Toward a Relevant Human Spaceflight Program

Brent Sherwood, Space Architect

Precis

On its present course, government-funded human space flight (HSF) will continue to self-marginalize its value proposition and underachieve its historic potential. For decades, the American HSF program has sought to replicate past glories rather than seeking to address needs critical to our society going forward. Consequently, HSF's value proposition is elusive, vague, and largely self-referential, and therefore remains arguable and easily sidelined.

The problem is not a limited NASA budget, nor the capabilities inherent in the Agency's laboratories and industrial suppliers. Instead the problem lies in how HSF's core purpose is framed. We perennially repeat the wrong debate: which unaffordable destination (Moon, asteroid, Mars) should be the next goal post? With the NRC's help, we might finally have the right debate: to what purpose should our 10^{10} HSF annual national investment be turned?

History

The purpose of Apollo was not to explore planets using humans. Rather, it was to upstage the Soviet Union in the hearts and minds of the world, by demonstrating cold-war technological prowess in a visible, peaceful arena. Man on the Moon was not the only option considered, but it was chosen and it succeeded. However, the Agency chartered to deliver that success, along with its contractor and political base, has ever since promulgated the self-serving meme that the purpose of HSF *is* indeed to explore planets using humans. Post Apollo, that stakeholder community clings to the von Braun blueprint: reusable shuttle, permanent space station, expedition to Mars.[1]

Our National Space Policy does not require humans to explore Mars,[2] but the blueprint is so baked into the HSF community's self-image that it has become axiomatic: even the Augustine Commission *began* its work by asserting that Mars is the ultimate goal of HSF.[3] Space is big, with few accessible bodies. When discussion fixates on choosing destinations rather than challenging purpose, debate collapses into irreconcilable factional arguments. Yet Apollo is a poor model altogether for future planning. Not one of eight Apollo-enabling conditions exists or can be recreated today.[4] This should give us pause as we wonder why Mars fails to galvanize.

Reframing the debate

The axiom that *Explore Mars* must be the ultimate goal of HSF is flawed. To create a sustainable HSF program it would be more productive to start with genuine boundary conditions and genuine societal needs, derive from them a destiny that HSF could actually fulfill, and then plan and execute a program to deliver it – whether it has to do with planets or not.

Genuine boundary conditions include available budget, appropriate roles for government, societal expectations, and achievable technology:

- **Budget** – $10[10] annually (about 2/3 of the NASA budget) is spent on HSF today, including direct program costs and the allocated costs that sustain HSF-focused Centers. Strong restorative forces keep this funding level from either shrinking or growing.
- **Role of government** – Optimally, government programs develop capabilities with widespread societal benefit but whose magnitude or risk exceeds the capacity or tolerance of private investors. Government investment in HSF can be justified either if it produces a critically needed service, catalyzes economic growth, or both.
- **Societal expectations** – Over half the world's population is younger than 30,[5] and many doubt that Apollo even happened.[6] Today's society is both more actively networked and more cynical than in the 1960s. Non-geographical frontiers like genetic engineering, nanotechnology, and artificial intelligence enjoy traction because of their evident, tangible value. Americans like having their NASA, but imagine NASA's budget as too high even without knowing what it actually is. While they still revere NASA "scientists" as deep experts, they casually assume we are boldly developing warp drive and transporters. They expect NASA to keep pace with Hollywood and to change their lives.
- **Achievable technology** – Mars is a far harder leap for today's NASA than the Moon was for Apollo's. NASA's spending power is a fraction of what it was in the 1960s, and the Agency has become a self-protective bureaucracy averse to failure-prone leaps. Technically, the sheer number of Mars-enabling technologies – almost a hundred even by HEFT's incomplete count[7] – precludes confident planning of cost or schedule runout. Mars by the mid-2030s can be declared, but cannot be guaranteed and is not likely to be delivered, even if the cost-growth patterns of Apollo, Shuttle, and ISS could be avoided.

But imagine that NASA's dream does somehow unfold as portrayed. Then we would face the unspeakable prospect, after several decades and $10[11] expended, of six civil servants (only two of them American) standing on Mars, once. Should we be surprised by the lack of general enthusiasm for this future?

Other options

We might try to justify *Explore Mars* on the promise of unforeseeable spinoffs and ineffable benefits like international high-tech collaboration and fulfillment of an "exploration imperative." Leaning on science would be risky; the dramatic discoveries being steadily made by robotic missions are likely to outstrip any potential for deep investigation by a singular, small crew of hero astronauts at one location.[8] The emperor has no clothes, and because this cannot be disguised forever, sustained support over multiple decades is unrealistic to hope for.

If there were nothing else noble for humans to do in conquering space, we would be stuck. However, there *are* alternative purposes for HSF. *Explore Mars* is only one of four potential goals, albeit the only one NASA takes seriously.[9] To first order all four would cost the same $10[11] over several decades; all could inspire the public; all would yield meaningful work for the

NASA Centers; and all would spin off advanced technologies. Yet the four options vary dramatically in both feasibility and return.

