Testimony

of

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Hearing on the Future of Human Space Flight

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Abstract

Justification for the human space flight program is discussed in terms of the importance of U.S. leadership in this historically inevitable expansion. The need for a steady funding and a long-term commitment to the space flight enterprise is discussed. Technology hurdles and suggested intermediate milestones are identified.

Mr. Chairman:

Thank you for inviting me to appear before the committee in this rare opportunity to discuss the vision, the goals, and the future of human space flight.

Allow me to begin, if I might, with some "truth in advertising". I am an unabashed supporter of space exploration in general, and of human space flight in particular. I believe that the human space flight program is in the long run possibly the most significant activity in which our nation is engaged. For what, today, do we recall renaissance Spain, King Ferdinand, and Queen Isabella? Unless one is a professional historian, the memory which is evoked is their sponsorship of Columbus in his voyages of discovery. For what, in five hundred years, will our era be recalled? We will never know, but I believe it will be for the Apollo lunar landings if for anything at all. And this is entirely appropriate. Human expansion into space is a continuation of the ancient human imperative to explore, to exploit, to settle new territory when and as it becomes possible to do so. This imperative will surely be satisfied, by others if not by us.

We know this, if not with our logic then with our intuition. We are all the descendants of people who left known and familiar places to strike out for the risky promise of better places, in an unbroken chain going back to a small corner of east Africa. Concerning the settlement of the American West, it has been said that "the cowards never started, and the weaklings died on the way." But this has been true of every human migration; we are all the descendants of those who chose to explore and to settle new lands, and who survived the experience.

The late Carl Sagan, and others, have argued that this biological imperative is soundly rooted in evolutionary biology. The divergence of a species throughout the broadest possible environmental range is a form of insurance against a local catastrophe. Sagan argued that human expansion into the solar system is the important next step in protecting the human species from known and unknown catastrophes on a planetary scale. The fossil record which has been unearthed in recent decades certainly gives credence to this view, revealing evidence of multiple large scale "extinction events" throughout the history of life on Earth.

However, to be important is not necessarily to be urgent, and it may be argued that we have many difficult problems in greater need of immediate attention and resources than is human space flight. But even recognizing this reality, space flight is sparingly funded. In round numbers, FY2003 U.S. budget outlays were approximately

$2.1 trillion, while the U.S. population is just under 300 million, yielding an average liability of $7000 per person, or about $20 per day for each man, woman, and child in the nation. With the NASA budget at $15 B/year, the civil space program costs each person in the nation about $50/year, or less than 14 cents per day. A really robust space effort could be had for a mere twenty cents per day from each person! I spend more than that on chewing gum. We as a nation quite literally spend more on pizza than we do on space exploration. So I don't think we are overspending on space. As wealthy as the United States may be, it is certainly true that we can allocate only a very small fraction of that wealth to the development of human space flight. But we *must* allocate that fraction, and we must spend it wisely. I don't think we are doing enough of either.

"This new ocean" – to use John F. Kennedy's famous phrase – has recently become accessible to us, albeit at great cost and difficulty. But despite the difficulty, it will be explored and exploited, it will be settled, by humans. The only questions are, "Which humans?", and "When?" While the answer to the first question will eventually be "all humans", I am parochial enough to believe that those from our nation should be in the vanguard.

Much in the news lately is the budding Chinese space program, which came of age yesterday with its first manned launch. The United States required only eight years to progress from our first manned space flight to the first lunar landing, and that while simultaneously developing the technology to do it. A committed nation could now achieve such a goal much more expeditiously. How are we going to feel when one of the Apollo lunar landing flags is returned to Earth and displayed in a museum – in Beijing? Do we really want a world in which the human space flight programs of other nations are on the rise, while ours is in decline? We are the sole factor in determining whether such a future comes about. No other nation can surpass us in human space flight unless we allow it to happen.

So, recognizing that others may differ, for me the single overarching goal of human space flight is the human settlement of the solar system, and eventually beyond. I can think of no lesser purpose sufficient to justify the difficulty of the enterprise, and no greater purpose is possible.

With these thoughts in mind, I offer the following in response to the questions posed by this committee in its formal invitation to appear.

