Transcript of

REVIEW OF U.S. HUMAN SPACE FLIGHT PLANS COMMITTEE

Public Meeting ■ Cocoa Beach
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8:00 A.M.

Committee Members

- Norman Augustine, Chairman, former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
- Phil McAlister, Executive Director, Designated Federal Official (DFO)

Members – Listed Alphabetically

- Bob Cabana, Director, Kennedy Space Flight Center
- Mike Coats, Director, NASA's Johnson Space Center
- Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
- Dr. Wanda Austin, President and Chief Executive Officer, The Aerospace Corporation
- Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
- General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
- Jeffrey Greason, Co-Founder of XCOR Aerospace
- Jeffrey Hanley, Program Manager, NASA Constellation Program
- Pepper Phillips - Constellation Project Office at Kennedy - Deputy Director
- Bob Ess, Mission Manager for Ares I-X Test Flight
- Edward J. Mango, Deputy Director of Launch Vehicle Processing – NASA's John F. Kennedy Space Center, Florida

Public Commentary Section – Speakers Listed Alphabetically

- Lou Jamison – Machinist Union Local 2061
- Don Beatty – Former NASA Employee
- Wally Nelson – Retired Aerospace Engineer
- Dale Ketchum – Spaceport Research & Technology Institute, Director
- Ken Bates
- Gregory Sacala – Ground Support Engineer for Constellation Project
- Brian Hathaway – Florida Resident
- Chris Ecksley
- Dave Fisher – Pheonix, Arizona Resident
- Leonard Arnowitz – Former NASA Employee

- Joel Howell
- Juliet Sisk – Teacher at Space Coast High School
- Robert Osband
- Joe Brown

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Presentation

Phil McAlister, Executive Director, Designated Federal Official (DFO)

Good morning and welcome everybody to the review of U.S. Human Space Flight Plans Committee Meeting. Welcome to everybody here in the audience. We've got a full house, which is great and welcome to everybody watching on NASA TV and through the internet. We have a good agenda for today and my name is Phil McAlister. I am the Executive Director of the committee and we are very happy to be in Cocoa Beach. I would like to remind the committee members that we are in Cocoa Beach because we have had three meetings now in successive cities and sometimes we forget. The weather has been remarkably the same in each city as well. But anyway we are very happy to be here. This is a public meeting discovered by the Federal Advisory Committee Act, (FACA) so the discussion today, the presentations; all the comments are on the record. There will a public comment period towards the end of the day. That will be announced ahead of time. It will be first come first serve and we ask that it be limited to about two minutes, two to three minutes each. And please no questions during the comment period. The committee does have a website at http://hsf.nasa.gov. So the committee is essentially open for business 24x7. You can send comments and questions at any time, but we prefer questions to be submitted through the internet, through the website so that we can respond with an answer and everybody can see. So the comment section is really just for comments. And also for members of the media today, Norm Augustine will be available at the end of the day, approximately 4 o'clock for a thirty minute press conference. So again for the public comment period we would like that to be for the public and the media will have their separate time at the end of the day.

Transcripts and video of today's meeting will be available also via the website probably sometime next week and we ask if you could please mute your cell phones. It is just like the movie theaters. And please do not interrupt the presentations or the committee discussions.

With that I would like to turn it over to the Committee Chair, Norman Augustine.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Phil, thank you very much and good morning everyone. Is my microphone working?

Phil McAlister, Executive Director, Designated Federal Official (DFO)
Yes.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
All right, let me begin by adding the welcome on behalf of our committee to everyone in this room and those who are watching on television. This has certainly been a topic that has stirred a great deal of interest. People's dedication to the space program is very obvious to us. We treasure the input we have received from the public and from people at NASA who understand the issues in great detail. As you have heard we have our own website. We even Twitter. We are on FaceBook. We receive emails.

We receive lots of regular mail. My secretary told me some time ago that we had just…I personally had passed over my thousandth email that I've received. I think I've heard from every NASA Director beginning with Jim Beggs and beyond. We treasure those inputs and anyone here who has anything you would like to add we would certainly welcome. The only challenge from our standpoint is that most of the inputs are contradictory with one another, but I think that is why we're here.

There is a signup list at the back of the room that if you would like to make comments this afternoon during the public time if you will sign up. Unfortunately, there is only a limited amount of time so we will have to limit the number of people who sign up, but we will do it first come and first serve. If you don't get on the signup list please send us input on our website.

We do have a very full agenda today. We will be devoting our time to hearing from the folks at the Cape a little bit more about the Constellation Program. We'll be having a discussion among ourselves, one of our subgroups will be reporting and there are a number of Congressional and State officials that have asked to make statements and they will be doing that this morning.

Our study is, we've been granted ninety days and the reason for that is that we're trying to match the budget schedule. We now have 33 days left and we're only beginning to make decisions. By and large you will find that we're just discussing not making decisions.

I guess I would like to emphasize two things. One is that the role of our committee is not to make any specific recommendation; our role is to offer several options to the White House and to NASA for the future of Human Space Flight Program and for the Robotic Program that directly relates to that. So we'll be offering options. We'll be measured by how well we configure those options and analyze them. It will be up, I assume, to the President and the Congress to decide which options to choose. Secondly, just as a caution to try to avoid misunderstanding, it is our practice as a committee to ask some very tough questions and to take positions in debate that we may not even believe in just to draw out the arguments. So please don't try to interpret something that we say as being a position that we hold. We may just be testing. I think many of us you would be in a position trying to read the mind of someone who hasn't made up their mind. So with those cautions I believe we should start right and the first speaker today is somebody that certainly does not need to be introduced to this audience. Bob Cabana, of course, holds one of the most responsible positions in all of the space programs. We are very lucky to have a person of his ability and experience there. Let me turn the floor over to you Bob.

Bob Cabana, Director, Kennedy Space Flight Center

Thanks Norm. I'd like to add my good morning to the team and welcome to sunny Florida. Let's hope that this nice weather sticks around one more day and we can lure Endeavor home tomorrow after another outstanding mission.

I appreciate this opportunity to address the panel, but I have to tell you it has weighed heavily on my mind. I can normally sleep anywhere, anytime. You can ask Leroy, I have slept under catapults on aircraft carriers. I could easily sleep the night before a

launch. Heck, I even took a nap out on the launch pad during one of the long holds. But I woke up this morning early and I couldn't get back to sleep because I was weighing the importance of what this panel is trying to do for U.S. Human Space Flight capability and I wanted to make sure that I was able to convey the right words to you. But given the qualifications of the panel and having listened to some of your deliberations, I have every confidence that you are going to deliver a quality set of options to our leaders to act upon. I certainly don't envy the task that you have. It really is important when you consider the enormity of it and the limited time that you have been given to come up with an answer. It's not easy and I thank you for it.

There is very little that I can present to this panel in thirty minutes that you don't already know. You have been bombarded with PowerPoint slides and every conceivable idea on how to get to Lower Earth Orbit, back to the Moon, and Mars. Having said that I do think it is important that we document KSC's capabilities for the record. Before I do that, however, I would like to share some thoughts with you.

Since coming to KSC last October, I've tried to provide this team with a clear, consistent simple message. Until directed otherwise we have a plan to execute. We must fly the shuttle safely, complete the International Space Station, and meet our commitments to the Constellation Program by delivering a quality project, on time, within budget. The shuttle program is going to end when we complete the International Space Station and it will result in the loss of a significant number of jobs here at Kennedy Space Center. The transition will be difficult, but in the end we have a great future. We have a great future because our future program provides an integrated architecture that allows us to go anywhere; to lower Earth Orbit, to Near Earth objects, to the Moon, to Mars, and beyond. It supports Human Space Flight not just for years but for decades. In this time of dwindling budgets and changing requirements I'm concerned about our future. Our nation needs a Space Flight Program, a Human Space Flight Program that is inspirational, obtainable, and sustainable. It is critical to our future if we are to remain a world leader and it is critical to NASA and the Kennedy Space Center.

So what are we doing at the Kennedy Space Center to meet our commitment to the programs and prepare for the future? Programs come and go, but the core capabilities at Kennedy Space Center have remained constant and continue to meet mission requirements. They include: launch vehicle processing to include ground, launch and recovery operations, spacecraft and payloads processing, in ground systems and infrastructure development. Our goal is to ensure KSC remains the premier launch complex for sending humans and payloads to space. We have the facilities, the engineering talent, and the commitment to do just that.

From Apollo through shuttle and into the future KSC's facilities and personnel have adapted and provided first class support to the resident programs including the acquisition and management of commercial launch services for NASA missions. We have a rich history in Human Space Flight at Kennedy and you will notice a theme throughout my presentation. The Kennedy Space Center has adapted from the past to the future to meet our agency's requirements and excel.

The vehicle assembly building is a one-of-a-kind national asset that is well suited for the future Constellation Program. As a young mid-shipman at the Naval Academy I had the honor of coming down here for the first time on a fieldtrip with the Physics Honor Society to see Apollo 13 launched in April of 1970. The day before launch we were given a tour of the KSC's facilities and even more than the launch I can remember standing inside the VAB seeing Saturn V rockets being stacked up to go to the moon. It is something I'll never forget and was a tremendous motivation for me to continue a career in aerospace. Today I can walk into that same facility and see the Ares 1-X rocket being stacked to support a new generation of exploration.

One of our greatest challenges is the maintenance of our aging infrastructure and facilities in light of our restrictive budgets. As one program manager put it we can spend our money to have the best facilities in the world but there won't be enough left to build any hardware in them. Fortunately with the supplemental funding we received from previous hurricane damage the VAB is in pretty good shape for right now.

The launch control center and complex 39 supported Apollo, Shuttle, and is now being modified Ares I. The firing rooms in the LCC have been continually upgraded over the years. Firing room 4 in the lower center currently supports the Shuttle. In firing room 1 on the far right of your screen has been modified to support the Ares 1-X flight this October and will be further modified to support the Ares I. You can also see a picture of the new mobile launch platform up there on the top. It is well under construction for the Ares I. Pad 39B is being modified for the Ares I-X test flight and the lightning protection system also supports the Ares I. You can see the three lightning protection towers in the top photo with the two shuttles on the pad and also in the lower center. The orbiter access arm and external tank vent arms have been removed and we're in the process of installing a stabilization system for Ares I-X.

I would like to point out that in order to keep the Constellation Program on schedule, design changes to the VAB as well as the launch pads and mobile launch platforms are being made in parallel with the vehicle design. If Ares I is cancelled, redesign changes can be made to these facilities but there will be an impact in both cost and schedule to the replacement vehicle and a significant investment will be lost.

The operations and checkout building (High Bay) have been fully updated in partnership with the state of Florida and Lockheed Martin to provide a world-class processing facility for the assembly and check-out of the Orion spacecraft. This facility represents a $35 million investment by the state of Florida to capture critical work for this area. Computer models that KSC developed through a Space Act Agreement with the state of Florida were provided to all offerers on the Orion contract and used to determine the best flow for processing of Orion in the O&C building. The use of this simulation also provided data that was fed back into the design of the spacecraft to improve processing.

As the final space station hardware is delivered to orbit the space station processing facility (High Bay) will also become available for future work. KSC is working closely with the JSC Altair project on developing concepts for final assembly of the Lunar Lander here at KSC and the SSPF is one of the facilities under consideration. The

computer model used to determine the best use of the O&C building will also be used to determine the optimum flow for the processing of Altair.

I put this next slide in because it covers a large range of KSC's engineering capabilities. From the development of ground systems on the left to vehicle sustaining engineering and microgravity research in the center and on to lunar surface systems development on the right. KSC's engineers have participated in the design of the launch vehicle and the spacecraft to improve operability during ground processing and launch operations and to help ensure mission success. They are also partnering with other centers and are actively involved in the development of surface systems required for sustained operations on the Lunar and Martian surfaces.

We are closely partnering with Johnson, Marshall, Langley, and Glenn in the design and development of flight hardware that will better enable us to assume the sustaining engineering role for the vehicle here as KSC when Constellation transitions from a developmental to an operational program. KSC's subsystem engineers have taken lead roles in structural loads testing and test integration for various Orion elements, in on-orbit shuttle issue resolution, in Ares modeling and simulation, as well as being assigned to serve as Chair for the Ares engineering review board. They have been active in the desert RACS and other lunar simulation exercises helping the Exploration Systems Mission Directorate and the Space Operations Mission Directorate define and develop lunar surface communications architecture In-situ resource utilization and other capabilities.

With a core of approximately 450 Civil Service engineers, KSC is meeting the demands of the program to develop the ground systems necessary to support a new launch vehicle and to provide the sustaining engineering for a new spacecraft.

I'm not going to go into details on all our collaborations, but I would like to point out the Space Life Sciences Laboratory in the left corner that was built by the state of Florida. This is a world-class biotechnology lab that is ideally suited for payloads processing for the International Space Station as a national lab. We are currently working with Space Florida to make it an anchor-point for an exploration park shown in the lower left. This will be a research park built on KSC's property but outside our fence to improve access. It will not only support research on the International Space Station but will also support future commercial opportunities.

KSC's engineering experience in expendable launch systems has also been provided to the Commercial Orbital Transportation Services or (COTS) developers. And you can see a picture of SpaceX breaking ground with NASA and Air Force personnel on launch complex 40 for their Vulcan 9 rocket. KSC facilitated in providing SpaceX and Orbital with excess pressure vessels and cryogenic tanks from the Santa Suzanna facility when it was closed. KSC is working to inspire the next generation by collaborating with numerous Florida and other state universities on applied technology projects. One example is our in-situ Resource Utilization Project where Carnegie Mellon University developed the rover we mounted our experiments on and the University of Hawaii integrated the Lunar Analog Field Demonstration. Our DoD collaboration is primarily with the 30th and 45th space wings for range operations and with the Air Force and NRO for launch vehicle procurement, but the picture in the lower

right shows a NASA launch from the White Sands Missile Range to demonstrate an autonomous flight termination system that we are now partnering with DoD on as part of the space base range. I think we've got a lot more room for partnerships and collaboration and we're working on it.

With all that is going on at KSC right now, challenges, are abound. First and foremost our challenge is to safely execute our current programs while transitioning to the new exploration program. Next we have to sustain center facilities and infrastructure during the funding gap between programs. And finally we have the challenge to retain critical skills post-Shuttle as the exploration program ramps up.

Safety in the execution of our day-to-day work is paramount. If we have another shuttle incident the future of U.S. Human Space Flight will be at risk for years. I can assure you that the Shuttle workforce fully understands this situation and in spite of the fact that layoffs loom in the future they are dedicated to ensuring the safe and accurate processing of our vehicles.

I don't have a good answer on sustaining our facilities through the gap. It is a real challenge with the existing budget. I can tell you we are working closely with the programs to identify those facilities that have firm requirements and to divest ourselves of the rest. We've recently gone to a number of facility's reviews and are in the process of consolidating our labs and shops.

As far as skill retention is concerned we've made a real effort to shift more of our design work from contractors to our Civil Service workforce so they have ownership of the project, are involved in the detailed design and are not just serving as a contract monitor. The goal is to have a strong Civil Service engineering core that has the in-house intellectual capacity to act as a smart buyer and sustain the KSC mission.

We are also working closely with Brevard Workforce Development Board in supporting our contractor personnel with job counselling and retraining to help ensure they have the skills that will be required post Shuttle.

This slide is really important. This workforce that we have is the most talented and dedicated workforce anywhere in the world and it is a real privilege for me to be a member of it. In talking with the technicians and engineers processing the vehicles I've learned that their job is not a vocation but rather avocation with them. They live to be part of this team and make it successful.

At the peak of Apollo, KSC's workforce numbered over 25,000 contractors and Civil servants. It dropped to approximately 8,500 in the six year gap between Apollo, Soyuz, and Shuttle. Today we have approximately 14,000 of which 2,100 are civil servants. Right now the civil service workforce is projected to remain constant in the out years. The current budget does not support flying the Shuttle beyond the end of September 2010. This is going to impact our contractor workforce. Based upon the FY09 budget and executing the current program KSC is projected to lose 700 contractors in FY10, another 3,900 in FY11 and then grow by 500 in fiscal years 12 and 13. Unfortunately recent budget projections now result in a delay to the Lunar Program which results in a longer period of time before the workforce begins to increase. Obviously changes to

the budget or the direction provided by the programs and to the programs will change the magnitude and the timing of these impacts. That doesn't sound very heartening. But I think the key message is that in spite of the future draw down that everyone sees coming, we have hundreds of motivated interns, co-ops, and young engineers who want to be part of this team with the hope of seeing us explore beyond Low Earth orbit. The excitement of space exploration is still a huge draw. Human Space Flight still inspires. We have about a million guests each year at our visitor's center and folks drive far and wide for the opportunity to witness a shuttle launch firsthand. Those who cannot get onsite line the roads and waterways adjacent to the center. The human aspect of what we do is gripping and personal. It creates a bond between complete strangers. You cannot help but have pride in what we do as a nation when you see a shuttle launch in person.

The Space Station is a phenomenal engineering achievement. Especially when one considers that it consists of hardware built from around the world that comes together for the first time in space and it works. In addition to the technical problems that it has overcome, it has also had to overcome the cultural differences between Japan, Canada, Russia, the United States, and the European Space Agency and all its partners. It wasn't always this way. I think this picture really puts it in perspective. A lot can happen in ten years. A little over ten years ago the Space Station hung on by one vote in Congress. Everyone said the technical challenge was too great. The design was too bad. You could never accomplish all the EVAs it required. It was over budget and behind schedule. Ten years ago when we powered up the computers for the first time no one was more surprised than me when they worked. A
tribute to the team at JSC and the team here at KSC after the many hours we spent of multi-element integration testing in the SSPF. Look at it now, a crew of six onboard a world-class microgravity lab and engineering test bed. It seems a shame to me that we would consider ending it in a few short years now that it is finally complete and not see it utilized to its full potential.

I see the Constellation Program much like the Space Station Program twelve years ago or so. Much of what was said about Space Station then is being said about Constellation now, but it is amazing what can be accomplished in ten short years when you put your mind to it. I wonder what we will say ten years from now when we look back. My sincere hope is that it will be much like looking back on that first Space Station assembly mission that when we look back we will have come a long way towards once again leaving Low Earth orbit.

KSC and the nation need a Human Space Flight strategy that is inspirational, attainable, and sustainable. KSC has an extremely talented workforce and infrastructure that are national assets with a proven capability to adapt and deliver mission success. We are a world leader and part of what it means to be a world leader is to be a world leader in space. It's what's expected of us. We are at a critical juncture in our nation's Human Space Flight Program. The team is ready to support. More than anything right now we need consistency and a clear path forward for the future. We cannot keep changing direction. We need to decide where we are going, properly fund it, and execute the plan. Leaders lead and that's what we have to do. Continue to lead in space. Be a leader. And we will only succeed in the future if we have clear direction that is properly funded.

I want to thank you for your time, your attention, your service to your country, and your service to the America's Space Program.

Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Bob, thank you very much for those comments. That provides a very sound basis for all we are doing and I hope you'll also thank all your folks who have handled the logistics and the administrative support for our visit. It has been handled terrifically. I also want to say special thanks to the team's prepared material for us. We are well aware that you have other things to do than to support this committee, but you have certainly done everything we could have asked and we thank you.

Bob Cabana, Director, Kennedy Space Flight Center
You're welcome.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

At this point I think we will move ahead with the regular agenda and we'll let you take a break.

Bob Cabana, Director, Kennedy Space Flight Center
All right. Thank you Sir.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Our committee as it carries on its responsibilities has held a number meeting such as this. We've also divided it into subcommittees since in the 90 days we don't have time for the entire committee to do everything because we all, of course, have other responsibilities as well. The major groups that we've divided ourselves into relate to some of the current activities, specifically the shuttle program and ISS and its future. Secondly, into transport from earth to near earth orbit, and thirdly, beyond near earth orbit and fourthly, the integration group that's addressing such issues as international involvement, coordination with other agencies of the departments of the U.S. Government and particularly industrial involvement in the program and other factors of that type. As you could tell, the little subjects are closely interrelated. They affect each other both technically and budgetarily. And given that, there's a great deal of integration that has to be done that has not yet been done. So, today you're going to hear a briefing from the fourth of those groups. The other three have been briefed prior in other meetings like this one, and that fourth group is the one that's been addressing beyond near earth orbit. They will be talking about some of the options, keying those options to goals, and then, when we leave here we will be focusing on integrating what

you hear this morning with the work of others. This group has been led by Ed Crawley. He, as you know, is the former chairman of the Department of Aerospace Engineering at MIT currently a professor there, and I need to state that the professor finished his homework about 20 minutes ago. So, Ed you're up.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Thank you, Norm. In my business there is no margin. Well, thank you ladies and gentlemen and those of you out in cyberspace listening to these. This committee has addressed the questions of why we explore, where we should explore and how we should explore. This is an enormous scope of opportunity space that we have before us. As Bob Cabana said in his last comment, the nation needs a program that is inspirational and sustainable and we will try to address that question today. The actual presentation starts with an introduction by me and then goes to evaluation measures by my colleague, Wanda Austin, a bit of science evaluation by Chris Chyba, a discussion of exploration options and measurements that I'll come back for, then, a set of scenarios that we commissioned to study an issue of the transportation issues that support those scenarios, recommendations from the subgroup to the full committee for discussion. This is the charter of the subgroup. In short, it's to identify options for consideration by the committee of the goals for exploration beyond low earth orbit, the destinations beyond low earth orbit, the means of reaching these destinations and the costs that would be associated with them keeping in mind the budgetary guidance that has been provided to us.

Norm, I want to offer to the committee these pieces of wisdom. I used to have what they call, “astronaut eyes” in the old days, but I can't quite read that little screen out there. So, I thought I'd fall back to the old fashioned paper in front of me here. Norm, I'd like to offer this insight into the elements of a desirable lunar program and I'll let you read it. In short, it said that I should fit in the time and economic framework of the nation. It should use the building blocks of the present space flight program. It should have a good probability of early accomplishment, possess flexibility but have immediate potential for limited operational capability, be adaptable for rapid expansion, have project cost in balance with its expected returns, not requiring huge single funding commitment and be within a foreseeable NASA budget and be attractive to the public and the security interest. This seems to us to be reasonable guidance for a future lunar program. In fact, it comes from the NASA archives from a presentation by George Lowe on January 5, 1961, 15 days before the inauguration of John Kennedy. This was the space program of the Eisenhower administration which was to go beyond low earth orbit and go as you pay. Eisenhower was a fiscal conservative and thought that this was an appropriate way to explore space. What John Kennedy did was that he changed it from a “go as you pay” to a “go in the decade” program, first, by making in a famous speech of May 1961 where he said, “We should go and land a man on the moon and return him safely before the end of the decade.” No single space project in this period will be more impressive to mankind or more important for long-range exploration in space and none will be so difficult or expensive to accomplish. This was a bold vision. “We choose to do these things not because they are easy but because they are hard because that goal will serve to organize and measure the best of our energies and skills”. Well, of course, twelve Americans succeeded by the end of the decade in walking on the moon, a success that we still commemorate even most recently in the last week. There was no shortage of vision at the end of Apollo. Here is

the roadmap that was laid out by the Apollo planning team in 1969. You probably can't see the charts, so, I'll give you a sense. The first line is earth orbital elements which would have a space station beyond Skylab by 1975. A more permanent lunar presence by 1982, planetary exploration including landing on the Martian surface by the mid 80s and the space shuttle, a nuclear shuttle and a Mars excursion module, which looks strikingly like Orion, by the late 80s. In short, by 1990 the plan had 100 humans in low earth orbit, 49 humans on the moon, and 72 humans on the Martian surface. This was a bold vision. Unfortunately, the politics did not support the bold vision. In the early 1970s, after the Apollo program and particularly after Apollo 13, the political organizations of the nation reassessed the risk/reward structure in view of the then current downward economic climate and President Nixon flipped the switch. President Eisenhower, President Kennedy, and President Johnson had called for an exploration program beyond low earth orbit and President Nixon redefined the space program to be one that would exploit low earth orbit. The shuttle was developed. As the shuttle came into operation, President Reagan approved the space station program as a fundamental element of our foreign policy. The picture in the lower left, as he and Margaret Thatcher at the White House looking at a model of the space station which President Reagan sought to use to cement the alliance of the so-called western or democratic nations against the evil empire as he would have called it.

Before the space station was built, the Berlin Wall came down and a new foreign policy task was assigned to travel to low earth orbit that of building an alliance of both the United States and its former allies and the new partners including the Russians.

In 2004, President Bush flipped the switch again. There are fundamentally only two human space flight policies only go to low earth orbit, or go beyond low earth orbit. And our committee has been charged to examine what the right plan is to go back beyond low earth orbit, beyond LEO again. We're all familiar with this vision to fly out the shuttle and develop what was then called CEV return to the moon and extend human presence across the solar system and beyond. What President Bush essentially did was to return to the space policy of President Eisenhower, go beyond low earth orbit, and go as you pay. The most interesting thing, I think, in this speech was the passage that almost slipped by but reminds the American people that since 1972 no human has set foot in another world or ventured farther upward into space than 386 miles, roughly the distance from Washington, D.C. to Boston, Massachusetts. Three hundred and eighty-six miles is as far as we have reached away from earth in over 30 years. It's time to change that. Candidate Obama said when he would be elected, we would have a vigorous debate on the future direction of the space program and once we have a sense of what's going to be most valuable for us in terms of gained knowledge, then I think, we'll be able to adjust the budget so that we're going all out on what it is that we have decided to do. Our panel has been asked to make recommendations to the President on what it is that we have decided to do, but the record shows that in 2006 and in 2008 both the Democratic and Republican controlled Congress vigorously supported the venture beyond low earth orbit. There is a national consensus to do this.

So why do we explore? I do not believe that the rationale for space exploration should rest solely on work force and industrial-base. I believe, it should be to inspire the nation to provide an opportunity for humanity to move off the planet and I'm joined in

that sentiment by my colleagues on the subcommittee. Our view that we recommend to the full committee is that we explore to chart a path for human expansion into the solar system that the moon is a way along this but Mars should be the intermediate destination for this exploration. The ultimate goal should be staying off the planet.

Norm, it was very interesting in this process how such a diverse group of people as the five of us who are on our committee with such diverse backgrounds, so quickly and unanimously came to this position.

So why do we explore? We've defined a set of topics which, Norm, we're going to recommend, when Wanda comes up in a minute, form the basis of the evaluation system that we will use for the options in our consideration and presentation to the White House.

Why we explore? If Mars is the ultimate goal, then part of our real role in exploration, up until that point, should be to prepare for further exploration. How can we develop our exploration systems so they will directly support and enable future missions of exploration? How will they develop technology? How can we rebuild NASA as a developer of new technologies, that enable its future growth and serve as much needed engine of economic growth for the nation? Science is an important reason to go into space, but as my colleague Chris Chyba points out, we have to be very careful about rationalizing human space flight in terms of its scientific objectives and in a few minutes, Chris is going to speak to that point. But it's undoubtedly true that for the time being we live on Earth, so the question is, what can we learn about our planet by studying others?

The National Space Policy calls for exploration beyond LEO to support the scientific commercial and security interest of the nation, and in fact, we think there is an important role in stimulating the emerging commercial space industry. How can we explore in such a way as to stimulate this industry, so that it takes up increasingly a larger share of the traffic to low earth orbit and becomes economically competitive in the world's stage. In fact, as we speak, there are commercial ventures to build commercially-funded rockets to low earth orbit, commercially-funded space craft that would carry cargo and humans and commercially-funded orbital facilities. We need to support and stimulate these. All successful human space flight projects have fundamentally been instruments of foreign policy. We have to have a strong rationale for going beyond low earth orbit as a mechanism of creating the new sort of alliance, the alliance that will allow the United States to provide soft leadership in the world. We need more opportunities as shown in these two pictures of ground ops and flight ops being carried out by colleagues from around the world.

We explore to expand human civilization, first, in such a way as to protect our planet. The image on the left was a surprise while we were all watching Neil and Buzz in the White House, a body struck the planet Jupiter creating a hole in its atmosphere the size of the Earth. We were not tracking this body. Part of the role of exploration beyond LEO is to understand the bodies that might cross our paths and to prepare for the eventuality or certainty that one day one of them will come very close to the Earth. The other part of human civilization is, of course, to prepare for the opportunities for us to become a species that might someday live on two planets.

We explore in order to provide benefit to the public. They are the primary stakeholders, the people, the nation, the school children, and the young people. This is a picture of a bunch of enthusiastic people looking up at a shuttle launch. This is the way that we engaged the public in the 20th century. We have to build the space program that engages the people in the 21st century that's new, that's exciting, that allows them to go online and get involved, that allows them to engage and participate, and in doing so, we will engage our youth and stimulate their interest in science technology, engineering, and mathematics, helping provide a stream a workforce that is critical to the strategic national interests of the nation. This is the broad brush of why we explore. These are not unfamiliar ideas. This is an attempt to sort of laid them out and embrace them.

I'm now going to ask Dr. Wanda Austin to explain how we're going to transition from these broad ideas to an evaluation scheme for the options we consider.

Dr. Wanda Austin - The Aerospace Corporation - President and CEO

Good morning and thank you, Ed. Ed Crawley has just tried to motivate the arguments for why we explore and to give you some insights into what our subcommittee is trying to assess in looking at options that can help us achieve that goal for the 21st century. Can we get the charts up? Great.

One of the things that's important as you take on the challenge of assessing a wide range of options that our subcommittee wanted to provide to the panel as a whole is to think apres ore about what are the things that we need to evaluate to insure that our nation is pursuing the best trajectory for the future of human space flight. We were given in our statement of task some of the evaluation criteria that were deemed to be important through panel fact finding. Other metrics have been defined by the panel specifically. We also looked at history to review what metrics and figures of merit have been used in the past and the areas that we reviewed very closely were the Space Act of 1958, the 1991 Synthesis Group and the VSC or the Vision for Space Exploration Report that was done in 2004. The interesting thing that we found was that there was a lot of similarity across all of those studies on what are the figures of merit and criteria that need to be evaluated.

So, we want to try to evaluate what capabilities would be enabled by each of the architectures or options that are considered. And in doing that upfront, it helps to, I think, set a level playing field for evaluation and to make sure that you keep your eye on the goal.

So, what are some of the evaluation challenges? Tom Young, when he did the National Security Space study, pointed out that you have several variables when you are running a program. You've got to look at cost schedule performance and if all three of those are given to you and defined for you, then the only real variable you have is risk. If those variables are not defined appropriately or with sufficient margin, then what you have is the opportunity for increasing risk. It's also true that getting the same amount of money later doesn't really help you because it forces you to make decisions early on that may not be the optimum solutions. They may be suboptimum solutions. So we defined benefit to stakeholders as really the performance direction. Budget is

the cost and schedule perspective, and then the risks are numerous and varied. They come in a number of flavors, some of which we can manage and some of which just happen in the course of the life of the program. Some of those are legislative changes, decisions that might be made by international partners or, unfortunately, sometimes there are anomalies which drive changes in programs. So, this is a really three-dimensional challenge that we face as we try to determine how best to evaluate the options. They are not independent. They are interdependent and the risk associated with each of those is relative to each other. So, our challenge is to figure out when better may be the enemy of good enough. We've identified a number of evaluation metrics that could be examined. I'm going to talk about those in detail in the next chart. I know it's hard to read from a distance, but the message here is that there's a lot of uncertainties about some of these measures, when you talk about how do you inspire, how do you measure public engagement, how do you measure the value of exploration that these aren't point solutions, that there are going to be solution spaces that we're going to need to examine.

Let's start with exploration preparation, and I'm going to just summarize for each of these a little bit of the intent including that measure. We think it's important to look at the options relative to their ability to help prepare us for further exploration for that ultimate goal that Ed referred to, that includes robust growth beyond LEO. It includes making sure that we've got a robust transportation capability and includes making sure that we're doing all that we can to mature our technology so that it is, in fact, at a risk level that is reasonable to expect it to support the performance that we need.

For science knowledge, Chris Chyba is going to talk about that in more detail, but I could summarize it by simply saying it's important that the science that we achieve is aligned with what our scientific community values and thinks that is important.

For human civilization, one of the things that you'd like the options to address is how it supports getting us to the point of sustained human presence. That means looking at things either demonstrations or technology that help with human factors and making sure that we can sustain life for long duration.

In the area of economic expansion, the options that we would look at we will want to understand how they contribute to growing a profitable industrial-based. We've heard from previous subcommittee reports that having the opportunity to engage the commercial market place more in support of our mission is something that has a tremendous benefit for the nation.

Global partnership, we also heard from our other subcommittee panel members the importance and the value that can be achieved by leveraging and expanding the relationships that we've already started with the space station and that there's and opportunity going forward to build on those relationships for the benefit of the nation not only for civil space but for national security as well.

