NASA and Engineering Integrity

Michael D. Griffin
Administrator
National Aeronautics and Space Administration

Wernher von Braun Memorial Symposium
American Astronautical Society

21 October 2008

Thank you for inviting me here to speak. This is a great symposium, named in honor of one of the most charismatic leaders NASA has had, Wernher von Braun, who accomplished great things here in Huntsville but became intensely frustrated with his later Headquarters assignment. I know how he felt.

While some people like to think that Washington, DC is the center of the universe, any aerospace engineer knows that it's more fun, more immediately rewarding, to be where the action is, to be part of a great team where great things are being built, contributing to a great cause that you can see in front of you. Yes, Washington has a crucial role to play in the management of any Federal agency, certainly including NASA, but it is not where the action is, especially when it comes to building, or in this case rebuilding, the capability for our nation to propel Americans beyond low Earth orbit, back out to the New Frontier of which President John Kennedy spoke.

This symposium includes panel discussions of NASA's and the Marshall Space Flight Center's history, as well as prognostications for what the next

President and Congress might wish to do in carrying out the grandest venture of our time. So for today, I will leave such topics to others. Instead, I would like to discuss something more fundamental, something that engineers cannot simply learn from a book.

No collection of books contains all the knowledge one must have to succeed in space flight. The unwritten lore of space system design and engineering fills volumes, all stored in irreplaceable human minds. And that is just the technical stuff. Engineering texts do not touch the most important of all elements in the success or failure of any space mission, the human system.

It is people who power our spacecraft, who build the machines to carry out every complex space mission. It is people that matter – how we organize and utilize their energy, how we bring their skills to bear, how we listen to and work with each other, how we inculcate an ethos where the best ideas take flight. It is people who have created the art and science of space vehicle design, the most challenging engineering problem of our age.

Now, while I know how important the management of the human system is to the success of any endeavor, I will not pretend to understand it very well, even in the relatively narrow context of aerospace program management. If I did, I could not possibly cover the topic in a single speech. Tomes have been written on effective management, most of which omit entirely the more crucial, yet even more

nebulous, quality we call “leadership”. These terms are not synonymous – to me, management is “doing things right”, while leadership is “doing the right things.” But they share a common element that I believe to be the foundation of effective human organizations – integrity – and that is what I would like to talk about today.

I am, of course, speaking about ethical decision making in our professional lives, about creating a culture within which all can act and speak with openness and honesty, about embracing the responsibility for our statements and actions. Integrity matters enormously. I personally believe that without it, there is nothing else which does matter.

Long stated as one of the core values of our agency, it is nonetheless hard to define integrity in the abstract. It is much easier to recognize it when we see it. It is a quality not well suited to self-assessment, a quality for which we are more easily judged by others than by ourselves. I’m sure that each of you has observed acts of notable integrity, as well as cases where people fell well short of expectations. We should examine the differences, make note of what integrity “looks like” in practice, and strive for it.

In engineering practice, integrity is speaking up in a meeting when you do not believe the facts match the conclusions being reached, or that certain facts are being ignored. Integrity is following the data. Integrity is refusing to fall in love with your own analysis, admitting that you are wrong when presented with new

data that should alter your earlier view. Integrity is keeping a promise or commitment or, when circumstances change, explaining why an agreement cannot be kept. Integrity is walking into your boss's office, closing the door, and speaking with frankness, openness, and honesty – and listening the same way. Integrity is being willing to put your badge on the boss's desk when you believe that an ethical breach warrants such drastic action.

