

**OPTIONS FROM THE REVIEW OF U.S. HUMAN
SPACEFLIGHT PLANS COMMITTEE**

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE AND SPACE

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

SEPTEMBER 16, 2009

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ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

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OPTIONS FROM THE REVIEW OF U.S. HUMAN SPACEFLIGHT PLANS COMMITTEE

WEDNESDAY, SEPTEMBER 16, 2009

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

The Subcommittee met, pursuant to notice, at 2:33 p.m. in room SR-253, Russell Senate Office Building, Hon. Bill Nelson, Chairman of the Subcommittee, presiding.

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

Senator NELSON. Good afternoon.

This is an exceptionally important topic, and I think that buzzer might tell us that a vote is starting.

[Laughter.]

Senator NELSON. No, it is not. It is a quorum call. Hallelujah.

We really want to peel back the onion and get into a lot of the specifics of the extraordinary work that you have done, Mr. Augustine. And thank you for the public service that you have rendered to this country over a lifetime that you have in Government and in the private sector, and then thank you for this unpaid service, enormous public service that you have rendered.

And we are looking forward to hearing from you, and I want to thank the Ranking Member of the full Committee, Senator Hutchison, for coming, and I want to turn to her for her opening comments.

STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON. Thank you, Mr. Chairman.

Mr. Augustine, you have come through for our country one more time. The *Rising Above the Gathering Storm* report has been really the Bible for those of us who want to promote science education, math, engineers to graduate from our colleges, and we thank you for that.

And now, you have done a great study about the future of NASA and space exploration. And I just want to commend you.

It was our Committee—it was Senator Nelson and myself—who had the United States' part of the Space Station designated as a national laboratory in the 2005 NASA Bill. And we did that because we saw so many NASA research funding shortages, and we knew that if we had it designated in that way that others could

come in and do research—universities, Federal agencies, corporations—in the future. And in fact, that is beginning to happen.

We are just on the cusp now of realizing the capabilities of this enormous investment that we have been making in the International Space Station. We are just beginning to realize it, and yet now we are talking about shutting down the Shuttles and not being able to fully equip and utilize the Space Station. And I commend you for the report that says we must utilize it in order to have the investment pay off that we have made in this International Space Station.

But you also pointed out that without at least \$3 billion, which was the suggestion of your committee, that without that increase, that we are facing some great shortages not only in being able to use the Space Station correctly and allowing it to reach its full potential, but also the gap in our ability to put humans in space, not only for the Space Station, but also for our national security. That gap will definitely happen unless we are able to put the money in that will allow us to do one of the options that you suggest.

I think I can speak for myself and say that I am hoping that we will be able to extend the Shuttle to narrow that gap. But I thank you for the great effort that you have put in, and I will want to ask you questions.

I thank you, Mr. Chairman, for holding this hearing, and also, Mr. Chairman, for your complete commitment to NASA and space exploration. Without your commitment and the vigor that you have shown, I think sometimes maybe Congress would have lagged behind in making sure that we are doing what we need to do to stay in the forefront of utilizing space.

So I thank you for calling the hearing. I thank you, Mr. Augustine, for leading the panel. And I will look forward to questions.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Thank you Mr. Chairman. Mr. Augustine, you have come through for our country one more time. The *Rising above the Gathering Storm* report has been important for those of us who want to promote science education, math, engineers to graduate from our colleges and we thank you for that.

And now, you have done a great study about the future of NASA and space exploration, and I just want to commend you. Know that it was our Committee, Sen. Nelson and myself, who had the American Space Station designated as a national laboratory.

And we did that because we saw so many funding shortages and we knew that if we had it designated in that way, others could come in and do research; universities, Federal agencies, and corporations in the future. In fact, that's beginning to happen now.

We are just on the cusp of realizing the capabilities of this enormous investment that we have been making in the International Space Station.

Yet, now we're talking about shutting down the Shuttles and not being able to fully equip and utilize and use the Space Station and I commend you for the report that says we must utilize it in order to have the investment pay off that was made in this International Space Station.

But your report also pointed out that without \$3 billion, we will be facing some shortages, not only in being able to use the Space Station correctly and allowing it to reach its full potential, but also the gap in our ability to put humans in space for the Space Station.

This will also affect our national security unless we are able to put the money in and do one of the options you suggest. I hope we will be able to send a Shuttle to narrow that gap, but I thank you for the great effort that you have put in.

I thank you Mr. Chairman for holding this hearing and also Mr. Chairman, for your complete commitment to NASA and space exploration. Without your commitment and the vigor you have shown, Congress would have lagged behind in making sure that we are taking the right steps to stay in the forefront of utilizing space.

So, I thank you for calling the hearing and I thank you Mr. Augustine for leading the panel and I will look forward to questions.

Senator NELSON. As you give us this report, Mr. Augustine, I think it is going to become increasingly apparent that the moment of truth for the future of NASA's human spaceflight is here. As you and others will point out, there is only one person that can lead America's human spaceflight program, and that is the President.

The work that your panel has done is in preparation for the President making a decision. Kay would like to lead it. I would like to lead the space program, but a Senator can't do it. Charlie Bolden, the Administrator of NASA, can't lead it. The human spaceflight program of this country can only be led by the elected leader of this country because he sets the priorities.

As a result of what you have said, if he is going to be wanting to increase and continue human adventure into the cosmos, he is going to have to pony up more money in his Office of Management and Budget. It has been stated from this dais over and over in the last decade that NASA was not getting enough money to do everything that it was asked to do. That is obvious now that we are about to complete the Space Station and shut down the Space Shuttle, and we don't have the next rocket ready.

If we are going to have a program, it is going to have to be the President who is going to have to put the juice to the program.

Second, is that the President is going to have to articulate to the country the vision of why it is important for us to go beyond low-Earth orbit, a subject that your panel has broached, but only the President can articulate. A majority of Americans don't even remember when we landed on the Moon and what an extraordinary accomplishment that was. So, why do we want to venture out?

Only the President can articulate as we move from here, severely underfunded NASA that is way behind the timeline and doesn't have another rocket ready as a follow-on to the Space Shuttle, to whatever that vision is that the President wants us to go on beyond low-Earth orbit. He is going to have to say how we take care of the workforce, this extraordinary workforce that is so talented and has so much historical memory and are not all ready to retire.

The President is going to have to set priorities of how do we not only keep some of them in work and able to get to the vision that I hope the President will articulate, but providing the means on a daily basis.

I would hope that when the President lays that vision out, that he is going to tell what NASA has done in 50 years. Not only the extraordinary feats in outer space, but what has happened here on Earth as a result of America's space program. The technologies that have been developed in health and medicine and transportation and public safety have made the lifestyles that we live better. Advances in our home, at the office, and in the environment are results of NASA spinoffs and microminiaturization. That is not even to speak of what NASA has done for computer technology and industrial productivity.

You can say it until you are blue in the face. I can say it. Administrator Bolden can say it, but the American people are going to listen only to the President.

What you have laid out is a blueprint, a menu for the President to make choices, and it is my fervent hope that he is going to say we are going to put the juice into it. We are going to have a vision that we are going beyond low-Earth orbit, and in the process, we are going to nourish that workforce so that we have them ready when we do the next huge leap for mankind.

Senator Vitter?

**STATEMENT OF HON. DAVID VITTER,
U.S. SENATOR FROM LOUISIANA**

Senator VITTER. Thank you, Mr. Chairman, for convening this really important hearing and thanks to you, Mr. Augustine, for all of your work and the work of your committee. It is very, very important. You have undertaken a big challenge, and we appreciate all of your service and those of your committee members.

I look forward to reviewing the full final report when it is available, but I appreciate the summary and your testimony today. And as you can tell, we thought it was important to start this discussion in earnest sooner rather than later. So that is what today is about, and I appreciate your being here.

You have made it really clear and underscored what so many of us and others have been saying that the funding profile for the exploration program has been inadequate, and it would be virtually impossible to sustain under the flat line out-year funding profile that was included with the original 2010 request. And I think that is one key point that all of us want to underscore and amplify.

Our other challenge, of course, is to clearly define what the Nation's human space exploration policy should be, what programs and tools we need to implement it, and exactly what financial resources are required to make it all work.

Another of the key messages of your committee, I believe, is that if we intend to have a viable human space exploration program in this country, we are going to need to step up to the plate and provide funds necessary to make it work, and that is a big part of the discussion.

And that is important because I believe one of the key elements of our decisions must be having a path forward that makes it possible to retain our highly skilled workforce and not lose so much of that human capital and to sustain more broadly our aerospace industrial capacity. A lot of that is human, but it has other elements as well.

So I look forward to exploring all those key issues with you, and thank you again for your work.

Senator NELSON. Mr. Augustine, as we discussed earlier, your written testimony will be submitted in the record, and you are going to share for us in a brief way some of your comments so we can get right into the questions.

I just want to say for our audience that Mr. Augustine has quite a pedigree. He has been a research engineer. He has been a program manager. He served in Government in the Office of the Secretary of Defense, Assistant Director of Defense Research and En-

gineering. He was Assistant Secretary of the Army, became Acting Secretary of the Army, and then he has served in academia on the faculty of Princeton.

Obviously, everybody knows him as a former CEO, and a member of every advisory committee in the world. So, Mr. Augustine, with that pedigree, indeed, we are honored that you are here.

STATEMENT OF NORMAN R. AUGUSTINE, RETIRED CHAIRMAN AND CEO, LOCKHEED MARTIN CORPORATION AND CHAIR, REVIEW OF U.S. HUMAN SPACEFLIGHT PLANS COMMITTEE

Mr. AUGUSTINE. Well, Mr. Chairman, thank you very much.