Public engagement, this is where we talk about how do we inspire, how do we have a program that answers the promise of adventure and builds to the achievement of a successful exploration program. This is really key in making sure that we have not only public support but that our public is engaged and understands the visible interim

milestones that are going to be achieved in their lifetime, so that there's a level of excitement. We had an input from the public comment recently where a teacher talked about her elementary school students who might have the opportunity to be the first to step on Mars. That's great for that student, but there are a lot of people who would like to see us make some significant progress before that time.

Technology development is the last item that it's important to make sure that we're developing technologies that help us achieve the goals of innovation and are forward-looking because they may, in fact, provide the benefit of getting us there faster, more effectively, and with less cost.

Programmatic risk. Mr. Chairman, I would suggest that in the risk areas we've had vigorous debates about how we would frame some of these issues as we try to evaluate different options, but things that came out to us as being very important are the operational flexibility, extensibility, and robustness. All of us have had experiences with the programs that have not been executed exactly the way that we thought they would be executed when we started out and the difference between successful programs and programs that get derailed, or at least one difference, is that successful programs have robustness in alternatives that they can fall back to so that you may not follow exactly the path you started out on, but you do have alternate ways of accomplishing the goal. There's also cost schedule and technical risk that would be managed and looked at from the programmatic risk perspective.

On the subject of safety, this is something that we've touched on in the last few days and it's really about the balance between mission reliability and human safety and making sure that we understand that there has to be a balance so that we are comfortable that we are not giving up mission capability because we're being risk-adverse that we pursue the opportunity to really be innovative but yet at the same time ensure a reasonable level of crew safety. We've seen over history, you know, we talked about Titan and Atlas being human rated but what's happened over time is we've evolved the definitions of human rating to a point where we're continually trying to do more. Somewhere in there we have to define what the right level or right aim point is for that.

Programmatic sustainability. This is an area where we would include things like lifecycle cost, making sure that the program has credibility and stability. There are a number of ways in which you'd want to ensure that sustainability. One of those is in budget, making sure that the budget that's laid out is in fact there for the program to manage to over the life of the program so that they could continue to execute and achieve the interim milestones.

Cost. This one is one that we have a specific point that we're all looking to find options that meet the President's budget. That is the target. The challenge and evaluation will be that you may have two programs that have the same cost but may drive different level of value or benefit to the stakeholders as such, and so, we'll have to work our way through that.

And then last but certainly not least, we want to look at the workforce impacts. This is really about making sure that the workforce is strategically aligned with the goals and

objectives of the mission that we undertake. The challenge here is making sure you've got the critical skills that you need; you've got the right skills that you need in balance and that you're doing what's necessary to maintain the intellectual capital and the knowledge management to transfer skills that may be lost as we work through these transitions. So, our input to the panel is that we feel that it is clearly something that we need to discuss and have some deliberations on about whether or not these are the evaluation measures that would be appropriate to look at the beyond LEO options and possibly as we merge the other options from the other subgroups these will be useful across the board in recognizing that not all measures will carry the same weight that we need to have some discussions about what the relative weight and relative values of each of these measures would be.

With that, let me turn it back over to Ed, to I'm sorry… Chris, to talk about science measures.

Christopher Chyba - Princeton University - Professor

Thank you. We should return to the main presentation if it's - yeah, great. I wanted to begin with a list of the science briefings that the subcommittee has received and I now see Ed's issue with the size of the display that I have, so bear with me for just a moment.

The subcommittee received a suite of briefings on science at various destinations in the solar system. There was a set of four different briefings on science on the moon that those included briefing on scientific findings relevant to human outpost or settlements on the moon, that is to say lunar resources, a briefing that focused on science about the moon, lunar geology primarily, science that could be done from the moon whether that's astronomy, solar and space physics or earth science and finally, we had a short briefing on using the moon as a planetary protection test bed for Mars exploration since planetary protection will be a challenge when humans go to Mars. We also received briefings on science at space destinations. So, not science on particular worlds but science that could be done on free space and one of those briefings, we asked to emphasize the contrast between the science that one would do on the surface of the moon and the science that one would do in free space. There was also a discussion of the role that humans can play in servicing scientific missions in free space, a brief discussion of the contrast between robotic and astronaut maintenance of those missions, although that is a kind of trade that is currently underway at the Goddard Space Flight Center and will not report out for another year. We reviewed science at near earth objects, the most important from the point of view of human civilization earth-crossing objects asteroids and comets that cross the orbit of the earth. We looked at the science of those objects and also possible missions to those objects. Okay, that's very good.

In addition, we reviewed science at Mars both from Mars but primarily on the Martian surface and we benefited from some presentations of overall scientific objectives including one from the Planetary Society which briefed their new road map for human exploration to us. One of the other subcommittees reviewed science that can be done at the station that was outside of our perview, but I wanted to include it in this list so that it's clear that a role science will play across the human space flight program.

Finally, when this committee holds its public meeting on August 5th, it will be briefed on four broad topics. There are four decadal surveys that incorporate a vast amount of input from the scientific community in four different areas of science, astronomy and astrophysics, earth sciences, biological and physical sciences and planetary science, that is to say the role that each of those plays in space exploration. These are coordinated by the National Academy of Sciences. One of those, the decadal survey in earth sciences is complete, the other three are underway. We need to be careful, of course. The chairs of those committees will not be able to brief us on results when there is still a consensus being forged within the community. But, of course, the committee needs to benefit from that work as much as possible because those the decadal surveys is really are the place where the scientific communities forge agreement on what the key objectives in space in those areas of science are.

And finally, I want to note, with respect to an information gathering that we have received, I think this slide says “considerable”, I would say enormous input from scientists and others outside of the committee and outside of these formal bodies about what our scientific objectives in space ought to be. I'm particularly deluged with such input and I welcome it. I've been trying to read as much of it as possible. I should add that in addition to the four decadal surveys, there are quite a few other documents that had been produced in the last few years that represent one or another sub-community’s point of view about scientific priorities in the solar system.

We have a few findings to present to the committee with respect to science beyond low earth orbit. The first is that there are certainly some cases where astronauts enable science at a pace that rapidly eclipses what robotic missions can achieve. In particular, that’s true in field geology especially on Mars and the moon and probably on near earth objects as well. It’s striking that some of the scientists who are most deeply involved with robotic exploration of those objects or rather among the biggest advocates for sending humans because as a competent field geologist, they're painfully aware of the comparative limitations of the robotic craft. Of course, that has to be tempered with the statement that there is an impressive disparity in cost between robotic and human missions.

A second finding is that astronomy about four decades ago it would have made sense to do it from the moon is often now, and I would say nearly always now, clearly better done from free flying platforms in space often at LaGrange point. We know how to do that now and the moon, in contrast, provides disadvantages rather than comparative advantages. The servicing of astronomy missions by astronauts as opposed to robotic servicing of those missions is being studied. There's a study underway at Goddard. The results of that are still a year out.

And finally, we want to emphasize this, given our current knowledge of the effects of galactic cosmic rays on humans, both with respect to long-term cancers and also with respect to damage to important organs, and also, coupled to that the current lifetime radiation limits that the program understandably imposes for astronauts and coupled to that the very strong limitations on our ability to provide physical shielding against galactic cosmic rays as opposed to, say, solar particle events. Human Mars missions cannot now be flown. The current limits, these vary by age and gender, but the current limits that the galactic cosmic ray background puts on the duration of human missions

in deep space is something like 200 days. That's the time it takes to either get to Mars or come back from Mars. And therefore, research on understanding these effects reducing the associated uncertainties, which are still quite large, and examining biological and physical mitigation measures needs to be prioritized.

Let me close these remarks with the discussion of the science figures of merit that we recommend to the committee to be adopted when evaluating different scenarios on the basis of science. First, I would just note that when I say science now in this context I mean fundamental science. There is clearly very important scientific research to be done regarding humans in space, understanding radiation, the effects of zero or low gravity environments and other crew-oriented effects, those are very important to apply as figures of merit, but we are bookkeeping those elsewhere in our chart of eleven figures of merit. Our criterion in this row is that the scientific outcomes or particular scenarios should significantly and appropriately address, important to established priorities of the scientific community including astrophysics, planetary and lunar science, solar science and earth science. The demarcation criterion among different scenarios would be whether the scenario doesn't accomplish that at all whether it addresses at least some established priorities of the scientific community, some priorities or many of the important established priorities. Ultimately, those priorities will need to be referred to the priorities brought forward by the decadal survey priorities. Until the decadal surveys are finalized for those that are still underway, we will have to do our best with the existing older decadal surveys and other documents from the community such as the scientific context for the exploration of the moon and many other documents analogous to that that are in the literature. I am trying to piece together our best account of the established priorities of the community. Thank you. Ed, the floor is yours.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Thank you Chris. So, now that actually brings us to the first real recommendation that we'd like to bring forward at this point to the committee for discussion which I hope you'll chair, which is simply that we used this framework that we have described in the last 20 minutes or so, as the basis of evaluating the options that we'll bring forward to the White House, that we adopt this system which has seven areas of benefit which Wanda enumerated and which additionally has the programmatic issues as cost reliability, programmatic risk, sustainability and so forth that she also identified a set of measures which are, as she said, traceable to the Space Act, traceable to the 2004 Vision for Exploration and directly traceable to the current administration OSTB the statement of task.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Ed, thank you and your group. Since the members of your group, I gather, are in agreement on the proposal, it's kind of left for the rest of us to ask question that we may want to raise. I've got several. I'll hold mine until last. Les, it looks like you got something there?

General (ret) Lester L. Lyles – National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program – Chair

Yeah, Ed, I think your subcommittee has done a fantastic job of laying out the potential measures of merit and the kind of factors that go into it. What I did not see, perhaps it is implied in a couple of the figures of merit, the kinds of measures that evaluate our space program option scenarios, et cetera against other societal or national needs. In some respect, I'm referring to the recent National Research Council study recommending aligning our space programs to help address other national needs whether it's dealing with climate change, whether it's dealing with environmental, whether it's dealing with health issues, whether it's dealing with energy, its scenario that I think, it's probably captured in some of the things that you mentioned, but it's not explicit to the point where to me it could easily get lost and so to the motivation behind my recommendation to you that we consider this is the issue of inspiration. I dare say, if I look around the room here, all of us here have drank the Cool-Aid to some extent and probably everybody that immediately said that they're inspired by space either drank the Cool-Aid or they're inspired for a nanosecond at the sight of a launch or something of that nature. What engages these people 23 hours and 59 minutes so today are the things that are bigger than just what people normally think about space, environment, healthcare, climate change, and those energy issues, economic development, et cetera, and I don't see that aspect of where our space programs, space scenarios fit in or could help address. I don't see that captured in the figures of merit that you laid out.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Les, that's an excellent point and I'll respond in several different ways. One is, as you are aware, because we've produced a more detailed briefing paper that we sent around to the committee, a layer down from these. There's actually a set of more detailed criterion that would assemble to produce the ranking system that Wanda outlined. But it is true that some of the other societal benefits are a little more buried and a little less visible than they should be in the discussion that we had today. So, for example, in the technology item, it's not only technology for exploration but technology to build a more robust technological infrastructure, you know, directly applicable to society on earth, although when I look at the summary briefing chart, it didn't look that way. You're absolutely right. It's certainly true, Chris, in the science criteria, it would be the broad scientific issues, may be you want to comment on that.

Dr. Christopher Chyba - Princeton University - Professor

Yes, yes, I mean, we did in that area. Of course, we did explicitly include earth science which would directly address climate change issues.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Great. But I think, I'll take as a very strong friendly amendment that may be you and I should sit down this with Wanda and we should actually go through the academy report of which you chaired which is obviously only recently become available broadly in the public in the last few weeks. We should go through the academy report and make sure that we synchronize to the extent that the committee thinks is appropriate the language and the scope of the measures so that it fits nicely within the framework of the National Academy recommendations.

General (ret) Lester L. Lyles – National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program – Chair
Yeah, Ed, and my comment was not self-serving because I chaired that study so I don't think…

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Yeah, let's say you're familiar with it.

General (ret) Lester L. Lyles – National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program – Chair
That's not the rationale. Really, the number one thing I'm concerned about is public engagement which is part of your measure of merit, and I dare say, the semantics that we used either in this room or around our community, things like earth science. If you go out in the streets of Washington D.C. which is my original hometown, and if you talk to somebody about space and its application to earth science, they'll think it is well above their head and they won't care. If you talk about space and how its going to address the things that worry people on a day-to-day basis, just describing what it is that we're talking about, has a big, big difference to me in inspiring the next generation that if we used our normal language of describing things. So, that's part of my motivation. It's really trying to inspire far more people than those of us who have drunk the Cool-Aid.

Dr. Wanda Austin -The Aerospace Corporation - President and CEO
Let me add a comment as well and in a spirit of full and open disclosure I served on that panel for that study as well, so I'm very familiar with it. I think you're point is well taken that we ought to take the opportunity to highlight that as being one of the potential benefits as we alluded to with soft power and we alluded to global partnership that there are opportunities here for us to really shine as really providing a tremendous service that helps people in their daily lives and we need to, you know, as you look at different options, some options may do it, you know, more in a scientific arena. Some options may do it in things that are easier to point to, but I think that that's clearly something that we would really highly value as we assess the options.

Dr. Christopher Chyba - Princeton University - Professor
One more very quick one, I want to use your phrase "footstomp" just as a little harder. We have a lot of internal discussion about the technological figure of merit and it's down in the next tier down to see this, but it's really not just technology for the sake of serving NASA. It's technology at the intersection of what serves NASA but also grows the whole nation's aerospace industry and its competitiveness, you know, in a more NECA-like heritage.

Bohdan Bejmuk – NASA Constellation Program Standing Review Board – Chair
Well, actually, instead of criteria, there is one thing that I personally find that it might be missing here. One of the benefits to our country is to capture youth. I have a 9-year-old daughter. She is a fourth grader. I bet you that a lot of guys in this room who have son or daughter in this age. This is the most impressionable time of their lives. She just got through, a week ago, attending a Sally Ride camp in Southern California in Cal Tech. She wrote me a journal everyday so I can read it. I think it's very important that we use one of the criteria is capture the young and have them

inspired because, let me tell you, when my daughter is 17, by the time we do something impressive, it'll be too late and there'll be a lot of other children like this. So my suggestion is we add the benefit to education at all level.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
That's right. That's a very important theme Bo, and certainly intended to that in our engagement of the public in support of the strategic workforce but I realized as both you and Les react, that these tend to be the inside the beltway, way we say these things and not the way we should say them to the people. I too go to work every morning and see 17- and 19-year-olds who seek to be inspired by the space program and I agree with you completely.

Dr. Christopher Chyba - Princeton University - Professor
It kind of sounding to me like it's not so much that we have the wrong criteria, but we really didn't do a very good salesmanship job on it, you know, or explaining job of it and that we need to take on a pass on that.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I think that's right. Now, Norm, there is implicit here the idea that it is not our job as a committee to weigh these various criteria. We are recommending that we show in our final report to the White House what our evaluation of the various options in terms of these criteria and basically, which ones are viewed by the political process as being relatively more or less important will then help guide their decision. I'm not a big fan of one of these formulas where you take, you know, one part of criteria A and two parts of criteria B and you produce a metric of goodness.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Leroy, do you want to weigh in here before I do?

Leroy Chiao - Engineering Consultant
No, go ahead please.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, alright. You touched on several of the items, one thing I should comment on to those who are listing, this sounds like a very general philosophical discussion, but it's awfully important because these are the criteria which we're going to weigh the options that we come up with so this is of profound importance. I have several comments that are somewhat just to add emphasis to what we've already discussed here, Ed and your team. One is the subject of ranking. I'm like you, I don't like assigning numbers and taking the square root of the cube or something like that and adding them up, but we do have to give some indication somehow of relative importance, and I'm assuming that we're going to do that. I also think that a number of the items that are covered and we've all had the benefit of seeing in more details which are on your charts. Some of the things, I think, it's so important they deserve elevated to the higher level even though they might be bundled under the other topics. One is this whole subject of impact on youth on education. That may have been one of the biggest impacts of the Apollo program, for example. These people of my generation that if you ask many of them why you studied engineering, they'll say, I saw Neil and Buzz on the moon and Mike up in orbit, and that's pretty cool.

So, I would like to see us put more emphasis on those topics, more visibility at least. You covered sustainability to some degree and you called it out, but one form of sustainability to me is the program that prescribes to have intermediate steps along the way that people could see progress. One of the things that I would worry about is that we don't have to go to Mars in 40 years, send money and we'll call back in 40 years. I don't think that's going to work. It won't get any engineers who'll want to work on it and it won't get anybody who'll want to pay for it. so, I think we ought to be very explicit as to sustainability has to include measurable, as I was commenting the other day on another venue, one of the problems with this whole thing is you can't go halfway to Mars and you can't announce every ten years, "We're ten percent there, we're twenty percent there, we're thirty percent there." You go or you don't go and that's one of the dilemmas here. We need intermediate milestones. Then the last thing I think I want us to see, you've obviously got it in here but this comes back, this whole question on inspiration and national leadership. If America is to be viewed as a great nation, we have to lead in some areas. Areas at which we lead had been diminishing, economics, science; we're clearly losing our lead. We have great universities that may be one of our greatest assets. They're in trouble today financially. We have our democracy. We have our free enterprise system and even the latter is being challenge now. Space is an area we have unquestionable leadership. Nobody can question that. You'll recall that, we conducted, I say we, the nation conducted the Apollo program during the height of a major war. We sometimes forget that. We somehow found a way to pay for it to stay focused on it and we all, who lived through those days, remember what a wonderful impact that had on the nation when we were suffering in a lot of other areas. I guess those were the main points. It seemed to me I had one other thing I wanted to raise but I have lost it, so does anybody else want to weigh in at this point? I think with those comment, could you accept those comments from, not mine but everybody's, in the form of bringing your corrections to the course?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I think we can take those as friendly amendments and we'll…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Well, okay terrific.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
We'll produce a draft which is…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Bo, please.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Ed, and may be you have said it, may be I'm sort of not quite…. heard it properly, is there a criteria that will measure or evaluate our scenarios by how well do they contribute to U.S. leadership in space? You can lead in a cooperative scenario. You can have partners but provide leadership, and I think it's important that U.S. maintains that. We don't want to relinquish it and I'm not sure that I've seen and may be you have said it Norm, but it wasn't obvious to me. I think that it should be that one of our criteria is how well the scenarios maintain U.S. leadership in space.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics Well, I think I'll defer to Les' not in real time. I mean this is, as we understand and we discussed yesterday in Huntsville as a little bit of a two-edged sword. We seek to have leadership in space but we seek to engage our international colleagues and finding a way to express that in such a way that it both makes sense and satisfies the national interest and are an implementable strategy, I don't know… Les, do you want to…?

General (ret) Lester L. Lyles – National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program – Chair
Well, just as in the recent National Research Council study, preeminence for the United States in space was a major tenant of that particular study but we were very, very careful to define what preeminence means and what leadership means. Specifically, to define that it does not mean dominance because you can have preeminence, you can lead, you can be a great leader, but probably more so when you don't try to dominate other participants in the situation. I hate to use this old military term, "lead, follow, or get out of the way." But that's the definition of a good leader, somebody who could recognize how to do those things and still stay out in front in terms of the respect he/she or a nation or an organization has with other bodies they have to interface with.

Dr. Christopher Chyba - Princeton University - Professor
I just want to say, you can have a team. It can be a great team. You can be a team where every member is essential but that team's still has got a leader.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Okay.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
If I could, Ed, I thought of the other item that I wanted to mention and I interpreted Les your earlier comments a little bit differently than Ed did and I suspect that Ed was right but what you're talking…you kind of… or Ed you picked up on the notion of how does the space program impact those everyday problems that we all worry about, the economy, the environment and so forth. One of the things that we need a caveat in here, we either need another line to make it very clear that we're not Rip Van Winkle or else we need to state in words that there are many other challenges that this nation faces that we didn't address when we put our ratings in here. And obviously, that's beyond our pay grade to do that. I think we need to make clear of that we do understand that there are demands on the nation beyond those in the space program, otherwise, I think people dismisses this as being myopic, anyway Ed, with all those friendly comments, if you can live with that. Does anybody have a problem?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I think that's well within scope.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, we're on our way then.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Okay, so we'll do a rev on that and circulate it for the committee's information. Okay, so now that we've established why we explore, it's useful to talk about for a few minutes where we might explore. There is a common perception that the only option presented to President Kennedy in 1961 was to go to the moon. In fact, NASA did quickly in what might even be called the 90-day study of three options which were to build a space station, to go to the moon or to go to Mars. The final recommendation to the President was obviously to go to the moon under the theory that that the Soviet Union could too easily beat us to a space station and that Mars exploration at that time was likely not to be achievable, but in fact, we have a neighborhood. We have a neighborhood around the Earth in the inner solar system which has in it the moon, our moon, asteroids and NEOs, many of which are..., near earth objects that is, many of which are of composition fundamentally different from either the Earth or the moon. We have Mars, the planet arguably most likely most like the Earth in its composition and evolutionary history and its moons which are also of different composition than Mars and we have Venus, our inner neighbor. And in addition, we have special points, the experts called them Lagrange points, I just like to think of them as locations at the edge of the influence of the Earth as a body. When you pass by the Lagrange points you've passed out into real space. You have passed most of the influence of the Earth. And all of these represent possible places, destinations of exploration. For the rocket scientists in the room, you'll recognize this. For the rest of you, let me try and explain. This is a way to think about how hard it is to get to these places. Along the scale on the bottom is basically how much difficulty or how much energy it takes to get to these places from the special points, the LaGrange points between the Earth and the moon and Lunar orbit on the left hand side, all the way up to the surface of Mars on the right hand side, and along with this scale, is a scale of increasing mass that it would take to get there, that goes up the left hand side of the chart, and increasing mission duration goes up the right hand of the this side of the chart. This is a notional chart. These aren't exact numbers. But actually, what we did, and I'll explain this in more detail in a moment, is that we defined a set of scenarios that allow us to look at particular cases where we might explore. They are listed here, and I'll come back to them in significantly more detail in a few minutes, scenario A is a Lunar base, B is a global Lunar Exploration scheme, C is to go quickly to the moon and then to Mars, D is to bypass the moon and go directly to Mars or Mars first and scenario E is an in-space or deep flexible path.

This is now not so notional but a more specific chart and it gives you some sense, again along the lower axis, and I'm sorry I can't from here point over there because of the arrangement of the room but I'll try and describe it to you. In the lower left hand corner are the easy missions. These are missions in the Earth-Moon system and to the special points, lunar flyby and so forth. Just to the side of them, not very different and somewhat less energetic in some cases than going to the lunar surface, are missions to NEOs, the asteroids that come close to the Earth, which of course are a potential hazard to the planet, are also, not coincidentally, not far away in terms of energy or time as we'll see in this chart, that you can do a mission of a few months to a NEO and back. To the right of those are the lunar surface, up in the area called E are things like Mars and Venus flybys and off in the distant upper right hand corner are the missions to the Mars surface, highly energetic and taking approximately 1000 days.

The next chart is a similar chart where we take rough estimates of the amount of mass that would have to be launched into Low Earth Orbit just to do the crude part of these missions. The scale on the right indicates about how many launchers would be required and you can see that the first column, the third column from the right, the one that goes from 1 to 5 is about the number of super-heavies, Ares V class launchers that would be required, about 5 just for the crude part, 4 to 5 at the top of the scale and of course for less capable launch vehicles there would be more of them.

So this is the domain in which we are reasoning, how difficult is it to get there energetically, how much mass is required to Low Earth Orbit in order to achieve the mission, how long does the mission take? These are the fundamental parameters of thinking about destinations in our neighborhood and what we did as I mentioned, created a set of scenarios that allow us to look systematically through these set of options. Another thing we did to simplify the problem is we created a 3-layer architectural model of exploration. There's the bottom layer that Bo worries about. This is how you do what's in fact the most energetically and risky thing, which is to get off the surface of the Earth to only a few hundred miles above us in Low Earth Orbit. This is the domain in which Bo's work...., Bo's sub-group is studying the options of using various vehicles of different heritage and size. We then subsequently divided the problem into the top layer which is "encounter and exploration" and this middle layer of in-space transportation. This does not coincidentally look like a 3-layer model of computation, where the application layer is up at the top and then there's the middle-ware and the operating system.

And the real value generated, much of the real value generated is up at the top in the encounter in exploration but a lot of the difficulty and cost is in the in-space transportation and transportation to LEO. Yesterday, Bo briefed the group in Huntsville, our group in Huntsville, on the transportation to LEO. In the next half hour or so, I'm going to talk about the encounter and exploration layer and then Jeff Greason will talk about the in-space transportation layer of this architecture, this way to think about the architecture.

One more chart just to explain, and I got to admit, this is the one where I really sound like a professor, if I haven't already, Oh!...this one. This is our way to reason through the space. We set out some goals and we framed some questions. The questions allowed us identify scenarios which encompass the broad options. We commissioned a set of very dedicated and extremely hardworking internal NASA teams with a few independent thinkers on the outside to do trade studies on these scenarios and these lead us to the options, Norm, that we'll propose to the committee today. The options really trigger capabilities, what does it take to do these things? And really, what we'll do in the next week or so, and deliberate at our two subsequent public meetings, is to play the capabilities against the options, to see what it is that should be built in order to build a robust architecture for the future exploration of space. These scenarios do not differ that much in what you actually have to build. You need some sort of launch vehicle off the planet. You need some sort of in-space transportation system. You need some habitation in space. You need some landers and the real issues are in what order you do these in order you do these in order to fit within a reasonably expected budget and how quickly they return benefit to the stakeholders and meet the evaluation criteria that Wanda outlined.

Very quickly, because it's been posted on the website, are the questions that we framed. Where should we go, the moon, the moon and Mars, direct to Mars, along the flexible path? What should be the mode of surface exploration, a semi-permanent base or outpost, more extended sorties to various places, or an idea that is not inconsistent with the recent proposal of the Planetary Society, that maybe what we should do is orbit planets with deep gravity wells and only touch those with less deep gravity wells initially until we develop a more robust capability in deep space, and then we go to a return to planetary surfaces. What's the strategy coordinated with the robotic program? What is the assumed launch vehicle to LEO? This is essentially our interface question with Bo's group. What are the options for in-space fuel and oxidizer transfer and depot-ing, that is, could we imagine an economy in which fuel is more readily available in-space so that we can free ourselves from the rocket equation in a sense, by assuming that the vehicles that we launch don't always have to carry all of the fuel they will need for all of their mission, that there is the capability to decouple the on-orbit or in-space supply of fuel? What's the role of technology research? How should we engage the internationals and what's our strategy for engaging commercial entities?

By the end of the discussion this morning, we'll actually have gone through the answers to many of these questions. We, the subgroup, defined five scenarios that we should consider. We had always intended to keep the Program of Record as a case that we would continue and carry in our studies, and we invited the Program of Record to provide some alternatives in view of the deep knowledge base that they have and the maturity of their systems, how would they respond to the opportunity, let's say created by the potential budget reductions.

So first, I'd like to discuss very briefly the Program of Record and the alternatives that they proposed. This is in fact just a summation of many of the briefings that the committee has received over the course of the last months. So the Constellation Program itself, over its evolution starting with the ESAS studies in 2005, have studied a very broad space of architectural options and they have been thorough. There has been a great deal of analysis and we have carefully examined those. The position of the program is that there is US policy, US law represented by the appropriation bills, there are requirement documents derived by the program from those, and the Program of Record is the one that satisfies these and demonstrates the greatest maturity. But of course now in the fiscal reality of the guidance given to our panel by the White House, it does not fit within the budget.

So essentially we provided this task to the program and they said well, there are really two options here. We can either stay within the content guidelines and move the schedule to the right, that is to say, extend the program so that we develop the capabilities as the budget allows, however, this produces as shift in human lunar return, no earlier by 2024 and other studies that we've commissioned would suggest it's even later than that, but well into the decade of the 20s, or within the budget, we can focus on a skinny down, a simpler, beyond LEO capability as soon as practical but then the requirements on us have to change. We have to be relieved of some of the requirements and we have to explore new capabilities including a more aggressive way

to get commercial access to LEO and the ISS and developing capability beyond LEO sooner.

I need not remind most of you about what the representative architecture of the Program of Reference is. It's a 1-1/2 launch scenario to Earth orbit, Earth orbit rendezvous of those components, injection into lunar orbit and decent to the lunar surface by a lander, return through a ballistic entry. This is the reference case that we'll use for comparison in most of the other scenarios. Constellation over the course of this study that has been commissioned by the White House, independently arrived at the following recommendations: The first is basically the baseline, the second is to push very hard on minimizing the gap, trying to hold it to about 2015, stay within the budget and slip human lunar return out well into the middle of the decade of the 20s.

The other option they proposed is what they call the Content Adjusted Option, which is basically to bypass US government access to the International Space Station, relying on the delivery of that service by commercial or international suppliers and focus immediately on the development of the heavy lift vehicles, to simplify somewhat the design of the Ares V and basically go to a dual launch strategy for lunar missions. They also proposed interestingly a higher confidence baseline which would include some interim beyond LEO missions, early lunar technology and robust ISS access by the government. So we will carry forward, Norm, in our evaluation in the next few weeks, these options which have been proposed by the program, the Program of Record as it stands, and the variance that they have proposed. That is, we recommend as we do this.

I think I'll just touch lightly on the next chart. What it basically summarizes is the key dates and the cost. In the baseline program, there's about $100 billion of expense in the decade of the teens, which will produce human lunar return as forecast by the program. If we cut the budget down to the 70ish level, $70ish billion, what this indicates is that the human lunar return goes out to the mid-20s at a minimum, and goes up in price. Norm, this should come as no surprise to any program manager, when things take longer, they cost more. And one of the messages that we have to convey I think in our report is cutting the budget year by year does not save money. It in fact increases the cost of the program. The other alternatives as I've laid out move in milestones beyond LEO and move out human lunar return at roughly comparable budgetary levels.

So this is what the Program of Record looks like on this chart that I'll show for each of the options that we covered, that first there's an Ares I-X test flight and we did these on years beginning in year 1 but for the Program of Record, there's actual years below it that goes with it. We get Ares and Orion going by about 15, Ares V by 19 and have a human lunar return by 20. This is a familiar schedule to us and the advantages of this system are of course that it's mature, it's got we think at this point relatively well-understood costs and risks. It efficiently uses the existing assets to perform the mission in the sense that it builds on much of the infrastructure here and the assets that are remnants of the Apollo and shuttle programs and it provides a very robust capability. As the former administrator often pointed out, the thing that you needed most in order to enable exploration robustly was a heavy lifter, and we were going to build one. We are going to build one.

Just one chart on the cost structure of the Program of Record, if you run the beyond the LEO group, this isn't really good news. That if you start from 12 o'clock and go around the clock, you see that about the first third of the budget is engaged in building the launch vehicles and about the next third of the budget it engage in building Orion, Mission Ops, Ground Ops and EVA, all necessary things really just to get to LEO Earth orbit and the slice subtracting off the reserves, the slice that's actually available in the next decade, to go beyond Low Earth orbit, is only about 15 percent of the budget. So if there's about a 30 percent budget reduction, this would imply that there is essentially, under the Program of Record, little or no beyond LEO program in the next decade. That's the budgetary reality. So in order to examine whether there were other significantly different options than this, we created, for the NASA study team, five scenarios which are the ones that have been posted and I will discuss here very briefly.

The first one is basically to focus only on a lunar base, to relieve from the program the requirement for anytime return, global access and to build the system such that it goes to a base or outpost at the south probably or north polar region. It relaxes some of the key driving requirements in an effort to reduce cost. This was an option that did not trade well and I'll dispense of it in one additional chart. In essence, taking the few hundred meters per second of delta V out of the lander system and rippling it back through the launch system causes you not very much change in the program cost and at the loss of benefit of being able to access most of the lunar surface. So the additional capability required to build a little bit more robust system than could just go to a polar region, does not provide any significant cost savings and therefore, Norm, the committee has decided to drop this one from the option space going forward.

Scenario B we call Lunar Global. This is a different view of going to the same destination. Instead of focusing, and I should make sure that for the record I say that the Program of Record actually has not identified unquestionably the mode of planetary exploration so that if you asked the program, they would say that this option is still within the space they're trading. However, since the program tends to be focusing on a polar outpost, we decided to put in a scenario that would explicitly cause us to look at a different mode of exploring the moon than the one that the program tends to be drifting towards or tends to be focusing on. So in this scenario, we would send assets to the moon first as short sorties and then as what you might call extended sorties or short term habitats that would build up the capability of going to the moon from 14 to 180 days but would do so in different locations so that we first had scouting missions and then we had short stays to various places and then if and when we decided that there was a place that merited a semi-permanent outpost, we would proceed in the on-ramp to that program farther downstream to build up a semi-permanent outpost on the moon.

