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S. HRG. 106–1095

NASA MANAGEMENT PROBLEMS

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED SIXTH CONGRESS

SECOND SESSION

MARCH 22, 2000

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

78–634 PDF WASHINGTON : 2003

For sale by the Superintendent of Documents, U.S. Government Printing Office
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ONE HUNDRED SIXTH CONGRESS

SECOND SESSION

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NASA MANAGEMENT PROBLEMS

WEDNESDAY, MARCH 22, 2000

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

The Subcommittee met, pursuant to notice, at 2:32 p.m., in room SR–253, Russell Senate Office Building, Hon. Bill Frist, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. BILL FRIST, U.S. SENATOR FROM TENNESSEE

Senator FRIST. Good afternoon. I would like to welcome all of our guests here today as the Subcommittee on Science, Technology, and Space convenes this hearing on the current management challenges at NASA.

This afternoon, although we hope to discuss where we have been in the past, we also want to take a look at where we are going in the future.

First, let us take a look at what has brought us to today's hearing. The year 1999 proved to be a very difficult and challenging one for the agency.

We have read the reports on workers searching for misplaced Space Station tanks in a landfill; loose pins in the Shuttle's main engine; failure to make English-metric conversions causing the failure of a $125 million mission to Mars; two-time use of rejected seals on a Shuttle's turbo-pumps; $1 billion of cost overruns on the prime contract for the Space Station, with calls from the Inspector General at NASA for improvement in NASA's oversight; workers damaging the main antenna on the Shuttle for communication between mission control and the orbiting Shuttle; urgent repair mission to the Hubble Telescope; approximately $1 billion invested in an experimental vehicle and currently no firm plans for its first flight, if it flies at all; and the lack of long-term planning for the Space Station, an issue on which the Subcommittee has repeatedly questioned NASA.

This Subcommittee recognizes and appreciates the technical challenges and hurdles NASA must address to make its missions successful. However, based upon our initial review of the various investigation reports on these problems, the real culprit may be management. We cannot and should not dismiss good basic management as an essential component of success. It still gets back to the fundamentals of planning, of leading, of organizing and of controlling.

Furthermore, we must ensure that every individual not only understands their job, but also performs it well.

Regardless of whether NASA's mantra is "Faster, Better, Cheaper," "Mission Success First," or some other phrase, "back to basics" should be—must be an integral part of the agency's infrastructure.

The bottom line is that we need to confirm that proper management is in place and functioning as it should be.

We cannot proceed until we have done everything we can to ensure that safety is at the forefront of every NASA endeavor. We must realize that human lives are at stake each time the Shuttle is launched, and therefore, we must take every precaution to guarantee the astronauts return home safely.

It is necessary that we have this hearing today. For $14 billion a year, the American taxpayers deserve better. So with the oversight responsibilities of this Committee, we hope to further discuss with our witnesses today how to get NASA back on track.

We are alarmed by the sheer volume of the reports that we will discuss today. Their recommendations are numerous and far reaching. It will take time for us to fully review these recommendations. In the meantime, I look forward to receiving NASA's implementation plan from these collective reports later this year.

Later in the hearing, we will be referring to, I am sure, a UPI article from yesterday that I read last night, that alleges that NASA currently holds the finding of the Young report, originally scheduled to be released earlier this month, but now delayed until final approval by the White House.

The content of the story, I am sure we will discuss, and I note that a press release has been released by NASA this afternoon in response.

I do want, in advance, to thank all of our witnesses for coming before the Committee today. I would especially like to commend the individuals who participated on the various review teams. Your work is clearly crucial to our oversight process.

[The prepared statement of Senator Frist follows:]

PREPARED STATEMENT OF HON. BILL FRIST,
U.S. SENATOR FROM TENNESSEE

I would like to welcome all of our guests here today as the Subcommittee on Science, Technology, and Space convenes this hearing on the current management challenges at National Aeronautics and Space Administration (NASA).

This afternoon, although we hope to discuss where we've been in the past, we also hope to discuss where we're going.

First, let's take a look at what has brought us to today's hearing. The year 1999 proved to be very difficult for the agency. We have read the reports on:

- Workers searching for misplaced Space Station tanks in a landfill;
- Loose pins in the Shuttle's main engine;
- Failure to make English-metric conversions causing the failure of a $125 million mission to Mars;
- Two-time use of "rejected" seals on Shuttle's turbopumps;
- $1 billion of cost overruns on the prime contract for the Space Station with calls from the Inspector General at NASA for improvement in NASA's oversight;
- Workers damaging the main antennae on the Shuttle for communication between mission control and the orbiting Shuttle;
- Urgent repair mission to the Hubble Telescope;

- Approximately $1 billion invested in an experimental vehicle and currently no firm plans for its first flight, if it flies at all; and
- The lack of long-term planning for the Space Station, an issue on which the Subcommittee has repeatedly questioned NASA.

This Subcommittee recognizes and appreciates the technical challenges and hurdles NASA must address to make their missions successful. However, based upon our initial review of the various investigation reports on these problems, the real culprit is management. We cannot and should not dismiss good basic management as an essential component of success. It still gets back to the fundamentals of planning, leading, organizing and controlling. Furthermore, we must ensure that every individual not only understands their job, but also performs it well.

Regardless of whether NASA's mantra is "Faster, Better, Cheaper," "Mission Success First," or some other leading phrase, "back to the basics" should be an integral part of the agency's infrastructure. The bottom line is that we need to confirm that proper management is in place and functioning as it should be.

We cannot proceed until we have done everything we can to ensure that safety is at the forefront of every NASA endeavor. We must realize that human lives are at stake each time the Shuttle is launched and, therefore, we must take every precaution to guarantee the astronauts return home safely.

It is unfortunate that we have to have this hearing today, but its necessity is vital. Furthermore, for $14 billion a year, the American taxpayers deserve better. So with the oversight responsibilities of this Committee, we hope to further discuss with our witnesses here today how to get NASA back on track.

We are alarmed by the sheer volume of the reports that we will discuss today. Their recommendations are numerous and far reaching. It will take time for us to fully review of these recommendations. In the meantime, I look forward to receiving NASA's implementation plan from these collective reports later this year.

Last night I read an alarming article that alleges that NASA currently holds the finding of the Young report, originally scheduled to be released earlier this month, but now delayed until final approval by the White House. If the content of the new stories is indeed true, this is very disturbing, and there is sure to be significant fallout from the facts the report will uncover. I intend to focus some of my questions towards this subject later in the hearing.

But first I want to thank each of our witnesses for appearing before the Committee today. I would especially like to commend the individuals who participated on the various review teams. Your work is crucial to our oversight process.

For opening statements, I will turn to Senator Hutchison.

Senator McCain, would you like to proceed?

Senator MCCAIN. I—I would like to go after Senator Hutchison. Thank you.

Senator FRIST. Senator Hutchison.

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

Senator HUTCHISON. Thank you, Mr. Chairman.

And I want to say thank you to the Chairman of the Committee. I am happy to step aside if you have other things.

Senator MCCAIN. No. Please go on.

Senator HUTCHISON. OK. Let me thank Senator Frist, as the Chairman of this Subcommittee, for convening the hearing. I think Senator Frist is certainly one of the most credible members of the Senate on this subject, and he is the perfect Chairman of this Subcommittee.

And I know that his goal is the same as mine, and that is that we have a healthy NASA, because we know there are mistakes. We also know that in any endeavor whose mission is to push the envelope into new horizons is going to have mistakes along the way.

But also, I think Senator Frist is right to ask the question so that we can strengthen NASA to make sure that it does meet its mission and continues to push the envelope of space.

It is interesting that 4 years ago today the Space Shuttle Atlantis was engaged in our nation's third linkup with Russia's Mir Space Station. A 6-hour space walk in the Shuttle's cargo bay was conducted by two American astronauts while docked with Mir, and additionally the Space Shuttle dropped off Shannon Lucid, the first American woman to live on Mir.

This historic journey signaled the cooperation that was forged between the United States and an international partner such as Russia.

I would like at some point in this hearing, for Mr. Goldin to comment on that international partnership with Russia. And I think we certainly should question if it is in our best interest to continue that partnership, and I hope you will speak to that.

We certainly should not lose sight of all that NASA has meant for our country. We should learn from our mistakes, but we should not be deterred in our cause. NASA's cause is nothing less than pushing the boundaries of our knowledge.

Today's hearing will examine many of the management issues of NASA, its successes and its failures.

NASA will present us with three reports that have been conducted to review the problems, including the loss of the Mars Polar Lander, Mars Climate Orbiter, the Wide Field Infrared Explorer and the Deep Space 2.

During the nineties, "Faster, Better, Cheaper," was embraced as the mantra of NASA. Perhaps the mantra for the next century should be "Faster, Cheaper, and Better Defined," or should it be, "Faster, Better-defined, and Not So Cheap"?

I think we have got to admit that we have pushed the limits. NASA has tried very hard to meet the Congressional mandate that it be more efficient. You have dramatically reduced the cost of space flight while launching four times as many missions during the nineties.

NASA is right to be ambitious. America expects that. But the American people also expect Congress to provide NASA with the resources the space agency needs to carry out its mission without having to cut corners, especially on manned space flight. As the Chairman said—and I would agree—space safety must not be compromised.

I have a particular interest in the Space Shuttle. The McDonald report focuses on our Shuttle program and has laid forth recommendations. These have been addressed by the contractor, United Space Alliance.

Certainly some of the questions raised in the report need to be continually reviewed. However, it is in the interest of all involved, including the contractor, that safety remain the top priority.

So, Mr. Chairman, I also saw the report through B.B.C. and UPI that you saw, which I hope that Mr. Goldin will address regarding the Polar Lander.

And with that, I will say thank you for calling the hearing, and I look forward to hearing from the witnesses.

Senator FRIST. Thank you, Senator Hutchison.
Senator McCain.

STATEMENT OF HON. JOHN MCCAIN, U.S. SENATOR FROM ARIZONA

Senator MCCAIN. I thank you, Senator Frist. Thank you for your stewardship of this Subcommittee, and for the outstanding work that you are doing.

Over the past year, I have continually been amazed by reports coming out of NASA about the mission failures and program delays. I am glad the Committee is examining these issues today.

I understand that four of the reports on these incidents will be discussed, while other reports will be released later this month, which may require another Subcommittee hearing, as you mentioned, Senator Frist.

The extent of mismanagement noted in these reports is somewhat startling. For years, I have expressed concern about the management, and I repeat my concern at this time.

I am pleased to see that GAO is testifying along with the other witnesses. It is my understanding that the GAO will offer preliminary findings regarding the Shuttle work force and safety issues. And I obviously appreciate their efforts.

In review of the various reports presented today, some of the overarching themes are apparent: staff complacency; inadequately trained personnel; lack of effective internal communication; and staff not following established procedures.

The funding impact of failures and delays is quite startling, estimated to be in the billions of dollars. Some costs we cannot even calculate. But we do know that: the International Space Station cost increases the amount to $9 billion; the two failed Mars missions cost $360 million; and X–33, the experimental reusable launch vehicle, the future of which is uncertain, has a cost to date of approximately $1 billion.

We know it will take some time for NASA to digest all of the recommendations that will be made here. As such, the Committee looks forward to a formal response from NASA very soon.

On a specific matter, which you have already referred to, Mr. Chairman, a press article reported that NASA knew of a fatal design flaw in the Mars Polar Lander even before its arrival on Mars, but that NASA withheld this information from the public.

The article goes on to say that the future Young report on the Mars Polar Lander will be "devastating." I have requested a copy of this report from NASA, but NASA has indicated the report cannot be released until cleared by the White House.

It has been brought to my attention that NASA earlier today "categorically" denied this report.

I had originally hoped that the Young report would be a part of today's discussions, but the report was delayed from its original release date earlier this month.

If the media reports are true, then the trust that is vital between the government and citizens has been violated and this warrants a very serious examination of how the agency operates. I hope that Mr. Goldin will specifically address this issue.

I want to thank you very much, Mr. Chairman.

I went to see a movie with my children last weekend, and the movie was called, "Mission to Mars."

I do not know if you have had the opportunity to see it. I think it is a very interesting and exciting movie. And obviously the work and effort that NASA has been involved in has captured the imagination of all Americans, young and old.

But we also have a responsibility obviously to the taxpayers. On numerous occasions, this Committee has some—in some ways been bypassed, in direct approaches to the appropriations Committees—not the first organization that has done that.

I think it is overdue perhaps that this Committee exercise more rigorously our oversight of NASA in light of recent events. And I hope that in working with you and other members of the Committee on both sides of the aisle, we can achieve that oversight in a more effective and more responsive way to the American taxpayer.

For example, there should be some cost caps on some of these programs. They have continuously been increased over many years. We have been assured almost on an annual basis there would be certain cost limitations, and then those costs continue to increase.

We have not demanded restraint in spending, but we have demanded accountability in cost estimates that continue to be exceeded year after year.

So I thank you, Mr. Chairman. I thank the witnesses for being here today. And, it is great to be back.

Thank you, Mr. Chairman.

Senator FRIST. Thank you, Senator McCain.

[The prepared statement of Senator McCain follows:]

PREPARED STATEMENT OF HON. JOHN MCCAIN
U.S. SENATOR FROM ARIZONA

First, let me thank Senator Frist for holding this hearing today and for his continual leadership of this Subcommittee.

Over the past year, I have continually been amazed by the reports coming out of NASA about the mission failures and program delays. I am glad the Committee is examining these issues today. I understand that four of the reports on these incidents will be discussed while other reports will be released later this month.

The extent of mismanagment noted in these reports is very startling. For years now, I have expressed concern regarding NASA's management and I repeat that concern at this time.

I am pleased to see GAO is testifying along with the other witnesses. It is my understanding that GAO will offer preliminary findings regarding Shuttle workforce and safety issues and I applaud them for doing so.

In review of the various reports presented today, some of the overarching themes are apparent: staff complacency, inadequately trained personnel, lack of effective internal communication, and staff not following established procedures.

The funding impact of failures and delays is staggering, estimated to be in the billions of dollars. Some costs we can't even calculate. But, we do know that:

—the International Space Station cost increases amount to $9 billion;
—the two failed Mars missions cost $360 million; and
—X–33, the experimental reusable launch vehicle, the future of which is uncertain, has a cost to date of approximately $1 billion.

We know it will take some time for NASA to digest all of the recommendations that will be made here. As such, the Committee looks forward to a formal response from NASA very soon.

On a specific matter, yesterday, a press article reported that NASA knew of a fatal design flaw in the Mars Polar Lander even before its arrival at Mars, but that NASA withheld this information from the public. The article goes on to say that the future Young report on the Mars Polar Lander will be "devastating" to NASA. I

have requested a copy of this report from NASA, but NASA has indicated the report cannot be released until cleared by the White House.

It has been brought to my attention that NASA, earlier today, "categorically" denied this report.

I had originally hoped that the Young report would be a part of today's discussions, but the report was delayed from its original release date earlier this month.

If the media reports are true that NASA withheld critical information from the public and elected officials, then the trust that is vital between this government and its citizens has been violated and warrants a very serious examination of how the agency operates. During today's hearing I hope Mr. Goldin will specifically address this matter.

Senator Frist, again I thank you for your leadership on these issues and look forward to working with you and Senator Breaux in completing the NASA Authorization conference with the House.

Senator FRIST: This positioning of me here, and you there—just a few more days, and you will be back up here. That is all right. You cannot stay away too long. That is right.

[Laughter.]

Senator MCCAIN. Thank you.

Senator FRIST. Senator Burns.

STATEMENT OF HON. CONRAD BURNS, U.S. SENATOR FROM MONTANA

Senator BURNS. Thank you very much, Mr. Chairman. And that is the only chair you get to lean back though on. I noticed how he uses that very well.

[Laughter.]

Senator BURNS. Mr. Chairman, thank you, and thank you for holding this hearing today. I think it is very apropos, because of what has become a swirl of information that is flying around the country, and most of it has been on the negative side.

But I would tell you that any time that we deal with the unknown and the sciences and especially in our R&D, and our work in that area, there is always a failure or two along the way. And they get a lot more notice than all of the successes.

I was struck by an article that I read. The difference between this country and, let us say, our counterparts, our Russian friends, all the years that we were in the space business, we were taking the technology that has been developed and the imagination of NASA and what they have learned and everything that they did, we had a way of taking that technology and transferring that into the private sector for the use of all American people.

Our friends in Russia did not do that. They took all their technology and put it in a safe, and they held it there because they were afraid for anybody else to find out or do anything with it. And, therefore, you got a big powerful country over there that had as—at one time probably as—technologically was an equal with us. But they kept it in a safe, and they did not grow with it, and we did.

All the time, we were transferring that technology into the private sector, and we were using it and become a part of our economy in this country, both in the medical field, the science field, the pharmaceuticals, all these where we have had great technological advances due to our space program.

The other day, I mentioned that we had good news that we had found the Mars mission. It was in North Dakota. But I say that

in kind of a joke, but basically we have got some undiscovered places there too.

But nonetheless, we are not going to find all of the things that we try, and all the missions we go on are not going to be a success.

And—and even though what—it is the negative parts that—that happen in NASA that get the ink, it is the successes that we should put in a list and find out who is ahead in the ball game.

So Mr. Chairman, I think oversight is very, very good, because it allows the agency to come before this Committee and to lay it out exactly what they know and their plans for the future, because we are still a society that reaches out. We are still a society that goes into the unknown.

Our curiosity is as strong as it ever has been, and sometimes we are allowed up because of technology and what we know and what we do not know, and what we find out.

So I want to congratulate you. You know, there are different programs that are sponsored by NASA across this country with our learning institutions and our young people, is absolutely dynamic, because they capture the imagination of young people aspiring into the sciences, into the mathematics, into the physics part of our every day life.

And let us face it, that is the last frontier out there, and we lead. And not every mission is going to be successful, but I would say there is a learning process on every mission that is probably more than you can ever expect to buy by money. So I am interested to see this.

I have got a bill I have got to get over on Energy, Mr. Chairman, but thank you for having this hearing and thank you for asking the hard questions.

And I thank the leadership at NASA for coming today, because this is the way we solve our problems. This is the way we attack our challenges. And we do have challenges ahead of us.

And I thank the Chairman very much.

Senator FRIST. Thank you, Senator Burns.

As is customary, each witness will be given 5 minutes to present his or her prepared oral testimony. And Mr. Goldin will have as much time as he would like. The witnesses' entire written testimony will be made a part of the official record. And we will begin the first panel.

Welcome, Mr. Goldin, Administrator, National Aeronautics and Space Administration. I think the opening comments reflect where our initial approach is, and so feel free to deviate from your—your presented testimony based either in response now or at the time of questioning.

STATEMENT OF DANIEL S. GOLDIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GOLDIN. Thank you, Mr. Chairman. I would like to read my prepared oral statement and then address the issue that you and Senator McCain brought up.

Senator FRIST. That would be fine, thank you.

Mr. GOLDIN. Mr. Chairman, good afternoon, and it is a good afternoon. Thank you for the opportunity to appear before you

today regarding the recent failure of two Mars missions and delays in other NASA programs.

At NASA, we push the boundaries. We spearhead revolutionary change. And on occasion, we experience failure. We do not flinch from challenge. We learn from our failures. And, we support the Committee's objective of examining us. This hearing is part of a great democratic process of open dialog and I, personally, welcome it.

To begin, we must not forget that these failures have occurred in the context of a magnificent record of NASA accomplishments. I am proud of our record of having saved nearly $40 billion from planned budgets for the American taxpayer and doing more for less.

Since 1992, NASA has launched 146 payloads valued at a total of $18 billion. Of this number, 136 payloads were successful. Our total losses amounted to ten payloads measured at about a half billion, or less than 3 percent of the total payloads launched.

Planetary spacecraft, once launched twice a decade at a cost measured in billions are now routinely launched each year at a small fraction of that cost. This is world-class performance by any reasonable standard.

Indeed, NASA has experienced some severe disappointments and problems this last year, as you pointed out, the back-to-back losses of the Mars Climate Orbiter and the Mars Polar Lander and the Deep Space 2 probes, wiring problems in a hydrogen tank leak in the Shuttle, and a failure of the X–33 composite tank to pass a qualification test. We are paying close attention to these failures, examining them, searching for root causes, and recommending changes.

Mr. Chairman, let me also say that I believe strongly that delaying launches is not a failure. While we are vigilant about unnecessary cost growth, NASA is all too aware that rushing to launch when mission success issues have not been resolved increases the potential for failure and loss.

In fact, NASA is deliberately—and I underline deliberately—encouraging a culture change in which any person can speak up to stop a program or launch if it is not ready or if it unsafe for the hardware or crew.

During the last week, NASA released reports of the Shuttle Independent Assessment Team, the Mars Climate Orbiter mishap investigation board, and the Faster, Better, Cheaper review.

The report of Tom Young's team will be released next week, followed by the X–33 review in the next few months. I will refrain from discussing them today, but would be pleased to return to address them after they have finalized.

I might point out that all these reviews were invoked by NASA, not by outside sources. Some of the common findings from these reports are, one, in some cases, program managers did not employ the risk management tools that would have alerted them to the inadequacy of their budget, schedule and performance margins, with the consequence that risk levels were higher than anticipated, particularly in planetary missions, with fixed launch dates, launch vehicles, and science payloads.

Two, at a time of major cultural change and a rapid increase in the number of programs underway, some programs were staffed with next-generation program managers, who had not been adequately trained and mentored, both in terms of resources for lessons from the past experiences and the use of revolutionary new tools and techniques, which I will talk about later.

There have been instances in which problems have been observed, but not effectively communicated. And in some cases, employees have not adhered to sound engineering and management principles, particularly with respect to timely, independent peer review of scientific and technical approaches being used to achieve program goals.

The cold facts of these reports do not convey the hopes and aspirations of the NASA/JPL teams that they would achieve what most people believe is impossible. And these failures are not a basis for reversing our course in pursuit of revolutionary change. NASA will not reverse our course.

As has been the case at various times throughout the agency's 40-year history, we are committed to learn everything we can from these losses, alter our approach and with the dialog with Congress, where it is prudent to do so, move on forward.

As I stated before this Committee in 1997, "At NASA, we do not shy away from difficult missions. We have tremendous successes, but we also have failures, and we learn from them. Often the learning we do from our failures leads to greater successes than we originally imagined. That is why it is important for the young people to see NASA take risks. We want them to see that we are not afraid of failure and that they should not be either."

I want to publicly salute the entire NASA team, civil servants and contractors, and especially the courageous Mars 1998 team for their perseverance and courage they have displayed in the face of change and transition.

Success cannot be prescribed only by returning to past techniques for conducting missions. Success in the past was often achieved at great expense, using large government contractor teams and massive documentation to verify the design and implementation of complex systems. This nation cannot afford to do business in that manner, nor do we need to.

Revolutionary new technologies and approaches to engineering are emerging. Success in the future will be achieved by using technology to enable small teams geographically dispersed, operating in virtual environments, using new tools such as soft computing, neural nets and learning systems to enable more fault-tolerant systems. NASA is a leader in developing collaborative engineering environments and design tools.

These new directions will in the future enhance the quality and productivity of Faster, Better, Cheaper approaches. This strategy is a key element of our fiscal 2001 budget, and I seek the support of this Committee in implementing this strategy.

Mr. Chairman, NASA has a strong commitment to excellence. Our response to failure is to take out a magnifying glass, examine what went wrong and why, and take corrective action.

We disseminate the lessons learned to our work force and contractors. A better NASA team emerges through the process, galva-

nized to meet the challenges with renewed energy and resolve. This is a self-critical process, but essential to future success.

In the near future, we will have compiled an integrated analysis of the corrective actions we will implement in response to the findings and recommendations of all the reports. We look forward to the future opportunity to discuss them with you.

And in closing, I make this promise on behalf of the entire NASA team: NASA is resolved to make a great record even greater.

Thank you and I am prepared to respond to your questions.

[The prepared statement of Mr. Goldin follows:]

PREPARED STATEMENT OF DANIEL S. GOLDIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today in response to your request that I provide testimony on several Agency programs, and I congratulate you for holding this hearing that focuses on NASA's failures. As you know, my own management style is to focus on what we need to do better, even while recognizing that almost all of what NASA does is done successfully. We learn from correcting our mistakes, by identifying the lessons learned from our endeavors and then ensuring that other programs apply those lessons. NASA is a research agency operating at the cutting-edge of science and technology. Even though we strive for excellence, we also must be aware that space launch vehicles and spacecraft must operate in an environment that is extremely unforgiving.

We have recognized these challenges ourselves, and, on our own initiative, have proactively initiated a series of reviews. At the same time, I salute the NASA team; they are wonderful men and women experimenting with change. I welcome this opportunity to give you our preliminary assessment today of the several reviews that have been conducted and the reports that have been issued. We intend to reflect further, and would be pleased to return later this summer to outline our conclusions.

Mr. Chairman, I understand that the Subcommittee's focus today is upon management issues, but I would like to remind the Subcommittee that NASA's record of accomplishment has been outstanding. I am proud of our record of having saved approximately $40 billion from planned budgets for the American taxpayer, and doing more for less. As testimony to the performance of the NASA team, since 1992, NASA has launched 146 payloads valued at a total of $18 billion. Of this number, 136 payloads were successful. We believe our success is a testimony to NASA's strong systems engineering capability. Our total losses amounted to 10 payloads, measured at about $1/2 billion, or less than 3 percent. The Mars 1998 failures alone accounted for 60 percent of this loss. Planetary spacecraft, which used to be launched twice a decade at a cost measured in the billions, are now routinely launched each year at a small fraction of that cost. This is world class performance by any reasonable standard. I would like to recount a few of the successes of the past year:

- We began the year with the successful launch of Deep Space One, a mission to test 12 revolutionary technologies necessary for the future of space science.
- STS–93, commanded by the first female Shuttle commander, deployed the Chandra X-ray Observatory;
- Deployment of the EOS series of satellites was begun, with the launch of Landsat 7, followed by QuikSCAT, Terra, the flagship EOS satellite, and AcrimSAT.
- The X–33 program made considerable progress by beginning testing of the world's first aero-spike engine, scheduled to be completed this summer;
- ISS hardware to support the first 12 ISS assembly missions was completed and stands poised for launch at the Kennedy Space Center.
- On STS–103, we repaired the Hubble Space Telescope (HST), and HST has now found a value for how fast the universe is expanding, after 8 years of painstaking measurement; and,

- STS–99, the Shuttle Radar Topography Mission (SRTM) achieved a breakthrough in remote sensing that will produce topographic maps of Earth 30 times as precise as the best global maps in use today.

As you know, 1999 was marked by continuing launch vehicle failures that directly and indirectly impacted NASA programs. The Russian Proton failures have had a significant impact on the launch of the Russian Service Module Zvezda. The Japanese, Europeans, and the United States struggled to achieve safe and reliable access to space. Just two weeks ago, the Sea Launch vehicle experienced a failure. And, in 1999, NASA also experienced some severe disappointments and problems: the back-to-back losses of the Mars Climate Orbiter and the Mars Polar Lander and the Deep Space-2 probes, wiring problems and a hydrogen leak in the Shuttle, and a failure of the X–33 composite tank to pass a qualification test.

You have specifically requested that I address the Mars Program failures as well as delays in Space Shuttle launches, the International Space Station, X–33, and Gravity Probe B. You also asked me to specifically address the manner in which NASA is using systems engineering to facilitate the successful conduct of these missions.

A number of independent reviews have been commissioned to examine these problems, search for root causes, and recommend changes. NASA worked closely with the Department of Defense and others on the Broad Area Review of DOD space launch failures. In July 1999, NASA requested that the former Mars Pathfinder Project manager conduct a study of NASA's approach to Faster, Better, Cheaper (FBC) program management, and make recommendation on a set of principles, tools, and processes for ensuring NASA's success in adapting the FBC approach to project planning, management and execution. In response to ascent anomalies observed on STS–93, NASA, in September 1999, chartered a Space Shuttle Independent Assessment Team (SIAT). The objective of the SIAT was to undertake a technical review of Shuttle maintenance and operations, and to bring to the Space Shuttle, where applicable, best practices of the external commercial and military aviation community. In October 1999, NASA chartered a Mars Climate Orbiter (MCO) Mishap Investigation Board to assess the actual or probable cause of the MCO mission failure. Following the loss of the Mars Polar Lander, the charter of the Board was expanded to investigate a wide range of space science programs, and to make recommendations regarding NASA project management based upon lessons learned from the expanded review. In November 1999, NASA and Lockheed Martin formed a review team to assess the causes and implications of the X–33 Liquid Hydrogen Composite Tank failure.

Additionally, following the failures of the Mars Climate Orbiter, the Mars Polar Lander, and two Deep Space 2 microprobes, I determined that an in-depth review of the entire Mars Program should be undertaken by independent observers. The Mars Program Independent Assessment Team (MPIAT) was chaired by A. Thomas Young. The MPIAT report is expected to be released by the end of March, and the independent review of the X–33 tank failure is scheduled to be completed in the coming weeks. I will refrain from commenting upon either of those reports today.

