

## Testimony

### Hearing on “Options and Issues for NASA’s Human Space Flight Program: Report of the ‘Review of U.S. Human Space Flight Plans’ Committee”

U.S. House of Representatives  
Committee on Science and Technology

Rayburn House Office Building  
Room 2318

Michael D. Griffin  
Eminent Scholar and Professor  
Mechanical and Aerospace Engineering  
University of Alabama in Huntsville

15 September 2009

Chairman Gordon, Ranking Member Hall, and Members of the Committee:

Thank you for inviting me to appear before this committee to discuss our nation’s plans for human spaceflight, and the findings of a highly respected Commission chartered to review those plans. For this Hearing, I have been asked to provide my perspective on the Commission’s summary report, especially as it relates to NASA’s Constellation Program and the issues that Congress needs to consider as it deliberates the future of U.S. human spaceflight. I am honored to have been asked.

I will begin by acknowledging my own gratitude to the Commission for highlighting, front and center, many issues with which I grappled for four years during my term as Administrator. The Commission has offered many observations with which I most strongly agree. Among these are:

- the reaffirmation of the fundamental strategic goal of human expansion outward into the solar system;
- the explicit enunciation of both intangible and concrete reasons – what I once labeled ‘real’ vs. ‘acceptable’ reasons -- for human expansion into space;
- the absolute criticality of stable policy direction to the success of such an effort, and the resources to implement that direction, across presidential administrations;
- the recognition of the impact of substantial, consistent, long-term real-dollar budget cuts at NASA (more than 20% in the last 15 years),
- the plain acknowledgement that more money is required if worthy goals are to be attained, and that without such funding, worthy goals in human spaceflight beyond the International Space Station (ISS) will not be achieved;

- the identification of a specific amount for a proposed increase, \$3 billion annually, rather than merely stating a requirement for “more money”;
- the value of U.S. leadership in a program of human expansion into space, while still embracing strategically critical contributions by international partners;
- the distinct but complementary natures of scientific discovery and human spaceflight in the expansion of the human frontier;
- the requirement to implement this expansion with a transportation infrastructure designed to last decades and enable numerous destinations;
- the importance of heavy-lift launch systems to that implementation scheme;
- support for the continuation of ISS operations through 2020 (and I would add “at least 2020”);
- the need for and benefit of a focused effort in technology development and maturation as part of the overall space exploration enterprise.

The Commission is to be further congratulated for its forthright willingness to engage some of the more contentious questions in what has been a long-term but still unsettled policy discussion. There are a number of “hot-buttons” in the report that have been and will continue to be debated passionately until finally settled by decisions and actions. Among these questions are:

- whether or not there is a need for independent U.S. government human access to space, and if not, the identification of those entities upon which we are willing to depend for such access;
- whether or not it is in the larger interests of the United States to invite international partnerships in regard to capabilities which are on the so-called “critical path” to a desired common goal;
- the degree to and roles in which the U.S. government should foster the development, and embrace the capabilities, of “commercial space” in the furtherance of national goals;
- the proper role of NASA in guiding the human expansion into space, and in particular NASA’s disparate functions as ‘innovator and technology developer’ vs. ‘designer/developer/smart buyer’ of new systems, and ‘system operator’ vs. ‘service customer’.

I have my own opinions on these matters, as do many others in the space policy community, and am pleased to share them if asked. Some of those opinions I hold in common with some members of the Commission; in other cases ‘not so much’. But the larger point is that these matters of national policy remain unsettled. I am truly gratified to see such substantive matters being raised by the Commission. They deserve correspondingly substantive debate, followed by decisive action.

So, at the strategic level, I believe that the Commission has done an excellent job of raising issues that matter and providing clear indications as to what the worthy and proper course for the nation’s future in space should be.

At the same time, however, the Commission also addresses numerous tactical issues concerning how to go about achieving the goals they support, and offers views as to the merits of various implementation approaches considered during their deliberations. I think it is fair to say that I am less enamored of their treatment of these tactical issues than I am of their strategic assessments.

I believe that this is an important distinction to make, and that both strategy and tactics are important. Non-specialists will, and should, place great weight on the findings of this Commission. Where key tactical assessments and findings are at variance with those of knowledgeable and experienced practitioners, it can result in a level of public discord such that it becomes difficult for policy makers to know how to proceed. Thus, it will be important to consider carefully many specific points which were addressed by the Commission before decisions are made by the president and finally codified into law – or not – by the Congress.