So the architecture for this option looks as follows. There is a sortie phase in which we called it four sortie missions, go to the surface to scout various interesting scientific and historical sites, about 7 days each with four humans. Then there's an extended duration trip to site A based on the input from sorties and by that point, extensive robotic exploration of the moon. This would allow up to 56-day duration stays and would be visited by a cargo flight and five crewed flights. Then there'd be a next site, we'll call it site B where we went up to 84-day durations with two cargo and six crewed flights and then C, with progressively more capability. You can see the progression

here. This is going up in capability as you move around the moon. There were trades in this study that focus primarily on this study that focus primarily on launch capability and how much infrastructure that was required on the lunar surface and I'll show you sort of a typical schedule chart for this now, starting in an arbitrary year one which is the year of the test flight to the moon of the robotically controlled lander. Then, there would be sortie flights to several sites. There would be the first extended duration which would take a habitat down on top of the lander, then a second site which would take a habitat and would have an unpressurized rover habitat and pressurized rovers and then several habitats and several pressurized rovers.

An advantage of this scenario is that this more closely replicates as we'll see in a few minutes this concept for operations that would be used on Mars that we would go to several sites with largely self-contained missions as opposed to, at least in the current reference architecture for Mars, building up an outpost on Mars.

So the principal distinction there is how we explore the planetary surface of the moon but we still go to the planetary surface of the moon. The one that follows B is C but I'm going to skip C for a minute and go to D. D is what we called Mars First. This is the all out, let's pull out all the stops and go to Mars, without any touching of the moon at all, not even as a test bed. So this is an incarnation of the concept that Mars is the primary objective and therefore that is where we should explore. We send progressive human missions to Mars of extended exploration time and this scenario was based extensively on the recently published design reference architecture 5.0 for Mars. The representative architecture is that we essentially assemble three very large spacecrafts in low earth orbit that we'll be taking many flights, between 8 and 12 would be the range, that two of these are robotically sent on missions to Mars, one deploys the habitat to the surface and one stays in Martian orbit awaiting the crew to come and Jeff for your reference, that little dot on the far left hand end of the second large spacecraft is Orion, which is what causes Brett to say "the small spacecraft" which he did yesterday. That when the humans arrive they move over to the landing habitat, it goes down, they spend an extended period, around 500 days on the surface, they move to the ascent stage and into the Earth return vehicle and come home.

The trades that were done in this, off of the reference, design reference 5 architecture include an examination of the crew size, an examination of the surface payload, and an examination of the propulsion system, and we challenged the Mars gang to think about what exploring Mars would look like if you had a smaller and a smaller set of payloads to see if this gave us any latitude in the cost trade space. And they did a superb job in the time that was available to them to book-end the system. There was a 6-crew, 40 useful metric ton payload landed to the Mars surface, and at the other end, a 4-crew, 20 metric ton to the lunar surface. The great challenge here of course is the technology to land even a 20 metric ton payload through the Martian atmosphere and then propulsively break it through the last kilometer or so of delta V to land. The milestones here are some early demonstration of in-space living, habitation perhaps on the ISS, maybe a test mission to a NEO and then directly to the robotic landings and then out to cargo to Mars and the first human on Mars in the year 14, this is the reference year, 14. But when played into the budget, it would be unlikely that these would occur Norm, before well into or at the end of the next decade, that is to say the decade of the 20s.

Of course, tremendous advantage of this scheme is that it goes where we think we ultimately need to go. It goes and explores Mars. It searches for ancient life and it makes progress towards the understanding of whether or not Martian life forms have persisted and continue to persist. The risk of this primarily from a programatic point of view, is that Norm, as you said earlier, this is the "you can't get halfway to Mars problem," that it's very difficult to show any intermediate progress, over a long period in which technology and systems are being developed. We actually asked in scenario C what would it look like if you actually designed to go to Mars but did a touch and go on the moon? You actually used the moon explicitly as a test and proving ground for a mission to Mars and we came back with some very interesting answers to this. The primary objective of course is still Mars exploration but now you see photo-shopped into the picture top on the right, the Mars lander, the Mars habitat lander landed on the surface of the moon. I think this is a particularly interesting picture and I think one of the most powerful ones that I saw in the last few weeks in addition to a lot of data and a lot of very good work.

The idea that a lander for the moon would actually look and feel like the lander for Mars, that not only would it be developing some technologies but it would actually be sort of working through the concept of design and the concept of operation of the eventual Mars mission, that we would in essence design the lunar systems more proactively to reduce the risk of going to Mars is an important idea that came out of this particular scenario. The reference architecture for this looks almost exactly the same as the reference architecture for Mars which it is of course based on. This is basically a test flight of the Martian system going to the moon. You build up the same rockets with the same propellants. You send them to a different planet through a significantly shorter timeframe a few days out, a few hundred days on the surface then a few days back, and all of the truisms that we have recited over the last 4 or 5 years about how using the moon as a test bed actually become a little more real here in the sense that we really are using the moon as a test bed. The problem with this scenario which we actually have some interest in, is that it shares the exact same delay problem as the direct to Mars, since you have to actually build all the Mars systems in order to test them. You don't get to test very much for a long time and the scenario as laid our here shows essentially the same plan as you saw a few minutes ago for the Mars First scenario D, but now there's a cargo and crew mission or perhaps two, to the moon to test those systems. So unfortunately, it actually moves the Mars expeditions out even a little bit more to the right. These of course, there's the time and effort and money spent to do the test flights which may be entirely a valid idea but even further complicate the issues of sustainability. But Norm, we have enough interest in this scenario that we recommend that in the coming few weeks we leave it in the space that we're continuing to consider.

The last of the scenarios we created we call flexible path or may more appropriately be called the deep space option or the in-space option. This is the idea that it is true that we need to gain experience exploring planetary surfaces but in fact, we've done some of that. There have been six missions to the moon, six piloted missions to the moon, and we have a robust robotic program that explores planetary surfaces. What we actually have almost no experience at all with, is operation in deep space, particularly where it couples to the radiation issues that Chris mentioned, the idea of progressively

sending humans on longer and longer missions so that we would be ready to accept the risk of 180-day transfer to Mars and return. So the flexible path essentially goes across stepping stones that are easily obtainable in progressively more challenging delta V and duration missions but avoid going down into the deep gravity wells like the moon and Mars initially. So what it would look like is a test flight around the moon to validate that we can do that and demonstrate to the international community that we've been there and done that. Flights to Earth-moon L1 where we might someday bring scientific payloads back from Earth-sun L2 to refurbish, then we go to Earth-sun L1 and L2 in progressively longer steps, longer duration steps, gaining experience in in-space operation and this is the way it unfolds. A minimum capability in a lunar flyby - this is Mercury, a near Earth 21-day duration to L1 or L2, this is Gemini, going to the Earth, maneuvering in the Earth-sun vicinity 30-90 days, this is Skylab, a progressive yearly demonstration of increasing capability of the system. Then, we go to a NEO, or potentially a Mars flyby, a direct return trajectory to Mars, testing a long duration, hundreds of days mission and then really there's a branch point and you say are you really ready to build up the surface systems to go to Mars or should you do an off ramp and develop the capability on the lunar system?

The real advantage of this option is this chart. It is the one that since it develops the least in-space systems, has at least the potential of showing the most steady cadence of progressive improvement in our in-space capabilities from 10 to 21 to 30 to 90 to 180 to 300 to 400 days in orbit, delaying the missions down into the deep gravity wells. There's another aspect of this which is that it potentially creates the opportunity to more highly synchronize the robotic and human systems that the humans in orbit around planetary bodies could in fact interact without time delays with robotics systems on the planetary bodies. The humans could certainly do sample returns from the low gravity bodies, the NEOs and Phobos and Demos, eventually, although those are highly energetic missions. And one of the interesting things that might occur in this scenario is the Mars sample return mission could be coordinated with a human orbit of Mars mission so that the human-piloted craft actually rendezvous with the sample returner in Martian orbit, captures it and brings it back as part of the crewed mission, rather than having to build up the infrastructure for robotic sample return. There are enough benefits to this option or perhaps grafting some of this option on to some of the others Norm, that we're going to recommend that we carry it forward in the next few days and weeks as well for further study.

So Norm, I come to the second of the charts that we'll pause on and say here we have some recommendations for the committee and these are really recommendations for further study. The only decision we're asking for the committee today as a whole is do you think this is about right? Do you think this is about right, do you think this is comprehensive and representative as a set of cases that we'll carry forward, knowing that the things that are scored and recommended or evaluated in our report to the White House, will likely come from these things, or variants of these things. So let me just summarize them for you because it has been 15 or 20 minutes that's taken me to run through this tour of the inner solar system.

The recommendations to the committee are to consider these options going forward. First, that we maintain the current Program of Record as an option. We were asked we feel by the White House to provide options, not decisions, and to not include the

Program of Record in the option set would effectively be making a decision on what we choose not to do. We think that there's great merit in the current program at the budget for which it was scoped and that we should carry that forward. Second, that we maintain the variant proposed by the program to essentially maintain content and stretch and I failed to mention as I went by those charts of the Program of Record, that those schedules did not consider the liens that Sally and her subcommittee proposed on Tuesday of an additional 5-year, several billion dollar program to extend several billion dollars per year program to extend the life of the international space station. That would be further rework of these schedules and as you know, Norm, it gets harder and harder to rework a schedule with fixed content as the dollars per year become less available but that we should maintain so that the White House can see the impact on the program of Record, the option where we just stretch it out. Third, that we consider the variant proposed by the program, the people who in fact go to work everyday thinking about how to make this work, that we bypass or defer the US government launch capability to low Earth orbit, and focus directly on the development of a slightly simplified Ares V which would create a more robust lunar scenario, giving greater launch mass capability to the lunar options and have other programatic advantages and disadvantages that we can go into the details of in our report.

So those, Norm, are the three recommendations based on the Program of Record and its variants. Based on the scenario work we've done, we've sort of collapsed it into three rather than five things we consider. One, which is essentially what I just explained as Lunar Global, an approach to exploration of the moon by visiting many sites, first in sorties and then in longer stays and still with the long term option of developing a base or outpost and in an approach which more directly focuses on Mars preparation, at least at the technology and system level and Con-ops level. The next option is the one that I called in-space, an in-space path with visits to Lunar Orbit, the special points on the boundary of Earth's influence to the LaGrange points, the Near Earth or Earth crossing objects and then eventually Mars orbit, but maintaining an option of a sortie to the lunar surface or visiting - visits to the Mars orbit and the moons of Mars later downstream. And finally, the Mars First option, but an exploration program that goes directly to Mars, but we think there is sufficient merit in the test flight to the moon that in a Mars scenario we would include that.

So Norm, those are the recommendations of the subcommittee of the options that we continue to study and evaluate based on the metrics that we discussed earlier in preparation for thinking how to go forward with the handful or small handful you've described as the output of the committee.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Ed, thank you and your group for that report and for the additional material that you've provided us here to study in preparation for our meeting next week. You've obviously put in a great deal of effort. I find I have 8 questions here that I'm sure everybody does, judging by the appearance of the table. The good news is I hope the members of your committee are still supportive. Why don't we just start around the table, I'll go last. We'll start out with the General.

General (ret) Lester L. Lyles – National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program – Chair

Ed, I thank you and your team. I think that was very, very illuminating and very, very comprehensive and to be honest with you with you, I stayed with you all until the last chart. And the flexible option which I thought personally had a lot of merit, seemed to be very, very logical and a very, very appropriate technical approach but then when you got to your last chart, you describe Lunar Global, In-Space and Mars First, all three of which have moon and Mars in them and so I'm not sure whether flexible option applies to all three of these or somewhere in the translation between the let's see, 81 other charts and then the last one, and I got lost.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Well General, you've once again commented that I didn't go to general school. So let me see if I can - it's a great question, let me say, if I can clarify that. Lunar Global is go to the moon but go to the moon through a slightly different way than the Program of Record is now focusing on and with an attempt to develop the technology as much as is possible to go to Mars but realistically, Mars is delayed a long time in the future. Mars First, the last one, is basically go to Mars, but in the process of going to Mars, it may make sense to do a touch and go on the moon, a test flight to the moon with exactly the hardware or very close to exactly the hardware that would be required to go to Mars. So that's really go to Mars. The one in between, which we called In-Space or Flexible is really don't go to any planetary surface initially. It's to sort of learn how to navigate for 30, 60, 90, 180, 360 days in space and use robotic assets to explore the planetary surfaces and the deep wells and orbit, which is essentially, rendezvous, with Near Earth objects and eventually Phobos and Demos, the moons of Mars, but to defer for a long time the technology and the expense of building the planetary surface transportation and infrastructure.

General (ret) Lester L. Lyles – National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program – Chair

Okay, well, thanks for clarifying that even though moon and Mars are in all three options for one degree or another, the real one, that's the Flexible one is the center one, the In-Space, okay.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics

Having clarified that, I now wish to slightly muddy it. These options were deliberately made as different as possible so that you could explore the corners of the trade space. Then when you take the next step and think about how you'd actually implement them, there's options to add flexibility back into all of them so for example you could do the In-Space space architecture in a way that it wouldn't require a lot of changes, just some additions to put a lunar sortie in. You could do the one in a way that you could add the capabilities back to the others - these aren't necessarily irrevocable, mutually exclusive decisions but you do have to decide which things you do first.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Leroy?

Dr. Leroy Chiao – Engineering Consultant
Thank you, and thanks Ed and your team for making this obviously very difficult, challenging assignment of narrowing things down for us. Like Les, I was with you 'til the end there and I want to clarify something because it may change what I have to say, the option Mars First, what you've written is a Mars exploration program with test flights to the moon, of the Mars system but what you've just said I think was test flight to Earth's moon, so is it?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Yes, that's right, you got it right. It's a test flight to Earth's moon, not the Mars, not Phobos.

Dr. Leroy Chiao – Engineering Consultant
Not Phobos or - okay, got you. In that case…

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
It's basically you will build the Mars system and the intent all along is to go to Mars but just like you do test flights of aircrafts and test flights of spacecrafts, you'd do a test flight of the entire Martian system and it would happen to be on Earth's moon.

Dr. Leroy Chiao – Engineering Consultant
Okay, that makes me feel better because I was going to say I'd like option C of using the moon as a test bed. Also, I wanted to point out that maybe it's implied in your presentation that we're also going to use the station as a test bed, because certainly on the station you can't test your rovers or your habitat, things like that, but you can certainly test things like the habitable volume that's going to go on your Mars departure spacecraft systems. You can test your systems for robustness of operations concepts, maybe even space suits although not for ambulatory things. Maybe even fuel depots. I mean, the station now we've got obviously a lot of stored fuel on the station so there's certainly - I think we could certainly entertain testing fuel depots.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
And increasing autonomy by artificially putting com delays and so forth as we've discussed yesterday.

Dr. Leroy Chiao – Engineering Consultant
Right, okay. I mean, that is kind of implied in your plan to use the station?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I think it's fair to say that that's the integration work that lies ahead of us. We did not either include or preclude the use of the station since we heard from the subgroup that discussed the station alternatives so forcefully on Tuesday, I think that this set of meetings as you know has been the first time when we've been able to come together

and share all these ideas in the appropriate public forum, and I think having been alerted to those opportunities and the recommendation set that you're considering, between now and the subsequent public meetings, we'll further consider this, do some additional fact-finding and come back with a sort of more integrated view.

Dr. Leroy Chiao - Engineering Consultant
Sure, okay. Finally, I just want to make a comment on the in-space, your flexible path. That's very attractive for a number of reasons and I'm sure you've thought about this. There's a little bit of a risk in it in that because it's flexible, because there are convenient places to kind of set your next goals and things like that, it also carries the risk that it could be a convenient place for policymakers to decide to stop altogether?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Flexibility is a two-edged sword in the policy environment.

Dr. Leroy Chiao - Engineering Consultant
Okay, that's all.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Let's see, Chris, do you want to ask anything at this point? Jeff, you don't get to ask questions, right?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Jeff gets to talk next.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Bo?

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
I don't want to get bogged down in semantics professor but we maintain current Program of Record as an option and I feel like we ought to recognize the fact that today's Program of Record is a baseline. And like I said, I don't want to get bogged down on what we call it but it is a baseline today so it's more than option, maybe in our evaluation it may turn out to be an option but today it's a baseline so that's just one comment. And the second on this number three, we considered a variant proposed by the program to focus on Ares V and I would suggest that Ares V - and I'm assuming that you mean in various variants of Ares V, smaller, you know, okay. But at this stage, I think it's too early to brush out - I would expected you to be energized by the fact that you don't see all these other heavy lifters…

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Stay tuned.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Okay, I'm staying in tune. Okay, go ahead.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Remember Bo that we gave the opportunity to the program to propose alternatives that they would propose and what they proposed not surprisingly was to do variants.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Yeah, but to maintain what - and we have been trying to be meticulous maintaining this level playing field for looking a the various launch systems, to support your scenarios, I would recommend that at this stage we say it's to focus on Ares V including its variants and other super heavy launch vehicles and we will show, let them be the survive or die based on numbers, on cost figures and other considerations, but I would not eliminate them…

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
That's fair, because we're really using the Program of Record here to represent both the transportation system and the above LEO exploration systems so your point is quite well-taken.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Thank you. That's all now.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Anybody else before I start out here? I do have 8 questions. I'll try to ask them quickly and unfortunately a couple may have subsets, maybe you can give concise answers and then do more work later if we need to.

The first one is that Chris makes an important point that we don't want to just pass by, and that is this matter of galactic, cosmic rays as a showstopper as we know it today and the question is we need to propose something to resolve that, to remove it as an obstacle and Ed, what's the group proposed to us on that?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Stay tuned.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I'm sorry?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Stay tuned. You're going to discuss that (cross talking)…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
You're going to address that? I will look forward to that. Let me add the subset to that one and that is we all know the impact of zero gravity on both bone structure and muscles, human muscles and bones over an extended period of time. The question is, when you have really extended periods of time such that we're talking about here and you land on something with a 6th of g or a third of a g or something like that, is that enough to give full recovery so you can stay around for another year or so and still function effectively? I don't know, you may want to add that to your list for later? Yes? Okay?

The next one has to do with the administrative question really Ed for you and that is that we've got quite a few options here. We need to get more cost and schedule data than we now have although you've got a great start. Are we still in a position that if we keep this many options floating here?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Well, Norm, you put your finger on the principal puzzle we have ahead of us. In essence, if you're keeping score, Sally proposed three options about one problem and three options about a second problem on Tuesday. Bo in various ways proposed let's called a handful of options of combinations of launch vehicles that make sense and we've just propose six, although we could probably whittle it down a little bit, calling one of the baseline and 3 or 4 of the others and we have to do some clear thinking, we as a committee, in view of the fact that this is the first time that we've had an opportunity in a public forum to present this and to reach decisions about how we narrow this space or prepare at hour next public meeting to narrow this space so that there's a small enough number that both can be costed and so the policy officials can reason through. And I just say that's the task ahead.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
My hope is that between now and when we meet next Wednesday in Washington, some of the chunks can be assessed. To some degree, these things are additive and could be moved around. I understand their limitations and then next week we'll have to make a final decision very promptly.

The third issue is we have talked during these various meetings about crew size but mainly as it impacts mass. It must also impact psychology to a great deal, these long missions and I don't know anything about that and have you done anything on that or is there any data available? I'm sure there is. Or what should we do?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
What we have done is try to look at the sensitivity of the system design to the crew size decision. That is to say we asked the Mars team to look at rather than a six which is their baseline, to look at four, which is at the, I would, say extreme lower end of what responsible analyses of the crew size that you would need on Mars would call for. We asked the Lunar team in addition to looking at four, to look at two, which would be the

extreme lower end of that and we have information in our back materials on those trades which not surprisingly in general do not show half the cost or mass for half crew size. There are certain systems that have to be carried and there's overheads and so forth not surprisingly and if you're going to design a half billion dollar ecosystem making it large enough to carry four people's load rather than two people's load is not much less expensive, so there are many fixed costs in the system. We have that. What we haven't done, and I'm not even sure Leroy how we would do this in the time available, is evaluate the importance of the various crew sizes away from the normal numbers that are accepted, which is roughly speaking four for the moon and six for Mars.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Leroy do you want to comment?

Dr. Leroy Chiao - Engineering Consultant
Yeah, I mean certainly crew size and composition changes the dynamics quite a bit and right now the ISS of course we have a pretty large crew until very recently, until the shuttle undocked, we had a very large crew. But when I was there, the crew size was only two and that was quite a different dynamic so you're right, it is important and there are a number of Earth-based studies that have looked at those interactions. The difference is that I think you have to take some of those studies with a grain of salt because like especially when it's really synthetic when you're inside of a chamber and you know psychologically you can, in the very worst case, you can get out. So, just one quick analogy on that and just, I mean, no conclusions, just that we do have to think about this is a lot of my Russian counterparts actually smoke and so I was wondering well, what do you guys do when you go to space? Do you quit cold turkey and is that a problem operationally? Do you feel badly? Does it impair your operations and I found that to a person they say no, it's not a problem. They have their last smoke before they get suited to go to launch. They get into space and I think the difference is they can't go down to the corner store and get a pack of cigarettes. They know that. So they act differently in space and it's fine. It doesn't impair them a single bit. So when you compare 1 g chamber studies of people having fights and all that, I mean, you have to keep in mind, they know even maybe just subconsciously that they can leave, that they can end this test and leave. Whereas if you're stuck there, you'll do more to be accommodating and get along.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
That's interesting.

Jeffrey Greason, Co-Founder of XCOR Aerospace
Can I add something to that?

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Sure Jeff.

Jeffrey Greason, Co-Founder of XCOR Aerospace
This is not a subgroup planning, right? We're discussing so I can have a personal opinion?

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Absolutely, you can have a personal opinion always.

Jeffrey Greason, Co-Founder of XCOR Aerospace
It's absolutely a mistake to minimize the psychological issues. You look at the history of exploration, not just space exploration but other exploration, those issues occur. But also if you look at that broader history of exploration, you know we're still working with the Mark 1, Mod 1, human being. It's amazing what people can make themselves do if they want it badly enough so I would not let those considerations deter us from stepping back from doing something just because it looks unpleasant. The people will be there if the systems are there.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
The reason I raised this is as an engineer, I would optimize around one astronaut as an engineer. I know there are other factors so there's crew load, work load. There is a psychological issue and I think my request is just that we see what is available and be sure there's nothing there that makes whatever we propose unreasonable.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I think as an engineer we could actually optimize around additional marginal benefit and additional marginal cost and that may not be one.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I stand corrected by the professor. The next item on my list concerns fuel transfer and could you talk a little bit about that from two aspects? One, how you might tie that in with the options that you kind of zeroed in on, maybe something in parallel and secondly, give us a little insight into your view of just how difficult this is? I have a little bit of familiarity with what it's like to transfer liquid hydrogen and oxygen here on the Earth and it's not very easy so just (cross talking)?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Jeff will cover that comprehensively. That's alright.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I'm sorry, next item, sixth item. Option C provides for no science on the moon but I gather you could always go back and do the science on the moon if you wanted to.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
That's correct. That is essentially correct although you would be on the moon for 180 or 200 days to simulate something like the stay on Mars. It's really a test flight. I mean, as with many human exploration systems, there's always a salience of availability but that would not be the primary objective, you're right. And that will cause it to, in our evaluation system, take hits for that.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Right, okay. The next to the last one has to do with transportation in space and are you going to say something about some of the more exotic forms of propulsion in terms of their readiness, their promise, you're going to do that? I should probably wait and hear the rest of this. I keep a book on you incidentally Jeff, so you got to cover these. Okay.

The last one really I think Les it was you that raised it, and that is I too was impressed with the flexible option and we want to be careful we don't bury it in here. That's all I had. Does anybody else have any questions? Les?

General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
Sort of related to that flexible option, you touched on the point of robotics or coupled with robotics and I think the statement you used earlier was we have a robust robotics program. I'm not sure if I agree with that descriptor robust. I wonder if your group expanded or looked at a little bit more detail as to the realm of things that could or should be done robotically, perhaps as part of the in-space option or even, this is heresy to say this even instead of a human space flight program at all, just focus on robotics? I'm playing devil's advocate here.

Jeffrey Greason, Co-Founder of XCOR Aerospace
No, that question once came up and we looked at our charter and we deemed that to be outside of our charter.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I think it's completely in charter to consider the coordination and synergy between a human and robotic program but I would agree with Jeff, I mean, we did read the charter and it said what is the plan for human in space flight? And therefore we did not consider the null option of there is no human in space flight. I think in the weeks ahead, particularly relying on Chris on our team, I think that the fleshing out and developing the synergy with the robotic program for the options that we're evolving will be an important component and I think there's now sort of widespread feeling that these are not in competition and we should look to allow them to cooperate and help each other.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Excuse me Ed, I was going to wrap this up, okay? If there are no further questions or comments, let me - sure, absolutely Bo.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
You know, there are many differences between the great picture that gets you excited and reality, many, many facets that go into their difference. One of them is cost and I'm listening to this and I'm seeing those pictures and I get all excited for me, for my daughter, for everybody else's daughters and sons and then I'm sitting there thinking, God, what is that going to cost and seriously, when I look at some of those pictures, I'm thinking half a trillion dollars. I don't know if I might be off by a factor of 2 but it's fairly easy for us to figure out what it takes to extend the station, easy enough I think to figure out what Ares V will cost and some of the stuff that you were talking about Ed, how are we going to address it or do you feel like you have an obligation to paint some picture of potential cost?

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I think we do. I think Jeff's going to cover that in his briefing.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
No…..We were asked to create options for the future but we have to be responsible. The things that we keep in the set going forward have to be within a credible stretch of the budget at the upper end and I think we are being very careful about your rocket my view graphs issue. We recognize the things that are mature have all the known flaws and things that are view graphs do not yet have the known flaws and I think your point is well-taken and you have to keep reminding us of it to keep us on that perspective.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Let me try to kind of wrap up this part of your briefing for the benefit of those in the audience who probably haven't read our charter as many times as we have. We were asked to provide options that could comport with the current president's budget. In subsequent negotiations, we had indicated that we would not be responsible if that's all we did and so we have an agreement that we will provide two options that do comport with the current president's budget and other options that we think are credible. Certainly, one of the two options that comports with the current president's budget will have to be some version of the existing program and the existing program obviously always wins ties in the sense that if you don't have a compelling reason to change, for goodness sakes don't change. That's one of the problems we've got in this program that everyone who reviews it wants to change it. That's not good and we'll never get there so we need compelling reasons if we are offered proposed change. We need to think about this more. You may be wondering why some of us aren't sure what's in the next briefing and some of this, we're required by law to not talk to each other until we

get in a meeting like this for reasons that I won't try to explain because I don't fully understand but that's the explanation.

So what I would propose Ed, was I think exactly what you said and that is that we all go study this, we do a little homework and that all of us collectively or separately in preparation for our next meeting on Wednesday of next week in Washington and at that time perhaps you could propose based on the comments that you've received sort of the blue plate special and at that time we will ask the group to approve or disapprove or modify what it sees as appropriate and in the meantime we ask that NASA and the aerospace corporation continue the intense pace that they've maintained to at least do those chunks that are sort of standard in terms of costing, schedule, risk and the things that we do conventionally? Is that acceptable first of all on behalf of your team Ed, can you leave with that?

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Yes, I think that's…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, and the rest of us, does anybody have a problem with that approach? Okay, hearing none, we'll do that and you can proceed with the next part of your briefing.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
As Jeff comes up, before I move off the scenarios, I want to recognize the enormous effort and contribution made by the folks at NASA who put those together from scratch in many cases, over the course of the last month or so. When I say from scratch, I mean based on many years of studies of many of these issues that have been done and some new work. It was a tremendous effort by those individuals and I want to recognize them all and thank them in this forum.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much Ed, and now we have that part of the day we've all been looking forward to.

Jeffrey Greason, Co-Founder of XCOR Aerospace
Okay, let me start by observing that we currently have 15 minutes of negative slack and I am scheduled to speak for 15 minutes and I'm not going to help one bit. Alright, also I'm about to do something I despise which is read the charts or more or less read the charts. I hate charts like that but so many people are following what we're doing right now just by seeing the charts, not by seeing the presentations, I have to do that. Okay, first chart. Do I have a clicker here somewhere, no? Very good.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
You're going to tell us how to go to Mars and you can't find the clicker?

Jeffrey Greason, Co-Founder of XCOR Aerospace

I may go ahead and tell you not to go to Mars and I cannot find the clicker. Alright. Let me start (cross talking) that's right, the other technical school. Let me start by describing how we see our interface to the great work that Bo's group has been doing. Clearly, the question of how we're going to leave the Earth is tightly linked; I might even say dominated by the question of what we do when we get there. If you don't know what you're doing, anything will work. The problem is very complicated. There are many options. You can't necessarily all pick one from column A and one from column B. So to simplify the problem, we have decomposed the question of what the launchers are into broad classes of boosters that in incredibly rough terms we think of as 25 metric tons, 75 metric tons and 125 or larger metric tons. That's the useful mass placed in LEO. You've got to be very careful with your bookkeeping because a lot of these systems use the Earth departure stage as the final stage of the launch vehicle and there's the questions of okay, how much of that is part of the launcher or how much of that is part of the payload?

Some of these members of each class of boosters might or might not be used as crew transport vehicles given appropriate measures for the booster like the launch escape. That forms an independent access of the trade although not all of them are that interesting. It's also possible that we might not employ any of the large boosters as crew transport vehicles. It's quite credible to consider turning all crew transport over to a crew taxi capsule which is not what you leave Earth orbit with, that allows you to launch the crew on something more in the 9 metric ton class and in that kind of scenario, something like Orion could be launched unmanned and the crew brought up separately. That leads to the question of human rating and crew safety on which a lot of words have been spoken inside the subcommittee as well. It's not a secret how you get low loss of crew. You combine a highly reliable launch vehicle with an adequate emergency detection system that tells you when it's about to have a bad day in time to trigger an escape system, a launch abort system that gets you far enough away from the vehicle to survive the bad day with as few ideally as possible or no black zones in which you wouldn't dare pull the abort handle.

It's also obvious that different launchers have different characteristics that require different launch escape systems. I will note in passing the issue of dynamic pressure. It's a significant driver. How hard you're smashing the air at the time that you want to try to get away. NASA has recently developed some new human rating standards. I think that's an encouraging process to see them going through. Those standards do appear to embody reasonably good practice for a new design. They're mostly an adaptation of received wisdom of how would you do it if you were doing it today? However, since no prior NASA manned launch vehicle, nor so used, appears to meet these standards, we've got to be careful that we don't take our desire as required and therefore it is our opinion that where there are existing or derivative launchers that meet the intent of the guidelines, they should be giving due consideration as to transport vehicles. There is data that shows that government's independent mission assurance process does improve booster reliability. This is one of the many Nixon goes to China moments in this presentation because there's a few things that I've said in the past that I have changed my mind about in the course of this process and there is good data out there that shows that.

There are many customers in the government that go through this mission assurance process successfully. The Air Force, the National Reconnaissance Office and NASA itself in the Launch Services Program and all of these are customers that launch billion or multi-billion dollar flagship national missions and this really speaks to the question of what would you do if you knew how to make the booster more reliable and you want to do that for the crew, why wouldn't you have done that for the multi-billion dollar national security mission of which we're going to launch one in 20 years? And the answer that we get back from people who do boosters is you wouldn't. If you knew how to make the booster more reliable for that class of mission, you would have done so. Therefore, because there are boosters out there that have gone through those kind of process, it's possible and an option well worth considering that providing an Atlas V 402-class launcher as the government furnished launch service to commercially supply crew taxi capsules, might provide a faster path to getting a NASA acceptable levels of mission assurance for those capsules and therefore might present an option to pull in some elements of closing the gap.

Finally, to everybody watching this process and to people within and without NASA, I have to say again more lengthily what I've said in questions. You have to use extreme care in interpreting probabilistic risk assessments. Over 90 percent of historical launch vehicle failures, and that's actually I'm being understated, are from causes that are not modeled by probabilistic risk assessment, things like the design's not right, the environment's not right, the testing didn't test what you thought it did, somebody plugged the connector in backwards, that kind of stuff. And therefore, first probabilistic risk assessments are always much better than demonstrated reliability of a launcher and will always be. And furthermore, because 90 percent plus of what you're going to fail from isn't even being captured in the process, assigning multiple significant digit significance to your probabilistic risk assessment is silly. At best, it tells you this is a lot better than that when you're comparing paper systems. Here's one of my action items from the Chairman, never let it be said we're not responsive.