Integrity is the foundation upon which other human virtues are built – trust, credibility, leadership – and that foundation can be damaged for a very long time, even irreparably, with the slightest crack in a person's or an organization's integrity. As a case in point, my long-time friend Arnie Aldrich, manager of the Space Shuttle Program at the time of the *Challenger* accident, has recently written about some of the long-term consequences of that event:

> "In addition to the tragic and unforgettable loss of life, the *Challenger* accident had, and continues to have, momentous effects on United States and international Space programs. In the near term, it led directly to an unprecedented restructuring of the Space Station *Freedom* program resulting in extensive redirection, massive delays and huge cost overruns. This was half a dozen years prior to the second massive restructuring of the Space Station under NASA administrator Daniel Goldin, which likely never would have occurred. A strong case can be made that if the *Challenger* accident had not occurred the Space Station would have flown and become operational a decade earlier than what has transpired, with attendant cost savings and opportunities to expeditiously move forward with future plans and programs. Also, the Shuttle was reined in from its full potential with decisions to move away from DOD and commercial customers, a large, flexible onboard upper stage and west coast launch capability. In the longer term, the play out of these events continues today as

> NASA struggles to plan for effective Space Station operations without the Space Shuttle while attempting to move forward with a vast new program of human space exploration beyond Earth orbit. The *Challenger* accident changed the course of history and the nature of both national and international space programs even as these programs continue to evolve in the 21st century. The full impact of the *Challenger* launch decision is still unfolding."

And, again, in late August 2003, when the *Columbia* Accident Investigation Board's (CAIB) report discussed NASA's organizational flaws, they noted that:

> "The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle Program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterizations of the Shuttle as operational rather than developmental, and lack of an agreed national vision. Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules."

Sadly, this damning indictment of NASA's engineering management culture was supported by the facts of the accident. It was in part for this reason that we implemented a new governance model within NASA. The approach that we chose is modeled on that used in the Office of Space Flight by former NASA Associate Administrator George Mueller during the *Apollo* era. It places our Mission

Directors and Center Directors on par with one another, and allows for the elevation of concerns and dissent by means of at least two pathways through equally-empowered programmatic and institutional lines of authority. This was a necessary but not sufficient condition to obtain the "independent technical authority" demanded by the *Columbia* Accident Investigation Board. Remembering that it is the people who count, I then worked – and continue to work – to select individuals of high integrity and established technical acumen *in space flight* to fill senior leadership positions. Too often in the past, senior managers at NASA have been allowed to begin their careers in the space business at the top. It doesn't work. An effective organization must be led by people who offer both unquestioned integrity *and* relevant domain expertise. If I were to be granted only one "legacy" for my tenure as NASA Administrator, I would want it to be this.

That brings me to certain accusations, both overt and subtle, that I have seen recently in various media, questioning our approach in developing the *Constellation* launch vehicle architecture, with its Shuttle-derived *Ares I* and *Ares V*. The *Orlando Sentinel*, in an article on June 22nd, accused NASA of "trying to stifle dissent about alternatives" to the *Ares* design. That's certainly "overt". More subtly, *Space News* published on July 21st an editorial entitled "*No More Studies*" – a premise with which I most certainly agree! But buried within the editorial are a

few words which are actually more troubling to me than those offered by the *Sentinel*, precisely because I know that they, on this occasion, aligned with my own view. From the editorial:

> "… TeamVision Chief Executive Stephen Metschan naturally questions the objectivity of NASA's analysis and is calling for an independent review of Direct 2.0 versus the Ares architecture, with the aim of convincing the next Congress and presidential administration to set NASA on a new course as early as next year.
>
> "It is perfectly understandable that Mr. Metschan would be suspicious that NASA's analysis was unfairly skewed in favor of Ares. …"

Oh, really? Why is that, exactly? Why is it "natural" to question NASA's objectivity? Why is it "perfectly understandable" for someone to be "suspicious" that analysis by NASA was "unfairly skewed"? This is the same as saying that it is to be presumed that NASA does not act with integrity – and I know that *Space News* did not intend to imply such. But, is that what some people really believe?

