

**Analysis of Commercial Funding Strategies for the Settlement of Mars**

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## **Abstract:**

With current technological capabilities it is highly unlikely there can be a sustainable private enterprise with its business adventures purely orientated towards space related business endeavors. The costs for a crewed-mission and settlement of Mars will far exceed any potential economic profit that can be generated. If space technology can advance far enough where interspace travel is cost effective, then the potential of Mars resource extraction can make a private space enterprise potentially profitable. There would be the need for public-private relationships for a commercial organization to travel to Mars.

## **Introduction:**

“I would like to die on Mars. Just not on impact”

-Elon Musk

The United States and other spacefaring nations have their sights set on a crewed-mission to Mars. NASA has plans to try to get people onto the Moon by 2024 and this mission is tied with learning more about how to get people to Mars<sup>1</sup>. Along with the United States many other countries also have their eyes set on Mars. Countries like the United Arab Emirates became the first country from the Arab world to send a satellite to orbit Mars and help build a better understanding of the Martian environment<sup>2</sup>. The race to Mars is still in its infancy, and countries like China and the United States are lining up missions attempting to explore the red planet<sup>3</sup>. However, the narrative of space being a field exclusive to countries is changing.

Companies like SpaceX are pushing the boundaries of a private enterprise launching an expedition to Mars. Originally the domain of space was dominated by government entities like the United States, Soviet Union, and China. But now, we see evidence that private companies are now entering the space domain with many government contracts being given to companies like SpaceX for cargo trips via their technology. The field currently looks to be dominated by Public-Private relationships between governments and private businesses. With the request of \$25.2 billion dollars from the US federal government, a portion of that money is given to private companies in the form of contracts<sup>4</sup>. This is a major source of revenue that draws in a lot of commercial interest. However, with goals such as putting people on the Moon and going to

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<sup>1</sup> Dunbar, Brian. “Moon to Mars Overview,” June 29, 2018. <https://www.nasa.gov/topics/moon-to-mars/overview>.

<sup>2</sup> “Hope, the United Arab Emirates' First Mission to Mars.” The Planetary Society. Accessed May 1, 2021. <https://www.planetary.org/space-missions/uae-hope>.

<sup>3</sup> Howell, Elizabeth. “A Brief History of Mars Missions.” Space.com. Space, February 8, 2021. <https://www.space.com/13558-historic-mars-missions.html>.

<sup>4</sup> Sheetz, Michael. “Space Companies to Win Billions from NASA's Budget, Including SpaceX, Blue Origin, Maxar & More.” CNBC. CNBC, February 11, 2020. <https://www.cnbc.com/2020/02/11/nasa-space-budget-billions-to-spacex-blue-origin-maxar-and-more.html>

Mars, the narrative of how we get there might begin to change. Companies like SpaceX have valuations of upwards of 74 billion dollars<sup>5</sup>.

This paper will focus the potential opportunities to earn capital on a mission to Mars to see if a commercial mission is profitable. The paper will evaluate the claim that a completely private mission to Mars is profitable and possible without the capital partnership of a government or other subsidiary operations. This strict condition will help to evaluate the commercial profitability of space because many companies that work in the area of aeronautics also have business practices in other domains. A proper evaluation of the avenues of space related business adventures cannot include business profit from avenues that are external to space. The paper will evaluate this claim with the premise that the company is exclusively making it money from space related operations. The scope of “space related operations” includes all business practices that are in direct connection to a mission to Mars. These assumptions will help narrow the scope of the paper to truly evaluate the commercial viability of a purely private space endeavor of space and a mission to Mars.

### **Cost Estimate of a Crewed-Mars Mission**

While current estimates for the cost of landing people on Mars vary widely, this section will examine existing literature to develop a sense of how much one can reasonably expect a mission to Mars to cost.

Perhaps the most high-profile private attempt to land humans on Mars was the Dutch Mars One project. The project, which sought to establish the first Mars settlement by the year 2025, estimated that it would cost around 6 billion US dollars. While Mars One argued that their comparatively lower costs was due to them only attempting a one-way mission, their 6 billion dollars estimate was widely criticized by experts for being too optimistic to the point of being delusional.

