

Cost Estimates for Sending Humans to Mars: A Continuing Conversation

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Since the mid-20th century, scholars and engineers have attempted to estimate the cost for humans to reach the Red Planet. While there is not a definite estimate yet, the most credible predictions suggest that the price tag for placing the first humans on Mars will reach \$500 billion – and exceed that number as inflation causes the future cost of needed hardware and services to climb. Still, the estimates vary considerably, some being much lower.

One of the first attempts to generate a cost estimate fell to the German rocketeer, Wernher von Braun. While working for the US Army after World War II in El Paso, Texas, von Braun wrote a fictional story about a human expedition to Mars. The novel envisioned a vast expedition with 70 crew members and ten spacecraft. Set in a sixty-two-page appendix, von Braun's technical calculations attracted the interest of publishers. The technical details dealt with trajectories and propellant mass. For his cost estimate, von Braun retreated to the fictional section of the book. When pressed for a cost estimate, the Space Force commander in charge offers a preliminary estimate: two billion dollars (Von Braun, 1950: 19, 21, 61).

The number had symbolic significance. It was the estimated cost of the World War II Manhattan Project that produced the first atomic bombs. A few years later, when magazine editors pressed von Braun for a cost estimate for his large Earth-orbiting space station, he presented the same number -- \$2 billion. The figure was not meant to be an accurate estimate, but rather a metaphoric symbol indicating that any effort to reach Mars would require outlays as massive and far-reaching as for the largest of undertakings. It meant "a really big number." Visionary cost estimates for specific undertakings at that time did not seem to get much bigger than the Manhattan Project.

As a point of reference, the \$2 billion Manhattan Project consumed outlays equal to 1 percent of the US gross domestic product as it existed in 1943. (The US gross domestic product in 1943 was \$203 billion.) In 2018, the US GDP exceeded \$20 trillion. An undertaking financially equivalent to the Manhattan Project would consume at least \$200 billion.

The first opportunity to establish an official estimate for a government-funded human Mars expedition occurred as the Moon race wound down. President Richard Nixon asked a three-person Space Task Group to propose a national space program for the post-Apollo years. In 1969, the group (headed by the US vice-president) released an ambitious agenda that included a winged space shuttle, an Earth-orbiting space station, a lunar base, an orbiting space telescope, and the first human expedition to Mars. If the US government

maintained the funding levels set during the race to the Moon, the group's leaders predicted, the Martian expedition could arrive at its destination by 1986. The noteworthy Option 2 placed a price tag on the expedition -- \$26 billion.

The Space Task Group's wide-ranging proposal would have required US civil space expenditures on the magnitude of \$6 to \$8 billion per year – essentially the spending levels attained by NASA at the height of the race to the Moon. President Nixon declined to approve such funds, reducing civil space expenditures to half that amount.

The next official attempt to organize a human expedition to Mars occurred in 1989. Celebrating the 20th anniversary of the initial Moon landing, President George H. W. Bush invited the three Apollo 11 astronauts to the steps of the National Air and Space Museum and proposed that the US return to the Moon and venture to Mars. An appendix to the supporting NASA document setting out the plan provided an estimate for the first Mars expedition -- \$160 billion (NASA, 1989). Like the previous Space Task Group's ambitious proposal, the 1989 Space Exploration Initiative died on the vine.

Rejection of the Space Task Group's ambitious exploration program – as well as the similarly bold presidential Space Exploration Initiative – set off a quest for lower-cost alternatives. The now bankrupt Mars One group, a Dutch and Swiss enterprise, estimated that they could put the first humans on Mars for \$6 billion. Following missions would cost \$4 billion. The plan contained an important caveat. The trip was one way. Like immigrants or settlers traversing a long trail, those who went to Mars would stay on Mars for the rest of their lives. (Mars One, 2011).

Using a similar logic, Robert Zubrin's Mars Direct aimed to place the first humans on Mars for less than \$30 billion (Mars Society, n.d.). Zubrin reduced his outbound costs by foregoing much of the material needed to return home – material that Zubrin planned to obtain by exploiting resources on the Red Planet. The benefits of such a plan in innovation and adventure, he believed, would easily exceed the costs involved.

A special committee conducting a review of US human spaceflight and chaired by aerospace executive Norman Augustine concluded that an expedition to Mars could be mounted for \$125 billion (Jones, 2016). However, this cost estimate required that the mission go *around* Mars, not actually land on the planet's soil (Augustine Committee, 2009). In a burst of subsequent optimism, space entrepreneur Elon Musk predicted that getting to Mars would one day cost just \$500,000 per person (Clifford, 2019).

Setting aside the optimism contained in these proposals, more carefully drawn calculations did not show that landing humans on Mars and returning them safely to Earth would cost this little.

Restrained by the negative response to the 1989 Space Exploration Initiative, officials promoting President George W. Bush's 2004 Vision for Space Exploration did not provide a specific cost estimate for the long-range Mars component. When President Barack Obama revised the Bush plan in 2010, the Congress directed the National Academies to prepare a detailed review of the nation's human space flight options. The National Research Council released the report in 2014. While thick on technical details, the report offered few specific estimates of cost. Technical details were based on NASA Design Reference Architecture 5, the fifth in a series of conception design studies aimed at sending humans to Mars. Regarding cost, council members announced that the journey would require spending "to a rough order of magnitude...of two to four times" the investment in the International Space Station. That placed the venture in the \$300-\$600 billion range. (National Research Council, 2014: 156-57).

When the chair of the council's technical panel testified to Congress, that figure stabilized. The first crewed mission to Mars could land in twenty to forty years after a "cumulative expenditure of on the order of half a trillion dollars (constant FY 2013 dollars)" (House Committee on Science, Space, and Technology, 2016). Henry Jones of the NASA Ames Research Center offered a similar assessment. Extrapolating figures from past human space missions including the International Space Station, space shuttle, and the Apollo missions, Jones estimated the cost to be around \$500 billion (Jones, 2016).

