REMARKS OF
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Thank you for the warm welcome. I would like to recognize one of the visionaries in America's space industry. While we're saving the space program, he's going to save America's market share in aeronautics. I know there are some international folks here. But when I accepted this speaking request from Alan Mulally, I told him that I wanted to speak to the American rocketeers. Now, this isn't to exclude our foreign partners but launch, in my mind, is the issue that we as Americans have to face.

We compete, in some areas like rocketry, and we cooperate in others like space science and the International Space Station. This is true not just in America but in other countries -- in Asia, in Europe and in Russia -- that we're going to compete in rocketry and there's nothing bad about that. But right now, I'm not happy with where the U.S. is in rocketry. So to all the international guests, I'm talking to the American folks when I beat them up, not to you.

We do have a real problem in launch. If you just take a look at the last four launches of our major vehicles we've had failures. Not because people are bad, not because we don't have quality, but our designs have inherent problems because the margins for error are razor thin, and costs remain high and reliability isn’t where we need it to be.

Our launch complexes are outdated and I'm embarrassed to take foreign dignitaries to some of our launch complexes when other countries that started after us have launch complexes that are much better. Again, the people operating them aren’t bad, and our friends in the Air Force are doing unbelievable things to try and get this fixed. The problem is money, and we need to deal with that.

So I'm going to have a series of consciousness raising talks to focus on launch. I went to the U.S. Space Foundation conference in Colorado Springs and I began a series of what will be about 5 to 10 talks. Each will have a common theme. Because at NASA, we have three priorities. Priority number one, safety of the public, of astronauts and pilots, our employees and our high value assets, and that could never be compromised. A second priority is get the International Space Station built and get on with thoughts of going to Mars. Our third priority, the theme for my upcoming talks, is to fix the problems we have in launch vehicle systems. It's been 25 years since this country has done anything radical or new in launch systems. By the way, it's been 25 years since we've done anything except small evolutionary change in aircraft. We're still at Mach 0.8 and we still have the same type of jet engines. Albeit, they're a little bit more reliable and the fan stage has grown in diameter, it's the same technology. And we've been sitting on our glory and we've been milking the cash cow.

Last month, I talked about the need for advanced technology and I established a case why we couldn't send out life-detection spacecraft to Mars, we couldn't send out spacecraft to detect life, if it exists, outside our solar system.
I established we couldn't afford to send spacecraft to image planets around the stars beyond our Sun if such Earth-sized planets exist, and I established we couldn't get our next fleet of weather satellites to space due to system reliability problems. That speech is on the website, www.nasa.gov. Look under "Administrator's speeches."

Today, I want to focus on safety and reliability as the principal objectives of the design process. For too long, our design process has been performance-based and cost-based. We don't understand where we're going. At this rate we will continue to lose vehicles if we don't deal with this. In a few months, I will talk about the cost implications of designing for safety and reliability instead of designing for cost and performance as program goals. And then in subsequent speeches, I'll talk about policy, architecture design tools.

Now, NASA's basic goal: in 10 years, we have the goal of achieving 10 to 100 times the reliability and in a generation, we hope to achieve 10,000 times the reliability. Therefore, within 25 years, we can begin to approach the reliability of today's long haul jet aircraft. Cost: we have the goal of reaching 1/10th present cost in a decade, 1/100th present cost in the next generation, and within 40 years, it will be 1/1,000th present cost. We need to know where we're going. How many operating cycles? The shuttle is good for 100. The next generation launch is going to be good for about 1,000 cycles and after that, 10,000 and perhaps a 20- to 30,000 as we approach the reliability of the 777 and then recertify every 20,000 flights.

Time between major overhaul, this is killing us. Time between major overhauls on the Space Shuttle is somewhere between 5 and 10 flights. We've got to get to a minimum of 100 flights, and then 1,000 and then 10,000 between major overhauls. What we want to do is get to a third generation vehicle that's not a highly tuned race car but is like an automobile that can drive every day and it’s good for 100,000 miles without a major tune-up, like the car my daughter drives and rarely has a problem.

We can't drive Indy 500 cars and expect them not to have problems, or worse, blow up or crash. And at the same time say we're doing everything safe and that we're going to make them cheap, but we'll still need ten- to twenty-thousand people to operate it. That is what I want to talk about today.