One study, conducted by several PhD students at MIT found the Mars One plan to be completely infeasible.<sup>6</sup> They found that the cost of just sending these supplies needed for the initial settlement would itself cost around 4.5 billion US dollars. Furthermore, the cost of resupplying a Mars settlement would balloon exponentially. They found that the cumulative costs to grow and sustain Mars One’s proposed settlement would exceed 100 billion dollars.<sup>7</sup>

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<sup>5</sup>Sheetz, Michael. “What’s behind SpaceX’s \$74 Billion Valuation: Elon Musk’s Two ‘Manhattan Projects’.” CNBC. CNBC, February 19, 2021. <https://www.cnbc.com/2021/02/19/spacex-valuation-driven-by-elon-musks-starship-and-starlink-projects.html>.

<sup>6</sup> Do, Sydney, Andrew Owens, Koki Ho, Samuel Schreiner, Olivier de Weck. “An independent assessment of the technical feasibility of the Mars One mission plan – Updated analysis.” *Acta Astronautica* 120. (2013): 192-228,

<sup>7</sup> Ibid

While Mars One ended up failing spectacularly, it is worth exploring other, more realistic, estimates of a human mission to Mars. In October of 2015, NASA published their “Journey to Mars” program which outlined the agency’s plan for Mars exploration and sustained human settlement<sup>8</sup>. The state goal of the program is to “extend human presence deeper into the solar system and to the surface of Mars.”

To do this, the Journey to Mars program breaks down the process of reaching Mars into three steps. First, is the “Earth Reliant” phase that focuses on conducting research on the International Space Stations to build the systems necessary for long term space travel. Second is the “Proving Ground” where NASA will validate and advance capabilities for Mars exploration. Finally is the “Earth Independent” stage where attempts at long term settlement of Mars begin in earnest.

While the agency has not produced any official cost estimates for the program, several estimations by NASA employees and government research reports exist. Brent Sherwood, manager of mission formulation at NASA’s Jet Propulsion Laboratory estimated that a crewed mission to Mars would cost around 100 billion dollars over thirty to forty years<sup>9</sup>. A comprehensive report authored by the National Research Council argued that in order to achieve a landing by 2050, the pathway to Mars would need to cost less than \$220 billion<sup>10</sup>. For context, the International Space Station required \$100 billion to build and costs roughly \$4 billion in maintenance every year with the vast majority of the cost, 83%, falling on the United States.<sup>11,12</sup>

Finally, it is important to note that it is highly possible that we will see massive reductions in costs, arising from technological innovations in space launch technology, propulsion technology, life support systems, etc. As an example, the advent of SpaceX’s Falcon 9 and Falcon Heavy rockets have dramatically decreased the cost of launching material into space because they can be reused.<sup>13</sup> SpaceX advertises a cost of 2,720 dollars per kilogram to launch into Low Earth Orbit (LEO). For comparison, NASA’s Space Shuttle cost 54,500 dollars

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<sup>8</sup> “NASA’s Journey to Mars - Pioneering Next Steps in Space Exploration.” NASA. February 3, 2015. [https://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008\\_508.pdf](https://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008_508.pdf)

<sup>9</sup> Wall, Mike. “Should NASA Ditch Manned Missions to Mars?” Space.com. 2013. <https://www.space.com/16918-nasa-mars-human-spaceflight-goals.html>

<sup>10</sup> National Research Council. *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration*. Washington, DC: The National Academies Press. 2014 <https://doi.org/10.17226/18801>.

<sup>11</sup> McKie, Robin “Twenty years of the International Space Station – but was it worth it?” The Guardian. October 25, 2020. <https://www.theguardian.com/science/2020/oct/25/twenty-years-of-the-international-space-station-but-was-it-worth-it>

<sup>12</sup> National Research Council. *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration*. 2014

<sup>13</sup> Sheetz, Michael. “Elon Musk touts low cost to insure SpaceX rockets as edge over competitors” CNBC. April 16, 2020. <https://www.cnbc.com/2020/04/16/elon-musk-spacex-falcon-9-rocket-over-a-million-dollars-less-to-insure.html>

per kilogram.<sup>14</sup> In the future, SpaceX's Starship could reduce costs even further. Musk plans for Starship to cost as little as 10 dollars kilogram to launch in LEO and as little as 20 to 30 dollars per kilogram for lunar payloads.<sup>15</sup>

