We Have a Long Way to Go

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I've had the pleasure of speaking to the Space Transportation Association each January for the past several years, and I'd like to thank Rich Coleman for this year's invitation.

Last year, I addressed the considerations governing the design of NASA's Constellation architecture, to get on the record why the design is what it is. However, judging by the many questions I receive on the topic, I didn't do a very good job, so I will try again today. And, while I will try not to repeat what I have said in prior speeches and testimony, I must admit that in tackling these issues I am reminded of Shakespeare's Henry V: "Once more into the breach, dear friends ..."

Constellation was designed to implement a new civil space policy, articulated by the president in the aftermath of the *Columbia* accident, and modified, extended, and enhanced by both Republican and Democratic Congresses in the NASA Authorization Acts of 2005 and 2008.

At this point, after five years of discussion, I think it is fair to say that the broad principles of the policy provide a reasoned, and reasonable, consensus on goals for the American civil space program. Briefly, the United States will meet domestic and international commitments by using the Space Shuttle to finish the International Space Station (ISS), after which the Shuttle fleet will be retired and replaced by a new system to support space station crew transfer and logistics, enable human lunar return and sustained lunar presence, and pave the way for future voyages to Mars and the near-Earth asteroids. Other important points are captured in both policy and law, including especially the intent to foster commercial development of space, but I believe this one sentence captures the essence of today's policy direction for NASA's human spaceflight program.

The policy is not without practical concerns. We are completing ISS and planning for the retirement of the Shuttle fleet by the end of 2010. At the same time, the first Constellation elements, *Ares 1* and *Orion*, are being built. These elements were originally required to be in service by 2014, given the budgetary allocations then thought to be available for development, and we identified design alternatives that could have provided capability as early as 2011. However, in the wake of numerous administration budget reductions and two Continuing Resolutions, initial operational capability for *Ares 1* and *Orion* is now projected for 2015.

At issue are the implications of this timing for ISS support and utilization, and the geopolitics of depending upon Russia for five years for crew transportation to the facility. A multi-year gap in independent, guaranteed U.S. access to the space station whose development we led seems folly, a matter concerning which I have been on the record for almost four years now. However, as I continue to remind people, "the gap" is not a surprise, it is a known feature inherent in the last four budget cycles. If, now that we are almost upon it, it seems a bad feature, the question becomes, what can be done about it, and at what cost in terms of money, risk, and foregone opportunities? I will have more to say on this later, but for the moment let's continue with larger issues.

This policy mandates hard things. Returning the Space Shuttle safely to flight – I and many others in this room can tell you how hard that was. Finish the station; harder yet, but we're doing it. Then, even harder: retire the Shuttle, a system we've been designing, building, and flying for forty years. The Shuttle is an American icon throughout the world, one that can be seen on billboards in Beijing. But it is also a system which, even when operated to perfection, cannot take us where we want to go again – out beyond low Earth orbit (LEO). And, finally, hardest of all, we are to build a new human space transportation system that *can* take us where we want to go, something we last initiated almost five decades ago.

This is a time of seminal change at NASA. While change is difficult, it was needed, and in my opinion we now have the best policy direction NASA has received in decades. We have clear goals which follow logically from choices that, considered one by one, are simple. Either we will have a human spaceflight program, or not. We will, because for the United States to cede leadership on the frontier of human action will spell the end of who and what we are as a people. History is not the story of those who stayed behind. As President Kennedy said so eloquently, "The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in the race for space."

If we are to have a human spaceflight program, it will either venture outward, or not. If not, then again we will be in retreat. The exploitation of low Earth orbit is vitally important to a spacefaring society, but it is no longer the frontier. When John Glenn flew into orbit the first time, it was. Today, we have had international crews working and living in space on the International Space Station for eight years. We have much to learn, but the frontier status of low Earth orbit is fading. We need to expand upon the knowledge gained there, but also press on to new frontiers.

So, if we are not to retreat, if we are to venture outward again, where do we go? The moon, the near-Earth asteroids, and Mars – these are the destinations that

we can reach with technology we possess today or can reasonably foresee. These are the destinations that can and will fully occupy us for the remainder of this century. These are the places where we will create new options for our grandchildren's grandchildren – or leave that privilege to others.

So in my view we have the right policy, not least because it directs us to follow the geography of the solar system in which we live as we go about rebuilding our spacefaring capabilities. We must surely do things right, but it is even more important to do the right things. With this policy, we are.