As you can see, NASA has taken the initiative to commission these reviews and examine ourselves. Within the last two weeks, the reports of the Shuttle Independent Assessment Team, the Mars Climate Orbiter Mishap Investigation Board, and the Faster, Better, Cheaper Review have been issued. The reports will be made part of today's hearing record, and you will hear from the leaders of each team today. Some of the common findings from these reports are:

- in many cases, program managers did not employ the risk management tools that would have alerted them to the inadequacy of their budget, schedule and performance margins, with the consequence that risk levels were higher than anticipated, particularly in missions with fixed launch dates, fixed launch vehicles, and fixed science payloads;
- at a time of major cultural change and a rapid increase in the number of programs underway, programs were staffed with next-generation program managers without, in some instances, ensuring that they had been adequately trained and mentored, both in terms of resources for lessons learned from past experiences and the use of revolutionary new tools and techniques.
- there have been instances in which problems have been observed, but not effectively communicated; and,
- in some cases, employees have not adhered to sound engineering and management principles and Agency standards and procedures with respect to timely,

independent peer review of scientific and technical approaches being used to achieve program goals.

In summary, these findings convey a less than desired effectiveness of our project management and systems engineering practices with respect to the failed missions.

These reports, and the pending Mars Program Independent Assessment Report, will provide a set of findings and recommendations that can serve as a strong foundation for executing the changes in NASA program architecture, management, systems engineering, design, and execution needed in the future. As has been the case at various times throughout this Agency's 40-year history, NASA is committed to learn everything we can from these losses, alter our approach where it is prudent to do so, and move on. NASA has undertaken a journey toward revolutionary change with the strong support of the Administration and Congress.

These failures are not a basis for reversing our present course in pursuit of revolutionary change. And NASA will not reverse course. We are committed to fixing our shortcomings and moving forward. However, I believe it would be unwise to issue a prescription for mission success to the NASA workforce. They must have the freedom to innovate and learn. At the same time, there are fundamental considerations that must be taken into account. We must ensure that clear and independent peer review of scientific and technical approaches is done. It is essential that men and women being placed in new positions of responsibility and new technical assignments be trained and mentored, not only in terms of retrospective experiences and leadership, but prospectively as well, in terms of what we are already learning from revolutionary new tools and techniques. Criteria for mission success must be clearly articulated. Resource estimates must be commensurate with mission goals. Margins must be adequate. And there must be clear lines of communication up and down the management chain, allowing for open discussion. These fundamental considerations were not applied as they should have been in the Mars 1998 missions. As I stated before this Committee in 1997, "At NASA we do not shy away from difficult missions. NASA has tremendous successes, but we also have failures and we learn from them. Often the learning we do from our failures leads to greater successes than we originally imagined. That is why it is important for young people to see NASA take risks. We want them to see that we are not afraid of failure, and that they should not be either."

There is no prescription that can eliminate the chance of failure. And success cannot be prescribed just by returning to past techniques for conducting missions. Imposition of prescriptions for mission success runs the risk of suffocating openness to change, risk taking, and willingness to fail. Prescription does not work because it does not allow for innovation and incorporation of new concepts and technology. We must recognize that we are at the leading edge of a transition toward a new generation of scientists and engineers. We need to examine failures experienced by NASA, other Government agencies, U.S. industry, and throughout Europe, Japan, and Russia. Within the broader context of the advanced development and science base of the United States, we are witnessing a demographic change. The engineering experience base of Apollo and the Cold War is retiring from the work environment, at the same time that NASA is facing very tough competition from dot.com organizations and the high tech industry for the best engineers and scientists emerging from our universities. Simultaneously, we are witnessing the emergence of new technologies and new approaches to engineering. Soft computing, neural networks, and learning systems, are being incorporated into design and operations to enable more fault-tolerant systems rather than reverting to techniques of the past. The United States must be at the forefront of these new approaches to engineering, and must have a new engineering education curriculum to prepare its new engineers. NASA is fully engaged in these new directions in engineering and design tools, in information technology, nanotechnology, biotechnology and Intelligent Synthesis Environments. A key element of the Intelligent Synthesis Environment is Advanced and Collaborative Engineering Environments. These engineering environments were highlighted in the Phase I June, 1999 report of the National Research Council on Advanced Engineering Environments as a historic opportunity to create facilities and tools in collaboration with industry and academia to design, analyze, and conduct performance trade studies of complex systems with unprecedented levels of effectiveness in terms of time, cost and labor.

NASA has taken proactive steps with the development of such tools, methods and facilities at NASA Centers since the early 1990's. The Project Design Center at JPL, and the Integrated Mission Design Center at GSFC are two examples of the application of such environments early in the formulation process to define requirements, develop design concepts, conduct performance trade studies, assess technology benefits, and provide parametric cost data on complex NASA missions. These environ-

ments also provide an opportunity to capture lessons learned in systems engineering designs and analysis. All of these are responsive to some of the concerns raised in the MCO and FBC reports and clearly represent a visionary step to take full advantage of the information, design and analysis tools revolution. The Agency recognizes that further integration into the physical and cultural infrastructure of the Agency is needed. The Aero-Space Technology Enterprise has already taken steps with its Lead Centers to develop business plans to address such concerns.

I want to salute the Mars 1998 team. They pushed the envelope. The mistakes made can and will be corrected. Learning from those errors will enable NASA to strive for even greater accomplishments in the future. The entire NASA team, civil servants and contractors, has done an incredible job in the face of change and transition to Faster, Better, Cheaper.

Mr. Chairman, let me also say that I believe strongly that delays in launch are not a measure of failure. Your concern about delays, and the consequent costs, is well taken. However, NASA is all too aware that rushing to launch when mission success issues have not been resolved increases the potential for failure. In fact, NASA is deliberately encouraging a culture change in which any person can speak up to stop a program or launch if it is not ready, or if it is unsafe in terms of hardware or crew. We are modifying NASA's performance goals and renegotiating contracts to remove the emphasis upon schedule, and refocus emphasis upon better design and quality.

I salute our employees for their determination to delay launches of the Shuttle this past year until they were convinced we could safely launch. There are other instances, some involving delays of spacecraft valued at more than $1 billion, in which we have employed new tools and techniques with which our employees have demonstrated that they are empowered to identify problems prior to launch in order to fully resolve those issues.

- In the case of AXAF, NASA delayed shipping the spacecraft to verify software and faulty printed wiring boards were safe to fly.
- In the case of the Hubble Space Telescope servicing mission, we delayed the launch to complete inspection, maintenance and repair of Shuttle wiring.
- In the case of Terra, we delayed the launch to ensure that the launch vehicle propulsion system was safe following a previous Atlas IIAS failure.
- In the case of Deep Space-1, the team at the Jet Propulsion Laboratory had problems; they delayed the launch, added resources, and fixed it.
- In the case of the SRTM mission, a delay to upgrade the Shuttle allowed for additional analysis and simulations to enhance safety and mitigate risk, helping us to better deal with an in-flight anomaly. The ultimately stunning results will benefit a variety of civil and national security interests.

Mr. Chairman, NASA is in the process of addressing the various recommendations included in these reports.

I have directed the NASA Chief Engineer to work with the four NASA Enterprises and NASA's Centers to develop an integrated implementation plan in response to recommendations emanating from all these reports for improvement in Program/Project Management and systems engineering and for the improvement of NASA's institutional infrastructure with respect to people, process tools, and technology. Actions will be defined in consultation with Enterprise managers, the NASA Academy of Program/Project Leadership, a training arm of the Agency's Office of Human Resources, the Program Management Council Working Group, an Agency-wide team of experienced project managers and system engineers and the various review groups. To accomplish this, the Chief Engineer will form an internal team of experts to assess all recommendations and develop Agency-wide approaches for improving the success of the Faster, Better, Cheaper class of missions. By August 2000, specific actions will be defined to ensure consistency of best practices during the formulation and implementation of programs and projects. Promulgation and deployment of the resultant actions will begin immediately thereafter. As I indicated earlier in this statement, the team will complete their proposed improvements by midsummer. I anticipate that those actions will result in revisions to:

- Agency policy and requirements for program/project management regarding staffing, systems engineering, risk management, peer reviews and other best practices as well as leadership plans;
- Agency approaches to attracting, developing, and retaining key engineering and project management skills;

- increased utilization of information technology-based tools to aid project execution during all phases; and,
- heightened attention to development of future mission technology needs.

Mr. Chairman, I would like to outline a series of proactive steps that NASA has undertaken during the past 2 years that are intended to strengthen our systems engineering capability and which, when fully operational, will help address many of the recommendations included in the various reports. These steps reflect NASA's commitment to world-class systems engineering throughout Agency programs.

1. NASA deployed an Agency-wide NASA Policy Directive 7120.4, in November 1996, for Program/Program Management, and NASA Procedures and Guidelines NPG 7120.5, in April 1998, for NASA Program and Project Management Processes and Requirements. The processes and requirements defined by these documents are an integral part of the Agency-wide management system established to meet goals of NASA's Strategic Plan. This management system provides the framework to govern the formulation, approval, implementation and evaluation of Agency Programs and Projects.
2. A NASA-wide Core Competency assessment was undertaken in FY 1999 to define the requisite NASA workforce skills in all critical areas to accomplish Agency missions. One outcome of this activity was reflected in the Administration's FY 2001 budget request to add additional civil service staffing, following a 20–25 percent staffing reduction over the last several years.
3. An Agency-wide working group has formulated a revised policy on program/project management focused on enhancing Risk Management and the establishment, in October 1999, of a Systems Management Office at each Center, led largely by senior project managers and systems engineers, to ensure requirement traceability and adherence to sound systems engineering practices. Additionally, a focused effort has been undertaken to safely reduce civil servants assigned to operational tasks and to redeploy those resources to Research and Development activities compatible with the Agency's strategic thrust.
4. An Agency-wide focus on safety was implemented last summer. The motto "Mission Success Starts with Safety" is intended to ensure that the NASA and contractor workforce remain vigilant in keeping safety (including the safety of ground and space assets) the #1 core value. As part of this continuing focus, NASA, in concert with the Aerospace Safety Advisory Panel, is highlighting opportunities to design for safety. A renewed emphasis will be placed on Failure Modes and Effects Analysis (FMEA), fault tree analysis, and probabilistic risk analysis in all of our projects and programs.
5. The position of Deputy Chief Engineer for Systems Engineering was established in February 2000, and filled with a highly experienced person, in order to ensure increased attention to sound systems engineering practices throughout the Agency. Responsibilities of this position include the development of the vision, strategies and objectives for the development and maintenance of a world class engineering capability. This includes assessing the discipline and systems engineering workforce (quality, quantity, capability, recruitment, training, life long learning, work experience, and organization), enabling tools, facilities and methods, and the development of action plans for continuous improvement.
6. An Engineering Excellence Working Group has been established to develop the vision, strategies and objectives for the development and maintenance of a world class engineering capability throughout the Agency. As part of the Engineering Excellence initiative, the Chief Engineer is formalizing an Agency-wide Systems Engineering Working Group (SEWG). The SEWG will work closely with the Engineering Management Council in guiding the assessment of the discipline and systems engineering workforce, enabling tools, facilities and methods, and the development of action plans for continuous improvement.
7. NASA is placing increased emphasis on performing rigorous independent verification and validation of mission success-related software by enhancing the capability and responsibility of the NASA IV&V Facility.
8. For each of the 26 missions scheduled for launch in 2000, a rigorous independent "Red Team" review has been conducted to ensure that cost and schedule considerations have not inappropriately influenced prudent risk decisions. Some of these reviews have already led to launch delays because of concerns raised. Additional risk mitigation measures stimulated by these re-

views have already demonstrated enhanced success on the Shuttle Radar Topography Mission (SRTM).

9. In order to improve the approach to independent assessment of projects, the Chief Engineer has been tasked to better integrate the full set of Agency, Enterprise, program and project reviews to assure effective balance of performance, cost, schedule, and risk considerations by the project and appropriate awareness of those considerations by management.

Mr. Chairman, I understand that you are considering introducing legislation that would require NASA to develop a systems engineering plan and implement it for every mission. We believe that appropriate responses to recent mission failures, particularly the planetary failures, must be the product of a comprehensive evaluation, to ensure that both the root causes and contributing causes are addressed. All the steps I have outlined above are designed to produce an integrated Agency response to report findings and to simultaneously strengthen our program management. We do not believe that success can be prescribed with legislation. We know that you care about the success of NASA's program, and that you want to help. Rather than pursuing a legislated prescription for systems engineering, we propose instead that you permit NASA to complete our assessment and provide you the result of our integrated response by late summer.

I know that you and the other Members of this Subcommittee share NASA's objective to secure the maximum return on the investment of the American taxpayer in cutting-edge research and technology. I again commend you for focusing your attention on our recent mission losses, so that we can have a full and open dialogue on how we intend to address them. NASA remains fundamentally committed to revolutionary change so as to provide our Nation the highest quality space and aeronautics program. I have appended to my statement detailed information concerning the reports of the SIAT, the MCO Mishap Investigation Board, and the Faster, Better, Cheaper Review, as well as detailed information concerning program status of the Space Shuttle, International Space Station, X–33 and Gravity Probe B programs, as requested in your letter of invitation.

Thank you. I would be pleased to respond to your questions.

Enclosure

Mars Climate Orbiter Failure

The Mars Climate Orbiter (MCO) Failure Mishap Investigation Board was formally established by NASA's Associate Administrator for Space Science (OSS) on October 15, 1999.

The MCO Mission objective was to orbit Mars as the first interplanetary weather satellite and provide a communications relay for the Mars Polar Lander (MPL) which was due to reach Mars in December 1999. The MCO was launched on December 11, 1998, and was lost sometime following the spacecraft's entry into Mars occultation during the Mars Orbit Insertion (MOI) maneuver. The spacecraft's carrier signal was last seen at approximately 09:04:52 UTC on Thursday, September 23, 1999.

The Board was established to gather information, analyze, and determine the facts, as well as the actual or probable cause(s) of the MCO Mission Failure Mishap in terms of (1) dominant root cause(s), (2) contributing cause(s), and (3) significant observations and to recommend preventive measures and other appropriate actions to preclude recurrence of a similar mishap.

An immediate priority for NASA was the safe landing on Mars on December 3, 1999, of the Mars Polar Lander (MPL) spacecraft, then en route to Mars. The Board's investigation was conducted recognizing the time-criticality of the MPL landing, and the activities the MPL mission team needed to perform to successfully land the MPL spacecraft on Mars. Hence, the Board's first report was to focus on any lessons learned from the MCO mission failure in order to help assure MPL's safe landing on Mars. The Board completed its first report, which was accepted, approved and released by the Associate Administrator for Space Science and the Associate Administrator for Safety and Mission Assurance on November 10, 1999.

On January 3, 2000, the Associate Administrator for Space Science revised the objectives of the Board's second and final report to broaden the area of investigation beyond the MCO failure. The Board was to investigate a wide range of space science programs and to make recommendations regarding project management within NASA, based upon reviewing lessons learned from this broader list of programs.

The Board was also asked to address additional MCO findings and recommendations not related to MPL (and thus not reported in the first report), the ideal project management process to achieve "Mission Safety First," the current project manage-

ment process and where improvements are needed, recommendations for bridging the gap between the current and ideal projects, and metrics for measuring project performance regarding mission safety. The Board completed its final report, which was accepted, approved and released by the Associate Administrator for Space Science and the Associate Administrator for Safety and Mission Assurance on March 13, 2000.

Summary of Contents and Major Recommendations/Findings Contained in the First Report of MCO Mishap Investigation Board, Released November 10, 1999

The first Board report focused on any aspects of the MCO mishap that had to be addressed in order to contribute to the Mars Polar Lander's safe landing on Mars. The Mars Polar Lander (MPL) entry-descent-landing sequence was scheduled for December 3, 1999. The Board determined that the root cause for the loss of the MCO spacecraft was the failure to use metric units in the coding of a ground software file, used in trajectory models.

During the 9-month journey from Earth to Mars, propulsion maneuvers were periodically performed to remove angular momentum buildup in the on-board reaction wheels (flywheels). These Angular Momentum Desaturation (AMD) events occurred 10–14 times more often than was expected by the operations navigation team. This was due to the fact that the MCO solar array was asymmetrical relative to the spacecraft body as compared to Mars Global Surveyor (MGS) which had symmetrical solar arrays. This asymmetric effect significantly increased the Sun-induced (solar pressure-induced) momentum buildup on the spacecraft. The increased AMD events, coupled with the fact that the angular momentum (impulse) data was in English units, rather than metric units, resulted in small errors being introduced in the trajectory estimate over the course of the 9-month journey. At the time of Mars insertion, the spacecraft trajectory was approximately 170 kilometers lower than planned. As a result, MCO either was destroyed in the atmosphere or re-entered heliocentric space after leaving Mars' atmosphere.

While mistakes occur in spacecraft projects, sufficient processes are normally in place to identify such mistakes before they become critical to mission success. Unfortunately, for MCO, the root cause was not caught by the processes in-place within the MCO project.

A summary of the contributing causes and recommendations for MPL are listed below.

Contributing Causes:

1. undetected mis-modeling of spacecraft velocity changes;
2. navigation team unfamiliar with spacecraft;
3. trajectory correction maneuver number 5 not performed;
4. system engineering process did not adequately address transition from development to operations;
5. inadequate communications between project elements;
6. inadequate operations navigation team staffing;
7. inadequate training; and,
8. verification and validation process did not adequately address ground software.

Recommendations for MPL:

- the consistent use of units throughout the MPL spacecraft design and operations;
- conduct software audit for specification compliance on all data transferred between JPL and Lockheed Martin Astronautics;
- verify Small Forces models used for MPL;
- compare prime MPL navigation projections with projections by alternate navigation methods;
- train Navigation Team in spacecraft design and operations;
- prepare for possibility of executing trajectory correction maneuver number 5;
- establish MPL systems organization to concentrate on trajectory correction maneuver number 5 and entry, descent, and landing operations;
- take steps to improve communications;
- augment Operations Team staff with experienced people to support entry, descent, and landing;

- train entire MPL Team and encourage use of Incident, Surprise, Anomaly process;
- develop and execute systems verification matrix for all requirements;
- conduct independent reviews on all mission critical events;
- construct a fault tree analysis for remainder of MPL mission;
- assign overall Mission Manager;
- perform thermal analysis of thrusters feedline heaters and consider use of preconditioning pulses; and,
- reexamine propulsion subsystem operations during entry, descent, and landing.

Summary of Contents and Major Recommendations/Findings Contained in the Report on Project Management in NASA, by the MCO Mishap Investigation Board, released March 13, 2000

Building upon the lessons learned from the MCO, and a review of 7 other failure investigation board results, the Board's Report on Project Management in NASA lays out a new vision for NASA programs and projects—to improve NASA mission success within the context of the "Faster, Better, Cheaper" paradigm. This vision, "Mission Success First," entails a new NASA culture and new methods of managing projects.

The Board's recommendation is that, to proceed with this culture shift, mission success must become the highest priority at all levels of the program/project and the institutional organization. The Board found that the institutional organizations were not appropriately engaged in assuring mission success. The Board recommends that all individuals should feel ownership and accountability, not only for their own work, but for the success of the entire mission. The Board asserted that, because people working on a project are the primary element of the mission-success equation, a new emphasis on people must be addressed across NASA programs.

Examining the current state of NASA's program and project management environment, the Board found that a significant infrastructure of processes and requirements is already in place to enable robust program and project management. However, these processes have not been adequately implemented within the context of "Faster, Better, Cheaper."

The MCO mission was conducted under NASA's "Faster, Better, Cheaper" philosophy, developed in recent years to enhance innovation, productivity, and cost-effectiveness of America's space program. The "Faster, Better, Cheaper" paradigm has successfully challenged project teams to infuse new technologies and processes that allow NASA to do more with less. The success of "Faster, Better, Cheaper" is tempered by the fact that some projects and programs have put too much emphasis on cost and schedule reduction (the "Faster" and "Cheaper" elements of the paradigm). At the same time, they have failed to instill sufficient rigor in risk management throughout the mission lifecycle. These actions have increased risk to an unacceptable level on these projects.

The Report summarized lessons learned from the September 1999 loss of the MCO spacecraft. The Board's analysis of the mishap concluded that program/project breakdowns occurred in 5 key areas:

- systems engineering;
- project management;
- institutional involvement;
- communication among project elements; and,
- mission assurance.

The Report then compared these breakdowns with other failed NASA missions—as well as with a long history of successful NASA missions—and from that analysis outlined a formula for future mission success, termed "Mission Success First." "Mission Success First" is a comprehensive project management strategy for improving the likelihood of mission success in every NASA endeavor. It addresses elements of project management that require greater attention throughout NASA:

- renewing the focus on choosing and training the right personnel;
- establishing and monitoring disciplined project processes;
- ensuring proper project execution with active participation of NASA institutional line management; and,

- aggressively developing and maintaining leading-edge technology.

Among the recommendations in the Board's Report on Project Management in NASA are:

- improved system engineering processes;
- better, more thorough reviews;
- improved risk assessment and management;
- stronger teamwork and communications among all parties;
- improved process for reporting problems;
- operations involvement from the outset; and,
- use of a checklist formulated by the Board as a guide for project managers and review panels (see Attachment 1).

Spear Report on Improved Faster Better Cheaper Project Management

The Faster, Better, Cheaper (FBC) concept of project management was initiated by NASA in the early 1990's to challenge project managers of smaller, non-human spaceflight projects to use innovative approaches to reduce the development time of projects from 8–10 years to 3 years, and to development cost from billions to hundreds of millions. A corollary challenge was to reduce the size and complexity of spacecraft, such that singular mission failures would not significantly impact overall program objectives, if multiple smaller spacecraft were designed and built to accomplish the same mission previously accomplished by single large spacecraft. The primary Centers responsible for these types of spacecraft are the Jet Propulsion Laboratory (JPL) and NASA's Goddard Space Flight Center.

The Mars Pathfinder was one of the first FBC projects that had extensive visibility and was a resounding success. The Project was accomplished for about $250 million, developed and launched in approximately 3 years, and successfully landed on Mars on July 4, 1997. The project was managed by JPL under the leadership of Tony Spear.

In early 1999, after the completion of several FBC projects, NASA recognized that the tools and processes for the formulation and implementation of FBC were variable between projects, and that an assessment of best practices would be useful to document and promulgate across NASA Centers. The Department of Defense had also expressed interest in FBC processes. As a result, NASA's Chief Engineer requested that Tony Spear assemble a team to review FBC with the objective of making recommendations on a set of principles, tools and processes for ensuring NASA's success in adopting the FBC approach to NASA project planning, management and execution. The NASA FBC Task Final Report was released on March 13, 2000.

Major recommendations of the NASA FBC Task Final Report are:

- develop and maintain "Mission Risk Signatures" with mitigation plans;
- certify FBC project teams as to experience and expertise;
- teach FBC Lessons Learned and Rules of Engagement to all Centers;
- develop a Project Performance Metric Checklist which is updated at the yearly Independent Review;
- empower an independent check of project success criteria;
- strike a better balance between challenge and risk;
- increase priority on people acquisition, motivation and training;
- assign a person at Headquarters responsible for advanced technology infusion into projects;
- strike a better balance between empowerment and assessment;
- improve teaming between NASA, industry and universities;
- increase priority of university involvement in space missions; and,
- increase use of information technology tools.

Space Shuttle Independent Assessment Report

As a result of ascent anomalies experienced on STS–93 in July 1999, NASA Associate Administrator for Space Flight, Joseph H. Rothenberg, on September 7, 1999, chartered a Space Shuttle Independent Assessment Team (SIAT) to review Space

Shuttle systems and maintenance practices. The SIAT was led by Dr. Henry McDonald, Director, NASA Ames Research Center, with a team comprised of NASA, contractor, and DOD personnel.

The SIAT began work on October 4, 1999 and concluded their activities with a written report, submitted to the Associate Administrator for Space Flight on March 7, 2000.

The SIAT focused their review on 11 technical areas: avionics; human factors; hydraulics; hypergols and auxiliary power unit; problem reporting and tracking process; propulsion; risk assessment and management; safety and mission assurance; software; structures; and, wiring. The team examined NASA practices, Space Shuttle anomalies, and civilian and military aeronautical experience. NASA's goal for the SIAT study was to bring to Space Shuttle maintenance and operations processes a perspective from the best practices of the external aviation community and, where applicable or appropriate, apply these practices to the Space Shuttle. The SIAT Report was released on March 9, 2000.

The SIAT made 81 specific Recommendations in the 11 Technical Areas they reviewed; 4 recommendations were dispositioned by NASA prior to the STS–103 Hubble Servicing Mission. The SIAT summarized their recommendations in 9 issues, listed in the Executive Summary:

1. NASA must support the Space Shuttle Program (SSP) with the resources and staffing necessary to prevent the erosion of flight-safety critical processes
2. The past success of the Shuttle program does not preclude the existence of problems in processes and procedures that could be significantly improved.
3. The SSP's risk management strategy and methods must be commensurate with the 'one strike and you are out' environment of Shuttle operations.
4. SSP maintenance and operations must recognize that the Shuttle is not an 'operational' vehicle in the usual meaning of the term.
5. The SSP should adhere to a 'fly what you test / test what you fly' methodology.
6. The SSP should systematically evaluate and eliminate all potential human single point failures.
7. The SSP should work to minimize the turbulence in the work environment and its effects on the workforce.
8. The size and complexity of the Shuttle system and of the NASA/contractor relationships place extreme importance on understanding, communication, and information handling.
9. Due to the limitations in time and resources, the SIAT could not investigate some Shuttle systems and/or processes in depth. An independent group may be required to examine these other areas and should be tasked with reviewing the Shuttle program's disposition of SIAT findings and recommendations.

The SIAT divided the remaining 77 recommendations into the following categories:

- 37 recommendations identified as "Short-Term" (solutions required prior to making more than 4 more Shuttle flights);
- 30 recommendations identified as "Intermediate" (solutions required prior to January 1, 2001); and,
- 10 recommendations identified as "Long-Term" (solutions required prior to January 1, 2005).

NASA's Johnson Space Center, the Lead Center for Human Space Flight and the Space Shuttle Program, is reviewing and evaluating the SIAT recommendations, and will formulate a plan or response, as appropriate, for each over the next several weeks.

NASA's goal for the SIAT review, as with previous independent assessments of the Space Shuttle, has been to identify opportunities to improve safety. It should be noted that the SIAT Report fully endorsed the continuation of Space Shuttle flights after disposition of the Team's immediate recommendations. The SIAT documented many positive elements during the course of their interviews with the Space Shuttle NASA/contractor workforce. Particularly noteworthy were the observations dealing with the skill, dedication, commitment and concern for astronaut safety and the entire Space Shuttle workforce. The SIAT report will provide additional input to the full range of activities already underway associated with Space Shuttle safety investments, including upgrades, maintainability, processes for Shuttle safety, and quality control.

Space Shuttle Workforce

As NASA continues to assemble the International Space Station and support the infrastructure and upgrades to the Space Shuttle program as well as Expendable Launch Vehicle (ELV) commitments over the next 5 years, the workload will increase steadily. Internal and external workforce assessments have convinced NASA management that NASA Human Space Flight (HSF) civil service FTE targets must be adjusted. From internal reviews, such as NASA's Core Capabilities Study, to external evaluations by the Aerospace Safety Advisory Panel (ASAP) and the Space Shuttle Independent Assessment (SIAT), it has become apparent that the HSF workforce required immediate revitalization. Five years of buyouts and downsizing have led to serious skill imbalances and an overtaxed core workforce. As more employees have departed, the workload and stress remaining have increased, with a corresponding increase in the potential for impacts to operational capacity and safety. HSF Centers will begin to accelerate hiring in FY 2000, in order to address immediate critical skill shortfalls. After the initial hiring of 500 new personnel across the 4 HSF Centers in FY 2000, HSF workforce trends will begin a one-for-one replacement process and will allow HSF Centers to attain a steady state in civil service employment by FY 2001. NASA will continue to monitor HSF Center hires and attrition, ensuring that workforce skill balances are achieved and maintained.

NASA will work with the Office of Management and Budget, in the coming months, to conduct a personnel review with an eye toward the future. This review will assess management tools and innovative approaches for personnel management that might best equip NASA to evolve and adapt our civil service workforce in the future. This will be particularly important as NASA continues our transition from operations to a focus on advancing the frontier with cutting edge research and development in science and technology.

ISS Cost Status

Last year, NASA testified before the Congress that the FY 2000 budget would provide stability throughout the assembly of the ISS, allowing us to uphold our commitment to our International Partners on the ISS program, while providing critical contingency capabilities. This has indeed been the case. Compared to the FY 2000 budget, the FY 2001 budget request reflects an overall reduction in the budget and runout estimates through FY 2005 of about $1.2 billion. Roughly $0.8 billion of this reduction is due to the movement of funding for the Phase 2 production of the ISS Crew Return Vehicle (CRV) to the Science, Aeronautics and Technology budget account. The FY 2002–2005 funding estimates for the CRV will reside in that account pending a decision in the next 2 years on whether to proceed with an X–38-based CRV design. This decision will be made in the context of broader decisions that NASA and the Administration will make regarding future space transportation architectures. There was also an approximate $0.4 billion reduction in other ISS funding, over 5 years, to fund Agency needs and other high priority activities such as the Bioastronautics initiative.

While the 5-year funding profile for ISS has decreased in the FY 2001 budget, overall development costs are projected to increase. This growth, as in past years, is driven primarily by projected delays in reaching Development Complete. Development Complete is the point at which the ISS crew complement can be increased from 3 to 6 crew. Our current estimate is that the Development Complete schedule milestone will occur between Fall 2004–Fall 2005, with the projected cost in the range of $23–25 billion. Our estimate is that Assembly Complete schedule milestone will occur between May 2005–November 2006, with the projected cost in the range of $24–26 billion. These estimates do not reflect the full cost of contingency reserve for additional development effort and Shuttle costs that would be required to accommodate a partner or partners having difficulty meeting ISS commitments.