At present, it is difficult to accurately predict how much landing humans on Mars would cost precisely because of this rate of technological advancement. As the report from the National Research Council Notes, many of the capabilities needed for successful settlement of Mars have not been actualized, making realistic budget calculations difficult. The National Research Council, for their part, used margins of 50% for development efforts and 25% for production and operations to formulate their cost estimates. Furthermore, their cost analysis was based on historical NASA acquisition patterns, derived from past examples like the Apollo missions or the launching of the ISS. They stipulate that costs could be reduced through "extensive use of broadly applicable commercial products and practices."<sup>16</sup> As SpaceX's ability to slash launch costs with their Falcon rockets demonstrates, this sort of technological innovation that brings down costs is likely to continue. Regardless, one thing is clear: reaching Mars will not be cheap.

## Space Tourism

One of the most prominent potential uses of space is the possibility of space tourism where people pay an upfront ticket price to venture into space or even to Mars. The most prominent player in this space is Virgin Galactic. Founded in 2004 by Richard Branson, Virgin Galactic has been attempting to develop commercial spacecraft in order to provide suborbital flights to space tourists.

Virgin Galactic has faced a number of difficulties and setbacks in its attempts to make commercial space tourism a reality. Their development of a viable commercial spacecraft has been beset by major delays, the biggest of these being a catastrophic crash of one of their spacecraft in 2014 that killed one of the craft's two pilots.<sup>17</sup> It was not until 2018 that Virgin Galactic was successfully able to reach Low Earth Orbit.<sup>18</sup>

Aside from engineering difficulties, one of the major problems the company struggles with is bringing in a consistent source of revenue. While Virgin Galactic was initially able to sell around 600 tickets at prices between 200 thousand and 250 thousand dollars, the company has

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<sup>14</sup> Jones, Harry. "The Recent Large Reduction in Space Launch Cost" 48th International Conference on Environmental Systems. July 8, 2018. <https://ntrs.nasa.gov/citations/20200001093>

<sup>15</sup> Zafar, Ramish. "SpaceX Could Bring Starship Launch Costs Down To \$10/kg Believes Musk" *WCCFTech*. May 8, 2020. <https://wccfttech.com/spacex-launch-costs-down-musk/>

<sup>16</sup> National Research Council. *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration*. 2014

<sup>17</sup> "Virgin Galactic spacecraft crash kills pilot" BBC. November 1, 2014. <https://www.bbc.com/news/world-us-canada-29857182>

<sup>18</sup> "Branson's Virgin Galactic reaches edge of space." *BBC*. December 13, 2018. <https://www.bbc.com/news/business-46550862>

struggled to earn revenue. By the company's own admission, they struggle to "generate significant revenue," only bringing in 238 thousand dollars in 2020.<sup>19</sup><sup>20</sup> However, the company remains optimistic that they will soon be able to leverage revenue from commercial space flights for tourists. Virgin Galactic CEO Michael Colglazier told investors that he sees each spaceport generating one billion dollars in revenue every year with each spaceport handling 400 flights. This works out to a ticket price of roughly \$400 thousand a piece.<sup>21</sup>

Furthermore, Virgin Galactic faces competition with Blue Origin, which has similar plans to bring tourists into space. Blue Origin has been routinely testing their Blue Shepard rockets with plans for a crewed launch later in 2021.<sup>22</sup> Tentatively, tickets aboard Blue Origin are expected to cost at minimum \$200 thousand and up to \$300 thousand.

In addition to sales of tickets, companies like Virgin Galactic and Blue Origin are also looking at other potential streams of revenue. Virgin Galactic says that their spaceflight system is also targeted at those looking to conduct microgravity research or for the training of professional astronauts.<sup>23</sup> Virgin Galactic, in fact, signed a contract with the Italian government to allow researchers to conduct experiments in space using Virgin Galactic's spaceflight systems.