Thus, I caution against changes in the broad direction of our space program, because I believe that today we are spending our resources in pursuit of the right goals. We must not allow indecision and uncertainty to cause, again, the waste of billions of dollars already invested and the loss of any momentum we might have hoped to achieve. We have seen this in far too many NASA human spaceflight programs over the years, a situation which the Columbia Accident Investigation Board justifiably called "a failure of national leadership". Those of us in the space community must surely ask, do we want to repeat those mistakes?

The Constellation architecture offers a system to meet the goals of today's space policy. It is fundamentally designed to return Americans and our international partners to the Moon, to allow but not to require permanent human

lunar presence, and to provide maximum utility of the near-term elements for later voyages to Mars and the near-Earth asteroids.

Constellation is also designed to support ISS but, as clearly stated from the outset, only if commercial service fails to materialize. Constellation is not focused on or designed for maximum efficiency in LEO operations. Our goal is to establish a market niche for commercial cargo and, later, crew transportation to ISS, a niche in which government systems ought not to be cost-competitive with commercial systems designed for efficient LEO access.

The programmatic implementation of the Constellation architecture fits within NASA's budget projections. Further, it is designed to accommodate funding reductions – which have totaled nearly $12 billion future dollars over just the last four years – by slipping schedule rather than by making technical compromises with which our successors would have to cope for decades. If we learn nothing else from the history of the Space Shuttle development compromises that were forced by budgetary considerations, I hope it is this: "late" is ugly until you launch, but "wrong" is ugly forever.

Constellation is a specific instantiation of a system designed to address stated policy goals. Others are certainly possible; it is almost never true in engineering that there is only one way to do something. It is reasonable to ask whether, given the goals and constraints that guided the Constellation design,

another technical approach would produce superior performance, or could be realized in less time or at lower cost.

Now, requirements can be altered, policies changed, and decisions, plans and architectures can be reviewed, altered, or reversed. However, such actions come with a price tag. In fact, merely asking questions carries a cost. It takes a good deal of time and money – consequential damages, if you will, for the legal minds among us – to conduct an effective technical review. If it is to be of value, an engineering review must be done carefully and thoroughly, with enormous attention to the groundrules and assumptions employed by both designers and reviewers in order to produce valid "apples to apples" comparisons. Further, the game must be worth the candle; to undertake a review with the idea of effecting serious change, there must be a reason to suppose that a significant gain is possible, and a healthy skepticism as to the likelihood of attaining that gain. It is bad engineering practice to "churn" a system design merely because one can.

In this vein, I call your attention to a book entitled "The Rickover Effect: How One Man Made a Difference", about Adm. Hyman Rickover and his stewardship of the nuclear Navy. There is a great story about the early days of reactor development, when Rickover's personal future and that of the *Nautilus* and the nuclear Navy were very much in doubt. Adm. Rickover offered an interesting definition of the difference between a paper reactor and a real reactor.

A paper reactor has the following characteristics. It is simple. It is small. It is cheap. It is lightweight. It can be built very quickly. Very little development is required; it will use off the shelf components. It is in the study phase.

A real reactor has the following characteristics. It is complicated. It is large. It is heavy. It is being built now. It is behind schedule. It requires an immense amount of development on apparently trivial items. It takes a long time to build because of its engineering development problems.

Sound familiar?

Moving on, it is also possible to produce a different design result by changing the policy goals and constraints which guide the design. Many suggestions offered with the intent of "improving" Constellation are of this form; the offeror neglects a particular requirement that is disliked, and with that omission is able to provide an "improved" approach to the goals which remain. Political transitions provide the best opportunity for reconsideration of broad policy goals if that is thought to be necessary. The other occasions upon which we typically do so are, sadly, in the wake of tragedies, as we saw after both *Challenger* and *Columbia*.

So with that said, and with this being a time of political transition, let's consider some of the ideas which have been offered as to how our present space policy could be better implemented than with the Constellation architecture, or

how a better result could be obtained by altering policy guidelines. Also, since this is my speech, allow me to offer my views as to the wisdom of some of these ideas.

Every week, it seems, we hear that NASA should be directed to halt development of the *Ares 1* crew launch vehicle, pay industry to develop a human-rated EELV to fly the Orion crew vehicle, and focus its own efforts on the *Ares 5* and *Altair*.