Senator Hutchison, Senator Vitter, and the Members of the Committee, I appreciate this chance to appear on behalf of my colleagues on our committee and describe to you some of our results, and I will submit for the record my prepared statement and briefly summarize it now.

You provided the proper opening, and that is that the human spaceflight program in America is at a tipping point right now. Probably more so than at any time since President Kennedy took the leadership to say that we should have such a program.

Before I begin, with your permission, I would like to acknowledge the enormous effort and dedication of the members of the Committee with whom I had the privilege of serving. I have rarely worked with a group who put in the hours and the effort that this group has.

I also would like to take note of the fact that the support we received from NASA was extraordinary—extremely competent people, very open and candid, very hard working, and very responsive.

Further, we had hired as a committee The Aerospace Corporation to work for us as a committee independently to provide us with a separate view of programmatic issues, technical issues, cost issues, schedule, so on. And they, too, have been all we could have hoped.

As you know, our committee consisted of 10 members. It was broadly constituted. It included scientists, engineers, educators, former business executives, astronauts, former Air Force general officers, former Presidential appointees, and so on—all with background in space.

We were given only 90 days for our effort. The reason, of course, being to try to match it to the budget cycle. That was not a great deal of time to address such a difficult issue. On the other hand, our members didn't start from zero. We did have some background. But I call that to your attention because as a caveat, there are limitations on what we were able to do, and the Committee should have that in mind as you review our work.

Our committee, and I need to really emphasize this, was asked to provide options, not to make a recommendation. That is very important because we tried to abide by that and to be very balanced in our assessment of the options. We have not endorsed any particular option.

We have said that it seems clear to us that the ultimate destination for the next major step in America's human spaceflight program is a human landing on Mars. We have concluded, reluctantly and with some disappointment, that, in our judgment, it would not be safe to attempt such a mission at this point in time.

In other words, we have concluded that the direct to Mars mission is not something that our Nation ought to undertake for safety reasons, let alone the financial impact that that would have.

The various parameters we looked at made it possible to define over 3,000 options that we could have offered to you. We tried to narrow that down, for obvious reasons, and have narrowed it to specifically five families, and I say “families” because it is possible to move an item from one family to another and to adjust the results if people want to do that. But they are representative families.

One member of that family is the existing program as it is being pursued today by the Nation through NASA. Let me define for you what we consider to be the existing program. It is the program that is the basic NASA plan that NASA has provided, and it is the budget that we were given by the Office of Management and Budget.

I won't describe to you the other four integrated options. You have them available, I am sure, and I will be pleased to address them at any time you would like. But to save time now, I won't do that.

Our committee, the bottom-line conclusion at which we arrived—a disappointing one, frankly—is that pursuing that existing program is really not executable and will not lead to a satisfactory outcome for America's human spaceflight program. The reason for that is the mismatch of goals and funds. There is more work to do than there is support to carry out that work. That is always dangerous, but it is particularly in hazardous undertakings like human spaceflight.

If we were to continue on the path of the existing program, which is one option—certainly, we could do that—let me cite what a few of the outcomes would be. The first is that we would have to launch six Shuttles in the next 12 months. One can question whether that would be a safe thing to have to do.

Second, that there will be no funds to enhance the existing technology program to provide the basis for a successful program in exploration later. In addition, there will be no substantial funds to make use of the Space Station during the next five years that it would be in orbit.

Third, we would have to de-orbit the Space Station in little over five years from now, after having spent over two decades building the Space Station and putting some 900,000 pounds into orbit. We would complete the development of Ares and Ares I, in the Committee's judgment, 2 years after the Space Station had been splashed into the Pacific Ocean. Of course, one of the main reasons for Ares I was to support the Space Station.

The heavy-lift launch capability, which is the thing this Nation really needs to get on into space, would be delayed until the mid to late 2020's because of the lack of funds. When we finally got the heavy-lift capability, based on an Ares V or whatever, there would be no upper stage to put on it, nor any lunar surface systems to use it. So, we are looking at the mid 2030's in this case before we would be able to do any real exploration, in our judgment.

That basically is the path that we are on. Our committee has offered other options that could give us a very exciting program, a

program that lets us, for example, circumnavigate the Moon again, circumnavigate Mars, land on one of the moons of Mars, to dock with an asteroid, a visit to a Lagrange point, with a large number of events over the next 15 years.

The problem with all the other programs that we have offered, the only programs that we have been able to find that we think are viable is that they require, roughly speaking, an additional \$3 billion per year to carry them out. And absent that additional funding, I am afraid our Nation is in a position where human spaceflight substantially goes on hold.

We can develop launch vehicles. Yes, we can do that. We can do a little technology. But there will be no really significant human spaceflight work, and the International Space Station (ISS), will come to an end five years from now.

I would like to close with just three observations. One is that we have intentionally been relatively conservative in our estimates of cost, schedule, and performance. We do that, frankly, to reflect our dissatisfaction with our record as a profession in that area in the past.

Second, we believe that not only are we in a current situation where ends don't match means or means don't match ends, but we believe NASA has been in that position for decades, and it is time that we take NASA out of that position. NASA is a national asset, and it is unfair to the people at NASA and, we believe, to the American citizens to continue in that circumstance. If we have to change the objectives to fit the means, so be it.

And then, last, that as this Committee would know so well and, Mr. Chairman, you would, human spaceflight inherently involves risk. We should do all those things we can possibly think of to make human spaceflight safe. And indeed, we have tried to propose those things. But at the end of the day, there still remains non-trivial safety risk, and any nation that hopes to be a space-faring nation has to face up to that situation.

And finally, I would conclude by thanking the Administration and you for the trust that you have put in my colleagues and myself to address an issue that affects what really is one of the great examples of America's leadership.

And with that, Mr. Chairman, I would be happy to address your questions.

[The prepared statement of Mr. Augustine follows:]

PREPARED STATEMENT OF NORMAN R. AUGUSTINE, RETIRED CHAIRMAN AND CEO, LOCKHEED MARTIN CORPORATION AND CHAIR, REVIEW OF U.S. HUMAN SPACEFLIGHT PLANS COMMITTEE

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to share with you the principal findings of the Review of the U.S. Human Spaceflight Plans Committee. I will speak on behalf of the members of our Committee and will do my best to reflect our consensus views. As you are aware, our final report has not yet been published; however, our decision-making deliberations were all conducted in public under FACA rules so I believe what I have to say will come as no surprise to anyone.

First, I would like to acknowledge the contributions and extraordinary effort of each of my colleagues on the Committee. Their names and primary affiliations are appended to this statement. I would also like to acknowledge the forthright, responsive and highly professional support we received from NASA as well as from the Aerospace Corporation, the latter of which the Committee employed to provide independent technical and cost assessments.

The Committee was comprised of ten members having highly diverse backgrounds. It included astronauts, scientists, engineers, former Presidential appointees, business executives, educators and an Air Force retired General Officer—each with considerable space experience. Due to the exigencies of the budget process we were asked to complete our task in ninety days—which we did, with the exception of finalizing and printing our report. The latter will be available soon.

Our assigned task was to identify alternative courses that the U.S. might pursue in the area of human spaceflight. One such alternative, of course, is to continue the present program. As noted in the Committee's report, changes to ongoing programs are generally warranted only for compelling reasons. Each alternative identified by the Committee is accompanied by a discussion of its strengths and weaknesses.

It was agreed that at least two of the alternatives would be compatible with the FY '10 budget plan extended through FY '20. We were also asked to examine the current plans for the Space Shuttle and International Space Station and, if appropriate offer alternatives thereto. It is important to note that we specifically were not asked to make a *recommendation* as to a future course of action. That decision is, of course, the purview of the President and the Congress.

Before addressing destinations and architectures the Committee sought to identify appropriate goals for human spaceflight. There are many possibilities that can be cited: strengthening the economy, conducting science, repairing and upgrading spacecraft on orbit, promoting international ties, protecting against asteroids and comets, encouraging science education, and more. It is, however, the Committee's view that although each of these benefits is important in its own right, none can, by itself, justify the cost and risk of human spaceflight. Rather, the *raison d'être* for such activity must, and in our view can, be founded upon charting a course for the expansion of civilization into the solar system. In so doing, one derives the leadership benefits of being among the world's space-faring nations—a nation that is committed to exploration, seeking knowledge, advancing engineering capabilities, inspiring its citizens, and motivating its young people to consider careers in science and engineering. To a not inconsiderable degree it is intangibles that justify the human spaceflight program, intangibles such as those that today help maintain America as a leader among the world's nations. The Apollo Program is an appropriate example.

In carrying out the charge to identify options the Committee narrowed over 3,000 theoretically possible outcomes to a set of five alternative integrated space programs. These can be thought of as representative families, since one can interchange certain elements among the individual alternatives. The Committee's attempt was, of course, to keep the number of nominal options to a manageable size.

The alternatives offered include the ongoing program, Constellation—that is, the Program of Record and the Budget of Record—and four primary alternatives, some having derivatives or "sub-cases."

Two of the five alternatives were in fact constrained to the current budget profile for human spaceflight. The first of these was the Program of Record; that is, today's program, modified to fly-out the Shuttle in 2011 rather than 2010 and including sufficient funds to de-orbit the International Space Station (ISS) in 2016 according to plan. Under this existing approach the Ares I launch vehicle and Orion capsule are unlikely to become available until after the ISS has been de-orbited. The heavy-lift vehicle, Ares V, would, in our judgment, become available in the late 2020s; however, there are inadequate funds to develop the exploration systems the Ares V is intended to support. The Committee concludes that this is not an executable option due to the incompatibility of the budget plan and the program plan.

