The Reality of Tomorrow

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This is the third year in a row that the American Astronautical Society has asked me to kick off the Goddard Symposium. The organizers of this conference really must be gluttons for punishment. But, as an AAS member for over 30 years, I am honored once again to be invited to speak to this gathering of so many of my old friends.

The first Goddard Symposium was organized in 1961, and the theme for that year's meeting was "The Interaction of Space Vehicles with an Ionized Atmosphere". This year's theme, "Exploration to Commercialization: Going to Work in Space", deals with some of the many aspects of spaceflight that are not simply about scientific discovery, or about the unique engineering problems of operating in this still-new medium. And, if you look at the changing themes of this symposium over time, you will notice that this is not an isolated example. The themes of this conference have gradually evolved from strictly technical subjects to the broader implications of spaceflight for human society.

This is good, and it should continue. The state of the art in engineering is a transitory thing at best. Those, like me, who once studied vacuum tube design and programmed in assembly language on "advanced" computers with 16 K of 16-bit core memory, know this all too well. And the burning scientific questions of one generation are the received wisdom of the ones after that. It seems quaint, and more, to realize today that Einstein received the 1921 Nobel Prize for his elucidation of the photoelectric effect, in part because relativity theory was then still too controversial. Our scientific and technical frontiers are transitory, but the deeper questions – which devolve, in one form or another, to "What does it all mean?" – will always be relevant.

The poster advertising this year's conference shows at first glance the range of space endeavors today. Near the Earth, we have burgeoning commercial space tourism, highlighting the role of prizes in spurring technological innovation, as with Burt Rutan's *SpaceShipOne*. Moving outward, we will place NASA's *Orion* Crew Exploration Vehicle in orbit around the Moon in the next decade, breaking out of low Earth orbit for the first time in forty-five years. And there is a stunning picture of a spiral galaxy, bringing to mind the vastness of space with all its possibilities. Of course, this poster is hardly drawn to scale... but it is always easier to be an art critic than an artist, so I better not stray too far out of my lane.

However, I do have one serious point to make about how we in the space community try to talk about these larger issues in an understandable way. My hope, as an engineer, is that we do not downplay the technical difficulties of spaceflight to the general public or to our stakeholders in the White House and Congress who don't do what we do for a living. I mean, this *is* rocket science.

As just one example, the energy which was harnessed to launch *SpaceShipOne* on its suborbital flights is about 2% of what is needed to get into low Earth orbit, never mind carry out missions to the Moon, Mars, and other planets. As I have noted on several occasions, I admire Burt Rutan enormously, and even more so the achievement of him and his team with *SpaceShipOne*. But their achievement was one of breaking – thank heavens! – organizational and institutional paradigms, not of pioneering new technical frontiers. We in the space community need to communicate these differences clearly.

While I am speaking of commercial suborbital spaceflight, I will note that I also very much hope that NASA researchers and astronauts will be proactive in taking advantage of such capabilities as they are developed by the nation's entrepreneurs. Last week, NASA's Science Mission Directorate issued a Request for Information on potential human-tended, government-sponsored flight experiments which could be flown on such commercial suborbital vehicles. I hope

this RFI generates a lot of good ideas, because all of us at NASA want to figure out how to engage the emerging commercial space sector to advance NASA's goals.

We would not be where we are today if it weren't for doers with big dreams, people like Robert Goddard and Burt Rutan. Burt continues to be an inspiration and mentor for many aerospace engineers, with his offices at Scaled Composites lined with *Aviation Week & Space Technology* magazine covers depicting his varied handiwork, along with a Collier Trophy or two on the bookshelf. In many respects, Burt is carrying on the tradition of great engineers whose work was initially dismissed, but recognized later.

Robert Goddard, the practical physicist whom we honor with this symposium, was another pioneer whose ideas were initially panned. One of the oft-told tales in the space business is of how, in 1920, the *New York Times'* editorial board questioned Goddard's technical acumen, noting that rockets could not operate in the vacuum of space and saying of Goddard: "He only seems to lack the knowledge ladled out daily in high schools." Goddard's simple, yet profound response: "Every vision is a joke until the first man accomplishes it; once realized, it becomes commonplace."

Of course, the truth eventually surfaced. Forty-nine years later, as Apollo 11 was on its way to the Moon, and buried on page 43 of its July 17th, 1969 edition,

the *New York Times* grudgingly admitted: "It is now definitely established that a rocket can function in a vacuum as well as in the atmosphere. The *Times* regrets the error."