The Commission notes, correctly, that NASA's Constellation program followed a design-to-cost strategy according to the budget profile of FY2005. NASA's budget as stipulated in 2005 was essentially constant in real dollars, with only a slight increase above inflation. Since then, it has since suffered some \$30 billion of reductions to the amount allocated to human lunar return, including \$12 billion in just the last five fiscal years.

The Commission notes that "Given the funding originally expected, the Constellation Program was a reasonable architecture for human exploration." In an earlier public statement, Commissioner Sally Ride noted that, "the program comes pretty close to performing as NASA advertised it would. ... NASA's planning and development phase of Constellation was actually pretty good." A veteran of the investigations of both the *Challenger* and *Columbia* accidents, Sally has seen her share of troubled programs, and so this comment was one I found telling.

Thus, one wonders why the Commission failed to recommend as its favored option the simplest one possible -- providing the funding necessary to do the job. Of all the options considered, this is the most straightforward. Yet it was not recommended. Other options are possible, of course, and the Commission would have been remiss not to explore them as well. But not to include this one is, in my view, simply wrong.

I say this because the civil space policy of the United States; e.g., "what NASA does", has been a matter of *law* since the passage in December 2005 of the NASA Authorization Act. This came about only after a full 23 months of fulsome, healthy, and productive debate on the merits of President George W. Bush's announcement of the "Vision for Exploration" in January 2004. The "Vision" itself was a response to another presidential commission, the Columbia Accident Investigation Board, which noted as a root cause of the Columbia accident the lack of a long-term strategic vision for NASA – a finding which I supported then and support now. In my view, the Congress extended and improved upon the original "Vision" in passing that Act, and did so again in 2008. On both occasions Congressional support for NASA's direction was heavily bipartisan.

Thus, when President Obama took office in January 2009, he inherited a civil space policy which had, in its essentials, survived six years of vigorous scrutiny, a space agency which had transformed itself to execute that policy, and could do so in a reasonable (if not very aggressive) timeframe on a constant-dollar budget as stipulated in 2005. The Commission itself speaks of the need for stability in direction and funding, if NASA is to make reasonable progress and to be accountable for so doing. In my view, then, the most important question that Congress could ask of the new Administration and its Commission is this: exactly why does the policy which we have established in law – twice! – need to be changed?

We cannot discuss the civil space budget, budget stability, or future plans for human spaceflight without also addressing the future of the ISS. Certainly, the Commission fully recognized this point in their deliberations and in their Summary Report. However, the report devotes considerable attention to the issue of potentially decommissioning the ISS in 2016, trading the funds required for its extension against those required for the expansion of human spaceflight beyond LEO.

I must be clear. In my opinion, any discussion of decommissioning and deorbiting the ISS is irrelevant to the consideration of serious programmatic options. While it is certainly true that the Bush Administration did not provide funding for ISS past 2015, it was always quite clear that the decision to cancel or fund the ISS in 2016 and beyond was not within the purview of that administration to make. In the face of strong International Partner commitment to ISS and two decades of steadfast Congressional commitment to the ISS, it has never been and is not now realistic to consider decommissioning it in 2015, or indeed on *any* particular date which can be known today. The United States will not take unilateral action to cancel an international program which is the centerpiece of human spaceflight in every one of its fifteen participating nations, just because a particular date arrives on the calendar.

It has long been known that some \$3+ billion per year will be required to sustain ISS operations past 2015. Failure to plan for this is, and has been, a glaring omission in the nation's budgetary policy. Thus, sustained funding of the ISS as long as it continues to return value – certainly to 2020 and quite likely beyond – should have been established by the Commission as a non-negotiable point of departure for all other discussions.

The United States is now the majority owner of a 450 ton laboratory in space, a facility without compare. The fact that it took too long to build and that we spent more money on it than we should have is irrelevant to future decisions. We have it. We should use it to the maximum possible extent, for as long as we can make it last. But we must also go beyond ISS. The existence of future exploration programs cannot be traded against sustenance of the ISS on an "either-or" basis, as if that were a realistic option. If the nation is to have a viable human spaceflight program, *the requirement to sustain ISS while also developing new systems to go beyond low Earth orbit is the minimally necessary standard*. If the nation can no longer meet that standard, then it should be so stated, in which case any further discussion of U.S. human exploration beyond LEO is moot for the next two decades.