- ***Explore Mars*** – Apollo redux: extends human reach as far as possible into space. Yields the historic achievement of heroes finally setting foot on Mars. Requires ~70 specialized, breakthrough technologies. Constrained by the NASA topline budget; no opportunities for capital investment, and few openings for new companies.
- ***Accelerate Commercial Space Passenger Travel*** – Opens Earth orbit to ordinary people. Yields 10^5 people traveling into space per year, diverse orbital enterprises, and 1-hr intercontinental travel. Requires several breakthrough technologies including five-9s-reliable launch. As NACA did for air travel in the 20^{th} century, NASA would mature capabilities that catalyzed private investment in new products, companies, and industries.
- ***Enable Space Solar Power for Earth*** – Opens space resources for direct benefit on Earth, by first industrializing geostationary orbit to provide unlimited, continuous, clean electrical power to the planet. Enables non-disruptive transition to post-petroleum economy; positions U.S. as the world's provider of energy and potable water. Requires scaling up known technologies, including launch, for space macro-engineering. NASA would mature capabilities then leveraged by the private sector for full-scale implementation.
- ***Settle the Moon*** – Makes humanity a two-planet species. Yields 10^4 citizens raising families, mining minerals for Earth, and supporting lunar tourism. Requires diverse technologies across the spectrum of human living, yielding many spinoffs for life on Earth. Onramps for diverse commercial enterprises, albeit likely with slow growth.

In analyzing and comparing the options, several points are key:

- **HSF ≠ exploration** – Perhaps an important metric for human space flight is actually flying people in space. Decoupling HSF from "exploration" would lead to flying more people, in ways that contribute to society directly, extensively, and fast. Of the four options, *Space Passenger Travel* flies the most people; *Explore Mars* flies the fewest.
- **Mars and the Moon are very different** – Only the Moon can be settled in a way that matters to Earth's economy. Spinoffs from enabling lunar civilization would reach far deeper into the lives of ordinary people than would spinoffs from a Mars expedition.
- **NASA budget as a catalyst** – The only way HSF can actually yield economic growth is by attracting private capital *in addition to* the NASA budget. *Explore Mars* cannot do this. Of the four options, *Space Solar Power* and *Settle the Moon* have the greatest potential to generate new wealth.
- **Technology decisions bind us for decades** – The technology investments required for each option are distinct and largely not transferable, so investing to enable one actually disables the others for years.[10] The type of launch is fundamental – five-9s reliablility for passengers, or very high rate "green" cargo launch at the lowest possible cost for space solar power, or a contemporary Saturn-V for exploration – as are many other investment choices.
- **First things first** – NASA cannot pursue all four options simultaneously with only $\$10^{10}$/year, and the sequence matters greatly because of technology precedence. *Explore Mars* is the last step of a sensible roadmap, not the first.

A roadmap that works

Figure 1 shows a straightforward roadmap that integrates the four options in a practical, implementable way. In the 20th century, government investment by NASA and its international partners developed a core set of capabilities that enable both HSF transportation and orbital habitation (left, bottom). Now, early in the 21st century, capitalists including Elon Musk and Bob Bigelow are leveraging those investments (top). As commercial transportation and habitation capabilities come together, an orbital passenger travel market can begin to develop, leading eventually to resort destinations overflying our world. Were NASA to invest to accelerate this industry (e.g., via higher-reliability reusable launch, big windows, food production, rotating artificial gravity) it would grow much faster.[11]

However, NASA presently plans instead to expand HSF operations throughout cis-lunar space, with SLS and Orion (center, bottom). Yet even here there is another fork: rather than attempting the "bridge too far" of directly leaping out deep into the solar system (right, bottom), NASA could invest to demonstrate routine human operations in geostationary orbit and practical end-to-end provision of power to Earth. Were it to do so, private capital could then be attracted into public-private partnerships that developed industrial scale power utilities that would buy their space transportation, habitation, and operations services from the ready commercial market (center, top).[12] By opening a future of unlimited energy, NASA could define the 21st century.

Finally, on the foundation of robust in-space services, extensive human space traffic, and a power-rich operating environment, and with space flight deeply embedded in the fabric of global society, NASA and its partners would be positioned to open the Moon to settlement and the rest of the solar system to human exploration (right).

The point of this roadmap is that, ironically, non-exploration HSF options would build a more solid basis for achieving the traditional NASA vision of humans on planets than can any amount of pleading today. The right question isn't how NASA can convince disinterested people to support its effete goal, but rather, "For what type of society would sending humans to Mars be a natural act, and how can we grow into being that type of society?"

Without question, adopting such a practical roadmap would require two conceptual shifts, both painful to the status quo: atypical patience; and willingness to break the false equivalence of HSF and exploration. Patience may be enforced anyway; 40 years of repeated, impatient efforts to make a Mars initiative "stick" have proven ineffective. But as long as our government-funded HSF program limits itself to a prosaic vision of just exploring planets, it will lose out on a far richer potential to pivot American and human history, and continue instead to suffer increasing irrelevance to society's biggest challenges.

