Human Exploration of Mars: Cost Reality.

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Introduction: NASA and Disney have been actively selling to the public the notion that Mars human exploration is in the near future. [1] Extremely optimistic cost numbers have been used to justify a human mission. The actual cost of a "footprint" mission is likely to be about $1T in real year $. If 50% of the current NASA budget were to be spent on it, it will take 100 years to implement. Such a program is totally unrealistic. A realistic fiscal plan is needed to carry humans to Mars.

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Is $1T the right number?: In the 80's, the number was $400B then in ~1990 Mars Direct came forward at $50B. For a footprint mission, a simple extrapolation from a Mars Sample Return mission study that brought back a few kilograms from Mars gives about $600M.[2] As NASA is ultra-conservative in respecting human safety, the $600B is likely to increase by many times.

We would all like to see a much lower number but the true costs will not be known until detailed designs are initiated. Mars human exploration (HE) has been extensively studied over the years [3]. Only when a comprehensive Phase A design has been completed will we know the initial estimate and the serious technology issues. At the present time the strategic knowledge gap list is large and the true cost of closing the gaps is unknown [4].

NASA history: We were able to go to the Moon, so why does it cost so much more today? In the post-war/Cold-War years test pilots had a low life expectancy, so our test pilots/astronauts were willing to take a chance flying in a delicate tin can. The winding down of Cold-War rivalries between the U.S. and former Soviet Union, combined with the losses of the Challenger and Columbia space shuttles have made NASA rather sensitive to the loss of life. In addition, other technical failures have increased the oversight costs. While future astronauts may say they would be happy with even a one-way trip to Mars, NASA, and the U.S. government, would never condone such risk.

Footprint Mission: For the sake of "bounding the box", the simplest mission is to send one or two people to the surface of Mars, place a footprint, and return to Earth safely. Orbital mechanics make even this "simple" proposition challenging from a reliability and expendables (air, food, and water) standpoint. Radiation shielding requires both some mitigation of long-term galactic cosmic ray exposure as well as an astronaut protection vault with sufficient particle absorption to protect against worse case solar energetic particles (SEPs) [5]. The size and mass of such a vault and the mean time duration significant event need to be traded against implications for system mass and loss-of-mission risk. This item alone is a significant mission-design driver, as it dictates how much infrastructure mass must be carried in transit as well as emplaced on the surface for such an eventuality. Of equal importance is protecting the electronics against unrecoverable radiation damage to ensure safe return. Ultimately the coupled issues of mission design, propulsion implementation, and radiation protection drive the initial mass in low-Earth orbit (IMLEO) and, thus, launcher requirements and mission cost.

Would such a footprint mission meet the public expectations?

Real Human Mars Exploration: Potential "action" activities for Humans on Mars include:

View Valles Marineris from the rim,
Travel down the bottom of Valles Marineris,
Climb Olympus Mons,
Watch polar avalanches,
Experience springtime at the poles,
Go caving,
Mine for water,
Look for fossils,
Build a radiation-protected habitat, and
Conduct scientific research

Many studies have shown the way to accomplish Mars exploration: Things like the Mars up/down escalators are essential for rapid transit times [6], yet consideration of the required propulsion requirements tend to rule such possibilities out. Indeed closing an engineering solution with conjunction-class missions, requiring ~3 years for the round-trip and over an Earth year in the Mars system, already strains the foreseeable state-of-the art for the next several decades.

Technology Issues: Sufficient radiation shielding is required for transit, Mars orbit, and operations on Mars surface.

Minimum trip times are possible using the up/down escalator orbits, but these, as well as opposition-class missions are not credible [7] without at least nuclear thermal propulsion (NTP) – abandoned by the U.S. in 1972 [8].

Pinpoint landings of large masses remains to be developed.

Fuel production at Mars from the CO_2 atmosphere and water sources (in situ resource utilization – ISRU) may enable simpler surface transport systems and return liftoff, but industrial production levels – hundreds of kg to metric tons of materials must be producible reliably and autonomously.
Failsafe, maximal food, water, and air recycling are required to minimize IMLEO and mission complexity.
Long-term, i.e., mufti-year storage of cryogens, notably LH2, is required for credible chemical or nuclear propulsion

Mission timeline: The "Real Mars Human Exploration" program could consist of three phases.
Phase1: has two distinct activities – Understanding Mars scientifically and developing technologies for expanded robotic exploration. This would include sample return, determination of optimum human landing sites, and initial investigation of ISRU and cryogen-storage.
Phase 2: Develop and demonstrate the technologies for human activities. This could include NTP development and reliability demonstration, e.g. on the Moon, aerobraking of large payloads, radiation protection strategy evaluation, pin-point landing, and large-scale propellant production and storage.
Phase 3: The first human expedition.

Summary: The current NASA budget is in need of an estimated 5X increase to meet the "footprint" mission needs and 20X to explore Mars fully. One can make the point that on a per-mass basis, to say nothing of selectivity flexibility, the return of Mars samples selected by humans is far more economical than with automated robotic probes; however, the "buy-in" cost will be higher by orders of magnitude [9]. It is a truism that money spent on space exploration is spent on the Earth and not on space. Such an endeavor is not going to contribute on a profit basis to the U.S. on a quarterly basis vi-a-vis trading partners. It would be, however, an investment in capital, including our most valuable resource, our people and the coming generations, in technological and scientific training that both inspires and enables problem solving of the type that has served both the U.S. – and the world – well in the post-World-War II years. Civilizations face the reality of either moving forward and stagnating and going by the wayside. Observers of global real politick will not miss the point.

The Stakes Are High: Von Braun once noted that the real costs of sending humans to Mars would likely equal those of "a small war." [10] And there is no real reason to think that has changed [11]. The Planetary Society and the Mars Society have been active in pushing for human Mars exploration for the past 20 years. Astronauts and Cosmonauts have been ready to go since the 80's. More than a science mission, such an undertaking is a choice of whether to follow the route of 15th century China (the fate of the treasure ships and the Nanjing shipyards [12] has an almost eerie connection with the fate of the Apollo 18 and 19 flight hardware), or boldly, but realistically, step forward to this challenge. Our economy is in need of a real stimulus package and Mars is the right answer for everyone.

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