Now, NASA is developing a technical blueprint and I'd like the chief architects of that blueprint to stand up. Art Stephenson and Sam Armstrong. When I talked with Art about becoming director of the Marshall Space Flight Center, I told him all I want you to do is focus on access to space instead of doing a broad range of things without focus or priority. Now NASA Marshall has one job in life and that's to go fix this launch problem by working with American industry. We want to work with small companies, medium-sized companies and big companies, and small and big universities. It's going to take the full intellectual power that this nation has. Marshall is developing a blueprint to achieve the goals I just said. We'll keep building, testing, flying and maybe even crashing, and new technology will come flowing out. We hope that with the new technology companies will benefit and build new systems. We call this technical blueprint Spaceliner 100.

Now, it’s not a program, it's not any specific design. The object is to get away from where we've been for 25 years, which is making one percent incremental change while tolerating an unacceptably low level of reliability. The average reliability of our launch fleet is 95 percent. The insurance companies love it and they drive their rates higher and higher. It's unacceptable. So we are not looking for a small evolutionary change. We want revolutionary technical developments, we want analytical studies, new concepts, ground testing and flight demonstrators. We're going to use the framework of our Advanced Space Technology Program and our Future X flight program to build the foundation for future launch systems. We are not interested in small levels of change. You notice I'm saying this over and over again. Because that's all I see.

As I discussed in my opening remarks, I was just at the Space Foundation and we had an executive forum. I talked about this tremendous need for revolutionary launch systems and I asked for some comments. Let me quote a just a few. Statement number one, “Dan, you don't get it. If we're going to be partners,” this is a contractor speaking, “you're going to have to meet our near- and mid-term goals. Don't tell me about long term goals.”

That's one partner we do not want. Another one said “the business case for next generation reusable launch doesn't close.” Of course it doesn’t close because very few companies are ready to step up and provide the spark for revolutionary risky change. NASA is willing to fund the technical risk reduction, so I don’t get it.

We have had mediocrity and inadequate designs for 25 years, and this is intolerable. NASA will not accept it. So my position is there is no negotiation. If you want to work with us, bring your ideas. If you want to fight with us, we will take you on.

In the coming years we expect to have dozens of experimental craft, not any one craft. We have already started the development on X-33, the X-34, the X-37 and the X-43. They're all going to do different things. Some are going to breathe air, some are going to demonstrate autonomous landing, some of them are going to demonstrate our composite structures, some of them are going to demonstrate that it's possible to build an ultra-low cost launch range. The key to it is develop the technology and transfer. As I said, this is a departure from past emphasis on designing to cost and performance. When you design for performance, you forget about the important things. You may get a low development cost but you inherently build in design defects because you're not paying attention to the reliability and safety. In the end overall operational costs are much higher than initial expectations.

So safety first is going to be the object of this process. To get a vehicle system to be safe it must be inherently reliable. It needs a robust design to allow significant derating for every mission critical function. And it must be able to eliminate ***a priori***, any serious and catastrophic failure modes. It must be functionally redundant in every aspect, not only numerically redundant.

It must minimize the opportunity for human error through automated intelligent vehicle health monitoring and management. This is the message: we're not going to have someone at the stick of all our vehicles when the response time of a human being doesn't match that available in electronics. People have been doing autonomous landing for years. The Russians, the first time they flew Buran had an autonomous landing. America still hasn't dealt with that issue. I'm not angry at anyone but it is time to address this concern. With intelligent systems we can design a handover control that optimally utilizes the skills of a pilot and the speed of a computer.

In the event of total vehicle failure, where all the available abort modes are ineffective, such as a launch pad explosion, we need a separate, reliable means of personal survival. We do not have it on the Shuttle. I have to tell you, as NASA Administrator, I talk to each and every astronaut and their spouses before and after their flight, because we all recognize the risks the astronauts take flying without an escape system.

Never again, at NASA, will we design systems like the Shuttle unless the systems have such a high inherent reliability like an aircraft. Only then will an escape system be unnecessary.

Now, similar to the computer revolution, we want to strive for functional simplicity while gaining dramatic improvements and capability. What we're talking about is what we're going to call a beautiful machine. First, it's safe, reliable and then, as a dependant variable, it's affordable in acquisition and life cycle costs.