But the quote from Goddard that I like the most is this one: "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.", because it is my own hopes for the reality of tomorrow that I would like to discuss with you this morning. Unfortunately, it is in my nature to be a realist. Some in the space community wish that I were more a cheerleader or a font of inspiration, but those of you who have known me for decades know that such irrational exuberance is not in my character. Thus, I sometimes point out the harsh realities with pernicious facts about our nation's space and aeronautics enterprise. Just the facts.

For example, it is a fact that as a matter of national policy spanning multiple Administrations and Congresses, NASA simply is not allocated the budget resources to accomplish all of the many and varied space and aeronautics missions that our many constituencies would like us to do. The President's request for NASA in FY09 is $17.6 billion out of $3.1 trillion for all U.S. government spending, less than 0.6% of the entire Federal budget. During the development peak of the *Apollo* program, NASA received 4.4 percent of the Federal budget and

employed over 400,000 civil servants and contractors across the country; today, we employ maybe 90,000 people. Adjusted for inflation, NASA's budget is $3 billion less per year than it was the last time I was at NASA, in the early 1990s. That is about 20 percent less buying power today than when I was Associate Administrator for Exploration. These are just facts.

To the Bush Administration's strong credit, NASA's budget *has* kept pace with inflation at a time when most other non-defense domestic discretionary budgets are not, showing the priority given to the agency's mission after the prior years of decline. In keeping with my sardonic side: when you care enough to send the very best, send money. This Administration has. But, the reductions made in prior years have not been reversed. Just a fact.

During this period of declining NASA budgets since I left the Agency in 1994, no viable replacement for the Space Shuttle was developed, aeronautics research funding declined significantly, funding for new space technology dried up, and science funding rose to an all-time high percentage of the agency's budget. Just facts.

Thus, a major focus during my tenure as Administrator has been to find some semblance of budgetary balance between the competing priorities of NASA's overall budget within the resources provided, while also returning the Space

Shuttle to flight after the *Columbia* accident, completing the assembly of the Space Station, and building new crew launch systems.

As Admiral Hal Gehman noted in the report of the Space Shuttle *Columbia* Accident Investigation Board five years ago, "previous attempts to develop a replacement vehicle for the aging Shuttle represent a failure of national leadership". Because of that, we now face a gap in U.S. human spaceflight capabilities after Shuttle retirement, and are reliant upon the Russian *Soyuz* system for transport to and from the International Space Station that we have built.

Thus, I must admit that our post-Apollo budget history and our posture today colors my view of the reality of tomorrow. While this is hardly inspirational rhetoric, my hope for today to become the reality of tomorrow is that NASA's budget will continue to grow at least in accord with OMB's inflation index for the next fifty years. This kind of budget, and this kind of stability, will produce a pretty good outcome if we manage it with a proper sense of purpose.

About a year ago I wrote a lengthy article for *Aviation Week* concerning what we can realistically afford to do under such a budget scenario. If we make the necessary strategic investments and maintain the sense of purpose that I find around the Agency today, then we can indeed be back on the Moon by 2020, have a lunar base by mid-decade, and be on Mars by the mid-2030s.

After I wrote the article, I was criticized for painting a rosy picture by using the prescribed OMB inflationary index, when some believe that, through no fault of our own, the real costs of aerospace goods is much higher. Others believe that, if aerospace costs are rising disproportionately in comparision to other high-tech sectors, the fault lies within our community and our culture, and should be addressed there. This is not an esoteric argument, but one that has profound implications for NASA's real purchasing power and ability to plan for multi-year projects and programs in an era when the costs of raw materials and high-tech labor are increasing higher than inflation. As Albert Einstein observed, "The most powerful force in the universe is compound interest." Thus, all I can say is that until someone else demonstrates a better model for inflation than OMB's prescribed index, while I might not be full of irrational exuberance, I am cautiously optimistic in my hopes for the reality of tomorrow.

So, given what we know of NASA's budget over the past several decades and what we might reasonably project for the future, we can either bemoan the underfunding of our nation's efforts in space and aeronautics research, wallow in pity about the lack of progress being made, or find some more productive and constructive approach to our problems. I choose the latter. So let me talk now about my second hope for the reality of tomorrow.