Now, while a smaller *Orion* capsule on a human-rated EELV could cost less in the short-term to develop, it would *only* be capable of supporting the International Space Station. The lunar mission is more difficult; we're trying to go beyond *Apollo*, not merely repeat it. Our goal is to develop the option for sustained human lunar presence at the minimal level of an international crew of four rotating on six-month centers. Existing EELVs, even leaving aside the issue of human rating, cannot lift a lunar-capable *Orion*, without substantially compromising what is meant by "lunar capable".

If "using EELV" doesn't really mean "using an existing EELV", but instead means, "using an upgraded EELV sufficient to carry a lunar-capable *Orion*", then I must note that this will require much more than the few tweaks that some have suggested. We would have to modify the first stage to carry heavier loads and for human rating, among other things, and then design, develop, and build a new human-rated second stage. But that's exactly what we're doing with *Ares 1*:

modifying an existing first stage and building a new second stage. Why is it thought that this is a good thing to do with EELV, but not for *Ares*?

Further, it is crucial to recall that we are designing an architecture, a family of space vehicles with synergistic commonality. We are not trying to optimize a single mission. Our analysis shows that for the complete architecture, the development costs savings for the *Ares* family are huge, about 25% lower than for an EELV-derived family, because of the commonality of *Ares 1* systems with those on *Ares 5*.

In fact, given that we must develop *Ares 5* for the lunar mission and, later, Mars, the additional development cost for *Ares 1* is $2.7 billion. I will repeat that: if you commit to lunar exploration and beyond with *Ares 5*, for an additional $2.7 billion you also get the new human-rated LEO transportation system mandated by the Columbia Accident Investigation Board. Aside from the upper stage tank structure, most everything on *Ares 1* – many elements of the 5-segment solid rocket booster, the J-2X upper stage engine, the upper stage main propulsion system, the guidance, navigation, and flight control systems – is common to *Ares 5*. Constellation is not a point design.

A spaceflight system designed for a single task – say Earth to LEO, or Earth to Moon – can clearly be optimized for that one task. In a world where NASA had substantially more money, it would certainly be desirable to build and optimize

different systems for different missions. We are not in that world. I believe that, if we are lucky, we are going to get *one* new human space vehicle to follow Shuttle. Anyone here think that Congress is going to provide funding for more than one? Raise your hand, please. Anyone? … I didn't think so. And if that's the case, then it would be a mistake to optimize that one vehicle for access to LEO. If we want to be a spacefaring nation, we have to be able to go to more than one place and do more than one thing, and we're going to have to sacrifice optimal performance on any single mission for versatility across an array of missions. That is why we must think "architecture" and not "point design".

Beyond the costs involved, our probabilistic risk assessment for loss of crew on *Ares 1* showed it to be twice as safe – I repeat, *twice* as safe – as a human-rated EELV-derived vehicle. This figure of merit was a significant factor in our decision to go with the Shuttle-derived *Ares 1*, yet is ignored by almost everyone suggesting that we make a change. I cannot responsibly ignore it, for reasons having nothing to do with money. But if to someone else it *is* just about the money, then the cost of unreliability must be considered. Incurring even one additional accident through the use of a less-reliable system wipes out all of the savings of the hypothetically cheaper vehicle. Solely from a fiscal perspective, we should be willing to pay a premium for safety, if necessary.

So, while I am truly concerned about the moribund state of our U.S. commercial launch industry and about the rising costs of EELVs to NASA as a result, our task was to develop a plan for human space exploration, not to buttress the EELV industrial base. We absolutely do not have the resources to do both, *and even if we did,* exactly what is it that makes the EELV industrial base more important to support than the Shuttle industrial base? I remind everyone that with the *Ares* family, we are retiring the Shuttle orbiter, but preserving many other segments of the Shuttle industrial base. Why is it, exactly, that in this time of transition in NASA spaceflight systems, we should make decisions to augment the existing Atlas and Delta workforce, while completely decimating the Shuttle workforce?

Now, as I say, I am concerned that rising costs for expendable launch vehicles will impact our ability to carry out our robotic science missions. In accordance with the Commercial Space Launch Act and national policy, the EELV will continue to be the foundation for launching NASA's robotic missions, and we will use them to the maximum extent possible according to our mission needs, performance, cost, and schedule requirements. We are also considering emerging commercial offerings, like SpaceX's Falcon 9 and Orbital's Taurus 2. When reliably flown, they will compete on a level playing field for NASA contracts. We are supporting the commercial launch industry where we can reasonably do so.