- What option should NASA pursue in human space flight?

  Accepting my premise that the proper goal of a publicly-funded space program is to enable the human settlement of the solar system, it becomes immediately clear that the relevant possibilities are few in number, and that we have not recently pursued any of them.

  The geography of the solar system shows us the way. Suitable and useful destinations for humans are limited in the near term, given technologies reasonably foreseeable in the next several generations. They include the moon, Mars, and certain near-Earth and main-belt asteroids. That's about it. Certain waypoints or "parking places" – not physical destinations but features of the orbital geography of the solar system – are also useful, including low Earth orbit (LEO), geostationary orbit (GEO), and possibly the lunar Lagrange points. We, and our grandchildren's grandchildren, will be fully and gainfully occupied learning to reach, survive in, and exploit these places to our benefit.

  It has been drolly observed that, "if God had wanted us to have a space program, he would have given us a moon", and I believe the truth underlying this witticism is correct. Development of permanent lunar bases on the moon, only three days away, will teach us much of what we need to know to press on to Mars. And in the slightly longer run, I believe the asteroids will be found to have immense value as a source of raw materials, as well as being of great scientific interest.

  So, to me, the proper sequence for exploration is the moon, then Mars, and then the asteroids. It must be recognized, of course, that any such sequence is for initial program planning only. Once begun, exploration and exploitation of the moon will continue for centuries or millennia, just as it will for Mars and beyond.

The waypoints – LEO, GEO, and others – should be developed as necessary to enable the exploration of the moon, Mars, and asteroids, and not as programmatic goals in and of themselves. For example, a LEO space station such as the present International Space Station (ISS) is of very little use in developing a lunar base, especially during the early phases of such development. Thus, in a human space flight program focused on "settling the solar system", construction of a LEO space station would not be an early priority.

Similarly, there has been considerable discussion concerning the utility of the lunar Lagrange points as transportation nodes for a lunar base. While I think the idea has considerable merit, it is merit that attaches mostly to the longer term, when a fairly robust space infrastructure has been put in place. In the early years, the best way to get to the moon is as directly as possible, and similarly for Mars.

- What is the U.S. likely to gain by pursuing this option, and why can such gains not be obtained in other way? Specifically, please describe why these gains could not be achieved by means of unmanned missions. What are the implications of the option you suggest for the future of the unmanned program?

One may search in vain for an argument justifying, in any immediate way, the danger, difficulty, and expense of human space exploration. I believe we have all heard enough about technological "spinoffs", stimulating education, maintaining the high-tech industrial base, conducting astronomical or geological research, developing space-based power systems, harvesting space resources, and so on *ad nauseam*. Such arguments are most annoying because, while they are true – the claimed benefit does exist – they are irrelevant. No thinking individual would undertake a multi-generation program of human space flight to achieve any of these objectives, or any other similar collateral benefit. Any such goal can and should be achieved more directly and efficaciously merely by allocating to it the resources judged to be necessary for its accomplishment. We do not need a human space flight program to stimulate our children's education, or for any similar reason. A more global rationale is needed for an enterprise that will occupy our attention for generations to come.

What the U.S. gains from a robust, focused program of human space exploration is the opportunity to carry the principles and values of western philosophy and culture along with the inevitable outward migration of humanity into the solar system. Is this valuable? The answer must depend on one's worldview, I suppose. But consider a map of the world today, and notice the range of nations in which English is spoken as a primary language, and in which variations on British systems of justice, politics, culture, and economics thrive today. Was the centuries-long development of the British Empire, based upon Britain's primacy in the maritime arts, a misguided use of resources? I believe not.

Consider also that Great Britain's influence, achieved through its mastery of the oceans, was not restricted merely to affairs in the colonies, the new lands. By virtue of its nautical superiority, Britain wielded a dominant influence in the Old World as well, an influence hugely out of proportion to its size and other resources.

Can America, through its mastery of human space flight, have a similar influence on the cultures and societies of the future, those yet to evolve in the solar system as well as those here on Earth? I think so, and I think our descendants will consider it to have been worth twenty cents per day.