Let us speak openly and honestly about the problems we face in carrying out our nation's space program. Over the course of my career in this business, I have often been disheartened by the large number of diverse "entrepreneurs" in search of NASA funding who place their self interests over the greater good of the aerospace community. They do not respect the priorities set out for NASA by our duly-elected stakeholders in the White House and Congress, or even the priorities of their own respective science communities in National Academy decadal surveys. Even worse, the rift and harsh rhetoric between proponents of robotic science and human spaceflight does not help our nation's overall space effort one iota, but it does cause division that weakens us. If we wish a better reality for tomorrow, we as a community must police this behavior; those who engage in it must be made to feel, and be, unwelcome in the community at large. My hope for today is that there will in the future be more respect for each others' work.

I must also point out that there have been many instances where proponents of individual missions have downplayed the technical difficulty and risk of their individual mission, or grossly underestimated the cost and effort involved to solve the problems, in order to gain "new start" funds for particular project. Everyone knows that, once started, any given mission is nearly impossible to cancel, so the goal becomes that of getting started, no matter what has to be said or done to accomplish it. I am speaking here not only to industry and scientific investigators,

but also to organizations within NASA. This is a matter of integrity for our community. NASA managers, the White House, and Congress have seen this behavior too many times, and the Agency has lost a great deal of credibility over the decades as a result. There was a time – I remember it, and many of you will also – when what "NASA" said could be taken to the bank. Anyone here think it's like that today? Show of hands? ... I didn't think so.

I have spent a good portion of my time as Administrator trying to rebuild that credibility with more rigorous technical review and independent cost estimating processes. But, folks, we are in this together. We will not be trusted with more funding to carry out great, new, exciting space missions in the future, human or robotic, if we oversell and underdeliver on our commitments today. Across the board, we must be realistic in our assessments of cost and technical risk if we are to be trusted with funds provided to us by the American taxpayer.

We must also change some of the ways in which NASA conducts its business. No one who has worked both in government and in the private sector, can fail to note the efficiency of commercial operations as compared to those of government. Just as we are conceiving plans for commercial suborbital missions, we also recently awarded a contract to the Zero-G Corporation to use their aircraft for NASA's microgravity experiments and astronaut training. We will be taking a hard look over the coming months to determine whether NASA should continue to

own and operate our current C-9 aircraft for parabolic flights. A couple of weeks ago, NASA signed a new, funded COTS Space Act Agreement with Orbital Sciences and another agreement with SpaceX, to spur private industry investment to develop and demonstrate cost-effective cargo and crew transport to the International Space Station. Our goal is for NASA to be able to purchase commercial delivery of goods to the Space Station after the Shuttle is retired in 2010. With the Space Station as a National Laboratory, we are opening it up to commercial use, as well as to other agencies of government like the National Institutes of Health. We are going to work in space.

Just down the road from here, the men and women of the Goddard Space Flight Center are going to work in space. The reality of tomorrow is that over the next few years, Goddard is playing a major role in launching nearly a dozen science missions, one of the busiest periods in the center's illustrious history.

First up this year is the *Gamma-ray Large Area Space Telescope*, or GLAST, a marriage of astronomy and particle physics to study black holes and the physics of extreme energies and what composes dark matter. This project, set to launch in late May, is also a marriage between NASA, the Department of Energy, and research institutions in France, Germany, Japan, Italy, and Sweden. Indeed, over half of NASA's missions involve some form of international cooperation.

One month ago, we asked the science community and the public to offer recommendations on renaming the GLAST mission. Let's hear from you.

Perhaps the most inspirational mission NASA hopes to carry out later this summer is the final servicing mission to the *Hubble* Space Telescope by the crew of STS-125 on Space Shuttle *Atlantis*. The *Hubble* servicing mission turns the unhealthy schism between human and robotic spaceflight into a meaningless argument. With four previous service calls, our astronauts risked their lives to correct the *Hubble*'s flawed optics, install new gyros, batteries, and solar arrays as needed, and install a series of powerful new instruments, dramatically boosting its capabilities and performance. It is a marriage of human ingenuity and state-of-the-art scientific know-how and perseverance. I saw that Frank Cepollina is speaking here at the Goddard Symposium tomorrow, and I would rather you hear directly from him what we have accomplished with the *Hubble*, our progress in carrying out this mission, and what's next.

The scientists and engineers of Goddard are also completing the development work for the *Lunar Reconnaissance Orbiter*, NASA's first mission to our closest celestial neighbor in a long time. The LRO, to launch late this year with the LCROSS lunar impactor, will create the most accurate and comprehensive topographic maps of the lunar surface to date, vital for pinpointing landing sites for future manned missions. As Doug Cooke observed last week

when unveiling the recent Goldstone radar maps of the Moon's south pole around the Aitken Basin, an area of great potential interest as a landing site, "We now know that the south pole has peaks as high as Mt. McKinley and crater floors four times deeper than the Grand Canyon. There are challenges that come with such rugged terrain."

