Challenges To Sustainability

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Good morning! It's an honor to be here with you today – and in particular to be able to follow Les Lyles and his thoughtful observations.

Forty years ago this month, Apollo 9 was launched into Earth orbit to perform the first in-space trails of the Lunar Module, the crew of Apollo 11 was announced, and the Earth rise photo recently taken by Apollo 8 was being distributed by NASA around the world. Since the theme of this year's Goddard Memorial Symposium is "sustainability" it seemed natural to start by recalling the beginning of space exploration.

In the beginning, questions of "sustainability" revolved around technical feasibility and political will. Could we catch up to the Soviet Union? Do were have the will to catch up? President Kennedy asked a simple, but profound question when he asked whether there was an area of space achievement where the United States had a chance of surpassing the Soviet Union. This lead to the decision to go to the Moon precisely because that goal was seen as both possible and very, very hard. So hard, in fact, that the Soviets and we would be competing on an equal basis.

The questions of sustainability today also involve technical feasibility and political will. Can we rebuild a human spaceflight capability to take us beyond low Earth orbit again? Do we have the will to do so? Unlike the early 1960s, however, there is less clarity as to

what questions we are answering with our space activities, and human space flight in particular.

Why is Sustainability an Issue?

In many sectors, the answers as to why we are engaged in space flight are much, much clearer and numerous today than in 1962 or even in 1992.

Space is crucial to national security. U.S. and allied space capabilities provide a source of strategic advantage to military and intelligence functions that has no parallel. Our forces are organized, trained and equipped to exploit the information advantages enabled by space such that it is virtually unthinkable to return to a world where we did not have those capabilities.

Space is crucial to the global economy. The web of communications, navigation, remote sensing, and environmental monitoring satellites that encircle the Earth are part of multiple critical infrastructures necessary to a global, information-driven, economy. The precision time and positioning signals of GPS alone have enabled the infusion of new levels of IT productivity on existing infrastructure worldwide. From agriculture to air transportation, from natural resource management to financial management, space capabilities are so embedded that it is unthinkable to imagine returning to a world without them.

National security, foreign policy, and economic interests are continuing to blend together as a result of space systems. Modernized air traffic management will likely require more GPS satellites than DoD alone would require. Environmental monitoring and data systems will be needed to verify new international climate change agreements that will impact a diverse range foreign policy and economic interests. Despite, or perhaps because of, the growth of fiber optics and terrestrial wireless broadband, satellite communications capacity is even more crucial to military and commercial interests.

Since the first satellite launch, the scientific exploration of space has been incredibly fruitful, rewritten textbooks, and changed our views of the universe. From the discovery of the Van Allen radiation belts to finding water on Mars and dark matter in the universe, there seems no question that scientific interests will continue to explore space. The completion of the International Space Station will hopefully enable similar creative discoveries in other fields such as life and materials sciences.

Space continues to be a source of international prestige. Independent access to space, the launch of satellites, and having a nation's citizen travel to and from space continue to be seen as major technical achievements that also reflect on a nation's organizational skills – and by implication on its military and economic power. This has not always been a cause for congratulations as in the case of China's first EVA or India's first mission to the Moon. North Korean and Iranian space launches are a source of international concern and UN resolutions due to the capability of those same launchers to deliver weapons of mass destruction.

Space is opening up to new private actors, with a new generation of space entrepreneurs creating opportunities for tourism and industry in low Earth orbit and perhaps beyond. There is a big, big chasm between suborbital flights and routine tourism to orbit, but space tourism and recreation may yet be the next "killer app" in commercial space. This is clearly a long, long way from the days when the Soviet Union compared private space activities as akin to piracy and the United States created Comsat to be its representative in an international satellite monopoly called Intelsat.

So with all this, why would we be even talking about sustainability? Isn't it enough to recognize the space dependencies that already exist for our nation and the world?

