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I appreciate the opportunity to speak to the ranks of my fellow engineers. As a Registered Professional Engineer myself, I have some idea of your commitment to this profession and to the discipline you have brought to it. As I've said to other audiences, when I was younger I had difficulty deciding whether to be a physicist, mathematician, astronomer, or engineer. And of course it didn't really matter; we need all of these people, and many more, in the space business today. But I have been very happy with my decision to become an engineer. Our discipline gives people the wonderful opportunity to have a hands-on role in shaping our world.

The great American author James Michener, who frequently had interesting observations about our society, once said. "Scientists dream about doing great things. Engineers do them." Although Michener was often right on target, I think this statement requires some modification. Obviously, scientists are capable of doing great things. But perhaps not as obvious is that some of the best engineers in the business are also dreamers, people who refuse to be satisfied with the status quo, who are able to determine new and better ways of achieving grand objectives, and then to implement them using the disciplines we have all been taught.

We at NASA are going to need these engineers, and plenty of them, to achieve the goals of the Vision for Space Exploration. Two years ago, on January 14, 2004, President Bush committed this nation to a new direction in space, and set forth a fresh, clear mission for NASA. The President's directive gave all of us who are privileged to work in this business a challenge bold enough to last a lifetime. Indeed, it is a challenge to last several generations.

NASA is undertaking a program of human and robotic exploration of the Moon, Mars and beyond that will enable human beings to do things that have never been done before, see things that have never been seen before, and discover things that may never have been dreamed

of before. If I were graduating today, I would want to work in the space program for no greater reason than to be a part of these amazing challenges and opportunities.

And in fact, we will recruit the best and brightest engineers out of college to help us develop the next generation spacecraft, launch vehicles and systems that will enable these voyages of exploration to unfold. These exciting missions will motivate today's grade school and high school students to want to work as engineers and scientists in the space program.

Nothing is more important to our future in space. Currently, the engineers of the Apollo era – which ended over thirty years ago – have nearly disappeared at NASA. Our present generation of engineers has largely cut their teeth on the Space Shuttle and Space Station programs. And even this “baby-boomer” generation of engineers, of which I am one, will for the most part soon be passing from the scene. So we will need the talented young engineers and the promising students coming up through the educational pipeline, because the era we are entering must have a steady flow of engineering talent for the next thirty years, and beyond.

With this in mind, I challenge the National Society of Professional Engineers to work as an advocate for and a strong partner of NASA in nurturing our schools and universities to establish and maintain excellence in our engineering curricula, and to motivate a new generation of engineering talent.

While NASA is not the Department of Education, consistent with our charter we do spend nearly \$167 million on education initiatives that are targeted to our future workforce needs and to developing the talent, skills and professions necessary to carry out the Vision for Space Exploration. We also spend a like amount in the context of education and public outreach efforts associated with individual space missions. We must ensure that these investments benefit not only NASA, but also the aerospace industry as a whole.

To be certain, what we and you do in this regard has broader implications. As the blue-ribbon panel of the National Academy of Sciences headed by Norm Augustine has so forcefully pointed out, there has been a steady erosion in investment in the kind of scientific and engineering brainpower that keeps a nation competitive—and a consequent decline in American inventiveness. So anything that we can do to arrest these trends—to inspire young students to pursue technical careers, and to motivate talented foreign-born graduate students to consider staying in the United States and work on the greatest exploration project of the 21st century—would be all to the good.

I'd now like to address how we are organizing our engineering work at NASA to achieve the kind of technical excellence that is necessary to execute our long-term exploration program successfully. As a central organizing principle of our work, and despite the fact that 80% of our total funding goes to industry and will continue to do so, I firmly believe that it must be NASA and its engineering staff, and not our contractors, who will assume the primary responsibility for making this program work. We are undertaking a multi-generational program of sustained exploration, and we must ask where our intellectual capital should reside. Should it be outside the government in the hands of a prime contractor whose interests may change over the years? Or should it remain in-house, where we can sustain the program's momentum, and retain an institutional memory of the system and cost trades that are made, and a strong understanding about why the architecture is the way it is? I do not believe that it is wise to contract out these vital functions. Making NASA engineers clearly responsible and accountable for our technical products at the system level will drive our team toward excellence.

Having decided this, we want to provide our engineers with an environment that will help them succeed, by giving them the best possible tools, facilities, training and processes. These will allow them to be competent in assessing risk and assuring mission success.