NASA has kept the Committee briefed on the challenges facing NASA and our International Partners on the ISS program. Both U.S. and Russian difficulties contributed to last year's schedule delay. The Russian delays were caused by a Proton launch failure investigation. The planned July 2000 launch of the Service Module is now about a year later than projected in March 1999. While there has been much discussion about the state of readiness about our Russian partner, NASA has also experienced schedule delays. U.S. launch schedules supporting the ISS have slipped as a result of the wiring safety stand-down of the Shuttle fleet. Development and testing of U.S. elements has proceeded somewhat more slowly than expected. However, the current Service Module launch schedule date provides several months of schedule margin for U.S. assembly flights.

At about this time last year, our Prime contractor reassessed their estimated level of overrun at completion of the ISS development contract. At the time, they had

completed about 80 percent of the developmental effort, and their estimate of a $986 million overrun represented about 11 percent growth. Due to the level of increase in their estimate, and the fact that the development program was coming to closure, NASA initiated several additional independent analyses to establish confidence in the new Boeing estimate and to reassess Boeing's performance management processes. One of these steps was to request the NASA Inspector General (IG) to provide their assessment of the performance management and Prime costs. The IG report highlighted that Boeing continued to make optimistic estimates of their overrun. NASA continues to budget to a level higher than the Boeing estimate. The prime contract will continue to make hardware deliveries this year, as the cost to go on the development contract decreases significantly.

Gravity Probe B

Gravity Probe B is the relativity gyroscope experiment being developed by NASA and Stanford University to test two extraordinary, unverified predictions of Albert Einstein's general theory of relativity. The experiment is intended to measure, very precisely, tiny changes in the direction of spin of 4 gyroscopes contained in a satellite orbiting at a 400-mile altitude directly over the poles. The gyroscopes are designed to be so free from disturbance that they will provide an almost-perfect space-time reference system. They will measure how space and time are warped by the presence of the Earth, and, more profoundly, how the Earth's rotation drags space-time around with it. These effects, though small for the Earth, have far-reaching implications for the nature of matter and the structure of the Universe. Since the initiation of Gravity Probe B in 1988, $453 million has been spent on GP–B development.

Although the completion of the GP–B program has been a schedule and cost struggle for some time, Stanford University has made significant progress in building over 85 percent of the complex subsystems of GP–B. These subsystems are meeting or exceeding specifications required to conduct a creditable experiment to verify Einstein's General Theory of Relativity. Stanford has considerable technical capabilities and a high degree of dedication.

As a result of a recent functional test of GP–B's Integrated Dewar & Probe, significant technical anomalies have surfaced, which required the de-integration of the payload as well as the implementation of design modifications. A re-integration and repeat of the functional testing to verify the effectiveness of the modification and to certify the flight worthiness of the payload will follow this activity. The complex nature of this integration process, which is unlike any payload ever built, coupled with the data readout sensitivity and precision requirements of the hardware, has resulted in a substantial schedule slip as well as the cost to complete the program.

With the focus to resolve the current technical issues, NASA is aware that new issues could surface as a result of the changes being made. We are taking a number of steps to ensure that our design modification are sound and that all possible steps are taken to minimize future technical issues:

- NASA has recently intensified the direct involvement of our existing External Independent Readiness Review (EIRR) team by asking them to work closely with Stanford and the Marshall Space Flight Center (MSFC) to review all aspects of the program. This includes the proposed design modifications and daily feedback to the Stanford/MSFC design team on recommendations that promote schedule and cost control with the emphasis on mission success. The EIRR reports the status of the program regularly to NASA's Associate Administrator for Space Science.

- NASA established an Independent Review Team comprised of nationally recognized industry and Government experts in building complex space systems. This team was chartered to "conduct an assessment of the programmatic health (technical, schedule, management) of the Gravity Probe-B program" and provide immediate feedback to Stanford University, MSFC and NASA Headquarters on any modification to the design or flight qualification of the payload necessary to ensure mission success. The Independent Review Team completed its review and reported back to the Associate Administrator for Space Science in late February with the following conclusions:

  Schedule Risk Assessment:

- poor prediction of progress on critical path;

- high probability that electronic boxes (already more than a year behind schedule) will impact critical path during environmental testing;

- probe repair is on critical path; and,

- additional funding needed to mitigate schedule.

Cost Risk Assessment:

- any schedule or technical issue could become a cost risk if not resolved quickly;
- need to install NASA management at Stanford for quick decision making and to insulate Stanford from outside distractions;
- refurbish Probe B as flight backup unit to mitigate potential payload recycle; and,
- technical Risk Assessment:
- Probe C neck temperature anomaly of most concern; root cause remains unknown.

As a consequence of the testing problems, GP–B has been delayed at least 18 months and is currently under consideration for an April 2002 launch. NASA's estimated cost to address the technical problems and the schedule delays is $65–100 million. As the Committee is aware, approximately $20 million of this increase has already been accommodated in NASA's FY 1999 and FY 2000 Operating Plans and in the FY 2001 budget request. Analysis is underway to define impacts to the Space Science budget to fund the remainder. A Headquarters-controlled critical milestone schedule is also in development.

During the late July timeframe, NASA expects to make a decision with respect to the future of the Gravity Probe B Program, based upon the extent to which progress is being made toward resolving the technical and schedule issues, and the extent to which remaining budget requirements will impact other Agency science priorities.

X–33 Status

The X–33 objective is to demonstrate technologies and operations concepts with the goal of reducing space transportation costs to one tenth of their current level. NASA is utilizing an innovative management strategy for the X–33 program, based on industry-led cooperative agreements, allowing a much leaner management structure, lower program overhead costs, and increased management efficiency. The X–33 program Phase II selection was made in July 1996 based on specific programmatic, business planning, and technical criteria. NASA selected the Lockheed Martin Skunk Works to lead an industry team to develop and flight test the X–33.

The X–33 is an integrated technology effort to flight demonstrate key Single Stage To Orbit (SSTO) technologies, and deliver advancements in:

1. ground and flight operations techniques that will substantially reduce operations costs for a Reusable Launch Vehicle (RLV);
2. lighter, reusable cryogenic tanks;
3. lightweight, low-cost composite structures;
4. advanced Thermal Protection Systems to reduce maintenance;
5. propulsion and vehicle integration; and,
6. application of New Millennium microelectronics for vastly improved reliability and vehicle health management.

The X–33 Program deals with cutting-edge technologies, such as large composite tanks, a metallic thermal protection system, innovative aerospike engines, and a lifting body approach to a launch system. The program has made considerable progress in the last year. The X–33 launch complex was completed and site activation begun. In addition, the structural testing of the liquid oxygen tank was successfully completed; the flight software was delivered and verification and validation was undertaken; the linear aerospike engine was delivered to Stennis and testing begun; the metallic TPS was flight qualified; and the liquid hydrogen composite tank was delivered to MSFC for testing. Three cryogenic and structural load tests of the hydrogen tank, based upon 105 percent of maximum flight conditions, were completed. However, after the completion of the third test, a partial failure of the outer skin of one of the 4 lobes of the tank was observed.

A failure investigation of the hydrogen tank, by a team of NASA and industry personnel, was initiated in November 1999. The failure investigation team will make a report on the root cause of the failure. Their report is expected to be released within the coming weeks. After reviewing the team's findings, NASA and the contractor will jointly agree on the approach necessary to recover from the hydrogen tank failure and then proceed with development of a recovery plan and schedule.

In an effort as technologically challenging as the X–33 program, incidents like the tank failure—while disappointing—are not unexpected. Furthermore, it is important

to remember that, thanks largely to our commitment to safety and the various independent reviews we have carried out, the tank failure occurred in the test stand rather than in flight.

As the X–33 program has evolved, our industry partners have been exceptional in accommodating such challenges. While industry's investment has grown significantly since the beginning of the program, NASA's financial investment in the X–33 has not increased. We have, however, utilized additional staff across the Centers to help resolve issues as they have arisen. As other challenges develop in the future, we will assist our industry partners to the extent that our program priorities permit.

Attachment 1*

MISSION SUCCESS FIRST

Checklist for Project Management and Review Boards

PEOPLE

Leadership

- ☐ Is an accountable, responsible person in place and in charge with experience and training commensurate with the job?
- ☐ Does the leader work well with the team and external interfaces?
- ☐ Does the leader spend significant time fostering teamwork?
- ☐ Is safety the number-one priority?

Organization/Staffing

- ☐ Is the organization sound?
- ☐ Is the staffing adequate?
- ☐ Are science and mission assurance elements properly represented in the organization?
- ☐ Does the organization enable error-free communication?

Communications

- ☐ Is **"Mission Success First"** clearly communicated throughout the organization?
- ☐ Is open communications evident, with all parties having an opportunity to be heard?
- ☐ Is a "Top 10" reviewed and acted upon weekly?
- ☐ Are all team members encouraged to report problems?
- ☐ Are line organization/project communications good?
- ☐ Do all team members understand that the only real success is mission success?

Project Team

- ☐ Is safety the number-one priority?
- ☐ Has team chemistry been considered, and personality profiles reviewed?
- ☐ Is staffing adequate for project size, and are the right people in place?
- ☐ Are people who could not demonstrate teamwork gone?
- ☐ Are all key positions filled and committed to a sustained effort over the project's life cycle?
- ☐ During team formation, has the project manager performed an Agency-wide search to identify key technical experts for membership on the team or sustained support to reviews?
- ☐ Is the team adequately staffed and trained in the processes?
- ☐ Are team members supportive and open with one another, review boards and management?
- ☐ Does the team actively encourage peer reviews?
- ☐ Are science representatives involved in day-to-day decision-making?
- ☐ Does the team understand that arrogance is their number-one enemy? Does the team understand that "anyone's problem is *my* problem?"
- ☐ Does the team have assessment metrics, which are evaluated regularly?

PROCESS & EXECUTION

Systems Engineering

- ☐ Are risk trades included in the scope of the system engineering job?

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* *Prepared by the Mars Climate Orbiter Mishap Investigation Board*

- ☐ Have risk trades been performed and are risks being actively managed?
- ☐ Have flight/ground trades been performed?
- ☐ Is a fault tree(s) in place?
- ☐ Are adequate margins identified?
- ☐ Does mission architecture provide adequate data for failure investigation?
- ☐ Is **"Mission Success First"** reflected in the trades and systems efforts?
- ☐ Is there a formal process to incorporate lessons learned from other successful and failed missions?
- ☐ Has the team conducted reviews of NASA lessons-learned databases early in the project?
- ☐ Is a rigorous change control process in place?

Requirements

- ☐ Was mission success criteria established at the start of the mission?
- ☐ Is **"Mission Success First"** reflected in top-level requirements?
- ☐ Are mission requirements established, agreed upon by all parties, and stable?
- ☐ Is the requirements level sufficiently detailed?
- ☐ Is the requirements flowdown complete?

Validation and Verification

- ☐ Is the verification matrix complete?
- ☐ Are the processes sound?
- ☐ Are checks in place to ensure processes are being followed?
- ☐ Does every process have an owner?
- ☐ Is mission-critical software identified in both the flight and ground systems?
- ☐ Are processes developed for validation of system interfaces?
- ☐ Are facilities established for simulation, verification and validation?
- ☐ Is independent validation and verification planned for flight and ground software?
- ☐ Are plans and procedures in place for normal and contingency testing?
- ☐ Is time available for contingency testing and training?
- ☐ Are tests repeated after configuration changes?
- ☐ Are adequate end-to-end tests planned and completed?

Cost/Schedule

- ☐ Is cost adequate to accommodate scope?
- ☐ Has a "bottoms up" budget and schedule been developed?
- ☐ Has the team taken ownership of cost and schedule?
- ☐ Are adequate cost reserves and schedule slack available to solve problems?
- ☐ Has mission success been compromised as a result of cost or schedule?

Government/Contractor Roles and Responsibilities

- ☐ Are roles and responsibilities well defined?
- ☐ Are competent leaders in charge?

Risk Management/Analysis/Test

- ☐ Is risk managed as one of four key project elements (cost, schedule, content and risk)?
- ☐ Are analysis measures in place (Failure Modes and Effects Analysis, Fault Tree Analysis, Probablistic Risk Assessment)?
- ☐ Have single-point failures been identified and justified?
- ☐ Has special attention been given to proper reuse of hardware and software?
- ☐ Has extensive testing been done in the flight configuration?
- ☐ Have potential failure scenarios been identified and modeled?
- ☐ Is there a culture that never stops looking for possible failure modes?

Independent/Peer Review

- ☐ Are all reviews/boards defined and planned?
- ☐ Is the discipline in place to hold peer reviews with "the right" experts in attendance?
- ☐ Are peer review results reported to higher-level reviews?
- ☐ Are line organizations committed to providing the right people for sustained support of reviews?

Operations

- ☐ Has contingency planning been validated and tested?
- ☐ Are all teams trained to execute contingency plans?
- ☐ Have mission rules been formulated?
- ☐ Has the ops team executed mission rules in simulations?

- ☐ Are plans in place to ensure visibility and realtime telemetry during all critical mission phases?

Center Infrastructure

- ☐ Is a plan in place to ensure senior management oversight of the project?
- ☐ Is a plan in place to ensure line organization commitment and accountability?
- ☐ Is a plan in place to mentor new and/or inexperienced managers?

Documentation

- ☐ Have design decisions and limitations been documented and communicated?
- ☐ Is a process of continuous documentation in place to support unanticipated personnel changes?
- ☐ Is electronic/web-based documentation available?
- ☐ Are lessons-learned available and in use?

Continuity/Handovers

- ☐ Are handovers planned?
- ☐ Are special plans in place to ensure a smooth transition?
- ☐ Do core people transition? Who? How many?
- ☐ Is a development-to-operations transition planned?
- ☐ Does development-team knowledge exist on the operations team?
- ☐ Is a transition from the integration-and-test ground system to new-operations ground system planned? If so, is there a plan and schedule to revalidate databases and procedures?
- ☐ Have there been changes in management or other key technical positions? How was continuity ensured?
- ☐ Have processes changed? If so, has the associated risk been evaluated?

Mission Assurance

- ☐ Is staffing adequate?
- ☐ Are all phases of the mission staffed?
- ☐ Is mission assurance conducting high-level oversight to ensure that robust mission success processes are in place?

TECHNOLOGY

Technology Readiness

- ☐ Is any new technology needed that has not matured adequately?
- ☐ Has all appropriate new technology been considered?
- ☐ Has it been scheduled to mature before project baselining?
- ☐ Does it represent low deployment risk?
- ☐ Is there a plan in place to train operations personnel on new technology use and limitations?

Mr. GOLDIN. But, first, if it is OK with you, I would like to respond to the issue that you and Senator McCain brought up. First, with regards to the Young report, we recognized that more time would be necessary for NASA to review the report.

We got our in-house briefing on March 14th. There is an appendix for the report we received electronically today by John Cassani. We will review that in detail.

I have a meeting scheduled with Tom Young on Friday to clarify a number of the issues. And we expect to issue the report early next week.

We made your staff aware about 3 weeks ago of this situation and said we would be prepared to have the hearing after the Young report was released, or to go ahead now, and then after the Young report is released, have another hearing. So this is the first point I would like to make.

Senator FRIST. And the Young report will be released when?

Mr. GOLDIN. I think Tuesday next week.

Senator FRIST. All right.

Mr. GOLDIN. Well, we will meet with him Friday. And then we will have it out Tuesday along with the appendix I referred to.

Senator FRIST. Is it being altered now, the report, based on your——

Mr. GOLDIN. No. The report is not being changed itself. But we needed to get the final version of the supporting appendices, which is quite a thick report, so we could review it, and be prepared to ask questions to get clarification. But, we do not change those reports. That is very clear.

Senator FRIST. And is it appropriate for our Chairman to see that report at this juncture?

Mr. GOLDIN. We were unaware that there was a request made. And I just asked my staff when that statement was made. We are unaware that there was any request made for that report.

Senator FRIST. OK.

[Pause.]

Mr. GOLDIN. Oh, I stand corrected. A request was made for the report and the NASA respondent said the report was not available yet, because we did not have all the appendices to that report. And that is what we received today.

Senator FRIST. So you have the appendices. Would you expect—well, you may not be able to answer—now, would you expect that our Chairman could—could see that report?

[Pause.]

Mr. GOLDIN. We are days away from making the report public.

Senator FRIST. OK. Proceed.

Mr. GOLDIN. OK. Secondly, with regards to the UPI story, there was an allegation made incorrectly in the story about testing of the thrusters. We identified that problem in November. There was an open press conference on it, I believe, November 11th, where it was thoroughly discussed and the contractor was made aware of the problem, and we had time to do testing of that propulsion system before the scheduled landing of the Mars Polar Lander.

There are a number of things that were very, very irregular in that press report. We have made our concerns known to UPI, and we believe we are doing all the right things.

Senator FRIST. Just—just for the record, the article is entitled, "NASA Knew Mars Polar Lander Doomed," by UPI, United Press International, March 21st, 2000, by James Oberg, O-b-e-r-g, UPI Space Writer.

Mr. GOLDIN. By the way, the press conference was November 8th, and at that point in time the team believed they had a real good chance of doing it. In fact, the head of the investigation team of the Mars Climate Orbiter, Art Stephenson, had asked the propulsion expert, a gentleman named Bob Sachiem to get involved.

He identified that problem at that time and they requested additional testing to get more confidence in that landing system.

[Pause.]

Senator HUTCHISON. So are you saying that you did—that NASA did not know there was a fatal flaw in the braking thrusters?

Mr. GOLDIN. We knew about that in November, and we asked for an additional test——

Senator HUTCHISON. And the——

Mr. GOLDIN. —set of tests to make sure we—and they did those tests and they reset the conditions on the spacecraft, so we did not believe it would be a fatal flaw after the tests.

Senator HUTCHISON. You thought then it had been fixed?

Mr. GOLDIN. Yes.

Senator FRIST. The—I do not—I do not want to belabor the press article, because I know we have so much to cover, but yesterday's press article also mentioned your safety memo issued on March 20th to NASA employees in which you stressed, and I quote, "the important of adequate testing."

Can you elaborate at all on that memo?

Mr. GOLDIN. I would be honored to elaborate. As the NASA Administrator, I give a safety lecture on Mondays. My notes from the safety lectures are put on the Internet. I announced to my staff that I intend to talk about safety at our Monday morning phone call. And that is the subject I talk about. And each week, I pick another subject to talk about safety. That was one of the subjects I talked about.

Senator FRIST. And those comments there were not related to the Mars failures in that memo?

Mr. GOLDIN. Those comments were related to a variety of circumstances that I had expressed concern about, proper validation and testing. It is fundamental to good, sound engineering practice and as the head of the agency, I feel it is crucial that that is what I talk about.

Senator FRIST. Well, let us move on again. I do not want to—the UPI article, you have rebutted in part with a—with a press release today; and rather than go through it, we can come back to it if people have specific questions.

Let me—was there anything else to respond to?

Mr. GOLDIN. Mr. Chairman, I would like to add one more point to it. Most responsible reporters, if they feel they have a story, always call and give the agency a chance to respond and rebut. We never received such a call.

And I believe among the people in the Nation that work on these cutting edge approaches, I am at the cutting edge of safety. And I take it as an affront that I would actually worry about a failure and cover up a failure when I talk about safety. My record is open and clear and I have absolutely no regrets, no concerns and no apologies.

Senator FRIST. Mr. Goldin, there are a number of reports—and as you looked through the recommendations and suggestions, a common finding seems to be that employees—and you acknowledge this in your written statement—have not adhered to sound engineering and project management principles, agency standards and procedures.

It—again this is from a number of the reports. How do you plan to correct these findings in the reports?

Mr. GOLDIN. OK. Again, I would like to provide a little context before I answer that. We have had spectacular successes. The Mars, the Lunar Prospector, the Pathfinder Mission.

We have had more than a dozen successful missions where execution was outstanding. But let me give you an example of one of them. We are in the middle of unbelievable change. And the Jet Propulsion Lab, in particular, went from an average of four projects to fifteen to twenty projects.

So we had a new team coming on. Some teams executed well. And other teams did not execute. On the Pathfinder Mission, which successfully landed on Mars, it was a radical new management approach, different.

We had wise old owls come in to critique it. And they constantly said, "Impossible, this will not work. It is a disaster." After we landed on Mars—but the people persevered in spite of the criticism, because they wanted to bring about change. They did a mission for one-tenth the cost of a prior mission. And they did it in 3 years instead of ten.

Of course, we are going to make errors. But after that spacecraft landed on Mars in 1997, the person who criticized it walked up to me and said, "Dan, I have been openly criticizing this approach. And I want to take this opportunity to apologize. You took a risk. You did it right."

Now, did we have problems? Yes. And I think that due to the fact that we pushed real hard on budget, and I am personally responsible for that, we wanted to see where the boundaries were.

It used to cost $600 million on average to build a spacecraft at NASA. And it used to take on average 8 years. And in 1992, we launched two scientific spacecraft. We now are launching more than ten. The average cost is $208 million and it takes 5 years. Did we push the limits? You bet. Did we push too fast? Absolutely. But we now are stepping back and saying, "Look, we found some problems. We are going to understand it. But we are not returning to $600 million a spacecraft. We are not returning to 8 years on average. And we are not returning to two launches a year."

I might also point out that we lost a spacecraft in 1992 called the Mars Observer. $800 million, and we had "proven techniques," but they tried something different and they failed. We should not blame the people.

Now, as a final point, we intend to take all these reports, Mr. Chairman, and we are going to have our chief engineer pull the key features together. And when we go through all these issues, within some months from now—we intend to come back to this Committee to tell you exactly what we think we need to do to fix these issues and we will hold education courses with every key NASA and contractor employee. We intend to set up a very major training program.

In later testimony, in the Stephenson report, he calls out a checklist, which I put into the written testimony. That is going to serve as a starting point for where we want to go.

And I believe that this will only strengthen our ability, but let me come back and say we had projected that in the 2000 to 2004 timeframe we would drop from $208 million a space craft to $86 million.

I think we are going to have to re-look at that and see if we want to moderate that, because it is clear we have now hit the limits and we probably cut too tight.

But this is a message to my associates in industry.

Senator FRIST. I want to move on to other questions.

I guess, again, looking through the reports, when we say inadequate adherence to sound engineering and project management principles, it goes beyond budget and doing things inexpensively,

because you are not going to be cutting management principles and—and sound engineering practices.

And so to me, there are two issues. That is why I do want to stay on management during this hearing as much as possible.

Mr. GOLDIN. OK. Good.

Senator FRIST. And—and you have—you have answered the question, what you plan, and to go through the checklist, and look to the future.

Mr. GOLDIN. Right.

Senator FRIST. But, again, on each of these statements when these critiques are there, even though we have been tremendously successful, when we are talking about management, when we are talking about sound engineering practices, agency standards and procedures, somewhere it is not working.

Mr. GOLDIN. I agree. We had just a few programs at NASA that lasted about a decade. There was tremendous stability in that. There was time to train people and bring them up the line.

Now, suddenly, we have increased the number of programs by about a factor of four or five. We are bringing on a new staff that has never been in leadership positions. I believe the problem was in inadequate training and mentoring of those people. Some of them took to it naturally and did not have problems. But I would say the key error that was made in judgment in executive management was not setting up an adequate training and mentoring program, which has nothing to do with money. And I think that is the point that you were driving at.

Senator FRIST. Yes. Thank you.

Senator Hutchison.

Senator HUTCHISON. Thank you, Mr. Chairman.

NASA has had to repeatedly fight for funding our existing human space flight commitments to complete the Space Station and upgrade the Shuttle.

I have been on the station and I have seen the potential that we have for medical research and new technologies that can be available from space research, but I—I wonder if there is a priority.

If short exploratory missions to Mars are the best way to advance NASA, should that be done at the expense of human space flight, research and development. Is there a priority that you see, or do you think we can do both with the—the limited budget that you have?

Mr. GOLDIN. The No. 1 priority at NASA is fly the Shuttle safely. The No. 2 priority at NASA is successfully complete construction of the Space Station.

The No. 3 priority at NASA is work with the industry in America, and develop revolutionary new ways of making the reliability of access to space for people and payloads a factor of ten better and one-tenth the cost.

The fourth priority at NASA is to do good science and technology and meet the expectations of the American people. It is in our strategic plan. It is part of our budget process. And that is——

Senator HUTCHISON. You put in the good science——

Mr. GOLDIN. —where we put the priorities.

Senator HUTCHISON. —and technology. Is the Mars exploration in that fourth category?

Mr. GOLDIN. Yes.

Senator HUTCHISON. Last fall we heard testimony from NASA and the USA prime contractor about the Shuttle wiring matter. And at that time, NASA and USA testified that safety was put first, and that, in fact, USA knew they might get a $3 million penalty, but nevertheless, chose not to launch the next scheduled vehicle and inspect all the vehicles from that time forward.

Is that consistent with the findings of the McDonald report, and are there any things that would be done differently today in inspection of those vehicles that are because of the report?

Mr. GOLDIN. Well, I think the report heightened our awareness, but what happened was exactly what I referred to in my opening statement. We want to encourage a culture at NASA where schedule is not the driving force, but the safety of the people and the high value assets is important. And that was correct.

But the McDonald Committee pointed out some other issues. But I might point out that when we went through this wiring, they indicated that there was one area we needed to look at a little bit more, and it was a key finding.

And, in fact, they said that we should do this before we launched the Shuttle, and that is, 70 percent of the wires were very, very visible and you could see where there could be abrasions, but about 30 percent of the wires were inside areas that blocked the visual sight.

So they recommended that we take the Shuttle Columbia which was in Palmdale, and since we were doing an orbital maintenance down-period on it, to open up areas that are invisible and see if we had any abrasion or any problems with the wires to validate that our assumptions were correct. And sure enough, when we opened up closed areas, we found almost no problem, so we were able to validate. And that's why we felt comfortable successfully launching it.

So, I think the McDonald panel pointed out something very, very important which caused us to think more and to delay a little bit more. It was a very valuable input.

Senator HUTCHISON. Last year we provided $25 million in new upgrades that were directed at placing a higher priority on keeping the Shuttle fleet properly maintained. You have mentioned to me that in your fiscal year 2001 budget, there is funding for new Shuttle upgrades.

Which new upgrades have you funded with the additional $25 million that was provided in last year's appropriation, and what do you plan to fund with the $156 million contained in this year's budget request, and are they all safety related?

Mr. GOLDIN. First, let me answer the second question. They're all safety related. And, in fact, the No. 1 priority on upgrades is to get rid of the hydrazine in the auxiliary power unit which was one of the major suggestions made by the McDonald Panel. They were very, very concerned about this equipment, and that $25 million from last year got us started on that.

The second priority is intelligent vehicle health monitoring and management which is a revolutionary new technique of being able to diagnose perhaps incipient failures and take action before they occur. We then have a series of propulsion upgrades that we are

exploring to give the Shuttle a more robust capability. And one that is very high on the priority of the Aerospace Safety Advisory Panel, is to separate out critical operational functions from mission payload functions on the Shuttle and have a separation of those computers and a very advanced avionics system. And the upgrades that we are working on all relate to that, but we are not stopping there. We have asked the NASA Advisory Panel to take a look at these upgrades, and rate them, and establish that the No. 1 goal is safety, and that we have a set of cost objectives that are commensurate with what we are going forward to in terms of safety objectives. And they will be reviewing that over this year, but I am very pleased with what we are doing. And we have $2.1 billion in the 5-year budget run out which will get us there.

Senator HUTCHISON. Let me just finish my last question, and that is the relationship with Russia. Many of the delays that have been caused have been because of Russian delays in doing their contractual obligations.

Do you think this is in our best interest to continue the relationship with Russia, or would it be more efficient for us to absorb the added cost but be able to go it alone?

Mr. GOLDIN. At this point in time, we have taken a number of steps, which in a way have led to some of the cost growth that Senator McCain has raised.

To be able to be more robust on the Station, we have an engine control module, a propulsion module, one of which will be ready in December this year, the other in 2003. We have made some very significant investments on our side to make it more robust.

The Russians have finally completed the service module. They have had some launch failures, but they have now fixed the proton rocket. They have showed us things we would never show them about rocketry. And we just had a team come back from Russia indicating they believe that the Russians are on track. They have had two successful launches, but we want three more successful launches, two to three successful launches before we launch the service module. At this point in time, I believe we ought to proceed because we are almost done.

Senator HUTCHISON. Thank you, Mr. Chairman.

Senator FRIST. Thank you.

Senator Dorgan.

Senator DORGAN. Mr. Chairman, thank you very much.

Mr. Goldin, thank you for being here. In some ways, I sort of think as I hear you, and listen to you, that you invite your own critics because you are very assertive, and very positive. You have developed a new model, "Faster, Better, Cheaper." You have turned that agency, in some ways, upside-down in the way it approached problems.

You operate as an agency on the edge of technology and knowledge. Inherently, that is very risky, and all of us have always understood that.

Some critics have argued, Mr. Goldin, that "better" has, from time to time, been sacrificed to "faster and cheaper." What is your response to that?

Mr. GOLDIN. My response is: Sometimes they are right; sometimes they are wrong. I contend that the Lunar Prospector, which

was built for $63 million, start to finish, was breathtaking, and if that is not better, and faster, and cheaper, nothing is. Pathfinder—we had the audacity to land on Mars with an air bag.

When you go to the people that had done it before, and they said to us, "It is impossible," we said, "We are not afraid." Did we make mistakes? I think the key mistake was the one I identified, and I feel personal responsibility for that, but I am not apologetic. For the whole issue, we saw this huge surge coming forward, and we did not think to take the time to mentor and train the next generation.