The Commission correctly addresses, front and center, concerns about the looming “gap” in independent U.S. access to LEO and to the ISS after the Space Shuttle is retired. To deal with this problem, the preference for “commercial” options for cargo and crew delivery to low Earth orbit appears throughout the Summary, together with the statement that “it is an appropriate time to consider turning this transport service over to the commercial sector.” It must be asked: what commercial sector?

At present, the only clearly available “commercial” option to lift Orion as designed is the European Ariane 5, designed from the outset to be human rated. Even so, Arianespace has estimated that several years would be required to prepare the Ariane 5 and its processing infrastructure to meet the demands of human spaceflight. I believe this to be correct. Launching a redesigned Orion crew vehicle on Ariane 5 is certainly a valid choice in the context of an international program. However, as an alternative to an independent U.S. government capability for human transport to LEO, it is a valid choice if, and *only* if, the U.S. is willing to give up independent access to low Earth orbit, a decision imbued with enormous future consequences. Are we really ready to take that step?

With an appropriately enlightened U.S. government policy there may one day be a domestic commercial space transportation sector. Such a policy could, as the Commission correctly notes, follow along the path laid out by government sponsorship of commercial air transportation in the last century (for cargo, by the way, not passenger traffic). No one in the space community wants that capability to exist more than I. But it does not presently exist, and will not exist in the near future; i.e., substantially prior to the expected availability of Ares-1 and Orion, if properly funded.

The key point is this: the existence of a guaranteed U.S. government option for cargo and crew delivery to ISS is what allows government to take prudent risks to help bring about the development of a viable commercial space sector.

The Commission acknowledges the “risk” associated with its recommendation, but is not clear about the nature of that risk. If no government option to deliver cargo and crew to LEO is developed following the retirement of the Space Shuttle, the U.S. risks the failure to sustain and utilize a unique facility with a sunk cost of \$55 billion on the U.S. side, and nearly \$20 billion of international partner investment. The Russian Soyuz and Progress systems, even if we are willing to be dependent upon Russia and are willing to pay whatever is required for their use, simply do not provide sufficient capability to utilize ISS as was intended. Further, they represent a single point failure in regard to such utilization. In my view, to hold the support and utilization of the ISS hostage to the emergence of a commercial space sector is not “risky”, it is irresponsible.

The Commission claims that safety “is not discussed in extensive detail because any concepts falling short in human safety have simply been eliminated from consideration.” Similarly, the Commission was “unconvinced that enough is known about any of the potential high-reliability

launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way." For those of us in the human spaceflight community, this is a "hot button". The Commission has dismissed out of hand the extensive work that has been done to assure that Constellation systems offer the safest approach in comparison to all other presently known systems. This is simply unacceptable. Work of high quality in the assessment of safety and reliability has been done, and independently validated discriminators between and among various system options do exist, whether the Commissioners believe so or not. Further, the Summary Report is confusing as regards the distinction between "reliability" and "safety", where it is discussed at all. The former is the only criterion of interest for unmanned systems; for manned systems, there is an important difference due to the existence of an abort system and the conditions under which that abort system can and must operate. Nowhere is this crucial distinction discussed.

The Commission recommends consideration of a lunar mission architecture featuring a dual-launch of the Ares-5 Lite vehicle, instead of the Ares-1/Ares-5 Constellation baseline. The rationale for this recommendation is difficult to understand, because economic considerations favor Ares-5 over Ares-5 Lite. Ares-5 costs 12% more to develop than Ares-5 Lite, but carries 14% more payload to LEO and 20% more payload to the moon (50 mt vs. 60 mt). Even more importantly, the operations cost for the dual-Ares-5 Lite lunar mission concept is several hundred million dollars higher than the baseline plan, for the same reference program of two human and two cargo missions to the moon each year.

The Commission agrees that a heavy-lift launcher is needed for human space exploration beyond LEO. Because of the economies of scale inherent to the design of launch vehicles, the cost-per-pound of payload to orbit nearly always improves with increasing launch vehicle size. Thus, a heavy-lift vehicle should be designed to be as large as possible within the constraints of the facilities and infrastructure available to build and transport it. This provides the greatest marginal capability at the lowest marginal cost.