In the process of developing and extending human space flight into the solar system, we will also collect all of the ancillary benefits mentioned above, and many more. But I cannot imagine that these benefits can be attained solely through the use of unmanned scientific and exploration spacecraft. While such efforts are incredibly valuable – and I have personally spent the majority of my career in the engineering development of unmanned space systems – it is not credible to

believe that they can substitute for human presence in the larger context that I have outlined here. Perhaps the most concise rationale on this point was provided by Norm Augustine in his 1990 "Report of the Advisory Committee on the Future of the U.S. Space Program". In that document, Mr. Augustine points out that "there *is* a difference between Hillary reaching the top of Everest and merely using a rocket to loft an instrument package to the summit". It cannot be said better, and again, I believe this difference is worth a few cents per day. Others may differ, but that is my view.

To this point, there is no inherent conflict between manned and unmanned space programs, save that deliberately promulgated by those seeking to play a difficult and ugly zero-sum game. But that is not the game at hand. In the context of a civil space program justified primarily in terms of the expansion of humanity into the solar system, it must be understood that "primarily" does not mean "entirely". Certain unmanned space systems having little connection with human space flight will be supported – as they are today – because of their inherent scientific or utilitarian value. Who today wants to return to life without weather satellites, global navigation, instantaneous worldwide communication, or high resolution overhead imaging? Similarly, that portion of our nation's scientific research devoted to using space assets to improve our understanding of Earth's environment, our solar system, and the cosmos beyond, will always, and should always, receive due attention in the allocation of resources. I personally worked, as a much younger engineer among thousands of others, on the Hubble Space Telescope, and will always be proud of having done so.

Human space flight advocates are not making a case that such programs should be deferred in favor of manned programs. On the contrary, the necessary requirements of human expansion into the solar system cannot be met without a greatly increased program of unmanned scientific exploration. This can only be seen as a "win-win" for all those involved in any aspect of space exploration. In the end, it comes down to letting robots and humans each do what they do best.

- What is your estimate of the costs of pursuing the selected option?

The cost cannot be easily estimated, because the task is so open-ended. A better way to think of the space enterprise is as an investment that will yield some benefits in the near term, but which cannot fully mature for generations. The appropriate fiscal policy for such an investment is to allocate to it an amount consistent with both its ultimate value and the sobering reality that it will be a long time before this value is returned. Our present assessment, as a nation, seems to be that the space enterprise is worth about $15 B per year, or as I indicated earlier, about 14 cents per person per day. I think we could spend a little more without wasting the money.

The nation's space program, and in particular its human space flight program, is not presently focused along the lines I have suggested here. We are burdened with a history of several decades of, in my view, misguided policy decisions, the legacy of which cannot be easily or quickly undone. For example, though I struggle to find value in the effort to match its cost, the international faith and credibility of the United States is tied, in part, to the orderly completion of the ISS. We must complete its construction, to include the original seven-man crew capability, and establish a utilization plan for the facility that returns as much value as possible. Yet, we must not mortgage our future to ISS, losing the next two decades as we have lost the last two. If no additional funding can be made available, it will be very difficult to complete ISS and, at the same time, embark on the development of those other systems that are required for a truly valuable and exciting human space flight program.

I would like to see an allocation of about $20 B per year to the U.S. civil space program. This would enable us to begin crucially needed programs to develop reusable space transportation systems, heavy lift launch, crew transfer vehicles, life support technology, and space power and propulsion systems that are needed to establish bases on the moon and Mars.

- How long will it take to achieve the specified goals of your option?

  Again, the program I have outlined is not a "goal", it is a way of life, an essentially permanent part of our nation's technical, cultural, political and, yes, budgetary landscape. We will achieve important intermediate milestones, such as a return to the moon, the first landing on Mars, and many other uplifting events. But one has only to fly over the United States from coast to coast to realize that, in a very real sense, the "settlement" of the America is hardly complete, even after five hundred years of European presence in the Americas. The settlement of the solar system can be expected to take a bit longer.

  The required time to achieve the intermediate milestones is irrevocably tied to funding constraints. If no new funding can be provided, we will spend the next several years – probably a decade – working our way out of the Space Shuttle and International Space Station dilemmas, even proceeding as expeditiously as possible. It will be difficult, likely impossible, to begin development of (for example) heavy lift launch vehicles and space nuclear power systems while restricting NASA to today's budget levels and simultaneously respecting current obligations to ISS. Yet, these technologies and others are crucial to any permanent step beyond LEO. There is a lot of ground to be made up, but with a $5 B annual funding increase for NASA, I believe one could expect to see the first lunar base within a decade.