The Committee's review noted that the Constellation Program has encountered technical difficulties of the type not unexpected of undertakings of this magnitude—problems which, given adequate funds and engineering attention, should be solvable. This was not, however, a significant factor in the overall conclusion with respect to the viability of the Program of Record.

The second of the options, also constrained to the current budget profile, flies-out the Shuttle in FY '11, but extends the use of the International Space Station for 5 years, to 2020. This option includes a robust technology development program—something the Committee believes has been lacking at NASA in recent years—and relies on commercial firms to launch cargo and crews to the ISS as soon as demonstrated capabilities exist. It includes development of a somewhat less capable version of the Ares V, known as the Ares V (Lite). This option is deemed capable of execution but cannot provide the space-borne hardware required to support a viable exploration program. In fact, the Committee could find no program within the current budget profile that would enable a viable exploration effort.

Given these findings, the Committee examined three options that exceeded the present budget plan. The most defensible funding profile, purely from a program execution standpoint, is one that linearly increases to \$3B above the FY '10 guid-

ance by FY '14 and then increases by an estimated annual inflation rate of 2.4 percent.

The first of these budgetarily less constrained options is termed the Baseline Case. It is the present Program of Record with funds added to extend Shuttle operations into 2011 and, as now provided in the budget plan, to de-orbit the ISS in 2016. This program would permit a human return to the moon in the mid '20s and begin laying the groundwork for a flight to Mars.

The second of the budgetarily less constrained cases is actually a family of variants that would extend ISS operations to 2020, provide funds for its de-orbit, and fund a strong technology program in support of ISS utilization and an eventual human landing on Mars. It would use commercial launch services for new access to low-earth orbit. There are, however, significant differences between the two variants under this option. The first of these variants would develop the Ares V (Lite) to support a human lunar landing in the mid 2020s—after which focus would turn to a human Mars landing. The second variant would extend the use of the (re-certified) Space Shuttle to 2015 and be accompanied by the development of a Shuttle Directly-Derived heavy-lift vehicle in place of the Ares family—with the eventual possibility of in-orbit refueling. This is the only practicable option the Committee could find to close the at least five-year gap during which the U.S. will, as currently planned, rely upon Russian launch services to lift U.S. astronauts to the International Space Station.

The third budgetarily less constrained case follows a rather different path of exploration from that heretofore pursued by the U.S. The Committee terms this option the “Flexible Path” and defines it as achieving periodic milestones prior to a Moon or Mars landing. These initial accomplishments could include a lunar fly-by, a Mars fly-by, a visit to a Lagrange point, an asteroid rendezvous, and possible landings on the moons of Mars, Phobos and Demos.

In summary, with the existing budget plan it would be reasonable to extend the use of the ISS for 5 years and to conduct a robust technology development program. The Committee concludes that no rational exploratory program can be funded under the existing funding constraint and that plans for America’s space exploration program would de facto be halted and human operations limited to low earth orbit.

With the less constrained budget option, requiring approximately \$3B per year in additional funding, a sound exploration program could be conducted. The reason for this seemingly “dead space” between the two budget options is, simplistically stated, that for sixty percent of the needed funds, one cannot go sixty percent of the way to Mars.

Each of the implementable options that was identified has its own set of benefits and liabilities that the Committee has sought to address. The findings of this effort are discussed in the Summary Report. The assessment gives overarching priority to safety and, as is noted in the Summary Report, the Committee believes considerable caution is in order when comparing analytical results in this area with flight results. Similarly, the Committee has sought to be conservative in its cost estimation practices—reflecting dissatisfaction with historical experience on a broad spectrum of programs. Finally, in defining a “Program of Record” the Committee has relied upon NASA’s current program plan and the President’s budget profile, the latter as provided by the Office of Management and Budget.

In the opinion of this Committee, as well as that of most of the persons with whom the Committee has had contact, NASA has for too long sought to operate in an environment where means do not match ends. In the unforgiving arena of human spaceflight this is a particularly hazardous policy to embrace.

The Committee also notes that NASA has become a mature organization, an organization long protected from restructuring Centers, facilities and personnel cadres. The consequence is an organization with high fixed costs of the type that make budgetary options highly limited. While NASA is unarguably the finest space organization in the world and a great national asset, it is overdue for a thorough management assessment of the type the aerospace industry underwent at the end of the cold war.

The Committee’s report will contain more detailed information that it hopes will prove of value. On behalf of my colleagues, I thank you for the trust that has been placed in us to review a pursuit which for decades has come to be a symbol of America’s leadership.

U.S. HUMAN SPACEFLIGHT PLANS COMMITTEE MEMBERS

Mr. Norman R. Augustine
Retired Chairman and CEO
Lockheed Martin Corporation

Dr. Wanda M. Austin
President and Chief Executive Officer
The Aerospace Corporation

Mr. Bohdan I. Bejmuk
Chair, NASA Constellation Standing Review Board

Dr. Leroy Chiao
Former Astronaut, Former International Space Station Commander and Engineering Consultant

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University of California, San Diego

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Dr. Sally Ride
President and Chief Executive Officer
Imaginary Lines

Senator NELSON. And since we have a vote and have 5½ minutes left, we will recess the Committee. We will come right back and get into the questions.

Thank you. The Committee is recessed.
[Recessed.]

Senator NELSON. The Committee will resume. Please excuse the interruption, but we were able to get two votes done on the floor.

Let me turn to Senator Vitter.

Senator VITTER. Thank you, Mr. Chairman.

Mr. Augustine, upon finding it impossible to identify a viable program with the out-year budget that we have now, your committee suggested an annual increase of roughly \$3 billion in NASA's top line, adjusted by inflation in future years at 2.4 percent. Can you give us a general sense of how you all arrived at those numbers?

Mr. AUGUSTINE. Senator, I would be happy to do that. We, first of all, analyzed the budget that we were given by OMB, which is today's baseline, of course. We then ran excursions.

The first excursion we ran was one that built up from today's budget to a \$3 billion add-on by 2014 and then goes up to 2.4 percent. We ran an excursion of \$1.5 billion and found that it really made little difference as compared with the baseline case. We ran an excursion at \$4 billion, and it gives you somewhat more latitude—more financial conservatism, if you will—than the \$3 billion case but doesn't let you do anything significantly new. So from the

various cases we ran, the \$3 billion run-out at the 2.4 percent inflation rate seemed to give us a very sound program.

Senator VITTER. OK. One of the consistent points that has been made up to now about the retirement of the Shuttle is basically that you take those funds and shift them over to next generation of vehicle development. And that has really always seemed to be the rationale for the whole idea of a clear retirement date for the Shuttle.

Your committee seemed to arrive at a very different conclusion in terms of the actual amount of financial wedge that would bring about. Can you describe the difference—this very different conclusion, and how you reached that very different conclusion?

Mr. AUGUSTINE. Yes, of course. First of all, our committee believes that we need to fund enough in 2011 to continue Shuttle launches through the first six months so that we don't have this compression of launches and pressure that tends to buildup, sometimes called "launch fever" in the vernacular.

The Committee—let us see. I lost my train of thought. Again, the question?

Senator VITTER. Explain the very different conclusion that you all reached versus the mindset of stopping the Shuttle by a more or less date certain and then being able to shift that money to next generation.

Mr. AUGUSTINE. Right. The common thinking up until now has been that stopping the Shuttle would free a substantial sum of money that, as you say, would let you do exploration in the future. But there are some offsets that one has to consider that I think probably haven't been considered adequately in the past.

One of those offsets is that if you were to continue the Shuttle operation, you would not presumably have to pay for the rides on the Russian launch vehicle. So, there is an offsetting saving.

In addition, as one looks at the costs of operating NASA, much of the overhead today gets billed to the Space Shuttle program just because the way the books are accounted for at NASA. So, if the Space Shuttle program stops, unless you make a major cut in NASA's overhead, and by overhead, I should say fixed costs rather than overhead. Unless you make a major cut in the fixed costs at NASA, then you have a situation where those costs have to be transferred somewhere, and the likely place for them to be transferred would be to the Constellation program, and so there is not really a saving. There is just a bookkeeping shift.

And when you go through these various nets and a few more minor things, it looks like the savings by shutting down the Shuttle fairly hard stop is on the order of \$2.5 billion a year, which is significantly less than some of the numbers that others quote.

Senator VITTER. OK. I think I understand your reasons for saying that as of now, we shouldn't plan on going to Mars in the way that has been described. We can't do it safely in that way based on our knowledge now.

My concern is that the way that will be interpreted is to basically take Mars off the table and, in doing so, suck most of the oxygen out of the room in terms of general interest in manned spaceflight. And to the average guy on the street, we are going to spend all this

money redoing what we have already done. What is the point in that?

Do you have a reaction to that concern about the public discussion and how that would be interpreted, or the sort of overarching political reaction to it?

Mr. AUGUSTINE. We very much shared that exact same concern and discussed it at some length. The report, when it is released, I think you will find puts a great deal of emphasis on the fact that Mars is to be the destination that we are aiming at and that there is some homework that has to be done on the way to Mars. And that homework includes such things as effects of long-term zero Gs on humans that then go into a less than one-G environment, the effects of galactic cosmic rays on humans, information you can't get from the Space Station, various operational things that one might need to do to go to Mars. So, our message has been to make very clear that Mars is still the goal, but we are just not ready to go directly there today. But we do intend to get there.

Senator VITTER. Well, I would really underscore that concern. And again, I am not arguing with either your analysis or what you intend to communicate. I am arguing about how it may come across.

Let me go at the same issue another way. What, short of Mars, in this list of possibilities, is there that is new and different and that can really excite a lot of people that we haven't done before?