We have the processes. We have the procedures. What we lacked was execution, so our performance was spotty. But, again, I want to point out, we need to focus on the failures, but we have had 10 failures and 136 successes. It cannot be perfect, but we are going to learn and we are going to make it better.

Senator DORGAN. We are not scientists or engineers. I mean, we have trouble parking in a two-car garage and want to criticize those that cannot land on Mars. So, I think all of us want the same thing. We want an agency that has the resources to do the job and to achieve the successes that all of us expect and want.

Let me ask you a couple of more general questions. I understand the failures. I have read about them and tried to understand what has happened. I have read some of these reports. There are some people who are critical of some areas of management.

Let me ask you about the successes just for a moment. In the past year—let us just take the past year—I have read about the failures in the past year. Can you tell us: What are your achievements in the past year? What are the successes at NASA?

Mr. GOLDIN. Well, let me bring up a few. Chandra: We have opened up a whole new window on the universe. The Hubble Space Telescope takes pictures in the visible the way we are accustomed to. We are looking at the dark energy, unbelievable energetic processes. This is the most spectacular machine ever built.

And in fact, the contractor was ready to ship it, and our leader, Ed Wallace, said, "We are not going to ship because it is not yet safe." We launched that. It was a spectacular success, and is going to turn in science that is going to be breathtaking for the decade ahead.

I have had Nobel laureates walk into my office and say, "This is an unbelievable machine. Thank you, NASA."

We fixed the Hubble Space Telescope, and I would like to clear up an issue that came up here. It was not an emergency servicing mission. What we did was we had the world's best attitude control sensors on board, Gyros. We pushed the limits with those Gyros, and we did not know when they would fail. But we designed the system to be fixable by astronauts.

When we lost the sensors, within 2 months of when we lost the sensors, we were up in space, and we were able to replace those sensors, replace payloads. And the Hubble Space Telescope resolved an 8-year-old question, relative to what is called the Hubble constant: How fast is the universe expanding? This will rewrite chemistry and physics textbooks.

So these are the kind of things we do. And my point is, we turned that mission around in record time by a factor of two.

Now the easy thing for the NASA Administrator to say is, "Hey, we may have a failure. We will be criticized. Let us play it safe."

I spoke to Joe Rothenberg, who is the head of the Office of Space Flight, and I said, "Joe, the scientists could be dark for as much as a year. Can you safely fix it in half the preparation time that we normally had?" He talked to his people and he said, "We are going to go." And I said, "I will be personally responsible for that failure."

This is what you have got to do. And when you say that "I am afraid," what you do is you set mediocre goals, and everyone is happy, and budgets go up.

And I would like to show you one chart at this point. This is a chart that says it all. The bottom line there is the normalized NASA budget from 1993 to the year 2000. And it is going down.

You see the defense budget there, and then you see the non-defense discretionary budget, and you see the total discretionary budget. Because NASA was determined that we were going to listen to the American people about doing more with less, we said, "We are not afraid of failure. We are going to set the beat of the drum in this nation, and we are not going to accept mediocrity, and we are going to push the limits. And when we have failure, we will be responsible and accountable."

I salute every NASA employee, including those who failed, and not one employee is going to be fired. They have destroyed themselves enough. I have got to tell you, they are down in the dumps, but we are going to recover.

Senator DORGAN. Mr. Goldin, one additional question: The second panel that will follow you talks about a recurring theme of people at NASA. I mean, NASA is made up of people—scientists, engineers, administrators.

Are you attracting the best young scientists and engineers to a career at NASA? What is your assessment of the talent that you are getting at NASA at this point?

Mr. GOLDIN. First let me say, and I will accept responsibility for this, our work force has come down from about 25,000 to about 18,500. We made a decision that we would have no forced layoffs in 1993 because we felt the people who were at the agency did not deserve to be fired to make a political statement.

So we went by attrition. It has been painful. We have almost not hired for the last 7 years, but we respected the dignity of the work force. And now, we have the opportunity to hire 2,000 new people. We are at a real turning point.

And is it going to be tough? You bet. We have to compete with dot-com companies. The President of one of the major technical universities said to me, "Dan, my smart kids are wanting to get equity in the companies, and they are looking at compensation measured in hundreds of thousands of dollars," but none of these dot-com companies, none of these high-tech companies have what we have, the NASA vision, and the American dream.

We are going to hire 2,000 people in the next few years. What we need to do is do a better job at mentoring. I am going to keep coming back to that. I feel terrible that I did not see it.

If we mentored properly, if we train properly, I do not think we would have seen the large variety of problems we have, and this is the area that is important.

And there is one other key issue, Mr. Frist, and it just came to me. We did not have a good communications system. The problems were there, and the fact that people were speaking and we did not hear them, is another major failure that has nothing to do with cost, and nothing to do with schedule. So that is another significant area we have to fix.

Senator DORGAN. If I might make, Mr. Chairman, one additional point.

Mr. Goldin, you have been an agent of change and that by its nature, inherits substantial risk. All of us understand that. The Chairman, I think, made a point, and I think all of us on this panel would agree with the point. We need to learn from failure. We have had some failures. We must learn from that. The agency must learn. Congress must learn.

You as an Administrator have indicated that you are learning lessons from those failures which are important to our future space program.

Thank you for being here today.

Mr. GOLDIN. Thank you for the comment. I am 59 years old, and I feel embarrassed. At this age, I am still learning, but we are committed to do what is right for the country.

And I spoke to the Chairman last night and I said, "I would welcome a very vigorous hearing when we sort through all these issues." We would like to work with this Committee in an open fashion to make sure you have confidence, and the American people have confidence that we are doing the right thing.

Senator FRIST. Senator Breaux.

Senator BREAUX. Thank you, Mr. Chairman, and thank you, Mr. Goldin for being with us, and for your presentation and response to the questions.

It is a great deal of pride, I think, that all of us in the Congress can have, and this Committee in particular, because of our responsibilities for the job that NASA does in general. This is an area where the United States is clearly the best in the world, and whoever is second is so far behind, that we can be justifiably proud.

And of course, you will never make any mistakes if you never do anything. And sometimes we in the Congress follow that rule more often than we should, I think.

You have had great successes, and when you have a failure, it is a big one. These things that you deal with——

Mr. GOLDIN. They are spectacular.

Senator BREAUX. They are spectacular failures, and they, unfortunately, get a great deal of the coverage. That is the way it is going to be, but I think we have to put it in balance.

I think maybe some of my colleagues previously commented on the UPI story that was read, and I would like to ask you to comment on it. And I think that if this issue is left out there hanging, someone may read it and come to the conclusion that there are some real problems at NASA.

I take it that the gist of the story was that on the Mars Polar Lander Project there were not one but two design flaws. It can be

expected every now and then that you would have things that were not designed properly.

I think the disturbing thing in the story was that it implies that in the testing of the hydrazine part of the landing mechanism on the braking thrusters they did not get the right results, and that the tests and conditions were changed until they got the right results. At least that is what I get out of reading the story.

It would be very unfortunate if it occurred like that. Can you make any comments to clarify and give me some information on this?

Mr. GOLDIN. I cannot remember the exact words, but it had to do with based on a whole bunch of rumors they heard, this was the case. Let me get the exact words because——

Senator BREAUX. While you are looking for it, I just want to mention that the quote from the story is, "They tested the CAT bed initiation process at temperatures much higher than it would be in flight." The UPI source said, "This was done because when the CAT beds were first tested at the low temperatures predicted out to the long cruise from earth to Mars, the ignition failed, or was too unstable to be controlled. So the test conditions were changed in order to certify the engine's performance. But the conditions then no longer represented those most likely to occur on the real space flight."

Can you comment on that?

Mr. GOLDIN. I would be pleased. When we lost the Mars Climate Orbiter, it was a real shock to us. I asked Art Stephenson, who is the Director of the NASA Marshal Space Flight Center, to lead the review team. This man came to NASA from the private sector at great financial sacrifice because I asked him to do it just a year ago. He had been in the private sector his whole career. He was imminently qualified to lead a nationwide team to look at it.

I said, "Do not just find out what was wrong with the Mars Climate Orbiter, but we have a spacecraft called the Polar Lander that is on its way to Mars right now, and if there is anything we could learn from the Climate Orbiter, let us make sure we address it in the Polar Lander."

One of the members of his team pointed out that there was a problem with the propulsion system, or a suspected problem relative to the operating temperature.

Senator BREAUX. But the Polar Lander had already been launched.

Mr. GOLDIN. It was already launched, so what JPL and the contractor at Lockheed Martin did is run a whole series of tests to see if they could control the start temperature of that propulsion system. Based upon that, they changed the operating mode, so when they got to Mars, they verified from—before the thrusters fired, that we were at the right point. This to my recollection. This is what we know.

And, in fact, in November when a press conference was held, November 8th, we talked about this issue so there is no new news, no surprise, no nothing that I know about except there's a statement here called, "Garbled Rumors."

If anyone in America has any information indicating that there was some bad things, or inappropriate things done, if it is brought forward, we will investigate it.

Senator BREAUX. Would NASA not have had in that department a record of the tests that were made on the landing facility before they——

Mr. GOLDIN. Sure they do.

Senator BREAUX. Was it retested at different temperatures in order to get a different result?

Mr. GOLDIN. You might want to ask Mr. Stephenson in the next panel the details of that, but I told you the process. And I like to make sure we are open, and what we have, we put on the web. We open up everything to everyone. So I believe we did everything we knew how to do. If there is something we did not do, if someone points it out, we will look into it.

Senator BREAUX. I guess failures are failures in the worst way when we do not learn from the failures.

Can you tell us, in general, what you have learned from the failures as far as making corrections in the process, or in any way that we have learned from the failures?

Mr. GOLDIN. I think there are a couple of issues that are fundamental that have nothing to do with money. And again, the Chairman pointed this out.

We changed the culture, and we were rapidly increasing the number of programs at the same time while a lot of veterans, the Apollo Air, and the cold war veterans of the space program were retiring, and we did not take the time to do adequate training, and adequate mentoring. And to do mentoring, you want to do on-the-job training. You want to give people real experience and follow along.

I view that as the most critical error we made. The processes were in place. It was execution. The second one is the one I brought up just as you were walking in. I told Mr. Frist we did not have a good feedback system on communications.

Some people actually believe that you rigidly had to stick to cost and schedule even though you saw problems coming. And the third lesson was we have terrific people. And I, as the leader of NASA, have to accept responsibility for those two very basic breakdowns.

Senator BREAUX. Well, I think that is encouraging to hear the Administrator, Mr. Chairman, say that, yes, there were mistakes made. You have learned from them, and you plan to correct them.

I do not want to harp on the failures because the successes greatly exceed the failures. Sometimes I get the feeling, as do other Senators, that when our constituents come up and we have done nine out of ten things for them, the only thing they ask about is the one thing that we were not able to do. They forget about the nine things that we were successful in helping them get them get accomplished—so we want to thank you for the good things that this agency has done and want to continue to work with you to make sure your good work continues.

Mr. GOLDIN. Mr. Breaux, there is one thing that I left out that I just realized. Fundamental to the engineering and scientific process—and I left this out in my answer to the Chairman's question—

is good strong peer review, not by your friends, but by people such as in the case of Pathfinder, who were really cynical.

Some of our inexperienced managers did not understand this concept, and it comes back to training. And the other area that we have to very, very carefully look at, and I have asked our chief engineer to do that, is to really explore the process for how we select the peer review.

We are not interested during peer review of hearing all the good things. And, in fact, this is my management strategy. Let us not concentrate on the 95 percent that we do right; let us focus on where we have problems. Let us magnify them, dissect them, understand them, and fix them.

We did not do an adequate peer review process on some programs because of this inexperience factor. We are going to go back and make sure we fix that.

Senator BREAUX. Well, that is very encouraging.

Thank you, Mr. Chairman.

Senator FRIST. Thank you, Senator Breaux.

Mr. Goldin, just a couple of other quick points—and again, you have been very patient and I appreciate both your testimony and answers to the questions. I am glad that we evolved back to this work force because I think in looking at it from a management standpoint, it is an area that you recognize great deficiencies.

And when you look at all these reports, and I am sure the Young Report will probably substantiate that as well, it does come back to this human aspect, work force.

And I look down, since 1996, the Aerospace Safety Advisory Panel has cautioned NASA that the Shuttle program has experienced an erosion of critical skills, a lack of younger people at entry level positions, and a decreasing capacity to accommodate a higher Space Shuttle flight rate.

In 1999, the panel recommended that NASA aggressively address work force problems to ensure safe operations.

Jumping ahead to the next panel, the GAO testimony today cites NASA's human exploration and development of space. Independent Assessment Office concluded that Kennedy Space Center had the minimum work force necessary to conduct daily business; "the minimum" meaning, "And also reported that NASA had little evidence of structured training plans for its staff, and inadequate resources to support the needed training, which we have mentioned, but we have separated."

Your response, again, has been mentoring, communication, and then peer review. And I think those three are the responses that you have come to give us. And then at our next hearing, we can come back and look at those more aggressively.

Is there anything else in this work force that you would like to add?

Mr. GOLDIN. Yes, and that is the Aerospace Safety Advisory Panel, in their 1997 report, presented to me in February 1998, really felt strongly that we needed to take some action. And we commissioned what we call the Core Review Team, the Core Capabilities Review, that went very systematically through each area.

Our people looked at stress indicators like: How many hours overtime is increasing? How many people are voluntarily giving up

vacation? How many people are going to the Employee Assistance Program for stress related problems? What is the health condition of the employees?

And we went through center by center. We looked and found that we were really thin. So as part of the process, last year we authorized the addition of people which is the fourth leg to the stool.

The first things I said, and then you have to go out and hire people. The panel expressed to us a concern that the Shuttle needed experienced people, and when we brought fresh-outs, which are people who are fresh out of college with a Master's, PhD, or a Bachelor's degree, we put them on programs a little less critical than the Shuttle in Station.

Give him his chance to train, put the experienced people on the Shuttle and the station, and then, as they learn, migrate them there. And that is exactly what we have done.

And I just spoke to Roy Bridges, the Director of NASA Kennedy today, one of the primary concerns of the McDonald Panel, and you can address that issue to Dr. McDonald, was that we did not have enough quality inspectors at Cape Canaveral. We had to add 25. We have already hired those 25 people. And 12 of those people are on board, and by June, all 25 will be there.

So, the fourth leg—it is the fourth leg of a stool. It is not symmetric, and it will bounce a little bit, but the fourth leg of what we have to accomplish is go out to America, hire the best and brightest, and over the next 2 years, we have an ambitious goal of bringing in 2,000 people, but we will have the world's best training program.

And the last point I want to make to say we learned, we are working right now with MIT. We set up a new course on systems management, and we selected our top 20 people that are starting this pioneering course.

So we are going to be working with a large number of universities, so that we do not do just in-house training, but we will go for the best in America. So when we combine these four principals to the first order, we need more time to think. I think we will be on the road to recovery, and we will be even better.

Senator FRIST. Thank you.

Let me just close with one last issue that has to do with the oversight in this Committee. And what we have heard today, both the importance of it, and Chairman McCain's comments earlier, that it really is our responsibility and our role that the $14 billion in taxpayer money is being managed in the very best way, and to identify what deficiencies there are and where we need to work.

As Chairman of this Subcommittee, last September, Senator McCain and I requested information from you, and from NASA, on the operational cost of the propulsion module which will add the additional capability to the Space Station. And that was September, and I have the letter here, but from September 1999, and we still have not received a response.

The importance of that request is not so much the challenge of whatever numbers are there, but it is to be a litmus test of whether we should proceed with that program, whether or not to proceed.

And the letter is just two paragraphs, and again, I just want to mention it, and I believe if you are not aware of it, your staff would

be. And the letter from me and Senator McCain to you basically says, "It was recently reported by the GAO that NASA has not developed a cost estimate for the cost of operating the propulsion module for the International Space Station. As both Congress and NASA proceeds to make a final decision regarding this alternative propulsion and guidance in navigation capability, a better understanding of the associated cost is essential," and then we just make the request for the cost estimate.

And again, it is not so much the particular numbers that I am interested in now, but it leads us to assume that your lack of a response means that the information is not available.

And given things like the National Academy of Science's recent finding of a lack of long-term planning on the station by NASA, the question comes back to us: Are we ready to proceed with propulsion module?

Mr. GOLDIN. Let me say the following. I am very surprised you did not get a response, and I just asked Mal Peterson about that. We have had a recurring problem, and let me assure you in terms of oversight, we are going to fix that issue because communication must go back to you, and the Chairman of the big Committee. We will fix that.

But we do have a very serious problem. Our contractor is a good contractor, but not outstanding. We made a commitment to transfer the things that NASA used to do in-house to our contractors, and we have a terrible time getting creditable cost proposals from our contractor. I think the reason you did not get a response is we did not have an answer to that question. So, this is something I will go back and look at. I can only say that right now from what I know and see, you have a right to be upset.

Senator FRIST. Thank you. Again, it is used as more of an illustration as we look at management, long-term planning, short-term planning, mid-term planning. If we cannot, or you cannot, both demand and receive that the information be shared with us, it will be impossible for us to give the adequate oversight expected by the taxpayers of America.

Mr. GOLDIN. All I can say is, yes, we do have these problems. But in terms of long-term planning, NASA is one of the only agencies of organizations in the country that has a 25 year strategic plan. We do long-range planning.

In some circumstances, we do not communicate all of the information that we have. So I will personally go back, look at it, and give you a formal response in detail instead of shooting from the hip which I just did.

Senator FRIST. No, and I understand, but the cost is a basic issue.

Mr. GOLDIN. I understand.

Senator FRIST. What is this going to cost the American taxpayer? If we cannot answer it, and you cannot answer it, and your contractor cannot answer it, something is wrong, and we should not be going to the American people and saying, "You are paying for it though nobody can tell you how much this thing is going to cost."

Senator BREAUX. Mr. Chairman——

Senator FRIST. We need to move to the second panel. Senator Breaux.

Senator BREAUX. Yes, just a quick question. I wanted to ask Mr. Goldin for his thoughts.

Next week, I think that Senator Burns is planning on bringing legislation to the floor dealing with satellite television access for rural areas.

I am thinking about adding to that legislation an amendment which would authorize, just authorize not fund, loan guarantees for space transportation for U.S. private companies to construct rockets in the U.S. to move into the satellite launch industry.

You had testified on this issue before this Committee once before, and I do not want to characterize your position, but I took it to mean that you thought such legislation would be useful. It would be one of the tools that would be helpful. I wonder if you still have any current thoughts that you could update the Committee with this issue.

Mr. GOLDIN. Yes, I think it is very, very innovative, what you had in mind. There has been a change since last year and that is the ability of small rocket companies to get commercial business just took a turn for the worse.

Iridium, which put up 71 space craft, went bankrupt, and now they are going to literally de-orbit all those space craft. In addition to that, it has put a chill on the financing for other, what is called, low orbit mobile communications and Internet communication functions. We hope that this is cyclic and perhaps in 5 years there will be a recovery.

Toward that end and the President's budget, we have $4.5 billion to do cutting edge research, but not to do the production and development which your bill could enable. And it is our hope that by 2005, we will have worked with small and big rocket companies to overcome all the critical barriers so we have technology that will allow us to improve the reliability ten times and cut their cost by a factor of ten.

When that happens, hopefully by 2010, we will have private launch services not involving the government. This bill that you are looking at makes sense to me. However, I want to add something and this is a message to my good friends in the space community. They fight with each other, and they kill each other.

You stepped forward with a good idea, and to prevent other rocket companies from getting business, some good people did terribly stupid, vicious things. I ask every executive in the rocket business to take a deep breath, sit back, loosen your tie, and do not be afraid of competition, and do not try to kill a good bill that is being presented to you.

Thank you very much.

Senator BREAUX. I think I heard some breaths in the back of the room somewhere.

Mr. GOLDIN. Oh, yes. I am winning more points again today.

[Laughter.]

Senator BREAUX. Thank you very much.

Senator FRIST. Mr. Goldin, thank you for your testimony today and your forthrightness with the issues that were brought forward, and we look forward to working with you as we go ahead.

Mr. GOLDIN. Thank you.

Senator FRIST. At this juncture, I'll ask the second panel to come forward. Our second panel will consist of four individuals: Mr. Allen Li, Associate Director of the General Accounting Office; Dr. Harry McDonald, Director, Ames Research Center; Mr. Tony Spear, former Mars Pathfinder Project Manager, from Jet Propulsion Laboratory, who is Task Leader, NASA's Faster, Better, Cheaper Review Team; and, Mr. Art Stephenson, Director of the Marshal Space Flight Center.

Let us proceed with our second panel. We will begin with Mr. Li, followed by Dr. McDonald, Mr. Spear, and Mr. Stephenson.

Mr. Li, welcome.

STATEMENT OF ALLEN LI, ASSOCIATE DIRECTOR, NATIONAL SECURITY AND INTERNATIONAL AFFAIRS, U.S. GENERAL ACCOUNTING OFFICE

Mr. LI. Mr. Chairman and Members of the Subcommittee, I am pleased to be here today to discuss our ongoing work on the Shuttle program's civil service work force.

In the context of today's hearing on management challenges, it is clear that NASA must, like other agencies, maximize its resources and accountability. In doing so, I believe NASA must focus on its most important asset: its people. I will now summarize the four points from my prepared statement.

Point No. 1: Several studies point to the fact that the Shuttle work force has been negatively impacted by years of downsizing and buyouts. A common theme in these studies is that the work force has been stretched thin—to the point where there is just one qualified person in many critical areas.

For example, NASA has identified 30 such critical areas at the Kennedy Space Center that do not have sufficient back-up coverage. In addition, studies have found that the work force is showing signs of overwork and fatigue. Also, not having enough people with the right skills impacts functions to be performed.

One study expressed concern with NASA's ability to perform mandatory Shuttle inspections. Initially, NASA believed that these inspections could be performed by the contractor. However, the agency later determined that a substantial number of inspections would still be needed to be performed in-house.

Unfortunately by then, many of these inspectors had already left NASA. In reviewing these studies, there is one frequently identified aspect that I found worrisome, namely, that NASA employees were experiencing an increasing level of stress.

This conclusion was based on multiple indicators such as increased forfeited of leave, absences from required training, and counseling visits through the employee assistance program. I defer to the Chairman as to the clinical significance of stress. But worker stress can result in problems in concentrating and difficulty in making decisions.

While increased workload and stress from downsizing is likely to be found in many agencies and their units, their impact on maintaining a safe and efficient Shuttle program is unique.

I have great respect for the hard work and dedication of all NASA employees, but I fear that their "can do" attitude may have masked some of the problems caused by downsizing.

Point No. 2: To its credit, NASA has responded to these work force problems in a number of ways. It has terminated its downsizing program and is increasing its budget to provide an additional 95 FTEs for the Shuttle program in fiscal year 2000. NASA has also increased its 2001 budget request to provide an additional 278 FTEs for the Shuttle program. In addition, the Administration has directed the agency's managers to consider ways to reduce workforce stress.

The agency has included improved health monitoring as an objective in its 2001 performance plan.

Point No. 3. NASA faces a number of challenges in addressing the current Shuttle work force imbalance. These include accommodating increased training needs, attracting and retaining technical skills, dealing with uncertainties related to the future of Shuttle privatization and commercialization plans, and achieving a higher flight rate.

Last year, NASA flew four Shuttle flights. If all goes well with the Space Station, the number of flights jumps to nine in 2001. Because the Shuttle is now projected to be used at least through 2012, safety upgrades are planned. A 5-year safety upgrade initiative will develop modifications to increase the safety of all major components of the Shuttle. According to Johnson Space Center officials, the safety upgrade initiative will require up to 300 engineers.

Point No. 4: The challenge of ensuring that NASA has the proper mix and number of staff to meet Shuttle objectives safely will require a structured approach. Just hiring more engineers next year is not enough. The Comptroller general has recently brought concerted attention to human capital issues in the federal government and the importance of long-term planning.

The term human capital recognizes the fact that work force is the government's greatest asset, whose value can be enhanced through investment. We believe that agencies must have a clear, fact-based understanding of its human capital situation.

In this regard, we have provided a checklist for agency leaders to use to help them develop human capital strategies. This checklist allows them to scan their human capital systems to determine whether their approach supports their vision of who they are and what they want to accomplish, and to identify those policies that are in particular need of attention.

The checklist helps to establish linkage between human capital programs and the agency's mission, goals, and strategies.

We have applied some of the concepts contained in the checklist during our review at NASA, and have provided copies of the checklist to agency personnel. We have been told that human resource officials are currently using the checklist as a guide in their work force planning and as part of the agency's ongoing discussions with OMB. It is our hope that it will enable NASA to perform more comprehensive evaluations of its human capital systems in the coming years.

Thank you, sir.

[The prepared statement of Mr. Li follows:]

PREPARED STATEMENT OF ALLEN LI, ASSOCIATE DIRECTOR, NATIONAL SECURITY AND INTERNATIONAL AFFAIRS, U.S. GENERAL ACCOUNTING OFFICE

Mr. Chairman and Members of the Subcommittee:

We are pleased to be here today to discuss our ongoing work on the National Aeronautics and Space Administration's (NASA) Space Shuttle program. We are currently responding to the Committee's request to review NASA's plans for meeting current and future human capital needs. We plan to finalize our work and report on this issue in the coming months. As a result, my statement today presents our preliminary observations.

NASA budget data shows that, since 1995, Shuttle workforce levels have decreased from about 3,000 to about 1,800 full time equivalent employees.[1] NASA based its downsizing efforts on optimistic programmatic assumptions. For example, NASA believed it could reduce its workforce by consolidating contracts for flight, ground, and mission operations under a single private sector contract. In October 1996, NASA awarded this contract. Under the contract, NASA was to provide incentives to eliminate unnecessary work and would no longer be involved in day-to-day Shuttle operations. However, because NASA was implementing a number of workforce reduction initiatives, NASA could not directly attribute specific reductions to the contract consolidation. Also, in 1994 NASA froze the Shuttle design in the expectation that it would be replaced. NASA now expects to operate the Shuttle for at least the next decade. As a consequence, it initiated an upgrade program. In addition, NASA's downsizing coincided with a decreased number of Shuttle flights: eight flights in fiscal year 1997, but only four each in fiscal years 1998 and 1999. However, the number of flights is projected to increase substantially as the International Space Station assembly schedule accelerates. NASA plans nine flights in fiscal year 2001. NASA believes this will require more staff.

Today we will focus on the Shuttle program's civil service workforce. Specifically, we will (1) summarize the results of studies on the impact of workforce reductions, (2) describe NASA's actions following these workforce assessments, (3) identify challenges NASA faces in the anticipated heavy workload imposed by the International Space Station, and (4) suggest a structured approach NASA can take to analyze human capital challenges.

RESULTS IN BRIEF

Several studies, one as recent as March 2000, have reported that the Shuttle program's workforce has been affected negatively by the downsizing, much of which has occurred since 1995. The studies concluded that the existing workforce is stretched thin to the point where there is just one qualified person in many critical areas. NASA has identified 30 critical areas at Kennedy Space Center that do not have sufficient backup coverage. These areas include Shuttle range safety systems and solid rocket booster and external tank electrical systems. In addition, the studies found that the workforce is showing signs of overwork and fatigue. For example, indicators including forfeited leave, absences from training courses, and stress-related employee assistance visits are all on the rise. Moreover, the program's workforce age distribution and skill mix now limit opportunities for mentoring newer staff. For example, throughout the Office of Space Flight, which includes the Shuttle program, there are more than twice the number of workers over 60 years of age than under 30 years of age. This jeopardizes the program's ability to "hand off" leadership roles to the next generation.

NASA has responded to the workforce problems in a number of ways. It has terminated its downsizing program and is increasing its budget to provide an additional 95 full time equivalent employees for the Shuttle program in fiscal year 2000. NASA has also increased its fiscal year 2001 budget request to provide an additional 278 full time equivalent employees for the Shuttle program. In addition, the administrator has directed the agency's managers to consider ways to reduce workforce stress.

NASA faces a number of challenges in addressing the current Shuttle workforce imbalance—especially given the anticipated increased workload. This includes accommodating increased training needs, ensuring adequate staffing levels for its safety upgrade program, attracting and retaining technical skills, dealing with uncertainties related to the future of Shuttle privatization and commercialization plans, and achieving a higher projected flight rate.

[1] Full time equivalent is a measure of staff hours equal to those of a full time employee working 40 hours per week over the course of a year.

The challenge of ensuring NASA has the proper mix and number of staff to meet Shuttle objectives safely will require a structured approach. GAO's internal control standards for the federal government discuss the importance of human capital management in achieving program results. The Comptroller General has brought additional attention to human capital issues and the importance of long-term planning. In this regard, we recently issued a checklist[2] for agency leaders to use, in order to help them develop human capital strategies. This checklist will allow agency managers "to quickly determine whether their approach to human capital supports their vision of who they are and what they want to accomplish, and to identify those . . . policies that are in particular need of attention." The checklist follows a five-part framework, including strategic planning, organizational alignment, leadership, talent, and performance culture. The checklist helps to establish linkage between human capital programs and the agency's mission, goals, and strategies. We have provided copies of the checklist to NASA. We believe NASA's attention to human capital issues will be essential to ensuring the agency's ability to achieve the goals of the Shuttle program.

RECENT STUDIES HIGHLIGHT SHUTTLE WORKFORCE PROBLEMS

Over the past several years, NASA and its Aerospace Safety Advisory Panel have studied the Shuttle program civil service workforce.[3] The studies concluded that the Shuttle program workforce has suffered significantly from the downsizing, much of which has occurred since 1995. For example, the studies conclude that the workforce may not be sufficient to support the planned Shuttle flight rate and many key positions are not sufficiently staffed by qualified workers. In addition, the studies found that stress levels have reached the point of creating an unhealthy workforce. The results of these studies are highlighted below.