In the context of a Mars mission, the sale of tickets to individuals becomes more complicated given the massively increased cost scale of reaching Mars, as opposed to brief 90-minute space flights offered by Virgin Galactic or Blue Origin. While Elon Musk optimistically predicts that ticket price to Mars could reach as low as 500 or 100 thousand dollars, relying solely on ticket sales to finance a mission to Mars is likely infeasible.<sup>24</sup> Current models for space tourism already exclusively target the ultra-wealthy who are able to afford spending hundreds of thousands of dollars on a brief space flight. The higher costs of Mars tourism would be restricted to an even smaller pool of ultra-high net worth individuals with an extreme affinity for space travel.

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<sup>19</sup> Sheetz, Michael. "Virgin Galactic delays next spaceflight test to May, with commercial service launch pushed to 2022." CNBC. February 25, 2020. <https://www.cnbc.com/2021/02/25/virgin-galactic-spce-earnings-q4-2020.html>

<sup>20</sup> "VIRGIN GALACTIC ANNOUNCES FOURTH QUARTER AND FULL YEAR 2020 FINANCIAL RESULTS" Virgin Galactic. Feb 25, 2021. <https://investors.virgingalactic.com/news/news-details/2021/Virgin-Galactic-Announces-Fourth-Quarter-and-Full-Year-2020-Financial-Results/default.aspx>

<sup>21</sup> Ibid

<sup>22</sup> O'Callaghan, Jonathan. "Blue Origin Launches Space Tourism Rocket On 'Dress Rehearsal' For Upcoming Human Missions" *Forbes* April 14, 2021. <https://www.forbes.com/sites/jonathanocallaghan/2021/04/14/blue-origin-launches-space-tourism-rocket-on-dress-rehearsal-for-upcoming-human-missions/?sh=7cb26be769d0>

<sup>23</sup> "Fourth Quarter and Full Year 2020 Investor Update." Virgin Galactic. February, 25, 2021. [https://s24.q4cdn.com/816362521/files/doc\\_presentations/Virgin-Galactic-Q4-FY-2020-Earnings-Presentation-2.25.21.pdf](https://s24.q4cdn.com/816362521/files/doc_presentations/Virgin-Galactic-Q4-FY-2020-Earnings-Presentation-2.25.21.pdf)

<sup>24</sup> Wall, Mike. "Tickets to Mars Will Eventually Cost Less Than \$500,000, Elon Musk Says" Space.com 2018. <https://www.space.com/elon-musk-spacex-mars-mission-price.html>

Furthermore, the possibility of tourism to a functioning Mars colony would only be possible after a relatively large, independent settlement is established on Mars -- a prospect that is likely decades out. The possibility of having any sort of leisure tourism to Mars would require a significant settlement with the infrastructure to not only support these tourists but also to return them to Earth, a prospect that would likely be years, if not decades after the first Mars settlements are formed. Even then, it would still require a months long journey only to reach a largely barren, inhospitable planet. As it currently stands, even space tourism to LEO is still likely years out. As Virgin Galactic demonstrates, the profitability of such a venture also remains to be seen. Given that the viability of LEO tourism is still an open question, any sort of "tourism" to Mars would likely be impossible for years after initial settlement.

## **Media and Product Revenue**

The holistic review of the potential sources of income for a mission to Mars encompasses the profit that is obtained before a ship even leaves the ground. It was estimated that close to 600 million people watched the Apollo 11 mission in 1969<sup>25</sup>. It was also estimated that broadcast news networks paid upwards of 11 to 12 million dollars to conduct the broadcast over one and half days<sup>26</sup>. That is close to 80 million in today's dollars. The Apollo 11 mission holds the record for the most viewers ever for a space launch. However, it may be fair to assume that the number of people watching a mission to Mars launch will be greater. A joint NASA-SpaceX launch was able to gather 10.3 million viewers to watch at one time<sup>27</sup>. Many similar missions have been done before, however, a first time human mission to Mars can be assumed to draw in a much bigger crowd. Furthermore, since 1969 the amount of people on Earth has significantly grown and the number of internet users also has significantly grown. As of 2016 there are nearly 3.4 billion internet users<sup>28</sup>. With an increased total population and high access to the internet it can be assumed that a potential crewed-mission to Mars will draw in an enormous crowd.