The use of "fuel depots" as recommended in the Summary Report is equally difficult to understand. The Ares-5 offers the lowest cost-per-pound for payload to orbit of any presently known launch vehicle design. An architectural approach based upon the use of numerous smaller vehicles to stock a fuel depot is inevitably more expensive than putting the necessary payload up in larger pieces. Further, a fuel depot requires a presently non-existent technology – the ability to maintain cryogenic fuels in the necessary thermodynamic state for very long periods in space. This technology is a holy grail of deep-space exploration, because it is necessary for both chemical- and nuclear-powered upper stages. To embrace an architecture based upon a non-existent technology at the very beginning of beyond-LEO operations is unwise.

Finally, there are a number of concerns as to the methodology by which the Commission reached some of its conclusions.

When trying to assess the relative merits of multiple options for an engineering design – in this case the design of spaceflight architectures – the core requirement to allow meaningful comparisons is to fix the goals and constraints so that these “boundary conditions” are common for all. In the Commission’s report, various options are presented which are not linked by common goals and constraints. Instead, differing options with different constraints are presented to reach disparate goals, rendering it impossible to develop meaningful cost/schedule/performance/risk comparisons across them. These options possess vastly differing levels of maturity, yet are offered as if all were on an equal footing in regard to their level of technical, cost, schedule, and risk assessment.

Significantly, *no* trade study was performed to assess how well each of the options considered by the Commission performed in meeting the goals and constraints of the existing U.S. civil space policy, as it is governed by the NASA Authorization Acts of 2005 and 2008.

The Commission cites “independent” cost estimates for Constellation systems. There is no acknowledgement that these are low-fidelity estimates developed over a matter of a few weeks, yet are offered as corrections to NASA's cost estimates, which have years of rigorous effort behind them.

As one example, it is common in cost analysis to apply a large historical cost growth factor to preliminary estimates for new designs. The size of the factor depends on the nature of the work being done and the maturity of the original estimate. Work done by Aerospace Corporation to model cost growth in certain classes of robotic space systems suggests that a growth factor of about 50% might be appropriate for the design and development of a new system. Hence, that factor was applied to the assessment of “clean sheet” options offered to the Commission. However, the same factor was also applied to NASA’s Constellation element designs. This is, effectively, “double counting”. Historical growth factors were incorporated into Constellation costs from the very first, and are reflected in delivery schedule projections for the various system elements, Ares-1, Orion, etc. To apply a new “growth factor” on top of those in the original models is misleading.

The Commission does not acknowledge NASA's commitment to probabilistic budget estimation techniques for Constellation, at a 65% cost-confidence level – higher than has ever been the case in the past. This is a fundamental break from past practice at the agency, a key to providing more realistic information on program status to agency managers and external stakeholders.

If the Commission believes that NASA is not using state-of-the-art methodologies to estimate costs, or is misrepresenting the data it has amassed, it should document its specific concerns. Otherwise, the provenance of NASA’s cost estimates should be accepted, as no evidence has been supplied to justify overturning them.

“Technical problems” with Ares-1 are cited several times in the Summary Report, without further discussion. Knowledgeable observers in and out of NASA would disagree strongly as to

the severity of such problems. Constellation's "technical problems" are on display because actual work is being accomplished. Other options have no problems because no work is being done. There are never any technical problems on viewgraphs.

To this point, in *The Rickover Effect: How One Man Made a Difference*, Theodore Rockwell recalls a priceless observation by Adm. Hyman Rickover. When confronted with a situation in which a variety of alternative concepts were being advocated to – and around – Rickover in place of the pressurized-water reactor design he favored for the nuclear navy, Rickover noted that there were two kinds of reactors, "paper reactors"; i.e., new reactor concepts, and "real reactors". A paper reactor has the following characteristics:

- It is simple.
- It is small.
- It is cheap.
- It is lightweight.
- It can be built very quickly.
- Very little development is required; it can use off-the-shelf components.
- It is in the study phase; it is not being built now.

In contrast, a real reactor has the following characteristics:

- It is complicated.
- It is large.
- It is heavy.
- It is being built now.
- It is behind schedule.
- It requires an immense amount of development on apparently trivial items.
- It takes a long time to build because of its engineering development problems.