So, the \$500 billion figure gained credibility. It also garnered opposition as lawmakers contemplated the true size of the outlays and the larger implications of launching the first expedition.

Focusing exclusively on the first Martian expedition, how could the costs grow so dramatically – from \$26 to \$160 to \$500 billion? Part of the answer lies in the price of needed goods and services. As time passes, those prices increase. The estimate established in 1969 (\$26 billion) grows to \$110 billion when repriced in 1991 dollars; the 1991 estimate of \$160 billion converts to \$308 billion in 2016 dollars. So, the earlier estimates are somewhat closer to \$500 billion than they initially appear to be.

Additionally, the first two cost estimates benefit from plans for additional spending that showed up on other accounts. Cost estimators placed the 1969 and 1989-91 Mars proposals on top of a lunar base. The lunar station contained technology – and hence spending – that could be applied to Mars.

If humans ever venture to Mars, they likely will do so with the intention of establishing a permanent presence. In a fit of cost transparency, the estimators who prepared the 1989 cost figures allocated an additional \$76 billion for eight subsequent years of Martian occupancy. They also added twenty years of spending for lodging on the Moon. The cumulative figures (placed on top of the \$160 first Mars expedition) brushed \$500 billion. That estimate – in 1991 dollars – lent credibility to the idea that any venture to Mars would require an outlay of a half-trillion-dollars. With little wonder, the US Congress at that time did not provide the funds.

Someday when the world's economies expand enough and our understanding of supporting technologies becomes sufficiently robust, humans may commit themselves to send representatives from the Earth to Mars. When they do, the preparatory spending will likely continue for twenty to forty years. (So far, various presidential administrations have had difficulty maintaining new spaceflight commitments for more than eight years.) So, an overall estimate of \$500 billion would be divided into twenty to forty increments, an easier pill to swallow. But, the actual appropriations year by year would expand with inflation, making the overall commitment larger and harder to sustain.

With that said, do you think it is worthwhile for the U.S. government to invest \$500 billion in today's money to send humans to Mars?

Sources

- Augustine Committee: Review of U.S. Human Spaceflight (Oct. 2009). *Seeking a Human Spaceflight Program Worthy of a Great Nation*. Retrieved from <https://www.lpi.usra.edu/lunar/strategies/AugustineHSFCmteFinal.pdf>
- Charania, A. C. (Sep. 1, 2005). *The Trillion Dollar Question: Anatomy of the Vision for Space Exploration Cost*. SpaceWorks Engineering, Inc. Retrieved from http://www.sei.aero/archive/AIAA-2005-6637_present.pdf
- Clifford, C. (Feb. 11, 2019). Elon Musk: Moving to Mars will cost less than \$500,000, 'maybe even below \$100,000. CNBC. Retrieved from <https://www.cnbc.com/2019/02/11/elon-musk-how-much-it-will-cost-to-move-to-mars.html>
- Day, D. (Feb. 23, 2004) *Aiming for Mars, grounded on Earth: Part Two*. The Space Review. Retrieved from <https://www.thespacereview.com/article/106/9>
- Hoffman, S. & Kaplan, D. (July 1997). The Reference Mission of the NASA Mars Exploration Study Team. NASA. Retrieved from <https://space.nss.org/wp-content/uploads/1997-NASA-Human-Exploration-Of-Mars-Reference-Mission.pdf>
- House Committee on Science, Space, and Technology. *Testimony submitted by John Sommerer: Charting a Course: Expert Perspectives on NASA's Human Exploration Proposals* [press release, February 3, 2016]. Retrieved from <http://spaceref.com/news/viewpr.html?pid=47821>
- Jones, H. (July 10, 2016). *Humans to Mars Will Cost About "Half a Trillion Dollars" and Life Support Roughly Two Billion* Retrieved from <https://strives-uploads-prod.s3.us-gov-west-1.amazonaws.com/20200000973/20200000973.pdf?AWSAccessKeyId=AKIA5EVSKC45ZTTM42XZ&Expires=1603149489&Signature=hJyMZn5M0oxvoeiM9IYM7xkVA8Q%3D>
- Mars One (2011). *What is Mars One's Mission Budget?* Retrieved from Space Task Group (Jan. 8, 1969) Report of Task Force on Space. Retrieved from <https://history.nasa.gov/SP-4407/vol1/chapter3-3.pdf>
- Mars Society (n.d). *Frequently Asked Questions*. Retrieved from <https://www.marssociety.org/faq/#Q2>

NASA (1989), Report of the 90-Day Study on Human Exploration of the Moon and Mars, Cost Summary, November 1989.

https://history.nasa.gov/90_day_cost_summary.pdf

National Research Council (2014). *Pathways to Exploration: Rationales and Approaches for a U.S Program of Human Space Exploration*. Retrieved from <https://www.nap.edu/read/18801/chapter/1>

Smith, O. Glenn and Paul D. Spudis, "Op-ed – Mars for Only \$1.5 Trillion," Space News (March 8, 2015). Retrieved from <https://spacenews.com/op-ed-mars-for-only-1-5-trillion/>

Space Task Group (Jan. 8, 1969) Report of Task Force on Space. Retrieved from <https://history.nasa.gov/SP-4407/vol1/chapter3-3.pdf>

Von Braun, Wernher (1950) *Project Mars: A Technical Tale*. Retrieved from <https://www.wlym.com/archive/oakland/docs/MarsProject.pdf>

Zubrin, Robert (1996) *The Case for Mars*. Free Press.