So let's focus on the areas of highest risk. Ascent propulsion clearly has to be fixed. Second, thermal protection must be durable, lightweight and be capable of surviving impacts and problems. No APUs and no hydraulics. They have to go. And we need more than one shot at landing. We have to have go around capability that includes multiple abort modes so we have the capability to go to multiple sites anywhere on the face of the globe. That way, in case something happens in orbit, we can come right down and we don't have to wait for hours or even days while mission control figures what to do. We'll have to have a high vehicle intelligence quotient with the capacity to learn, adapt and evolve to dynamic, complex situations. When we took a look at the Shuttle, the two phases of ascent and descent are equally critical to safety. Therefore, we have to address them as we develop our concepts.

Now let me explore the whole issue of design robustness. There are three issues that pertain to design robustness. One is the knowledge of the operating environment that we undertake. Second is the operating capability. The problem is there's a variability and uncertainty to both. Right now, we're at an overlap region. This is because our design tools are inadequate and we use deterministic approaches to attempt to bound this uncertainty. That overlap causes problems to pop out 10, 20 and 25 years after we design things.

A case in point, on STS-95, the door that contains the parachute on the orbiter fell off due to a design flaw. We've been flying that door for seven years since I've been Administrator. But there's a flaw in the design process. The problem was the variability and we didn't have the focus of our design tools to understand that variability down nor did we have a thorough test program to do it. No one's bad, but with modern information systems and the tools I'll talk about later, we should first reduce variability and bound uncertainty in the design process.

Second, I'll give you an example of how you reduce the design envelope environment because what you really want to do is reduce the design environment and increase the capability to get the derating and still have unbelievable performance. It sounds like a paradox but it could be done.

An example, what if we eliminate APUs, which have high pressure, high temperature turbo pumps that drive them, and we go to a passive system, a polymeric fuel cell that's contamination insensitive and operates at room temperatures. All of a sudden, the design environment comes down, capacity goes up, we get rid of all the moving parts, we have power by wire and we could get incredible flexibility. One is to reduce variability, I'll talk more about this, second is to reduce the design environment, and third is to increase the capability.

Let me talk about increasing the capability. We have got to deal with rocket engines. The benchmark, the SSME (Space Shuttle Main Engine), was developed 25, 30 years ago by wonderful engineers at Rocketdyne and NASA Marshall. We have yet to beat the thrust-to-weight ratio of that engine. That engine is finely tuned, it has unbelievably high temperature, high pressure and there are unbelievable stresses in that engine. What we need to do is get away from metallics and get the capability up perhaps by a few thousand degrees by going to ceramic composites and advanced metal matrix materials. All of a sudden, you put unbelievable separation between system capability and operating design load environments (thermal, mechanical, acoustic, etc).

There are proprietary advanced concepts that may also get at this and allow us to make those engines much simpler. Instead having all the plumbing complexity we have in current designs and trying to get rid of the plumbing with composites, there are a variety of approaches where the engine might be really simple. One approach is the post-detonation engine. You have a virtual turbo pump by spewing in fuel, exploding it and all of a sudden, you no longer need to have a turbo pump. It's a simple engine. It is a beautiful engine.

That's one way to get capability. And we have set a goal that we're going to triple the thrust-to-weight of the SSME with these fundamental technologies. To get to the goal, we're going to initiate an unbelievably comprehensive material development program, with the intensity we had during the Cold War.

Secondly, another way of improving capability, we keep squeezing out another few seconds of Isp. People come into my office and they're all excited, “we got two more seconds.” Big deal. We want a factor of 2. We initiated and we will intensify, if we get the money we need, an unbelievably aggressive program in air breathing engines that doubles the Isp. This will open many options for combined cycle engine concepts and enable us to tailor engine performance capability over the flight speed regime.

Third, aerodynamic enhancement, another way to get capability. We have a number of people at NASA Ames who have ignored the evolution and went to revolution. They're developing some really advanced materials that could cause us to make a fundamental change in the concepts of how you design a rocket. Up until now, we've been designing rockets with blunt leading edges because we cannot tolerate the high heating heating rates that come with sharp edges. You make a sharp edge, you get double the heating rate and the peak temperatures go way up. That's one of the reasons we failed with NASP (National Aerospace Plane). We were never able to deal with the technology that is associated with sharp leading edges.