Already under way is an effort to upgrade our computer assisted design tools, and the infrastructure that supports our engineering workforce at the ten NASA Centers. With respect to training, NASA's Academy of Program and Project Engineering Leadership provides a variety of training and learning opportunities for engineers to help develop their competencies and skills throughout the life cycle of a career in engineering and project management. The curriculum of the Academy employs state-of-the-art methodologies based on the best empirical research and the latest developments in industry. One of the innovations of the Academy is the Academy Sharing Knowledge, or ASK Magazine, which gives NASA managers the opportunity to swiftly tell each other about successes, failures and lessons learned. These "after action reports" were featured in a recent issue of *Government Executive Magazine* as a model for what every federal manager should be able to tap into.

But as valuable as this training is, there is no substitute for hands-on experience. Our Associate Administrator for Safety and Mission Assurance, former astronaut Bryan O'Connor, recently asked a senior Southwest Airlines captain to explain why his airline had the best safety record in the world. The pilot responded by saying, "We always fly manually during the high

risk parts of the flight.” The pilot then explained that if something goes wrong during takeoff, climb out, approach and landing, he and his colleagues would be better able to react to an emergency situation if they were already flying the aircraft. As a much less accomplished pilot myself, I absolutely believe this observation. And I want NASA to have the same approach. Our engineers will be better able to react to problems in a development activity if they are directly involved. In the past, it has been possible to be an engineer working at NASA over a 25 year career devoted to managing engineering, observing engineering, and yet never once *doing* engineering. That will change. We will give our engineers the opportunity to learn, experiment, and succeed or fail on in-house work as part of their normal career progression. This will make them smarter buyers on our contracted efforts, and better leaders as they mature.

We must also be able to develop within NASA good processes that will help us execute our mission objectives with careful and sober attention to the management of risk. First and foremost, we will continue to encourage our people to speak up whenever they have safety concerns. And we will listen to and respond to those concerns. The Columbia accident and other mishaps have shown that we in this agency have not always listened as carefully as we should have.

The Columbia Accident Investigation Board (CAIB) observed that the agency had not been exercising its engineering curiosity sufficiently. Accordingly, we are benchmarking other organizations involved in complex systems engineering projects, such as DoD research, development and engineering projects, and those in the nuclear safety industry. In another response to the CAIB, we are taking a fresh look at some of the hazard analysis and engineering models that had been developed in the past, and updating them to incorporate new experience and current thinking.

We are upgrading our ability to provide independent assessments of our work, so that at key steps in a project we can check progress, make appropriate adjustments, and catch the things that people miss when they are focused on crucial details but, possibly, are missing the big picture. This gets directly to the issue of programmatic authority vs. technical authority in the management of large, complex programs, a topic upon which the CAIB spent considerable time. I’m convinced that it is necessary to have independent technical and programmatic lines of command at NASA, because there will always be a healthy tension between the programmatic imperative to accomplish tasks within cost and schedule, and the technical imperative to do

things perfectly, regardless of cost or schedule. Without this organizational separation, one imperative or the other must dominate, always to the detriment of either the project or the institution, in my experience. By having this separation, the valid viewpoints of both are preserved, to the benefit of both the program and the institution. I believe that this approach will restore our ability at NASA to provide independent technical review of programs in a way that the CAIB found lacking in the Shuttle program prior to the loss of *Columbia*.

To provide a further independent engineering assessment capability, we have a group at the Langley Research Center called the NASA Engineering and Safety Center (NESC), comprised of some of the most talented engineers in the Agency. This organization draws upon engineers throughout NASA to assist on some of our most difficult technical problems. The NESC has contributed greatly to the Shuttle return to flight effort, in part by leading more than a dozen independent assessments of important technical issues. One of these assessments led to the design and building of an insulating wrap, utilizing a sacrificial retainer made of shrink wrap and aerogel, that can be used to preclude the buildup of ice on the Space Shuttle External Tank liquid oxygen feedline bellows. Another assessment, done in conjunction with the Lawrence Livermore National Laboratory, brought to light a potentially catastrophic failure with composite overwrapped pressure vessels due to stress rupture not revealed by earlier studies, but unearthed by more recent analyses. The NESC is now working with the Shuttle program office on lifetime assessments for the remaining Shuttle hardware.

Through diligence like this, we are working to establish standards of technical excellence that will enable a program of the complexity and promise of deep space exploration to move forward over a period of decades. As I said in the beginning, all human knowledge and skill will be needed to push the frontier out beyond low Earth orbit. But as Michener suggested, engineers will have a special role in the doing of it. That's why I am devoting so much of my own time to working with our team to make sure that our engineering workforce is given the best possible opportunity to acquire and demonstrate technical excellence in all of its facets.

In closing, I thank all of you for your commitment to excellence in engineering, and for your strong interest in what we are trying to accomplish at NASA.