Mr. AUGUSTINE. To the point of your question, we defined a "Flexible Path" option. If you happen to be following in our report, it is, Option 5. A concern we had, even if you were to set out for Mars today, you have about a 15-, 20-year period during which we don't get to Mars. How do you hold the public's interest when you say send money and in 20 years, we will put a flag on Mars?

So we tried to define a program called this "Flexible Path" program that has intermediate milestones where, as you go along, you could have things that not only engineers could point to, but the average citizen would look at and say was significant. We think those intermediate milestones would include, the most straightforward of which is circumnavigating the Moon. Another, is possibly landing on the Moon, although we don't think that is mandatory.

Another, would be to circumnavigate Mars, with humans I am talking about. Another, that is of interest would be to dock with an asteroid and not only for the scientific interest, but to begin to learn how you conduct operations like that. And should some day we find a large asteroid flying in the direction of the Earth, it would be nice to know how to dock with it, what they are made of, and so on, what role humans might play.

Then there is a possibility of landing on a Mars moon, Phobos or Deimos, with the notion that not only would that be an interesting place to land from a scientific standpoint, it is also interesting in terms of helping conduct robotic exploration of Mars. The presumption our committee has is that well before we go to Mars with humans, we would send additional explorers there.

But, it is relatively difficult to operate a robot on Mars, in part because of the transit time for communications. Even at the speed of light, you are talking about tens of minutes to get a signal out

and get a signal back, depending where you are in the orbit. With that, it is very hard to operate a rover or something on Mars.

The notion has been put out that if you had astronauts on one of the moons, where the transit time to the surface of Mars is very small, that the astronauts on the moons could operate explorers on the planet and learn a great deal before you committed a human to landing on the planet Mars. This is a much easier task probably because if you think of it, the scientists talk about space as having gravity wells in it that once you get into one of those wells, it takes a lot of energy to get out of it. You are probably familiar with this. The Earth is a very deep gravity well. Mars is a deep gravity well. The moons of Mars are quite shallow. It offers a nice promising approach.

Another place that is of interest, is what are called Lagrangian points that are points in space when you have two large bodies and a small body, or three bodies, where that point, if you put a spacecraft there, it will essentially remain fixed in that relative position to the two large objects—in this case, the Moon and the Earth.

Some of those points are stable in the sense that if you put a spacecraft there, it will stay there. Others, it will very slowly try to drift away, and you have to push it back. Those points are interesting to put telescopes. They are interesting for refueling stations, filling stations in space, and we could fly to one of those.

So it is our belief there are a lot of exciting things that one could do along the way.

Senator VITTER. OK. Thank you.

Mr. Chairman, I have several other questions, but let me defer to someone else for now.

Senator NELSON. Mr. Augustine, right out of the box, the President is going to have to answer the question whether or not the cost of human space exploration is worth it. So I think, as I said at your opening hearing in Washington months ago, that the report of your committee is going to be very decisive in influencing the White House.

Why don't you just state for the record what your committee feels about the cost of human exploration being worth it?

Mr. AUGUSTINE. It is a question that we obviously addressed and one that I wish I could provide an answer better than I am able to. The reason I say that is our committee wasn't in a position to compare—it is a question that says where would you spend that money? There are other places you could spend it.

We don't have background in healthcare. We don't have background in many of the other things that you face. So, I will try to answer the question, with that caveat, that really it is only the President, and perhaps yourselves, who can make that judgment.

We think that the argument about human spaceflight being worthwhile because, for example, of the science it gathers has been an unfortunate argument to make because we don't think that you can justify the human spaceflight cost based upon the benefits it gives to science. Nor do we think you can justify it purely on the basis of the impact on technology or the impact of education.

All those things are important. It, indeed, has a positive impact. But we think we have, to put it very bluntly, trapped ourselves by

trying to justify human spaceflight because of the benefits to science or what have you.

We think the justification has to be an intangible justification. It is a justification that says that the purpose is to prepare a path to put human beings into the solar system which shows America's leadership, the benefits of the American system, the leadership of our technology.

It provides inspiration to our students, to our young people to go into math and science. It can have the kind of an impact that the Apollo 11 had during a time of some travail in our country. These are intangibles, but we think they are not unimportant. We think they are important. We don't diminish or minimize these other benefits. They are real. They are there. But they, by themselves, probably don't justify a human spaceflight program.

The question—and I will stop in a moment here, Mr. Chairman. The question, of course, arises perhaps should you spend money on human spaceflight or on cancer research? I would argue that that is an unfair question. We live in a nation where we spent \$7 billion gambling on the Super Bowl last year. We spent \$32 billion on videos and going to the movies. We spent I think it is \$65 billion on illegal drugs. It is clear to me that this Nation could afford—I am speaking for myself now—it is clear to me that this Nation could afford a strong human spaceflight program. It is simply a question of priority.

Senator NELSON. As your committee discussed these intangible benefits, no doubt you noted also some of the tangible benefits. What do you think they are, as we continue to push forward?

Mr. AUGUSTINE. Let me take the International Space Station as an example, if I may? We spent over two decades constructing the ISS, and we now are talking about using it for only 5 years. During those 5 years, we don't have much money available to pay for the science that would produce these tangible benefits.

There at one point was a large number of scientists who wanted to conduct science on the Station. They have somewhat dwindled away because of the slips in the program and the lack of funds. Given funds, there is significant microgravity work to be done. There is significant biosciences work to be done.

We have done some amazing things in terms of technical operations. Extravehicular activity has become—I am not going to use the word almost routine, but certainly more common. We know how to do that. We know how to dock routinely, and there are benefits like that.

In addition, there are always the spinoffs that one gets where you develop technologies for the Space Station or for other things in space that impact commercial products.

Senator NELSON. Senator Hutchison?

Senator HUTCHISON. Yes. If I understand correctly, and you correct me if I am wrong, yesterday in the House, you indicated that, if adequately funded, the Constellation program currently underway is a good program and coupled with the Shuttle flight continuation until a replacement human-rated capability is developed, either through Ares or commercial vendor, that the gap in human spaceflight could be closed and the International Space Station support and utilization could be ensured.

Is that your view? And is, in your view, the \$3 billion, with the cost of living or 2.4 percent increases per year, adequate for that kind of approach?

Mr. AUGUSTINE. Yes, let me try to be clear. It would not be our view that you could conduct that kind of a program with the existing budget. It would be our view that with the \$3 billion inflated profile that you, indeed, could conduct such a program. As you know, there are no funds to take the ISS in the current program beyond 2010. Excuse me, 2015. The Shuttle, 2010.

Senator HUTCHISON. And is it also your view that the Constellation program, together with an extension of the Shuttle flight program, would be a good approach to closing the gap and utilizing the Space Station?

Mr. AUGUSTINE. We looked at a lot of options to try to close the gap, and it is our view that the gap is likely to be more like 7 years instead of the 5 years that people have talked about. The only option we could find, viable option to close that gap is to continue to operate the Space Shuttle.

To do that, one, of course, has to commit funds to the Shuttle that otherwise could be spent preparing for the exploration program. And one would certainly have to recertify the Shuttle to be sure that safety issues were taken care of. But the answer to the question is not only is the Shuttle a way to close the gap, it is probably the only way to close the gap.

Senator HUTCHISON. So you think that option is an acceptable—I know you didn't pick a recommendation, but that that would be an acceptable option?

Mr. AUGUSTINE. It is a viable option, yes.

Senator HUTCHISON. Yes. And then on the safety issue, do you believe that the *Columbia* accident investigation recertification standards are adequate, and if those were continued to be met that that would—you could never ensure safety because you never know all the factors—would it give us a solid safety assurance for continuation of the Shuttle—for as much as you can ensure that?

Mr. AUGUSTINE. Yes. I appreciate your qualifying that. One of the frustrating things to an engineer like myself is that 90 percent of the reliability failures that we encounter, and I separate that from safety, but 90 percent of them come from causes that aren't even in our models. They are a human error. They are a design flaw.

With that caveat, it is our belief that were NASA to complete those requalification steps that we could continue with reasonable safety. We base that partly—of course, one of our members, Dr. Sally Ride, was a member of the *Columbia* and also the *Challenger* failure evaluations. But it is our belief that that could be done.

Senator HUTCHISON. OK. On the issue of the commercial development, I have been certainly a supporter of the COTS, the Commercial Orbital Transportation System. I think that is a viable area for private investment and also for a kind of a fallback position where we need it.

But I do want to ask you if we pursue that private capability, but do not also have the Orion or the Ares ready to go and we still have a potential gap in our own NASA capabilities, do you think that exclusive reliance on the commercial development is justifiable

in the face of the need to utilize the Space Station, or does that concern you?

Mr. AUGUSTINE. The reason we offered options that depend heavily on commercial development are that we are trying to free NASA's money and talent to tackle the tough problems of going beyond Earth orbit rather than running a trucking service to Earth orbit.

We think we are in a situation a little like the airlines were when the Government stepped in and awarded contracts to carry the mail. That was the thing that made the airlines viable.

Today, NASA has and NASA is pursuing this opportunity that you describe. It certainly bears risk. Many of the firms that are involved have not built major launch systems. In our evaluations, we were particularly conservative in assessing their capabilities.

For example, some of them claim that they can have vehicles ready within 3 years. We think it is more like 6 years. But certainly, there is no reason that these companies can't produce a viable capability, given the support of NASA.

Senator HUTCHISON. And would you be comfortable that they could provide that service to try to fill the gap and that that is reliable enough?

Mr. AUGUSTINE. I think the answer is yes. But fortunately, we don't have to answer that at this moment. But there are other alternatives available, including French launch vehicles, continue to use the Russian launch vehicles, none of which are attractive to me as an American, although I believe in international programs. I believe that if you are going to have international programs that are meaningful, we are going to have to get used to having other nations on the critical path.

