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Humans to Mars: A feasibility and cost–benefit analysis☆

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Abstract

Mars is a compelling astrobiological target, and a human mission would provide an opportunity to collect immense amounts of scientific data. Exploration alone, however, cannot justify the increased risk. Instead, three factors drive a human mission: economics, education, and exploration. A human mission has a unique potential to inspire the next generation of young people to enter critically needed science and engineering disciplines. A mission is economically feasible, and the research and development program put in place for a human mission would propel growth in related high-technology industries. The main hurdles are human physiological responses to 1–2 years of radiation and microgravity exposure. However, enabling technologies are sufficiently mature in these areas that they can be developed within a few decade timescale. Hence, the decision of whether or not to undertake a human mission to Mars is a political decision, and thus, educational and economic benefits are the crucial factors.

Keywords: Mars; Human; Mission; Feasibility; Technical; Political

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1. Introduction

In the past decade, we have monitored the Martian weather, constructed a geologic history, are presently characterizing the radiation environment [1], and have learned that water ice is likely to be present underground [2]. Presently, NASA's Mars exploration program includes orbiters, rovers, and in the distant future, a sample return mission. However, we consider a new direction for Mars exploration: preparation for a *human* mission.

As a result of our analysis of the mission's technical and political feasibility, the 2002 Astrobiology Academy proposes that NASA adopt a human mission to Mars as a clear and articulated goal of the agency. Since the 1960s, NASA's paradigm has shifted from destination-focused missions, i.e. "We will put a man on the Moon", to research-driven goals, including space-based monitoring of Earth and the study of life in extreme environments. The Astrobiology Academy advocates a return to a more mission-centric NASA, namely a human mission to Mars, driven by scientific objectives. By coupling science to a human Mars mission, the United States will create a program of exploration that excites the world and is an investment, not only in basic scientific knowledge, but also in strengthening the global economy and creating technologies that improve life around the world.

Below we present a rationale for the choice of a human mission to Mars. Of all the world's space agencies, NASA is the one with the most mission experience; presently, it is the one most capable of initiating a human mission to Mars. For this reason, our analysis focuses on those factors which will enable NASA to undertake such a mission. We examine the state of science and engineering education in the US today, using reports from the National Science Foundation and Congressional commissions, and investigate the effects that a human mission to Mars would have on the science and engineering disciplines. We explore the likely costs of a human mission to Mars in the context of other federal expenditures. The extent of the research and development initiative that would be needed and "spinoff" technologies that might emerge from a human mission are identified. Throughout, we assess the advantages and disadvantages of going to Mars, focusing not only on the science benefits of a human mission, but on broader societal implications.

2. Exploration

2.1. Why Mars?

Mars presents a feasible destination by virtue of its relative proximity to Earth and its analogous surface conditions. It has neither the crushing gravity nor the noxious atmosphere that make human exploration of other solar system bodies all but impossible. Furthermore, Mars is a compelling target that is both scientifically interesting and appealing to the public at large. Since earliest Greek mythology, Mars has intrigued humans and continues to do so as evidenced by numerous recent "pop-culture" movies and books. Four decades of US and Russian robotic exploration have led us to understand that Mars, at least in the past, was a planet not very different from our own.

The robotic science program has focused on understanding Mars' geologic and climatic past, especially understanding why it diverged from that of Earth. The current strategy of NASA Mars exploration is "Follow the Water". Liquid water is essential to living organisms, and the history of a planet's water is used to assess paleohabitability. We are relatively certain that Mars' climate several billion years ago was warm enough that liquid water would have existed on the surface (e.g. [3 and 4]). This may have been the case even within the past few million years due to periodic obliquity changes in the orientation of Mars' axis [5]. Recent Mars Global Surveyor and Mars Odyssey data have shown that liquid water may be present ephemerally on the surface today as discharge into gullies [6] or meltwater in snowpacks [7]. Frozen water has also been found in the top one meter of soil at abundances of up to 35% [1].

On Earth over the past several decades, researchers of life in extreme environments have found microbes growing in quite inhospitable conditions, indeed, almost anywhere that liquid water is present [8]. Coupled with what we now know of the abundance of water on Mars, this suggests that life was, and is, possible on Mars. Additionally, the study of Mars habitability helps us to answer the fundamental questions "Where did we come from?" and "Are we alone?" and to understand better those factors shaping the history of life on our own planet. Mars is then an ideal target for NASA exploration.