Since my thesis in this speech is that nothing matters more than personal and organizational integrity, let's take a moment to review the bidding from the top down. NASA is a Federal agency, an arm of the United States government. NASA employees don't get stock options, they don't get bonuses for concluding mergers and acquisitions, and they do not have financial interests in the industrial concerns that actually implement about 85% of the work managed by the agency. We go to tremendous lengths to ensure that NASA employees do not have real or

perceived conflicts of interest in connection with their work assignments, to the point that employees must fully disclose their financial investments, regularly attend ethics training, and sign legally binding oaths attesting to the absence of conflicts of interest.

What NASA employees do have, to varying degrees, is executive power delegated by Article 2 of the Constitution, and specified in great detail through many laws. NASA is *the* entity charged with the implementation and management of government civil space development activities. Public funds allocated to meeting U.S. civil space policy objectives are spent largely according to the technical and programmatic judgment of NASA civil servants as to how it can best be done. NASA employees have the power to decide such issues.

That, of course, is what some critics, many of whom who *do* have financial interests in the outcome of the decisions we make, find to be objectionable. But the management of appropriated funds to accomplish national policy objectives is the very *purpose* of Executive Branch agencies. Making decisions in connection with such matters is a core function of government, and for civil space programs, that function is performed by NASA. If we didn't have a NASA, we'd have to invent one, or assign the required functions to some other government entity. The key feature to which some apparently object – that decisions about the allocation of

public funds to some alternatives in preference to others are made by government employees – would remain. Only the names would change.

Now, I am not so naïve as to believe that NASA managers are exempt from Lord Acton's observation that, "Power tends to corrupt, and absolute power corrupts absolutely". It is absolutely necessary to have interlocking checks and balances between the Executive and Legislative branches of government, as specifically provided by the framers of the Constitution. Our Constitution provides that NASA as an Executive Branch agency should be overseen by the people's elected representatives. It is. Quite thoroughly, I might add.

But with that said, it is trivial to observe that there can never be enough oversight, never enough checks and balances, never enough watchers, to restrain a large group of people who are determined to behave badly. The effectiveness of institutions generally, and certainly of government institutions, is heavily predicated on a fundamental tenet: most of the people, most of the time, are trying to do their jobs well, and fairly. The assumption of well-intentioned competence in government must be the norm, not the exception, in the functioning of a democratic society.

We at NASA cannot possibly make everyone happy with our decisions. Most decisions will produce an unhappy outcome for someone. However, that unhappiness is not by itself a symptom of incompetence, bad intentions, or a lack

of integrity on our part. Allocation of public funds to any particular alternative inevitably leaves aggrieved parties who believe, with their own logic and passion, that their proposed alternative was the superior choice. It is not reasonable to expect that responsible managers can make decisions pleasing to all interested parties. What the taxpaying public and its elected representatives, our overseers, can and do expect from NASA can be summarized in two words: objective expertise.

NASA cannot be effective as an organization if the decisions of its managers are judged by the space community to be generally lacking in either competence or fairness, and that is why such criticisms in *Space News*, *The Orlando Sentinel*, and elsewhere, especially the blogosphere, are deeply disconcerting. If it is not obvious that objective expertise underlies NASA decisions and actions, then the civil space program will grind to a halt in response to one searching examination after another by various other governmental entities which claim the right of agency oversight, and can make it stick. Thus, it is incumbent upon us to be able to explain how a decision was reached, why a particular technical approach was chosen, or why a contract was awarded to one bidder instead of another.

We have all lived through times, some of them recent, when technical competence at NASA was called into question. But today, I believe that is not an issue. The management team in place at the agency today is, I believe, second to

none in our history. And I think that most of those with even more gray hair than I, who have worked with NASA over the decades, share this belief.

That then leaves the question of objectivity, which of course is exactly the point of comments about "stifling dissent" or "unfairly skewed" analysis. Such accusations are deeply troubling because, in the end, they are accusations that we lack integrity. They chip away at the foundation of the high-integrity organization we strive to build at NASA. The efficacy of our team is predicated upon our ability to "follow the data", to communicate constructively the differences of technical opinion throughout the organization. Accusations to the contrary, such as those in the mainstream media or as found on many web postings, reverberate as echoes of lessons *not* learned from the *Challenger* and *Columbia* tragedies.

