those would not even consider. Recently, we had an opportunity to have Mr. Gerga Bringen, cofounder of Google here as a guest, one of my colleagues, Rick Novak has put a little group here and we started talking just about how information is managed, stored, retrieved and prioritized on groups of computers on the internet and he was trying to find models among how the neurons of the brain and parts of the brain work together to see whether there are some things that can be learned from these different disciplines to apply to a new project. I just wanted to end saying there is tremendous opportunity with—what we'll learn in this process and what can be applied through technology transfer along the way and with the infrastructure we have in place now, like the third frontier project that Governor Taft is putting together in Ohio and many other states are doing this technology transfer and opportunity for new civilian benefit will occur at more of a real time basis than ever before, so we're stepping -- we're stepping into a river again, but it's never the same river.

Pete Aldridge

Thank you very much.

Alan Thompson.

Alan Thompson

Thank you, Chairman Aldridge, members of the Commission—

Pete Aldridge

Would you get closer to the microphone, please.

Alan Thompson

Is that better?

Pete Aldridge

Yeah.

Alan Thompson

First, I would like to state I support the ultimate goals of the President's mission. However, the implied strategies to implement this appear to be the same strategies we have used in previous policies. Today, we had a group of students here. If we wish to motivate and retain this knowledge in the future, we must utilize strategies that can sustain the policy, educate, and create jobs independent of government programs.

I think everyone would agree that implementing a space policy currently proposed will require all resources within the manned space flight sector, solely dedicated to lunar and mars exploration. However, we also understand that sustaining—that we must sustain the policy, and it will only be sustained if the American public perceives manned space flight as affordable.

We could agree that the public's perception of affordability would be significantly improved through implementation of strategies that could include the development of a manned space flight sector, which is independent of federal funding. My question, is the Commission looking at these types of strategies? And if so, would the Commission recommend these strategies within the framework of the proposed policy even if it means adjustments to this policy? If it is not, is the Commission suggesting that the U.S. focus solely on science and its resources solely on science? And exploration?

Pete Aldridge

We're not here to answer questions at this point in time.

Alan Thompson

It's just a question. Because our group has formalized a strategy that we have put out on a website and we are being requested from foreign interests to respond and actually work with them. And it's not really something that fits into the President's space mission, but it does fit into an independent commercial space sector.

Pete Aldridge

Ok. got it. Please provide your input to the website.

Alan Thompson

In fact, you guys already have it at the website and I believe Dr. Tyson has my card.

Pete Aldridge

Thank you.

Ray Symanski.

Ray Symanski

Good afternoon. My name is Ray Symanski. I spent 31 years here at Wright-Patterson Air Force Base, home of the little green men. What I have to say is probably not as deep as my predecessors or what's been going on. This is a really serious Commission. But I want to personally thank you for taking time out of your busy schedule yesterday to show your support for a local science fair. This is going to be presented to Mrs. Georgia Rosier, who spent nearly 40 years teaching the sons and daughters of the scientists and engineers who have worked on this base, and our only question is whether or not she's going to faint from the excitement, and I hope you don't mind that Senator Glenn added his autograph to the top of this.

Pete Aldridge

Terrific.

Ray Symanski

I would like to say that if you need another grain thrown into the big bin of things to do while you are up on mars, I mentioned the little green men and Wright-Patterson Air Force Base you recall since 1947 the UFO term has been in our jargon, and perhaps after 50 some years we might want to put another set of eyes and ears up there to determine whether or not we are alone. A famous man was once asked, "Do you think we're alone in the universe?" To which he responded, "I certainly hope not." Thank you.

Pete Aldridge

Steven Solich.

Steven Solich

Good afternoon. I wish to thank the Commission, first, for opening up this forum to the general public so that we can express our vision for exploring the solar system. My name is Steven Solich and I'm a systems engineer, born and raised in Dayton and educated at Wright State University next door. My partner and I own a small business headquartered here and our company, digital concepts incorporated has been providing information technology services to the Air Force and to commercial clients for about 20 years. But I believe our company represents those companies that are the backbone of innovation and creativity here in this nation.