It is often said, and we have heard many times on this commission that if you want to go beyond LEO, you've got to have a big rocket. I don't think that's right and the consensus of our subgroup is that's not right. What should be said is to go beyond LEO, you've got to have a big Earth departure stage for the propellant. Now if you choose to launch that wet or mostly full as a single large launch element, that does imply a very large rocket for going to the moon. And if you're going to Mars, it implies a very large, I'm tempted to say improbably large rocket. Alternatively, if you launch a lot of little EDS stages and gang them together in some fashion, you can solve that problem but it becomes a very large in-space assembly problem that's been compared to sending ISS to Mars every time that you fly and it becomes very unwieldy in the larger systems. There's a significant mass penalty for the smaller tanks that are all ganged together.

The third way is if you launched a lightly loaded, or in the extreme case, dry Earth departure stage, that does require the ability to transfer propellant, and later in the exploration architecture to store propellant for extended periods of time in space, you can now do much larger missions with the same size booster. That technology is also being called a depot. There are no new ideas in this business. I appeal to St. Wernher

that this is actually what he had in mind; this is how he wanted to go to the moon. He called it tanker mode and he wanted to go to the moon this way because he knew if we went to the moon this way we would've been on Mars by now but we didn't and we aren't, so let's see if we can fix it.

Because of the question of the Chairman, I will spend a little more time than I planned on why propellant transfer is such a big deal. It really is a game-changer in Earth to orbit transportation to have this capability. It decouples the size of space systems from the size of the launcher to an extent. The large launcher has driven the development and much more importantly the sustaining cost of exploration programs since the Apollo era. We still do face the problem that you have to launch what we're calling the biggest smallest piece in one piece. This small launcher idea, there's a threshold past in which it gets silly and we aren't sure quite where that threshold is yet. What we are pretty sure is that 75 metric ton vehicles are above that threshold. We're not at all sure yet and again this is Nixon goes to China, I came in absolutely convinced that 25 metric tone vehicles were big enough to launch all the pieces. I am by no means convinced of that today. However, the majority of mass launched in any architecture that we see is propellant, and that can be launched in any sized launcher and it is not a high value payload. We have spare oxygen. Therefore, the canonical charts that many people have seen that say you can never have many launchers in your architecture because they'll have an N percent of chance to fail when you do Y of them. It's N to the Y chance of the thing not working at all. That chart's not right because while you don't have a spare crew and you don't have spare Earth departure stages, you do have spare propellant and you simply get in the mode of saying I launch a lot of propellant and if I lose one once in a while, that's okay, the next one's coming up next Tuesday. This allows the widest possible competition in Earth in orbit launch and it allows significant involvement by international partners. We believe it will simulate greatly an expanded commercial market for launch. It may, if coupled with a significant exploration effort that needs a lot of propellant finally provide the steady, reliable large payload for raw mass in orbit that's been the missing piece for doing our commercially re-useable launch vehicle. We have surveyed many NASA and industry experts. There appear to be no significant technical barriers to propellant storage and transfer if you use settling acceleration during the transfer. There are other approaches that don't require settling acceleration. They're very interesting but they are at lower technology readiness level. But that is not to say that we don't nee flight demonstrations and technology maturation efforts. These things are generally in TRL 5 to 6 category right now. There is work to do and there has always been work to do and no one has ever done it and that's why we never do it in a nutshell. Also, this whole notion of changing over to an architecture that has a high flight rate of small vehicles component is a very foreign way of doing business in this country. It's not at all a foreign way of doing business for example in the way that Soyuz was developed and operated but to us, this looks new and scary and different and no program ever wants to do the new and scary and different because that's their career on the line. So I'm up here saying it instead. Also, this would have been unthinkable as a rational option before the international space station and before DARPA's orbital express mission, 20 years ago in-space operations, in-space docking certainly autonomous docking and certainly propellant transfer all seem like scary things. We have now done all of those things. Some of them we do every couple of months.

Just a quick flip chart created by some of our partners on pictures of some of the key technologies, just showing you, these are generally not view grafts. These are generally pieces of hardware being demonstrated in the labs. The one obligatory rocket science graph provided by Ed Crawley and thank you. I will summarize this in words. It is an I-chart. If you launch your Earth departure stage with the payloads that you plan to carry, tanking in orbit gives you a roughly factor of 2 potential improvement in throw weight to trans-Earth or trans-lunar injection or trans-Mars injection. If you launch the EDS as a stand-alone element, bring the payloads up separately, the EDS can be very, very large in comparison to its mass on the way up. You then become limited by the fairing. We're still studying and our NASA colleagues are helping us study the fairing limitations but it looks like we can get a 6 or 8 multiplier on the throw weight of the size of your booster that way, which if you're thinking about going to Mars, that is getting really interesting.

In-Space transportation to address the interaction item, there are a lot of options. The baseline is this chemical propulsion because that's what we got. The original baseline of course was all propellant comes from the Earth. We want to challenge that. You can start - and as you go down this chart you're starting to change the game on how much additional technology you insert. You can add propellant depots and other locations beyond LEO. That in turn fosters the possibility of doing in-situ super-propellant production in other locations beyond Earth and that as Ed said cheats the rocket equation because now your whole mass, instead of multiplying two large numbers to each other, you only got to pick one of the large numbers, you pick up gas on the other end. Beyond that, there are many options for advanced space propulsion. This has been the holy grail of what you'd like to do if you wanted to go to Mars for a long, long time. It is a big ticket item. I'm going to speak a little more about it. The one take away from this section I want to give is there's a false dilemma that people get into saying well, we've got to do a phased based propulsion but it's going to cost a fortune and it's got to be nuclear and nobody's ever going to let us do it. It's not obvious that it has to cost a fortune. It's not obvious that it has to be nuclear, but the people who are working on these alternatives are doing it on shoestrings and colleges and laboratories of individual people. They've essentially got no money and if we don't like the same answer always coming out, we'd better change the question.

With chemical In-Space propulsion, clearly this all revolves around some kind of Earth departure stage. We have defined for NASA to give us additional data three Earth departure stages that simply map to the three classes of launch vehicles that I discussed earlier. In the case of the 25 ton case, it's obvious that the EDS launch dry is the only competitive alternative. You can just barely think about doing the mission with a 25 ton anyway. You certainly can't do it if you compromise. Therefore, a 25 ton vehicle would require a depot right from the get go. You can't go anywhere without one. The 75 ton class vehicle, we're defining an EDS that will support some initial exploration missions in what we call top off mode where one EDS transfers propellant to another but you don't yet have a depot. You will still need a depot but it can come in a little later in the architecture and with the 125 ton class, you can do everything you want to do on the moon without a depot and the depot comes in when you start thinking about going beyond the moon.

I'm running late on time so I will pass more lightly over this than I'd wish but let me just say that as a result of and since Apollo, we have learned a lot more than we knew in 1962 about the places in the solar system, what you can get there and there isn't any place we're interested in going that you can't get propellant of one kind or another. There's differences in the amount of equipment that it takes. There's differences in the kind of equipment that it takes. Nobody has done flight demonstrations of any of this yet but it's in the category that I as an engineer refer to as just work. In some cases it's just a lot of work but no miracle is required. This clearly requires the same kind of propellant storage and transfer technology. There's no point in making gas on planetary surfaces if you can't hang on to it and pump it from place to place. This also leads to the possibility of a Cis-lunar depot which turns the moon from an interesting place that you visit along the way into our first mining outpost in space. You bring the propellant that you store not initially just to help the moon transportation architecture but as you make more and more of it you start exporting it up to L1 and now the Mars guys can buy it from you.

This is a chart I wish I saw NASA produce more often. It's what in the semiconductor industry we used to call a technology roadmap. In the semiconductor world, we routinely, our entire business depends on the assumption that 10 years from now we will have technologies that we have no idea how to do but we're going to boldly go forward, assuming we're going to figure it out along the way but we don't just hope and pray, we list how we might do it. We pick out a couple of leading candidates. We fund real technology programs so that by the time we get there we have what we need. The takeaway message that we took as a subcommittee from DRA V, it's a great piece of work on how you might go to Mars with current and easily visible near-term achievable technologies. The takeaway message that at least I personally took away is we're never going to Mars that way, not because it couldn't be done but because it shouldn't be done. We shouldn't go to other planetary bodies at what I call $1 billion per footprint because we won't stay. It'd be Apollo all over again. We go and we do it a couple of times and the next election would come and somebody would say it's too expensive and we should stop.

If we want to go for real, we got to go in a more affordable way. If we want to go in a more affordable way, we've got to start working on the technology to do it. And when I call out particularly the cosmic ray issue, it's something Chris and I have talked a lot about, it really hasn't received enough attention as a rate limiting factor on human expeditions to Mars. There are two classes of ways to deal with it that we know about already but we know much less about these phenomena than we should. For a phenomenon that might be the limiting factor on human transport to and from Mars, the amount of resources being played on studying and understanding this and even figuring out is it as bad a problem as some people think is laughable. It is sometimes said that well, there's nothing we can do about it so why study it? That's not true. There are things we can do about it. Cycle our "habs" are a possible way of doing it because, and that for those who don't know, that's an architecture where you don't launch the "hab" every time. It just sort of stays in a permanent free return trajectory and you ferry the crew to and from it and although it's expensive, it's at least possible to think about making those things massive enough that they can provide shielding from galactic cosmic rays but we should be working on that but for every dollar we spent on

that, let's at least spend a dime on figuring out whether it's a problem or whether there's biological countermeasures that we can take to do something about it.

Last is my get off the stage chart is changes in the business model are at least as powerful as changes in the technology. We have heard a lot of stories from a lot of people, a lot of people laboring mightily in the trenches of NASA to do the impossible and we've got to be clear to all the national policy stakeholders that changes in how we specify and acquire and operate systems and in what NASA is allowed to do in that respect, have as strong an effect as technology on what we can achieve for a given budget. NASA is constantly asked to do more with less. Now, at some point, no matter how clever you get, it is not enough. And if NASA is going to do more with less without exactly saying how much or how little, they have to have for example the flexibility to adjust the size and composition of their workforce and their facilities to the job that they've decided to do, whatever that is. Furthermore, if you want to get the maximum leverage from what the commercial sector can do, you have to be able to make commercially bankable commitments to future purchases. No one today is going to loan a company money to develop a NASA system on the grounds that NASA will be a future market because no one can predict what NASA will do in the future any more than NASA can predict itself what NASA will do in the future but there are mechanisms that other government agencies have to do things like loan guarantees that NASA currently does not have that Congress could change that would give it the ability to make future purchase commitments in a way that would stand up. And the converse of this is true, if NASA can stand up and present credible markets, you will no longer have to develop everything yourselves. People will do it with their own money hoping to make it back from you in the future.

Finally, NASA should be the source of research and development, the source of technology maturation, the source of system requirements, the designer of the architecture. NASA should not primarily be its own supplier. There are a lot of - and I want to say why that is, all programs, public or private, face a critical problem of distinguishing between what I call desirements and requirements or mission creep or call it what you will. There's always limited resources. There's always limited time. There's always unlimited things that you'd like to do. A separation between the people who decide what we want and the people who decide how much we can afford and the people who decide how we're going to do it and are responsible for doing it, is critical to helping to manage that process. And that's not unique to NASA. I've seen the same thing in other environments. Now there are many tools available to NASA to do this different way of doing business. They can do straight purchase if the service exists. They can do space act agreements. They can do COTS like cost sharing arrangements with private industry. They can do fixed price contracts which I think of as a risk sharing rather than a cost sharing mechanism in which the private sector might be willing to commit the resources to handle any overruns but not necessarily to commit the resources for the initial purchase. There's prizes if you want out of the box ideas. I'd love to see some of those on this cosmic ray question because there's a lot of room for creativity there. There' a lot of things we can do. Let's go do them.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Jeff, thank you very much. I think you've covered our actions items so why don't we go ahead and we'll pick up any questions to the very end.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Now Norm, we have, just to update you, we have a short summary by me now, sort of our interim answers to the questions we've post as much more discussion time as you want to allow the committee to have and then Chris is going to wrap up and then the discussion, right?

Okay, so these are listed either as no recommendations or recommendations. As of yet, and I'll just touch on the high points here, as of yet, we have no recommendation on launch to LEO. This is a - we have considered it. Jeff gave you some indication of the way we are leaning but we have ongoing a number of studies of the largest mass that needs to be launched, the largest diameter, the possibility of refueling and the availability and reliability of multiple coordinated launches that we want to get information on before we make any. We think we will probably do that by next Wednesday.

Second, on on-orbit refueling, we do recommend that NASA vigorously pursue this as an option. It's enabling for 25 metric ton class launchers and it certainly is significantly enhancing as Jeff outlined for the super-heavies. It builds a national capability with potential aid to other stakeholders, and it creates a second and larger market for commercial launch services to LEO. The idea that we can decouple the launch of relatively non-complex, non-critical payload that rely more on the commercial industry to supply that for Low Earth orbit. The recommendation to the committee on technology is that NASA develop and fund with the support of the White House, a long range innovative technology program that would develop technologies that enable its future missions. I would emphasize that NASA has an unprecedented opportunity to do this at this time. That rarely does an organization, either governmental or commercial, have a vision of what it's going to do over a decade or two and rarely does it have as much understanding of where the hard points are, the need for In-Space propulsion, cosmic or galactic radiation, that what we have to carry forward to the White House is a very strong recommendation on this to strengthen NASA's workforce and capabilities, to engage the larger national community, universities and other national labs and private industry, and to focus the NASA workforce as Jeff mentioned on the things that the NASA workforce is exceptionally prepared to work on, working on the tough the problems, developing new technologies, creating new systems and writing specs.

This recommendation in particular is consistent with two recent NRC reports, guidance the agency has received from OSTP and Congressional guidance from last year's authorization rules. We recommend that NASA develop an architecture that proactively engages the commercial space community, making an explicit space-based market for services, that we support COTS. The current COTS that we should consider recommending, a commercial crew launch capability for which NASA by the way is not the only market. There are credible business cases for other markets for launch to low

Earth orbit, and the real question we think we have before us is if we have sufficient confidence now that we can count on this commercial supply? Or is it now the case where we still have to keep the option alive of having a US government supplied service of crew transfer to Low Earth orbit.

In addition, we want to as I've we said build a market for In-Space propellants and other potential on-ramps of commercial community contributions but we want to be careful that this is not a new source of funds. Ultimately for many of these things, the government is the eventual customer so the benefits here appear potentially due to efficiencies, due to synergies with other markets and due to defrayal capital expenses on the part of the government. In contrast, although we have no specific recommendation pending the discussion with Les's group on the engagement of internationals, this is a new source of funds, international partners are willing to put their national capital at play and we think that there are a number of opportunities where we can build a program that engages them.

So the last two charts that I'll mention are why we explore and what it means. There's a strong consensus among the subgroup that the underlying reason why we perform human space flight is the extension of human civilization beyond Earth and that t is highly likely that the first destination for that will be Mars, that the Earth's moon is a potentially enabling resource and will serve as a demonstrator of technologies and operational capabilities. The second, that the current architectures for initial human exploration of Mars with the currently available and near term technology, likely present a recurring cost which is too high to be sustainable, that if we could get to Mars, the likelihood that we would go back very often is unlikely. And that does not necessarily pave the way for permanent presence. Therefore, we recommend that the committee include in all of its options, a strong and appropriately funded research program and developmental activities that incrementally reduce the cost of exploration beyond the moon so that those technologies can be inserted into exploration activities as soon as possible.

So finally, in my transition to Chris, I'll wrap up with our recommendation to the committee on ultimate objective, that our ultimate objective should be viewed as the exploration of and eventual extension of human civilization within the solar system. This is not at all inconsistent with the vision that President Bush created in 2004. It's just that we have to keep our eye on the big prize. This will take a long time but the time has come, the political alignment is here to allow this to be a goal for our nation and it's goal worthy of a great nation.

Now I'm going to ask Chris to sum up the effort of our group in a slightly different way, as if we were thinking about how to brief this to a policy community rather than a technical community.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University

Thank you, Ed. As Ed has said, and there are no charts for this presentation, as Ed has said, my role now is to pretend that I have a five or more realistically a 10 minute - more realistically for the purpose of how much time I need, a 10 minute hallway briefing for a policymaker in Washington and I'm trying to describe what we've concluded. So

our subcommittee was charged with making recommendations to the full committee for what human space flight should do beyond low Earth orbit. To answer that question, you have got to be able to answer the question what is the goal of human space flight?

Everyone agrees that whatever the answer to that question is, it ultimately lies beyond Low Earth orbit. This is now a consensus. We're going to go beyond Low Earth orbit. Even if we choose to extend space station after 2020, the intention of the overall program would nevertheless continue to be to get beyond low Earth orbit. So since this has been the beyond low Earth orbit subcommittee, the question what is the goal of human space flight is necessarily the fundamental question that faces the subcommittee. Notice that I'm referring to goals, not to destinations. Destinations aren't goals, rather the choice for destinations for human space flight have to follow from the goals that you set. If we make the mistake of choosing destinations first, either in principle or de facto, then we risk reaching that destination and then casting about for justifications of why we went there or perhaps even worse, why we are staying there.

So what's the goal of human space flight? Our subcommittee endorsed 11 metrics or figures of merit for evaluating different scenarios for future exploration beyond Low Earth orbit. Most of those represent either important benefits from human space flight that should be maximized they represent risks that have to be mitigated and all of them are important but most of them are not the primary goal. Let me use science as an example. It's not credible to maintain at this point that the primary goal of human space flight is fundamental science. Most fundamental science in space is better done with robots than with astronauts. Of course, there is good and even great science that can and should be done by astronauts and we should try to maximize that, just as one example, let's see what the alpha magnetic spectrometer accomplishes on the international space station? It could be spectacular. There's also science that can be strongly enabled by astronauts through servicing missions though even here there's a need to better understand the trades with respect to robotic servicing missions and understanding those trades is underway.

Someday, when we have humans on Mars, the situation will be very different. One geological competent astronaut on Mars will rapidly outpace what our current robotic rovers can to. It's also significant that some of the strongest advocates of astronauts returning to the moon are lunar geologists for much the same reason. And forgive me for a personal comment here, one of the things that was striking to me about at the time of the 40th anniversary of the moon landings, and because I'm on this committee, I hardly had time to pay comprehensive attention to the celebrations but with respect to the media coverage, I was struck by how little mention there was of a scientific output from sending humans to the moon. Because it's my field, I can say that it was tremendous. What we understand about the early inner solar system, the impact history of the solar system, the history of the Earth-lunar system and maybe most profoundly, the history of the early Earth especially with respect to the environment, for the origin of life on earth and even to some extent the evolution of life on Earth, strongly derived from what we've learned in the Apollo program. It's too easy to lose sight of that, especially since we recognize that Apollo was driven by geo-politics, not by science.

So there is substantial lunar science to be done, but nevertheless, much of the science that 40 years ago we imagined that we might do from the moon, astronomical telescopes as just one example, is now clearly better done from free space. As important as science is and as important as inspiring the next generation of scientists and engineers is and as important as engaging with international partners is and of developing the commercial sector, the subcommittee decided that the goal for human space flight that is sufficient to justify the necessary commitment beyond Low Earth orbit is to chart the path for the expansion of human civilization into the solar system. Some will choose to say this differently. Some say that the goal is that humanity should become a space faring civilization. I'll take that to be synonymous with our committee's formulation, our subcommittee's formulation. Now this sounds terribly ambitious and dramatic but if that is not the point of human space flight, which now is exactly about finally once again going beyond Low Earth orbit, what the hell are we doing? None of the other figures have merit, however very important each is, is sufficient by itself to justify the commitment that going beyond Low Earth orbit requires and in many cases, there are alternative routes to those ends.

Charting the path for human expansion into the solar system has never been quite the goal before. Apollo is not primarily about this. It was about geo-politics. The shuttle may have started out intended to be the first step along this road but then it became the path to the station and the international space station was not in the end funded for the sake of expansion into the solar system. In both cases, foreign policy was an important driver and it will and should remain so but it cannot any longer be our fundamental goal in space nor can our goal be to win the race to be second to land on the moon. It can't be that every time some other nation is about to go and land on the moon we have to hurry up and land on the moon all over again just to prove a point. As Americans with the space program that we have had and that we do have, we can certainly be more self-confident than that.

So at this point, where we are today, we believe that any space exploration architecture, our subcommittee argues that any space exploration architecture that does not lead towards a sustained presence in space is missing the point. You could apply this to international space station scenarios as well. By this criterion for example, extending the station may be important for exploration beyond Low Earth orbit. If it's important for building a robust commercial capacity for sending cargo and then humans to low Earth orbit, a capability that would underguard further exploration or for example if it maintains important international relationships that are vital to future exploration or if as Leroy has emphasized today, using the station as a technical test bed, we can use the station as a technical test bed for things that we need to work through such as the deep space habitat or fuel depot'ing and so on. As the subcommittee discussed the goals of human space flight and then the figures of merit that should apply, it also considered some 9 or so scenarios for mission architectures beyond Low Earth orbit. The Program of Record and 2D scoped versions of it, plus the version that drops the Ares I rocket plus five scenarios of the committee's own devising. The subcommittee agree that these scenarios should be scored against 11 figures of merit, figures of merit that capture the benefits and risks of each scenario. And we have recommended to the full committee that these figures of merit as modified by our discussion in this room today, should be carried forward all the way to the White House as a way of summarizing for policymakers the strengths and weaknesses of each scenario and I

think we have embraced Norm's suggestion that we need to also be clear that some of those figures of merit are especially important.

Devising those metrics was easier than we might first have imagined because we discovered, I should say Ed really pointed this out, that there has been significant agreement on those metrics all the way back to the space act of 1958 that chartered NASA, through the vision for space exploration by the last administration and up through our own committee's terms of reference. Our discussion today with the full committee has emphasized that some of these figures of merit are especially important, inspiring a new generation and beyond this high priority, the priority that proposed scenarios have to be aligned with other important national priorities. So certainly the committee needs to make those points.

The subcommittee has recommended collapsing our own five original scenarios down to three and also carrying forward the program of record, the version of the program of record that maintains content but stretches schedule, and finally a version that drops Ares I and goes to dual launch. The full committee needs to consider whether this list needs to be further narrowed before we proceed towards our meetings in the next couple of weeks. The subcommittee has also made further recommendations. It recognizes that NASA has a chronic problem. NASA does not have the budget or the ability to simultaneously develop new systems and continue to operate existing ones, hence the gap in access to this international space station.

In fact, it's unclear whether NASA has he funding for any scenarios that do anything important beyond low Earth orbit prior to 2020. Recall that the Program of Record was originally budgeted at $108 billion for fiscal year '06 though 2020. It is now at $81.5 billion over that time period and if we extend the station to 2020, that's another 10 or 14 billion Dollars removed from that total. All of us saw Ed's pie chart today which I think makes that point in a powerful but somewhat different way. The subcommittee is still sorting out launch requirements for its different beyond low Earth orbit scenarios. However, we recommend that NASA vigorously pursue In-Space refueling and depot'ing as a feature of all options going forward, whatever the launch vehicles chosen. In-Space refueling can be a gain-changer in our ability to explore, and it would also have the very important impact of providing a market for commercial space, a further market for commercial space, helping that sector to develop in ways that ultimately could underpin a more ambitious exploration program led/spearheaded by NASA. Along those same lines but more broadly, we recommend that the committee should consider proposing that NASA develop an architecture that proactively engages commercial space by creating an explicit market for services. The subcommittee also recommends that NASA develop technologies that enable future missions. There are many that were included in our list and we've had great emphasis today on the galactic cosmic ray background limitation.

And finally, the subcommittee is still debating how best to involve international participants and has to interact with the international subcommittee on exactly that point. In conclusion, there is a national consensus, one that is reflected in the language of two different Congressional appropriations, that it is time for the United States human space flight program to once again go beyond Low Earth orbit. However, that programatic commitment was initially coupled to a budget that was 10s

of billions of dollars larger than it is today through 2020. And if we fly the station out through 2020, and one has to say considering that it's an asset that the US spent $55 billion to construct and their international partners contributing another $15 billion to, so it's hard to imagine bringing it down into the ocean five years after it's completed but if we fly it out to 2020, we may lose another 10 or 14 billion dollars from that budget.

The full committee will endeavor to provide at least two scenarios that somehow fit within these constraints but what the United States government cannot do is to promise the American people and especially our young people a glorious future in space that remains nothing more than a paper tiger. If we really want to do this, we have to provide a realistic budget for it. Otherwise, let's be clear about the limits placed on us by the actual budget and let's not pretend. Thank you Mr. Chairman.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Thank you Chris for that great summary which even drew applause. When you teach, you don't get that very often. So Norm, we're either ready to discuss this a bit more or wrap up as you choose to manage the meeting?

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
We've asked questions as we went along. I don't know if there are a lot more questions. I've got one while others are thinking and that is, do you have some proposal of how we tie the notion of propellant transfer in space to any of the options? You can carry it in parallel as you've said but it seems to me it feeds back to the size of the booster you develop in the first place and the schedules don't work?

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
Our recommendation to the committee was that depot'ing be part of all the options going forward.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
So you would commit to a smaller booster you can count on…

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
That, that….there you go farther than we are yet, okay, but we are recommending that we basically say we need this capability, we're going to plan it. We're going to make it part of the architecture. Now we need to think about what that means.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, other questions, Les?

General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
Just related to that, I don't disagree with that recommendation but I think we have to make sure it's coupled with a technology maturation program associated with that so that you don't jump on that horse before you're supposed to if you will.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
I couldn't agree more.

General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
One other comment if I could?

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Of course.

General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
On the commercial engagement, the determinant to use is NASA - if I can find my chart here, make an explicit commercial market. I'm not sure if that's the right sort of terminology. This may be semantics if you will, I would prefer enable or encourage - encourage is probably too mild but enable, making a commercial market would imply to some people a major budget commitment on the part of NASA to create that market. I'm sure that's what others might think. Enabling the market can be done to some extent through processes, to open the door, through communication, through architecture determination, through requirements. That may seem like a very simple word change but I think there's a big potential difference in terms of the commitment on the part of NASA and the budget on the part of NASA.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Well, I think this is some that at our next public meeting we could have a good debate of. If I asked the guy across the table who tries to raise money for his commercial space venture, whether you would rather have NASA make a market or enable a market, I imagine I know what the answer from his…

General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
That's why I looked at you when I said that, I didn't look across the table.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
Actually, let me confound that expectation, okay? NASA in my view, this is a personal view and not a consensus, NASA should not just go out and buy things from the private sector for the sake of having a private sector industry but NASA has to buy a lot of things and if we buy them, if instead of developing them in a way that NASA is the sole supplier and customer of those capabilities, if we procure them maybe is a better way of doing it, in a way that they can be competitively supplied by capabilities that also have other customers, that is a good thing for the nation.

General (ret) Lester L. Lyles, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, Chairman
I agree whole heartedly and again, that's I qualified it by saying it may just be semantics. What you described I call it acquisition strategy process, procurement strategy which might be a little different from making a market if you will.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
The Airmail Act has been mentioned a couple of times as an analogy.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Well, without objection, we'll proceed as I described earlier…we have an objection.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
No, I just have one summary comment.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
By all means…

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
I just was reading the paper on Sunday morning and it's as often the case that Dilbert showed up just in time, so I have to - it's on the screen Mr. Chairman, and I have a little bit of trouble reading it from here so I'll sort of make it up. "Norm comes in to the office and says to Ed, how much is our new product, our new space program beyond LEO going to cost?" And Dilbert/Ed says back, "about as much money as there is in the budget to do it". And Norm says – "what does Norm say, I can barely -- how much money should I put in the budget?" And Ed says if you put a big amount of money in the budget, boy, we're going to have a program that will make the nation proud and inspire the future of humanity. And then he says, "and if you put less than that, well, maybe it won't be quite so good". So Norm leaves and he says "well, on my way to the executive office building, I know I might be beat up but I'm going to ask for a lot of money" and Dilbert turns around and says sometime in the future when I'm dreaming, this will make me proud.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

That's an appropriate finish to your presentation, thank you and it was very well done. I am not quite sure of what you said there, but…., I can't read it from here and it is probably just as well. I think Chris summarized the sentiments of many…., particularly with regard to this notion of…., let's be sure that what we ask people to do, that we give them the resources to do it. This committee is convinced to make that point and I think that this committee is also well aware, and I should probably say, that Chris applied it, that when you do that, that there are other demands in this country for money and you might get bad news and that goes with the territory.

Having said that, I think we should move ahead, we have a number of the political leaders from the state who have asked to have an opportunity to make a few comments or to provide letters or videotapes and we have had some input from leaders at the other places we have been. We have had a lot of mail, contacts on the Hill and so I would like to begin that session. We are going to over-run, by about 30 minutes or 20 minutes….(Gap in audios)….Before lunch time, I hope that's not a problem for anyone. I'd like to begin because he's here in the room with us I understand with Lt. Governor Kottkamp who is asked to make a few comments to the committee and to this group. Lt. Governor, please, would you care to come up? Welcome.

Lt. Gov. Jeff Kottkamp

Good morning Mr. Chairman, members of the committee. I want to thank you for this opportunity to speak with you this morning on behalf of Governor Crist and the citizens of the state of Florida. I also want to thank you and each of the members of this committee for your service to the citizens of this country. This is important work. Our nation's past successes in the space program helped define our country as the world leader in innovation for the past five decades. The level of our commitment to space exploration in the future and the development of technology to support that exploration will define our country's standing in the innovation economy for the next five decades.

It seems fitting that we gather this week right here in the state where the genius and the courage of mankind literally launched Americans from NASA's John F. Kennedy Space Center on a mission to the moon which shaped the future of space exploration not just for this country but for the world. Florida has been the center of gravity for our nation's space launch program for NASA for those 50 years, when space exploration sparked the imaginations of generations, inspiring the nation and the world and all of us in this room. This inspiration continues today as we await the return of STS-127 tomorrow morning. We all know the benefits of America's space program are numerous and have lead to inspired advances in science and technology, including the fields of medicine, transportation, public safety, environmental preservation. Today, there are more than 3000 products that we use in our daily lives, all the result of research and development for the space program.

The path to space has never been easy and it never will be. Together with the aerospace industry, Florida has a proud history of not only hosting our nation's space activities but also investing in infrastructure to make space exploration possible. We've done this more than any other state and there's no reason to think we will stop and we won't. We've invested in launch pads, processing facilities, assembly buildings,

laboratories, control rooms and hangars that have saved the federal government hundreds of millions of dollars. We are a people trying not only to solve the challenges of the present but we are also dedicating ourselves to helping build the foundation for a brighter future. We hope that the decisions and commitments that follow your report to the White House provide Florida a major opportunity to significantly contribute to the Nation's space future. These are critical times for Florida and our space sector. The challenges we face including the NASA transition and funding issues that you just mentioned, the emergence of commercial space, and heightened interest by our own DOD in space are significant. Despite the very challenging global fiscal environment, we have taken a long term view and decisive action will serve both Florida and our nation's future.

As your committee on the future of US Space Flight has gathered input across the nation over the past few weeks, consistent themes have emerged. I'm here to address four this morning, the gap, ISS impacts, heavy lift vehicle and commercial space initiatives. Many have testified before your committee on the negative impact the gap in US Human Space Flight will have on national and economic security, the full utilization of the taxpayer-funded $100 billion space station, the dispersion of our work force, the best workforce in the world and US Human Space Flight, the global image of the US Human Space Flight program as a symbol of peaceful international cooperative research, and the motivation that Human Space Flight provides for our children to study math and science. Now I'm not going to repeat everything that you've heard in each one of these areas other than to say that the extended gap from the perspective of the state of Florida is unacceptable we think not just for our state but for our nation and if there was any option that can bridge that gap, the state of Florida implores you to give it the strongest consideration.

Due to the impending gap, Florida is bracing for a hardship, the magnitude of which this state has not seen in decades. NASA's current plan to retire the space shuttle by the end of 2010 and pursue the current Constellation Project of Records, are not expected as you know to provide human space flight capability to replace the shuttle until 2016. We are anticipating the loss of up to 7000 direct jobs at the Cape, and upwards to 20,000 more with indirect impacts throughout the state of Florida, far more than any other state. But the raw numbers of planned job cutbacks at Kennedy Space Center do not tell the whole story. As you know, the Kennedy Space Center processes and launches our nation's space shuttle fleet and KSC is an operational facility. Thus, the gap between the current and future programs will impact the KSC community differently than any other NASA centers and communities. More than half of Florida's thousands of Human Space Flight workers are highly skilled engineers and technicians. This workforce represents the enormous, unique engineering and technical skill sets that provide the core capability to sustain the nation's future Human Space Flight program which may scatter to other unrelated industries if the gap is not addressed.