Challenges to Sustainability – Near Term

The most immediate sustainability concern is U.S. human access to space. This is more than just the lamented gap between the end of the Shuttle program and the first flight of

Ares 1 – or even the reliance on Russia for access to the International Space Station for all the partners during this time. It's the challenge of shifting the incredibly complex combination of people, contracts, hardware, and facilities that constitute the Space Shuttle program and moving to the Constellation architecture. This is the most demanding challenge NASA has.

The central risk of the "gap" is not from wounded pride – we had no problem in relying on Russia to sustain the International Space Station after *Columbia*. Rather it is the risk of the U.S. human space flight talent base evaporating. The longer the gap, the bigger the risks of evaporation as talented people seek to find more secure or challenging employment. The answer is not to just continue flying the Shuttle, as, aside from the risk, this wouldn't give talented people assurance that they have a future beyond the Shuttle.

The transition from the Shuttle is expensive, difficult, and not without a great deal of risk. But there is no realistic alternative to doing so after 2010, although it can be argued that the United States spent 20 years looking for one and avoiding the answers.

The Shuttle transition represents the cumulative retirement of several illusions as well as Orbiters. The loss of *Challenger* ended the illusion of Shuttle as some sort of routine space truck fleet, flying 24 times or more per year. The loss of the *Columbia* ended the illusion of extending the Shuttle's operational life to 2020 or even beyond. The intervening period between those two events ended the illusion of there being a dramatic technical solution to routine space flight as represented by the National Aerospace Plane and X-33. The budget reality means that extending the Shuttle several more years takes funds directly from efforts to develop its successor.

I know there are calls for a review of the Constellation Architecture and that is a natural and appropriate action for a new Administration. I would like to suggest that given the momentum current efforts have gained that a review be done expeditiously. I would also bet that the redesign and development of what's being now being built for missions beyond LEO will cost more than developing the current architecture just once.

And it is in development, not operations or research, that the most immediate sustainability challenges lie. The questions we're facing in sustaining U.S. human space flight are the questions of a development program:

- Do we have clear objectives?
- Do we have the resources?
- Do we have coherent processes to make decisions?
- Do we have the intellectual, technical, and management capabilities in both industry and government?

The U.S. Space Exploration Policy and the back-to-back NASA Authorizations of Fiscal Year 2005 and 2008 have provided clear performance objectives for what NASA is to do. Of course there are major questions, such as the eventual fate of the International Space Station and realistic dates for returning to the Moon. But keep in mind – if performance requirements don't change and we don't have enough resources, the only free variables left are schedule or increasing risk.

The Obama Administration is proposing to bump-up NASA's top line budget with a combination of stimulus dollars, FY09 appropriations and the FY10 budget request. However, the budget is flat-lined in the out years for a net loss compared to the prior Administration. In addition, key details remain to be seen and it is not clear if the agency is going to be asked to take on additional efforts (such as COTS-D) rather than improve the schedule confidence for Ares and Orion.

Cost overruns certainly don't help the NASA budget. Acting Administrator Chris Scolese recently testified on the many factors that contribute to and cause cost overruns and schedule delays in NASA programs. Some of these factors are under the control of NASA…such as the definition of requirements, technical optimism, and inadequate reserves. Other factors are not…such as funding instability, congressional direction, and technical surprises.

Given the reality that the NASA top line does not increase when cost growth occurs, the consequences of increased cost are fewer missions, delays in starting new missions, and instability in current missions. Thus NASA needs to control as many cost growth factors as it can, especially system-level requirements. For external factors NASA cannot control, it needs to accurately communicate the programmatic impacts of underfunding, funding instability, and changes in direction. In essence, development programs need to be well managed so that project and program managers know the "prices" associated with internal and externally imposed constraints.

For the sake of short-term convenience, we didn't always manage the natural tensions between missions and institutions to ensure both were healthy. There is the need to get the missions done today and the need to ensure capabilities are there for the missions coming tomorrow. As facilities age and decay, they will impose costs on projects and programs even if no one program or project wants to pay for dreaded "overhead."