- In its November 1999 report, NASA's Human Exploration and Development of Space Independent Assessment Office concluded that, even with a relatively low flight rate, the Shuttle Processing Directorate at Kennedy Space Center had the "minimum" workforce necessary to conduct daily business. For example, the report expressed concerns with NASA's ability to perform mandatory Shuttle inspections. NASA believed that these inspections could be performed under its flight operations contract. However, after the departure of many inspectors, the agency determined that a substantial number of inspections would still need to be performed in-house. The report also found that NASA provided little evidence of structured training plans for its staff, and the resources to support needed training were inadequate. Given these concerns, the report concluded that NASA might not be able to support higher Shuttle flight rates projected in the future.
- During the fall of 1999, NASA chartered a team to review the overall Shuttle systems and maintenance practices. The team, chaired by the Ames Research Center Director, assessed NASA's standard practices in these areas and concluded that the current workforce was inadequate. In addressing human capital issues, the study noted that important technical areas were understaffed. For example, during a recent Shuttle wiring investigation, the team found that "workforce skill shortages created the need to use . . . personnel inexperienced in wiring issues to perform critical inspections." In addition, the study team found that work stresses had impacted the downsized Shuttle workforce. For example, one center employee survey suggested that hypertension, gastrointestinal, and cardiac conditions could have resulted from work-related stress.
- In an internal study completed in June 1999, NASA concluded that the Office of Space Flight, which includes the Shuttle program, had (1) an inappropriate skill mix for current and future work, (2) a growing lack of younger staff to assume management and technical roles, and (3) an overworked and aging workforce. The study also concluded that there was an overall shortfall of workers. In response, NASA adjusted the agency's workforce targets by providing one new hire for every two additional losses.
- In the fall of 1999, NASA decided to build on its earlier workforce study to further define resource requirements. This second phase, completed in December

[2] *Human Capital: A Self-Assessment Checklist for Agency Leaders,* Discussion Draft (GAO/GGD–99–179, September 1999).

[3] *Independent Assessment of the Shuttle Processing Directorate Engineering and Management Processes,* NASA's Human Exploration and Development of Space Independent Assessment Office (November 4, 1999); *Report to Associate Administrator, Office of Space Flight,* Space Shuttle Independent Assessment Team (March 7, 2000); and *Annual Report for 1999,* Aerospace Safety Advisory Panel (February 2000).

1999, included an evaluation of stress-related issues. In terms of resources the study found that a "revitalization" of the workforce was required to prevent "significant" safety concerns. For example, at the Kennedy Space Center, the Shuttle program has only one qualified person in 30[4] critical systems areas. These areas include Shuttle range safety systems and solid rocket booster and external tank electrical systems. In addition, the study found that, throughout the Office of Space Flight, there were more than twice the number of workers over 60 years of age than under 30 years of age. This represented a reversal of the age profile just 6 years ago, creating a potential problem in developing future qualified leaders.

- As for health issues, the study concluded that the agency was experiencing an "unhealthy" and increasing level of stress. This conclusion was based on multiple indicators including increased forfeited leave, absences from required training, increased payment of overtime, and counseling visits through the employee assistance program. This level of worker stress resulted in (1) problems in concentrating, (2) difficulty in making decisions, (3) inability to cope, (4) insomnia, and (5) anxiety.
- Perhaps the most persistent voice stressing the consequences of Shuttle workforce downsizing has been NASA's Aerospace Safety Advisory Panel. This Panel is an independent group of experts consisting of nine members appointed by the NASA Administrator. Since 1996, the Panel has examined the potential safety impacts of downsizing and has consistently cautioned that the program has been experiencing an erosion of critical skills, a lack of younger people at entry-level positions, insufficient training opportunities, and a decreasing capacity to accommodate higher Space Shuttle flight rates for sustained periods. In its 1999 annual report, the Panel recommended that NASA ". . . address its workforce problems aggressively" to ensure safe operations. It added that "emphasis should be placed on eliminating critical skills shortfalls and recruiting younger [engineers] who can develop into experienced and skilled future leaders."

NASA IS BEGINNING TO ADDRESS WORKFORCE PROBLEMS

In response to the workforce studies, NASA is now implementing actions to address its workforce problems. For example, the agency has terminated its downsizing plans and expects to add 95 full time equivalent employees to the Shuttle program in fiscal year 2000 to address critical skill shortages. In addition, in its fiscal year 2001 budget request, NASA is seeking authority to add another 278 full time equivalent employees to the Shuttle workforce.

In addition to these immediate actions, NASA's Administrator has announced that the agency will soon begin a joint review with the Office of Management and Budget to identify NASA's overall future workforce needs. According to the Administrator, this review will assess potential tools and approaches for overall personnel management for the agency.

NASA believes the stress-related indicators that were reported in the December 1999 workforce study were critical evidence supporting the need for increasing NASA's workforce. In October 1999, NASA's Administrator directed the agency's highest level managers to consider ways to reduce workplace stress. NASA subsequently included improved health monitoring as an objective in its fiscal year 2001 performance plan.[5] According to the plan, NASA plans to develop and implement supervisor-specific and individual training to identify, manage, and cope with stress in the workplace.

NASA WILL CONTINUE TO FACE HUMAN CAPITAL CHALLENGES

In dealing with its workforce problems, the Shuttle program will have to deal with a number of complicating factors. These include accommodating increased training needs, ensuring adequate staffing levels for its safety upgrade program, attracting and retaining employees with critical skills, dealing with uncertainties related to the future of Shuttle privatization and commercialization plans, and achieving a higher projected flight rate.

For example, according to one NASA study, it could take 2 or more years to fully train new engineers, while the current Shuttle workload leaves little time for training. Also, the Shuttle program has just begun a 5-year safety upgrade initiative. This initiative involves developing modifications to increase the safety of all major components of the Shuttle vehicle. According to Johnson Space Center officials, this

[4] This study identified a total of 87 critical systems areas at Kennedy Space Center.

[5] The Government Performance and Results Act of 1993 requires agencies to prepare annual performance plans.

initiative will require up to three hundred engineers. Moreover, some critically needed skills, such as software engineering will be hard to attract and retain. In August 1999, we reported on this concern as it related to the Space Station program.[6]

In recent years, NASA has considered ways to maximize private sector involvement in Shuttle operations, including transitioning management functions and marketing of payloads for commercial applications.[7] Regarding the future Shuttle privatization and commercialization plans, the Human Exploration and Development of Space Independent Assessment Office study noted that strategic planning, workforce deployment, and prioritization will be difficult. The study concluded that NASA "must begin to analyze how its workforce will evolve in the [new] environments and prepare a plan for this evolution." All of these challenges will have to be faced while the program attempts to double its current flight rate. In recent years, NASA has flown four flights a year, but plans to fly nine times in fiscal year 2001, primarily to support the International Space Station assembly.

STRUCTURED APPROACH FOR MEETING HUMAN CAPITAL CHALLENGES IS NECESSARY

We believe NASA must build on its renewed emphasis on a healthy, diverse, and properly deployed Shuttle workforce. Our Standards for Internal Control in the Federal Government, as updated in November 1999, address these workforce issues. The standards state that "only when the right personnel for the job are on board and are provided the right training, tools, structure, incentives, and responsibilities is operational success possible."

GAO's Comptroller General has made improved human capital management throughout the federal government one of his top priorities. In testimony[8] on March 9, 2000, he stated that ". . . human capital management recognizes that employees are a critical asset for success, and that an organization's human capital policies and practices must be designed, implemented, and assessed by the standard of how well they support the organization's mission and goals." He also noted that we had recently published a human capital self-assessment checklist that provides a structured approach to identifying and addressing human capital issues. This checklist will allow agency managers "to quickly determine whether their approach to human capital supports their vision of who they are and what they want to accomplish, and to identify those...policies that are in particular need of attention." The checklist follows a five-part framework, including strategic planning, organizational alignment, leadership, talent, and performance culture. It also provides a linkage of human capital programs to the agency's mission, goals, and strategies.

We have applied some of the concepts contained in the checklist during our workforce review at NASA and have provided copies of the checklist to NASA. We have been told that human resource officials are currently using the checklist as a guide in their workforce planning and the agency's ongoing discussions with the Office of Management and Budget. It is our hope that it will enable NASA and other agencies to perform more comprehensive evaluations of their human capital systems in the coming years.

Mr. Chairman, this concludes our formal statement. We would be happy to answer any questions that you or members of the Subcommittee may have.

Senator FRIST. Thank you.

Dr. McDonald.

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[6] *Space Station: Russian Commitment and Cost Control Problems* (GAO/NSIAD–99–175, August 17, 1999).

[7] In the past, the Shuttle program has performed commercial activities for which it has been reimbursed by the private sector. However, it has been limited from flying reimbursable payloads by federal regulations. NASA is in the process of reviewing these restrictive policies with their initiators with the objective of removing them as obstacles to a fully commercialized Shuttle program.

[8] Testimony was given before the Subcommittee on Oversight of Government Management, Restructuring, and the District of Columbia, Senate Committee on Governmental Affairs (GAO/T–GGD–00–77). Also on March 9, 2000, GAO testified on similar human capital concerns related to the Department of Defense. This testimony was given at a joint hearing involving the Subcommittee on Military Readiness, House Committee on Armed Services, and the Subcommittee on Civil Service, House Committee on Government Reform (GAO/T–GGD/NSIAD–00–120).

STATEMENT OF DR. HARRY MCDONALD, DIRECTOR, AMES RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, MOFFETT FIELD, CALIFORNIA

Dr. MCDONALD. Thank you, Mr. Chairman, and thank you for the invitation to come here this afternoon. It is a pleasure and a privilege.

The Shuttle program is one of the most complex engineering tasks undertaken anywhere in the world at the present time, and the Space Shuttle independent assessment team was chartered in September 1999 by the Associate Administrator for Human Space Flight, Mr. Joe Rothenberg, in light of several, in his mind, disturbing maintenance issues reflected in in-flight anomalies, i.e., problems encountered in the flight of the Space Shuttle mission.

Mr. Rothenberg invited me to form a team comprised of both NASA and a contractor, together with DOD experts in the area of aircraft maintenance, wiring, and other technologies required in the maintenance of the vehicle.

In performing this review, I would like to say at the outset that a very positive nature was observed in doing the review, not the least of which was the commitment, dedication, and outstanding skill of our work force, the NASA work force involved in maintaining the vehicle, including the very great concern for the safety of the astronauts. So that was really moving to see that commitment on behalf of the technician work force, in particular.

It is very unfortunate that the nature of the type of review that we performed, that we were not able to dwell on that very positive aspect. We were there for the critical elements of the program. In this we noted that in the last few years, since 1995, there had been a massive change in the operation of the Shuttle. It had been transferred to a space flight operations contract.

There had been significant slimming down of both the NASA and the contractor work force involved in supporting the Shuttle, in particular, from the maintenance point of view. All this had been accomplished without significant problems, and, indeed, with a very considerable cost saving to the agency.

However, the assessment team did identify some problem areas, some significant problem areas that we felt should be addressed to maintain a safe and effective program. Some specifics are given in the body of the report, and I would just like to touch on a couple of them here.

The assessment team was asked by the Space Shuttle Program Office for its views on the return to flight in December of last year, which occurred during the period of time in which we were undertaking the review, and we had concluded that a suitable criteria for the return to flight would be that the vehicle would then possess less risk than, for example, the STS–93, whereby two anomalies had occurred, one, the wiring short, the other is the pin injection. It was clear at that point in time, in December 1999, that that would be the case.

There had been extensive reviews, extensive repairs, and many of the questions that we had raised had been answered, so that we were quite comfortable with the return to flight and the continued operation of the Shuttle.

We were pleased to learn that following the STS–103 flight that only minor in-flight anomalies had been encountered in that flight, which continued a downward reduction in the number of in-flight anomalies that had been occurring over the last six or 7 years.

However, one of the continuing and major concerns among the assessment team members was the concern with the reduction in allocated resources, including appropriate staff required to ensure that the critical processes were being adequately and rigorously implemented, and continuously improved.

Our findings showed to us, at least, that there were important technical areas that were undermanned, staffed one-deep, and this type of vehicle, given its severe environment in which it operated would require extensive maintenance, major amounts of touch labor, where actually technicians would replace and go on board the vehicle, and also it required a high degree of skill, a high degree of expertise, and significant on-the-job training. Touch labor, in particular, always creates the opportunity for collateral damage, and that was our belief that it occurred with the wiring issue.

The technicians looking to repair other components on the vehicle, repair, or renew, maintain, would inadvertently damage the wiring by stretching, touching, standing, whatever, so that this emphasized the need at the present time, given the present level of technology, for increased inspection and attention to these particular areas.

In addition, we observed that the program was using an increase in the standard repair designation and the use of fair wear-and-tear allowances, essentially hid the extent of some of these problems from the management.

They were not reported into the problem reporting and corrective action data base that would allow management to see that there were very significant numbers of repairs being done on, for example, the wiring. So we were a little concerned about that.

We were also concerned that there is an operational philosophy within the program to only fly what you test, and test what you fly. Clearly, for various reasons, this had not been adhered to with regard to the pin problem. That was an example that came up.

There was also the issue, and we believe that the Shuttle upgrades program will present us with the opportunity to correct a number of the observed efficiencies, in particular it might enable us to reduce the 76 areas where redundancy is compromised on the vehicle, and incorporate design for maintainability.

So follow-on, we believe, activity is required to examine some of the other systems that we have not been able to examine in the light of our limited amount of time. We concentrated on the orbiter vehicle, and we believe that a similar type of review should be carried out in terms of the solid rocket motors and the external fuel tank, for instance, and that this follow-on activity should review our recommendations for implementation.

In conclusion, shortly before delivering the part to NASA, the team was very gratified to learn that a number of steps had already been taken by the agency to rectify some of the problems, some of the adverse findings that we had reported on.

It was particularly pleasing to know that the targeted staffing additions which had been authorized and were referred to earlier

this afternoon by the Administrator, targeted staffing increases were directly mainly at quality assurance function, which we felt would be particularly beneficial to the program. With that, that is the end of my statement.

[The prepared statement of Dr. McDonald follows:]

PREPARED STATEMENT OF DR. HARRY MCDONALD, DIRECTOR, AMES RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, MOFFETT FIELD, CALIFORNIA

Space Shuttle Independent Assessment Team

Report to the Associate Administrator
Office of Space Flight
October-December 1999

Executive Summary

The Shuttle program is one of the most complex engineering activities undertaken anywhere in the world at the present time. The Space Shuttle Independent Assessment Team (SIAT) was chartered in September 1999 by NASA to provide an independent review of the Space Shuttle sub-systems and maintenance practices. During the period from October through December 1999, the team led by Dr. McDonald and comprised of NASA, contractor, and DOD experts reviewed NASA practices, Space Shuttle anomalies, as well as civilian and military aerospace experience.

In performing the review, much of a very positive nature was observed by the SIAT, not the least of which was the skill and dedication of the workforce. It is in the unfortunate nature of this type of review that the very positive elements are either not mentioned or dwelt upon. This very complex program has undergone a massive change in structure in the last few years with the transition to a slimmed down, contractor-run operation, the Shuttle Flight Operations Contract (SFOC). This has been accomplished with significant cost savings and without a major incident. This report has identified significant problems that must be addressed to maintain an effective program. These problems are described in each of the Issues, Findings or Observations summarized below, and unless noted, appear to be systemic in nature and not confined to any one Shuttle sub-system or element. Specifics are given in the body of the report, along with recommendations to improve the present systems.

Issue 1

NASA must support the Space Shuttle Program with the resources and staffing necessary to prevent the erosion of flight-safety critical processes.

Human rated space transportation implies significant inherent risk. Over the course of the Shuttle Program, now nearing its 20th year, processes, procedures and training have continuously been improved and implemented to make the system safer. The SIAT has a major concern, reflected in nearly all of the subsequent "Issues", that this critical feature of the Shuttle Program is being eroded. Although the reasons for this erosion are varied, it appears to the SIAT that a major common factor among them is the reduction in allocated resources and appropriate staff that ensure these critical processes and procedures are being rigorously implemented and continually improved. The SIAT feels strongly that workforce augmentation must be realized principally with NASA personnel rather than with contract personnel. The findings show that there are important technical areas that are staffed "one-deep". The SSP should assess not only the quantity of personnel needed to maintain and operate the Shuttle at anticipated future flight rates, but also the quality of the workforce required in terms of experience and special skills. In the recent fleet wiring investigation, work force skill shortages created the need to use Quality Assurance personnel inexperienced in wiring issues to perform critical inspections. Note that increasing the work force carries risk with it until the added work force acquires the necessary experience.

Issue 2

The past success of the Shuttle program does not preclude the existence of problems in processes and procedures that could be significantly improved.

The SIAT believes that another factor in the erosion referred to in Issue 1 is success-engendered safety optimism. The SIAT noted several examples of what could be termed an inappropriate level of comfort with certain apparently successful "ac-

ceptance of risk" decisions made by the program. One example was the number of flights with pinned liquid oxygen injectors flown without prior hot-fire testing that did not experience pin ejection before the STS–93 pin ejection rupture incident. These successful flights created a false sense of security that pinning an injector could be treated as a standard repair. There were 19 incidences of pin ejection that did not result in nozzle rupture prior to STS–93 and this created an environment that led to the acceptance of risk. Similarly the wire damage that led to the short on STS–93 is suspected to have been caused 4 to 5 years prior to the flight. The SSP must rigorously guard against the tendency to accept risk solely because of prior success.

Issue 3

The SSP's risk management strategy and methods must be commensurate with the 'one strike and you are out' environment of Shuttle operations.

While the Shuttle has a very extensive Risk Management process, the SIAT was very concerned with what it perceived as Risk Management process erosion created by the desire to reduce costs. This is inappropriate in an area that the SIAT believes should be under continuous examination for improvement in effectiveness with cost reduction being secondary. Specific SIAT findings address concerns such as: moving from NASA oversight to insight; increasing implementation of self-inspection; reducing Safety and Mission Assurance functions and personnel; managing risk by relying on system redundancy and abort modes; and the use of only rudimentary trending and qualitative risk assessment techniques. It seemed clear to the SIAT that oversight processes of considerable value, including Safety and Mission Assurance, and Quality Assurance, have been diluted or removed from the program. The SIAT feels strongly that NASA Safety and Mission Assurance should be restored to the process in its previous role of an independent oversight body, and not be simply a "safety auditor." The SIAT also believes that the Aerospace Safety Advisory Panel membership should turnover more frequently to ensure an independent perspective. Technologies of significant potential use for enhancing Shuttle safety are rapidly advancing and require expert representation on the Aerospace Safety Advisory Panel. While system redundancy is a very sound element of the program, it should not be relied upon as a primary risk management strategy; more consideration should be given to risk understanding, minimization and avoidance. It was noted by the SIAT that as a result of choices made during the original design, system redundancy had been compromised in 76 regions of the Orbiter (300+ different circuits, including 6 regions in which if wiring integrity was lost in the region, all three main engines would shut down). These were design choices made based on the technology and risk acceptance at that time. Some of these losses of redundancy may be unavoidable; others may not be. In either case, the program must thoroughly understand how loss of system redundancy impacts vehicle safety.

Issue 4

SSP maintenance and operations must recognize that the Shuttle is not an 'operational' vehicle in the usual meaning of the term.

Most aircraft are described as being "operational" after a very extensive flight test program involving hundreds of flights. The Space Shuttle fleet has only now achieved one hundred flights and clearly cannot be thought of as being "operational" in the usual sense. Extensive maintenance, major amounts of "touch labor" and a high degree of skill and expertise by significant numbers of technician and engineering staff will be always required to support Shuttle operations. Touch labor always creates a potential for collateral and inadvertent damage. In spite of the clear mandate from NASA that neither schedule nor cost should ever be allowed to compromise safety, the workforce has received a conflicting message due to the emphasis on achieving cost and staff reductions, and the pressures placed on increasing scheduled flights as a result of the Space Station. Findings of concern to the SIAT include: the increase in standard repairs and fair wear and tear allowances; the use of technician and engineering "pools" rather than specialties; a potential complacency in problem reporting and investigation; and the move toward structural repair manuals as used in the airline industry that allow technicians to decide and implement repairs without engineering oversight. The latter practice has been implicated in a number of incidents that have occurred outside of NASA (Managing the Risks of Organizational Accidents, Chapter 2, p. 21). When taken together these strategies have allowed a significant reduction in the workforce directly involved in Shuttle maintenance. When viewed as an experimental / developmental vehicle with a "one strike and you are out" philosophy, the actions above seem ill advised.

Issue 5

The SSP should adhere to a 'fly what you test / test what you fly' methodology.

While the "fly what you test / test what you fly" methodology was adopted by the Shuttle Program as a general operational philosophy, this issue arose specifically with the Space Shuttle Main Engine (SSME). For the SSME, fleet leader and hot-fire (green-run) testing are used very effectively to manage risk. However, the concept must be rigorously adhered to. Recent experience, for instance the pin ejection problem, has shown a breakdown of the process. An excellent concept, the fleet leader is also applicable to other systems, but its limitations must be clearly understood. In some cases (e.g., hydraulic testing, avionics, Auxiliary Power Unit) the SIAT believes that the testing is not sufficiently realistic to estimate safe life.

Issue 6

The SSP should systematically evaluate and eliminate all potential human single point failures.

In the past, the Shuttle Program had a very extensive Quality Assurance program. The reduction of the quality assurance activity ("second set of eyes") and of the Safety & Mission Assurance function ("independent, selective third set of eyes") increases the risk of human single point failures. The widespread elimination of Government Mandatory Inspection Points, even though the reductions were made predominantly when redundant inspections or tests existed, removed a layer of defense against maintenance errors. Human errors in judgment and in complying with reporting requirements (e.g., in or out of family) and procedures (e.g., identifcation of criticality level) can allow problems to go undetected, unreported or reported without sufficient accuracy and emphasis, with obvious attendant risk. Procedures and processes that rely predominantly on qualitative judgements should be redesigned to utilize quantitative measures wherever possible. The SIAT believes that NASA staff (including engineering staff) should be restored into the system for an independent assessment and correction of all potential single point failures (see also the concerns concerning the Safety and Mission Assurance function in Issue 3).

Issue 7

The SSP should work to minimize the turbulence in the work environment and its effects on the workforce.

Findings support the view that the significant number of changes experienced by the Shuttle Program in recent years have adversely affected workforce morale or diverted workforce attention. These include the change to Space Flight Operations Contract, the reduction in staffing levels to meet Zero Based Review requirements, attrition through retirement, and numerous re-organizations. Ongoing turbulence from cyclically heavy workloads and continuous improvement initiatives (however beneficial) were also observed to stress the workforce. While the high level workforce performance required by the Shuttle program has always created some level of workforce stress, the workforce perception is that this has increased significantly in the last few years. Specifically, the physical strain measured in the Marshall Space Flight Center workforce significantly exceeded the national norm, whereas the job stress components (e.g., responsibility levels, physical environment) were near normal levels. This typically indicates the workforce is internalizing chronic instability in the workplace. Similarly, feedback from small focus groups at Kennedy Space Center indicates unfavorable views of communication and other factors of the work environment. Clearly, from a health perspective, one would seek to reduce employee stress factors as much as possible. From a vehicle health perspective, stressed employees are more likely to make errors by being distracted while on the job, and to be absent from the job (along with their experience) as a result of health problems.

The SIAT believes that the findings reported here in the area of work force issues parallel those that were noted by the Aerospace Safety Advisory Panel. The SIAT is concerned that in spite of the Aerospace Safety Advisory Panel findings and recommendations, supported by the present review, these problems remain.

Issue 8

The size and complexity of the Shuttle system and of the NASA/contractor relationships place extreme importance on understanding, communication, and information handling.

In spite of NASA's clear statement mandate on the priority of safety, the nature of the contractual relationship promotes conflicting goals for the contractor (e.g., cost vs. safety). NASA must minimize such conflicts. To adequately manage such conflicts, NASA must completely understand the risk assumptions being made by the contractor workforce. Furthermore, the SIAT observed issues within the Program in the communication from supervisors downward to workers regarding priorities and changing work environments. Communication of problems and concerns upward to the SSP from the "floor" also appeared to leave room for improvement. Information flow from outside the program (i.e., Titan program, Federal Aviation Administration, ATA, etc.) appeared to rely on individual initiative rather than formal process or program requirements. Deficiencies in problem and waiver tracking systems, "paper" communication of work orders, and FMEA/CIL revisions were also apparent. The program must revise, improve and institutionalize the entire program communication process; current program culture is too insular in this respect .

Additionally, major programs and enterprises within NASA must rigorously develop and communicate requirements and coordinate changes across organizations, particularly as one program relies upon another (e.g., re-supplying and refueling of International Space Station by Space Shuttle). While there is a joint Program Review Change Board (PRCB) to do this, for instance on Shuttle and Space Station, it was a concern of the SIAT that this communication was ineffective in certain areas.

Issue 9

Due to the limitations in time and resources, the SIAT could not investigate some Shuttle systems and/or processes in depth.

Follow-on efforts by some independent group may be required to examine these areas (e.g., other propulsion elements, such as the Reusable Solid Rocket Motor, Solid Rocket Booster, External Tank, Orbiter Maneuvering System, and Reaction Control System, and other wiring elements besides those in the Orbiter). This independent group should also review the SSP disposition of the SIAT findings and recommendations. The Shuttle Upgrades program creates the opportunity to correct many of the observed deficiencies, e.g., the 76 areas of compromised redundancies (300+ circuits), and to incorporate design for maintainability and continuous improvement. However, without careful systems integration and prioritization, some of the deficiencies observed by the SIAT will be exacerbated, e.g., in wiring, hydraulics, software, and maintenance areas. Additionally, the elements of maintenance must be rigorously analyzed, including training, maintainability, spares support maintenance, and accessibility.

Return to Flight

The SIAT was asked by the SSP for its views on the return to flight of STS–103. The SIAT had earlier considered this question and had concluded that a suitable criterion would be that STS–103 should possess less risk than, for example, STS–93. In view of the extensive wiring investigation, repairs and inspections that had occurred this ondition appeared to have been satisfied. Furthermore, none of the main engines scheduled to fly have pinned Main Injector liquid oxygen posts. The SIAT did suggest that prior to the next flight the SSP make a quantitative assessment of the success of the visual wiring inspection process. In addition, the SIAT recommended that the SSP pay particular attention to inspecting the 76 areas of local loss of redundancy and carefully examine the OV102 being overhauled at Palmdale for wiring damage in areas that were inaccessible on OV103. Finally, the team suggested that the SSP review in detail the list of outstanding waivers and exceptions that have been granted for OV103. The SSP is in the process of following these specific recommendations and so far has not reported any findings that would cause the SIAT to change its views.

Shortly before completing this report, the SIAT was gratified to learn that a number of steps had been taken by NASA to rectify a number of the adverse findings reported above. Of particular note was the strengthening of the NASA Quality Assurance function for the Shuttle at Kennedy Space Center. Upon completion of STS–103, the SIAT was pleased to learn that only two orbiter in-flight anomalies were experienced, a reduction from past trends (see **Appendix 11** of the final summary).

Senator FRIST. Thank you, Dr. McDonald.

We will be back for questions for all of the panelists. Mr. Spear.

STATEMENT OF TONY SPEAR, TASK LEADER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION'S FASTER, BETTER, CHEAPER REVIEW TEAM, PASADENA, CALIFORNIA

Mr. SPEAR. Mr. Chairman, thank you for this opportunity to summarize the Faster, Better, Cheaper Task results. I got this job directly from Dan Goldin early in 1999, and finished up this February, during which I incorporated my personal experience and my team's experience on the Mars Pathfinder mission with the results of a series of interviews and workshops with representatives from NASA, other agencies, industry, and academia.

For most of my career, I worked at JPL, and retired in 1998. In 1992, I was asked to plan and implement Mars Pathfinder, not only to land on Mars, but to invent a new way of doing business out there at JPL. I was asked to treat cost and schedule as importantly as technical, and to develop and operate under cost and schedule caps.

My summary conclusions, but first, let me answer a question often asked: Why did not the Mars 98 project use the Pathfinder airbags? On Pathfinder, we were midway through our airbag development without a credible design, when 1998 had to make their decision on their approach, so they chose a proven approach derived from Viking, a prudent approach at the time.

Now, listed in my testimony is the rules of engagement, how to get into a Faster, Better, Cheaper mode. In my four pages there are ten steps. I am going to highlight No. 4.

We formed an excellent team comprised of a few old-timers, scarred with experience, but most of the team were bright, energetic youth, bringing enthusiasm and new methods. Our Pathfinder team was the major reason for our success. By the way, at the start I was one of the bright, energetic youth.

Now, in our interviews and workshops, it was not surprising that other successful, better, cheaper teams reported similar findings as to what made Faster, Better, Cheaper work. It was not anything magic, nothing new. It was back to basics, especially the importance of people, teaming, and good communication.

Then after much debate, we concluded that Faster, Better, Cheaper is simply attempting to continuously improve performance through efficiency and innovation, just that. But in addition, there is a teaming spirit associated with doing Faster, Better, Cheaper, and this intangible, the humanist versus the technicians won out, and this intangible element was made a part of our definition of Faster, Better, Cheaper.

So then Faster, Better, Cheaper equates to all of NASA. It applies to all missions, and work, and support, and all others in the Nation are at it, too. Everybody understands that we must improve, continuously improve to compete in the twenty-first century.