While I know that you understand the critical skill sets will be lost, skills that will be needed after the gap that cannot be easily or readily replaced. It will take an enormous funding and a Herculean effort to rebuild the capability of these skilled workers if they go away. It does not serve the nation well to be constrained by the 2010 completion of the current manifest, allowing a continuation of shuttle flights into the currently defined period of the gap, introduces a prudent element of risk management to the program. It

is a very prudent way to try and ensure that we maintain and keep intact this incredible workforce that we have. Now, albeit there is a cost for this longer period of shuttle flight, it reduces the overall risk to the nation's Human Space Flight program however, reduces the dependence on Russia for support of the international space station, and gives additional time for commercial companies to take up their role of supporting Low Earth orbit.

Simply stated, failure to address the gap in human space flight operations will temporarily demolish the nation's space program, decimate a significant portion of Florida's workforce, and send a devastating and statewide economic shockwave to an already struggling economy. The gap directly relates to the second issue, ensuring maximum utilization and return to the nation from the international space station. The ISS is a platform for scientific discovery, many of which we can only dream about today. It recognizes both the $100 billion-plus financial commitment that the taxpayers of this country have made as well as our obligation to our international partners. Consistent with statement by senior Obama Administration officials, broad consensus appears to be developing around the international space station serving a real, ongoing role as a platform for scientific discovery. Florida remains fully supportive of this objective and supports extension of ISS operations to span at a minimum to the year 2020. Now that the ISS is designated as a national laboratory, the potential to combine the power of this designation with the space life sciences lab creates that ground node of a national laboratory complex and holds great promise of discovery for both the government and scientific industry sectors.

Most importantly, it will help preserve the experienced workforce so critical to manned flight operations. At a time when US leadership in space as well as a host of other technology-intensive fields is under assault from nations around the globe, it seems illogical to put such highly skilled workers who contribute significantly to our nation's global economic and national security position, out of work. It very well could mitigate the possibility of the Constellation schedule slipping further to the right by keeping open the option of utilizing a shuttle-derived propulsion system to provide the next generation of heavy lift capability, in lieu of development of a new heavy lift rocket. Further, it mitigates risk around both human and cargo access to the ISS by preserving a baseline level of proven capability that is 100 percent built and operated in the United States and this brings me to my third point.

There is consensus regarding the potential of the commercial space sector serving an increasingly important role to provide US access to the ISS. NASA is investing commercial entrepreneurial service to the ISS by financially assisting in companies build-out of their commercial cargo and crew vehicles to service the international space station. Those companies expect to have their cargo vehicles ready for station support in 2012 or 2013 with their crew escape capsule ready in 2013.

The state of Florida supports NASA's current plans for commercialization of station resupply. As you know, one of the contractors selected by NASA to fill this role, Space X, will launch its ISS resupply missions from the Cape and the state of Florida has invested several million dollars in assisting Space X in preparing launch complex 40 for operation. The success of Space X, Orbital Science and other commercial companies is crucial for providing cost-effective options for reaching low Earth orbit and will have

the potential to evolve future capabilities to help preserve America's leadership in space.

My fourth point has to do with the nation's future space exploration program and the alternatives you may present to the White House. Preservation of US heavy lift capability is probably one of the most difficult issues the committee will consider. In Florida's view, preservation of this capability is imperative both for future manned exploration missions to the moon, Mars or other deep space objectives as well as to appropriately manage risk around future human and cargo access to the international space station. Whatever vehicle you may choose for the nation's heavy lift capability, a commitment to heavy lift and a commitment to a robust lunar exploration program are good for the nation and good for Florida. Return to the moon is not trivial just because we've done it before. True exploration on the moon for extended periods of time will stretch the nation's technology goals, as will finding ways to develop technologies for supporting human operation, long duration lunar missions. A commitment to a heavy lift concept that will provide long term exploration potential and robust ability to go beyond low Earth orbit will meet the goal of retaining America's leadership in space and greatly assist in bringing the benefits of space technology advances back to mankind here on Earth.

Our country must remain the leader in human space flight launches and in military, commercial and civil operations and exploration in space and for our nation to succeed in this endeavor, we urge you to seriously consider every option that will enable you to do so. That also will be good for the great state of Florida. There are many reasons to maintain our nation's space leadership from Florida, our geography, our aerospace workforce which is second to none in the world, the billions of dollars worth of facilities and infrastructure at the cape, safety processes, our launch complexes, runways and assembly facilities just to name a few. As you consider the future heavy lift, Florida urges the committee go give strong consideration to options that will close the shuttle-to-Constellation gap, both from the left and right side of the schedules. We are different from other states because we have the only US based heavy lift launch capacity or capability, which if America is going to maintain its competitive advantage and leadership role, must be preserved for future development. We pledge to support you with bipartisan public and private partnerships at multiple levels, the governor, our administration, the Florida legislature, state-wide bipartisan support from our congressional delegation in Washington, along with NASA/KSC, Space Florida, state and local economic development organizations, local chambers of commerce, county commissions and city councils. The state has truly united in its efforts to demonstrate its strong commitment to support the nation's space goals and the growth of aerospace here in the sunshine state.

So how can NASA leverage Florida's workforce, infrastructure and other support to advance its exploration agenda. Florida offers the following suggestions:

1. Establish a policy to maximize the use of existing infrastructure, retain strategically skilled workers, and explore new opportunities for state/federal collaboration.
2. Commit to the development or retention of a near-term heavy lift launch capability that matches or exceeds the capability of the space shuttle.

3. Close the human space flight gap from both sides by allowing the continuation of the shuttle program, without the constraint of the 2010 deadline, and accelerating the development of a next generation launch system.
4. Accelerate and maximize the use of commercial launch services for space station cargo and crew transport.
5. Establish KSC and the state-developed Space Life Sciences Lab as an official part of the international space station's national laboratory that will remain in operation at a minimum to 2020.
6. Expand Kennedy Space Center's value-added role in appropriate areas, including early involvement in the design and testing of next generation launch vehicles, a greater role in applied R&D for space transportation technologies and Lunar/Mars based systems and responsibility for logistics and supply chain management for NASA's exploration efforts.

Kennedy Space Center is NASA's center of excellence for launch, and the Governor and I are convinced that Florida must remain a significant center of gravity for this new era in the aerospace industry as well. We sincerely believe with your support we can maintain that role for our nation's future as well.

Mr. Chairman, I again just want to close by thanking you and each member of this committee for your service. This is critically important for the future, not just of aerospace, but for the future of this state and this country and we're all deeply grateful for your service. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Lieutenant Governor, thank you. Thank you very much Lieutenant Governor for sharing those thoughts and if you would not mind giving us a copy of the presentation, I actually would like to incorporate that in our file. Thank you. We also had a request by Senator Nelson that we play a pre-recorded tape. He met with us at our meeting in Washington and spoke to us in person but he has a tape that he has asked that we play and so let's do that at this time.

Senator Bill Nelson Videotape:

I appreciate this opportunity to visit with you by means of this video since the Senate is in session the day that you're having the hearing in Brevard County and thank you for moving around the country and thank you for going to the Kennedy Space Center. It's very important to our people because I said in the first time that I visited with you in your first meeting in Washington, what you come out and recommend in this commission is going to be especially important because I think it's going to give the weight, your report, the weight for the president to make the decision because you all have the credentials.

And so I'd like to iterate a couple of other things. First of all, we just had the 40th anniversary celebrations of Apollo XI and on that occasion, I with others was able to pass the congressional gold medal for not only the Apollo XI astronauts but also John Glenn, harkening back to the recognition that their accomplishments as part of the

NASA team were extraordinary and symbolic for the pressing forward of this nation technologically. Although it was a different time and we were in the great space race with our mortal enemy, the Soviet Union, nevertheless, that technological achievement and having the resources and the will put together to accomplish that, starting with Allen Shepard, Gus Grissom and then John Glenn's three orbits and then on to the Apollo program. It produced a generation of math and science, a generation of engineers, of kids being so excited about the space program that they wanted to go into those fields and that gave us the competitive edge for generations to come in a global economy, and of course it produced extraordinary spin-offs that have improved our daily lives here on planet Earth.

Now, why do I say all of these? I say it because it's important to keep that magic going. It's important for you to come out with the recommendations that does not starve NASA to death like it's been in the last decade, that does not give the emphasis to NASA that brings us to the situation, a deplorable situation as we are now where when we complete the space station, that the shuttle is going to be shutdown and it's going to be a 4 or 5 or 6-year gap before we have another human rated vehicle that can take our own astronauts to our own space station that we have spent $100 billion for and been the major reason that it has been constructed with our international partners. Don't make that mistake again. And I think you have within your hands the credentials to start turning this around because I think if you give a strong report, it is going to cause the Obama administration to think long and hard before they would have lean out years as they have proposed in this last budget.

On the other hand, if you propose budgets that will accomplish a great space program, it's going to enable people like me to be able to have a prayer session with the new administration to point out to them the advantages of the space program. Now first of all, you clearly ought to get rid of the notion that I don't think anybody's taking seriously, that we're going to get rid of the space station in 2015. If we have built this station with our international partners and spent upwards of $100 billion on it, and are just getting some of the main scientific instruments to it as we will with the AMS, why in the world, would we budget for shutting it down in 2015.

Second, you need to definitely consider the fact that there will be potentially massive layoffs because of this ill-considered set of budgets that have occurred over the last decade that leave us to where we will not have a human-rated vehicle that is in time for the space shuttle to be shut down and therefore we have to rely on the Russians to get us to our own space station, barring some commercial ventures such as Space X being able to produce its vehicle for cargo and hopefully at a later date also for human rated.

So you've got to address that fact of layoffs that take away the corporate memory, the extraordinary wealth of information and experience in the launch teams and the design teams and so forth. And then as you look to the future, understand that we should not only fulfill President Obama's goal of being on the moon by 2020 but what is the real goal? The real goal is to send a human mission to Mars and to explore that planet and to continue to press the boundaries of the frontiers so that we understand this universe in which we are a part.

Now it's my understanding that you are going to come out with two options within the President's budgets and two options outside of the budget. I understand and I commend the Chairman, Norm Augustine, for having said that you're not going to be constrained to stay within the President's budget. I thank you for that. And the initial instructions that you received that you had to stay within the budget, I think, were extremely ill-considered and I don't think reflects the President's thinking. I think this president understands almost in the mindset of President Kennedy, what this nation's space program can do for us as a people and for us as a people of humans on planet Earth. And so I implore you to let your creativity come up with the recommendation of what you think is best for our American space program joining our international partners.

And finally, I would say as you know, I have the commitment from the administration that if we cannot get this next set of space shuttle flights off in time by the end of fiscal year 2010 or by the end of calendar year 2010, that they in fact commit to flying out all of these space shuttle flights to complete the station and to equip it. There had been various figures about what it would cost. I put in the budget that we passed for 2011, an additional $2.5 billion. Some think that you could continue to fly the shuttle each year for an additional $1.7 billion. Whatever it is, I wish you would consider extending the shuttle to a point in time that would lessen the gap so that we could have Americans riding American vehicles to get to our station and then on to the moon and then on to Mars.

Thank you for letting me share these thoughts with you and thank you for your public service.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

We also have a statement from Senator Martinez which is pre-recorded and we'll listen to that now.

Senator Mel Martinez

Hello. It's good to have an opportunity to appear before your commission and offer some thoughts about our nation's space program. Our nation's space program is at a crossroads. For the first time in generations, we're facing the real possibility of not having the means to send a man into space until we transition into the next phase of our space program. As a senator from Florida and a long time Floridian, I feel a special pride in the work that is done at the Kennedy Space Center, and strongly support increasing any opportunities for human space flight. I'd like to offer just a few recommendations to consider as you continue your study. Just as the Obama administration has suggested, the remaining space shuttle flights should be completed without setting hard time limits to avoid mistakes that could result from pressure to launch. At the same time, I do no believe that the shuttle program should be extended beyond the current manifest.

While such an extension could help to limit job losses in the short term, I am concerned that it could further delay progress on development of our next heavy lift launch vehicle. This could have a devastating long term impact on the space program and our nation's

space program. Instead, I believe that we need to expedite the development of our next manned heavy launch vehicle, to mitigate these job losses and retain as many of these talented workers as is possible.

With regard to the decision on the proper launch vehicle architecture, I am not an aerospace engineer so I will leave the physics and engineering debates to those that are far more qualified. On the other hand, as a member of the Senate Arms Services Committee, I have seen firsthand the cost and delays of major weapons systems brought on by constantly shifting requirements. The Constellation Systems Program was studied and chosen after careful review. And while no administration should have its decisions dictated to it by its predecessor, I believe that changing requirements and moving to a different architecture at this point would only increase the cost and likely delay to the successful launch of our next heavy lift launch vehicle. I support the current mission of returning to the moon, a manned mission to Mars and the exploration of other Near Earth objects. This vision of exploration has been endorsed by congress twice, once by a Republican-controlled congress, and again, three years later, by a Democrat-controlled congress. Unfortunately, this vision has not received the necessary funding from the appropriations committees, nor through the budgets produced by the Bush or Obama administrations. If we collectively support this vision, there is no excuse why we can't fund it.

Finally, with regard to NASA's current mission and its allocation of resources, I believe congress needs to increase its commitment to space exploration and the research and development of new aeronautics technologies within the NASA budget. Each year, NASA is funding a tremendous amount of Earth science and life science research. And while these endeavors have merit, we're now facing a five-year gap in human space flight, and we risk losing our place as the world leader in space.

The administration ought to consider this fact during future budgets. Our country has a proud tradition in space exploration and I applaud the work of all the men and women who have dedicated their lives to NASA's mission. The state of Florida strongly supports you work and we all stand ready to support your leadership into the future. I thank you for the opportunity to offer my testimony before this important commission, and I wish you success as you continue shaping NASA's future. Thank you very much.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

We also have a written statement from Congresswoman Kosmas that will be read by a member of her staff.

Congresswoman Suzanne Kosmas' Staff

Mr. Augustine and members of the Committee, thank you for allowing me to share my thoughts and concerns with you today on behalf of my constituents in the 24th District. And thank you for assuming your daunting challenge. We understand the difficult task this panel faces and how high the stakes are for everyone involved in our space program. A robust human spaceflight program is essential to our nation's future - it drives technology and innovation, fulfills our innate human impulse to explore, and

inspires future generations of engineers and scientists. A strong space program is crucial to our national security and our economy and it is in the best interest of our nation.

The issues you are working to address, including the retirement of the shuttle program, the development of the next generation spacecraft, and the continued use of the International Space Station, will have economic impacts on communities across the country. This is especially true for Central Florida. Local studies show the total direct and indirect impact of the looming spaceflight gap could approach 20,000 jobs lost. The professional Space Coast workforce possesses unparalleled skills and dedication. These workers help to ensure our nation remains at the forefront of exploration and discovery. They support a program that is vital to our national security and they contribute enormously to our national and local economies.

This workforce, if lost, will not be easily reassembled for future projects. A five year or longer - human spaceflight gap is simply unacceptable. Minimizing the human spaceflight gap, ensuring the full utilization of the ISS beyond 2015, and bringing future work related to research, development, and testing to KSC will help to minimize the loss of our unique workforce, ensure our continued commitment to America's leadership in space, and transform how NASA does business. I understand that you are considering presenting options to the President related to the extension of the space shuttle program. As launch delays mount, it is becoming increasingly likely that we will need to fly the Shuttle past 2010, which is why Senator Nelson and I fought to include Shuttle funding for 2011 in the Congressional budget. I am pleased that the Administration has made a commitment to flying the scheduled missions without a deadline and I will keep working to ensure that NASA has the funding necessary to maintain jobs and complete the manifest.

Dr. Sally Ride's working group has also persuasively outlined the merits of adding additional shuttle flights. Preserving the highly skilled workforce at KSC and throughout Central Florida is one of my highest priorities, and I would support additional flights as long as we can launch them safely and provide funding levels that do not increase the gap by delaying the next generation of human spaceflight. The International Space Station is a national asset that has bipartisan congressional support. The value of a National Laboratory in space should not be underestimated. There is enormous potential for discoveries that will enable us to explore our universe and improve life here on Earth.

We have already invested a great deal in the ISS. Extending its use beyond 2015 will ensure that we maximize our investment while helping to retain the specialized Florida workforce through payload preparation at the Space Life Sciences Lab and additional launches at KSC. Under the current plan, much of the effort to support the ISS between the retirement of the shuttle and operation of the next generation spacecraft will be undertaken by the emerging commercial sector. I believe this sector should be fostered in order to maintain access to the ISS, utilize the workforce, and ensure a healthy industrial base that can support future defense and civil programs.

Furthermore, the potential for complete reliance on the Russians for crew transport, for a price that could amount to billions, will mean American taxpayers' dollars will be

shipped abroad instead of invested at home. This is unacceptable, especially at a time when we are threatened with losing jobs here at home. I urge you to include in your presentation to the President options that will support the rapid development of domestic commercial capabilities. One common responsibility for each of the working groups of this committee is that each is focusing on industrial skill base. Nowhere is that issue more critical than here in Florida. To that end, I urge you consider offering an option that would establish a program office at KSC to manage the supply chain and logistics for the next generation spacecraft.

As the final destination of the vast majority of the components and systems purchased by the Federal Government before departure into space, KSC could lead the way to a more sophisticated procurement mentality, which would reduce operating costs and create a healthier industrial base for NASA, the Department of Defense, and commercial launch activities. I would also like to urge you to include options for new types of work to be located at Kennedy. Kennedy's operation's expertise should be applied to the development and testing of the next generation spacecraft and associated hardware. The folks that process, maintain, and launch our vehicles know better than anyone else what elements are necessary to ensure a safe, efficient, and reliable program. Embedding the operations mindset into development processes will not only utilize an experienced workforce and existing infrastructure, but will also result in increased affordability and sustainability.

Finally, with regards to funding, I believe that the investment in NASA is one of the best we as a nation can make in our future. The benefits of human spaceflight are numerous and far-reaching. I urge you to provide an honest and adequate assessment with every option you present to the President. We cannot complete our important missions if we continue shuffling funding from one program to another and pitting NASA projects against each other. Since entering office, I have fought at every turn to increase funding for NASA, and I will continue working with my colleagues from both parties to secure the funds necessary to maintain our leadership in space and preserve jobs. How we choose to address the challenges NASA currently faces will have a lasting impact on our standing as the world leader in space, science, and technology. We need innovative and effective solutions to these challenges to ensure a strong human spaceflight program, to support America's strategic interests, and to protect jobs and revitalize our economy.

Thank you again for your dedication to our nation's space program and for affording me the opportunity to share the views of those on the Space Coast. Our community is relying on your expertise to help determine the best path for the future of human spaceflight. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Thank you very much for those remarks and we have one other member of congress who's requested to make a statement, that's Congressman Posey, and I understand that there's a member of the staff that will be here to present that.

Congressman Bill Posey's Staff

Mr. Augustine, members of the committee, welcome to Florida space coast. The history of America's ventures in space exploration is intertwined with this region in east-central Florida, and you will not find a more dedicated, accomplished and hardworking group of people that you will meet here to ensure that the shuttle safely completes its scheduled manifest. Your task is paramount. You have the ability to shape the future of America's Human Space Flight Program for generations to come. Your charter gives you a rare opportunity 'to identify and characterize the range of options that spans the reasonable possibilities for continuation of U.S. human space flight activities beyond retirement of the Shuttle. With limited time and resources at your disposal, and to be of practical use for policymakers, your report cannot help but convey that some courses of action may be far more promising than others for the United States to maintain its leadership in space

By virtue of your expertise, you, the members of this committee, will appreciate the thousands of benefits and spin-offs derived from America's efforts in space exploration. However, the overwhelming abundance of NASA spin-offs, cell phones, laptops, GPS-to name a few, have meant that many Americans take for granted or fail to realize altogether how space exploration directly affects their lives and benefits them. Your review, upon which major decisions are expected to be based, has the potential to determine whether cutting-edge technology of the future is pioneered by the United States or by a foreign power. As we know, the international competition is real and it is fierce. Importantly, we all realize the vital implications at stake in regards to our national security: whoever dominates space will control the security of the Earth.

Our international competitors are already nipping at our heels. Russia, China, India, and others are challenging our position as the world leader in space. Who would have thought that what the Wright brothers began more than 100 years ago would have led the United States to world preeminence in aerospace, and that it would be our nation's leading export. We should not and cannot afford to surrender this leadership to others. We must press the envelope and lead the world, not for the sake of national pride but because it is an integral part of our future and will inspire future generations of Americans.

Remember that what the Wright brothers accomplished was more than just set our nation to flight. They inspired a generation and that generation inspired the next. President Kennedy, like the Wright brothers, inspired a generation with his vision of "landing a man on the moon and returning him safely to earth". As young man, I was inspired by that vision and joined thousands of other Americans to work on the Apollo program to see the vision fulfilled. We did it 40 years ago, almost to the day, we succeeded.

But in the wake of that victory, tens of thousands of us received our pink slips. As we approach the space gap and our dependency on the Russians to access the space station, we must carefully not repeat the mistakes of the past. Our talented workforce cannot simply be laid off and then rehired a few years later. I speak from personal experience. I watched the exodus from this very community as our nation's space team had no option but to move away. Regardless of the path decided, the transition is unlikely to be seamless in regards to the thousands of men and women on the Space Coast who have the skill set to assure American access to space. To that end, I believe it is critical that your report highlight options to minimize, as much as possible, the gap with the Shuttle's successor program, presumably Constellation, in the interest of maintaining our skilled human space flight workforce.

While directed to undertake your study within the current profile NASA exploration activities, I encourage you to note that this consideration falls after the greater priorities of:

1. Expediting a new U.S. capability to support utilization of the International Space Station.
2 Supporting the missions to the Moon and other destinations beyond Low Earth orbit.
3. Stimulating commercial space flight capabilities.

As a legislator, I remind you that budgets are subject to change, often arbitrary, but good public policy calls for their alignment with public priorities. Space exploration is the one thing for which the United States is undeniably, unequivocally, and universally respected around the world. If we as a nation are serious about maintaining our leadership in space and wish to continue to be the beneficiaries of space exploration, then policy decisions will depend on your judgment and accentuate the possibilities that best fit our nation overall, notwithstanding hypothetical budgets of the future. Budgets are a reality, but proper leadership can and should match the mission - not the mission to the budget. I, and many of my colleagues in Congress, look forward to reviewing your report and to see within the range of options some that call for additional funding, if current budgetary trends are insufficient to accomplish our space objectives as a nation.

This commission should fully explore options beyond the limiting restraints of an arbitrary budget number that has been placed upon NASA. Our nation's NASA budget is $18.8 billion out of a total $3.6 trillion dollar budget. This accounts for less than one-half of one percent of the entire federal budget. Consider in totality all of the benefits of this nation's space program will bring to the next generation of Americans. What is the vision of today's youth? I would say to you, the members of this commission, you will play a large role in answering that question. Consider what vision you lay out for the next generation of Americans. Let's look forward. Let's do what's right. The leaders of tomorrow want to be inspired, please don't let them down. Thank you for your time.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Thank you very much for that statement. Before we break, I'd like to just reiterate two open action items with regard to the presentations that we heard earlier so that we can close them out at the meeting next week. One is to really nail down this question of risk in propellant transfer and I know you've gone into that in some detail but our recommendations, it sounds like might well hinge on the - some of our options might well hinge on the ability to do that safely and effectively. Second, we need to know how we are going to propose to resolve this cosmic ray question that is open and of great consequence, how we're going to deal with the question of the cosmic ray issue. With that, there are two administrative items. One is that as I've mentioned earlier, there are sign-up sheets located at the registration desk for those who would care to make comments during the public period. We'd ask that you limit those to no more than 3 minutes and there unfortunately will be a limited number of folks we can hear, just two at a time so it'll be first come first served. Secondly, a very important announcement, the hotel says that it has an $8 soup and salad buffet for the public. Once again, first come first served. With that, we will adjourn until 1:15PM. Thank you.

AFTERNOON SESSION:

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Well, good afternoon. Welcome back everyone. This afternoon we'll be focusing on the Constellation Project with briefings from NASA. The committee has had the benefit of the number of briefings previously. Today will be, I believe, the final briefing. The formal briefing that we received, we're indebted to the folks on the Constellation Project for the support and effort they've given us. In fact, we're indebted to a lot of people at NASA and elsewhere that it's dangerous to start naming names but I do think there's one person that the committee here has to acknowledge and that's Donna Connell who has kept this whole committee on time, well fed, if not well slept.

All right, the first speaker will be Jeff Hanley, whom I think everyone in this room knows who we've had the privilege of speaking with at some length before. Jeff, thanks for joining us again and the floor is yours.

Jeffrey Hanley, Program Manager, NASA Constellation Program

Okay sir, thank you very much and thanks for having us this afternoon. We're going to talk primarily about ground operations as it pertains to all the activities we have going on here at the Kennedy Space Center this afternoon. Before I get into them, just a couple of offers to the committee, we resonated very much with Jeff's (Greason) comments this morning on Probabilistic Risk Assessment and we offer him more dialogue on that. I think we find ourselves in pretty well agreement on how the program is applying that and we'd like to share more of that with you.

On the commercial engagements, it's we think important to point out that 80 percent of the Constellation budget goes to industry. We have competitively procured these contracts. The subcontractors, some of whom you've heard from yesterday during our public session, all are engaged in working towards the Constellation goals as we've laid them out.

And then, on internationals, we'd offer also more dialogue on that, General Lyles, on what we've done in the Constellation Program these last three years to get going with our international partners on the Constellation Lunar Surface System's activity. This afternoon, as I said, our focus is just ground operations. We have here at the Kennedy Space Center a great legacy from Apollo through the Shuttle Program, to today. We have the Shuttle Team, is processing our first test flight. It's the Space Shuttle USA workforce that is today stacking the Ares I-X rocket and we're enjoying great progress there.

Pepper Phillips is going to provide you an overview of what we've done here at the Kennedy Space Center, on launch infrastructure. I would point out that there are other parts of what happens here at Kennedy that we unfortunately we won't have time to touch on, that being the fact that the Orion factory is here on site in the ONC Building, the building that used to be used to process the Apollo Spacecraft and then also manufacturing for elements of the first stage of the Ares I also occur here on the

Kennedy Space Center premises, but today's focus is operations and I'm going to hand it to Pepper.

Pepper Phillips - Constellation Project Office at Kennedy - Deputy Director
I'd like to say thanks, Jeff. Good afternoon, Mr. Chairman and good afternoon to the panel members. My name is Pepper Phillips. I manage the ground ops project at KSC. Like my colleagues, I recognize the importance of the work you guys are doing and the effort you got in front of you. It's a difficult task. I hope not to add to that today. What I'd like to do… next chart…share with you some of the progress and I do appreciate the opportunity to talk about the progress of the ground ops project.

What you see in this first chart here is our exploration capability's chart. Again, this is a chart that you guys have seen before. What I'll tell you is the ground ops project is the enabler for the broad capabilities that the Constellation Program has.

Next chart.

What it conveys here are the specific goals of the ground ops project. These flow down from the NGOs that you guys saw and referenced earlier from ESMD through the Constellation Program and down to us. These are specific for the ground ops project. What I intend to do today is talk you through those goals and what we're doing related to each and the progress associated with each. So, next chart…

I'll start you with goal 1, that being to develop the ground infrastructure and we are to leverage existing shuttle and international space station assets to meet the Constellation mission.

Next chart.

So, when we started down this adventure approximately four years ago, the first daunting task was to make sure we had a launch complex baseline, and what we attempted to do was to step back and say is the infrastructure that we have appropriate and appropriately-sized for the architecture that we are planning on embarking on. We went and kind of look at the trade space here on the east coast and kind of looked at the eastern test range, came up with a number of options that outlined what potential trade space we could go look at. Part of that was complex decisions for Ares I and then associated complex decisions for Ares V. Ares V, of course as you know, ESAS was sized for the launch complex 39 infrastructure and it is limited on what it can do because of its size. So, we looked at launch complex 39 as outlined in ESAS. We also looked at a new launch complex for Ares V.

We had a little bit more flexibility on the Ares I side. We actually looked at an open complex, launch complex 40 at that time. It is now being utilized by Space X, but we went and looked at that infrastructure as well to say is that an option for us and does it provide any benefit to us in our emphasis in how we execute ground operations. Ultimately, we chose the launch complex 39 area and its assets mainly for a couple of reasons, biggest being lifecycle cost. As it played out, lifecycle cost utilizing the assets that were available from shuttle turned out to be the, by far, standout lifecycle cost profile. It did have cost benefits but it had some other benefits as well. It kept the

architecture on a common area. It capitalized on the knowledge base that exists within the executing operations team. So, this was the first trade study that we went and executed and from there will narrow that trade space.

Next chart.

These next couple of charts will kind of tell you what we looked at when we evaluated the complexes, specifically launch complex 39 and launch complex 40. The first chart here shows complex 39 and what you'll see is there is a number of assets available at this pad that are coated in green which means they are available and ready for use for the architecture for Ares I. The yellow and red were areas that we either had to work or something that we couldn't use but the condition of complex 39 was very favorable for the Ares I vehicle.

Next chart.

Conversely, you look at complex 40 and there were a number of systems that were either in the demolition state, had been removed, were not available for use or didn't fit the needs of the Ares I vehicle so we quickly dismissed launch complex 40 as an option.

Next chart.

This kind of outlines what I was telling you. There are a couple of areas we looked at both at development cost and lifecycle cost. If you'll notice the profile of the complex 39 and complex 40, it shows that launch complex 39 is significantly better in terms of development cost and lifecycle cost.

Next chart.

Okay, the other areas we looked in launch in complex 39 was the VAB and crawler-way assets. One thing the Shuttle Program has done and done well is maintain the VAB as a facility system. We did capitalize on some of the hurricane funding several years back and in fact have rehabilitated the VAB into a fairly good state. If you hadn't noticed from standing afar, it does have new siding on the sides so it looks really clean. It's got a new roof. VAB doors have been modified and improved and it's got enhanced hurricane protection all yielding lower O&M cost. We, in turn, will have to do a few specific things in order to execute this program. Notably on this page, we'll be installing cable raceways specific to this architecture and that'll keep it clean from the existing architecture that's in the VAB.

Another asset that we looked at was a crawler-way in fact, the crawler-way system. Again, what we've done is to have done some studies of the crawler-way and its capacity. It is in good shape. In fact, the Corps of Engineers did an outstanding job when they built that crawler-way back in the 60s. So, that's another asset that's in really good shape that we're going to capitalize on.

Next chart.

So that was essentially an initial baseline that we went and looked at. Really the launch complex trade, the crawler and the crawler transporter trades. What we wanted to do was dive them down into a deeper level to look at potential options to get us an updated baseline which is kind of what you see in that middle block. What I'll tell you from this page is from guidance that we've received, certainly from our NGOs, (the needs, goals, and objectives) and communication down from the program, operability is the driver for our operations concepts and has been driven from the start and I'll talk about that some more as we go throughout the day.

Next chart.

Okay, one of the first things we did after establishing our initial baseline was we opened a broad area announcement and opened it to industry. We had four major contractors, aerospace contractors that were awarded a 90-day contract. You see them listed there in the left side of the page. Our general guidance to them was the same that we took which was your range of options are limited to the eastern test range as a launch site, and from there it was up to them what were the best options for us to go pursue. They in fact, conduct their 90-day studies. They gave them back to the NASA team individually and then, once we had evaluated them individually we then sat down with the group as a whole and debated the relative merits of each proposal. What you'll see there is they largely validated the concepts that the NASA team had come up with mainly launch complex 39 was the best option. Several of the others you see listed there, I'm going to talk a little bit more in depth as I go through the trade space, but I'll note that we also found some bright ideas from the industry and the aerospace community that we adopted and further studied in our subsequent analysis.

Next chart.

Okay, so the first area that we looked at was the launch pad. Our trade space was really centered around whether or not you affect every operation at the pad or you do things prior to getting into the pad. What we had was stack on-pad and a service on-pad option, a mobile launcher concept that also serviced on the pad and a mobile launcher and a clean pad concept. The stack on-pad option was really a non-starter in limitations of the lifting requirement and the fact the bridge crane that's able to lift 175-tons worth of capability, that largely limited you not to mention the exposure that you have while you're trying to do those hazardous lifting operations. So we kind of focused on the mobile launcher concept and the service on-pad. Our studies indicated that if you kept services off the pad much like the Apollo community did or you didn't have a fixed infrastructure in the pad that you had to maintain, there was significant O&M savings that could be realized by not having to build the infrastructure and maintain it at the pad. Also, we found that minimizing pad processing time helped with our critical path timelines and helped us with our launch availability which were key attributes that we were looking for. So, we settled on the mobile launch clean pad concept.

Next chart.