Ames has had a breakthrough. They call the program SHARP (Slender Hypervelocity Aerothermodynamic Research Probes). If it's successful, it appears that there are new possibilities. Any one of these things may not happen but when you RSS (root-squared-squared) them together, they will. But they have found that they could perhaps double the lift-to-drag ratio by going to sharp edges with a material system that can handle the high heating rate loads and withstand temperatures of 4000 to 5000 degrees Fahrenheit routinely.

By accommodating this increased heating rate, using a passive, ultra high temperature ceramic composite thermal control system, we have eliminated the risk and reliability concerns of actively cooling very sharp leading edges.

Now, we ran a few preliminary calculations. Let me give you a sense of why this is important.

For a rocket system like the Venture Star or X-33, a one-percent reduction in drag, brings a 6/10ths percent improvement in payload mass fraction. For an air breathing system, because you're going more horizontally through the air and you have more drag to worry about, a one-percent reduction in drag, brings a payload increase of 4.5 percent. Now, I don't know how accurate these are and I'd love people to go out and validate these numbers.

Now, a side benefit. On descent, you can get a two to three time increase in the cross-range if you can handle the heating loads and you can double the footprint range from orbit to 10,000 to 20,000 miles. All of a sudden, if something goes wrong or if there is bad weather at a landing site, you still have a chance of coming down from orbit and landing anywhere on the Earth. We would have a whole new system with flexibility that changes everything. It wasn't set by cost, and it wasn't set by performance. It was set by reliability. That's what we need.

Now, there are other approaches associated with advanced aerodynamic enhancements. There are some preliminary results, and I emphasize preliminary. Using mild plasmas that ionize the air we could dissipate the shock wave and some early experiments indicate up to a 20 percent drag reduction is achievable. So you may have to put some more energy in, but we don't know how much energy is needed. NASA is spending all of zero dollars right now and I spoke to the contractor, he's spending a quarter million dollars out of his own pocket. NASA's not paying enough attention to this, so how will the contractors. That's a message to my NASA employees who are listening.

Now, let's also see what other things we could do. Let's say we lose aileron control. Think about the possibility of putting variable movement into sharp leading edges and you could regain control authority in a different way. So now I can put in functional redundancy.

Another possibility. Let's say that we get orbital debris damage and the leading edge takes a huge hit. Some other things we can do, we can give up cross range or we can give reduce the total range footprint and we could put a little shield over it, one shield, so we don't have to worry about these things. These are all theoretical. I don't know if it's going to work, but I'd like to see some creative work in designing systems for safety first, not performance.

Another possibility, launch assist. The NASA Marshall staff, after much discussion, ran an analysis that said it may be possible to get a 25 percent improvement in propellant mass fraction by using launch assist at Mach .8. And they're building a 50 foot magnetic levitation system down at Marshall. If that's successful, we go to 300 feet. If that's successful, we'll go to 900 feet at Cape Kennedy. At 900 feet, that same system could be used for electro-magnetic catapult of planes from aircraft carriers.

Think of the reliability that you gain. I want to come back to reliability. One of the nice things about planes is when you sit on the runway and sit still, the pilot runs the engines up and knows they're okay and then you start going down the runway. Before taking off you reach a point of no return where you don't have to take off. So having horizontal take-off, horizontal landing, all of a sudden you're taking care of the problems on ascent. All of these things are being done not to give us more performance but to separate out operating environment and capabilities. It's being done to give us extra thrust to weight on takeoff so all of a sudden return to launch site doesn't cause us to fly in our own flames, a maneuver we haven't had the courage to check out. It doesn't require us to be worried about any particular landing site. We could get anywhere we want. It allows us to have one and two engines out on ignition and still get to orbit. That's why we're doing these things. Now, will they work? I don't know.

I present these ideas to inspire more creativity and other approaches. If I'm being particularly passionate, I intend to because I have the vantage point of seeing most of what is going on in the nation and I'm not seeing enough creativity. I salute Art Stephenson and all his people at Marshall who have really buckled down and looked at these things.