At the same time, there is no more critical path, I think, than being able to carry astronauts to low-Earth orbit, and that might be the one exception where I think we should have a capability. So my answer is there is risk, nontrivial risk. But in our mind, it is a risk worth taking.

Senator HUTCHISON. Thank you.

Thank you, Mr. Chairman.

Senator NELSON. Following up Senator Hutchison's question on commercial capability, you are really looking at the cargo capability on commercial, because the next step, the question of safety, for human capability, what did your committee come up with on that?

Mr. AUGUSTINE. It would be our recommendation that as NASA develops new launch vehicles, most new launch vehicles, that it would make arrangements so that they could be human-rated at an appropriate time. So, we think it would be wise to begin addressing how would you human-rate those commercial vehicles?

Senator NELSON. Did your committee have a time at which you think that they might be ready for human-rated commercial vehicles?

Mr. AUGUSTINE. I think, Mr. Chairman, I better provide that for the record. We did evaluate that, and I can't remember the time. It is not within the next 6 years or so. I will provide that for the record.

[The information referred to follows:]

The Committee estimated that commercial crew services could begin approximately 6–7 years after they were initiated.

Senator NELSON. Senator Vitter?

Senator VITTER. So, to directly follow up on that, is that to say that you would agree with ASAP in their 2008 report that it is unlikely that COTS would be done in time, human rated, to minimize the gap?

Mr. AUGUSTINE. That is our view.

Senator VITTER. OK. Going back to the gap and extending the Shuttle, if you extend the Shuttle at least slightly into 2011, as you have talked about, simply to ensure that there is no launch fever, but not beyond that, and you accept a gap versus extending the Shuttle beyond that to close a gap, how much—let me put it this way—how much do you sacrifice in extending the Shuttle beyond that to close all the gap in terms of pushing forward next-generation activity?

Mr. AUGUSTINE. I am doing this calculation mentally, but it would probably be about \$18 billion over to close the gap by using the Shuttle would be the incremental cost.

Senator VITTER. And what does that translate into time, in terms of otherwise using it to pull next-generation forward?

Mr. AUGUSTINE. Well, I guess the way I would characterize that would be if it would let you go with the \$3 billion additional profile for 6 years. These are not precise numbers, Senator Vitter. But I think the most important thing is not so much the time it pulls forward, but when you reach these big milestones of having new launch vehicles, you would have money to develop things to put on top of them to go somewhere.

Senator VITTER. Wouldn't you also presumably develop the new launch vehicles at least somewhat sooner?

Mr. AUGUSTINE. If you have used that money, you would probably be able to accelerate the launch vehicle some, but I don't think it would be—certainly, if you spent the money, for example, on the Ares V, you could clearly drive forward, and I don't know the amount, but probably significantly.

Senator VITTER. I am not asking for a yes/no answer. How would you suggest we analyze that difference? In other words, extend the Shuttle and close the gap versus accept a gap, try to minimize it, but be able to use that money toward where we are ultimately going?

Mr. AUGUSTINE. We did do that analysis, and we will provide it. It was our conclusion that continuing the Shuttle to close the gap is a viable option, and it is one of the options we offered.

The rationale, benefits, and liabilities of each of the options put forth by the Committee, including the option that extends Shuttle operations to 2015, are provided in the Committee's Final Report. See pages 86 and 87 specifically for a discussion of Option 4B which extends the operations of the Shuttle to 2015.

I am trying very hard not to make a recommendation here. But it runs into the problem that the more money you spend in the near term, the less you can do in the exploratory program. The cost of continuing to operate the Shuttle is quite high.

Senator VITTER. Well, that is where I was going. So you would certainly agree with my reaction to those figures that that is a lot of money—

Mr. AUGUSTINE. Indeed.

Senator VITTER.—to continue the Shuttle. You know, I represent Louisiana, which includes Michoud. I am all for the external fuel tanks. But my concern is once you start putting off the next generation that much, you threaten ever getting there. You threaten really building a consensus and a reality that people think we are ever going to get there, and so we don't.

Do you have a reaction to that?

Mr. AUGUSTINE. Yes, I think you are coming back to the fundamental problem of NASA's, and that is that with the budget constraints it has had on it, it doesn't have enough money to develop the next-generation system while it continues to operate the current system. So, the consequence of that today is the gap with which most of us are not particularly happy.

There will be another problem, when we complete the Ares I, there will be another gap. What are we going to do with the Ares I and the Orion once we get them? When we complete the Ares V, there will be no lunar excursion module, if you will, lunar lander, nor a surface system to use it. So this may be just the first of three or four gaps.

Senator VITTER. And so, just to be clear, this concern of mine in terms of this trade-off isn't solved by the extra \$3 billion? I mean, that mitigates it, but that trade-off is still there, even at the higher funding levels you are talking about.

Mr. AUGUSTINE. The programs we have that add on the \$3 billion, one of them includes the Shuttle and it has the problems we have just discussed. The other ones did not include the extension of the Shuttle beyond mid 2011.

Senator VITTER. OK. That is all I have right now, Mr. Chairman.

Senator NELSON. I want to ask a series of questions around the major themes of your report. If we are going to have a robust human space program we are going to have to commit the resources to it. You have specifically talked about \$3 billion a year.

Your architecture is various, and engineers such as yourself and NASA leadership are going to have to determine that architecture. But the goal that the Committee has set is to get out beyond low-Earth orbit, that NASA ought to be exploring the heavens with the human space program. In the meantime, we have got to worry about the work force.

I want to pick up on those three themes, which I think are going to be the major themes that the President is going to have to make his decision on. You came up with this idea of \$3 billion a year. If you had additional resources, what would you do?

Mr. AUGUSTINE. Beyond the \$3 billion? The primary things that we think need to be done in the near future are largely covered in the \$3 billion figure. If you had additional funds, you would be able to probably move forward somewhat some of the work on Ares I, but I think it would be a modest amount that you could accelerate that. You could clearly move Ares V forward or an alternative to Ares V, which would be very important because that really is the long pole in our space exploration tent.

Senator NELSON. Is the Ares V?

Mr. AUGUSTINE. Is a heavy-lift capability of which—

Senator NELSON. Heavy-lift capability.

Mr. AUGUSTINE.—the Ares V is a good example.

Senator NELSON. So you have come up with the idea, a consensus that you feel like the \$3 billion is enough in order to support a robust human spaceflight program in the near term without having to shortchange other missions in science and aeronautics?

Mr. AUGUSTINE. We believe that is true. We, of course, assume good management of that additional money, which there is every reason to believe we would have. We have also proposed creating a firewall between the human spaceflight funding—and I emphasize funding, not technology or mutual support—and the science program. As we all know, the human spaceflight program is so large that when it has problems, it tends to cannibalize the science program.

Senator NELSON. Do you feel that the realities of this gap are unavoidable and the fact that we are going to have this gap, with that \$3 billion, that you can keep things going by developing the new technologies on down the line in order to maintain the most robust human spaceflight program?

Mr. AUGUSTINE. To eliminate the gap or significantly reduce it would have a significant negative impact on the long-term exploration program. I think the gap is something that we are presented with based on decisions that were made in the past, perhaps good decisions. I don't know. But I think that we are, to a considerable degree, stuck with a gap.

Senator NELSON. Did the committee look at taking the Constellation program, as it has been defined, and see how much it would cost to execute the Constellation program?

Mr. AUGUSTINE. We did. This \$3 billion profile that is added permits either the Constellation or several other options to be carried out. So the answer is we did, and it can be done.

Senator NELSON. But according to one of your charts, which we can show up here, in what you called the less constrained budget, in other words, the \$3 billion additional each year, with Ares V as the heavy launch and with Ares I and Orion as the crew to LEO, which is the Constellation program as envisioned now, under that funding scenario, lo and behold, the Space Station is going to go in the drink in 2015.

Your committee also said that is unacceptable. I happen to agree with you. Why would we spend \$100 billion building the Space Station and then put it in the Pacific? But that is what the funding profile is for that \$3 billion and with an extension of Constellation. Is it not?

Mr. AUGUSTINE. Yes. I think you are—I can't see that chart. But I think you are referring to Option 3?

Senator NELSON. It is Option 3.

Mr. AUGUSTINE. Option 3 was intended to take the baseline Program of Record, apply a less constrained budget to it, just as we did in the other cases. The Program of Record, as you say, splashes the ISS in early 2016, completes the flight, the use of it in 2015.

Senator NELSON. Well, how is it, with what you call the constrained budget, which is the present, and inadequate I will say, OMB budget. I will not ascribe that to the President.

Mr. AUGUSTINE. Nor me, I hope.

Senator NELSON. Yes, what you just said I think is very important. What you just said, "I hope." From your lips to the President's ears.

Option Number 1—constrained. You could do that. No \$3 billion extra. You are still putting the ISS in the ditch in 2015, and you have got Ares V and Ares I. So what are you buying extra from Option 1 to Option 3? In Option 3, you are getting an additional \$3 billion.

Mr. AUGUSTINE. Option 1 is the Program of Record, of course, with the current funding, and with that, you basically get launch vehicles with nothing to put on top of them. I am oversimplifying here, Mr. Chairman.

With Option 3, you are able to develop the Ares V at an earlier time. You are able to carry the International Space Station for an additional 5 years. We have also provided the full amount of money one needs to de-orbit the International Space Station in that option. One gets a technology program that is rather substantial to begin laying work for the exploration program, and one gets funding to carry out science and technology onboard the ISS over that 10-year period.

Senator NELSON. I think that is the answer. It is the additional science and technology that you get under that. But let me just point out that on the chart—and maybe the chart needs to be refined before your final report comes out—Option 1 and 3 are a difference of \$3 billion, and yet it looks like they present the same result because in Option 3, you are putting the Space Station in the Pacific in 2015. The difference with Option 4 is that you have replaced Ares I and Orion with a commercial vehicle to get to low-Earth orbit.