A couple other features that are on the pad that I wanted to talk about, obviously Bob Cabana talked about the lightning protection system that we've put in effect, out of the

pod, that's a three-tower, 600-ft tower, Faraday cage protection system. We started out on the study much like our ELV counterparts with a four-tower system. Our engineers did an evaluation and figured out the geometry of the Faraday cage and the catenary wire system such that a three-tower system became a better option and that helps in the, certainly, in the development cost and in the O&M arena. So, the lightning protection system is off and running. Also, the Emergency Egress System was another system that we evaluated. Right now, the shuttle uses a slide wire system. We, in fact, gathered key stakeholders including the flight crew office human factors personnel, the health and medical team, and did assessments on future and better potential Emergency Egress System that included things like the slide wire the shuttle system uses, the slide tube, elevators, a rail system and escape chutes. After that study, the team came to the conclusion that the rail-based system was the best system really in effect getting a crew away as rapidly as you can in a controlled environment. As of today, we're still using the bunker option that the shuttle pad uses, but it's a much safer system much more reliable, robust system. So, the team decided on that rail approach as the best option.

Next chart.

Okay, so from an accomplishment standpoint on the pad, the lightning protection system is obviously the horizon-changing event at the pad, something really notable. We're about 91% complete, still need to install the catenary wire system in its entirety. We do have a portion of that system installed already and it is planned to support Ares I-X for its mission.

You see, FSS and RSS demolition design, that's 100% complete. We're expecting to pick up where that demolition starts, March 2010. The Emergency Egress System design is nearly complete and we expect to have CDR for that system in October of this year, and we have completed Pad PDR overall and expect an effective CDR in October 2010.

Next chart.

A couple of accomplishments specific to Ares I-X. What we're doing with the Ares I-X system is unique. We're using the existing assets and infrastructure of the shuttle in order to be able to launch Ares I-X. You'll see on this page at the top, really the things that we had to remove in order to prepare that in the pad for Ares I-X, the lightning mast on the left, GOX vent arm in the middle and then removal of the Orbiter access arm. All of those are complete. Then at the bottom of the page you'll see where we needed to install assets to gain access to the Ares I-X vehicle and its unique configuration. So, you see we installed upper stage system access and also the FSAM access both the left and in the middle. Vehicle stabilization system is being installed so, the ports, as you see there, are being assembled on the pod's surface.

Next chart.

Okay, moving on to the VAB, I thought I'd walk you through some of the trade space that existed there. Really, the big driver for us was whether or not we used the existing platform system in the VAB or go to a new VAB platform system. Again, the biggest

driver here for us, is cost. So, we looked at the relative cost options and the access requirements that we have. One thing we found, and by the way from a historical standpoint when Apollo converted to shuttle they used the existing Apollo platforms and modified them to fit the shuttle configuration. Once we got in and looking at the requirements, we found that there's a load margin issue on the VAB if in fact, we had to modify the existing platforms. So, it was prudent for us to go ahead and install new platforms that lessen that risk of maximizing those loads. So that's one of the things we did. The other thing this new design does for is to allow individual platforms and individual platform access to the areas that you need. If you'll notice on the top drawing, the kind of ganged platforms where when you slide to one of the existing platforms against the vehicle, you're essentially drawing three or four different levels of access up against the vehicle. That, from an operations standpoint, is a little bit cumbersome because all operations need to be complete or at least in a secure state before you exercise those platforms and this individual state that the new version it is much more clean and it's better for the operations team as they execute their task.

Next chart.

So for accomplishments on the VAB, you'll see that we have completed 100% design for the platforms, and we've, in fact, released an RFP to industry for construction of those platforms. VAB PDRs are completed and we're looking for CDR on October 2010. I'll point your attention to a couple other pictures there. You'll see on the left side of the page, we're moving the C north platform which was an interference platform for Ares I-X configurations specifically that has been removed. In the middle of the page you'll see a separate upper stage platform that has since been installed in the same high bay.

Next chart.

Okay, I'm going to skip the next two if I could. These are both operations progress for Ares I-X and Bob Ess is going to speak to those so, page 20 if I could, okay?

Okay, I'll move you to the mobile launcher trade space. When we did some evaluations on what are our options were for mobile launcher we really looked at being able to use the existing the shuttle assets versus a new mobile launcher and again, this is for Ares I. The biggest driver here was availability of the mobile launcher assets. The shuttle community is using three mobile launchers and continues to use three mobile launchers. They have made available the one mobile launcher for Ares I-X being able to execute that mission and in effect build a new design with a launch tower on it was not feasible. So, that drove us specifically for Ares I to a new mobile launcher. That did a couple of things for us. It reduced the weight. Since we are, in fact, going back to the Apollo configuration with the launch tower on it. Now, you've got this rocket with its solid motors. You got a big tower planted on top. So, we have to watch the load margins on the crawler transporter. This does reduce that weight, the specific designed us and it does provide flexibility and retrofitting and reduced O&M cost.

Next chart.

Some further trade space we went off and looked at while we're looking at the mobile launcher concepts and, in fact, operations in the VAB, our team came up with the concept of offline stacking and this is really a critical path time driver where we could in effect stack the first stage offline, while, and keeping it off the critical path, while we could do other operations. We looked at a separate offline stacking facility again cost prohibitive. It'll be in the realm of about $500 million to build a new facility, but the team pressed further and looked at options that said, “Hey, I can potentially build that offline stacking capability right there adjacent to the integration cell in the VAB,” is a very, very innovative concept and one, in fact, that the Constellation Program really liked. The problem was the requirement for development cost and construction cost….. were in a very bad time period for the program, so it was determined to be cost-prohibitive for the immediate implementation of that option.

One of the things that we found when we're looking at that option was you're required a launch mount which is the lower right hand picture. In order to be able to effect that option we did look at the launch mount independently while we're doing this study and said even if we cannot put into effect this offline stacking, this launch mount concept does allow for a better turnaround because you can work the turnaround of the launch mount offline and, in fact, when you have two launch mounts you can have one that’s refurbished and ready to go and take the other off-line so it's out of the critical path. So, again from a time savings, the launch mount was very valuable. The other thing that we liked about the launch mount is that it allows you to make changes to the vehicle…. minor changes to the vehicle either in height or specific requirements that exist in the hold down mechanisms in the launch mount. We are able to effect those changes in a singular unit where you don’t have to take the entire mobile launcher offline in order to effect the changes. So, a lot of flexibility provided by the option and this is one that the Constellation Program asked us to pursue.

Next chart.

Okay, a little further on the trade space. We looked at several options on T zeros. Again, we have a lot of history here that have the benefit of many of the programs that we looked at. We also have done a lot of benchmarking of other programs including the ESA community and the Russian Team’s concept. What they came out with was a tilt-up umbilical arm and it was really selected for its operability and benefits namely that’s a simple mechanical counterweight design and it's highly reliable. It doesn’t use any hydraulics or pyrotechnics in its operations. So, in fact, we have pursued that design. It is a common architecture that we can use across multiple T-zero locations, and in fact, we've got prototype testing underway.

Next chart.

So, this is what we ended up with as far as the mobile launcher. For our final concept, again, the new mobile launcher you see on the left with the launch mount bottom right and then the TUP concept, tilt-up umbilical arm at the top of the page.

Next chart.

Okay, from accomplishment standpoint for the mobile launcher, you'll see here, we're about 51% complete. That's on the structure itself. We still have a ways to go on outfitting, but what you see in red here are the structural completion pieces. The red on the… or the square on the left there is the mobile launcher base. And again, it's standing offline, Bob showed a picture of that and I'll show a couple of subsequent pictures. It looks fairly complete and I hope you get a chance to go see it while you're here. The tower itself is being constructed in tiers or pieces. What you'll see when you go visit that mobile launchers, you'll see a lot of these tiers constructed already to the side. So, you can see predominantly nearly all of that structure in their individual tiers completed.

Next chart.

Okay, these are the pictures I promised about the mobile launcher. You see the base there at the mobile launcher refurb site that's being constructed on the right side. You see a flooring of that base, so you see it's getting enclosed pretty well. At the bottom of the page and on the next page you're going to see several pieces of those tiers that I talked about. Again, those are to be assembled separately on the side and then we're going to stack those tiers on as we get ready to do that, to construct the tower.

Next chart.

Again, a couple of more pictures of those tiers as examples. Okay, moving into other areas that we're developing, launch equipment, test facilities, again, this is to say, Apollo era test facility that we'd used for the Apollo Program, subsequently for the Shuttle Program and now we're using for Constellation. It is really our test and verification area. We made quite a substantial progress on this. I told you about the tilt-up umbilical assembly. You see that in the middle of the page. That's where we're doing our prototype testing. We also have several other areas that we're in fact, developing and will be using for that verification testing, things like the vehicle motion simulator, cryogenic systems, hazardous gas detection systems, et cetera. So, we've got a lot of development underway and making good progress there.

Next chart.

Okay, we have talked a little bit about the pad option and offline servicing. The original concept that we had with that at the pad was that we were going to do all the servicing on-site. As we conducted the trade space, there were a lot of advantages to taking that critical path work and taking it offline and bringing it out of the critical path. There was also the advantage of doing some of this hazardous work in a controlled environment and not at height as you would have to at the pad. So we studied options about how we could do that and trade space was doing hazardous processing servicing on the path or doing it offline. We looked at some facilities that existed across the Kennedy Space Center, one of them being a fairly new and little-used facility called the Multi-payload Processing Facility. It was built by the station program, I think, to do some propulsion work that never eventually came to the center. So we had a real opportunity to use a facility that was in good standing and good shape to do our offline servicing. So, in fact, we effected that change and our new baseline became doing hazardous processing servicing offline.

Next chart.

As far as accomplishments in that area, we're really in the design phase. The modification of this facility since it's in such good condition, requirements are very few. We're still working with the Orion Project to understand what exact requirements we have. So, we're right now under the facility modification and design review state we are at the 30 percent there. Similar with the GSC that goes associated with that facility and we have completed a PDR for that particular development.

Next chart.

Okay, a different system command, control, and communication. Again, our team did a lot of benchmarking and benchmarking of other systems to look at the command control and communications capabilities that these systems brought to the table. We also have a rich heritage with the knowledge-base that we've gained on the different programs that we've flown. So, we narrowed down our trade space after looking at all those options to some of the existing systems that we have namely the LPS system that the Shuttle Community uses, TCMS which is what the Space Station Community uses, Atlas V derived architecture because we have a lot of experience from our friends across the river. And then, we looked at standards-based architecture which is really an open platform that uses COTS hardware. This one seemed to be a fairly simple answer and it was once we got into the trade space it was readily apparent to us from a cost standpoint. Open architecture that highly leverages COTS was the answer. The supply chain, the ability to service the equipment, the ability to change, I mean, not keeping things unique for Constellation all seem to pay off in the overall lifecycle cost of the CCC System. So, in fact, the standards-based architecture is what we chose.

Next chart.

Okay, I thought I'd walk you through some of the accomplishments associated with command and control. We have, in fact, modified our Firing Room 1 which is the Young-Crippen Firing room you see at the top right of the chart, a couple graphs that show that same firing room in use both for Apollo and Shuttle. At the bottom left of this page you'll see where we started to do our modifications at that facility and, in fact, have completed the facility modifications and it is ready to go for Ares I-X. That middle chart or the middle picture you see on the right hand side is the configuration of what we're using for Ares I-X and, in fact, we held our first launch SIM on the 22nd of that facility, so it's up and supporting. The bottom right picture is the final configuration which will incorporate the entire vehicle and that’s how we plan to be able to exercise the room as you see there.

Next chart.

Okay, so after all of that trade space that got us to a baseline of what you see here, what we essentially have is a single-string capability for Ares I and a single-string planned capability for Ares V namely, we have one VAB integration cell for Ares I, one mobile launcher, a crawler transporter available for that mobile launcher and then a pad

LC 39 B specifically for Ares I. We used a similar set of assets for Ares V and you'll see those listed.

Next chart.

Okay, and from a facility standpoint at Kennedy Space Center, these are the lists of the facilities that we intend to use. The majority of them are heritage Shuttle assets, a couple of those being ISS assets specifically the MPPF and the SSPF.

Next chart.

So, what we've got with this architecture in its single-string is really a pretty grand flexibility, extensibility, favorable architecture. We're pretty proud in the fact that we have with this clean pad mobile launcher architecture we are able to scale as we require the asset. So what we've done with this single-string asset is determine our own flight rate and with the assets that we have we were able to meet the near-term flight rate of the Constellation Program. If the program decides that they need to operate at a higher flight rate than we can provide, we're able to buy additional assets that'll enable us to go do that namely, things like an additional mobile launcher and we've got other high-bay assets in the VAB. You can also affect even higher flight rates for things like I described earlier, the offline stacking capability which we have not precluded and an integration facility out towards the pad, separate from the VAB. We were calling it a vertical integration facility. We could also affect those changes. The other thing this ground architecture does for us is enable us to fly vehicles of different configuration but like size. As you're well aware, the flame trench size for Ares V was compatible and enabled the design of the Ares V. It is the size of the Saturn V class flame trench. So we can operate systems in that same class from this infrastructure. Same thing with the clean pad concept, really the mobile launcher serves as an adaptor between the vehicle and a generic launch pad.

We have our VAB integration cells that are available and that can be configured for different configurations. And, in fact, if you actually wanted to pursue a vehicle of a different height that is limited by the VAB itself, you could build an integration facility that’s taller than the VAB if so chosen. Of course, you can only get so tall and we had built the lightning tower protection out at the pad to be appropriately sized for what comes out of the VAB but you do have some flexibility in the size or the height requirement.

Next chart.

Okay, progress-wise for our schedule, you'll see that we have completed our ground ops SRR and SDR and we're proceeding towards PDR. Expect to accomplish PDR in the spring of next year. One thing you'll also notice on this page is the major development operations for Ares I are well underway. You'll see that the PDRs are well behind us as I've mentioned and we're approaching CDR.

Next chart.

I apologize for the kind of busy chart here. My intent is not to drive you towards the specific detail on the chart, but I want to point out that we do have a lot of procurements and procurement efforts underway. So, there's really two messages here, one is we're well underway with procurements and contract efforts for this project. The other message here is the NASA Team is the lead of this. We don't have a prime. We are, in fact, managing these contracts ourselves and doing the integration efforts ourselves.

Next chart and the next please.

Okay, so from there, I'll move you into goal 2 which is ensuring ground operations to consider in-flight hardware designs and manufacturing.

Next chart.

Early in this program, one of the leading themes was, "We're going to drive this to be a highly-operable system." Some of the criticisms in programs past and our friend, Bo has been very aggressive in making sure we met these challenges, was a lot of times they felt like the development efforts didn't consider ground operations and the cost that it drove to not have it considered. So, we were asked early to make sure that we drove from our knot-hole with expertise that we've gained in the ops world, drove it back into the flight vehicle design. So early, what we did was establish teams of this highly-skilled expert operations folks to go live with the design teams for the flight vehicles. We have in effect done that and we've had great success in affecting their designs. It was a little bit interesting because we thought when we first started we would be, you know, the design teams are so focused on meeting the technical objectives that they would push back on the operability inputs. What we quickly found once people got accustomed to the idea of operability being a focus was they couldn't get enough of the operational expertise that existed at KSC. So, we quickly started making gains in driving operability successes into their designs. The two pages you see here, both on Orion and Ares, do that. I'm not going to go into the specifics of those unless you'd like me to, but they more or less capture things that are important to the operations community to drive cost, drive capabilities, drive a number of people that have to do to execute the operations. It's really the assembly service test and monitoring capability that we're worried about and the flight designs teams have responded very favorably to the suggestions that we've had.

Next chart.

And again, we've done that with both flight systems, the Orion and Ares I.

Next chart.

Okay, I'll move you into the last goal, which is really to develop ground operations methodologies and implementation strategies including cost and schedule for prelaunch, launch and recovery of program elements.

Next chart.

Okay, this is the other, this is the nighttime job or the daytime job that we have, but this is the operations planning and analysis piece of the responsibility that we have. So, we're really building the plan for how we're going to execute operations at this center. So, we needed a couple of tools to drive out exactly how we're going to operate this vehicle. When we started earlier, we had initial concepts. We planned those concepts. We built budgets against those concepts that we matured in the design. We've gotten to a point where we need to develop lower level detail. The first bullet you see there, the ground operations planning database is that lower level detail. We have volumes of work requirements that we built into this database. It looks at specific task as they're executed, things like whether or not things can be executed in parallel in some instances with some operations or as serial critical path work. We've also started on the contingency requirements.

We've largely focused on nominal operations but we're now delving into contingencies and how those will be handled. We also developed an integrated timeline that's really a tool for program at level 2. This is really to support vehicle change impact assessments. We report routinely to Jeff at his level 2 board about our progress on these timelines and as vehicle changes are put into effect, they're measured against the timelines and determined whether or not we're improving on our timelines or we've, in fact, caused a problem and how we're able to operate here at KSC. We have several requirements that we're expected to meet at the program level. These are how we measure how we're performing against these requirements. We have discrete event simulation tools where we're able to look at trade studies and identify potential areas of cost saving. Similarly launch availability and reliability analysis are conducted at ground system and subsystem level. We have design visualization techniques that really helped us with operational impacts. And we are doing contingency risk assessment prioritization and analysis. These all look at high potential risk and how we can solve them.

Next chart.

And so, we've spent a lot of time and focused a lot on Ares I but we have not taken our eyes of the lunar planning efforts and, in fact, they work closely with the program to look at options and potential designs for the same infrastructure underground and how we can utilize the existing assets that we have. So, we have looked at several Ares V configurations and how that affects the ground systems. We looked at facility concepts and transportation approaches and really how they affect processing timelines.

Next chart.

What you'll also see here are a number of trades that are in effect. Again, they're similar to the trades that we conducted on Ares I. We're going through the same process and hoping to develop the same level of maturity in the concepts and the concepts trade and ultimately yield the greatest bank for the buck.

Next chart.

So, I'd like to summarize essentially for this ground operations team, we developed a very dedicated team of experts. We've tapped into a lot of expertise, not just shuttle,

not just station. We have Apollo era expertise. We also have launch vehicle expertise from the expendable program that we've infused under this hoping to embody the best of all of the operations experiences out there. We have contemplated how best to use heritage infrastructure and balance that with new infrastructure and I think we've achieved that. And I think it's a pretty good architecture that we formed. We partnered with industry. BAA was an outstanding experience for us and we've effected that since in the program. We partnered with the State of Florida for potential solutions and solution sets that can benefit both the State of Florida and the program. We have operability considerations that have been overtly driven into the vehicle and ground systems designs and we've had many, many success as a result. I'll tell you, the team has met all its milestones. SSR is behind us. SDR is behind us and the ground systems element PDRs as you've seen. They're all behind us. So, we've made great progress and on schedule. And finally, I'd tell that we're well underway on construction and operations planning and we're on track for the 2015 IOC commitment.

And that's it for me. I'll… Mr. Chairman, if it's okay with, I think our plan is to complete the Constellation Program briefings and then offer you the opportunities for questions. So, I'll introduce the mission manager for Ares I-X, Bob Ess.

Bob Ess, Mission Manager for Ares I-X Test Flight

Should… I should stop now, right? all right, good afternoon. Thank you very much for your time today and giving me a chance to talk about Ares I-X. As Pepper said, my name is Bob Ess. I'm the manager of the Ares I-X Test Flight. You can see on this first chart, I-X is as what call a developmental test flight. It's the first one for Constellation in the Ares-Orion configuration and developmental test flight is a flight you do early, early enough so you can use the data to improve your design from both the engineering side and from the managerial side so we understand we're on the right track. A big picture overview of our vehicle, I know yesterday in Huntsville Steve Davis, one of my deputies went through this a little bit for you. A couple of things that I wanted to point out just a reminder, this is a 327-foot long vehicle. It's 1.8 million pounds. It's being assembled as we speak over in the VAB and I'll show you some photographs in a second. We broke this down into five major primary objectives and then as a key secondary objective.

First and foremost in the lower left, this demonstrates controllability of Ares/Orion configuration in a relevant environment. And we wanted to do was take the Ares flight control algorithms put them into a test vehicle, so we purposely built this test vehicle to be what we called, dynamically similar. The flight control system doesn't know it's flying an Ares I-X versus an Ares I. The bending modes and stiffness are similar enough to Ares I that the flight control should behave the same way. In addition, we designed the trajectory to fly the same dynamic pressure profile that Ares I does, from tower clear up to about Mach IV. That's the critical phase of flight for Ares I so we get a very good test of how the flight control will work with a long slender vehicle. Once we do that, we go up to the separation area. We separate at about 130,000 feet and we're using the shuttle 4-segment booster that we had. We don't get quite as high as Ares I using a five segment, but the four segment gives us what we need to go, to do the ascent through the Mach dynamic pressure range up to the separation point.

So our secondary objective is to perform that separation. Just like Ares, we have booster tumble motors, booster separation motors, and check out the operation and performance of those and with we get into an actual separation event. Now, the good thing about our vehicle, we have a simulator or spacer to give it the same length as if we had a 5-segment simulator. So going uphill, we only have four segments of propulsion. Once we burn out, it's about 122 seconds just like a shuttle, it's about 130,000 feet, we do the separation sequence. This is exactly like Ares I. Ares I expends to 5 segments, we'll have what we have, as far as our expended four segment plus a spacer. So, we're using a prototype Ares I parachute, that is 150 feet in diameter, a cluster of three. It is a key test for Ares for us to use these in this test with the same mass properties, the same staging sequence and approach. So, we expect to get superb data for Ares Project for the separation. Of course, the booster will be recovered by the SRB recovery ships and the upper stage part of it, you can see from the graphic, it keeps going on a ballistic trajectory and it'll end up in the water. And that part will not be recovered.

So, we have those key objectives, controllability doing the booster separation sequencing. We're also teaching ourselves again how to put together a new vehicle. So the objective down at the bottom of number 3 talks about the assembly of such a vehicle. That in itself has been and continues to be a learning experience for the agency to understand how different this vehicle is from a shuttle teaches now on Ares I-X what things that need to be changed, what things work, what things don't work, and we've already captured lots of lessons learned for us to use in Ares I so we can be smarter or quicker after this test flight.

Next page please.

Now, a good part about I-X is that there's no more view graphs. It's all photographs. Everything we designed is built here in Florida. It's all being put together and I'll just show you photographs of where we are. So, the Orion crew module launch abort simulator, this was designed and built by Langley Research Center up in Virginia. And this is the top of the rocket, of course, and you see it completed here during its testing. And you'll see more of that when we talk about our stack I.

Next page.

Upper stage simulator designed and manufactured by Glenn Research Center up in Ohio. It's comprised of eleven segments that were shipped separately, put together into a logical grouping and was tested, retrofitted with instrumentation.

Next page.

Now, the roll control system is a very interesting story. It's mostly decommissioned Peacekeeper fourth stage hardware. The Air Force, gave us these, the hardware basically for the price of transportation. They had to decommission it for treaty reasons and Marshall Space Flight Center, Teledyne Brown took the tankage, the thrusters themselves and associated valves and regulators, repackaged into two modules. We have two modules as opposed 180 degrees, each with two thrusters to give us this roll control system in very clever way.

Next page.

Now, first as I mentioned the first stage is a shuttle booster with the same aft skirt, same thrust vector control, same four segments. It's identical to what we use for the shuttle. We haven't done any changes from that. And what you can not see in this photo, you'll see subsequent is we also have the first stage guys through ATK build new hardware. They built that five segment spacer that I mentioned. Also built, we called the forward skirt, forward skirt extension. That's where the parachutes themselves and the sequencing hardware is all housed. Then the big Frustum in the middle which ties the two piece of the rocket together goes from the 12-ft diameter booster up to the 18-ft diameter upper stage.

Next page please.

Avionics is another thing and I should have mentioned upfront that I-X is really an opportunity to take as much heritage hardware that we have available and put it together in a way that reduced our cost and our timeframe from project initiation to the actual flight. I mentioned the Peacekeeper hardware. I mentioned the shuttle assets, now avionics through Lockheed-Martin brought the Atlas V avionics. It's the primary avionics for I-X. It comes from the Atlas V rocket. So, it's proven. It has a lot of history. It has a lot of technical support. It's all over the vehicle, top to bottom as well as over 700 different measurements which is our key secondary objective to collect as much sensor data as we can. We have 700 measurements to help us correlate our models and for the engineers, so that we will be a little smarter after this flight.

Next page please.

Bird's eye view of the Vehicle Assembly Building, slanted view, you can see basically a lot of our pieces there getting ready for final stacking and this is all done in High bay 4 in the Vehicle Assembly Building. Once they're ready to be put together, the photo I showed you of the MLP and the boosters in High Bay 3 and it's all happening today.

Next page.

Real quick, from a confidence of the flight, this is a long slender vehicle and we're using the flight control system that's new. It's primarily driven by how we set that flight control and the bending characteristic of the vehicle. We wanted to make sure that our predictions were as we expected, so we have three model tasks on our book. We've completed two of them. The most recent one is over here. This is what we call Stack 1 which includes our critical piece of the inner stage, the roll control system, the frustum, and the 5-7 simulator, that's the part of the vehicle most susceptible to bending. We completed that. We matched our predictions. We completed a previous one for the top of the rocket and matched our predictions and then in a couple weeks, we have the whole vehicle put together. We'll do one again on the full scale vehicle and make sure that we match our predictions.

Next page.

All right, when we go through, you'll see the hardware again. This way it's through stacking order, so we have “six stacks”. One is called stack 0 only because this is a current shuttle stack no different than we do it for a typical shuttle mission. This is the MLP and VAB High Bay 3 with the aft skirt and with the four segments. And that’s been complete for a couple of weeks.

Next page.

This shows you where we are today and the right is a cartoon showing what part of the vehicle is stack I. Stack I, as we're talking here today, was brought up over, is on top of the shuttle booster. So, right now, from the top of that purple line, top of the frustum area down is stacked in the VAB ready to go on its flight configuration.

Next page.

Stack 2 is a separate ballast segment and a venting segment you can see there. That is scheduled to go on Monday. This coming Monday we'll take that stack and bring it up and over.

Next page.

Stack 3 has four segments put together. Inside it are platforms and ladders for access and a lot of sensors up and down the vehicle. I mentioned there are over 700 sensors on this vehicle for us to collect data.

Next page.

We get into another ballast segments. The ballast segments correspond to the liquid oxygen tank in the previous stack 2 which is why it is down below. And then stack 4 which simulates where the liquid hydrogen tank would be for the Ares configuration, about 130,000 or so pounds of ballast in our vehicle.

Next page.

All right, the top of the wedding cake here, stack 5, this should be about a week and a half or so we'll get this one up and over and again, you'll see a lot of protuberance on there and that one is ready to go.

Next page.

All right. full scale integrated vehicle. This is what it looked like with the cartoon as it rolls out. It rolls out directly attached to the MLP. There's no stabilization system or hold down. It's the four hold-down post that will have the vehicle out until it goes to the pad. Pepper did a good job of showing you some photographs of the modifications at the pad and the VAB to enable all this. So I won't repeat those but we're quickly getting to the scenario right here. Our launch date is October 31st and it's coming quickly and we're going to be ready.

Next page.

That's all I have for I-X. You saw some yesterday and then after me, Ed Mango will talk to you about the Constellation planning office, whatever you call it… Space Transportation Planning Office, sorry.

Edward J. Mango, Deputy Director of Launch Vehicle Processing – NASA's John F. Kennedy Space Center, Florida

Good afternoon. My name is Ed Mango. Good afternoon, Mr. Chairman and members. Let's see, I wanted to talk to you about a portion of the Constellation architecture and the Constellation Program that deals with what happens when they get ready to go operate this system. And so, what we've done is the Constellation Program and NASA has put together a charter for "How to Go Do That" development and that's what I'm going to talk about, so next page. And this is just our quick agenda that we'll go through and…. the next page.

Last fall, SOMD and ESMD, the operations portion in NASA and development portion in NASA got together and they said, "Let's go create this planning office with the scope of the planning office with the scope of the planning office to figure out the methodology and/or processes that we're going to go use or corporate processes to operate a human system as well as develop the continuation of future human systems." And the idea here is you're doing those in combination with each other. Once the Space Transportation Planning Office, which I represent, will turn into a program over the next couple of years, it will then once the system is fully developed and certified, it will take that Ares I system and Orion and manufacture it, produce it, process it, launch it, fly it to ISS and recover that system. And again, that will happen after the certification processes is completed by Jeff Hanley and his program.

Next chart.

We're starting out slow and I'll talk a little bit in a couple of chart about why start out now, but the idea here is to get started to understand what are processes are going to be and to build the corporate capability to go do this. It's going to take us a couple of years to get there and the reason for that is we want to be able to marry as much as we can into what Jeff Hanley is doing, so that the operations program folds right into what the development program has given them. This is a model that isn't following in any other areas of government especially in the DoD realm where they have a developing system or developing program and the sustaining program that comes on line and participates with that development program to make sure that it can truly be operated.

Next chart.

This is not something that just started last December. NASA has been thinking about this for the last number of years, about 2, 2-1/2 years in which a number of studies were put together because in the Human Space Flight Systems for NASA we've not done this before in which we had a developing program and the ops program that's going to take that developing capability and move it forward. So, back in 2007, this was started by a couple of review teams and it was established, like I said, at the end of last year. And will continue for the next couple of years in the planning state before it's ready to become a program. The idea will become a program by the time we get

through CDR and then it'll be in combination, I'll show a chart here in a second, in combination with the development program.

Next chart.

Let's. see, the next chart talks about our establishment of a partnership between ESMD and SOMD. I work under the SOMD side of the house, so, the operations side. And then, of course, we're very much tied in to what Jeff Hanley and his program is doing. In fact, we want to be connected very closely. Once the first system Ares I and Orion are set to go to ISS and that has been certified, then this Constellation Transportation Program will go ahead and take care of the budget schedule and technical content of that system from that point on. This will enable basically Jeff and his team to go continuing on development of the next series of development tasks and the development of those systems. And it frees them up from having to operate the system that we will have to go to ISS during that phase. It also allows the operating program, that is the program that I'm helping set up to be able to get back to those folks that did the actual design work and work the number-crunching back during this period of time and be able to use that skill when we need to especially for bouncing against certification-type issues.

Next chart.

So, what is that timing for this? Well, we are really dependent of course on development of the DDT&E effort by the Constellation Program. Under the current schedule, it basically says that as Orion and Ares get to their test flights in 14 and 15, they will begin to back away after certification is completed and we will then take the control of that particular system at that point. You notice that really, there's a handover that's overlapping by a least a couple of years and that's on purpose, so that we know that after the first flight or two, the system is not operational, but we are doing operations with the system to get to ISS. So, you have to have that overlap between the two programs, very important. At the same time, it doesn't mean we need to use 100% of DDT&E effort in order to go do the operations. So, it frees them up to go do next series of developments in order to continue on with the exploration initiatives.

Next chart.

So why start in 2009 and progress for the next couple of years? I'm hoping this chart will kind of show what we're trying to do there. What we're trying to show is that we have to embed ourselves at a number of different levels, first in the engineering level. We're going to have our future sustaining engineers now become part of the design teams. Pepper talked about how he's influencing the operability after the hardware is here at Kennedy and after we're assembling the hardware. In addition, we need to have flight sustaining engineers that are going to be looking at the hardware from beginning to end on the design and its manufacturing capabilities as well as its operating capabilities, both during ground and also during flight.

So today we have a limited number of those engineers and each year we'll be increasing those numbers as we come up to full speed by around 2013 or 2014. At the next level, at the project level, we also want to be highly engaged with the individual

projects, that is, the Constellation and Ares, to make sure we fully understand what the cost drivers are to their implementation of their design and their manufacturing capabilities. The idea here is we need to get to a point where we understand the sustaining production, we can make that as efficient as possible and we can help influence the lifecycle cost not only during the PDR to CDR timeframe, but also as we go through systems certification and qualification.

And last is at the program level, that is, between myself and Jeff. Basically, Jeff is going to use our organization as the ops and sustaining arm of his program as his program matures and wants to focus more on that ops and sustaining role as a day to day activity. And so it's that partnership that'll allow this entire growth to happen over the next 2-3 years. The other reason to do this now is we have learned from our past that the time to learn about flight hardware and know how it's going to operate once you get on orbit, is during your time of going from PDR to CDR and during the time you're going through qualification and certification testing. Even today on the shuttle environment when we find problems during a mission, there's many questions that we ask about what was the basis of the certification, what do we learn from that certification and what were the limits from that certification. By enabling the operations program to get started now and get embedded into the development program, we will have that capability in order to have the answers to those questions when we're actually flying the systems in 2016 and beyond.