These companies generally have less than 50 employees and a revenue base of about $6 million or less a year. My hope is that the vision of this Commission include a strong recommendation to involve and exploit small-business capabilities to solve the technical issues that need to be solved for this exploration goal. The space initiative must progress over a longer time frame than any previous space program in the past, and to be successful we must go back to stay.

And I believe that small business such as ours have the long-term vision to engage these goals and to provide the required creativity to help advance the necessary technology. Imagine the impact to our economy as many small businesses join together with the Air Force and NASA to solve these technical problems. But even more important, these small businesses would help sustain the national vision, the critical ingredient to what we're trying to accomplish here.

I believe that if the small business becomes significantly engaged in the space exploration initiative that the positive impact to our economy and the advancement of technology will dwarf even the results of the race to the moon. Thank you very much for this opportunity.

Pete Aldridge

Thank you.

I think your goal is to make small businesses big businesses someday, right? Ok.

John Bernoch, is that right?

John berneki

I'm John Berneki. Two comments. The first one. The propulsion technology -- The propulsion systems are the primary system determining factor. The technical specifications of the propulsion systems determine everything else, really, determines duration of the mission, number of people that you can carry, the logistics. So I'm kind of wondering. The plan that's been put forth and I know it's similar to the Zubrins book may be putting the cart before the horse, that's my concern. Maybe we should instead be focusing on propulsion technology and make a crash program out of that and develop the high-thrust, high-ISP engines that are necessary to make this mission occur faster—make the flight times lower by having higher thrust and that sort of thing.

The second issue that I hear various speakers talking about the costs, overall program costs, the need to keep it contained. Well, I have—I have the solution to that. I know how to keep your program costs under control. In fact, I can tell you how to do this whole project for about 30% of some of the numbers that have been put out, and it's very simple. It's outsource to China and India.

To give you some idea of where I'm coming from, I started off as a starry-eyed kid who liked math and science, and the first 10 years of my career was in the aerospace industry. I was highly productive and enjoyed it a lot. Then in the recession of 1991 and 1992 I got out and went into the telecom industry, where I have been. Well, the biggest trend over the last three or four years in telecom has basically been relocating sources to China, training Chinese engineers, implementing ISO, and getting them to think in a process-oriented way and based on this experience I have with training Chinese engineers the it's

patently obvious to me that the next step up in this evolution that the economy has been taking is to migrate the aerospace industry to China. It can be done.

We can do it with cell phone technology and computers. It can be done with—you know, fighter planes and turbojets and avionics and navigation systems.

Pete Aldridge

John, is that the bottom line? Your time is up.

John Bernecki

I'm just concerned as a taxpayer, is it all going to go to China? Is that what this systems management and infrastructure are going to allow us to do?

Pete Aldridge

Thank you.

John Livingston.

John Livingston

My name is John Livingston. I'm from this area. I have been work—design engineer at Wright-Patterson since 1969 right out of high school. I went to school down at the University of Cincinnati. I worked my entire career in development planning and an organization by that name at Wright-Patterson Air Force Base for almost my entire career until that was disbanded and I now work for the Aeronautical Systems Center.

I have been working on access to space since 1979. I first worked the transatmospheric vehicle programs. I then worked the NASP programs and I was involved to some extent with Venture Star. Three multibillion-dollar programs. Three failures. All had one thing in common. They had an ill defined set of requirements. And there were solutions out there that were ignored and simply because they were not technically challenging enough. And I'm talking about fully reusable two-stage to orbit.

We have been involved with a lot of studies over the last few years here at Wright-Patterson on those areas, and I guess I want to make sure that you all are perfectly clear that there are near-term reusable launch systems, solutions out there that require—that could be fielded with IOC's in the 2012-2015 time frame. These are two-stage, fully reusable, hydrocarbon lock systems with the current state of the art technology—we're not using any advanced technologies. These systems close quite nicely with reasonable design margins and could be readily developed in those time frames. Now they won't have the extreme operability.