There are two major challenges for Faster, Better, Cheaper. No. 1, in our zeal we have gone too far in challenging projects to cut costs. We need to slow down some, move from a fixation on cost and near-term gain, and to do more careful planning. We have

made mistakes, and the mission failure rate, in my opinion, is too high.

No. 2, Faster, Better, Cheaper precipitated a major transition within NASA from few to many missions, requiring many more project managers, teams, and institutional support, including review teams.

Where do you go get suddenly all these new people? We caught the institution by surprise. At the same time there is a talent drain due to requirements, due to retirements, downsizing, and the loss to industry.

The future for Faster, Better, Cheaper, the future equates to people, technology, and methods. On people, we must place a higher priority on acquisition, motivating, and training of people. We must develop incentives to attract good people and well-respected leaders to come work for NASA. Generating interest in NASA must start early in the schools.

The results of this task need to be combined with the other investigations to derive a common set of Faster, Better, Cheaper, lessons-learned, and principles to form the basis for training the newly formed project teams. Now, this is within NASA, industry, and throughout academia.

On technology, advanced technology is the better in Faster, Better, Cheaper, and we have not yet scratched the surface on its potential. Technology, in one way, is reducing the amount of work that projects need to do, as well as bringing down the cost of powerful, but small spacecraft, and accompanying reduction in launch vehicle costs is necessary, and must be a national priority if we are to remain a world leader in space.

Combined with the low-cost spacecraft, this will lead to a major move into space by universities, developing countries, high-roller individuals who decide they want to have their own mission to Mars.

On methods, methods involve expanding the multi-mission institutional infrastructure support to the Faster, Better, Cheaper project teams. There is a list of things in my paper as to what that means.

So core teams, with less project-unique systems to build, using more advanced multi-mission capability, and aided with a larger base of advanced technology, will become smaller in size. You will not need as big a team to do the job. The multi-mission capability will aid better the smaller teams.

Then finally, the future of NASA is bright. I believe personally that Dan Goldin is right on with this Faster, Better, Cheaper thrust. He set the stage, created the proper environment, now all we need to do is follow through on implementation.

The key word nowadays is implementation, a gaining from our lessons learned. Working hard in the trenches, executing, following through on the details and getting it right.

Thank you.

[The prepared statement of Mr. Spear follows:]

PREPARED STATEMENT OF TONY SPEAR, TASK LEADER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION'S FASTER, BETTER, CHEAPER REVIEW TEAM, PASADENA, CALIFORNIA

Mr. Chairman and members of the Subcommittee thank you for this opportunity to summarize the NASA FBC Task results. I was asked by the NASA Administrator, Dan Goldin, to undertake this study of the Agency's implementation of Faster, Better, Cheaper (FBC) in mid 1999.

The FBC Task was conducted from July 1999 through February 2000, during which I incorporated my personal experience on the Mars Pathfinder Mission with the results of a series of interviews and workshops with representatives from NASA Headquarters, the NASA Centers, other Government Agencies, Industry, and Academia. This has led to the conclusions presented here.

INTRODUCTION

For most of my career, 1962 to 1998, I worked on Deep Space Missions at the Jet Propulsion Labs, JPL, in Pasadena CA. I retired from JPL in 1998.

In 1992, I was asked to plan and implement Pathfinder, challenged not only to land on Mars, but to "invent a new way of doing business at JPL."

I was to treat cost and schedule as importantly as technical and to develop and operate the mission under a cost cap of $265 million, including the lander, rover Sojourner, flight operations and launch vehicle. Project development from start to launch took a little over three years.

SUMMARY FBC TASK CONCLUSIONS

First let me answer a question often asked:

After the Mars 1998 Lander failure and during the final stages of this Task, I was asked: Why the Mars 1998 Lander did not use the Pathfinder airbags?

In Pathfinder development, there was concern over our airbag landing approach, and we were only midway through its development when the Mars 1998 Project needed to make their landing approach decision. Since we had not completed a credible design yet, the Mars 1998 Project choose a derivative of the proven Viking landing approach—a prudent decision under the circumstances at that time.

HOW TO GET INTO THE FBC MODE—"FBC Rules of Engagement"

Some of the key elements of Pathfinder's success form the basis for the "FBC Rules of Engagement" developed in this Task:

- We were given latitude to adjust mission scope to fit within the cost cap and initiated the project with adequate reserves to handle uncertainty.
- Requirements did not change, and funds were provided at the right time.
- Team members were extracted from their institutional home base at JPL and co-located in one big room around out test bed. We sought out the best expertise inside and outside of JPL. Our team was Nationwide.
- We formed an excellent team comprised of a few old timers scarred with experience, but with mostly bright energetic youth bringing enthusiasm and new methods. Our Team is the major reason for our success.
- Each team member reporting directly to the project, removing layers of management in between, was truly empowered with cost and schedule as well as technical responsibility for their project element.
- We accomplished thorough mission, system and subsystem engineering and strict project planning, monitoring, and control.
- Open and candid communication was important inside the Team and outside as well to management, the press and public. We agreed to place our data immediately on the Internet and to have CNN show our landing to the world.
- We continuously assessed and mitigated risk throughout development and operations, and did not think for a second we could fail because we were experimenting with new ways.
- We emphasized testing and training and followed through on details.
- And, very importantly, we subjected ourselves to extensive peer review, informal interactions with experts outside the project on all important project events—the best check and balance for FBC projects.

Not surprisingly, other successful FBC Teams throughout NASA, other Agencies, industry and academia reported similar findings as to what made FBC work, especially the importance of people, teaming and good communication.

And after much debate on just what is FBC, its definition, we concluded that FBC is simply attempting to continuously improve performance through efficiency and innovation.

But in addition, there is a "Teaming Spirit" associated with doing FBC which distinguishes FBC Teams, this intangible element was made a part of the definition. On Pathfinder, all vendors, NASA Centers and other Agencies in support of Pathfinder also got into the FBC Spirit.

And FBC equates to all of NASA, applying to all missions and work in support of missions. Other Government Agencies, industry and academia are at it too. All realize we must improve to compete in the 21st Century information age and world economy. Of all the hundreds of people interviewed during this Task, no one said we should go back to the old way. All said we need to gain from our lessons learned and improve our FBC approach.

SOME MAJOR CHALLENGES FOR FBC

- In our zeal to do FBC, we have gone too far in challenging projects to cut cost. We need to slow down some, move from a fixation on cost and near term gain, and do more careful planning.

For the 1st generation of FBC Missions, including Clementine, Near Earth Rendezvous, Lunar Prospector, Mars Global Surveyor, and Mars Pathfinder, scope fit well within cost and schedule caps. However, for some of the 2nd generation missions, the challenge bar was raised too high. The cost cuts were too much.

- FBC precipitated a major transition within NASA from few to many missions requiring many more project managers, teams, and institutional support including review teams. Management attention has become diluted across these many missions. At the same time, there is a talent drain due to retirements, downsizing, and loss to industry.

Before with fewer missions, project managers worked up through the ranks for many years with "on the job training" to gain significant experience before they became project managers. Now with many missions this is not always possible, making training, mentoring, and peer review even more important.

FUTURE FOR FBC

To take FBC to the next level will require much dedication and teaming among NASA Headquarters, the NASA Centers and its industry and academia partners. It's one thing to do FBC projects experiments, it's another thing to institutional it.

Future FBC equates to PEOPLE, TECHNOLOGY, METHODS.

On people: We must place a higher priority on acquisition, motivation, training. We must develop incentives to attract good people and well-respected leaders to come to work for NASA. Generating interest in NASA must start early in the schools. While there is good work here, it needs higher priority. There is nothing better than involving students in real live missions, with some managed by students, with strong, encouraging assistance and mentoring by NASA expertise to give them a better chance to succeed. Let them navigate rovers on the Moon and Mars.

The results of this FBC Task need to be combined with those of the two Mars Investigations to derive a common set of FBC lessons learned and principles to form the basis for FBC Training of newly formed project teams.

On technology: Advanced technology is the "Better" in FBC and we have not scratched the surface yet on its potential. Soon projects, who now develop their communications links with their spacecraft, will be provided proven, advanced, multi-mission communications and data systems with "bug free" software—this will be like not having to build your own telephone every time you call home.

Advanced tailor-able, multi-mission micro-electronics with intelligent systems will bring the cost of small, but powerful, reliable, automatic spacecraft matched to automated, Internet driven ground support systems down to a few $ million so that universities, developing countries and companies can explore space, have their own Mars mission.

An accompanying reduction in launch vehicle costs is necessary and must be a National priority if we are to remain a world leader in space. Combined with the low cost spacecraft above, this will lead to an major move into space.

This is what NASA in the FBC mode must be about—paving the way for others to do space exploration by accomplishing high risk, but high payoff, enabling advanced developments.

On methods: Methods involves expanding the institution's multi-mission support infrastructure in support of FBC project teams.

Core FBC project teams with less project unique systems to build and aided with larger base of multi-mission support can become smaller in size. They will be supported by:

- Multi-missions pools of technical and managerial expertise and peer review experts.
- Advanced computer aided tools, processes, templates, model based design techniques, management standards and checklists, risk evaluation tools and training.
- Readably available lessons learned data bases.
- Powerful electronic information links among NASA Headquarters, NASA Centers and their industry and university partners; graphic visualization tools for virtual spacecraft design and for display of mission results.

As well as:

- The advanced, multi-mission technology mentioned above.

The future for NASA is bright—looking for life "out there" and in building the bridge for humans to space. Dan Goldin is right on with his FBC thrust. He has set the stage, created the proper environment. Now all we need to do is follow through on better implementation of the exciting roadmaps and visions that have been generated. The key word is *implementation.* Getting it right.

Senator FRIST. Thank you, Mr. Spear.

Mr. Stephenson.

STATEMENT OF ARTHUR G. STEPHENSON, DIRECTOR, GEORGE C. MARSHALL SPACE FLIGHT CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. STEPHENSON. Good afternoon, Mr. Chairman, and members of the Committee. Thank you for the opportunity to discuss the Mars Climate Orbiter Mishap Investigation Board's report on project management in NASA. I have a brief opening statement, but I would ask that the Investigation Board's entire report be entered into the record.*

I am speaking today on behalf of the board members. It is our hope that this report will significantly help those involved in project management at NASA, and within the aerospace industry to successfully manage their projects during an era of limited resources.

We believe that mission success can be achieved under the Faster, Better, Cheaper paradigm, but the approach to project management must be carefully managed with strict attention to four distinct areas: Selection and training of the right people, use of proven project management processes, with a new emphasis on risk management, disciplined execution of the project, and use of new, but adequately matured technology.

Our initial report in November, 1999, addressed the root cause of the loss of the Mars Climate Orbiter mission as the failure to use metric units in the coding of ground software Small Forces used in trajectory modeling. This failure led to the navigator's not fully understanding the trajectory of the spacecraft. This, in turn,

*The information referred to has been retained in the Committee files.

led to errors in the trajectory correction propulsive maneuvers, and thus the spacecraft approached Mars too low for spacecraft survival.

The Board recognizes that mistakes and deficiencies occur on all spacecraft projects. It is imperative that spacecraft projects have sufficient processes in place to catch mistakes before they become detrimental to mission success.

Unfortunately, for the Mars Climate Orbiter, the processes in place on the project did not catch the root cause, nor did these processes enable the contributing causes, which we pointed out in our November report, to catch and correct this mistake.

Following the loss of the Mars Polar Lander, Dr. Ed Wiler, NASA's Associate Administrator for Space Science, amended our Board's charter to develop recommendations based on an examination of recent spacecraft failures.

Our report on project management in NASA provides the following: Observations and lessons learned from the Mars Climate Orbiter mission; a description of a well-run Faster, Better, Cheaper project; an assessment of NASA's current project management guidelines and procedures; and recommendations for improved project management.

Let me summarize the most significant findings and recommendations documented in this report. Some projects have gone too far in emphasizing the importance of meeting cost and schedule, thereby introducing too much risk into the project. Project management, as well as NASA and industry senior managers, must be willing to push back and ask for more people and dollar resources in order to keep risk levels in check. An alternative might be to reduce project scope.

However, if neither additional resources nor a reduction in project scope is achievable, then project management should recommend cancellation rather than proceed with a project that carries too much risk.

Within the eight failure investigations we examined, six reported that failure could be attributed to inadequate technical reviews, inadequate risk management, and/or insufficient testing, analysis, and simulations. Our Board recommends that reviews must be conducted with the right highly qualified reviewers, including strong representation from functional line management.

We recommend that risk management be raised in importance on NASA projects to a level equal to that traditionally given to cost, schedule, and project scope. In effect, this would make risk management the fourth element in project management.

Clearly, on some projects we have cut corners in testing, analysis, and simulations. We must not give in to cutting corners when schedule and cost are tight.

Communication on any team effort is key. We found inadequate communications on five of the eight failure investigations we looked into. Projects must have disciplined processes in place to enable communications. This is not new to successful project management. It has just been shortchanged under the pressure to do more with less.

Adequate staffing is another area that is sometimes shortchanged because of limited resources. We must make sure that not

only is the staffing adequate, but also that people are the right ones and work well together.

Last, let me say that technology is the key to Faster, Better, Cheaper strategy. We must have adequate funding to provide a pipeline of enabling technology to feed the daring missions we undertake.

Cheaper does not mean just cutting cost. Cheaper missions result from the use of better technology. One needs only to look for a moment at the information revolution we are experiencing. Technology is the key to this success.

Our board believes mission success is achievable on what I have called daring missions if we do these things. Sure, we will experience failures, but that is because we are challenging the unknown, and we must learn as we go. Space exploration is inherently difficult. There is not a lot that is new in these suggestions. We are underlining the need for execution of the fundamentals of project management, but without a return to the old ways of excessive government oversight.

Faster, better, cheaper is a great innovative approach. It does not mean throwing out the fundamentals of project management. It means using improved processes and improved technology in a disciplined way.

Thank you for the opportunity to share this report with you today. I believe our efforts, along with all of those asked to review recent mission failures, will help us better address current and future projects.

[The prepared statement of Mr. Stephenson follows:]

PREPARED STATEMENT OF ARTHUR G. STEPHENSON, DIRECTOR, GEORGE C. MARSHALL SPACE FLIGHT CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE MARS CLIMATE ORBITER MISHAP INVESTIGATION BOARD'S REPORT ON PROJECT MANAGEMENT IN NASA

Good afternoon Mr. Chairman and members of the Committee. Thank you for the opportunity to discuss the Mars Climate Orbiter Mishap Investigation Board's "Report on Project Management in NASA." I am speaking today on behalf of the Board members. It is our hope this report will significantly help those involved in project management at NASA and within the aerospace industry to successfully manage their projects during an era of limited resources. We believe that mission success can be achieved under the "Faster, Better, Cheaper" paradigm but the approach to project management must be carefully managed with strict attention to four distinct areas:

1. Selection and training of the right **people**
2. Use of proven project management **processes** with a new emphasis on risk management
3. Disciplined **execution** of the project
4. Use of new but adequately matured **technology**

Our initial report in November 1999 addressed the root cause of the loss of the Mars Climate Orbiter mission as the "failure to use metric units in the coding of ground software 'Small Forces' used in trajectory modeling." This failure led to the navigators not fully understanding the trajectory of the spacecraft. This, in turn, led to errors in the trajectory correction propulsive maneuvers, and thus the spacecraft approached Mars too low for spacecraft survival.

The Board recognizes that mistakes and deficiencies occur on all spacecraft projects. It is imperative that spacecraft projects have sufficient processes in place to catch mistakes before they become detrimental to mission success.

Unfortunately for the Mars Climate Orbiter, the processes in place on the project did not catch the root cause. Nor did these processes enable the contributing

causes—which we pointed out in our November report—to catch and correct this mistake.

Following the loss of the Mars Polar Lander, Dr. Ed Weiler, NASA's Associate Administrator for Space Science, amended our Board's charter to develop recommendations based on an examination of recent spacecraft failures.

Our "Report on Project Management in NASA" provides the following:

- Observations and lessons learned from the Mars Climate Orbiter mission
- A description of a well-run "Faster, Better, Cheaper" project
- An assessment of NASA's current project management guidelines and procedures
- Recommendations for improved project management

Let me summarize the most significant findings and recommendations documented in this report:

- Some projects have gone too far in emphasizing the importance of meeting cost and schedule, thereby introducing too much risk into the project. Project management, as well as NASA and industry senior managers, must be willing to push back and ask for more people and dollar resources in order to keep risk levels in check. Or, an alternative might be to reduce project scope. However, if neither additional resources nor a reduction in project scope is achievable, then project management should recommend cancellation rather than proceed with a project that carries too much risk.
- Within the eight failure investigations we examined, six reported that failure could be attributed to inadequate technical reviews, inadequate risk management, and/or insufficient testing, analysis, and simulations. Our Board recommends that reviews must be conducted with the right, highly qualified reviewers, including strong representation from functional line management. We recommend that Risk Management be raised in importance on NASA projects to a level equal to that traditionally given to Cost, Schedule, and Project Scope. In effect, this would make Risk Management the "fourth" element in project management. Clearly, on some projects we have cut corners in testing, analysis, and simulations. We must not give in to cutting corners when schedule and cost are tight.
- Communication on any team effort is key. We found inadequate communications in five of the eight failure investigations we looked into. Projects must have disciplined processes in place to enable communications. This is not new to successful project management—it has just been shortchanged under the pressure to do more with less.
- Adequate staffing is another area that was sometimes shortchanged because of the limited resources. We must make sure that not only is the staffing adequate, but also that the people are the right ones and work well together.
- Lastly, let me say that technology is key to the "Faster, Better, Cheaper" strategy. We must have adequate funding to provide a pipeline of enabling technology to feed the daring missions we undertake. "Cheaper" does not mean just cutting cost. Cheaper missions result from the use of better technology. One needs only to look for a moment at the information revolution we are experiencing. Technology is the key to it.
- Our Board believes mission success is achievable on what I have called daring projects if we do these things. Sure, we will experience failures—but that is because we are challenging the unknown and we must learn as we go. Space exploration is inherently difficult.
- There is not a lot that is new in these suggestions—we are underlining the need for execution of the fundamentals of project management but without a return to the old ways of excessive government oversight. "Faster, Better, Cheaper" is a great, innovative approach—it does not mean throwing out the fundamentals of project management. It means using improved processes and improved technology in a disciplined way.

Thank you for the opportunity to share this report with you today. I believe our efforts—along with all those asked to review the recent mission failures—will help us better address current and future projects.

Final Report on Project Management in NASA

by the Mars Climate Orbiter Mishap Investigation Team

Released March 13, 2000. The report is available at *http://www.nasa.gov/newsinfo/publicreports.html*

Executive Summary

This second report and final report, prepared by the Mars Climate Orbiter Mishap Investigation Board, presents a vision and recommendations to maximize the probability of success for future space missions. The Mars Climate Orbiter Phase I Report, released Nov. 10, 1999, identified the root cause and factors contributing to the Mars Climate Orbiter failure. The charter for this second report is to derive lessons learned from that failure and from other failed missions—as well as some successful ones—and from them create a formula for future mission success.

The Mars Climate Orbiter mission was conducted under NASA's "Faster, Better, Cheaper" philosophy, developed in recent years to enhance innovation, productivity and cost-effectiveness of America's space program. The "Faster, Better, Cheaper" paradigm has successfully challenged project teams to infuse new technologies and processes that allow NASA to do more with less. The success of "Faster, Better, Cheaper" is tempered by the fact that some projects and programs have put too much emphasis on cost and schedule reduction (the "Faster" and "Cheaper" elements of the paradigm). At the same time, they have failed to instill sufficient rigor in risk management throughout the mission lifecycle. These actions have increased risk to an unacceptable level on these projects.

The Mishap Investigation Board conducted a series of meetings over several months with the Jet Propulsion Laboratory and Lockheed Martin Astronautics to better understand the issues that led to the failure of the Mars Climate Orbiter. The Board found that the Mars Surveyor Program, agreed to significant cuts in monetary and personnel resources available to support the Mars Climate Orbiter mission, as compared to previous projects. More importantly, the project failed to introduce sufficient discipline in the processes used to develop, validate and operate the spacecraft; nor did it adequately instill a mission success culture that would shore up the risk introduced by these cuts. These process and project leadership deficiencies introduced sufficient risk to compromise mission success to the point of mission failure.

It should be noted that despite these deficiencies, the spacecraft operated as commanded and the mission was categorized as extremely successful until right before Mars orbit insertion. This is a testament to the hard work and dedication of the entire Mars Climate Orbiter team. The Board recognizes that mistakes and deficiencies occur on all spacecraft projects. It is imperative that all spacecraft projects have sufficient processes in place to catch mistakes before they become detrimental to mission success. Unfortunately for the Mars Climate Orbiter, the processes in place did not catch the root cause and contributing navigational factors that ultimately led to mission failure.

Building upon the lessons learned from the Mars Climate Orbiter and a review of seven other failure investigation board results, this second report puts forth a new vision for NASA programs and projects—one that will improve mission success within the context of the "Faster, Better, Cheaper" paradigm. This vision, **Mission Success First,** entails a new NASA culture and new methods of managing projects. To proceed with this culture shift, mission success must become the highest priority at all levels of the program/project and the institutional organization. All individuals should feel ownership and accountability, not only for their own work, but for the success of the entire mission.

Examining the current state of NASA's program and project management environment, the Board found that a significant infrastructure of processes and requirements already is in place to enable robust program and project management. However, these processes are not being adequately implemented within the context of "Faster, Better, Cheaper." To move toward the ideal vision of **Mission Success First,** the Board makes a series of observations and recommendations that are grouped into four categories, providing a guide by which to measure progress.

(1) People

The Board recognizes that one of the most important assets to a program and project is its people. Success means starting with top-notch people and creating the right cultural environment in which they can excel. Thus, **Mission Success First** demands that every individual on the program/project team continuously employ solid engineering and scientific discipline, take personal ownership for their product

development efforts and continuously manage risk in order to design, develop and deliver robust systems capable of supporting all mission scenarios.

Teamwork is critical for mission success. Good communication between all project elements—government and contractor, engineer and scientist—is essential to maintaining an effective team. To ensure good teamwork, the project manager must guarantee an appropriate level of staffing, and all roles and responsibilities must be clearly defined.

(2) Process

Even the best people with the best motivation and teamwork need a set of guidelines to ensure mission success. In most cases NASA has very good processes in place, but there are a few areas for improvement.

A concise set of mission success criteria should be developed and frozen early in the project life cycle.

During the mission formulation process, the program office and the project should perform the system trades necessary to scope out the expected costs for mission success. This should be accomplished independently of any predefined dollar cap. If necessary, consider mission scope changes to drive the costs to a level that the program can afford. Scope should never be decreased below a minimum threshold for science and for technical achievement as defined by the mission success criteria.

Both the project and the program should hold adequate contingency reserves, to ensure that mission success is achievable. Projects and programs that wind up with inadequate funding should obtain more funds or consider cancellation before proceeding with inadequate funds.

Close attention should be paid from project outset to the plan for transition between development and operations. Adequate systems engineering staffing, particularly a mission systems engineer, should be in place to provide a bridge during the transition between development and operations, and also to support risk management trade studies.

Greater attention needs to be paid to risk identification and management. Risk management should be employed throughout the life cycle of the project, much the way cost, schedule and content are managed. Risk, therefore, becomes the "fourth dimension" of project management—treated equally as important as cost and schedule.

Project managers should copy the checklist located in the back of this report, putting it to constant use and adding to it in order to benchmark the performance of their project team. Moreover, this checklist should be distributed to all members of the project team as a 360-degree benchmark tool, to identify and reduce potential risk areas.

(3) Execution

Most mission failures and serious errors can be traced to a breakdown in existing communication channels, or failure to follow existing processes—in other words, a failure in execution. To successfully shift to the **Mission Success First** culture, it is necessary for the institutional line management to become more engaged in the execution of a project. As such, line managers at the field centers need to be held accountable for the success of all missions at their centers.

Let us be clear that this role of institutional line management accountability should not be construed as a return to the old management formula, wherein NASA civil servants provided oversight for every task performed by the contractor or team. Instead, we recommend that NASA conduct more rigorous, in-depth reviews of the contractor's and the team's work—something that was lacking on the Mars Climate Orbiter.

To accomplish this, line management should be held accountable for asking the right questions at meetings and reviews, and getting the right people to those reviews to uncover mission-critical issues and concerns early in the program. Institutional management also must be accountable for ensuring that concerns raised in their area of responsibility are pursued, adequately addressed and closed out.

Line organizations at the field centers also must be responsible for providing robust mechanisms for training, mentoring, coaching and overseeing their employees, project managers and other project team leaders. An aggressive mentoring and certification program should be employed as the first step toward nurturing competent project managers, systems engineers and mission assurance engineers for future programs.

Line organizations, in conjunction with the projects, also must instill a culture that encourages all internal and external team members to forcefully and vigorously elevate concerns as far as necessary to get attention within the organization. Only then will **Mission Success First** become a reality.

(4) Technology

Technological innovation is a key aspect in making the "Faster, Better, Cheaper" approach a reality. Through such innovation, smaller, lighter, cheaper, and better-performing systems can be developed. In addition, innovative processes enable quicker development cycles. To enable this vision, NASA requires adequately funded technology development, specifically aimed at Agency needs. Programs and projects must conduct long-range planning for and champion technology infusions resulting in delivery of low-risk products for project incorporation.

Mechanisms which minimize technology infusion risk, such as the New Millennium Program, should be employed to flight-validate high risk technologies prior to their use on science missions.

Agenda for the Future

The Mars Climate Orbiter Mishap Investigation Board perceives its recommendations as the first step in an agenda that will be revisited and adjusted on an ongoing basis. The aim is to make **Mission Success First** a way of life—a concern and responsibility for everyone involved in NASA programs.

The recommendations of this report must trigger the first wave of changes in processes and work habits that will make **Mission Success First** a reality. To implement this agenda with a sense of urgency and propagate it throughout the Agency, NASA Headquarters and the NASA centers must address the recommendations presented in this report. NASA must further assign responsibility to an organization (such as the Office of the Chief Engineer) for including the recommendations in Agency policy and in training courses for program and project management.

These actions will ensure that **Mission Success First** serves as a beacon to guide NASA as the future unfolds.

Senator FRIST. Thank you, Mr. Stephenson.

Mr. Li, you mentioned a number of Shuttles last year, I guess it was four last year. We talked about downsizing. Could you relate the two to me? You mentioned that NASA's downsizing on the Shuttle program coincided with the decrease in the number of flights in 1996, 1997, and 1998. Would this downsizing have been possible without the decrease in the number of flights? What is that relationship?

Mr. LI. I believe that it is a serendipitous relationship. The fact of the matter is, with the decreased work force, they were able to maintain and provide safe operations with the Shuttle fleet. However, had they gone to the higher rate, which they were expected to have, to build the Space Station, I am afraid that margin of safety would not have been as great. And I believe that Dr. McDonald's report supports that statement.

Senator FRIST. With the increases slated for fiscal years 2000 and 2001, are those increases sufficient for the expected increase in workload that you pointed out will take place in the Shuttle?

Mr. LI. What I have done is, I have reviewed the Office of Space Flight projects for what that organization would need in order to support the Space Station and to perform their Shuttle flights. I believe that those numbers are reasonable within that realm.

I cannot say that those numbers will, indeed, be sufficient, but I think it is going in the right direction. However, I would like to add that, as I said in my prepared statement, adding engineers is not sufficient to resolve the problem. They need to have an overall implementation strategy that is much broader in scope.

Senator FRIST. Dr. McDonald, in your comments and your old testimony on touch labor, increased numbers of inspections, you had mentioned that the wiring damage that led to the short on the STS–93 is suspected to have been caused four or five years prior to that.

Last fall, NASA conducted extensive wiring inspections on all the Shuttle orbiters. In accordance with NASA procedures, how often is this type of wiring inspection required?

Dr. MCDONALD. The standard procedure would require the wiring to be examined on every flight.

Senator FRIST. Is that sufficient? Again, you mentioned the fact that you have people working side by side, where damage is inadvertently caused. Is inspection with every flight sufficient?

Dr. MCDONALD. Our recommendation was that they enhance the degree of inspection and make it a focal point, particularly in the area where redundancy had been compromised. We also believe that the agency should embark upon technology to relieve the rather difficult task imposed on the inspectors. The inspectors in many cases have to use a ten-times magnifying glass and a light, an intense light beam, and we felt that technology could assist in that process.

So we know the realization of the damage that can and has occurred to capped-on wiring on the vehicle, the renewed attention to details by the staff should mitigate the problem, but it will require intensive surveillance to ensure that this is kept safe.

Senator FRIST. The databasing that you mentioned, I understood it to mean that if you had an adequate computerized database and identified certain deficiencies, that it would—the collection of that data, analysis of that data would bring things to management's attention earlier on.

Dr. MCDONALD. Yes, sir. That was the observation.

Senator FRIST. That would seem to be a standard practice. Does that mean more computerization, or more data entry, or what does it mean, more importantly?

Dr. MCDONALD. The problem goes back a number of years, actually the Rogers' Commission suggested that a computerized database be constructed, so it was constructed in the mid-eighties.

And as such, in the present time, it is a legacy system that is somewhat outdated, and the agency is now undertaking a very serious look at that system to see how it could be modified in light of the significant process and database management that has occurred in the last 14 years.

Senator FRIST. Mr. Spear, in your written testimony, the Faster, Better, Cheaper strategy you say precipitated a major transition within NASA from few to many missions, requiring many more project managers, teams, and institutional support, including review teams.