Because these tragedies are still fresh in our collective consciousness, nothing better serves to cause attention to be focused on NASA's choices – a fact not lost upon those who object to our choices. Such accusations are strong claims indeed. They require strong justification by the accuser, and a clear response from the accused. As a manager, I need facts when such charges are levied. Otherwise, it is impossible for me to address them, to prove or disprove their validity, or to provide a cure for the cause if there is one.

What must be understood is that differences of technical opinion, based on a given set of facts, are common among engineers. Such differences of opinion do

not mean that data is “unfairly skewed”. A decision by a manager to follow one path rather than another is not evidence of “stifling dissent”. To do our jobs, to make forward progress, we must make decisions every day on matters that, unlike the problems in most textbooks, do not have clear, simple, right or wrong answers found in the back of the book. Judgment calls are required; we then often wait years to find out whether they were correct. Not everyone has a taste for the kind of pressure that this brings to bear on senior institutional and program managers, but it is inherent to the nature of our business.

Allow me to offer a specific example of how false accusations can be made by taking selective snippets of information out of context. Managers of large, complex projects, such as the *Ares* rocket development, use simple “stoplight charts” with red, yellow, and green as useful indicators as to where management attention might best be focused. That’s all we use them for. They do not begin to convey the subtleties and complexities of managing technical and programmatic risks. But such charts, taken out of engineering and management context from internal NASA briefings, are regularly featured on various blogs, generally accompanied by uninformed and typically anonymous judgments that the *Ares* rocket will never work, and by accusations of lying and malfeasance by NASA managers. Of course, no supporting evidence is ever offered.

So – differences of engineering opinion are cited as evidence of lying, of malfeasance? This is not how any of us were taught to conduct an engineering discussion. Quite frankly, it is demeaning to the profession.

I wonder what Webb or Seamans, von Braun or Gilruth, Mueller or Low or Kraft, would have thought if they had had to deal with such vitriol during *Apollo*? Viewed in hindsight, the success of Apollo can appear to be an unbroken record of progress from President Kennedy's speech to Neil Armstrong's first footstep. But it was hardly so. It took those folks – heroes in our business – eighteen full months after Kennedy's declaration of the lunar goal merely to determine that lunar orbit rendezvous would be the best flight mode. The original Apollo spacecraft design, with its embedded assumption that Earth orbit rendezvous would be used, had to be substantially modified. An unanticipated procurement of a completely new vehicle, the lunar module, had to be conducted some two years after the *Apollo* program was supposedly well underway. Combustion instability plagued the F-1 engine well into its development, and pogo oscillations nearly destroyed the *Saturn V* on its second mission – an event, by the way, that resourceful flight controllers managed to turn into a success anyway by making great decisions literally "on the fly". But the managers and engineers of that era pressed on, solved the *Saturn V's* technical problems, and sent three men around the moon on its *very next flight*. If

there had been blogs in the 1960s, they would have had so much grist for their mills, they wouldn't have known where to start.

And by the way – just in case anyone has forgotten – *Apollo* actually turned out pretty well.

So let's fast-forward to the present. Our choices for the Shuttle-derived *Constellation* launch architecture have been especially subject to external criticism by those who would have preferred a different outcome. I strive to be objective in considering the data before me, so let's look at the data we used to make the decisions we made.

The probabilistic risk assessment for the Shuttle-derived *Ares I* Crew Launch Vehicle showed it to be twice as safe as an Evolved Expendable Launch Vehicle (EELV)-derived system for missions to the International Space Station and the moon. The analysis for the Shuttle-derived *Ares V* Heavy-Lift Launch Vehicle showed it to be approximately 1.4 times more reliable than any EELV-derived concept we saw.