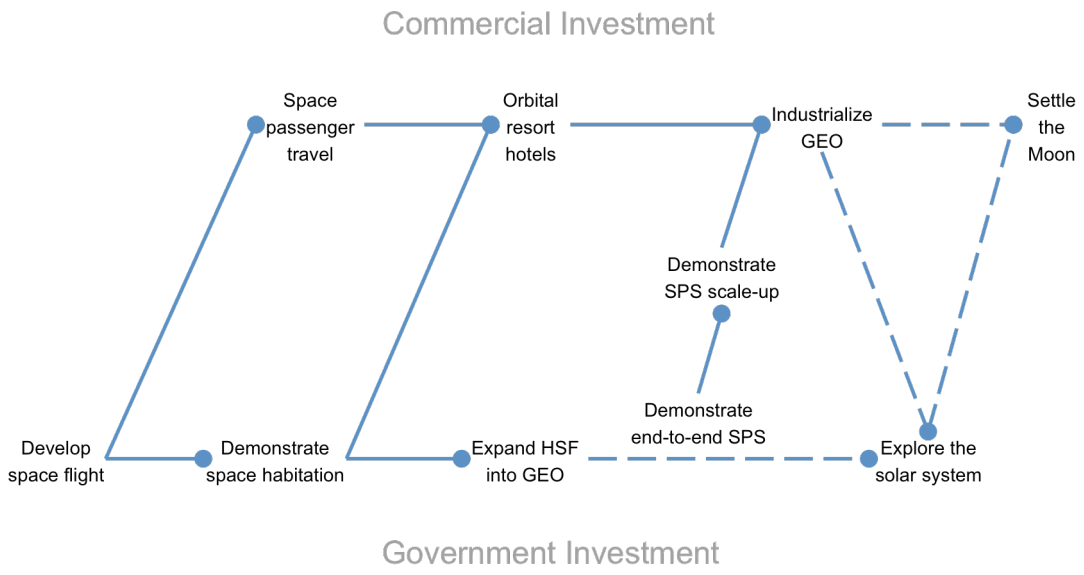

Figure 1. A practical human space flight roadmap would be centrally relevant to 21st century needs, broad-minded in accepting non-exploration goals, and patient in reaching out to the planets.

References

[1] Von Braun, W., Das MarsProjekt, 1948. Reprinted as The Mars Project, University of Illinois Press, 1991.

[2] National Space Policy of the United States of America, June 28, 2010. U.S. Printing Office.

[3] Augustine, N., et al., Review of U.S. Human Spaceflight Plans Committee, "Seeking a Human Spaceflight Program Worthy of a Great Nation," NASA, Washington, DC, Oct. 2009.

[4] Sherwood, B. What's the Big Idea? Seeking to Top Apollo. IAC-12.D3.1.6, 63rd International Astronautical Congress, Naples, Italy, October 2012.

[5] U.S. Census Bureau (Qualman, E., Over 50% of the World's Population is Under 30, in Socialnomics, http://www.socialnomics.net/2010/04/13/over-50-of-the-worlds-population-is-under-30-social-media-on-the-rise/ accessed August 24, 2012.)

[6] The Telegraph, July 17, 2009. http://www.telegraph.co.uk/science/space/5851435/Apollo-11-hoax-one-in-four-people-do-not-believe-in-moon-landing.html accessed August 24, 2012.

[7] Muirhead, B., Sherwood, B., Olson, J., Human Exploration Framework Team: Strategy and Status. Institute of Electrical and Electronics Engineers, IEEE-1759, 978-1-4244-7351-9/11, Big Sky, Montana, March 5-12, 2011.

[8] Sherwood, B., Mars: on the path or in the way? GLEX-2012.07.4x12239, Global Exploration Conference, International Academy of Astronautics, Washington, D.C., May 2012.

[9] Sherwood, B., Comparing future options for human space flight, Acta Astronautica 69 (2011) 346–353. (61st International Astronautical Congress, Prague, Czech Republic, IAC-10-E5.3.2, Sep. 29, 2010.)

[10] Sherwood, B., Technology Investment Agendas to Expand Human Space Futures, AIAA 2012-5131, Proceedings of the AIAA Space 2012 Conference and Exposition, Pasadena, California, September 2012.

[11] Sherwood, B. and Fowler, R., Feasibility of Commercial Resort Hotels in Low Earth Orbit. *Space: A Call for Action*, Proceedings of the 10th Annual International Space Development Conference, eds. Robert C. Blackledge, Carol Luckhardt Redfield, and Steven B. Seida, 1991, 404p, ISBN 0-912183-05-5, International Space Development Conference, 1991.

[12] Sherwood, B., Space Architecture for Industrial-Scale Space Solar Power. AIAA 2012-3574, 42nd International Conference on Environmental Systems, July 2012, San Diego.