  What is needed is a different view of spaceflight in the affairs of men and nations than we have so far seen. Space programs in the United States have so far have been just that – programs. They are justified individually, each on its own merits, and have defined goals, funding, start dates and, it is hoped, completion dates. Space activities so far have been largely episodic, when in fact they need to become, again, a way of life.

  NASA and the space community generally, whether civil or DoD, receive frequent criticism for the high cost of what we do, the cumbersome pace at which it often seems to proceed, and the not infrequent failures which occur. This may not be entirely unfair; it is my own belief that the nation is entitled to expect a higher standard of performance on space projects than has often been the case in recent years. But we in the space community – the engineers who must execute a multiyear vision one budget year at a time – are, I think, entitled to expect a higher and more consistent standard of commitment by the nation, through its policymakers, to that vision.

  As an example of the mindset I advocate, I note that the United States has a Navy, which institution in fact predates our present form of constitutional government. Even in difficult times, we do not debate whether or not the United States will continue to have a Navy. We do not debate the Navy's function; by common understanding, it is the Navy's purpose to provide mastery and control of the high seas for the benefit of the nation. We may debate ways and means of achieving this, but withdrawal from the basic enterprise would be unthinkable. So it must be with human space flight. We are not yet to that point.

- What technical hurdles must be overcome in pursuing the option, and what steps that must be taken to overcome those hurdles? Are there intermediate program goals, and when might these be achieved?

  I will comment on specific technical issues below, but before so doing I feel compelled to note that the technical challenge does not seem to me to be the biggest problem we have. We did not retreat from the moon because of technical difficulties, we did not fail to go to Mars because of technical problems, and we have not taken twenty years to put a space station in orbit because of technical matters. In each case the issues are matters of politics and leadership. Without a bipartisan, leadership-driven consensus that a vigorous space exploration program is essential to America's future, we will not have such a program, whether or not there are technical challenges to be overcome. It has been forty years since a Chief Executive has propounded such a vision, and no Congress has ever taken the initiative to do so. If the nation's leaders cannot say that space exploration is important, and why, it will not occur.

And technical challenges do exist. They include both human and engineering elements. We have considerable experience in the microgravity environment, and some practical and effective countermeasures have shown promise in minimizing bone loss, though more work is clearly needed. The most practical long-term microgravity countermeasure may well be to design our spaceships to supply artificial gravity by spinning them to generate a centrifugal force. Planetary surfaces are another matter. We have at present no clear understanding of how the human organism will respond and adapt to fractional gravitational environments such as will be experienced on the moon and Mars. The most difficult issue is likely to be that of cosmic heavy-ion radiation. The human effects of and countermeasures for heavy ion radiation, encountered in deep space but not in the LEO environment of the ISS, have received little attention thus far.

On the engineering side, the first order of business is largely to restore capabilities that we once had, and then to make them more reliable and cost effective. It may not be impossible to consider returning to the moon, or going to Mars, without a robust heavy-lift launch capability, but it is certainly silly. Our last Saturn V was launched thirty years ago, and while I do not necessarily advocate resurrecting an outdated design, this is the class of capability which is needed for the human space flight enterprise.

At the same time, much cargo (including humans) does *not* need to be launched in very large packages. We desperately need much more cost effective Earth-to-LEO transportation for payloads in the size range from a few thousand to a few tens of thousands of pounds. In my judgment, this is our most pressing need, for it controls a major portion of the cost of everything else that we do in space. Yet, no active U.S. government program of which I am aware has this as its goal.

As I have tried to indicate earlier, it is very difficult to comment on the nature and timing of intermediate program goals and milestones without reference to funding constraints.

