AN INTEGRATED SCIENTIFIC AND SOCIAL CASE FOR HUMAN SPACE EXPLORATION

A White Paper submitted to the US National Academies Committee on Human Spaceflight

by

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Abstract
Human spaceflight has the potential to advance human knowledge in a number of areas simultaneously, including materials science, life sciences (including human physiology and medicine), astronomy, and planetary science. Moreover, the benefits of human space exploration extend to a wide array of potential economic, industrial, political, educational, and cultural benefits. These benefits will be especially strong within the context of a global space exploration programme such as envisaged by the Global Exploration Strategy.

1. Introduction

Human space exploration has the potential to confer a wide range of scientific, technological, economic, political, and cultural benefits on society. All of these multiple factors need to be taken into account to appreciate the full strength of the scientific and social case for public investment in human space activities.

2. Scientific benefits of human space exploration

A full assessment of the scientific case for human space exploration requires careful consideration of at least three separate research fields: microgravity, space astronomy, and planetary science, as discussed below:

2.1 Microgravity Research

The microgravity environment of low Earth orbit provides unique opportunities for research in the life sciences (including human physiology and medicine), materials science, and fundamental physics (see [1,2] for comprehensive reviews). Note that the space life sciences, and especially human physiology and medicine (which may yield medical benefits here on Earth), absolutely require people in space because people often form the experimental subjects for this research.

2.2 Astronomy

The five successful servicing missions to the Hubble Space Telescope clearly showed that access to a human spaceflight infrastructure can greatly increase the lifetime, and enhance the productivity, of space-based astronomical instruments [3]. In addition, as noted by another National Academies' Report [4] the development of a human spaceflight infrastructure sufficient to return humans to the Moon would enable a wide range of ambitious astronomy missions, including large space-based telescopes to study planets of other stars and radio telescopes on the lunar far-side to study the earliest evolution of the Universe [5].

2.3 Planetary Science

A human spaceflight infrastructure capable of returning humans to the surface of the Moon, exploring asteroids, and eventually sending people to Mars, would have multiple scientific benefits [e.g. 6-8] including:

(1) More intelligent and efficient collection of samples from a more diverse range of localities, and over wider geographical areas, than is practical robotically. The Apollo experience (especially when compared with the *Luna* robotic sample return missions and the *in situ* analyses performed by the Mars Exploration Rovers) indicates that astronauts, when suitably equipped with the means of surface mobility, are very efficient at this task [8]. Indeed, one of the major, but often unspoken, benefits of human planetary exploration is that, because the astronauts have to return to Earth, a large quantity of geological samples can be returned with them.

(2) Facilitation of landing, operating, and maintaining more massive and complex

geophysical and other scientific equipment than is likely to be feasible robotically. Because human missions, by definition, have to land a lot of mass on planetary surfaces, the additional marginal cost of landing massive or bulky scientific equipment is relatively modest (as the range of equipment deployed by the Apollo missions clearly demonstrated [9]), and, as demonstrated by both Apollo and the HST servicing missions, human beings are uniquely capable of maintaining and 'troubleshooting' problems with complex equipment at risk of failure. Examples of scientific equipment that would benefit from a human presence on planetary surfaces include, but are not limited to, long-range surface rovers, drilling equipment, and sophisticated geophysical and astronomical instruments.

(3) Increased opportunities for serendipitous discoveries – human beings are unique in their ability to recognize new observations or phenomena to be of importance, even if not anticipated in advance.

The very strong, scientific benefits of renewed human exploration of the Moon are discussed in [10,11] and references cited therein. Similar arguments apply to the exploration of Mars. The scientific case for the human exploration of asteroids is less clear-cut -- the benefits of human exploration scale with the complexity of the objects being explored, and asteroids are relatively simple geological bodies (although some benefits of human exploration can still be identified [12,13]).

3. Societal and cultural benefits of human space exploration

Despite the strength of the scientific arguments for human space exploration outlined above, it is important to realise that science is only one thread in a much larger overall case for human spaceflight. These other, largely societal, threads are discussed in more detail in [14,15], and include:

- Economic benefits. These include enhanced employment in key industries, and the resulting positive multiplier effect on the wider economy [16], as well stimulating the development of new skills and innovative technologies likely to have wider applications.
- Educational benefits. These relate particularly to the inspiration of young people to take an interest in science and engineering, although they extend to the entire population. Sagan [17] put it well: "Exploratory spaceflight puts scientific ideas, scientific thinking, and scientific vocabulary in the public eye. It elevates the general level of intellectual inquiry."
- Geopolitical benefits. These arise out of the opportunities for, and encouragement of, peaceful cooperation between nations in a challenging and high-profile activity. These benefits are explicitly recognized by the Global Exploration Strategy [15], which was approved by 14 of the world's space agencies (including NASA) in 2007.
- Cultural benefits, including the inspiration of art, literature and philosophy, resulting from the enrichment of our world view that must inevitably follow from expanding the horizons of human experience.

4. Response to specific questions asked by the Committee

4.1 What are the important benefits provided to the United States and other countries by human spaceflight endeavors?

These are benefits discussed in detail in the sections above and in the references cited therein. From a UK perspective, we note that in 2005 the Royal Astronomical Society commissioned a special study to investigate the scientific and other benefits of human space exploration [18], which concluded that the overall case was compelling and recommended increased UK involvement in human space exploration. We stress that these benefits would be maximized in the context of a truly international space programme, such as envisaged by the Global Exploration Strategy [15] and the Global Exploration Roadmap [19] that has been developed from it. Such international collaboration was explicitly recommended in the Augustine Committee Review of US Human Spaceflight Plans [20] which noted that "*The U.S. can lead a bold new international effort in the human exploration of space. If international partners are actively engaged, including on the "critical path" to success, there could be substantial benefit to foreign relations, and more overall resources could become available*."

4.2 What are the greatest challenges to sustaining a U.S. government program in human spaceflight?

The greatest challenge appears to be a lack of political vision and leadership, and an inability to stick to a course of action once decided upon. Despite the Augustine Review [20], we are not aware of any well-thought-out reason for the cancellation of the Vision for Space Exploration which, had it been allowed to continue, would have ensured that the US regained leadership in space exploration. This in turn has caused a lack of momentum behind space exploration elsewhere in the world, especially in Europe. There needs to be a decoupling space policy and the political agenda set by changes of administration -- the long term nature of developing space projects means that policy needs to outlive a four-year Presidential term. Our preferred solution would be for the US to fully commit itself to play a leading role in an international space exploration programme such as envisaged by the Global Exploration Strategy [15] and Roadmap [19]. Such international commitments may act to help stabilize US space policy.

4.3 What are the ramifications and what would the nation and world lose if the United States terminated NASA's human spaceflight program?

Clearly, the ramifications of NASA terminating its human spaceflight programme would be that the US and the world would not reap the scientific and societal benefits outlined above. This would be a scientific, educational, and cultural catastrophe, and a dark day for the human race.

5. Conclusions

Human spaceflight has the potential to advance human knowledge in a number of areas simultaneously, including materials science, life sciences (including human physiology and medicine), astronomy, and planetary science. Moreover, the benefits of human space exploration extend to a wide array of potential economic, industrial, political, educational, and cultural benefits. Any responsibly formulated public space policy must take a holistic view, and weigh the totality of the scientific and non-scientific arguments together, before deciding whether or not an investment in human spaceflight is worthwhile. It is our view that collectively these benefits make a compelling case for human space exploration, and that these benefits will be especially strong within the context of a global space exploration programme such as envisaged by the Global Exploration Strategy [15].

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