Systems that we could put together starting tomorrow and field in that time frame would have return times of in the neighborhood of 1-3 weeks. But with a little bit of technology help that you have seen outlined here today, that time could probably be dropped down into the 1-5-day time frame. So I just want you to be aware I know we have had so many failures in the last 10 years and spent so much money on advanced technology, we have had a technology out there that's been adequate to do the job, reusable two-stage to orbit that we could have started development at any time in the last 25 years. Now, you have to ask why haven't we? And the simple answer is missions. We do not put enough things up on an annual basis to justify reusable launch system. The ELV's, expendable systems, are adequate for the job, but if we plan to grow our market we have to not step away from the RLV's, we need to wade into that arena and solve those problems and get those things IOC'd --

Pete Aldridge

John, thank you very much. I understand you made your point. Thank you. The next speaker asked a question but I'll have him come up and maybe make a point. Danny Cooper.

Danny Cooper

Good afternoon. I'm a recently retired Air Force missile engineer. I have had recommendation—I have an answer to your question on why we're doing this. The recommendation I have is maybe looking at—look at what Senator Glenn provided as far as experience to the team today, adding somebody like that to your Commission I think would be somebody who can test your ideas and strategies, so somebody from the astronaut corps like John Young.

Secondly, answer a question why. I'll go back to 1961 when I was about five years old when John Kennedy said "why not? Some people look at the world and asked why. He looked at the world and asked "why not?" Okay. He said we don't do it because it's easy, he said we do it because it's hard. That's why we do things. Ok We need to be challenged as a society and a world and we've accomplished some goals in the last century. We need this for this century. And the main thing is for the children.

We don't just need this. Our children need this. End of Apollo 15, Colonel David Scott, the first Air Force crew quoted Plutarch and said the mind is not a vessel to be filled it's a fire to be lighted so we need to light the children's interest in this and they need this as a goal like we need this. Thank you very much for your time.

Pete Aldridge

Thank you. James Brown.

James Brown

The question why I think destiny is why we go, and I just wanted to say that. Sorry. I'm a little nervous. I think a few things I just want to say. One, why don't we create a robot slash satellite to scoop you up all the planetary—not the planetary but the junk—

Pete Aldridge

Could you get a little closer to the microphone?

James Brown

Sorry, I don't like hearing myself. Why don't we create a robot slash satellite system mathematically engineered to go across the out sphere and pick up the junk? First of all, we'll be introducing a chaos factor into all the mathematical equations, which is needless, and it's basically waiting for something bad to happen. Second, symbolically, why don't we go to mercury first instead of going out?

Because we need to go in first and everybody who is spiritual should understand what that means. Thirdly why don't we send a man and a wife to mars and why don't we land a woman on mars? And as far as a mission, why don't the mission be to find another planet? Because we have done a pretty good job of destroying this one.

And then as far as our mission here should be—and I think President Bush is close with the war on terror, standing with religion but he's not standing with nature. He's not standing with the planet and protecting it and finding a way we can live with it instead of consuming it. That's about all I have to say. Thank you.

Pete Aldridge

Thank you. Monica Ice.

Monica Ice

Hi. Let me adjust this here. I'm Monica Ice. I'm with the Mars Society and I'm actually here to give something to you. The mars society actually has, and I don't know if you can see the picture of this, we have prototype habitation units that can be used on mars or adapted for other planets such as the moon, europa or beyond that. We have been field testing for four years now. We have mars rovers that have been built and internationally tested. We've got five of those. Those are kind of like a car and laboratory all in one sort of like an all-terrain vehicle, we have an inflatable greenhouse at our mars desert research station in Utah and we're learning how to explore mars.