Now, how do we get at reducing variability. We have a set of traditional deterministic design tools. This is the problem. I had the chief engineers from NASA in my office and I asked how many of them were familiar with a non-traditional concept called soft-computing -- fuzzy logic, neural nets, genetic algorithms. And out of eleven people, one person raised their hand. I go to conferences, I talk to my engineers and all we focus on is deterministic, hard numerical computing. We'll never get at the real world design problems using this approach. Sam Venneri, NASA's Chief Technologist, has been leading the charge to get what we call Intelligent Synthesis Environment, based on physics-based models, biological-based models, with a real time simulation and visualization using non-deterministic tools. Some think this is frivolous and NASA just wants to play around. If we want to get real design system uncertainty understood and bounded we've got to deal with a new tool set and engineering processes that aren't available to our engineers today.

I was just at NASA's Ames Research Center and I had the privilege of meeting one of our researchers. He said Dan, "I want to show you a concept for a non-deterministic, neural net learning system that addresses a fundamental problem faced by Pratt & Whitney and General Electric jet engines. They faced a significant problem that results from a shock between the compressor rotor and the stator blades. And we haven't been able to get a design to fix this, because it’s trial and error and costs could reach $90 million. So I used the neural net learning system. We now have a design that eliminates the shock between rotor and stator. As a result we significantly increased the life and probability we won't induce a major failure mode in these engines.

Now, this is the first glimmer of hope that I've seen. We've got to get at this situation using new non-deterministic tools coupled with networked collaborative computing environments that are geographically linked and accomodate heterogeneous software and hardware systems for real time computational steered total immersive visualization, 3D environments and with physics-based simulation and modeling tools that encompass the total life cycle design process – from conceptual design to manufacturing to operation and maintenance. This is crucial for launch.

Functional redundancy is the second variable in my new design approach. We need a truly integrated vehicle health monitoring and management system. It's a system that is a hiearchechal distributed system that wherever possible, involves functional redundancy from the subelement upward to each component and ultimately to the total system. It has distributed intelligence and it mimics the hierachy in the body between the brain, the spinal cord and all the nerves. So an understanding of biology is going to be necessary to develop these systems. That's why the body is so beautiful, it protects itself. It doesn't have a preset set of algorithms, predetermined, precooked failure modes, where you have to go validate it by tests. If we had an intelligent system the parachute door wouldn’t have fallen off from the Shuttle.

Now, we are flying an F-15 at Dryden with a neural net learning control system that will adapt to failed control surfaces as well as failures in the hardware and software. It was inspired by the DC-10 crash in Sioux City. When that DC-10 went down, the pilot had the sense of mind to use thrust vector control to compensate for the failed hydraulic system. That's what I mean by functional redundancy. We are getting some outstanding results in this neural net system on the F-15 aircraft. You design it to live within the flight envelope and it learns as it goes along and follows each actuator and each sensor, each wire, and it knows each individual characteristic. It's always learning. In the real world, actuators are non-linear and they don’t behave as modeled.

Now, let me give you an example. Future aero shells, made of smart skins, where you could control the contours in three dimensions. We could sense pressure, air flow and temperature and monitor the stress, strain and deformation and learn using neural nets. The IVHMS system determines how much safe life has been used up and what areas have wear. It will predict where and when detailed inspections must be made instead of taking a quarter and tapping it on the side to see where we have stress fractures. That would be a refreshing improvement. And you couple that with an aircraft control system to recover from failure.

Now, let me talk about a few of the functions. We intend to evaluate the ideas to have complete control by wire, or to control by photons and perhaps control by wireless, that could be IF or IR. One of the major problems we run into when the Shuttle takes off is answering the question, was it the sensor or was it the propulsion system? We've had to make gut wrenching decisions in the absence of intelligence without sufficient time to do it. Now, we have to rely on thousands of people and their intelligence and their good judgment to do it. What if someone had a bad night? Now, again, I'm not emphasizing we have bad people or bad systems. I'm just saying the time has come to really take a look at the future and see it with clarity.

I now point back to where I started, with real intelligent systems within a specified bounded envelope, we could actually reduce the variability and have a known specified design with bounded uncertainty and quantified risk levels. With that capability, we could assure safety for the system.

Now, how do we move to the next point, eliminate catastrophic failures.