The next chart is just a summary. Basically it says it's good to start early at this particular point in order to get sub-system experience under our belt in order to follow the flight hardware evolution. We're doing that at all the critical phases, both at the subsystem level, at the SC&I level, at the program level and also in the mission operations and MOD levels. We as NASA now recognize that in order to implement the full capability of doing an exploration architecture, we've got to be able to operate a system while other folks within NASA are continuing to develop the next system and we believe that this architecture that we've set up is going to go ahead and do that and we're in full concert with what Jeff and his team are doing and getting closer to them everyday. So that's all I had to present and I'll turn it back over to Jeff.

Jeffrey Hanley, Program Manager, NASA Constellation Program

Okay, I just have some closing remarks, I think, to kind of sum up what you've seen this past three days, these past several weeks of presentation material and response to questions and queries and so forth.

First, on behalf of the 10,000 civil servants and industry partners, contractors around the nation that have worked on and have worked to create the Constellation program, I want to thank the commission for the opportunity over these last three days to highlight the four years of progress to grow from concept to real designs and hardware. In these closing remarks, I would like to take us back to 50,000 feet if you would, to revisit the decision space that underpins NASA's present Constellation architecture depicted here. We visited this chart many times over the past couple of months. Through the last four years, NASA was given explicit guidance to define a program to meet three essential goals, those being significantly reduce the net cost of Low Earth orbit access and achieve unprecedented levels of crew safety and extend the sphere of human operations beyond Low Earth orbit, that is, from 250 miles to greater than 250,000

nautical miles. To achieve any one of these would have been a significant accomplishment. To contrive an architecture that does all three would be truly historical.

As a nation we are now confronted with some crucial and perhaps course-altering decisions in human space flight. Now we must ask, do we press forward or retreat to reformulate our strategy? How important is crew safety? Do we really need or can we really afford heavy lift? Why can't all these be done commercially, and maybe we shouldn't even consider exploration beyond Low Earth orbit in the first place?

For me, the crux of these challenges centers around the axis of risk and about what NASA's core purpose is. To me, it's pretty clear. NASA's value to our nation stems in part from trailblazing, from the government taking the risks that no one else can afford to take. In a word, risk is our business, not because it is easy but because it is hard is the quote that Ed pointed out this morning and the wonderful and poignant quote from JFK in the 60s. Commerce is a consequence of exploration. The physical trails we blaze pull on technology which pulls our economy which pulls our way of life. The evidence of the collateral benefits echoes across NASA's 50-year history. Governments blaze trails. Commerce exploits them and economies grow. This is what the history of exploration and indeed of human behavior tells us. The silk roads, the mastery of the seas, the manifest destiny of our nation all were driven by government-funded trailblazing.

Government literally laid the track across America in transcontinental commerce and immigration consequently flourished. How fitting that the golden spike sits just a few miles from where we will soon test the Ares I first stage rocket in August. In the human exploration of space, it is on the frontier we should be taking our risks. I believe most would agree today that the frontier in space is beyond Low Earth orbit. But in order to cross the ocean, we need to have mastered crossing the harbor first, thus creating the safest Earth to obit launch capability in history, is teaching us the hard technical lessons that remain. What does it mean to human-rate a launch system? How does one provide a high probability of crew survival if something goes wrong?

The commercial sector will need these tough questions answered for truly commercial crew access to space flourish. Until the risk is sufficiently low to bet on a return on investment in the cargo, be it crew or hardware. And as you know, we are using Ares I derived from the investment we are making in heavy lift to address these remaining barriers to human rating a launch system and achieve higher levels of safety for the first 100 miles of every exploration journey so that as we push out into the frontier, the acceptance of higher risk to mission success or crew safety is toward the objective.

Heavy lift addresses risk in another fashion. It stems from the unfortunate, inconvenient truths of physics, that being, God has made it a real chore to climb out of Earth's gravity well. The propulsive technologies of our time are nearly at the limit of what chemical systems can do. In our judgment, when the performance and cost are fully accounted for, to explore beyond Earth's gravitational influence within the next decade or so takes a launcher that can accelerate at least 50 tons to escape velocity in one shot. While one could express an architecture that could do it in more than one launch, simple statistics suggests that a segmented approach pushes mission risk

unacceptably high and simple economics suggests that the permission cost consume more money that could be used in other ways such as exploration systems at our destinations.

Heavy lift in the class we are discussing is unique. No one else is building it. It is not something one can just go to industry and purchase. Our country built a heavy lift production and launch infrastructure, some of it here at the Kennedy Space Center, in Apollo, only to convert it to a Low Earth orbit only capability in the space shuttle and discard the rest. The space shuttle is in fact a medium-lift class system built on the remnants of a heavy-lift infrastructure. Now we face a choice, take this unique industrial capacity and either convert it or discard it, either retool and rejuvenate our nation's heavy lift capacity or abandon it. These are not simple questions. There are benefits and costs associated with either path.

Constellation as it is defined today is the manifestation of one of those paths. The path where heavy lift is the key to human exploration beyond Earth's influence, the path where the risk we take, be it technological risk or astronaut safety risk, should be on the frontier and not in the first 100 miles. We are executing this path today and you've seen the evidence of it here this last three days. Our team has real hardware and test and fabrication, real designs we are maturing and we are learning hard lessons everyday as a team.

We are indebted to our national leadership for the opportunity once again to dream and plan and build boldly as an agency and as a nation. It is at the heart for me anyway, of what it is to be NASA. Teddy Roosevelt in speaking of the American spirit said it this way. "Thrice happy is the nation that has a glorious history, far better it is to dare mighty things, to win glorious triumphs, even though checkered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much because they live in the great twilight that knows neither victory nor defeat". Daring mightily is what our father's generation did at the expense of human life and national treasure, in order to blaze the trails necessary to even be here today, having this choice to make. They created the art of human space flight. Heavy lift, unprecedented crew safety for the first 100 miles, these are the choices that color our present plan and we appreciate the burden that the committee sits with, in weighing these options for our collective future. In these economic times it is challenging to think of sizeable financial investment to stimulate untold commerce and we know you sit with our nation's constraints and challenges and environment, not unlike 40 years ago.

We anxiously await your findings and decisions that rest in front of the nation and we'll execute that plan whatever shape it takes to the best of our ability. Thank you for listening. I'll be happy to take questions.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Well, thank you very much. I suspect some of my colleagues do have questions. I've got a couple as always but who would like to start out? Please Bo.

Bohdan Bejmuk - Constellation Program Standing Review Board - Chair
I have a question for Pepper if I may, do you know what is your cost to go in building Ares I unique infrastructure?

Pepper Phillips - Constellation Project Office at Kennedy - Deputy Director
Do you mean how much do we have left?

Bohdan Bejmuk - Constellation Program Standing Review Board - Chair
Yes, how much you have to go. What will be the expenditure to go to finish your unique Ares I infrastructure.

Pepper Phillips - Constellation Project Office at Kennedy - Deputy Director
I'll have to get that number to you Bo, I don't have that number off the top of my head.

Bohdan Bejmuk - Constellation Program Standing Review Board - Chair
If you can provide it to me, please, thank you. And I have one more question, can I push my luck? Bob, in Huntsville we heard about acoustics being one of the top risks on Ares I, are you guys going to get data in high Q on Ares I that is meaningful enough to help those guys address the high Q acoustics? If so, do you measure it, are the Q's approximately equivalent?

Bob Ess, Mission Manager for Ares I-X Test Flight
Yes, to all those. We purposely put air acoustic, high frequency instrumentation on our vehicle in locations requested by Ares and Orion to get the data they need specifically to address and get a better correlation for their models.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Okay, thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Other questions, Chris?.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
Thank you. This is for Jeff. I just wanted to ask you if you could say a bit more clarifying your remark. You said that one of the hard technical questions that remains is what does it mean to human-rate a launch system and you also said that the commercial sector will need to have these tough questions answered. I wasn't quite sure what you were trying to say there, could you just expand on that a bit.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Sure, sure. I think it centers around the issue of launch abort and launch abort I think for our team has shown to be one of the toughest technical issues that we are wrestling with, be able to abort throughout the trajectory, what we call no black zones. It's very tough to do and then it also gets into the human rating requirements and how do we comply with them.

The first iteration of the human rating requirements from 3 or 4 years ago prescribed the peanut buttering of redundancy in systems, just two-fault tolerant everywhere and everything will be okay. And what we found out culturally, what that did was it caused designers to kind of disengage their brains a little bit. We particularly - that particularly came to the fore not just for launch abort but also in defining the Orion to be able to go to the moon and come back. Every ounce we take since the Orion crew module particularly, goes through the entire gear ratio all the way back to the Earth's surface. Every ounce we put in the Orion is precious. It costs us from a performance perspective, many, many times more than in other elements.

So for every component we put in the Orion, we want to make sure that it is there for a reason, it's providing real value, it's mitigating real risk and so this has tentacles into the topic Jeff brought up this morning on PRA. PRA is a tool. It's one piece of the data but what we're really talking about is risk-based design, risk-based systems engineering, that is what we're really trying to foster around this notion of human rating. So the human rating requirements were recently, just in the last year or so, updated to prescribe only one fault tolerance and then demonstrate robustness in the design and that can be done through either adding redundancy, just wrote… out or adding redundancy, or using a risk-based design approach to demonstrate why the robustness is sufficient with less than that and that's kind of the approach. But that's the space we're living as we develop Orion and Ares I. We're living the hard lessons of what does it mean to comply with these human rating requirements and feeding back those lessons to those that prescribe them to us.

It should be pointed out, the human rating requirements are not Constellation's requirements. They're the agency's requirements imposed on us and we are doing our level best to comply with them, just as any user that would want to be human-rated would have to.

Mike Coats, Director, NASA's Johnson Space Center
Norm, may I just followup? I think you've just described between the 2A and the 2B versions of that document, is that right?

Jeffrey Hanley, Program Manager, NASA Constellation Program
Correct.

Mike Coats, Director, NASA's Johnson Space Center
In your view, is the 2B version sufficiently transparent for the commercial sector? Can they use that document and sort of tell transparently what they need to do to human-rate a vehicle?

Jeffrey Hanley, Program Manager, NASA Constellation Program
I believe that the B version of the document went a step in the right direction for helping anybody who wants to go about engineering a system to be human rated, to really give them some flexibility, whereas wrote two-fault tolerance everywhere, the prior prescription as an example, was going to be problematic for a lot of folks. In a lot of cases, redundancy is not necessarily the right answer to manage risk.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Followup?

Dr. Christopher Chyba - Princeton University - Professor
Just a quick comment, I understand all you were just saying about the human rating standards and the lessons learned there and there are valuable lessons there. I'm a little move vague on the lessons learned for the commercial, for vendors who may follow in the launch abort system because I don't think anybody is designing a vehicle that has a comparable set of environments that it would have to abort from to what the Ares I is going through. It's much more of a unique solution.

Jeffrey Hanley, Program Manager, NASA Constellation Program
I think you're referring to the high Q environment that we fly.

Dr. Christopher Chyba - Princeton University - Professor
High Q, solid versus liquid, there's a whole host - it looks very different than any class of vehicles that would be following it.

Jeffrey Hanley, Program Manager, NASA Constellation Program
And I think - what I'm referring to is sort of the methodology and thought process that would surround, not the details of the physics of the design so much but the thought process about how does one reason through and analyze and demonstrate them to the folks that they would have to be convinced that you've met 8705.2, the NASA standard for human rating. That methodology really is not written down anywhere. We're kind of going through it from our perspective, it is the first practical application of the standard and somebody trying to meet it…., so the lessons learned that we will have would be really more along the methodology line that we'd be more than happy to share.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Anyone else?

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
May I have one more?

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Yeah, sure.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Pepper, in your briefing, you mentioned MLP for Ares I is 51 percent complete, for the construction and then you said that CDR is scheduled for June 2010. My question is, it sounds to me like there's a little disconnect. Is the production too soon or is it CDR too late?

Pepper Phillips - Constellation Project Office at Kennedy - Deputy Director
No it's not. What you see, 51 percent is the structure itself. There's a lot more to the mobile launcher than just the structure and what we've got to do is now outfit that structure so all the ground systems, GSC that has to be built has to be functionally tested out, all of that has to occur and that's part of that overall lifecycle for the mobile launcher itself.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
But typically on any project that I've been involved with, you have a lot of changes between PDR and CDR and you're halfway down manufacturing the things that is at PDR level and my question is… it still appears to me that it's a high-risk approach. You're building things before you have design that's gone through CDR.

Pepper Phillips - Constellation Project Office at Kennedy - Deputy Director
Well, I mean obviously you'd like to have or I'd like to have all the vehicle requirements before I build the mobile launcher, yeah, we're doing so at risk but you have to execute the basic structure first and then you have to follow with the interface requirements which is really what we're going to build in the subsequent builds so from a development standpoint I think the risk is reasonable, given, that we don't have the opportunity to have all of the requirements on our plate when we're building the mobile launcher.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Okay, thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Anyone else? My turn. I was pursuing I think the same line of thought that Bo was and trying to understand the schedule chart here. The VM2 in FY10 TBD, is that date…?

Jeffrey Hanley, Program Manager, NASA Constellation Program
Okay, VM is a virtual mission. It is a process exercise to walk through the mission integration process.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Got it, okay, that makes sense. Then the Ares I-Y is a launch in '14, does that have operational payload or is it strictly…?

Jeffrey Hanley, Program Manager, NASA Constellation Program
Today, it is defined as essentially not much more than a boiler plate, Orion. It has been defined as a high-altitude abort test. The upper stage also has no engine because the engine will not be ready by then.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Alright, how about the one that's just marked 1 about six months later.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Okay, Orion is a full up production stack of the entire Orion-Ares I system.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
With an operational mission or strictly test?

Jeffrey Hanley, Program Manager, NASA Constellation Program
It'll be an orbital flight test, unmanned orbital flight test.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
But not carrying any deliverable or anything?

Jeffrey Hanley, Program Manager, NASA Constellation Program
No, no.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Let's see, then I want to ask - I'm trying to get a sense of what percent of the Orion I program is completed and for example if you could give us the latest data on the total dollars to complete, time zero to the total cost to complete and the total dollars expended or earned or whatever earned value or whatever, both as a dollar and as a percent and maybe the percent of drawings released, the whole program, not just the flight article but the ground missions. I'd like to get some sense of what the investment is as a fraction of where we have to go. And lastly, I don't recall seeing, I may have missed it but a cost per pound to LEO plot for – did I just say?… I just said Orion, I mean the whole Constellation program….., I'm sorry…..

Jeffrey Hanley, Program Manager, NASA Constellation Program
For phase I, which is Orion-Ares I ground missions…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Exactly, I'm sorry, I mis-spoke. I haven't seen a cost per pound to LEO for the Ares I compared with the other interesting launch vehicles. I'm sure you've got that. If I could get a copy, Ed you may have it, I don't know but I haven't seen it.

Edward J. Mango, Deputy Director of Launch Vehicle Processing – NASA's John F. Kennedy Space Center, Florida
Well, I was going to say Norm, that we have at work with the program fairly detailed budget analysis or cost profile analysis so that before we task them to go off and do something else which is probably a subset of that, we ought to coordinate while maybe looking from additional information.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Yeah, I'd like to have apples and apples cost per pound versus alternative launch vehicles.

Edward J. Mango, Deputy Director of Launch Vehicle Processing – NASA's John F. Kennedy Space Center, Florida
That's a different request but in terms of the percent complete and cost to go and so forth, we've got that in the works.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, why don't you hold on the first one and Ed, if you don't come up with it, if you would alert the folks and otherwise, I'll assume that we'll get it.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Okay, at a high level, I think Steve Cook described this yesterday, is we're roughly in the 30 percent complete range where we kind of expect to be at PDR.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Yeah, that's helpful. I think that was all I had. I think that takes care of it. Or I know it was, I did want to ask to what extent is this schedule defined by the amount of funds that are available and if you were to have an optimum schedule from an engineering standpoint, what would it do to the IOC?

Jeffrey Hanley, Program Manager, NASA Constellation Program
Well, it's definitely not optimal from an engineering standpoint today because of the shape of our funding curve as we've discussed and I think Aerospace touched on yesterday.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
But if you were to do an optimal…

Jeffrey Hanley, Program Manager, NASA Constellation Program
To do it optimally, the confidence in achieving the March 2015 date would obviously increase. Would be we able to accelerate earlier than March 2015?, that's problematic

at this point. There's so much water under the bridge at this point. We're so far down the road in terms of getting long lead items and engineering development units procured, more money in FY10 would improve our situation but it's probably just going to increase our confidence that we'll achieve March of 2015 and not really accelerate anything.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Really, I had more of an academic in mind, that was the penalty we paid by not laying out an optimal engineering program in terms of schedule for a given confidence level.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Correct. The confidence level planning, I hope I'm answering your question; confidence level planning that we had done really is where the March of 2015 date came from. Today, the program sits at 67 percent confidence on cost. I wish I could say that on schedule but that's not true. Today, we have a suite of schedule confidence assessments, 6 or 8 different models and ways of looking at the scheduled confidence that range anywhere from just a few months late on the March of 2015 date to up to two years late. That's again as I've touched on events like hurricane forecasting and where you're going to make landfall. It has more meaning here I think today than it did in Huntsville.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, I guess I was just going to make an observation too. I was struck by the earlier discussion on reliability that with the expendables, where we put large expensive military payloads on them and the point we do go to a lot of effort to be sure they're reliable just because of the dollar investment and the operational implications and then I think back again to when we man-rated Atlas and Titans early on, and those vehicles were designed as ICBMs which I don't remember the design criteria but I remember some of what we used operationally in theory targeting and it was not a very reliable vehicle and yet we got those man-rated.

Jeffrey Hanley, Program Manager, NASA Constellation Program
And I would say that the human rating requirement as they exist. There are provisions for tailoring, for the specific situation so someone in an Atlas or a Delta or Space X could come in and work with NASA to tailor a human rating plan that NASA would then review and either accept or not and then go forward and then that entity just meets their plan.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I think that's an important point to be made and I guess I might - does anybody else have they want to say at this part of the discussion? Okay, Wanda and then Bo, let me get Wanda first. I saw here first. Go ahead.

Dr. Wanda Austin, President and Chief Executive Officer, The Aerospace Corporation
I would just offer, and we touched on it in the evaluation process that it is striking the balance between the mission capability and how safe do we need to be. We mentioned the early days of human rating on the Atlas and the Titan and I don't know that anybody's gone back and looked at the difference between what we considered human rating then versus what we're aiming for now but I suspect that we'd find a big difference.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I do too….

Dr. Wanda Austin, President and Chief Executive Officer, The Aerospace Corporation
I think the opportunity is to make sure that we provide or enable the commercial folks to come in and understand what we mean by human rating and as Jeff just described it, that you need to demonstrate the robustness and if we have a standard that applies across the board that everybody understands that we have an opportunity to have new entrants.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Standard is definitely the beginning of the conversation, not the end.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Yeah, exactly. Bo?

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Norm, I just want to make sure that we understand what Jeff said, and see if you agree with what I'm going to say. You say you have a 67 percent schedule confidence…, cost confidence level. You have low, you didn't say it but I heard you say it previously, you have a low schedule confidence today and let me read this the way I heard it and see if you agree, that means that if you're blow schedule, you will spend additional money and your cost confidence really isn't all that meaningful?

Jeffrey Hanley, Program Manager, NASA Constellation Program
Well, you have to combine that with these reserves that we have protected. We have a one year slip of reserves in our budget already set aside in addition to the run-out cost that coincides with the 67 percent cost confidence number. Now, I should point out that the program is still in the formulation phase. We will not be complete with formulation until next year. We are taking significant remedial action on our schedules to increase the schedule confidence so that when we petition to the agency to be an approved program next year, we can close our business case because the business case is on cost, is on schedule and is on technical performance.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Your high confidence in cost does not reflect the fact that if you blow schedule, your cost was going to be higher, it does not reflect the coupling, which I think was a source of some of the differences we saw in Aerospace numbers and in your team, Jeff. I just want to make sure that we understand that.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Yes, and those are some of the details and assessments that we will share when we meet with Aerospace next week at the request of the panel. We'll share with them all the assessments we've done on both; cost confidence, schedule confidence and joint cost and schedule confidence level.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Ed also shared with your team how they showed this coupling between cost and schedule confidence.

Jeffrey Hanley, Program Manager, NASA Constellation Program
And as discussed yesterday, we may agree to disagree or we may be able to close some gaps.

Bohdan Bejmuk - Constellation program Standing Review Board - Chair
Jeff, I used to live in a country where everyone agreed it was under communism. Thanks be to God we live in America, we can disagree as long as we understand each other.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Well thank you very much - oh, did you want to say something Ed?

Edward J. Mango, Deputy Director of Launch Vehicle Processing – NASA's John F. Kennedy Space Center, Florida
Jeff, could you just give us a few words on what is the critical path through to the first Ares-Orion flight, because we've heard from various people that we might be able to accelerate this, we might be able to accelerate that and I understand that there's a lot of fuzz on it but are the booster and the capsule basically both on the critical path at this point?

Jeffrey Hanley, Program Manager, NASA Constellation Program
They're very close. The pacing item on the booster is the upper stage engine, the J2X. We've moved forward as rapidly as we could. A rocket engine development historically takes on the order of 7 years. We're going to have an engine to test in about 40 months which is historically very good for rocket engine development.

We'll get it into test at the end of next year, getting enough run time on that engine to certify it, is the pacing items essentially on the rocket side. The spacecraft has really been affected greatly by the budget, the shape of the budget. The ability to buy long lead parts and engineering development, risk reduction hardware has been limited. We've prioritized our work. We've spent our money on the most critical things but

because not everything has been able to be purchased and get in the pipeline, that's essentially the critical path for Orion that runs right through the supply chain, at this point. So that's what we're scrubbing on right now and we're working very closely with Lockheed Martin, with their suppliers to see if we can improve that. And I will say we've already improved it by the budget that I've provided to the project in the most recent budget exercise. I was able to plus them up in '09 and '10 by several hundred million dollars and that is going to help greatly with improving Orion's schedule.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Well thank you so much. You've taken a great deal of your time to keep us up to speed here during this, what, 60 days or something we've been working, particularly this week. We appreciate it a lot. We'll probably be back with more questions in the next week or so but we'll give you a break here for now. Thank you.

PUBLIC COMMENTARY SECTION

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

And since that completes the technical discussion for today, I might just, since we were talking about the reliability of expendable launch vehicles, I might just take a moment to share a story that seems apropos.

The company I used to serve was preparing to launch and expendable launch vehicle but a very valuable one from a cost standpoint and on top of it was a spacecraft we had built that was extremely valuable from a cost standpoint. We had one of our members of our Board of Directors was the CEO of a very large insurance company in this country and he came to me and said - he was not technical guy at all, he came and said that he'd like to go watch that launch and I said well, sure, we'll arrange that but why your particular interest in this launch because he never expressed any interest. He looked at me and said because I've never seen a corporation's entire equity rise off of a launch pad before.

I think that's a little bit the challenge that we're looking at here. With that happy thought, we now turn to the part of the meeting that we found to be very valuable and that's the public comments. We have 15 people who have signed up. I said the limit was 14 but since its 15 and the last one's a retired NASA employee, we can't say no so we'll do 15. If you would hold your comments to the three minutes maximum out of courtesy to your fellow commenters and the others in the room, and there are microphones in the middle isle. If you would go to the microphone, please identify yourself and your affiliation and forgive me if I mispronounced names.

Let me start out, I'm going to call a couple of names here so that we could get people lined up but save a little time in the movement. First is Lou Jamison and second is Don

Beatty and third is Wally Nelson. Perhaps the three of you could come to the microphone and speak in that order, Lou, you're up.

Lou Jamison - Machinist Union Local 2061

Thank you Mr. Chairman. My name is Lou Jamison, President of Machinist Union Local 2061 representing approximately 1500 members employed by various companies at Kennedy Space Center, providing base operations and maintenance and ground support systems operation and maintenance to the prime shuttle contractor.

I…., you know…., running the risk of getting up here and having people say well here' comes that union guy again advocating for his member's jobs, I have to tell you there's certainly an element to that. But you know, with so many of my members, it's much more than that, it's much more than that. A lot of my membership didn't have to drink the Kool-Aid. They were bottle fed the Kool-Aid at a young age. This is a lifestyle and a way of life to a lot of my members. We love the space program because it challenges this country's vision and creativity and ingenuity and courage and we truly love the program but when we look around, I think you made mention Mr. Chair in your opening remarks this morning something to the effect that be it real or imagined, the perception is that we're losing leadership in various segments of society in the world. And certainly to my membership, that's very real. It's incomprehensible to us that we could be contemplating turning over access, to gain access to space, we have to turn to a foreign country to get there.

Many of us are second generation space brats. We even have third generation members whose fathers and grandfathers worked in the space program. It's inconceivable that we could conceivably go through that flight gap and have to depend on another country for access to space. I have no idea what you're recommendations to the White House may be and I know that with no certainty can any of us even begin to predict what the funding levels will be but, we would ask, we strongly urge you, the Machinist Union members do, that one of the guiding lights to any recommendation that you may make is to look at either eliminating the gap, or significantly reducing that gap between shuttle and whatever the next generation vehicle turns out to be.

I'm going to conclude my remarks because there are people who talk much more eloquently this afternoon about what the space program means and things of that nature but I would be remiss If I didn't first of all welcome you and the commission to our community and the members of the machinist union thank you for your service and thank you for your time.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Thank you for your comments.

Don Beatty – Former NASA Employee

Don Beatty, former NASA person. Let me move quickly through this statement. A few comments about the shuttle. There have been six main engine upgrades since 1981 that have improved flight safety. Since the Challenger and Columbia accidents, the design and manufacture of the ET (external tank) has been improved as well as the

SRB's. Shuttle avionics have been updated and many other upgrades have been made including the ability to make some repairs in orbit, but perhaps most importantly, NASA management practices before and during flight have been changed that make flight safer.

All these changes cost taxpayers billions of dollars. The May 2009 NASA report to congress, providing two options for continuing shuttle flights, states that flights could continue to 2015. The major problem is funding., not safety. There are no reasons why the STS can't continue to fly after 2015. The oldest B-52 in service has been flying for 57 years. The navy's B-3 Orion fleet has been flying on the average over 30 years and the B-1 bomber came into service the same time as the shuttle. There'll always be risks involved in air travel or space flight. However, based on all the upgrades I've read about and as an old navy pilot, I conclude that the STS is safer to fly today than on day 1 in 1981, ASAB statements not withstanding.

The STS must continue to fly until a suitable replacement exists. Supplier contract terminations and layoffs now underway must be stopped immediately and it's the only way you can continue to use the ISS completely. As to the future of human space flight, returning to the moon should not be a high priority. I have not read any arguments to justify returning that would survive close inspection. For example, an independent panel of scientists convened by the American Astronautical Society in 2005 did not identify any major questions related to solar system exploration that might be answered by returning to the moon, not one.

And I should also add that the themes that NASA has been saying to justify returning to the moon including using the moon as a site to try out other systems, all of those can be clearly shown to be not very, very good and based on what you've said this morning, I can only assume you are not going to recommend returning to the moon in the near term. If other nations say they plan to send missions to the moon, that should not be used as a reason for us to return. I hope you will take time to review Buzz Aldrin's suggested human space flight program and Noel Hender's submission that discuss why returning to the moon is not important.

Now, I hope that before you make a recommendation, if you go and make a recommendation to the moon, you will have done due diligence, reviewing for example all the NRC decadal surveys that explain why NASA won't be able to follow their recommendations because funding needed to return to the moon will take precedence, okay? My two highest priorities of course are to use the space station and to be able to repair and take care of assets that are in space like the James Webb space telescope which as you know is going to be available too, a very complicated deployment. So thank you for your time.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you.

Wally Nelson – Retired Aerospace Engineer

Mr. Chairman and distinguished members of the committee, my name is Wally Nelson and I'm an 85-year-old aerospace engineer, a retiree from the Kennedy Space Center, a graduate from the University of Wisconsin and an ex prisoner of war. Having begun my career firing rockets out into the Atlantic Ocean from Wallops Island, I consider myself eligible to be called a rocket scientist. For the past 8 years, I've been making movies, writing, lecturing to civic groups, student engineers about space travel and exploration.

This activity led to production of a movie called The Way to the Moon and Mars. I have copies here for each of you. Last year, copies were delivered to NASA Administrator Mike Griffin and Senator Bill Nelson. In addition, I invite each of you to view my YouTube blog called colonizing Mars. There are many human and technological problems that come with placing man outside the gravitational attraction of the Earth. Briefly, I wanted to address two of these particularly difficult problems.

One, keeping the astronauts alive during an expedition to Mars and the burdensome cost to the world for such an endeavor. In all of history, no group of men has ever existed in a confined space for years under continuous and repeated threat of catastrophe without the possibility of re-supply or rescue. After Administrator Griffin received my DVD, he stated in US news and World Report we have to be confident in our ability to conduct it before we send astronauts to Mars. Otherwise, the crew we send to Mars will not come back.

Now about cost. The Viking program may be used as a benchmark for estimating the cost of placing a pound of stuff on Mars. In 1976, Viking rockets delivered two payloads to the surface of Mars weighing a total of 2540 pounds and a total program cost of $1 billion. That equates to $3.5 in 2006 and when projected to 2036, that cost becomes $12.25 billion or $4,800,000 per pound. In the Mars Rising program website, it says that the astronauts will need 1,144,000 pounds of material on Mars to complete the mission. This means that the projected cost for the first manned mission to Mars will be $5.5 trillion. Moreover, the late Mr. Walt Lowrey, the Viking Program Manager, consulted me in the preparation of this DVD and it's quoted as follows.

"An excellent way to present the complexity of going to and landing on Mars with current technology a very large and very risky undertaking for a human mission. Many suggestions are being discussed for some potential research programs that will minimize some of the problems but even then, this mission will be much more hazardous than the public may be willing to undertake."

Thank you Mr. Chairman for this opportunity to address the committee. I sincerely hope my remarks will be beneficial to the committee findings.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Thank you sir. The next three on the list are Dale Ketchum, Chris Holland and Ken Bates. Perhaps you could come to the mic and speak in that order.

Dale Ketchum – Spaceport Research & Technology Institute, Director

Well, I'm Dale so I guess I'm up. Thank you Mr. Chairman. My name is Dale Ketcham. I'm the Director of the Spaceport Research and Technology Institute at Kennedy Space Center which is run by the University of Central Florida. I've been living in this community since 1955, had the opportunity to grow up around the original 7 astronauts and be a part of the excitement of Gemini and Apollo and have been involved in this business ever since and I'm very proud to be as I'm sure everybody else in this building is as well.

I think what I want to talk about just briefly, to touch on the comments that Lou said originally when he first got up to speak, I realize you all have very difficult decisions to make of trying to stick 10 pounds of space program in a 5 pound budget bag but if you can find a way to slide some of the shuttle activities, I think the critical skills that are there are so important that you ought to look at it as a risk reduction investment because if you get to a new generation of vehicles and there's nobody around that remembers how to do launch processing, the impact to cost and schedule could be substantive but I think that leads to the more important issue that I work with a lot of the stakeholders here in Florida and we're keenly interested in the conversations that were held this morning and yesterday in Alabama about growing the commercial sector as a mechanism for providing the services and products that NASA will use in the future. This state has made significant investments certainly, as the Lieutenant Governor said, more so than anybody else, in trying to grow that business and we're prepared to continue to do so in the future, whether it's creating a more healthy environment for those business to come here and provide launch services or facilitating the development of the capital that they need to do so. Florida has got the skill sets and we're working with them hoping to help that become a reality and I applaud you all, recognizing the importance of that.

Additionally, I think it's important from those of us in Florida - like I said, I've been here my whole life, this is going to be my second experience of going through mass layoffs because when the vision was announced by President Bush a couple of years ago, it at that point became Florida's fate that we were going to endure a very painful transformation here. There is no recommendation that you can make to the President that won't result in thousands of jobs lost here. We recognize that. But it's also in our interest here in Florida that one of the reasons we endured it originally and we're going to go through that again is we are purely an operations center. Those of in Florida are working aggressively as Lt. Gov. mentioned, as Susan Kosmas' representative mentioned, we're trying to broaden our capability beyond just launch operations to get more tests and manufacturing and R&D and we're going to continue to do that but that's our fight. Your job here is to - and I want to impart to you most is this country's in a real economic bind and we recognize the challenges of budget as clearly everyone on that panel recognizes. Okay, we want you to provide the President with the innovative excitement and bold initiatives that this President can get behind because I have no doubt that this President wants to lead boldly on this issue and if we can make the new space program a part of the new innovation agenda that will help pull this country out of the economic doldrums, I have no doubt you will get the leadership from this President that you need to get the budget you need so we can go out into the future. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much. I assume Ken Bates is not here, let's see, we've got – Oh here he comes - please, the next three I'll call now so you can get up, Gregory Sacala, Chris Ecksley and Brian Hathaway. Mr. Bates?