Should NASA decrease its number and scope of missions, do you think, if success and safety, which we come back to again and again over the course of the hearing today, is accomplished?

Mr. SPEAR. One of the things we recommended is that NASA slow down a little, and do better planning. In our major report, which I entered into testimony, I recommend that there are not only project reviews, but program reality checks as to whether the projects really do, in fact, fit under the funding profile.

I believe in training. I believe in a mix of experience-based people, with the young people. The young people can do a lot. I believe in what I call three badges of courage. Each project needs to have some type of informal certification by the institution, not some bu-

reaucratic process, but some way of assessing, hey, this is a good mix of a team.

The second badge of courage is a risk signature. Each project has its own fingerprints, per se. Some projects are higher risk, some are less risk. On one sheet we can illustrate that risk for each project. I think we owe that to the nation, this risk signature.

A third thing, we will now compile all these checklists, and all the lessons learned, all the rules of engagement into a set of Faster, Better, Cheaper ways of doing business. There ought to be a metric, a simple check, as Art Stephenson as laid out in his report, yearly, or maybe every 6 months, as to how well each project is doing in this Faster, Better, Cheaper mode. Those three things, which could be three pieces of paper, would be dramatic, visual status reports on a project.

Senator FRIST. Mr. Stephenson, is that consistent with both your findings and recommendations?

Mr. STEPHENSON. Yes, it is.

Senator FRIST. Thank you. Mr. Stephenson, you mentioned unacceptable level of risk management in your testimony on the Mars Climate Orbiter. How would that have been determined in advance? We had this whole Faster, Better, Cheaper paradigm. How would we have figured that out earlier?

Mr. STEPHENSON. Well, when we were asked to go look at the failure, following the failure, we were asked first of all for the risk management processes, so that we could see what had been conducted in terms of risk assessment, and we found that it was lacking, and that was the finding of our report. We would expect to see a "fault tree" analysis, and we did not see that.

We did not sense that there was enough in the review process, and I mentioned inadequate reviews, that said what could go wrong with this mission, and in searching for the possibilities of failure, and what we found in the case of the Mars Climate Orbiter was that there was not even a peer review of the navigation team. So there was not an adequate effort toward assessing risk and dealing with it.

Chairman FRIST. Thank you. Senator Breaux.

Senator BREAUX. Thank you, Mr. Chairman, and I thank all of our distinguished panelists this afternoon for being with us and providing very valuable information. I am just trying to figure out who is doing what and who is on first.

We have everybody looking at one aspect of NASA. We have GAO, I guess, looking at all of it. Dr. McDonald, you are in charge of the Space Shuttle Independent Assessment Team.

Mr. Spear, you are doing the "Faster, Better, Cheaper" Review Team, Mr. Stephenson, you are doing the Mars Climate Orbiter Mishap Investigative Board report on project management in NASA. I mean it looks like everybody is out there just sifting through all the information that could possibly be turned up in NASA.

I mean is it too much? I mean are we coordinating here? It seems to me, it must be awfully crowded. It looks like you are all looking at some of the same things, and maybe from a different perspective. That may be good. I do not know.

Mr. STEPHENSON. Well, I can respond to that. I think, at least in the case of the Mars activity, of course, Tony was already underway in his studies, and so our Board, when we expanded our role in looking at mission studies and failure, asked Tony to come and brief us, so we were aware of the findings that Tony was coming to, and incorporated those in our report.

So I think we had an opportunity to exchange ideas and test on our own what Tony was saying. So I think our two reports are consistent, not the same, but we agree on what our findings are.

Senator BREAUX. Mr. Spear, did you have a comment?

Mr. SPEAR. I appeared in front of both Tom Young's and Art Stephenson's Board, and we shared our experiences and our results, but after a post-task debrief, I had a meeting with Dan Mulville, and he indicated that the NASA chief engineer is going to now consolidate all the findings, interact with us as to, OK, is this really representative of the results of all the three investigations, and then that is going to spawn a training course, a training course on Faster, Better, Cheaper, as to, here is the definition, here are the checklists as to how you do Faster, Better, Cheaper, and then this is going to be taught all around NASA, but not only NASA, with industry and universities.

Senator BREAUX. So is that going to be one book then as a result of all of this on recommendations?

Mr. SPEAR. That is my understanding.

Senator BREAUX. It would seem to me, if we have all these different reports running around, one group is going to read one, another group is going to read another one, another group may not get them all.

It would seem to be very helpful if we had everything in a concise book of recommendations on what needs to be done and what type of process needs to be followed for the future, and coordinate what we are doing. Otherwise, it is going to be uncoordinated, and not very useful.

Mr. LI. Senator Breaux, I would like to address your question in terms of the three gentlemen on my right here, obviously, all are NASA individuals.

Senator BREAUX. Yes.

Mr. LI. The General Accounting Office is here to assist the Congress in its oversight of NASA, and we perform an independent assessment, an objective assessment of the facts, and we provide that to the Congress.

Senator BREAUX. Well, I want to followup on that. Dr. McDonald, I know that you led the team effort, but you also had NASA and contractors. I mean is your Space Shuttle and independent assessment team reoport truly independent, if you have NASA involved in looking at NASA?

Dr. MCDONALD. Well, I believe it was, sir, because the NASA employees were not from the centers involved directly.

Senator BREAUX. They still get paid by the same check.

Dr. MCDONALD. Yes, sir, but I think the overriding consideration for all the NASA people was the safety of the Shuttle.

Senator BREAUX. I understand that, and I appreciate what you are saying, but I think Mr. Li knows why we depend on GAO so much, because it is separate and truly independent in everything

it does. I am not criticizing the report, but it seems to me that the fact that you called it the "independent assessment team," and it has people from NASA doing it, seems like it compromises the independence of the investigation.

Dr. MCDONALD. Well, I do not believe it did, sir, and I think anyone who tried to muzzle, for example, Rear Admiral Don Eaton would be on a losing track.

Senator BREAUX. Well, I understand that, but I mean it would be like asking the Commerce Committee to assess the Finance Committee. I am sure that you may not get the best results.

I think it is within the bosom of the law, looking at each other and saying, you know, how are you doing, and there is a tendency to say, "Well, we are doing really well. Thank you very much."

Dr. MCDONALD. As you say.

Senator BREAUX. No, it is not. I mean I am here to learn from you guys. I mean I am just disturbed by the fact that it is called an independent assessment team, and part of the people on the team are part of the group that you are looking at and assessing. I just do not know how that is possible.

Dr. MCDONALD. Sir, I think the basic observation is that there were a few NASA people on it. None of them were directly involved in the human space flight program. There were a majority of non-NASA people, DOD, and some contractors were——

Senator BREAUX. Were the contractors also doing work for NASA?

Dr. MCDONALD. No, sir, they were not.

Senator BREAUX. They are not?

Dr. MCDONALD. They were from McDonnell-Douglas Air Frame Systems, or no, Boeing Aircraft. They were working on the MD–11 investigation.

Senator BREAUX. Well, I mean, I think that you heard Dan Goldin speak very clearly that he appreciates and wants it to be independent, and not to have him investigate his own shop, I think. I think it is very important to maintain that independence to the degree that we can.

I take, Mr. Spear, when we talk about faster, better, and cheaper, it seems like you are saying we have been focusing too much on the cheaper and the cost.

Mr. SPEAR. That is true, and there has been much pressure, and now we need to back off a little bit, and do better planning, and continue, but continue in a more disciplined approach, according to the rules of engagement, we call them, the Faster, Better, Cheaper rules of engagement, that are now coming out of my report, Art's and Tom's reports—investigation.

Senator BREAUX. I asked Administrator Goldin about the article by James Oberg from UPI and I think he shucked it to Mr. Stephenson, to comment on.

Mr. STEPHENSON. Yes.

Senator BREAUX. I do not know what happened or what did not happen, I was just reading this as a concerned member of the Commerce Committee. Some of the things contained in this article disturb me, and I think probably disturb everybody. We are looking for some answers because, according to this writer, he said, as explained privately to him, the Mars Polar Lander vehicle's breaking

thrusters had failed acceptance testing during its construction. Rather than begin an expensive and time-consuming redesign, an unnamed space official simply altered the conditions of the testing until the engine passed.

Now, there is an awful lot of openness to that statement. So you can take it to say that the test conditions were changed in order to certify the engine's performance.

That, to me, is an incredibly serious charge, that if the equipment does not pass the test, do not change the equipment, change the test. I know a lot of students would probably like to have that happen to them in school, if you cannot pass the test, throw out the test and get a new test. It is, in essence, what they are saying here, and it is very disturbing. Can you shed any light, whatsoever, on how that occurred, or what happened, in fact?

Mr. STEPHENSON. Well, I can tell you that we have been trying very hard to understand that statement, because we can find no evidence anywhere that that was done.

Senator BREAUX. You would have records of, or have access to the records of the testing of various systems——

Mr. STEPHENSON. Yes.

Senator BREAUX.—such as this.

Mr. STEPHENSON. Yes. I would expect that NASA, with Lockheed Martin, would have records, and we have not——

Senator BREAUX. You have not seen the tests on this particular piece of equipment to certify whether, in fact, the test was given, that the equipment did not pass, and then a different test was given, and then the equipment was certified.

Mr. STEPHENSON. I have no knowledge of that, and I have asked over the last 12 hours everyone I can find, and I am not aware of it. We certainly were not aware of it during our investigation.

We pointed out an issue that was pursued with vigor by JPL and Lockheed Martin, and I have no knowledge that anyone surfaced during any of these investigations any evidence of what I would consider a probable——

Senator BREAUX. Has anybody in your shop had a chance to review the actual tests that were given to this particular piece of equipment?

Mr. STEPHENSON. I cannot say that we have in the detailed level that we are talking about here. My shop——

Senator BREAUX. It would be helpful to pull up in the files what the tests were, and to say whether, in fact, there was one test that was not successfully completed, and then there was a second different test that, in fact, was.

Mr. STEPHENSON. I have no knowledge of that. Let me say that when we uncovered the issue, we discovered that the test program had not been tested at the cold temperatures that we felt it should, and Mr. Sackhiem, who was on my Committee, who is a propulsion expert, recommended that they go back and reexamine it, and there was a team formed by JPL and Lockheed Martin to go back and conduct an investigation, and to run tests.

What they found was that they needed to raise the temperature of those cat beds before going into Mars, and they did redesign the mission to turn on the power to heaters on those cat beds, on the

thrusters, about ten or twelve hours prior to the use of the thrusters. So there was an acknowledgment that there was an issue.

I would not be surprised if they tested at a temperature that was too warm, because they did not produce the test data when we asked the question. They went back and did a ground test less than a month prior to landing on Mars.

So we uncovered an issue, it was addressed, I think, adequately and thoroughly by JPL and Lockheeed Martin, and they changed the mission design to address it. I have no knowledge of anyone running a test and falsifying the results.

Senator BREAUX. Do you feel confident that you have explored every avenue in that regard, to determine whether, in fact, it may have happened without your knowledge?

Mr. STEPHENSON. No. I think we need to go back and look at it real hard, based on this allegation, but I am telling you, at this point, we have no knowledge, and we will certainly be happy to——

Senator BREAUX. It would seem to me, and good Lord, I am the last person to become an expert on the internal operations of NASA, by a far stretch, but it would seem to me that the tests that NASA administers to certify equipment would be a matter that the record is kept somewhere.

Mr. STEPHENSON. Absolutely.

Senator BREAUX. So if this particular piece of the breaking thrusters, I guess, was tested for the first test, you would have the results, and if you had a second test or a third test, you would have the results of each one of the tests, and they would be pretty simple to find.

Mr. STEPHENSON. Correct. I just do not have that confirmation. Let us take that action and get back to this Committee, and give you that answer.

Senator BREAUX. Yes. I would think it would be helpful to find out exactly what happened, because I guarantee Members of Congress are going to be getting letters from constituents—and rightfully so—saying, look, I read this thing, this is not a good story, and can you respond to it. I am going to say, well, I am going to do that as soon as I hear from Mr. Stephenson.

Mr. STEPHENSON. Our initial——

Senator BREAUX. Should I just tell them to call you?

Mr. STEPHENSON. Our initial response is, we do not believe that this is correct statement, but we need to go back and look at the data again.

Senator BREAUX. Well, I appreciate it. I am not being critical of you at all. I think that we just need to have it looked at, and then we can be given a definitive response as to whether there is any information that maybe the tests were done several times, and then changed.

Mr. STEPHENSON. I will do that.

Senator BREAUX. Thank you. I appreciate the panel. Thank you very much.

Senator FRIST. Mr. Li, you mentioned that the age profile of the workers at Kennedy reversed just 6 years ago from twice as many workers under 30 years of age to twice the number of workers over 60 years of age. Why is that?

Mr. LI. I think it is obvious, NASA was not able to hire. They had no stream of new employees that were able to come in and create new blood.

As a result, that percentage, as you are saying—in fiscal year 1993, the Office of Space Flight, for the people who were under 30, they comprised 17 percent of the work force. In fiscal year 1999, now they comprise 3 percent of that work force. Obviously, something is happening.

Senator FRIST. Say the reason again. Obviously, what?

Mr. LI. Because they were not able to hire. NASA——

Senator FRIST. They were not able to hire. What does that mean?

Mr. LI. They did not hire, because they were in a downsizing mode. It is not a matter of them not wanting to. They had a strategy that they were going to drop from over 20,000 employees down to 18,500. Their strategy was obviously not, as we heard earlier this afternoon, to have any involuntary separations. They wanted to have voluntary separations. They had buyouts, and through that downsizing, they did not hire anybody.

Senator FRIST. As this great hiring process goes on, as everybody has said, it cannot be just the hiring process itself, do you think those ratios will turn back to what they were?

Mr. LI. I am hopeful. I think there is one thing that the Administrator mentioned last week in a hearing that I thought was very important, in that he feels that the hiring of employees should be looked at from two perspectives, one, from a short-term perspective, because, as he said earlier this afternoon, it is very difficult to retain these bright, bright people coming out of college, they are not going to stay in the government, we just cannot compensate them enough; however, the excitement of working at NASA is enough to keep them for, perhaps, two or 3 years.

He has that plan to keep those people there for a while, but he also recognizes that he has to keep institutional knowledge, and he also wants to hire people for longer periods.

Senator FRIST. When we talk about a mentoring program, and it has been mentioned indirectly by a lot, you had these sort of short-term focused projects, team spirit, people pulling together, you know, going through the night, you have all these visions of a real team. Can it really go on in that environment on a project, like Mr. Spears? I mean if you basically said I have to be in the job of mentoring at the same time I have this three-, or four-, or 5-year project, what do you do?

Do you take the gray-haired person who has been around a while, one of the old guys, whatever your words were, and you pair him up, and you say, OK, you are the mentor, because this young fellow may or may not leave, and they are more likely to leave if they are not—how do you——

Mr. LI. I think there has to be a specific goal, and it has to be explicit that the Agency's strategy and objective is to have that mentoring. In the environment that has happened recently, because they had so much work, and also, obviously, because they did not have enough young people to mentor, that did not happen.

But I really think that if there is that push now to do and perform mentoring—mentoring, to me, is taking somebody under their

wing and trying to teach them on the job, this is how you do these things.

Senator FRIST. What incentive is there—Mr. Spear, you can jump in. How do you reward that person? You said mentoring is important. Are you going to get paid more? How do you incorporate that in this Faster, Better, Cheaper team spirit, pull ahead, we are going to produce in a short period of time for less? Is it possible? How do you incentivize it, Mr. Spear?

Mr. SPEAR. First of all, Senator, mentoring can only go so far. You can only teach this new person, this young person, your experience, to a certain degree. Sometimes it is just hard for them to fathom what you are telling them. So the team has to be a balance. It always has to be a balance.

It cannot just be youth and inexperience. There has to be people with on-the-job training. Nothing works better than on-the-job training.

The best, by far and away, mentoring process is in this peer review process that we talked about, where every key decision, every test result, every walk down prior to launch, is reviewed by a peer group. Now, in that peer group, you want the best expertise and the best experience.

Senator FRIST. In the Mars Pathfinder project, how many of those employees, workers, members of that team are still with NASA now? Are the people that are in there really a part of this so-called team? And I have the image, but are they all full-time NASA people who are there?

Mr. SPEAR. That is a very good point. A large fraction of the original Mars Pathfinder team, a young bunch of people, are still at JPL, and what a way to carry on lessons learned. They have gone on to do projects now. Some of them, however, very close to me, are somewhat more scarred than I imagine they would get scarred so soon. OK?

But the experience, on-the-job training is extremely important, and then—but this is a very healthy process. The fact that we do projects now in 3 years, and we do more than two per decade, we do 20 to 30 now, we are going to benefit from this.

Now, we have had some problems, but NASA soon will have a lot of people with experience, real live experience, because the missions only take 3 years. That is a very healthy process that is going to come out of this, but we are going to have failures, OK, from time to time.

Let me tell you, that is very, very traumatic to these young people, that I know very well.

Senator FRIST. Well, the failures, and then the stress of Mr. Li's findings, and the alternatives that are out there in the private sector now, where we have this gap, where there is an age gap, or an experience gap? However we define this gap, it is very exciting. This experience can build if people stay around, are retained, and see a great future with NASA.

Mr. SPEAR. Right.

Senator FRIST. Dr. McDonald—and I know it is very late, so I have just a couple more questions. Dr. McDonald, pin injection problem, break down, and fly what you test, test what you fly ap-

proach methodology systems. Are there other instances where that methodology was not adhered to, broke down, did not work?

Dr. MCDONALD. Not to the best of our knowledge, Senator. We would pull on threads as we went through things that looked askance, and pull on those threads and go into them, but that was the only case we could find of a direct ignoring the regulation, yes.

Senator FRIST. Mr. Spear, cost caps, International Space Station, do you believe that Mr. Goldin could apply the successful lessons that you have learned managing Pathfinder under a cost cap-type scenario?

Dr. MCDONALD. It is my personal belief that all projects can employ the Faster, Better, Cheaper approach, and work with accountability to a cost cap. Now, that is not to say that they tried to stuff an arbitrarily large, say, a challenging large scope into an arbitrary cost cap, but they have been given the opportunity to work from the bottom up, a good cost estimate, and then declare to NASA, to Dan Goldin, hey, I am going to do this task, on this schedule, and under this cost cap. I am a firm believer that most work within NASA should be done that way, across the board.

Senator FRIST. Then you would understand my frustration a bit earlier in questions to Mr. Goldin. The fact that I cannot get cost estimates for a project, he cannot get it from his contractor, and if you cannot even get the cost estimates, you much less cannot have the cap or the accountability built in to it.

Dr. MCDONALD. That's the problem.

Senator FRIST. Mr. Stephenson, eight failure investigations that your Board examined, each one suffered from poor and inadequate technical reviews. Who traditionally performs these technical reviews? Is it the prime contractor? Is it people from within NASA?

Mr. STEPHENSON. It's a combination of both. It depends on what programs we are talking about. In the case of the Mars program, there was a shift to rely on the spacecraft's contractor, in this case, Lockheed Martin, to conduct the reviews on the spacecraft design development and readiness for flight.

On other programs, where NASA is more integrated, and we think we should move to more integration from NASA, and more involvement in institutionalized line management, in that case, being JPL's technical experts being involved in the reviews, we think that is where we should be going more, and not have this reliance on a contractor to make the right decisions without any insight from NASA.

Senator FRIST. Thank you. Well, again, the hour is late, and I do want to thank each of our witnesses for taking time, being patient, and being with us for this afternoon. Your expertise, your knowledge, and your input are absolutely crucial, as you can tell from our questions, to our fully understanding the very complex issues confronting NASA today.

The recommendations of all of your reports and the usual outstanding testimony of GAO goes a long way in helping us answer our questions, and ask the right questions of NASA, as we go forward.

We will continue in this Subcommittee and in the full Committee to review NASA activities as additional reports come on-line over the coming weeks and months. As you have heard, NASA will be

coming back in a few months, after we have had time to digest further all of the reports, to digest the Young report, which will be out shortly.

Again, I want to thank all of you for participating in today's discussions, and thanks again to all of the members of your respective review teams who have put forth the time and the effort to make these reports possible. Thank you.

[Whereupon, at 4:58 p.m., the hearing was adjourned.]

APPENDIX

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO ALLEN LI

Question 1. You mentioned that there are twice as many workers over 60 years old than there are under 30 years old. What percentage of the overall workforce does this over 60 years old represent? Also, in what areas are these workers found?

Answer. This statistic refers to personnel in NASA's Office of Space Flight (OSF). It was provided to us as part of NASA's "Core Capability" Critical Staffing Review dated December 10, 1999. Specifically, the data shows that for fiscal year 1999, the workforce over 60 represented 8 percent of the OSF total, or 407 workers. Workers under 30 represented 3 percent of the total workforce, or 144 workers.

According to NASA's data, these categories of workers are represented in four general classifications, including science and engineering, professional administrative, clerical, and technicians.

Question 2. Given the uncertainties related to the future of Shuttle privatization and commercialization plans, what impact are they having on the overall program, both current and future?

Answer. NASA has not established a schedule for the privatization and commercialization of the Shuttle. In November 1999, a Space Shuttle independent assessment team found that, because the milestones for privatization and commercialization were uncertain, there was no foundation from which NASA could accomplish strategic planning and workforce deployment. The study recommended that NASA should begin the analysis of how its workforce will evolve in the privatization and commercialization environment and prepare a plan for this evolution.

NASA took a step toward privatization with the award of the space flight operations contract, but full privatization has not been accomplished. Regarding commercialization, there are currently federal laws and regulations that limit the Shuttle's ability to fly commercial payloads.

Although NASA does not have an approved plan for privatizing and commercializing the Shuttle, the Office of Space Flight is reviewing laws, regulations, and policies that are seen as barriers to achieving that goal.

Question 3. Can you elaborate further on your human capital checklist? Which agencies are employing it?

Answer. The checklist is still in discussion draft form. It is our understanding that a number of government organizations are reviewing it and have expressed interest in applying it. These organizations include the National Partnership for Reinvention, the Office of Personnel Management, the Office of Management and Budget, and the Environmental Protection Agency. To our knowledge, NASA is the only agency that has provided written comments regarding their actual use of the checklist.

Question 4. Your statement mentioned that many key positions are not staffed by qualified workers. Can you elaborate on this? Are you saying that some functions are being performed by unqualified personnel? Is this a violation of established NASA procedures?

Answer. See Question 5.

Question 5. You mentioned that an earlier study found there was one qualified person in 30 critical system areas. How is "qualified" being defined?

Answer. We did not intend to leave the impression that "unqualified" workers were tending to key Shuttle program positions. The issue we raised is captured by Question 5. That is to say, while NASA maintains that its front line Shuttle workforce is qualified, there are many areas in which redundancy and depth are lacking. NASA's Space Shuttle Independent Assessment Team (SIAT) report also spoke to this issue. It concluded that "there are important technical areas that are staffed one-deep." The example we used in Question 5 relates to Shuttle personnel at Kennedy Space Center.

Question 6. Your testimony stated that during a recent Shuttle wiring investigation, personnel unexperienced in wiring issues were used to perform critical inspections. Has GAO work confirmed this finding?

Answer. The study we referred to is the SIAT report. The team expressed a concern that reductions in staff make it difficult to ensure that critical flight safety processes and procedures are being rigorously implemented and continually improved. The team also expressed the belief that Shuttle program workforce augmentation must be realized with NASA personnel rather than contractor in these critical areas. In this context, the team concluded that, because of workforce shortages, NASA had to use quality assurance personnel who, although certified, lacked specific experience with wiring issues. In general, our work confirms the concerns expressed by the SIAT report.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO TONY SPEAR

Question 1. One of your recommendations is to improve the participation of universities in space missions. Can explain the merits of this approach?

Answer. **Witness did not respond.**

Question 2. Would you suggest adjusting current project schedules to avoid the risk of excessive cost-cutting? That seems to be your overarching sentiment in your testimony as a result of your vast management experience.

Answer. **Witness did not respond.**

Question 3. Do you believe that Mr. Goldin's "no prescription for success" strategy is the right approach to resolving these management problems given the prescriptive nature of some of your recommendations?

Answer. **Witness did not respond.**

Question 4. In the Faster, Better, Cheaper report, Colonel Pete Rustan, the Clementine Project Manager, is quoted by saying that "careful FBC pre-project planning and costing are as important as ever before." Has NASA applied those principles to the International Space Station and other ongoing projects?

Answer. **Witness did not respond.**

Question 5. Is NASA adequately and aggressively taking steps to reverse the talent drain that is outlined in the Faster, Better, Cheaper report?

Answer. **Witness did not respond.**

Question 6. If technology is the key to implementing the Faster, Better, Cheaper strategy, what happens to Mr. Goldin's paradigm if technological advances do not occur quickly enough? Does Faster, Better, Cheaper still work?

Answer. **Witness did not respond.**

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO ARTHUR G. STEPHENSON

Question 1. You stated in your written testimony that the processes in place on the Mars Climate Orbiter did not catch the root cause. Can you please describe these processes and why they were inadequate? Is NASA still employing them following your investigatory report recommendations?

Answer. The process in place on MCO did not catch the unit conversion error or the inability of the teams at JPL and Lockheed Martin to get together and discover the navigation error. One process was the process of raising concerns and formally logging those concerns so that the concern was formally addressed. The Navigator did raise a concern to his supervisor but it was not formally documented. Another process that failed was the design review process. Although design reviews are standard practice, the navigation process was not reviewed.

Following our MCO report and other Mars failure reports, NASA took steps to place more rigor into these processes, thereby greatly reducing the likelihood of this type of problem in the future. As we said in the MCO report, errors will occur, the process will breakdown at times, but there needs to be checks and balances in the system to catch these errors. I think NASA has put processes in place now to catch errors.

Question 2. According to your testimony, you believe that if neither additional resources nor a reduction in project scope is achievable, then project management should recommend cancellation rather than proceed with a project that carries too

much risk. Can you apply this dilemma to any current projects at NASA? Do you believe that other project managers would agree and carry out your management principle?

Answer. I believe cancellation is better than proceeding with a project that is too risky. Usually a high-risk program can be brought to a reasonable risk but only with the infusion of additional funds. If the cost/benefit does not warrant the additional funds needed, then the project should be cancelled rather than carry excessive risk. This past week, I announced cancellation of the X–34 project for this very reason. I believe other NASA managers are willing to do the same (i.e. Pluto Kuiper cancellation).

Question 3. What are the major technological breakthroughs that would enable NASA to cut costs and effectively integrate Faster, Better, Cheaper agency-wide?

Answer. The major technical breakthroughs that would enable NASA to cut costs and effectively integrate Faster, Better, Cheaper (FBC) Agency-wide are program or project specific. What would make one program FBC is not the same as another. One technology breakthrough area that applies to all NASA space programs is lower cost, higher reliability space transportation. Every project NASA undertakes that involves going into space requires launch and often in-space transportation systems. If we can dramatically lower the cost of access to space and space travel, we can dramatically change the commercial, military and scientific impact on earth that derives from space assets.

The Space Launch Initiative is designed to lower the cost of access to space by developing more reliable, lower cost-to-operate second generation reusable launch systems. This will be done by funding risk reduction activities, like space launch architecture option studies and funding risk reduction technology development, like lower cost, higher reliable reusable propulsion systems.

NASA's Advanced Space Transportation Program addresses third generation reusable launch systems that will approach airline-like operations into space.

Question 4. Do you believe that Mr. Goldin's "no prescription for success" strategy is the right approach to resolving these management problems given the prescriptive nature of some of your recommendations?

Answer. Mr. Goldin agrees with the findings and recommendations of the NASA Integrated Action Team (NIAT) report. This report reviewed and integrated the recommendations of four reports—two related to Mars failures, one that addressed FBC philosophy and one that addressed the Shuttle. The NIAT report has specific recommendations, some coming from the MCO Committee I chaired. At the end of the day, the best practices ("prescriptions") are dependent on the people who do the work. That is what I think Mr. Goldin meant by there are "no prescriptions for success." NASA and NASA's contractors employ excellent people. NASA and industry senior management must instill a culture that does not allow risks to be excessive while encouraging projects to stretch to new levels. Only experienced, well-trained leaders will get it right. Mentoring, training, and hands-on experience along with well grounded procedures and processes are key to the success we are counting on.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO DANIEL S. GOLDIN

Question 1. Given yesterday's press article on the Mars Polar Lander and the Young report, have you personally reviewed the report? If so, do you feel that Dr. Stone's statement on "difficult times ahead" applies across NASA as well?

Answer. Mr. Young and his team did a fine job and provided NASA with a very thorough review. This report has caused us to step back for a moment and rethink our approach with regard to some of our missions. I still believe that faster-better-cheaper is the right direction for NASA, but it has become clear that perhaps we pushed a little too hard, too fast. We are looking at all of our programs to ensure that we have the right mission scope and the appropriate resources identified to ensure mission success. This review has identified some programs that need to be realigned—Outer Planets is a prime example—and we are doing that now. We've also found programs that are exactly on the right track. I think this kind of review is a valuable tool. We will continue to undertake efforts to drive down mission costs but will seek to more carefully assess and manage risk as appropriate to different types of missions in the future. We made some mistakes; now we are learning from them and moving ahead so that we can continue to deliver the science results that the American public both expects and deserves.

Question 2. Should the Shuttle orbiters be re-examined given the use of unqualified personnel during last year's test?