Let me now turn to the proposal that we should simply leave ISS support to U.S. commercial providers when and as they materialize, and to international systems in the meantime, and that NASA should not even design *Ares 1* and *Orion* with the capability to support the space station. With this approach, there would *never* be a U.S. government transportation system to support ISS. All I can say about this proposal is, if you like the present "gap" in U.S. government access to LEO, you'll love this one.

Contrary to what has been asserted in some quarters, I am the very last person in this business to view commercial launch alternatives as a "threat" to NASA. I have stated on innumerable occasions that I would love to see commercial capabilities for placing astronauts in LEO and supporting the space station, and that we as a nation should establish and embrace policy incentives to help bring about this outcome.

At NASA, we've backed these thoughts with money.

We have staked $500 million toward the development and demonstration of nascent COTS capabilities, and billions more are payable on commercial resupply service contracts to provide logistics support for ISS after the Space Shuttle is retired. With present NASA funding constraints, I cannot recommend doing more, absent demonstrated progress by the commercial space sector. If commercial companies wish to, and can, develop crew transport capabilities, then I applaud

them, and we would be legally bound to make use of their services, per the 2008 NASA Authorization Act. But when we use the term "commercial", it implies an arms-length transaction for an existing product or service. It does *not* mean, "give me enough front money so that I can become another prime contractor".

So, while you simply will not find more of a "true believer" than I am about the importance of providing incentives for the development of commercial space endeavors, I am also a realist. It is my considered judgment that the risk of relying for ISS support solely upon not-yet-existing commercial products is simply too high. We need a better plan than that to support a facility in which our nation has invested over $50 billion, and which is the centerpiece of the international human spaceflight program. I believe that it would be reckless for the United States to leave the ISS hostage to fortune, its utility contingent upon international partner capabilities and the hope that, eventually, commercial systems will be available. Hope is not a management tool.

Human access to low Earth orbit cannot be a commercial set-aside. A government system offering independent, guaranteed LEO access, even if it is not as efficient as it could be if designed solely for that purpose, is necessary. It is necessary for ISS support. It is necessary as a control on the price we are willing to pay for commercial or international substitutes. And it is necessary if we want to imagine ever doing anything in low orbit that goes beyond merely flying back

and forth to ISS. Want to do another Hubble servicing mission, or something like it? Want to do something else in the future that you haven't thought of today? If so, you're going to need something more than commercial transportation.

Human spaceflight is a strategic capability pioneered by our nation. We must treat it as the important thing that it is. We must not make decisions today that would cause a future NASA administrator to be forced to ask the Congress, as I was last year, for legislative relief from INKSNA and the "privilege" to use U.S. taxpayer funds to pay Russian aerospace engineers. This situation is unseemly in the extreme, but we are where we are. This is the "failure of national leadership" of which the Columbia Accident Investigation Board spoke so damningly. Let's not repeat it.

It has been proposed that we should continue flying Shuttle until and unless commercial systems come into being, again with the proviso that no new government system for access to LEO should be built. I do not need to reiterate my disagreement with the second part of this proposal, but the first part – continuing Shuttle flights – deserves consideration. We at NASA have recently updated our estimates of the cost to do it, and the bottom line is this: for $3 billion per year, we could continue to fly the Shuttle twice a year from 2011-15 for ISS crew transfer and cargo logistics, with about a one-in-eight chance of losing another crew on one of those ten flights.

So, it can be done. Whether it should be done is another question. I will offer two perspectives on the matter.

As an engineer and program manager, my immediate thought is that we have better uses for $3 billion per year than flying the Shuttle to reduce – but not eliminate – dependence upon *Soyuz*. Russia has been a reliable partner on the International Space Station. Without equivocation, I am glad to be working with them. While "partnership" should not be confused with "dependency", and while I do think it is unwise for the United States to be dependent upon others for crew and cargo access to ISS, I can accept it for a few years in the context of the International Space Station partnership, and as the price of poor decisions made in the past. We can accept it for a time, if it allows us to move forward with the development of new systems.

However, from a purely geopolitical perspective, a different conclusion could be reached. One could argue that America's international standing will suffer as a result of our demonstrated inability to provide transportation for crew and cargo to the space station we have built. Is it worth $3 billion per year, and the risk of additional Shuttle flights, to prevent this loss of stature, image, and clear preeminence in spaceflight? It might be. If a decision were made at the highest levels of government to continue flying Shuttle to preserve American preeminence

in space by guaranteeing uninterrupted access to ISS, I would support the decision, as long as we all clearly understand the risk.