If we were to try to undertake a lunar mission using existing EELV systems, at least seven launches would be required to conduct one lunar mission, and more than thirty would be required to mount a future Mars expedition. That is not a realistic concept of operations.

If we were to extend existing EELVs to meet our requirements, the development cost would be higher than with the Shuttle-derived approach. While a new upper stage would be needed in either case, the *Atlas V* was preferred over the *Delta IV* due to its more straightforward development path, but at a cost 25% higher than the Shuttle-derived approach. We would need changes such as pad modifications for crew access, booster structural modifications, improved flight termination and integrated health management systems, and a new flight dynamics database to deal with the new outer mold line and abort scenarios. We would need to invest in facilities for U.S. co-production of the Russian RD-180 engine, or accept long-term dependence upon Russia for a critical capability by continuing to purchase it directly. The latter course further implies the receipt of a perpetual waiver of INKSNA legislation from the Congress for such purchases. If we were to make the necessary changes to the EELV, the new vehicle would differ significantly from today's EELV, thus obviating the supposed advantage of commonality with DoD systems for our nation's launch vehicle industrial base. Finally, the transition from the Shuttle to the *Ares* launch vehicle family is less disruptive for our workforce, and makes more efficient use of existing facilities and ground support equipment than an EELV-derived system.

These are not trivial issues. These facts matter. And while I appreciate that many proponents of EELV systems were upset with our decision, and some still

are, I stand by it. We are following the data, not opinion, emotion, or a course of action based upon any personal benefit.

Turning now from the launch vehicle architecture to the overall Exploration architecture, NASA's *Constellation* systems are designed for the moon, but must support the International Space Station as well. Thus, we are sizing the *Orion* crew capsule and *Ares* rockets appropriately for both missions. Now, from numerous conversations with people who are genuinely friends and colleagues, I completely understand that some would prefer to replace the Shuttle with a new system to support ISS, and nothing more. They are either uninterested in venturing beyond Earth orbit, or regard it as a problem for another generation. In my view, such a narrow focus would – again – leave NASA and our nation stuck in low Earth orbit. This is not the direction provided to NASA by President Bush and the Congress in two successive authorization bills.

While some pundits have opined that we will receive new direction from a future President or Congress, we will continue to follow the law of the land as it exists today, unless and until such new guidance is provided. I, for one, devoutly hope that we do not reverse course. Let me be very blunt: We have spent the last thirty-five years conducting the experiment of confining our ambitions for human spaceflight to low Earth orbit. It did not turn out in a manner befitting a great nation. Let's not continue it.

Finally, I would like to speak openly and honestly about the criticism that NASA did not study space access carefully enough in our 2005 Exploration Systems Architecture Study (ESAS). So, I'll put it on the public record again: we conducted a thorough study by engineers who have considered this technical challenge for many years. ESAS was the culmination, not the beginning, of these studies. Further, when and as we learned more after ESAS, we continued to incorporate new ideas, resulting in beneficial changes. For example, we eliminated over $5 billion in life cycle costs by adopting the RS-68 core engine, and going directly to a common five-segment solid rocket booster and J-2X upper stage engine for both crew and heavy-lift launch vehicles.

The key cost and safety advantages of the Shuttle-derived launch architecture remain as clear today as in 2005. If someone has better data, or specific examples where the data I reviewed either in 2005, or since, has been "skewed" or is incomplete, please come forward. I receive a lot of emails on this subject, but none offering new or better data – only conjecture and opinion. To date, on the rare occasions when data is offered to support contrarian opinions, I have found it to ignore engineering reality, funding constraints, or the law of the land. Finally, I would add that if we are stifling dissent, then we are doing an extremely poor job of it, given the amount of ink provided to so many dissenters.