Derating the engines. How about 20 percent derating and its impact. A 20 percent derating of the Shuttle main engine could result in 17 to 30 percent reliability improvement. We're talking about whopping big numbers in reliability improvement. How about getting rid of staging. Many people come to me and say Dan, “the answer is obvious. You've got to get away from single stage to orbit, you've got to go retrograde technology, build a two-stage to orbit, put a crew in each vehicle and voila, you're in nirvana.” That's not going to work.

Staging brings in unreliability. If staging were smart, when we developed the jet transport, we would have had two stages. We would have refueled in the middle of the ocean. We didn't go to staging because staging has an inherent unreliability in it. Now, from our analysis, it looks like we have a good shot, not tomorrow, but in 10 years or 20 years. Because if someone thinks that two stage to orbit using retrograde technology is commercially viable, let them go out, let them take commercial money. NASA is not about development of market-driven resources. We develop technology. So we will give you all the encouragement and if you have something that is less expensive, we will buy it. But we will not take hard-earned taxpayer dollars to subsidize an industry and go with retrograde technology that will not deal with the issues I just talked about.

We need better ways to reduce the extreme operating environment for power generation on the vehicle. As I talked about high pressure, high temperature turbo machinery, the APU really gives us major concerns. And sometimes, we have to wait to come down till we figure out about APUs, and sometimes we have to wait to take off if all the APUs are not all up and running. And there's some very, very highly stressed valves in that APU that are right on the limits of where we want to be. And we have the best minds in the country addressing it but instead of putting the butter to a sharp edge, why not go for a huge improvement and separate the environment with the operational capability.

Debris detection. It's an afterthought for the Shuttle. Let me tell you, it's getting pretty tough up there. We need fundamental research into the ultra-strong, ultra lightweight, ultra-effective orbital debris protection. It needs to be part of the initial design, not an add-on later.

We need real crew escape. Not a bunch of wires with little carts that go running down, but real crew escape.

I'm overwhelmed with what the Russians have done with the Soyuz rocket. Vladimir Titov, a friend of mine, sat on top of a Soyuz rocket that exploded on the pad and he walked away from it. So if we design a beautiful system, we will pay attention to this up front and until we can get the reliabilities of parts of a million when we don't have the money to develop such systems, we just say “no.” It is not right to the astronauts and their families.

I am personally responsible for the lives of these astronauts and after I leave, I will still be responsible for the lives of those astronauts, and I don't ever want to have to go tell them that we didn't do everything we could. So people who come after me I hope will have the backbone to say no if resources aren't provided because safety must be an inherent feature of what we do. Now we will do everything humanly possible with the system we have because we're going to fly. But we've got to pay attention.

When we get to orbit, we need to figure out how to isolate a crew compartment, a safe haven. So if there's a catastrophic failure to the overall system and it can't come back, they will have 24 to 48 hours because we will be able to turn vehicles around in hours. And the rescue vehicle is going to come up. So we'll have to have breathing units, it will have to have communications and it will have to have some energy storage, maybe chemical.

Another issue we have to deal with. I call it the fail fix cycle and we talked to a number of corporations, this is what dominates aerospace engineering, automotive engineering, aircraft engineering, as Alan Mullaly is finding out, in the end of the 21st Century. Failure modes are inherent in the designs with unknown margins and unknown variability. And we never know if we removed all the failure modes because you can't afford all the testing and because we're doing deterministic hard numerical computing and we're not using physics-based models, we're using Nintendo tools, video games, to check these things out. We're not going down to the real hard physics based solutions at scales that range from fundamental material system behavior to subcomponents such as cryotanks to the overall vehicle system. We have to develop new analytical and certification processes that can bound uncertainty and provide real assessment of risk levels. We can then implement a design for safety or reliability approach versus a design to cost and performance approach which is where our current engineering practices results in today's aerospace systems.

So we need to deal with this. If we deal with understanding, bounding and removing those failure modes, 75 percent of the cost of developing new vehicles whether automotive or rockets is tied up in the failed fix cycle. We could cut the cost by a factor of three to four, if we develop new tools and engineering practices. For the lack of time, that will be the subject of a future discussion.

If you think of what could come out of this it is unbelievable. It is the way to open the space frontier. It is the way to regain the dominance of space. It is a way to assure we have a secure defense for the Nation. It is a way to generate hundreds of billions of dollars worth of revenues, and hopefully in my lifetime, it will get astronauts to Mars.

Thank you very much.

Thank you.