However, I must be clear. *In my opinion, continuing to fly the Shuttle without the extra money to do it would be unwise and strategically short-sighted.* If the required funds are taken from NASA's existing appropriation, we cannot "close" the gap, we merely postpone it until, inevitably, the Shuttle is flown no more. Existing appropriations are insufficient to fly the Shuttle and at the same time complete the development of new systems. In the bluntest of terms, preserving our nation's preeminence in space by *eliminating* the gap might be worth $3 billion per year and the attendant risk of life. Spending that money and taking those risks to *postpone* a gap, is not.

Yet another proposal is that *Ares 1* should be cancelled, lunar missions should be carried out by means of a dual *Ares 5* launch sequence, and ISS support should be accomplished through some combination of Shuttle extension and continued use of *Soyuz* until reliable commercial space transportation capability emerges. Again, I do not need to reiterate my thoughts on the wisdom of a decision to eliminate government access to LEO, or on Shuttle extension. However, the dual *Ares 5* lunar mission concept makes sense, if the budget is available to support it. It costs 32% more per mission than our *Ares 1+5* baseline, but offers 69% more payload to the moon, so on a marginal cost basis it works

well. We considered it as a growth option during the Exploration Systems Architecture Study. This is one reason why I directed, early on, that the design of *Ares 5* should not include any feature that would need to be redesigned to allow future human rating.

But having a growth option to fly lunar missions with two *Ares 5* launchers does not mean that cancelling *Ares 1* makes sense. As I have stated above, if we are going to develop *Ares 5* to go to the moon and beyond, then spending $2.7 billion to get a human-rated launcher that can put 23 metric tons in ISS orbit is a bargain. If we think a government system for human access to LEO is important, and I do, then this is absolutely the cheapest way to get it.

Let me now turn to some of the reports in the press that "technical troubles have dogged the design process for the *Ares 1*", or that "weight issues have required redesigns of both the capsule and the rocket". Now, the plain fact is that we have not yet finished the design of *Ares 1* and *Orion*, let alone needing to "redesign" them. The design isn't final until we have passed critical design review (CDR), at which point we can begin manufacturing. CDR for *Orion* is toward the end of 2010 and for *Ares 1* in early 2011. We cannot go faster, not because of technical troubles or weight issues, but because we simply do not have the money to do so until after the Shuttle retires. In fact, as things stand today, the critical

path on Orion includes the purchase of certain long-lead parts which are needed irrespective of design details. We just don't have the money.

Specifically with regard to weight issues, I have never – never – worked on a space project that did not have weight issues – unless we ran out of volume or power first. This is why good system engineers are conservative with the margins they hold for these quantities. Quite simply, there is no upmass problem for *Ares 1* and *Orion* on ISS missions. And, a decade before we fly again to the moon, the lunar mission mass closes to within a few hundred kilos with all margins intact. The actual mass problem for *Orion* is the return weight on the parachutes. And yeah, we're working it, and we will resolve it.

As for the always enjoyable topic of thrust oscillation in the *Ares 1* first stage solid motor, we did not see it at detrimental levels on the most recent Shuttle flight, the first in recent history on which we were able to instrument the SRBs to measure it. If it occurs in flight on *Ares 1*, we expect about five seconds of exposure to vibration levels which might prevent the crew from effectively taking necessary actions during or shortly after the exposure event. That's it. But we want to get any vibration down to the ±0.25 g level set in 1962 for the *Gemini* program, and at the same time we want to understand how crew performance degrades with intensity and duration of exposure. We're working those things too.

These sorts of concerns are not new for NASA, nor to anyone in the rocket business. If you really want to scare yourself, read "NASA Experience with Pogo in Human Spaceflight Vehicles" by NASA Technical Fellow Dr. Curtis E. Larsen. Curt summarizes the history of flight experience with, and engineering mitigation of, liquid-rocket thrust oscillation, or "pogo", as it was aptly named. I'll give you the bumper-sticker version: the solid rocket motor guys have it easy.

In today's environment, we're doing engineering design in public. There is almost no such thing anymore as an "internal" meeting. That isn't going to change. Accordingly, I believe that those of us who care deeply about the future of our nation's space program must consider how we can better communicate technical matters to non-engineers. We are simply going to have to learn how to explain better what it is that we do to get from a sketch on a piece of paper to a marvelous flying machine.