Government space efforts in general are being challenged to do more with less, to innovate and sustain global leadership. But their ability to do so is limited by many factors. There is a lack of risk-taking in government technology portfolios and focus has shifted to operations and development. There is little support for the transition of immature government technology to practical implementation, especially in today's risk-adverse commercial environment. There are few mechanisms aside from SBIR (Small Business Innovative Research) to deal with small firms and non-traditional organizations – although models like the CIA's In-Q-Tel fund and NASA's Centennial Challenges program exist.

Underlying erosion of the space industrial base has further exacerbated the problems of cost growth and weak innovation. I am chagrined to recall that I helped write a report on the state of the U.S. space industrial base for the National Space Council in 1992 and the concerns expressed then have become even more severe. With limited technology spending the civil and military sectors, increasing reliance on global supply chains, and

export controls that limit the size of addressable markets for space technologies we should not be surprised by evaporation of the U.S. space industrial base from the bottom up. The concern with counterfeit parts coming into the aerospace supply chain is just one more symptom of trends that the current economic turmoil will only worsen.

Most crucially, what has happened to our ability to do large-scale systems engineering? What happened to the days when NASA was able to import crucial Air Force systems engineers off ICBM programs to work on Apollo? What happened to the cadre of innovative officers, civil servants, and FFRDC staff who led our nation's premier national security space programs?

I would suggest that what happened is that there became fewer opportunities to practice systems engineering. People cannot be proficient at skills they don't practice. Government organizations choose to value attributes other than experience and technical competence in personnel management. We didn't think that being a smart government customer required – in the words of Werner von Braun – an ability to "penetrate the contractor." We engaged in the illusion that with clever contracts, we could pay someone else to have our interests in the center of their hearts for systems engineering decisions. It didn't work out.

Under pressure to get the most out of every project and with fewer flight opportunities, our space projects grew to be larger and fewer. I won't go into the arguments about small spacecraft, faster, better, cheaper, etc. That's about as old and stale as debates about humans versus robots in exploration. Objectives, constraints, and architecture should drive systems design, not specific technical approaches to implementing those designs.

One of the consequences of these trends was a decline in developmental experience within government management teams. This was true of human spaceflight and national security programs, and the fact that conditions were not worse in space and Earth science was largely due to the wise practice of keeping at least one project in-house at places like JPL and Goddard. They retained people with hands-on experience.

Another consequence from less "through put" of development projects was that fewer members of the space community experienced matrix management and instead spent most of their careers in a single pyramid organization. They naturally identified with the needs of the project they were assigned to, but sometimes at the expense of the standards demanded by their technical profession. Great loyalty, not just fear, can be a cultural inhibitor to communicating technical concerns if there are no other projects to work on.

The lack of large-scale systems engineering skill is not just a concern for space, but also a strategic loss for the nation. It is not possible to look at the challenges facing the United States without seeing that meeting them will require multi-disciplinary technical skills, international engagement, immense resources, and decades-long dedication. There is no more multi-disciplinary, large-scale example of these characteristics than found in the space community, and human space exploration in particular.

Thus, while the U.S. government should and must seek ways to tap into the commercial and international networks, it also needs to rebuild it's internal intellectual capital so it can define requirements, conduct systems engineering trades, negotiate with contractors as intellectual equals, and even help fix development problems that inevitably arise.

In short, an immediate challenge to sustainability is for the government to rebuild its systems engineering capabilities so that it can once again be a manager of development programs, rather than just a patron of them.

Challenges to Sustainability – Far Term

The space community is increasingly aware of long-term, external threats to the sustainability of space activity as well. These arise from the recognition of how space is a "global commons" that we need to protect.

Let me just cite a few examples:

Improving space situational awareness is a topic of great interest across all sectors and among all spacefaring nations as orbital debris can threaten any spacecraft. The environment is a lot more crowded than in 1962, 1992, or even 2002. International discussions on "rules of the road" and "codes of conduct" reflect the differences in today's environment.