Ken Bates
Yes, thank you Mr. Chairman and thank you committee. Everyone here has been assembled here today to support something we all feel close and dear to our hearts and you can see that in the room and the passion that's been spoken here numerous times on stage and as you've gone across the country. I've written down a few comments so some of these things may be rhetorical but I'll have to say the Space Program is a national asset that the United States has. It began a long time ago with the Apollo program and we actually ventured into that as a lone partner and we were able to succeed in that because we made a commitment to it. We've then since brought in international partners to help support our space program and do the ISS that we have which is something that we're all very proud of.

We seem to be able to find money to bail out Wall Street on their debacle. GM, AIG, certain other global aspects that are out there with money found over there but we seem to hesitate to find the money to fund our space program to continue what we have begun. The benefits that we have for space, they benefit everyone, all of mankind has benefited from what we have been able to accomplish. I would say that we had a Presidential candidate that came in this local area which thus became our President, Mr. Obama. He made a commitment to the national space program to fund it. Now is the time for him to go ahead and fulfill those promises that he made to not only this local area but nationwide.

We've seen this talked about here at Florida but we're talking about nationwide jobs and commitments to technology that goes beyond just Florida, who just happen to be the starting point for launches here and I would just say the closing of the gap as has been mentioned here many times to retain the experienced workforce that we have here locally here at KSC and other areas again not only at KSC but other areas, once these people don't have jobs for some time, I think we understand they have to feed their families, they'll have to find alternative means and ways and we may not ever to be able to get those people back. So I thank you for your time and I hope that you're able to make a strong presence to the President to support our program.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you for your comments.

Gregory Sacala – Ground Support Engineer for Constellation, KSC
Ladies and gentlemen of the committee, my name is Gregory Sacala. I work at KSC as an engineer designing ground support systems in support of Constellation. Before I go on, I wish to point out these are my opinions and thoughts, not Kennedy Space

Center's or my employers. There is a situation here at KSC that you may not be aware of but I am certain the situation exists at every NASA site where Constellation program work is being performed. Anyone following Constellation sees Ares I is in trouble. Speaking metaphorically in medical terms, Ares I is very sick, is on life support and its prognosis is not good. Morale here at KSC is sinking quickly due to the pending abandonment of both Ares I and the entire Constellation 1-1/2 launch architecture. Continuing work at full speed ahead on a project that is clearly doomed is both frustrating and demoralizing. It is difficult to remain focused working on a project that will be abandoned sooner or later. Change is coming and the quicker the change is announced and implemented, the better for all involved.

Let's take a quick look at the likely replacement architectures. First, not shuttle C, using either a 2-1/2 launch or a 3-launch architecture. This has the apparent advantage of being quicker and less expensive to implement but not shuttle C offers only a very limited Lunar ability which falls far short of the current constellation requirements. Additionally, it is very limited in future growth potential, is very restricted in maximum payload faring diameter and is questionable in suitability for manned launches. Second, Ares V light using a 2-launch architecture. This proposal could support extended Lunar stay missions and Mars missions without question. It also has the best future growth capability and would offer the largest, reasonably possible Lunar and Mars mass throw but the cost in both money and schedule are impractical at this time considering the current economic conditions. The federal government could very well afford the funding considering how they've been throwing money around lately. But I highly doubt congress would be willing to commit long term to the funding required to support Ares V.

Lastly, we have Direct to Jupiter, a 2-launch architecture. This proposal exceeds current Lunar throw mass requirements and is no more expensive in terms of funding and schedule than not shuttle C. Direct could perform the current Constellation Lunar mission with margins to spare. Direct can be used for manned launches and has a very reasonable growth rate capability. Direct has also the ability to fly large diameter payloads that not shuttle C cannot. So it comes down to too small, too big or just right.

In closing, the panel will make recommendations that will very likely become the new policy. Please make the choice based on the two unmovable criteria, those being likely funding from congress and the laws of physics. Please do not let politics change your view. Remember, this is our second and likely our last chance to get it right. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you. Mr. Ecksley?

Brian Hathaway
No, I'm Brian Hathaway.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, fine.

Brian Hathaway – Florida Resident
Okay, Mr. Chairman and ladies and gentlemen of the committee. Thank you for allowing me the opportunity to speak today. My name is Brian Hathaway. I've been a Florida resident for 20 years and I've been a supporter if Human Space Flight efforts by NASA since the early Mercury days. The main skin in the game I have is here I pay my taxes on time every year. I'd like to offer three opinions and then a suggestion.

First, I believe we should commit to a manned mission the Martian surface. In light of recent discoveries, Mars looks like an extremely exciting place to visit and should be the goal of our next two decades into space.

Second, I believe we must sustain ISS operations past the 2016 end date. There were many opinions expressed over the past few days before this committee but the bottom-line is that it is wasteful to de-orbit such a facility after so many years of development and so little experience fully utilizing it.

Third, I believe we must close the US manned space flight gap and some of the ideas offered here have considerable merit, particularly the option of extending shuttle operations and selecting a vehicle with strong shuttle heritage to minimize development time and cost. It seems counter-intuitive to me to have our government passing stimulus packages on one hand, while cutting thousands of highly skilled aerospace jobs on the other. Having been unemployed since about the end of February, I can say it's not a fun space to be in.

The challenge I see, and I'm sure you'll all appreciate, is that top line budget constraints limit our ability to do the three things that I see as most important, exciting and realizing the potential of years of Human Space Flight development efforts to date. I suggest that the committee should consider some out of the box thinking. Since NASA's mission is to foster development of space flight for further exploration of the cosmos, we must consider how to deal with the sunk cost of space operations as opposed to exploration. So much of our Human Space Flight costs are due to operations that we seriously constrain our ability to explore. For example, if we could separate ISS operations, logistics and support cost out of the NASA budget, the amount available for exploration grows considerably. I believe we need to change the paradigm with regard to ISS operations and how they may be funded.

There is a historical precedent for this going back over a century. Large, capital-intensive projects with long operational development periods have been managed by either governmental corporations or multinational consortiums. Some examples and their start dates include the Suez Canal 1856, the TVA 1933, the St. Laurence seaway in 1959, IntelSat in 1964 and Group Eurotunnel started in 1986. By creating a not-for-profit multinational corporation for the funding and operation of ISS, we could separate the operational cost that are not directly tied to the NASA mission. We may then be able to use this model to offer partnership opportunities with other nations who are now

only marginally involved in manned space operations. In this matter, we can capitalize upon the international nature of this facility and build upon the level of international cooperation that is now only starting to bear fruit in a fully crewed ISS and then move on to Mars. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much.

Chris Ecksley
Good day, and thanks for the opportunity to address the committee. I'm Chris Ecksley, a private citizen. I was in grade school in 1957 when the soviets launched Sputnik. For the next 30 years, I was a fan of all aspects of our space program, 1957 also marked the beginning of international geophysical year on July 1, 1957. This international scientific year ran 18 months and ended on December 31st, 1958. Can we assume that the 18-month year was also at least 50 percent over original budget? My attitude towards the space program changed with the August 17, 1987 Newsweek magazine special report titled Lost in Space, along with the companion article Big Dumb Rockets, maybe you've read them.

After reading the articles, I felt betrayed by the NASA administration that promised so much and delivered so little. The articles highlight some of the history that led to the loss of the Challenger and her crew and the status of NASA and its rocky road of administering our nation's space program. It is not flattering. It also provided some suggestions, guidance and ominous words that have become hauntingly true in the 22-year interval since its publication. I recommend both articles.

But now is not the time to dwell upon the past, except for the powerful lessons that the history of our space program can provide for the future. The big question is, will we repeat the last 40 years? I am not optimistic. I believe and I appreciate some of the words of the other gentlemen, I believe you ignored or trying to come to terms with the elephant in the room, which is the Ares launch program. The big dumb rocket that's described in the article, was first conceived over 50 years ago by Arthur Schnitt, an engineer who developed the concept while working for the Aerospace Corporation, you may have heard of that. The basic premise of BDR's was low-cost and low tech using liquid fuels that were stored at normal temperatures. This morning's pie chart showed 1/3 of the total cost of the program to be the Ares rocket. I believe the cost could be significantly less than 1/3 if you were to change to another type of program.

NASA already has experience with big dumb rockets. Actually, they're little dumb rockets. The lunar excursion module descent engine was a little dumb rocket. It performed flawlessly and when the time came, it did what it was never asked to do, by bringing the Apollo XIII astronauts safely home. Somebody this morning quoted Wernher Von Braun's wisdom. Wernher Von Braun would never sign up to a manned launch program that used solid rocket boosters. That's the basis of the accounts that I've read. NASA has failed to remember one basic principle in any human flight, whether it's space or just winged aircraft, and that's the KISS principle. We all know what that is, K,I,S,S, keep it simple stupid. If I were a cartoonist - I'm reminded of the

cartoon that starts out what the customer wanted versus what they got and they got this elaborate piece of hardware when all they wanted was the tire swing hanging from the branch of the tree. Please keep that in your thoughts. I believe if you continue with the Ares program you will have major, major problems for the entire program.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much. Let's see, Leonard Arnowitz, Dave Fisher, I hope I pronounced that correctly, and Joel Howell.

Dave Fisher – Resident Pheonix, Arizona
Chairman Augustine, members of the Commission, my name is Dave Fisher from Phoenix, Arizona. NASA's job is exploration. This means that NASA must develop Human Space-Faring Capability rapidly enough so that when our robotic missions find exploration problems requiring human work, we'll be able to do that work. NASA must develop human space-faring capability as cost effectively as possible so that we can afford the robotic missions that will find exploration problems requiring human work.

NASA's role is exploration. Done properly, the fur traders, the miners, the ranchers, the farmers, the merchants and even the school teachers will follow the path blazed by NASA. Thank you very much.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much.

Leonard Arnowitz – Former NASA Employee
Mr. Chairman, members of the committee and ladies and gentleman. My name is Leonard Arnowitz. I'm formerly with NASA and I'm here to talk about a subject which I'm very surprised has never been mentioned during this meeting.

I remember way back in the 1950s when an article appeared in the Baltimore Sun that the United States was going to send a man into space and an irate reader wrote a letter to the editor saying if the Almighty had intended for a man to go into space, he would have created man with wings. The editor wrote back if the almighty had intended for man to smoke, he should have built him with a smokestack.

Well today, I'd like to talk to you about one of my experience in NASA and I remember when I was called down to NASA headquarters. I think I was a division chief at the time and I was asked to listen to some man who had some kind of an idea and what was the idea? He invented a pen that the astronauts could use and he had a lot of trouble using it or promoting it and what was the big idea anyway? It was a ballpoint pen. And he asked would we be good enough to let an astronaut write with a ballpoint pen to show that this pen could be used in space to know when no other pen could. I told him give me a couple of dozen of them and I'll try them out and we tried them out and today you see that these ballpoint pens are around.

But what I want to talk about is the program that came about when they suddenly decided the shuttle was going to become operational. At the time, they were looking at the shuttle flying sorties. These are like bombing missions and I was asked to come down to headquarters to listen to them or help them and the question was we got so many sorties planned we don't have enough science to put on it and you were on the sounding rocket division, you got a lot of people who you fly on rockets, can you convince them that maybe they ought to fly on the shuttle or maybe give them a hand flying on the shuttle and I said we'll think about it and we'd come back and talk to you and we came back and talked to him about a new program they ought to think about and we called it the getaway special. What was the getaway special? It came out from a TWA announcement about getaway special that showed this busy executive running out of the office with an overcoat on one hand and a briefcase on the other and dragging his wife in the other and TWA had a series of specials. You left your office on Friday afternoon, they took you to some exotic place and then they put you back on the plane Sunday morning and got you back to work in the middle of the morning.

And we then proposed to have the idea of getaway special for school children, high school students, college students and post docs in which we made available a space on the shuttle, it was a canister space. You could put up to a couple of hundred pounds in it. You could add a couple of commands to it, if you wanted to and all you had to do was make sure you fit the mounting plates that came with the getaway special canister.

Well, we flew over 400 - we had over 400 getaway specials built by school kids and what have you and one that comes to mind to me is the Principle of the school in Camden came to talk to the Chamber of Commerce about what was happening to the school system and she painted a very dismal picture that her school system was going to pot because all the people were moving out of the neighborhood and what have you and they couldn't interest kids in school. It turns out that Jack Clark used to be the senate director at Goddard at that time. He had just left and he was working on RSCA and he was at this meeting and he took her aside and he suggested that she come talk to me about the getaway special program and we did that and that school adopted the getaway special program and instituted a whole program for several years in which the first year was devoted to just learning about space, everything about it and then at the end of the first year coming up with ideas about what to do in space. That group of kids…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I'm going to have to cut you off out of fairness to the other people who want to talk.

Leonard Arnowitz – Former NASA Employee
I've left a copy of my comments with someone on the committee. If you need another copy I'd be happy to give you one.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
That'd be fine. Thank you very much. Let's see, Mr. Howell?

Joel Howell
Six years ago, I was given a copy of this book of Augustine's laws…

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you for the plug.

Joel Howell
… to teach me how to be a good manager in the aerospace industry. I thank you for the ability to stand here today to brief you and the committee. It's a tribute to democracy and opportunity. General Lyles suggested this morning that the committee make the benefits of our country's civil space program more visible within the report. Usually when we talk about benefits, we talk about technologies that are spun out of NASA that make it into other industries that affect our lives. Generally, we acknowledge that the public doesn't care where these technologies come from, just that they have them and that they can't live without them. When we look at what the public has and is focused on during this economic crisis, it is, and I think creating a stable Afghanistan and Iraq so we can bring our troops home safely, bailing out Wall Street so we could save our stock portfolios and 401K's, saving the auto companies through funding and Cash for Clunkers programs and now healthcare, so that everyone in our country can have access to good quality care.

How can NASA compete against these issues? I think the answer is still pride, progress and the expansion of human achievement. So the question is not how do we connect with the American people, I think it is how do we connect the American people and I think the answer to this could be involvement and inclusiveness. One aspect of this is the stem dilemma which is that more of our kids are steering away from math and science and I think the less that they study math and science, the less directly they're going to be involved in our space program and they will be less likely to support, through giving their money in taxes and that sort of thing.

The second aspect is diversity. At the senate confirmation hearing for NASA Administrator Bolden, Senator Nelson outlined some of the major barriers our new administrator broke through in his military career on his way to becoming the NASA administrator. This was the first time in my six years as a manager in the aerospace industry that I realized the lack of diversity in this industry, at least at the management level. The face of the decision-makers and people with money in this country has changed since the Apollo era or since the Apollo XI landing 40 years ago and I think that actively pursuing their involvement in our industry is the only way to maintain its relevancy as our country continues to progress. That's it.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you very much. The next group of three are Juliet Sisk, Robert Osband and Joe Brown.

Juliet Sisk – Teacher at Space Coast High School
Thank you for allowing me to address the committee. My name is Juliet Sisk and I teach at Space Coast High School in Port St. John right across from Kennedy Space Center. I teach aerospace, engineering and technology in this STEAM Academy. STEAM stands for science, technology, engineering, aerospace and manufacturing. I have two comments. I have heard repeatedly from the committee and other people that have made comments, that you would like for the Constellation program to inspire our your to take the math and science courses that will enable them to become involved in space exploration programs. That is exactly what the STEAM Academy is doing and we have four engineering academies in Brevard County.

We need the help of the space committee, both with educational grant money, and with your expertise. I doubt if you know that it costs between $200 and $400 just to get a school bus for a half day field trip and of course all of you are familiar with the way the budget is for the school system so that's what we're up against, trying to fund an academy beyond a bare necessities program. I have my business cards here if anybody would like more information.

Number two, there's a cadre of between at least 2-3000 teachers and they're highly trained, dedicated teachers. They've been trained through NASA programs and individual contractors programs. For one example, imagine the excitement of the 60 Brevard County teachers who were given scholarships to fly on the zero gravity plane last December. This flight was sponsored by Northrop Grumman. I ask you right now in your mind to imagine how you would have felt in elementary, middle school, high school classroom when you have a teacher in front of you that has just come off of doing – I think it was 15 parabolas, several for 1/3 gravity as if you were on Mars, several for 1/6 gravity and of course that's the moon and then the rest of them were free-floating, doing scientific experiments while you were trying to learn to float and not get kicked in the head. It would not cost a lot of money to get teachers from across the United States that I say that are already trained. They're dedicated and they actually start glowing when they start talking about space. There is a true attachment, a love of space among a huge number of teachers and if we could get them all back together again, you would see miracles happen in a classroom. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Thank you.

Robert Osband
Chairman Augustine, members of the panel, my name is Robert Osband although here in Brevard County I'm known as Ozzy the area code guy. 10 years ago I went through a public service commission hearing and explained that Cape Canaveral, the

countdown capital should get area code 321. I've never worked for NASA. I've never worked for a NASA contractor. I've just always been a space fan and a bit of a phone freak so the combination of telephones and space came easy to me. On launch day, I am usually in Titusville, at Space View Park. I have a website, spacelaunchinfo.com. I publish a small newsletter that I sell to the tourists on launch day that explains a bit of the flight because mostly the people that come to space view park on launch day are folks taking who are taking time out from their vacations. They came to Florida because they didn't know there was a launch on, but once they found out, they threw the kids in the station wagon and headed east.

Some of them went on the internet first, found my webpage and found their way to Space View Park. I'd like to invite you to Space View Park on a launch day and meet the people from across the country. Folks from around the world who have found their way to the park to watch a launch as Bob Cabana said this morning, they line the Indian River around here. They line the causeways across the Banana River. They hang out along the Atlantic coast, all to watch a launch and I got to tell you, it's not just the manned launches, for unmanned launches we'll be down on Route 528, one of my ham radio clubs, LISATS, the launch information service and amateur television system runs the ham radio repeater.

If you've ever been down here with a scanner listening on 146.940 megahertz, that's my ham club and we're out there with the NASA feed so that everyone, including those guys out in the boonies at the space center who can't find out what's going on otherwise, they can hear the countdowns. They can find out what's going on, get the word and enjoy the launch which for many of those people is a once in a lifetime experience. For those people, the thousands of Americans, I just want to give a message to you from them, please, whatever you do, keep them flying. Thank you.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Okay, thank you.

Joe Brown
Thank you. Welcome to Broward County, the home of the United States greatest active monument and museum. The VAB, LC 39, where 40 years ago we launched three astronauts to the moon, the miracle with God's help, LC 26 our first astronaut in 1958 where I worked at the complex as a docent, and LC 5 and 6, our first US astronauts in 1961. We were there near 200,000 acres, over 25,000 active aerospace workers, team workers, members, launching astronauts to the moon and satellites to space. Who am I, I'm Joe Brown, a God-loving American, an AACE international fellow, certified cost engineer who helped bid and build the VAB, Apollo, Skylab, shuttle, international space station and is a consultant for the Constellation Program. Yes, when we designed the VAB in the 60s, we designed it to go higher. When I was on the roof recently, you could see the beams sticking through the roof so it can go higher.

In addition to that, we designed it for two more bays, 5 and 6 to go out north. I believe that we American, God-loving people are for an expanded, accelerated space program

to the moon for its natural resources such as moon mining of helium 3, a new, exciting, clean energy source more powerful than uranium where one shuttle load can power the United States electrically for one year with very low radioactivity and why, over 1 million good paying American jobs to build the helium 3 power plants, new clean energy, less pollution, multi-million, trillion dollar industries, that's what America needs now for a stronger US economy and yes, I did talk to Buzz Aldrin just recently, July 18th about the challenges and how we can solve those challenges.

I believe this nation, with President Obama's support, should continue itself to go to the moon, to mine helium 3 and beam clean energy back to earth, cost-effectively within this coming decade because that is a challenge that we can win for all of mankind. Thank you very much and for those that need more information on my website, a little bit of video, The Big Challenge and expanded space videos and some other information on that. Thank you very much.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program

Thank you very much. And thanks on behalf of the committee to each of the public speakers that have shared their views with us.

COMMITTEE DELIBERATIONS:

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
That completes that part of the presentations. We have time, ten minutes under the normal schedule. I have a press conference. I have to step out for thirty minutes, but the committee can continue to deliberate if you would like. As we've gone today I think we've done a pretty good job of closing out the items that we had, but we do have some free time here if anybody has anything you would like to talk about or raise or discuss.

All right. Bo.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Yes. You know, we have done a lot I think to come up with scenarios that involve technical aspects because that is what we are good at and we enjoy that. We are guys that spent many years in the aerospace business. What I feel like we could do perhaps more in trying to help NASA; is to look at how NASA does business in America and see if we can be helpful in that arena. I was sitting here thinking here a little earlier and I'm thinking we have a Chairman who is an icon in the business world. I'm not trying to kiss up to you Norm, but seriously. And I was thinking under this gentleman's leadership we ought to try and look at things that we ought to suggest to NASA to be more effective. In other words, okay we're trying to figure out how to make technical content that fits the budget. There are two other areas. We haven't really talked a lot how to help NASA get more budget and the third one is how to help NASA to use the budget they get more effectively. I feel like that there is probably some room for a little dialog and I still count on your leadership in that area. You know this stuff. We are a bunch of technical people here. Yeah.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
I'm an engineer that descended into management.

[Laughter]

No, but your point is a very good one. You know in the chapter we've talked about in our report. I think we will want to make some comments along those lines. I think there are some lessons that perhaps we could make a contribution and should. I know Jeff has got some thoughts and has lived in this world as well. So we welcome the idea.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
When my friend Jeff was talking earlier he touched on one page on I think new way of doing business. I had some discussion prior to our meeting here with some of the previous NASA managers and I asked that question how can NASA be a little more effective in getting better value for the dollars they do have. Things like… and some of

the suggestions went along the lines that NASA has this traditional way of acquiring, buying things from contractors. Putting in big chunks, go through the competitive procurement. Contractors work very hard to compete. They award the contractors the work and then the contractors stay in the business for decades. In some case maybe that's the only way to do it, continuity, continuity of experience of honing your skills, but there are pieces of NASA engagement I believe that could be treated a little differently. Put them in smaller pieces and provide something more of the continuous, not the periodic but continuous competitive atmosphere. Just like you know when you go to the grocery store you can buy ten brands or milk. That to me is a continuous competition. Maybe this is easy to talk and harder to do but I feel like we ought to try to at least maybe put something in our report that has to do. How could NASA in some cases do (something) to get #1 better value and #2 stimulate newcomers, guys who come and make milk in our business. So, I don't know if anybody else thought of this idea or am I a lonely wolf here on this committee?

Jeffrey Hanley, Program Manager, NASA Constellation Program
I obviously couldn't agree more. I've asked that question before. I am always told we can't possibly afford to have… we can barely afford to have one competitor doing something, we certainly can't afford to have two and then you watch the problems and the overruns and then you go you couldn't afford not to have two. If you had two you would have had to spend less money than if you had the one, but of course you can't do that as Bo alludes to if your idea of the competition is who gets the next $100 billion ten year program. You have to break it down into smaller pieces and I think one of the really key aspects to some of the technical ideas I talked about earlier is not that there are technically neat in and of themselves, but they allow a disaggregation of the requirements so that you can break up the individual pieces so that they are more competition friendly.

Norman Augustine (Chairman), former CEO of Lockheed Martin, former Chairman of the Advisory Committee on the Future of the United States Space Program
Ed I saw you had a comment.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Yes, sorry. I do. I actually had an idea that came about during Senator Nelson's comments and I should preface this for the people out there in blogosphere who are checking my credentials that at one point I was both educated in Leningrad and a lecturer in Moscow at the Aviation Institute. But I was listening to the comments from Senator Nelson about funding the provision of launch services in the interim on the Russian launch system, which I have nothing but the greatest admiration from but it is basically paying another government for a service that Americans might otherwise provide. It occurred to me that this is one of those rare instances, Norm, where the American government can actually do an IRR calculation and say what fraction of this payment that we know that we will likely have to make to a foreign government could we invest in American industry to provide a capability sooner so that we don't have to make the payment to a foreign government. It is actually a relatively simple business case to think about. It makes you realize that if you accept the fact that we are going to have a gap which is almost inevitable of some duration it's just the argument about the duration, you can actually estimate how much we would have to pay and what fraction

of that it made sense to reinvest in Americans producing the capability. It is actually a fairly simple argument that closes. So we might want to consider that.

Jeffrey Hanley, Program Manager, NASA Constellation Program
I agree and I...

[Applause]

Jeffrey Hanley, Program Manager, NASA Constellation Program
And if as I suspect the answer may not be overwhelming but it comes out close. You have to factor in the fact that you know… It is obvious which way ties break in that calculus.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Close goes to the runner.

Lady Speaker
Our chair sends his apologies but he did have to step out to meet with the media and to answer questions so we'd all rather be here than there as it turns out. But we are free to continue discussion if there are some other comments that you would like to offer.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
So we give a little more time?

Lady Speaker
A little more time, yeah Bo, go ahead.

Jeffrey Hanley, Program Manager, NASA Constellation Program
Well I want to raise a question as to wether we want to raise a question. Are you our chair in-absentia here?

Lady Speaker
I was left with the cattle prod…

Jeffrey Hanley, Program Manager, NASA Constellation Program
All right. So I am ready to cower here. But you know we have this giant trade space of n-dimensions each of which has y-options and all of which we have to somehow combine over the next week. Do we want to sleep on that before we talk about it or are there any elements of it that we want to talk about now so as to focus on our work between now and then more narrowly?

Lady Speaker
Well, I guess I would speak personally that we've had a deluge of info today. Most people will need to go back and probably review some of the charts, process a little bit, but I think if there are questions that we think need to be answered it would be great if we could raise those now so that we can sort of get some help on getting those questions so when we get back together next week it's not search for additional data.

Jeffrey Hanley, Program Manager, NASA Constellation Program
I just need time to think about it.

Lady Speaker
Chris.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
I think Bo was ahead of me.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
No, go ahead Chris.

Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University
Somewhat relevant to that, I think it is relevant to that and also I've been struck, you know, as a committee we get to sit back and pretty much criticize everybody and maybe a little bit of self-criticism is useful too.

Today we emphasized the fix that the program is in with respect to budget. So much less in the current budget than was budgeted circa 2006, plus if you extend station another $10 to $14 billion and then what we went and did today was to say "And you know what, NASA should also have a robust advanced technology program. And you know what NASA should also develop Depots. And I think if I was trying to put the best face on and I think that would be that we would try to justify that by saying that we are in a fix and if we want somehow to breakout of NASA's chronic problem of not having enough money to do operations and developments simultaneously there will have to be some game changers and the advanced technology and the Depots are ways of trying to change the game. And nevertheless when we try to incorporate this into our report I think we ought to try just as I berated Washington by saying that we are going to be honest about how much our budget can buy, we ought to be really up front in our report as well as saying just how much a hit these different technology development items are going to represent to the extent that we can estimate that and factor that in as we think through the budget. We don't want to be guilty of just hanging more bobbles on the Christmas tree, doing exactly what we say needs to be avoided.

Jeffrey Hanley, Program Manager, NASA Constellation Program
I couldn't agree more.

The chart said it has to be a funded technology program and that means we have to think about how fast we want to do it, we have to put a line item on that, and we have to figure out what we're going to beg for or what we're going to cut to get it.

Edward F. Crawley, Ph.D - Professor of Aeronautics and Astronautics
Chris, I couldn't agree more. I think the reality is that we have an administration that is interested in technology investment and the ironic part is that as you know in the last few months they've made several decisions about giving additional resources for technology development to the agencies that they consider to be technology developers and on that list is the NIH, the NSF, and the DoE and not NASA. NASA

has not been a beneficiary of the additional funding in the stimulus packages and others that are associated with new technology investments. And the perception is that the current technology program within NASA is a supporting technology program for Human Space Flight for short-term needs of Human Space Flight and therefore doesn't count in that category. I think that along with this, you know, we need the vision and the request in this one. We need the vision of what the technology program would be in NASA that would as Les, whose seat I am in, pointed out this morning would not only provide technology for NASA's missions but as Jeff points out provide the role that the NACA did for many years as being a technology engine for a commercial space industry and by the way if it also helps with human health and other issues in the traditional spin-off model that's fine. I think we have to help NASA craft that vision and make it part of the package we carry forward.

Lady Speaker
Why don't give Bo the last word here?

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Well, I'm sure along the line of this… I think NASA has an opportunity today to maybe not create because it creates by itself. The vibrant, commercial space industry. We have visited guys who spend their own money to get to space to create an industry. NASA could help that, you know. NASA, we are some people, I won't mention names I guess because maybe there are somewhat proprietary information but we asked the questions you know how important was NASA business to you succeeding in commercial space and the answer was very important. NASA can be a catalyst to go and expand commercial space industry if it becomes one of their objectives. You can accomplish things when you want to do. This happens in spite of you. You have to actually want to do it. But I think at NASA, if NASA could do that, and I don't think we are talking about a big portion of NASA's budget, I think it would elevate NASA in the eyes of every small businessman. People whose buddies are trying to get in the business who talk up NASA and I think that would be a positive image NASA creating a new aerospace industry and assisting it in being successful. I don't know that we really have to come up with some concrete recommendation for NASA how to do that. We might have to talk some more about it but I think it is very important.

[Applause]

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
Thank you whoever is on my side.

[Laughter]

Lady Speaker
We've got one lone person on your side. That's great! Jeff do you want to wrap us.

Jeffrey Greason – XCOR Aerospace - CEO
Yes. There are two thoughts that during the course of the last couple of days that I mentioned to other committee members and I want to take these minutes to surface them for everybody else to think about. Not to try to reach an answer.

The first one of them I want to raise is now that we have come to this point of realizing how critical propellant transfer initially and maybe Depots later can be to the exploration architecture. And now that at least I personally am getting more interested in a midrange booster as being a piece of that. A question that was previously didn't make sense to ask floats up and that question is; is ISS the Depot? It certainly is a very logical place to do flight demonstration and technology maturation, but as we have listened to the concerns about propellant transfer architecture, one of the concerns that comes up is well it's not just propellant you have got all of these pieces on orbit. The orbits have to be maintained. They need to keep alive power. If you are really smart you might want to launch the Earth departure stage last because it's kind of the big piece but then you would have to have the crew up ahead of time. You can't have the crew waiting around in orbit. And I'm listening to these pieces going okay I know ISS is kind of in the wrong orbit for this and I know that we're going to pay a performance penalty for a long time if we did that, but gosh it does provide orbital maintenance, keep alive power, people there, place to store the crew, mechanics if something goes wrong and I think it is worth thinking about again.

Lady Speaker
I was going to say that we're going to expand on the options and probably try to make like Lego's and break and reconnect a little bit next week so I think that's one of the things we ought to keep in the hopper here. Hey Jeff, I'm going to call for time because I know that we're behind schedule.

Jeffrey Greason – XCOR Aerospace - CEO
Okay, I will be very quick.

Lady Speaker
Okay.

Jeffrey Greason – XCOR Aerospace - CEO
Okay. The other one I want to raise is that we talk a lot about cost but I don't think it has been clear, not all cost are created equal. For the government in particular, a program with very high ongoing operations cost poses a real problem and that problem is the budget is never constant. It goes up, it goes down. They can't hold program reserves. It's a problem we have heard from everybody. I cannot hold on to enough reserves, OMB takes them away. Well if your fixed costs are 25% of your cost neither of these are that big of a deal. If the budget goes up I fly more missions, the budget goes down I fly fewer missions. I have a program that slips out or overruns. I fly a few fewer missions. If it under-runs I fly more. But if your fixed costs are 50, 60, 70% of your budget and your budget goes up or down by 25% you are out of luck. That is essentially the situation we find ourselves in. If we want a sustainable architecture it's not enough to be cheaper, it has to be cheaper on a recurring cost basis even if, ironically enough, I mean has to be cheaper on a fixed cost basis, fixed costs have to be a lot cheaper. Even if, ironically enough that means the marginal cost goes up a little bit in some optimized architecture where the budgets are perfectly flat, level and predictable in the real world you're better off.

Bohdan Bejmuk – Constellation program Standing Review Board - Chairman
I have a question for Jeff. Do think time has come where we can start thinking of privately owned gas stations in space?

Jeffrey Greason – XCOR Aerospace - CEO
Yes, I think time has come where we can start thinking about it. Whether the time has come where we are ready to start depending on it will need more discussion.

Lady Speaker
Okay at this point Bo I'm going to let you guys go off in the bar and continue that discussion.

[Laughter]

Lady Speaker
But our chair is famous for trying to have a little margin at the end of the day and we've blown that. But I do want to on his behalf and on behalf of the entire committee thank all of our public participants today those of you who spoke as well as those of you who endured for several hours here in person and online. We really appreciate it. We are taking in all of the inputs and processing them as quickly as we can, but as you might imagine we are going to be very focused on getting our report out by the end of August. So thank you all again and travel safely.