I have said that I believe that the fundamental direction which the president and Congress have given us is the proper unifying vision for space exploration called for by the Columbia Accident Investigation Board. To that end, I have advocated that our nation's policy makers maintain a constancy of purpose for NASA. This has come back to haunt me; some have taken it to mean that I am opposed to any change in our nation's civil space program. That is hardly the case. I think the plan we have today is the best we can produce given our budget

constraints, but there are many things which could be improved or enhanced if more funds were made available.

When I say that NASA needs constancy of purpose it is because, while we are making tremendous progress in the design and development of new systems, they take a long time to build. Any changes in direction must be carefully considered if we are ever to produce anything beyond studies and cancelled programs. That is why I applaud Chairman Gordon and Ranking Member Hall on the House side, and Chairman Nelson and Ranking Member Vitter on the Senate side, as well as the many other members of Congress and their staff who crafted the 2008 NASA Authorization Act. In its preservation of the core of the 2005 Authorization Act, the new Act offers exactly the constancy of purpose which is essential to achieve the strategic objectives set out by this nation's leadership.

The fundamental goals of both Acts provide a foundation for the agency. Other goals can be added. One might be to utilize fully and aggressively the space station we have built; it's going to be around for a long time, if we take care of it. Right now, we have little commitment to ISS past 2015 other than to take no action to preclude its continued operation. That is not much for a facility that has been in design and development for a quarter of a century. Or we might consider re-establishing a significant technology development program, not tied to existing mission requirements. We should consider augmenting the Earth observation

program to restore the climate sensing capability once planned to be done by NPOESS. And we might want to consider whether our aeronautics program is accomplishing all that we might wish. But, any goals we add should be adopted only if the resources are provided to achieve them in a credible manner.

During preparations for my Senate confirmation in April 2005, every member of Congress whom I visited told me, in some cases quite sternly, that NASA was lagging in its response to the new space policy direction, and that we needed to put together a credible, executable plan to carry it out. I hope that I have been clear in my testimony to Congress, and in various speeches over the years, that the projected schedule for delivery of Constellation systems are far from perfect. But it is the best plan which we can offer with the resources we are projected to receive in the years ahead.

I am always open to suggestions as to how better to implement our policy direction. There is no pride of authorship for good ideas, nor any not-invented-here attitude at NASA. If there is a better idea, then after careful consideration, we would be happy to implement it.

But no matter what decisions we make, we at NASA cannot possibly make everyone happy. Most decisions will produce an unhappy outcome for someone. That is not by itself a symptom of incompetence, bad intentions, or a lack of integrity on our part, as some have contended. Allocation of public funds to any

particular alternative inevitably leaves aggrieved parties who will not receive those funds.

In this vein, and especially in this time of transition, the concerns which President Eisenhower raised in his farewell address to our nation speak to us today: "[i]n the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist." To "guard against" this, what the taxpaying public and its elected representatives, our overseers, can and do expect from NASA can be summarized in two words: objective expertise. Making strategic decisions about the expenditure of public funds is a core government function. It is not reasonable to expect that responsible government managers can make decisions pleasing to all interested parties.

In conclusion, I would like to remind us all that we have something to celebrate this year, the 40th anniversary of the first human footprint on a world other than our own. It is a time for our nation to look back at what has worked right in space exploration, and also at what has not. Going forward, it is also time to re-commit ourselves to taking the next steps.

I have said that we engineers must learn to communicate better the reasons why we explore space and the technical challenges we face in doing so. No one

was better at this than President John F. Kennedy. I never fail to marvel at how his words speak across the decades to us today. So I would like to leave you with his thoughts from San Antonio, Texas on November 21, 1963, the day before he was assassinated:

"For more than three years I have spoken about the New Frontier. This is not a partisan term, and it is not the exclusive property of Republicans or Democrats. It refers, instead, to this Nation's place in history, to the fact that we do stand on the edge of a great new era, filled with both crisis and opportunity, an era to be characterized by achievement and by challenge. It is an era which calls for action and for the best efforts of all those who would test the unknown and the uncertain in every phase of human endeavor. It is a time for pathfinders and pioneers…

"We have a long way to go. Many weeks and months and years of long, tedious work lie ahead. There will be setbacks and frustrations and disappointments. There will be, as there always are, pressures in this country to do less in this area as in so many others, and temptations to do something else that is perhaps easier. But this research here must go on. This space effort must go on. The conquest of space must and will go ahead. That much we know. That much we can say with confidence and conviction."

Thank you.