But American explorers like Daniel Boone, Meriwether Lewis and William Clark, Zebulon Pike, and many others who followed, are used to rugged terrain. Thus, when our astronauts return to the Moon for the first time in nearly fifty years, they will be blazing new trails and carrying on a rich tradition of exploration on the "New Frontier" as President John F. Kennedy framed our nation's first forays into space.

The LRO mission is one of many demonstrating the marriage between human and robotic space exploration. LRO, Mars Reconnaissance Orbiter, the Mars Exploration Rovers, the Phoenix Scout, and Mars Science Laboratory missions are examples of some of the robotic missions which will enable future manned exploration as we take the first, rudimentary steps out into our solar system.

Another mission which will also enable future manned exploration is slated for liftoff at the end of this year. NASA's Solar Dynamics Observatory, also built here at Goddard, is another mission which the men and women of Goddard are

turning into the reality of tomorrow. SDO will be an unblinking eye on our Sun, using the technique of helioseismic imaging, to look inside our Sun and deliver images with ten times better resolution than even high-definition television. This mission will revolutionize our ability to forecast solar storms that disable satellites, scintillate GPS signals, cause interference to satellite communications and cell phone calls, and endanger our astronauts from solar radiation. The importance of space weather data is evident in that more than 250,000 customers from 150 countries around the world receive almost 200 data products monthly, approaching 30 million file transfers a month.

Very recently, the STEREO mission, built by my nearby alma mater the JHU Applied Physics Laboratory, witnessed the tail of a comet being completely blasted away by a coronal mass ejection from the Sun. It's an amazing thing to watch, and it's posted on the STEREO website if you haven't seen it already.

The Goddard Space Flight Center is also our nation's premier center for global warming research and developing climate change monitoring satellites. NASA satellites, many built by Goddard, supply more global climate change data than those of any other organization in the world. NASA is also the largest contributor to the inter-agency Climate Change Science Program (CCSP), providing the more grant-based funding for such research than any other organization. We can take great pride in the recognition on the part of policy-

makers and the public of the value of the research coming from NASA's Earth scientists. NASA's work in developing so-called green technologies, like fuel cells in cars and clean water treatment systems for rural villages in Africa and Iraq, is featured in an article "Space is the Place" in this month's issue of *Sustainable Industries*. This is one part of turning the hope of today into the reality of tomorrow.

Today, we are living in exciting and tumultuous times, and now is the time, this is the juncture, and we are the people to turn our Vision for Space Exploration into reality. In order to do so, we must cast aside many old chestnuts – like the divisiveness between those of us who work on robotic space and those who work on human missions – to appreciate that many things we do in space are conducted for entirely other reasons than science.

So, in conclusion, I would like to repeat a story I told two months ago in Houston, the heart of our nation's human spaceflight endeavors. We lived in similarly tumultuous times forty years ago, in 1968, when I was a college sophomore. Former NBC News anchor Tom Brokaw recently wrote a book titled *Boom! Voices of the Sixties* about that year. With the Vietnam War, the assassinations of Martin Luther King and Robert Kennedy, the struggle for civil rights and women's rights, protests on college campuses, and the Presidential campaigns and election that year, 1968 was a time of great upheaval for our nation.

Tom Brokaw points out a number of parallels between 1968 and today. He ends his analysis of that year with a reminder of what the inspirational Apollo 8 mission in December 1968 meant to our nation and the world. On Christmas Eve, the crew of Apollo 8 – Frank Borman, Jim Lovell, and Bill Anders – read from the book of Genesis as they cruised in orbit around our Moon; they saw our fragile Earth rise over the barren horizon of the Moon; they took the first photograph of our Earth in full with blue oceans, white clouds, green and brown land without any artificial national borders. Jim Lovell looked back at the Earth, held up his thumb, and blocked the Earth out from his view. He has since said that he realized in that moment how small the world he once knew was when compared to the vast frontier of space. With all the turmoil of 1968, the Apollo 8 mission and this transcendent moment helped all of us to realize that we must overcome our common struggles if we are to achieve better things for ourselves and future generations.

With both human and robotic eyes, we see our planet, our solar system, and our universe in ways we never imagined. Space exploration has brought many nations together in ways unimagined when NASA was first founded fifty years ago. "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow." Robert Goddard speaks to us even today.

Thank you.