Improving space weather predictions is important for protecting terrestrial telecommunications and power networks, spacecraft, and human crews living and working beyond the Earth for long periods of time. Improvements in space weather prediction are also of interest to all space sectors and nations.

Protecting the space allocations of the electromagnetic spectrum is vital for multiple economic, scientific, security, and public safety reasons. There is increasing pressure on the "noise floor" in restricted bands used for space systems as a result of the spread of ubiquitous wireless devices. If the spectrum environment is harmed, the damage is likely to be permanent as satellite power can't be easily increased or unlicensed devices confiscated. Continued international vigilance and cooperation are necessary.

Great international attention is being paid to creating interoperable standards for communication and navigation. The NASA rovers on Mars have the ability to communicate through both European and American spacecraft in orbit above Mars as the result of open, international standards. Such standards are especially important in light of increasingly capable players such as China and India as they help ensure realistic options exist for cross-support as political conditions warrant.

There are also areas of the global space commons which are not well understood or defined, such as:

- Roles and responsibilities for acquiring and distributing climate change data needed for international agreements.

- Space surveillance and tracking capabilities to detect and characterize potentially threatening near-Earth objects.
- Internationally accepted recognition of property rights for the commercial development of in-space resources.

Today, we have the Global Exploration Strategy as an international common approach to human and robotic exploration of the Moon, Mars, and beyond. As I noted at the beginning, there is no question about the practical, scientific, and even diplomatic value of space exploration and this is recognized by other spacefaring nations as well.

It is less clear what questions we are trying to answer with such a bold effort. What are the questions that will drive and sustain us, if not beating each other in Cold War-like competitions for prestige?

Challenger forced the question of whether we should risk humans flying payloads that could be launched in other ways. The answer was no and we moved satellites to expendable launch vehicles.

Columbia forced the question of why are we risking humans at all. The Columbia Accident Investigation Board (or CAIB) said that travel beyond Low Earth Orbit was necessary to if we were to justify the risks involved. The U.S. Space Exploration Policy and Global Exploration Strategy are consistent with the views of the CAIB.

I agree with the CAIB and the approach taken by the Global Exploration Strategy, but I'd like to suggest we do more. We should take a page from our science colleagues in asking simple, but profound questions to shape an implementation strategy. In science, questions such as "Does life exist elsewhere in the solar system?" or "What is dark energy?" help shape and sustain scientific strategies and programs over long periods.

What is the question for human spaceflight?

I believe it's asking whether there is a human future beyond the Earth.

Dr. Harry Shipman posed two questions in his 1989 book "*Humans in Space*" whose answers lead to very different human destinies. The first is: "Can extraterrestrial materials be used to support life in locations other than Earth?" And the second is "Can activities of sustained economic worth be carried out at those locations? Or as I shorten it: "Can we live off the land?" and "Can we make it pay?"

If the answer to both is yes, we will see space settlements and the incorporation of the Solar System into our economic sphere as former Science Advisor Jack Marburger suggests. If the answer is no, then space is a form of Mount Everest – good for personal challenge and tourism but nobody really lives there. Other answers might remind us of Antarctica or perhaps a North Sea oil platform.

Many people seem to have faith-based answers to these questions but I would suggest a greater humility in that we don't really know. And therefore our efforts should be to answer these questions as in the course of human and robotic exploration beyond the Earth. The quest to do so will teach us much of practical benefit as we seek to do things that are hard. The experiences we gain will give us new insights into who we are and what humans can do.

When Apollo 8 took that iconic picture of Earth, people around the world looked at themselves in a new way. So too will the effort to know whether humans have a future beyond this one planet will allow us to know our future in a new and profound way. Answering question of whether mankind can productively live and work on another world than our own planet will challenge, guide, and I hope, sustain us in the years to come.

Thank you.