Mr. AUGUSTINE. Your point is a very good one. This chart is somewhat misleading in that regard. There is also the matter that the dates change when things become available. For example, under Option 1, you are probably in the 2030s when you can conduct human exploration missions. That is our view. It is not necessarily NASA's view. Whereas, under Option 3, you could do it considerably earlier.

Senator NELSON. Since we have a consensus of opinion that we need to get NASA out of LEO, do you have a preference on the architecture? I know you said you are not in the business of recommending a specific course, but do you have any personal feelings that you want to share with the Committee?

Mr. AUGUSTINE. Well, Mr. Chairman, we have all tried very hard to not put you or the President in a position where we have come out and endorsed an option and that you then, if you don't agree with it, have to rebut that. So my answer is that I think I could speak for the Committee that Options 1 and 2 we deem to be just not viable. Of the remaining three primary options, each has some advantages and some disadvantages.

Our committee has never discussed what our personal preferences are. By intent, we have not done that. So I have no idea

what my colleagues believe. I would go so far as to say that these flexible path options are particularly interesting to me because I am concerned that if we commit to going to the Moon, there is a reaction—as a primary objective, many people’s reaction is, “Well, we did that years ago. Why do that again?”

If we take down the ISS so you don’t have things happening between 2015 and 2020, you have the problem you just described, Mr. Chairman. If you say we will go to Mars right after the Moon, there is such a long period of time that how do you excite young engineers to want to commit their career to that? How do you excite taxpayers to want to pay for that?

There is great merit to having some interim milestones along the way to Mars, still going to Mars ultimately. But where you can point to significant technical engineering, scientific, if you will, advantages and accomplishments.

What I am saying, to be more specific, is that, clearly, Option 5 carries that opportunity. Now you can marry that opportunity with some of the other options as well, and indeed, we have done that with Option 5A, for example, which ties into a version of the Ares V.

Senator NELSON. At the end of October this year, NASA is well on the way to doing a full-up flight test of the Ares I, what they call X. It’s the four segments of existing solid rocket boosters with a dummy fifth segment, Orion, on the top. To fly it, see its dynamics, the avionics, et cetera.

Did your committee discuss any attitude about that particular test that is right down the pike less than 6 weeks away?

Mr. AUGUSTINE. The Committee did not discuss that. I did discuss it, myself, with the Administrator of NASA, and that is, of course, his call to make. I have enormous respect for his ability and judgment.

Were it my call, I would fly it. The reason is we will gain technical knowledge that we have paid a great deal to get, and we should get it.

If we continue with the Ares I program, it is an important step. And if we don’t continue with it, it is an important piece of information to have that relates to the Ares V and other possible options. It is our committee’s view that the Ares I, while it has technical problems, some not insignificant, there is no reason to believe that good engineering and sufficient funds won’t make the Ares I a very good vehicle in time.

Senator NELSON. Let us talk about my third major category that I think that the President is going to have to look to in making his decision. How is he going to keep this extraordinarily talented workforce operating? Share with us what your committee deliberated about that.

Mr. AUGUSTINE. That is a very key part of this whole question. Needless to say, this is a rather esoteric business. It takes years, I have observed, to begin to understand some of the subtleties and to gain the culture that goes with launching rockets. One of the reasons being that this is such an unforgiving business. We generally don’t get recalls in this business.

NASA has, without question, the largest talent base in the world today to conduct space activities, both human and robotic. That is

a national treasure to us. The options we have offered, beyond the two that I have suggested are probably not viable; all have about the same overall budget, and unless one makes a major shift in how one conducts business, the overall NASA employment should stay about the same. However, the mix of that employment will certainly change. We will need different talents.

For example, if we terminate the Shuttle in 2010 or early 2011, the people who have been focusing on launching shuttles are different people probably than some who would be needed to build an Ares or an Ares I or an Ares V or whatever, a shuttle-derived vehicle. So there will be changes in skill.

We looked at two kinds of asset when it comes to human talent. One is just the overall work force, namely jobs. Not an unimportant subject at this time. On the other hand, it is our view that it would be tragic to view NASA as a jobs program. NASA has so much more to offer than just creating jobs.

The other we looked at are those critical skills that only people at NASA or in the industry are likely to have. Those we think are very important to preserve, and we need to consciously go out and do that. An example would be the large, segmented solid rocket motors. It is an art, as well as a science, to build those things safely. If we lose that capability, it will be very hard to get back.

Ability to work with liquid hydrogen, liquid oxygen—we would like to see us learn how to do that in space as well as here on Earth. So those special skills we have to find a way to preserve for sure.

And I guess, Mr. Chairman, if I could extend your question just a little bit, one last comment, and that would be that NASA has, as I said before, a very high fixed cost base. It makes it extremely hard to create new opportunities and options when you have that fixed cost base.

Part of that fixed cost base is the centers, the work force, the facilities, and it would be our hope that the President and the Congress would give the Administrator of NASA a great deal of latitude to manage the resources that he is responsible for.

Senator NELSON. I want to underscore that very important comment so that these dislocations of the work force, albeit as you said with the more robust funding is going to keep NASA at a fairly level amount of employment, that is going to change among the different centers according to what their particular workforce does.

Needless to say, in consideration of if we are not launching humans on an American vehicle, there are going to be less launches at, for example, the Kennedy Space Center, even though we might be building the new rocket with the new technologies and the new money that you have laid out. I hope that the President and the Congress will give the Administrator exactly what you said, the flexibility so that he could utilize that workforce in different places with different missions so as to minimize the economic devastation.

In this regard, I will put on my parochial hat. The center that is going to get hit the hardest is the Kennedy Space Center because of the smaller number of launches of humans. If, for example, the President were to pick the commercial option, that would ameliorate some of the layoffs, but it is not going to step in. We need to

give the Administrator of NASA a lot of flexibility there. So thank you for that statement.

I want to ask you, what if you had more time? You had 90 days. If you had more time, do you think the results would change?

Mr. AUGUSTINE. Well, the first thing that would have happened would have been my wife would have divorced me.

[Laughter.]

Senator NELSON. I understand.

Mr. AUGUSTINE. All 10 of us, of course, have regular jobs, so to speak, and when we began, I questioned whether 90 days was adequate to take on a task of this type. We clearly could have done a more thorough analysis given more time.

But it is also my belief that if the differences are small between the new options and the current program, we should stick with the current program. I think we are not discussing small differences. There need to be significant differences, and those are the kinds of things we tried to identify. Our conclusion was that it would have been easier for us and we would have been able to get the third significant figure much more accurately. But, in terms of the basic thrust of the options we have offered and their assessment, I think we can stand behind them.

Senator NELSON. You had testified earlier that your panel's recommendations are to not rush the Shuttle fly-out and keep safety paramount. Which, by the way, parenthetically, I assume will be a theme that will run throughout your report once it is produced publicly. Of these items, safety has to be paramount, given the very tragic experience that we have had in the past.

You indicated in your testimony that you thought that it is realistic to think that at least part, if not all, of Fiscal Year 2011 would be consumed by the fly out of the Shuttle and the remaining missions to supply and equip the Space Station.

Did you attach a dollar figure to 2011 in that fly out? Since the President's budget right now, and I will refer it to the OMB budget, and I say that sarcastically, only provides for Fiscal Year 2010 for the fly-out of the Shuttle. Did you attach a cost to it?

Mr. AUGUSTINE. We did, and we have spoken with OMB about it. They are aware of the number. I can't speak for OMB, obviously. My recollection is the number is like \$1.5 billion. But, Mr. Chairman, you should check that to be exact.

It is our view that that is very important to add that to the Fiscal Year 2011 budget, and as you say, it is not there today. The problem with it not being there is it introduces pressure on getting the launch off by a given time. I referred to that as launch fever, something we always tried to fight in the company I used to serve.

It is a subtle pressure, and the *Challenger* CAIB spoke to that pressure as one of the causes, they thought, of the *Challenger* accident. Having said this, I would hasten to add we have spent a good deal of time talking with the people who are responsible for launching the remaining Shuttles, the six remaining ones. They are very conscious of this. They are taking an attitude that they won't be hurried.

I think they are doing everything right. The problem is they are going to run off of a budget cliff 12 months from now, and we need

to fix that for them. I think if we do, they will manage things very properly.

Senator NELSON. I have been amazed as I have watched this entire space team knowing that the Space Shuttle is likely to come to an end, and they haven't missed a beat with still high morale. To me, I am just amazed and very appreciative.

Mr. AUGUSTINE. And I say, too, I never cease to be amazed when having to close a plant, terminate a program, of the commitment of the people to doing just what you said, and that is particularly true in the space arena and the defense arena, where what they are doing is more than building widgets.

Senator NELSON. That is correct. And thank you for putting that on the record. I think it is important that the White House and OMB hear what you just said. The Congress has provided in its budget for the out-year 2011 an additional budget authorization of \$2.5 billion in order to fly out the Space Shuttle in year 2011, but that is in a budget planning document. It has to be put into reality, and only the White House can do that with the Congress concurring.

What is your opinion about a constant source of funding and an adherence to a defined plan once the option is chosen as a key success for NASA's future?

Mr. AUGUSTINE. That clearly would be a key factor to success, particularly if that number included a reserve to account for the unforeseen—reserve in time, reserve in funds, reserve in technology. It is almost impossible, as you know, to manage a program that goes out to the year 2030 when you don't know what the funding commitment is and when you have to redesign the program each year.