Does any of this sound familiar?

Finally, the Commission did not do that which would have been most valuable – rendering a clear-eyed, independent assessment of the progress and status of Constellation with respect to its ability to meet the goals which have been established in two successive NASA Authorization Acts, followed by an assessment of what would be required to get and keep that program on track. Instead, the Commission sought to formulate new options for new programs, treating these options as if their level of maturity was comparable to that of the baseline upon which NASA has been working now for more than four years. This ignores the established body of law which has guided NASA's work for the last four years and which, until and unless that body of law is changed, must serve as the common standard for any proposed alternative to Constellation as the "program of record" for the nation's existing human spaceflight program.



With the above having been said, where do we go from here? In the end that is the only important question. Let me be as clear as possible on a further point. When I noted above that the best option is to restore funding, I do not want to mislead this Committee. It is not possible to recover fully, in terms of schedule, personnel morale, and programmatic decisions, from the damage which has been done to NASA and to Constellation by reductions in funding, particularly in the last couple of years, when the program has moved into full-bore execution. Past decisions and actions are a form of sunk cost. So I do not propose to render the program somehow magically "whole" by restoring past funding cuts. That cannot be done. But NASA does know – or can shortly assess – what is necessary to get Constellation back on track with regard to the best achievable schedule, *from where we are today*, for regaining access to LEO, returning to the Moon, exploring some of the near-Earth asteroids, and eventually voyaging to Mars.

The details will, as I say, best come from NASA. However, I can suggest what I think might be the most viable alternative if we remain committed both to continuing ISS operations and to human exploration beyond LEO, yet cannot return all of the money to the NASA budget that has been removed in the last few years.

In such a case, at least in my opinion, it would be logical to delay lunar lander development in order to make progress on the other elements. I don't think it is a very good idea to try to make it "smaller" or somehow less capable in some other way. Current planning is for a crew of four on the moon. Carrying two pairs of two EVA crewmembers is very logical, for all the reasons that apply to Shuttle today. It also has the advantage of providing ample opportunities for crew from international partners.

If that rationale is accepted, then I think it makes more sense to delay the lander development than to compromise the design of a machine that will be in use for a very long time. So, the Altair lunar lander would be built when the money to do so becomes available. Ares-1 and Orion should be completed as quickly as possible to support ISS, and then Ares-5 should be built. They should not all be done in parallel; that causes them to stretch out and costs more in the long run. It makes more sense to start some elements later. In the meantime, once Ares 5 becomes available but prior to human lunar return, Orion could be used for some of the "Flexible Path" options cited by the Commission. Such options were, in fact, considered from the first during ESAS. The use of Constellation hardware for destinations that were not included in the Vision for Space Exploration (as initially stated) was a core part of our thinking during ESAS. I considered that to be a strong point of the chosen architecture – it was flexible about destinations. An Orion spacecraft that can take care of itself for six months around the moon can go a lot of other places.

I think that some variant of the approach outlined above makes the most sense going forward. It would position us as well for the future as we can be, given where we are today, unless a substantial sum of money can be allocated to the original plan for lunar return by 2020.

The Summary Report suggests inviting international partners into the critical path of program development. This is a valid alternative if we are willing to depart significantly from prior policy. Europe, Japan, or Russia could build a lunar lander just as well as could the United States. Politically and culturally, this would be a big step. I sat in front of this Committee, with a different Chairman, when former Administrator Dan Goldin was advised in very direct terms to "keep Russia off the critical path on the ISS". But, if we wanted to be more "inclusive", we could decide that the United States will develop the heavy-lift launcher and deep-space crew vehicle, but a return to the moon will depend upon international partner contributions. I personally do not favor such an approach, but it is a technically feasible option.

I would like to close with a quote from the Commission's Summary Report: "Finally, significant space achievements require continuity of support over many years. One way to ensure that no successes are achieved is to continually pull up the flowers to see if the roots are healthy. (This Committee might be accused of being part of this pattern!)"

I couldn't agree more. As I see it, the Commission didn't find anything wrong with the current program, didn't find anything safer, more reliable, cheaper or faster. The roots are healthy. So, why throw away four years and \$8 billion pulling up the flowers? Let's apply some plant nutrient and watch them grow.

This, to me, is our best option for re-affirming a stable civil space policy.

Thank you.