A Vision for the Exploration of Mars: Robotic Precursors Followed by Humans to Mars Orbit in 2033.

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The reformulation of the Mars program gives NASA a rare opportunity to deliver a credible vision in which humans, robots, and advancements in information technology combine to open the deep space frontier to Mars.

The questions to be pursued at Mars are as fundamental as "*Are we alone*?". President Obama presented his view of this larger challenge to NASA and the US in a speech on 15 April 2010 by declaring: *"Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space. So we'll start -- we'll start by sending astronauts to an asteroid for the first time in history. By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow."*

There is a broad challenge in the reformulation of the Mars exploration program that truly sets the stage for: ' *a strategic collaboration between the Science Mission Directorate, the Human Exploration and Operations Mission Directorate and the Office of the Chief Technologist, for the next several decades of exploring Mars'.* Any strategy that links all three challenge areas listed into a true long term strategic program necessitates discussion. NASA's SMD and HEOMD should accept the President's challenge and vision by developing an integrated program that will enable a human expedition to Mars orbit in 2033 with the goal of returning samples[1] suitable for addressing the question of whether life exists or ever existed on Mars

Figure 1 –An integrated plan can begin with robotic missions that lead to an orbital human mission that enables the return of samples.

Building on existing commitments and developments within SMD, a clear, well-defined, milestone-driven course of exploration will be established starting with:

- The flight of the *Mars Science Laboratory* (MSL) in 2011 as an the essential first step toward discovering which martian surface materials must be cached and later returned to Earth for the purpose of understanding the biological potential of Mars [SMD; see 1].
- The development of the SLS and MPCV to carry humans into space with the resources required to ultimately implement a mission to Mars orbit [HEOMD].
- The flight of *OSIRIS-Rex* to a near Earth asteroid in 2016 as the essential robotic precursor to inform engineers and human spaceflight experts on how human explorers may or may not be able to interact with such small bodies [SMD].
- The implementation of a Mars context orbiter, in 2018 (or soon thereafter as budgets allow) to expand reconnaissance that might enable the National Academy of Sciences recommendation for return of surface samples from Mars as a science priority for NASA [SMD possibly with HEOMD].
- The development of human spaceflight activities and excursions beyond low Earth orbit during the 2020's, with capabilities well-suited for longer-term deep space habitation, transits, and telerobotic operations [HEOMD].
- The commitment by the early 2020's by NASA and its partners to implement a human mission to Mars orbit for the purpose of returning compelling surface samples suitable for pursuing the question "Are We Alone?" [HEOMD, SMD, etc.].
- The necessary robotic precursors to Mars by the late 2020's to ensure that multiple samples can be available for rendezvous and pickup by a 2033 human mission to Mars orbit [SMD].
- The development of a teleoperated surface robot for sampling recently-exposed martian materials in challenging settings (cliffs, gullies, layers) for operation by the crew of the 2033 mission with a suitable Mars Ascent Vehicle for transfer of sam-

ples to Mars orbit [HEOMD and SMD]. Low-latency teleoperation of robots from Mars Orbit would greatly enhance our ability to access high-value samples.

These activities leverage a SMD/HEOMD partnership and present a tangible set of milestones with high impact and benefit to the US and are optimized to sustain forward progress toward a common goal, as per the vision first stated by the President in April 2010.With a specific date (2033), goal (humans to Mars orbit and back to Earth), and compelling set of pursuits (return of high-value samples), NASA and its partners would embark on a tangible "quest" that would provide the nation and its leadership with coherent management tools to enable the vision.

The goal is consistent with the US National Space Policy and with the President's 2010 speech and presents a natural evolution from long-standing NASA investments in robotic exploration of Mars as well as in human spaceflight. It naturally integrates the effectiveness of SMD's robotic scientific exploration with new technology (OCT) and human spaceflight (HEOMD's SLS with MPCV and other elements). It offers "off-ramps" as stepping-stones toward the 2033 human expedition to the Mars system with opportunities for human exploration beyond low Earth orbit in the 2020's, including potential visits to geosynchronous orbit, lunar orbit, or rendezvous with an accessible near Earth object (NEO). It ties National Academy of Sciences recommendations[1] (Mars sample return) to human spaceflight with the potential to optimize and extend the scope of what an all-robotic program can do by orders of magnitude, thanks to the capabilities that human spaceflight systems would bring (i.e., larger mass, operations, telecommunications, and performance requirements associated with people in space). Ultimately, sending humans to Mars is an understandable, achievable, and worthy goal for NASA which connects to public perceptions of what NASA should be doing, but at a price-tag consistent with realistic investments over the next 20-25 years.

As with the voyage of Apollo 8 in December 1968 and with the series of Hubble servicing missions, the Humans to Mars Orbit concept (Fig. 2) offers compelling benefits across the Agency, as well as for industry and international partners. Even in a de minimus implementation, such a mission would greatly exploit the emerging synergism between humans and robots.

Figure 2 – Teleoperation of Mars assets from a suitable Mars orbit can extend the human/robotic partnership in pursuit of Mars science, including return of samples.

Whatever the specific implementation, a Humans to Mars Orbit expedition will extend the human/robotic partnership developed most recently in the construction of the ISS and in HST servicing to an exciting deep space destination (Mars) where high-value human activities are required. By connecting high-priority science recommendations (samples from Mars) with both human and robotic spaceflight at NASA, the Agency will once again present a unifying vision for where it is going that will offer the public, Congress, and all stakeholders with a concrete roadmap for NASA for the next 25 years.

By developing, nurturing, and sustaining the partnership between SMD and HEOMD over the next two decades, the NASA that will emerge will be poised to go to the obvious, albeit challenging, next step – human landings on Mars perhaps by the 2040's. No such voyage will be more dangerous and awe-inspiring than people on the martian surface, but without the step of humans to Mars orbit with supporting robotics, the confidence and technological capability to undertake such an endeavor will not exist.

An integrated program which culminates in humans reaching Mars orbit in 2033 offers us a clear destination, a timeline, a sense of urgency, and clearly identifies the return on investment in terms of worthwhile exploration achievements and opportunities for far-reaching scientific discoveries . The Mars program reformulation allows us to consider what may be viewed by history as one of the the greatest expeditions of the 21st century: humans to Mars by 2033 and back home to Earth with an invaluable cargo.

References: [1] Visions and Voyages for Planetary Science in the Decade 2013 - 2022, NRC Committee on the Planetary Science Decadal Survey Space Studies Board, 2011