This is a program that probably involves tens of thousands of contracts and subcontractor agreements. When you change the budget, you have to renegotiate those, and rarely do they go down when you renegotiate. So your total costs go up.

Stability of funding would have an enormously positive impact. Having said that, I also recognize the difficulties that you face in your chair when you don't know that the economy is going to collapse on us a year ago and that the Government's receipts are going to drop. It is not clear to me how one can guarantee a program budget for the kind of time period it takes to undertake these major pursuits. But, anything that can be done by the Congress and the White House to put stability in the funding and to let the NASA leadership know ahead of time what that funding is going to be so that they don't have to guess would be one of the greatest contributions you could make to the human spaceflight program or to any spaceflight program.

Senator NELSON. Let's talk about these options in 4A through the end, where the crew to low-Earth orbit is launched by the commercial provider instead of a NASA vehicle. You know the history of developing spacecraft. Do you think that you really could have one of these commercial operators able to get a human crew up to the Space Station in 7 years?

Mr. AUGUSTINE. I think if you were to have several paths with several operators, several commercial firms, not necessarily only the smaller firms that are very quick on their feet, but also some

of the larger, more experienced firms that are probably less quick on their feet but have more scar tissue, I think if you could have several firms involved through a competition that the chances would be very good that one would have a success.

I think back to earlier in my career when we had ICBMs as launch vehicles. You are familiar. I speak to the Titan and the Atlas. ICBMs in those days when I was involved were designed to reliabilities that don't even approach the reliabilities we talk about today for human-rated vehicles, and yet we did find a way to—we called it man rating in those days, incorrectly. We did find a way to man-rate those vehicles and to use them in the Gemini and the Mercury program, and they performed very well.

There is no fundamental physical reason why this shouldn't be possible, but I would say again it is not without risk. There are backups that one can consider that is other launch vehicles, including foreign launch vehicles, during that period of time.

Senator NELSON. And so, when it comes to U.S. commercial cargo capability, your committee felt pretty confident of that capability?

Mr. AUGUSTINE. I think that is true, and NASA has, of course, embraced this idea, provided NASA technical oversight and NASA help, which gives me greater assurance. These firms have some very talented people, and I think there is every reason to believe that they can be successful.

Senator NELSON. Do you want to talk to us about the differences between the Ares V heavy capability and your discussions as an alternative to an Ares V Lite?

Mr. AUGUSTINE. I would be glad to do that. The Ares V, of course, is part of the current Program of Record, although, unfortunately, it has not been able to be funded because to keep the budget for the Ares I and the Orion unchanged, we have been delayed in starting the Ares V and things that might go with it.

The Ares V Lite is very similar to the Ares V, but it has less payload capability, and the basic measure, as you know, it is 150 metric tons. See, am I getting mixed—140 metric tons, I guess, for the Ares V and 130, I think, for the—there is about a 20-metric ton difference in terms of payload throw-weight.

The Ares V Lite basically has one less engine, has half a segment less on the solids, and can be designed to have more margin. That is important to us because the Ares V, even today, many years from first launch, has very shallow margins. If there is one thing we have learned, it is that having margins is the blessing of the space program, to be able to de-rate things.

The Ares V would be used in companion with an Ares I that is referred to by NASA as "Ares I and a half." Whereas, the Ares V Lite would be used with another Ares V as its companion. That also has the advantage that you only have to have spares at launch facilities and so on for one launch vehicle of the type. So you would use two Ares V, which gives you—my numbers, for some reason, are escaping me at the moment. But let me just check.

Senator NELSON. It is 160 metric tons for the Ares V, and for the Lite, it is 143 metric tons.

Mr. AUGUSTINE. That is why I couldn't make it work, thank you. So, you have 320 metric tons throw-weight with the 2 Ares IV Lites, and you have 40 less—excuse me, you have, well, substan-

tially less throw-weight with an Ares I/Ares V combination. So we think there is a good deal of merit to the Ares V Lite approach. The disadvantage, of course, is that the Ares I is partly developed, and the Ares V is not.

Senator NELSON. And according to your much more complicated chart, you could have the Ares V Lite ready to go in the early 2020s, if you went the flexible path, if you went to the Moon first. So it would be the early 2020s.

Of course, you remember that the President said in the campaign, he wanted to be on the Moon by 2020. So that is pretty much out the window according to your panel, isn't it?

Mr. AUGUSTINE. That is true.

Senator NELSON. So you are talking early 2020s you could have Ares V Lite ready, and you would have a scenario by which you could get Ares V up with a crew with a lunar vehicle and do rendezvous perhaps in lunar orbit?

Mr. AUGUSTINE. We are speaking to the larger budget level, of course, and the answer would be yes.

Senator NELSON. Yes. Do you want to for the record give me any comments about the alternative on the EELVs, the expendable launch vehicles?

Mr. AUGUSTINE. Yes, the expendable launch vehicle family, of course, is one that has been with us for many years, traces its history to the ICBM programs, in fact, and has been extended by the Department of Defense. These vehicles have been used in various forms, some not yet in the form or carrying the full throw-weight that would be needed for this mission. The vehicles are proven. They are not human-rated, and they would require additional development. They offer a legitimate alternative. They also offer the advantage that the Department of Defense and the intelligence community might find them useful, and we could have some savings there. That offers the disadvantage of having to coordinate vehicles coming down the line of who gets what and who gets first priority.

But it would be our committee's view that the EELV family is a viable option worthy of consideration, and we have not attempted to make specific choices here, in part because it would require a great deal more analysis than we have done in addition to our not wanting to take a position. It is a choice that good engineering can make.

Senator NELSON. I am curious. One of the earlier years of accomplishment is under using an EELV, going the flexible path, and you are looking at the years 2015–2016. Can you comment on that?

Mr. AUGUSTINE. Yes. The reason for that, of course, is that the goal is changed. The goal is a much less demanding one under this flexible path option.

Senator NELSON. So that would still get you out on things like asteroids or one of the Martian moons utilizing an EELV?

Mr. AUGUSTINE. Yes, and human-rated.

Senator NELSON. And you could do that within the span of 2015–2016?

Mr. AUGUSTINE. No. No, it would be well beyond that. I, unfortunately, don't have the numbers here with me, but it would be well beyond that.

Senator NELSON. OK. I was looking from this complicated chart.

Mr. AUGUSTINE. Yes. I don't have that chart here.

Senator NELSON. Right. Well, under that plan on this same chart, you would be late 2020s with an actual landing on the Moon?

Mr. AUGUSTINE. That sounds more correct.

Senator NELSON. Did your committee discuss an Atlas or a Delta on the EELVs?

Mr. AUGUSTINE. We did. They are both certainly plausible candidates. Oh, I do have it. Thank you.

Senator NELSON. How did your committee arrive at the cost estimates for the different options?

Mr. AUGUSTINE. The Committee, as I mentioned, hired the Aerospace Corporation to assist us in this regard, and we also had a good deal of help from NASA. We obtained the NASA estimates that they have and the probabilities of confidence levels that go with them.

The Aerospace Corporation has some models that are based on a large number of prior programs. I believe it is 77 prior space programs. Those models show correction factors to account for real-world experiences compared with estimates that were made at various points in those programs.

We took the work—I should say “we,” the Aerospace Corporation took the work breakdown structure line-by-line and considered what was the maturity of the work under that line item. Is this a component that exists? In which case the factor they would add was 1.0. If it was a component that was just beginning, depending on the kind of component, on average, they have used a factor of about 1.5. If you go through that whole set of items, the average is about a 1.25 factor they have used in estimating cost.

The factors, as I say, weigh in the maturity of the item in question, and so that tends to reduce the factor that was added somewhat more. NASA has raised the point that they consider that some of these factors or, in fact, many of them were included in their original estimates and that when Aerospace has taken this step, they have double counted.

The Aerospace Corporation and ourselves believes that is not the case, and even if it is the case, it is unlikely that we have been too conservative. I will give you one reason. That if you look at the set of programs that the Aerospace Corporation uses to derive the factors—I think it is 77 programs—for the whole set of programs, they have a given factor.

If you take only the human spaceflight programs from that set, you have a factor that is almost twice as great. Even if we have double counted, chances are we have double counted on the order of 10 percent or so, and experience would suggest that is probably not a bad thing to do.

Senator NELSON. How do you answer this question that we have spent \$8 billion thus far on the present architecture, which includes Ares I, and now we are going to abandon that, having spent \$8 billion?

Mr. AUGUSTINE. My answer is that we have offered a set of five options. We have not suggested abandoning Ares I. Some of the options do abandon it. We could continue with Ares I, no question

about it. The same thing, we could continue with the Space Shuttle. We could have ISS longer.

It gets to be a question that if you do all of those things, you just don't get to do some of the things in the future like build an Ares V or a heavy-lift vehicle, which we think is what this Nation has badly needed, frankly, since the first of these studies I was involved in and recommended at that time.

So Ares I, in our mind, we haven't recommended that it either be continued or that it be abandoned. If it were to be abandoned, we think there ought to be compelling reasons to abandon it. One of the strong sentiments I have derived in my career is that constantly changing programs is one of the worst things you could do, and you should only make changes for very compelling reasons.

We have offered the pros and cons, and it is up to the reader to judge what the definition of compelling is in their mind. There are liabilities to continuing with the Ares I. One of those liabilities is that under the current program planned, as I mentioned at the outset, we won't even get it until 2 years after the ISS is at the bottom of the Pacific Ocean, by our estimate.

If we extend the ISS, we will only be able to use the Ares I for about 3 years to support it. Then there won't be that much to do with it, frankly, until we get the Ares V. But we will get the Ares V later because we have spent the money on Ares I.