What do we do when we get there? What are the problems we face? Do we send men or women? These are the stats we're looking at. One of the stats that surprised us is that women use 28 liters of water a day for everything. Men use 32 liters of water a day for

everything. So if we send an all-female crew at least on that stat then we would have less payload that we have to launch from earth. The basis for the mars society is what we call the mars direct plan. We can send five launchings of three missions, two of them manned for less than what we have already paid for the international space station by a simple plan of living off the land.

We send a little hydrogen; mix it with carbon dioxide in the air of mars and we come out with rocket fuel in the form of methane and water as a byproduct. By using the resources there we reduce cost. This is something we can do in the next 10 years and we can have people on mars by 2010 by using this. We started the mars gravity biosatellite project, Boston, MIT, University of Queensland, University of Washington; we are the only ones to look into what happens to a lower gravity effect on the human physiology.

Everyone has studied microgravity but not lower gravity, and we are doing that, so we have already addressed things like medical issues. What happens when pills are in space, biology in space, all these things we've already worked on. All of our papers are on our website at www.marssociety.org, and this is all yourself for the taking. I'm here to give this to you. Use our resources. Use our research. We don't copyright our material for a reason. This is for you. So—

Pete Aldridge

Monica, thank you very much.

Monica Ice

Thank you.

Pete Aldridge

We'll use it. You have done so well I'm going to pick two more speakers if that's ok then we'll end this particular session. Mike Snead, are you in the audience? Right there.

Mike Snead

On the spot. My name is Mike Snead. I'm also an aerospace engineer working at Wright-Patterson for a little over 30 years now. I've worked on the transfer program, the National Space Plane Program, I was chief flight plane engineers and consultant on the DC-X program in the early 1990s, right now I'm speaking more in capacity as chair of the IWA. Space logistics technical committee and I would like to emphasize to the panel that you give serious consideration to forming a basis for this initiative as built around a very robust space logistics infrastructure.

I think we have the industrial capacity in this country, as one of the previous speakers talked about to establish that infrastructure built around fully reusable access to space with near term two-stage to orbit fully reusable systems on orbit, logistics support for

both human and robotics systems and transportation throughout the central solar system, quite literally, to mars and the earth asteroids. Those capabilities can be achieved. Those can provides a different way of looking at how to implement this exploration initiative as well as formulating a strategy for sustainability of this initiative over a period of 25-50 years. Thank you.

Pete Aldridge

Thanks, Mike.

George Campbell.

George Campbell

Thank you very much. I'm a retired manager and formally president of the -- Management association in Columbus. My interests are function-versus-cost. What I'm seeing here, I'm not getting a clear picture of what really is the primary function of this exploration. Is it scientific? And I assume it is. And if it's scientific, it seems to me, following the lead of the Air Force, here, we're going to pilot less planes and so forth, that the most efficient way to approach the problem of gathering the information and analyzing it is to use more robotry. We have it on mars right now. By developing that, expanding its capabilities, improving the communications between the robots and the United States, that it seems to me that would be the most efficient way to accomplish something that's quite worthy, actually. Thank you very much.

Pete Aldridge

Thank you very much. Well, I appreciate all of the inputs.

Again, if you have—those in the audience who didn't have a chance to make their views known, go to http://www.moontomars.org/, and we have a process by which all the inputs will be read, and considered, and acted upon as appropriately. With that, we're going to end the formal session and we'll turn it over to a—we'll have a press conference. First, I would like to thank all the audience for being here. This is a big turnout. And we really appreciate it. Last but certainly not least, it is an enormous task to bring together an activity like this, a hearing at Wright-Patterson Air Force Base. We certainly appreciate all the members of the staff—I know who have been working hard behind the scenes to make this all possible here at the Air Force museum as well as those in the Wright-Patterson Air Force Base protocol office and public affairs offices and all the escorts that have been assigned to us to keep us out of trouble, and they have done a very good job, because we have been good, and again, we close the formal presentation and we'll take a two-minute break and then we'll turn it over to the press for question and answers.

Thank you.