I am not putting my thumb on the scales. I believe our leadership team upholds the philosophy that we strive always to be receptive to constructive criticism in solving a problem. However, we are now well past the time when we can simply 'stop work' to conduct more architecture studies. In my opinion, the propensity to conduct too many studies with too little action has in recent years been a profoundly detrimental characteristic of this nation's broader aerospace enterprise. It is long past time to *do* something. We are deeply engaged in the design, development, and testing of the *Orion* and *Ares I*, and we will be ramping up our work on the *Ares V* and *Altair* in the months ahead. We're making good progress. Let's keep it up.

We have – I have – explained quite carefully over the past several years why our new spaceflight architecture looks the way it does, with our eyes wide open to the fact that this transition to a new system for human spaceflight transport will be the greatest challenge NASA has faced in decades. Now, with all that said, if you have a better idea that doesn't conveniently ignore one or more of our many constraints, we'll listen. But bring data, and be prepared to have the technical discussion. Simply saying that an idea is better does not make it so.

Now, please do not infer from my comments that I believe we have a perfect answer to the problems facing our nation's human spaceflight program. We don't. Our solution is simply the best we can construct with the funding provided to meet

our long-standing commitment to complete the assembly of the International Space Station, while building new ships to embark on new ventures beyond low-Earth orbit.

It has only been five years since the report of the *Columbia* Accident Investigation Board, and we have made tremendous strides as an organization in that time. It is my sincere hope that we have learned the lessons of past mistakes, taken them to heart, and emerged stronger from that adversity. We did so after the *Apollo 1* fire, we did it when *Challenger* was lost, and we can do it again now. NASA celebrates its fiftieth anniversary this year. We should celebrate our achievements, but we must also remember those days when we failed to meet our own expectations. If we are to act with integrity, we must remember these failures by learning from them.

Dealing with failure is the essence of engineering. In his book, *To Engineer is Human: The Role of Failure in Successful Design*, Professor Henry Petroski notes, "No one wants to learn by mistakes, but we cannot learn enough from successes to go beyond the state of the art." Petroski expands greatly upon that theme in other works, including *Success Through Failure: The Paradox of Design*. If you have not read these works, I highly recommend them to you. You will come away from them with the understanding that, as unfortunate as it may

be, most of the great advances in engineering have been the result of learning from failures. That willingness to learn is a sign of integrity.

I too am eager to learn of better ways by which NASA can accomplish its missions. However, I cannot learn from proposals that, in the end, come down to saying what NASA should or could do if we had more money. While I too personally wish that NASA had more money, it would be irresponsible for me not to be honest with our stakeholders at the White House and Congress about the careful balance we have reached with the resources provided. When the law and policy directives cannot be carried out within known funding limitations, or defy our best engineering and management judgment, it is our duty to say so. We cannot simply do more with less. We should not over-promise and under-deliver. Saying "no", when that is the honest answer, is also a sign of integrity.

In his book, *Good to Great*¸ Jim Collins evaluated how 'good' companies become 'great' companies. The primary task in becoming 'great' is "to create a culture wherein people have a tremendous opportunity to be heard and, ultimately, for the truth to be heard." Collins further recommends that such 'great' companies "face just as much adversity as [others], but respond to that adversity differently. They hit the realities of their situation head-on. As a result, they emerge from adversity even stronger."

The same holds true for high-performance government organizations like NASA. We need the best ideas to come forth, to learn from our experiences, and for there to be civil dialogue and debate, not vituperation, before setting forth on the best course to follow.

The men and women of NASA are writing a new chapter in the history of space exploration. It's a complex story, a rich story, full of drama and despair, pride and pathos. It is a story we need to tell our children and grandchildren, lest they forget why it is we explore what John F. Kennedy referred to as the "New Frontier" of space. I believe it is necessary for us to discuss openly and honestly the principles that led us as a nation to embrace space exploration five decades ago, and the need to continue that journey. But first and foremost, we must tell our story with integrity.

Thank you.