On the other hand, the Ares I is designed to be probably the most reliable vehicle that has ever been built, and we think there is a good chance that will be the case. As you say, we have spent \$8 billion on it, and although that is a sum cost issue, nonetheless, we have spent \$8 billion. There are a lot of people working on it. We are getting ready to conduct a test of what one might call a prototype of that vehicle, and it, too, is a very viable vehicle.

So I would like not to make a choice here, but just to point out the pros and cons.

Senator NELSON. Well, if the President were to pick the option of Ares V, heavy lift, or the Ares V Lite, you are certainly going to be able to utilize the technology that you have developed for the Ares I so that you don't lose all the value of that \$8 billion that has already been spent. Is that what the Committee concluded?

Mr. AUGUSTINE. That is absolutely true, and similarly, if you pick another option, you can always complete the Ares I by adding money. As I recall, again, I don't have my data, but I think it is a \$1.5 billion or so. But pretty soon, you add up these things—we tried very hard to scratch for money so that our profile was \$3 billion and not \$6 billion or \$5 billion.

Senator NELSON. What was the Committee's thinking on promoting the development of on-orbit refueling?

Mr. AUGUSTINE. Interesting question. As a matter of fact, Wernher von Braun, in some of his writings you may be familiar with, pointed to the enormous advantages of on-orbit refueling. Over the years, we have had some efforts begun to look at the subject but have never really carried them to any great fruition, principally for financial reasons, cost reasons.

It is our belief that on-orbit refueling will be a major factor in space exploration one day. We clearly aren't ready to undertake it today. We just don't know enough. It would be too dangerous. But

there is no reason that we know of from an engineering standpoint that one can't do it.

We would like to use some of the money that we propose spending under these Options 3, 4, and 5 to run tests first on the ground and then in the general vicinity of the ISS of refueling on orbit. Once that has been done, it could have a significant impact on some of the options. For example, some of the closely derived Shuttle options benefit substantially from on-orbit refueling. So we think it is something that is ready for a major technology effort today, but not anything further beyond.

Senator NELSON. Did you have in your discussions any idea of the time in mind as to when we should try to target for on-orbit refueling?

Mr. AUGUSTINE. I would like to provide that for the record, if I could?

[The information referred to follows:]

The Committee did not prepare a specific plan for the development of on-orbit refueling. However, in some of the Committee's exploration options, a refueling capability was assumed to be available in the early 2020s. It was the Committee's judgment that an on-orbit refueling capability could be developed by that time, given an appropriate amount of funding for research and development.

Senator NELSON. OK. Does any of the staff have any additional questions? We will keep the record open for any of the members of the Committee.

I know Senator Pryor was trying to get here, and he was with his father, the former Senator Pryor. So I am sure he will have some.

Can you give us an estimate of how much it will cost to continue flying the Shuttle until Ares I or a commercial solution is available in that range of 2016–2017?

Mr. AUGUSTINE. That was the——

Senator NELSON. And let me just complete the Station because it is one of your options, and that would also support the ISS until 2020 and maintain the development of a heavy-lift capability by the early 2020s.

Mr. AUGUSTINE. If you were to continue the Shuttle to support the ISS through 2020?

Senator NELSON. That is right.

Mr. AUGUSTINE. You would probably have to add I think——

Senator NELSON. Just until a new commercial human-rated vehicle would be developed.

Mr. AUGUSTINE. Human-rated, of course.

Senator NELSON. That doesn't seem to be one of the options. Yes, what staff is pointing out, it would be the best of all worlds. You continue to fly the Shuttle, and the question is what is it going to cost? Until you had a human-rated capability commercially, you keep the Station up there until 2020 so that we have the value of that, and at the same time, you do your technology development of a heavy-lift capability by the early 2020s.

Mr. AUGUSTINE. My estimate would be that the additional cost would be of the order of \$10 billion, probably a little more.

Senator NELSON. Over that whole time period?

Mr. AUGUSTINE. Yes.

Senator NELSON. That is the above the \$30 billion over that 10-year period, which was the \$3 billion per year?

Mr. AUGUSTINE. Exactly, you would have to add that or else take it out of the \$30 billion, and if you take it out of the \$30 billion, you slip the other things we would like to be doing.

If you did continue the Shuttle, one benefit of that, another benefit other than closing the gap is that it makes the closely derived Shuttle vehicle options very much more interesting because if you still have the Shuttle operating and in production for that period of time, then driving from the external tank and so on becomes a much more plausible option. The difficulty, of course, is that we only have three Shuttles left. The launch rate will be very low, and when you go to low launch rates, you start worrying about safety.

Senator NELSON. Well, that would be then more like Option 5C, flexible path Shuttle derived?

Mr. AUGUSTINE. It would be like that except—

Senator NELSON. Except the Shuttle life would continue to service the Space Station until a commercial human capability is ready?

Mr. AUGUSTINE. Yes. You have described a derivative of Option 5C where you would continue the Shuttle operation.

Senator NELSON. Right. Any further questions from the staff?

[No response.]

Senator NELSON. OK. The record will stay open for a couple of days.

And again, I want to thank you for what you have done. This was very unselfish work.

I think the President really has a major decision here. There is nothing like a President making a bold decision to focus the Nation on where we ought to be going technologically, and he is at that point. You have laid out a lot of parameters for him.

I think it is going to be up to the President. We will certainly advise him, but it is his decision, and it is at a tough, tough time because of what we are facing with the budget deficit. Just look at these gyrations that we are going through right now in the Senate Finance Committee trying to come up with a consensus on trying to meet the healthcare problem straight on. It is very difficult.

But I believe the President is a visionary, and I believe that the President is going to make a bold stroke, not unlike President Kennedy. He set this Nation on a course that was extraordinary, and it is my belief that President Obama will do that.

And so, with that optimistic note, thank you, Mr. Augustine.

The hearing is adjourned.

Mr. AUGUSTINE. Thank you, Mr. Chairman.

[Whereupon, at 4:49 p.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. JOHN D. ROCKEFELLER IV,
U.S. SENATOR FROM WEST VIRGINIA

I want to thank Mr. Augustine for testifying before the Subcommittee today and I want to express my gratitude to him and the other 9 members of the Human Spaceflight Plans Committee for their service.

The task of examining NASA's human spaceflight plans in a mere 90 days is not an easy one. As the Committee states in its Summary Report, it is in fact rocket science. Thank you for your commitment to the process and its smooth progress.

I am concerned, however, that the Committee seems to have largely accepted the value of human space exploration as an underlying assumption without ever fully discussing it.

In this difficult budget environment where the Federal deficit sets new records with each passing month, our country does not necessarily have the resources to do everything that we want to do. The economy has not yet recovered, we are fighting two major wars, and we can't even manage to find a solution to provide healthcare for Americans.

The review committee recommends increasing NASA's budget by an additional \$3 billion by FY2014, then increasing it at an inflationary rate of 2.4 percent. We must ask, quite simply, what are the specific benefits to the Nation of making NASA a \$22 billion agency?

Let me be clear, I am not advocating that we abandon space exploration. The case, however, has not yet been made. And I think now would be an appropriate time to ask those tough questions and carefully evaluate the responses.

This is no longer the era of Apollo and the Cold War where the payoffs for advancing the space and Moon agenda are entirely clear.

The President, I am sure, will continue to struggle with these same questions as he reviews the Committee's findings and options. I am committed to making sure that together we can get the answers right.

Again, I want to thank Mr. Augustine for his service and testimony today. I look forward to the Committee's final report.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TOM UDALL TO
NORMAN R. AUGUSTINE

Question 1. Mr. Augustine, you certainly know the arguments both for and against investing in human space exploration at a time when the Nation has a large deficit and many unmet needs for people here on the ground. You note that intangible benefits to the Nation will accrue from such an investment. Yet given the billions of dollars necessary to reach Mars, should NASA instead focus on unmanned missions?

Answer. The committee found that America is best served by a complementary and balanced space program involving both a robotic component and human component.

Question 2. Mr. Augustine, the summary report you provided notes that NASA has an opportunity to spur the growth of the commercial space industry, much like the Federal Government encouraged the development of the aviation and commercial airline industry in the 1920s through the "air mail" program.

New Mexico, for example, is building Spaceport USA and hosts the X Prize Cup. You mention that a technology development program at NASA could help reengage academia and private industry with NASA. How should NASA do more to encourage such private sector involvement in space exploration?

Answer. The committee found many ways that NASA could encourage more private sector involvement in space exploration, namely: extending the life of ISS and increased support for ISS utilization; making loan guarantees or employ other mechanisms by which it could assure a market for commercial providers; more aggres-

sively utilizing commercial authorities already granted to the agency; providing a potential government-guaranteed market for fuel in low Earth-orbit; turning the transport of crew to low Earth orbit over to the commercial sector; and investing more heavily in technology development.

Question 2a. What NASA incentive programs for private companies might spur inventions and innovations that would save the agency money in meeting its space exploration goals?

Answer. Other than those listed above, the committee did not investigate the use of any specific incentive programs.

Question 3. Mr. Augustine, your committee's report seems to suggest that NASA could contract with commercial space companies to supply and service the International Space Station. Some private companies already participate in NASA's Commercial Orbital Transportation Services (COTS). Private firms also compete in the "Google Lunar X Prize" to land a robot on the moon. Did your panel consider the idea of having a "Lunar COTS" program for commercial companies to deliver payloads to the moon?

Answer. The committee did not deliberate on the concept of a "Lunar COTS" program. However, that concept has been discussed in the media and some committee members are undoubtedly aware of it.

Question 3a. Could competition among commercial companies for such contracts help lower NASA's costs of returning to the Moon and other destinations?"

Answer. The committee did not specifically analyze this situation; but, in theory, competition among private companies for providing lunar-based services would most likely result in cost advantages for NASA.

