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Human Exploration using Real-Time Robotic Operations (HERRO): A space exploration strategy for the 21st century ☆

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ABSTRACT

This paper presents an exploration strategy for human missions beyond Low Earth Orbit (LEO) and the Moon that combines the best features of human and robotic spaceflight. This "Human Exploration using Real-time Robotic Operations" (HERRO) strategy refrains from placing humans on the surfaces of the Moon and Mars in the near-term. Rather, it focuses on sending piloted spacecraft and crews into orbit around Mars and other exploration targets of interest, and conducting astronaut exploration of the surfaces using telerobots and remotely-controlled systems. By eliminating the significant communications delay or "latency" with Earth due to the speed of light limit, teleoperation provides scientists real-time control of rovers and other sophisticated instruments. This in effect gives them a "virtual presence" on planetary surfaces, and thus expands the scientific return at these destinations. HERRO mitigates several of the major issues that have hindered the progress of human spaceflight beyond Low Earth Orbit (LEO) by: (1) broadening the range of destinations for near-term human missions; (2) reducing cost and risk through less complexity and fewer man-rated elements; (3) offering benefits of human-equivalent in-situ cognition, decision-making and field-work on planetary bodies; (4) providing a simpler approach to returning samples from Mars and planetary surfaces; and (5) facilitating opportunities for international collaboration through contribution of diverse robotic systems. HERRO provides a firm justification for human spaceflight—one that expands the near-term capabilities of scientific exploration while providing the space transportation infrastructure needed for eventual human landings in the future.

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1. Introduction

During the Apollo era, NASA's approach to space exploration settled into two distinct paths that have defined the US space program to this day [1]. One path sees the extension of human presence into the solar system–regardless of whether it is done for science, economic development, national prestige or sheer destiny–as the overarching goal. It has been dominated by an intense desire to return humans to the Moon and ultimately to establish a foothold on Mars. This has been the long-term goal for human spaceflight ever since the days of Wernher von Braun. Most recently, it served as the basis for President Bush's 2004 "Vision for Space Exploration" [2].

The other path embraces robotic, unmanned missions as a more practical, cost-effective way of exploring space. This view has been bolstered by the tremendous success of robotic missions (e.g., Voyager, Galileo, Cassini, Hubble), and their unprecedented contributions to our

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understanding of the universe. Although many advocates of this path recognize the potential value of hands-on field research on the surfaces of other worlds, they see human spaceflight as being too difficult, and more importantly, as too expensive for scientific exploration [3].

Now, more than 50 years after the start of the space age, we face a dilemma. Human spaceflight has become repetitious and routine, bound to the confines of Low Earth Orbit (LEO). The earlier dreams of sending astronauts back to the Moon and onto Mars have been eclipsed by the practicalities of limited national budgets and other challenges. In the meantime, robotic science has continued its forward march, every year ushering in a host of new discoveries and insights into the universe. Most importantly, it has done this on a budget less than that of human spaceflight.

At this juncture, it is reasonable to ask if human spaceflight within the context of space exploration still makes sense? If the answer is yes, then its justification should rest on a rationale that provides clear and immediate benefits. It should also be practicable within realistic budget constraints and a political environment that would probably not sustain a large-scale national program like Apollo.

This paper discusses HERRO, an exploration strategy that makes human spaceflight relevant to scientific exploration [4,5]. In addition to expanding near-term capabilities of space science, HERRO gradually builds the capability to conduct deeper forays into interplanetary space by focusing on development of crewed in-space transportation systems, which will eventually be needed for human missions to any planetary surface.

The paper first outlines the main challenges for human spaceflight, especially for missions beyond LEO. It then discusses HERRO, and how it could overcome these challenges, while providing considerable benefits to space science. The paper concludes by summarizing how HERRO could lead to more active support of crewed endeavors beyond LEO, thus ushering in a new era of human exploration for the 21st Century.

2. Challenges in achieving a sustainable human exploration strategy

2.1. Other destinations

The conventional strategy for human exploration is illustrated in Fig. 1. It is characterized by a methodical "lily pad" expansion of humankind into the solar system. It begins with the return of humans to the Moon, and then uses the Moon as a site for proving out new technologies or as a permanent outpost for settlement and expansion. The next major jump is Mars, starting with long-duration surface missions, followed eventually by establishment of a base and permanent settlement. Missions to other destinations, such as Lagrange Points and Near Earth Objects (NEOs), have been considered, but only as steps on a path leading to the Moon and Mars.

This "lily pad" view has become less dominant over the last 20 years due to the recognition that other destinations could serve as viable targets for human activities in space [6,7]. One with significant potential is space servicing [8]. The value of space servicing was first demonstrated during the Space Shuttle era with repair of the Hubble Space Telescope. There is interest in continuing this type of work on observatories and high-value assets in the future. Unlike Hubble, many of these assets will reside at Lagrange Points, regions of gravitational-dynamic stability in the vicinity of cislunar space and Earth's orbit about the Sun (Fig. 2).

Since the Apollo era, much has been learned about NEOs. The number of known NEOs (~6800 in 2010) continues to grow every year. Many in the spaceflight community feel that human exploration should focus on these planetary bodies, since these objects could represent an easier, more realistic first step for humans beyond Earth orbit [9]. From a scientific standpoint, these objects could yield new insights into the evolution and structure of the solar system. They could also contain raw material that could facilitate establishing a space-based manufacturing economy in the future.

Often included in the advocacy for NEO exploration are the Martian moons, Phobos and Deimos. As shown in Fig. 3, they are close in size to some large NEOs, and are hypothesized to be captured Mars-crossing asteroids. These bodies are in close vicinity to Mars and represent excellent staging points for exploration and eventual missions to the surface. The moons are also interesting for their science value, and could harbor water and other utilizable resources [10].

The advent of these alternative destinations has enriched the human spaceflight debate, but has diminished the chances of obtaining a consensus for a single path forward. Some people have argued that a consensus is not needed, and that, at least in the case of the US, it is the leader of the nation's responsibility to select a focus.

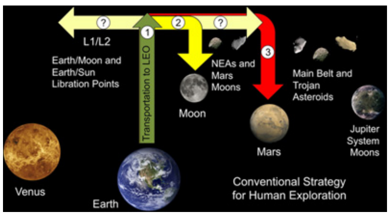

Fig. 1. Conventional strategy for Human Exploration (Not to Scale).

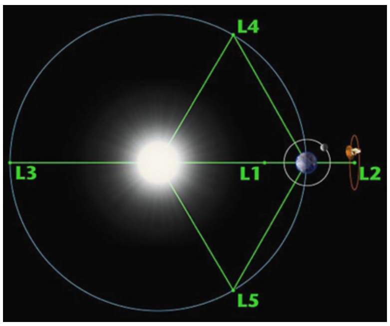

Fig. 2. Sun–Earth (S–E) Lagrange Points (Not to Scale).