Answer. Our research into this question failed to show that "unqualified" personnel were used. In addition, we reviewed again the Space Shuttle Independent Assessment Team report (released on March 7, 2000) and found no mention there to use of "unqualified" personnel. Space Shuttle program policy has been and will be to use only qualified personnel for every aspect of system processing and launch and landing operations. Lessons learned from each flight (In-Flight Anomalies and problem reports) will be addressed in a timely manner and so as to assure that process changes include workforce training.

Question 3. If "acquiring, motivating, and keeping good people," is one of the top priorities of NASA to ensure the future of Faster, Better, Cheaper, why have you continued to cut or stagnate the agency's funding for academic programs over the last few years? Doesn't NASA actions contradict what you're saying?

Answer. In recent years, NASA has been increasing its budget and expenditures for training and development of the Agency workforce. Our expenditures in these areas have increased from $30 million in 1997 to over $47 million in 2000—from 2.5 percent of salary in FY 1997 to 3.6 percent of salary in FY 2000. In concert with discontinuing downsizing and beginning to hire and revitalize the workforce, the Agency has encouraged an environment of continual learning so that employees can possess leading edge skills and competencies to fulfill NASA missions. In order to foster such an environment, we plan to expand delivery methods being utilized to develop the workforce and to develop e-learning alternatives that can be accessed at all locations and levels, increasing the ability to expand participation across the Agency. New capabilities are also being developed to facilitate learning within intact teams, delivering learning experiences tailored to a project team at the point in time it is needed. In addition, some Centers are also increasing their resources for Center-specific needs. Other learning alternatives which require very little funding are also being emphasized, such as providing hands-on developmental experiences, mentoring of lesser experienced employees by more senior members of the workforce, and other career development initiatives. We continue to emphasize training and development in the areas of systems engineering, high quality technical training, project management, and leadership skills. We have also taken steps to encourage additional advanced academic study and attendance at technical conferences and symposia by providing additional funding to NASA Centers specifically designed for these purposes.

With respect to Academic Programs, designed to serve the needs of the education community and inspire an interest in math and science in students at all grade levels, NASA's FY 2001 request of $144 million for Academic Programs represented an increase of 12 percent over the FY 2000 enacted level (minus Congressionally directed programs). This request maintained a core program of $100 million with an additional $44 million embedded in the Enterprises, as shown below.

NASA Funding for Academic Programs

(in Millions of Dollars)

	Actual FY00	NASA FY01 Request	Actual FY01
Baseline Program	100	100	100
Enterprise Contributions	29	44	44
Total Baseline Program	**129**	**144**	**144**
Congressional Add-ons *	39	0	33
Total Funding	168	144	177

* Congress added funds for specific programs designated for a particular fiscal year that were not included in NASA's request.

Even in times of declining budgets NASA has made a commitment to maintain the stability of the Academic Programs budget. We believe this represents a strong commitment to invest in the future science and technology workforce and in greater scientific and technological literacy in general, which is the Nation's foundation for future discoveries and economic prosperity. This is truly an investment to embark on a bright new future.

Question 4. You mentioned in your written statement that you will not issue a "prescription for success" to the NASA workforce. Can you elaborate on this assertion? Does this mean you plan to let them solve their own problems?

Answer. As an agency responsible to the American taxpayers, NASA can be justifiably proud of its scientific and technological success during the past decade, particularly in light of accomplishments achieved while faced with budgetary and workforce reductions. Nonetheless, we strive to continually understand our present state and analyze what needs to be done to plan a path of continual improvement. We do not want to issue a "prescription for success" to the NASA workforce if it is a one-size-fits-all prescriptive checklist that must be rigidly adhered to. This would stifle the very innovation that we strive to enhance within our talented workforce. Instead, we are providing general principles and guidelines that can be tailored and allow for innovation. Based upon the Mars program failures and other activities, the Agency recognized the need to assess and respond to various findings and recommendations that could be more broadly applied to a wide range of NASA programs and projects. This resulted in an assessment chaired by the NASA Chief Engineer and an analysis and report of the NASA Integrated Action Team. This report found that to be successful in our project planning and execution, there remain several elements that must be considered which are indicators of future success.

The people of NASA and its partners are the linchpins of our present and future success. Challenging work, executed in a safe and productive work environment by people who are well prepared for and supported in their work is an essential element to successful project planning and execution. Well-defined and executed formulation and implementation is also required. These processes must be driven by thorough understanding and controlling of risks, where open communication will allow for problems to be found early, and when the right people can be involved and resources needed to solve them are less substantial. Innovation needs to be encouraged while integrating sound management and engineering fundamentals.

State-of-the-art tools and methodologies are also essential. The cutting edge of research and technology will only be achieved through advancing the way we do work. Technology must be cutting edge and advance and address both the needs of today and also those of tomorrow. A sustained investment in America's future through advancing technology development will be essential to our Nation's global competitiveness and leadership.

The recommendations of the NIAT report provide a framework and important guidelines for us to take NASA into the future. Through this vision for the future, we will further strengthen our capability to be effective stewards of the public trust.

Question 5. Your written statement indicates that NASA's steps over the past two years demonstrate its commitment to a world class system engineering program.

How do you explain the findings of several external review reports calling for better systems engineering efforts? Also, would you outline how you are incorporating systems engineering in the Space Station program given the review two years ago by the Cost Assessment and Validation Task Force?

Answer. NASA takes great pride in possessing a knowledgeable and skilled engineering workforce capable of world-class performance in the development, integration, and operation of complex space systems and aerospace technologies. Over the last several years, changes in practice, skills, and knowledge of the workforce, coupled with the demand for innovation in aerospace science and technology, particularly the revolution in information technologies, presented a tremendous challenge to NASA.

NASA is committed to the revitalization and sustainability of its engineering capability. With the support of the Administration and Congress, NASA has started to fill critical engineering and other skills essential to health and safety of the Shuttle and ISS programs. In February 2000, the NASA Administrator created the position of Deputy Chief Engineer for Systems Engineering. This position was established to develop the vision, objectives, and strategies for the development and maintenance of the Agency's world-class engineering capability in the Agency.

In March 2000, NASA released a series of reports that were the product of activities chartered by the Agency in response to failures in the Mars Program, Shuttle wiring problems, and a generic assessment of NASA's approach to executing "Faster, Better, Cheaper" projects. Some of the specific recommendations on systems engineering contained those reports were:

Mars Climate Orbiter (MCO) report

- Establish and fully staff a comprehensive systems engineering team at the start of each project.
- A core group of system developers and systems engineering personnel should assist the operations team in developing nominal and contingency procedures, mission rules and operational.

Mars Program Independent Assessment (MPIA)

- Appropriate levels of systems engineering need to be in place throughout the formulation and implementation phases of all projects.

Also in March 2000, the Office of the Chief Engineer chartered a NASA-wide senior team, the NASA Integrated Action Team (NIAT), to develop an integrated Agency strategy to respond to the recommendations of these reports. The NIAT report, released in December 2000, made several observations regarding systems engineering. It said that "The reports expressed concern as to the consistency of competency across teams in light of the need to establish teams that are multiskilled, including systems engineering, operations, and scientific expertise." It went on to say that "The increased number of projects amplified the challenges on the systems engineering pool by placing equal demands for project managers from the same talent pool." In the section of the report addressing the need to revitalize engineering capability, the NIAT report discusses "the need for a comprehensive plan to ensure a world-class engineering capability that includes the development and application of advanced engineering tools and capabilities. Much of this effort will focus on strengthening capabilities in systems engineering."

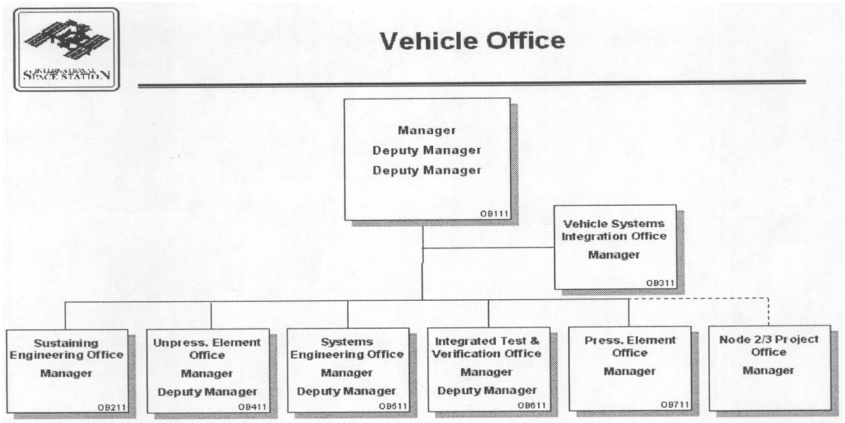
The report concludes that an "ingredient in the assessment of NASA's engineering capability is consistency in process, and execution. Over time, each of the NASA Centers has developed internal processes for systems engineering that have made them largely successful in their mission. However, as we strive for greater integration, consistency, and sharing of expertise among NASA Centers, industry, and academia in collaborative environments, it appears that the Agency could benefit from appropriate Agencywide standards in the systems engineering process." Furthermore, it concludes that "Specific considerations are needed for systems engineering skills at the "mission" level, and below, to ensure the "systems" perspective is maintained at all levels throughout the life cycle."

Some of the NIAT recommendations specific to systems engineering capabilities are:

- Enhance education and training for engineering capability including real-world hardware experience and partnering with academia to develop curriculum such as systems engineering, advanced engineering environment, risk assessment, and cause-and-effect analysis tools and methods.
- Develop Agency-wide process standards, requirements and guidelines for the effective implementation of systems engineering in programs and projects.

The proactive steps taken by NASA over the last two years demonstrate the Agency's commitment to the sustenance of a world class program/project management, and systems engineering capability. The concerns raised by the reports are a reminder that the NASA business is inherently high risk, and that as steps are taken to further improve the program/project management and systems engineering capability, we must remain ever vigilant to minimize the probability of failures that are preventable.

NASA has taken a very broad view of the systems engineering for the Space Station and integrated that function across NASA and the contractor activities. Development, systems integration and sustaining engineering activities are all managed, including contractor technical oversight, in a single NASA organization (see chart below). As the development phase is incrementally completed critical skills are transitioning to sustaining engineering to support the assembly stages.



Recently, the Space Station program began a major activity to assure continuity of skills and a seamless handoff from development to operations was the initiation. In late 1999, a statement of work for Integration and Operations (I&O) was initiated within the prime contract. The transition planning and skills retention is now taking place through this portion of the contract. The same engineers who are currently, and have been, designing, building and integrating the Station are working on the I&O contract to assure its safe and effective operation.

NASA has clearly delineated and documented the systems integration responsibilities for which each party is accountable and currently performing.

Question 6. What is NASA's response to the Comptroller General's checklist for human capital management? Is it being used at NASA? Where and to what extent?

Answer. NASA has applied the checklist's framework to its human resources policy and oversight functions in several ways. In developing the Office of Human Resources and Education Functional Leadership Plan last year, we reviewed and incorporated into our thinking the basic principles from the Comptroller General's checklist for human capital management. The final plan is based on the strategic concept that *"Our greatest strength is our workforce"* and mirrors basic principles reflected in Part 1 and 2 of GAO's checklist. Secondly, since the mid-eighties, NASA has been recognized for its strong human resources' self-assessment program. The core component of our program is local accountability, with Agency guidance in the form of a reviewer's complete checklist on merit principles and other national goals in law and regulations. This approach relates to the GAO checklist's cross-cutting considerations. Moreover, in January 2000, we incorporated the GAO checklist as a companion piece to our self-assessment protocol. Finally, we have used, and plan to continue to use, basic premises of the checklist as guidance when reviewing the effectiveness of our human resources programs to identify additional needs and enhancements. One recent example was the development of our Agency's improvement plan in response to National Performance Review survey results.

Question 7. What is NASA doing to address recruitment of new employees, especially software engineers, to meet both current and future program needs? How can NASA remain competitive with the alluring packages of the high tech industry?

Answer. We must be innovative and energetic in our efforts to attract the best and the brightest to NASA. The most effective recruiting tool we have is the NASA mission. People generally come to work for NASA not for the money or benefits, but because they enjoy the work and want to be a part of the mission. We need to take full advantage of the attractiveness of our mission, but that alone is not enough. While NASA will never be able to match some of the compensation packages offered by the private sector, we must do our best to narrow the gap so that we are at least competitive. This will require using the financial incentives at our disposal, emphasizing the non-financial incentives, streamlining the hiring process, participating in programs that provide sources of future talent for the Agency, and being active in a wide array of recruitment initiatives.

Our Centers use various financial incentives in order to make competitive job offers. Special salary rates are in place for some hard-to-fill occupations, covering many of NASA's scientist, engineering and engineering software positions. To make offers more attractive, our Centers are able to offer starting salaries above the minimum rate of a grade through the superior qualifications appointment authority. They offer recruitment bonuses to attract exceptional candidates to NASA. Very soon they will have a new financial incentive available for their use: the authority to repay federally insured student loans. In offering jobs, we emphasize the entire Federal package—not just the starting salary level—since our retirement, health, leave, and life insurance programs are competitive with those offered by many private sector companies. We also emphasize the other benefits we can offer such as flexible work schedules, family friendly programs, an array of professional development opportunities, and tuition support.

Unfortunately, despite these incentives, many of our new employees must still make a personal or family sacrifice in order to work for NASA. The alluring packages (salary and benefits) offered by high tech industry cannot be matched by NASA. The impact is national in scope but is particularly acute for NASA Centers located in higher cost of living areas. The fierce competition for information technology workers, including software engineers, puts NASA at a competitive disadvantage.

We are committed to marketing NASA as the "employer of choice." One of our greatest advantages in competing for the best and the brightest is our ability to excite individuals about NASA's mission, commitment to excellence, and professional challenges and opportunities.

In order to compete with employers who have streamlined hiring procedures, we are automating our processes with software that will enable individuals to apply for our jobs easily and receive timely responses.

We recognize that we must have a continuing presence on college and university campuses to maintain an effective influx of college graduates into NASA. The more than 140 on-campus recruitment trips scheduled over the next year are typical of this presence. We plan to continue to use the Presidential Management Intern Program and student employment programs as sources for entry-level hires as well. In order to recruit more effectively with the cooperative education program, we are developing new qualification requirements for these students. A new hiring authority recently established, the Federal Career Intern Program, soon will be available as another tool for hiring quality candidates under streamlined procedures.

Another means of developing a future pipeline of talent from which NASA can draw is the NASA Undergraduate Student Research Program, piloted in FY 2001. One of its purposes is to provide undergraduates with challenging research experiences that stimulate continued interest in the disciplines aligned with NASA's mission. Another is to build a national program bridge—from existing NASA K–12 Education Program activities to NASA Higher Education Program options—to encourage interest in future professional opportunities with NASA.

Our marketing techniques and efforts have become more expansive in order to compete in today's environment. We established a unified NASA jobs web site to provide easy access to information on jobs, with direct links to information on NASA's mission and Centers as well as links to the application procedures. We will continue to promote the Internet as a recruiting tool. A new National Recruitment Team, based at Headquarters, is being established to develop new Agency-wide recruitment strategies and tools to meet NASA's current and future hiring challenges in attracting and retaining a world-class, highly technical and diverse workforce. This team will facilitate and complement the Centers' recruitment efforts; collaborate with the Institutional Program offices and Functional Offices, enhance relationships with universities, and facilitate targeted diversity and disability recruitment.

Question 8. You mentioned that Station runout costs have decreased by $1.2 billion, of which $.8 billion is due to a shift of tiding for the Crew Return Vehicle to another budget account. What is the rationale for this transfer?

Answer. The statement was made in the context of the Station funding line. During the formulation of the FY 2001–2005 budget, the Agency reallocated the FY 2002–2005 funding estimates for the Phase 2 (production phase) of the CRV to the Science, Aeronautics and Technology (SAT) account as part of the funding for the Space Launch Initiative. The funding is in SAT pending a decision on whether to proceed with an X–38-based CRV design (which could only be used for emergency crew return from the Space Station) or a design that could also provide a crew transfer function to bring crew to and from orbit as part of a new space transportation architecture. This decision is within the context of broader decisions that NASA and the Administration will make regarding future space transportation architectures. A design decision on whether to follow the X–38 path or to incorporate alternative design concepts is expected to be made within two years.

Question 9. Who pays for the efforts to correct problems on the X–33 program?

Answer. NASA and Lockheed Martin have negotiated an extension to the cooperative agreement that extends the Period of Performance from December 31, 2000 to March 31, 2001. The agreement allows Lockheed Martin to re-plan the flight schedule based on recovery from the composite tank failure. No additional funding has been added to the cooperative agreement. NASA's investment of $912 million remains fixed.

Question 10. What will NASA do if the industry partner decides to discontinue the X–33 project?

Answer. If Lockheed Martin chooses to discontinue the X–33 project, the project will be terminated. As a result of the negotiations to extend the cooperative agreement, the government has the right to request the transfer of the title of ownership for all X–33 hardware and data.

Question 11. How can you state that "NASA has saved approximately $40 billion from planned budgets for the American taxpayer and is doing more for less," when the International Space Station has experienced cost overruns and increases over $9 billion and we just lost two Mars missions worth $360 million? Where is the savings to the American taxpayer? How can I explain this to my constituents in Tennessee who want to know what their investment is funding?

Answer. Failures and cost overruns are expected when the implementation of technology is pushing the state-of-the art; and projects with the highest risk are often the ones that reap the biggest benefits with the highest payoffs in the future. While some of the projects at NASA have experienced problems, most have not. Between 1992 and 2000, NASA launched 146 payloads valued at a total of $18 billion. Of this number, 136 payloads were successful. We believe our success is a testimony to NASA's strong systems engineering capability. Our total losses amounted to 10 payloads, measured at about $500 million, or less than 3 percent. The Mars 1998 failures alone accounted for 60 percent of this loss. Planetary spacecraft, which used to be launched twice a decade at a cost measured in the billions, are now routinely launched each year at a small fraction of that cost.

Question 12. Given the problems on the X–33 program, is it time for NASA to pursue an incremental approach to technology development rather than the evolutionary one used on the X–33 program?

Answer. NASA has undertaken a Space Launch Initiative and developed an Integrated Space Transportation Plan to pursue new approaches to reducing NASA's space transportation costs. A brief description of ISTP and SLI follows but more information can be found on the web at http://std.msfc.nasa.gov/spacelaunch.html.

The goal of the Space Launch Initiative (SLI) is for NASA, by 2010, to meet its human space flight needs on commercial launch vehicles that will reduce costs and improve safety. If successful, SLI will dramatically alter the economics of space launch. SLI is based on lessons learned by NASA and industry from working together on the X–33, X–34, and X–37, and on inputs from Space Transportation Architecture Studies commissioned by NASA and led by industry over the past two years. The initiative is designed around four principles:

- Commercial Convergence—flying on privately owned and operated launch vehicles
- Competition—bringing innovation and new ideas to bear
- Assured Access—ensuring alternate means of getting to space despite launch mishaps

- The Ability to Evolve—adding new capabilities affordably as new mission needs emerge.

SLI is funded at $4.5 billion over five years ($290 million in FY 2001 ramping up to $1.3 billion per year). NASA is undertaking three major activities through SLI:

- One, invest in technical risk reduction activities to enable competitive, full-scale development of privately owned and operated launch vehicles by 2005 (Risk Reduction and Competition, $2.4 billion);
- Two, develop hardware that can be flown on these commercial launch vehicles to meet NASA's unique needs, such as crew transport (NASA-Unique Systems, $1.6 billion); and
- Three, pursue procurements of existing and emergent vehicles for select Space Station needs as a means of providing near-term, assured access and demonstrating new, innovative approaches (Alternative Access, $300 million).

In addition to these three major activities, the Space Launch Initiative also funds ongoing x-vehicle programs like X–34 and X–37 and critical systems engineering and requirements definition activities that will tie these elements together ($200 million).

The Integrated Space Transportation Plan (ISTP) is the framework NASA uses to coordinate its space transportation investments. Specifically, ISTP coordinates ongoing investments (Space Shuttle safety improvements, the Crew Return Vehicle for the International Space Station, base technology investments in space transportation) with investments in new vehicles to reduce NASA's space transportation costs (SLI as described above). For example, Space Shuttle safety investments are now focused on improvements that will be fully in place by 2005 so that Shuttle can benefit from these safety investments before a potential replacement would be available through SLI in 2010. In another example, prior to a full-scale development go-ahead decision on a Space Station Crew Return Vehicle, NASA will fully examine a range of designs to for other, cost-effective options that meet both the crew return need and other NASA-unique needs, such as crew and cargo transport, on future launch vehicles developed under the Space Launch Initiative.

SLI and ISTP differ from previous approaches by providing multiple, competing paths to future systems with back-up alternatives. For example, the Space Launch Initiative seeks to reduce technical risk for at least two, competing Earth-to-orbit launch vehicle designs to enable full-scale development decisions in 2005 with operational vehicles by 2010. By pursuing at least two competing designs, NASA intends to spur industry innovation and have more than one development path if technical issues pose roadblocks to a particular design. If technical issues or market conditions delay development decisions in 2005 or operability by 2010, ISTP is making concurrent investments in Space Shuttle safety to ensure continued U.S. human access to space. In the near-term, the Space Launch Initiative also seeks alternate means of access to Space Station for cargo on existing or emergent commercial launch vehicles to back-up the Space Shuttle in the near-term.

With respect to X–33 and other existing x-vehicle programs, decisions on continuing investments in those vehicles (e.g., a re-planned flight schedule for X–33) will be tied to industry proposals under the larger Space Launch Initiative to reduce technical risk and prepare viable, competing designs for the 2005 competition. In this way, ISTP coordination and Space Launch Initiative goals provide an important context for decisions on specific space transportation investments.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO DR. HARRY MCDONALD

Question 1. Your statement mentioned a "success engendered safety optimism." Can you elaborate on what that term implies?

Answer. The Shuttle is a complex, well-defended, yet aging system that operates in an unforgiving flight environment and requires extensive, often intrusive maintenance. In its review, the SIAT observed an "erosion" of some Shuttle safety-critical defenses. Although the perceived erosion is attributable to a number of different factors, one factor of concern to the assessment team is "success engendered safety optimism." Success engendered safety optimism refers to *the tendency to accept risk solely because of prior success.* The manifestations of this tendency may include: the assumption that risk decreases over time with each successful launch; the perception that the Shuttle is now an "operational" vehicle requiring only routine attention; the discounting of precursor incidences; and the reliance on redundancy for

risk management. Because past success does not preclude the existence of problems in processes and procedures that could be significantly improved, the SIAT believes it is imperative that the SSP rigorously guard against success engendered safety optimism.

Question 2. You mentioned that risk management erosion was created by the desire to reduce costs. Who led this cost reduction effort—NASA or the operations contractor?

Answer. The cost reduction effort, part of the overall effort to privatize and streamline Shuttle operations in the mid-90s, was led by NASA in response to the past Administration's directives.

Question 3. You also mentioned the need for more frequent turnover on the Aerospace Safety Advisory Panel. Can you elaborate on the current membership format and tenure and the type of expertise that needs to be added?

Answer. The Aerospace Safety Advisory Panel is an independent group of experts consisting of nine members who are appointed by the NASA Administrator. As stated in its charter, appointments are for 6 years and reaffirmed annually. To provide continuity of service and preserve integrity, not more than one-third of the Panel members may be appointed every 2 years. Consultants are appointed as needed by the Panel Chair, with the concurrence of the Administrator, and reaffirmed annually.

The tenure of individual Panel members currently averages almost 11 years, with one member serving since 1977, and a former member, now a consultant, serving continuously since 1982. An ISO 9000 Headquarters OfficeWork instruction, dated April 14, 2000, addresses the appointment of new ASAP members. Central to this process is the determination of additional expertise needed by ASAP to perform its function. Additionally, issues of tenure and renewal are being vigorously addressed in the revised ASAP charter which will be signed in April 2001.

The SIAT believes, and NASA concurs, that a balance must be maintained between familiarity and independence to ensure appropriate review. Further, with the rapid advance of technologies that may enhance Shuttle safety, members and consultants with expertise in emerging disciplines will be needed with increasing frequency. Whereas the current expertise on the panel leans heavily toward established aerospace technologies, new members with knowledge of intelligent systems, human-machine interfaces, and vehicle health management, and advanced risk assessment tools may become important.

Question 4. You have commented that despite the findings and recommendations of your review team and the Aerospace Safety Advisory Panel, workforce stress issues remain. Do you feel that NASA's management will resolve these problems?

Answer. In performing its review, the SIAT was continually impressed with the skill, dedication, and concern for public and astronaut safety of the entire Shuttle workforce. The high level workforce performance required by the Shuttle program has always created some level of workforce stress; however, the workforce perception is that this has increased significantly in the last few years. It became apparent to the SIAT that the significant number of changes experienced by the Shuttle Program in recent years has affected workforce morale or diverted workforce attention.

Observations of workforce issues have been reported consistently by the ASAP since 1996. The SIAT was concerned that some of these issues and their potential impact on safety were still evident in workforce assessments (e.g., Occupational Stress Inventory) and in climate indicators (e.g., overtime hours worked) obtained during its review.

The SIAT was gratified by an immediate response to its findings by NASA management whereby they increased NASA Quality Assurance personnel resources for Shuttle processing at KSC. The response of the SSP to the SIAT recommendations also indicates renewed commitment toward addressing workforce morale and attention. As reported to the SIAT, communication processes have been examined and improved; access of "floor" personnel to higher management has been increased; and workforce analysis studies have been, and will continue to be, used to monitor employee stress. Further, teams have been formed to address human factors issues in processing, work instructions and environments, and error resolution. Finally, NASA management continues to emphasize the development and delivery of state-of-art-technology to assist Shuttle personnel in performing their complex activities with greater fidelity and safety.

Question 5. Do you know of any efforts by NASA to address any of your team's recommendations as part of the Shuttle upgrade program?

Answer. The SIAT did not directly or extensively address Shuttle upgrades in its assessment. However, several of the planned upgrades were discussed in the Shuttle

Program's response to several of the SIAT recommendations. Specifically, planned improvements to the Auxiliary Power Units (APU), the Reaction Control System (RCS), and the Orbital Maneuvering System (OMS) were described as addressing SIAT recommendations (parts of, or in their entirety) for these subsystems.

Question 6. You address the erosion of flight-safety critical processes due to a reduction in allocated resources and appropriate staff in your SIAT report. Do you believe that Administrator Goldin and other NASA top officials anticipated this erosion prior to last year when several internal reports confirmed this fact? If so, did anyone acknowledge it?

Answer. The Shuttle program has recently undergone a massive change in structure with the transition to a slimmed down, contractor-run operation, the Shuttle Flight Operations Contract (SFOC). This has been accomplished with significant cost savings and without a major incident. The Administrator and his staff were aware that the changes would stress the system and that careful scrutiny would be necessary to identify and assess potential erosion in flight-safety critical processes. When two in-flight anomalies on STS–93 occurred, they were viewed as potential indications of problems related to processing and aging of the Shuttle system and the present assessment was initiated. The report's findings and recommendations are being considered seriously and actions taken appropriately.

Question 7. Your review team suggested in its final report that prior to the next Shuttle flight, the Space Shuttle Program should make a quantitative assessment of the success of the visual wiring inspection process. Did this occur? What was the response to this suggestion from the KSC leadership?

Answer. The SIAT did recommend that, prior to STS–103 (first flight after STS–93), the reliability of the wire visual inspection process be quantified. This recommendation was dispositioned at the Pre-Flight Readiness Review held at JSC on November 2, 1999. The Shuttle program fulfilled the requirement by performing two independent inspections of the wiring in OV103 at KSC and two independent inspections on OV1O2 at the Palmdale facility. Reports from the SSP indicate that on OV103, the first inspection identified 70–80 percent of wire defects; the subsequent 20–30 percent were found during the second inspection. For the reliability assessment on OV102, slightly better results were obtained, with 86 percent of the total number of defects found during the first inspection.

Question 8. Do you believe that Mr. Goldin's "no prescription for success" strategy is the right approach to resolving these management problems given the prescriptive nature of some of your recommendations?

Answer. As with any independent assessment, benefit comes from a fresh perspective, a very refined focus, and being unrestrained by typical constraints. Programs, on the other hand, require in-depth familiarity and constant balancing of constraints and goals. The SIAT realizes that its recommendations must be pursued within the context of the Shuttle program: while the recommendations are prescriptive in the sense that they require specific issues to be addressed, there is room for expert, creative implementation by the Shuttle program.

Question 9. Mr. Li's testimony stated that during a recent Shuttle wiring investigation personnel inexperienced in wiring issues were used to perform critical inspections. How serious is this finding in terms of risk to the overall safety program?

Answer. The SIAT has a concern similar to Mr. Li's. The specific finding in the SIAT report states: "The technicians that are working on the wiring are certified, yet some lack detailed specific experience with wiring. Some of these technicians have extensive experience working on many Shuttle operations yet limited time inspecting and repairing wiring. In some cases the technicians were given training just prior to the start of the recent wiring inspection and repair effort." The SIAT gave a recommendation to the Shuttle program to assure that certification of inspectors and technicians be conducted by experienced domain experts. The Shuttle program has responded that instructors represent the most knowledgeable individuals in their field of expertise and that periodic audits and evaluations of certification training are performed to ensure training adequacy.

Currently, visual inspection remains the best defense against wiring faults. However, visual inspection is fallible and can actually cause wiring defects because of its intrusive nature. As long as visual inspection of wiring is used to discover wiring defects, residual risks will remain. Substantial reduction of these risks can be made only with the development and deployment of reliable, remote, nondestructive wiring inspection techniques.

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