For interplanetary flight, something more than chemical propulsion is clearly needed for other than return to the moon or, possibly, the first expeditions to Mars. Nuclear propulsion makes the most sense to me; several options are available, including both nuclear-thermal and nuclear-electric concepts. We once had an operating, ground-tested (though not flight-tested) nuclear-thermal upper stage intended for use on the Saturn V. The program was cancelled thirty years ago, when it became clear that a Mars mission was not in the nation's immediate future. Numerous nuclear fusion concepts potentially applicable to space propulsion exist, most notably those involving electrostatic confinement of the nuclear core, but none of these is receiving more than token funding. There also exist a number of promising approaches to electric propulsion, notably the Vasimir engine concept. In the long run, some form of nuclear-electric propulsion is likely to offer the best combination of efficiency and packaging capability for interplanetary flight.

- What is the implication of this option for the current human space flight program? To what degree does the current human space flight program contribute to or impede the option you suggest? What recommendations do you have for the Space Shuttle and International Space Station programs?

I have alluded above to some of the technical hurdles that we face in a commitment to a permanent program of human space exploration. Broadly, the tools necessary for this enterprise include:

- Heavy-lift launch capability, in the 100 metric ton to LEO class or greater.
- Reliable, efficient, and cost effective transportation to LEO for moderate size payloads.
- Compact space qualified nuclear power systems.
- Nuclear and nuclear-electric upper stage vehicles for application to interplanetary flight.
- Space and planetary surface habitat and human suit technology.
- Technology and systems for utilizing the *in situ* resources of the moon, Mars, and asteroids.
- Reliable and routine Earth-to-LEO crew transfer systems.

These are the things we would be working on, and would have been working on for decades, had we a consensus that the primary purpose of the nation's human space flight program was to

begin the exploration of the solar system. The fact that we are largely *not* allocating the human space flight portion of the NASA budget to these tasks illustrates more plainly than any rhetoric that our space flight programs are directed to no useful end.

I will repeat only briefly my remarks above concerning ISS; we should do what is necessary to bring the program to an orderly completion while respecting our international partnership agreements, obtaining where possible as much scientific value as we can from the enterprise while accommodating ourselves to the fact that such value is inevitably limited.

Regarding the Space Shuttle, I have previously offered my opinion to this Committee that we should move to replace this system with all deliberate speed. While the Shuttle's capabilities are extensive and varied, it has proven to be extremely expensive to use, unreliable in its logistics, and operationally fragile. It is extremely risky for the crews who fly it because, while its mission reliability is no worse than other launch vehicles, there is seldom any possibility of crew escape in the event of an anomaly. The shuttle has met none of its original goals, despite the best efforts of some of our nation's best engineers to achieve those goals. Neither NASA nor the nation as a whole saw, or could see, these problems looking forward in 1972, when the shuttle program was approved. But, three decades later, I think we must admit to ourselves that it is time to move on.

Witness Biography

Michael D. Griffin is President and Chief Operating Officer of In-Q-Tel, the independent, nonprofit venture group chartered to identify and invest in cutting-edge commercial technologies for CIA and other intelligence community applications.

Mike was previously CEO of the Magellan Systems Division of Orbital Sciences Corporation, and also served as General Manager of Orbital's Space Systems Group and as the company's Executive Vice President/Chief Technical Officer. Prior to joining Orbital, he was Senior Vice President for Program Development at Space Industries International, and General Manager of the Space Industries Division in Houston.

Mike has served as both the Chief Engineer and the Associate Administrator for Exploration at NASA, and as the Deputy for Technology of the Strategic Defense Initiative Organization. Before joining SDIO, he played a leading role in numerous space missions while employed at the Johns Hopkins Applied Physics Laboratory, the Jet Propulsion Laboratory, and Computer Sciences Corporation.

Mike holds seven degrees in the fields of Physics, Electrical Engineering, Aerospace Engineering, Civil Engineering, and Business Administration, and has been an Adjunct Professor at the George Washington University, the Johns Hopkins University, and the University of Maryland. He is the lead author of over two dozen technical papers and the textbook *Space Vehicle Design*. He is a recipient of the NASA Exceptional Achievement Medal, the AIAA Space Systems Medal, and the DoD Distinguished Public Service Medal, and is a Fellow of the AIAA and the AAS. He is also a Registered Professional Engineer in Maryland and California, and a Certified Flight Instructor with instrument and multiengine ratings.