Technology now allows almost anyone to quickly access media and this greatly affects the potential earnings from a potential space launch for Mars. The Superbowl and its revenue can be used as a possible estimation of revenue for a broadcast of this magnitude. In 2019, CBS generated 336 million dollars from ad revenues for the Superbowl<sup>29</sup>. Additionally, with 21st century technology a Mars space launch can generate sustainable passive income. Compared to

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<sup>25</sup> CNN Editorial Research. "First Moon Landing Fast Facts." CNN. Cable News Network, July 10, 2020. <https://www.cnn.com/2013/09/15/us/moon-landing-fast-facts/index.html>.

<sup>26</sup> Ibid

<sup>27</sup> Wall, Mike. "SpaceX's 1st Astronaut Launch Was NASA's Most-Watched Online Event Ever." Space.com. Space, June 2, 2020. <https://www.space.com/nasa-spacex-astronaut-launch-viewer-record.html>.

<sup>28</sup> Roser, Max, Hannah Ritchie, and Esteban Ortiz-Ospina. "Internet." Our World in Data, July 14, 2015. <https://ourworldindata.org/internet>.

<sup>29</sup> Adgate, Brad. "What You Should Know About Super Bowl LIV Advertising And Broadcast." Forbes. Forbes Magazine, January 30, 2020. <https://www.forbes.com/sites/bradadgate/2020/01/27/super-bowl-liv-fun-facts/?sh=3989734e718e>.

the Apollo 11 launch, a modern day Mars launch has access to online video platforms like Youtube.

The Perseverance rover landing on Mars has 21 million views on Youtube. NASA boasts close to 8 million subscribers on Youtube and Space X has close to 5 million. A platform like Youtube can present an opportunity to post videos of a Mars launch and be monetized. Viewers can watch videos on the channel related to the launch which can include the launch itself and videos before and after the launch. The profit that is collected from Youtube will vary, based on the types of ads and number of viewers. The exact amount received is unclear, but it is important to highlight that the income received from Youtube can be sustainable. People may watch and rewatch any videos and each view results in a small amount of revenue generated. Therefore, even after the launch of the ship, uploading videos to this platform will generate income for the enterprise. A modern-day Mars space launch as noted can generate income from media outlets and streaming, but it can also generate income from merchandise.

NASA shirts and memorabilia are common things sold throughout stores. The NASA logo is public domain and NASA hold certain restrictions around its insignia, but companies are free to use it on their merchandise as long as they get it approved<sup>30</sup>. However, we can look at companies like SpaceX and see that they have a full website of countless merchandise that can be sold<sup>31</sup>. They sell an assortment of items on the website from clothes to backpacks. There is not a measurement for the amount sold therefore it is difficult to calculate the potential revenue that can be earned through this channel.

The total amount earned from pre-launch avenues can be a major source of capital in funding a mission to Mars. The versatility and diversity of media and product income helps provide a platform for building a robust portfolio. They are important factors that can be further clarified through customer surveys and data analysis. Furthermore, the media and products are an element to a much bigger portfolio of sources of revenue in a crewed-mission of Mars.

## **Mars Extractable Resources**

Studies of the Martian environment reveals the remnants of old volcanoes and the solar system's largest volcano Olympus Mons; the area may hold enormous deposits of nickel, copper, chromium, and etc<sup>32</sup>. In addition to the volcanic resources on Mars, there are also valuable ores and minerals from impact craters. An economic estimation of North America's craters was

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<sup>30</sup> Dunbar, Brian. "NASA Regulations for Merchandising Requests." NASA. NASA, November 15, 2005. <https://www.nasa.gov/centers/ames/multimedia/merchandising.html>.

<sup>31</sup> "Official SpaceX Store." SpaceX Store. Accessed May 1, 2021. <https://shop.spacex.com/>.

<sup>32</sup> West, Michael D. and Jonathan D. A. Clarke. "Potential Martian Mineral Resources: Mechanisms and Terrestrial Analogues." *Planetary and Space Science* 58, no. 4 (2010): 574-582.

determined to be five billion dollars a year<sup>33</sup>. The craters contain valuable minerals from asteroids that hit in these areas. There is an estimation of 43,000 impact craters present throughout Mars. The current literature that has been discussed has yet to be confirmed because there have not been any samples analyzed from Mars yet on Earth. However, if it is similar to Earth's impact craters then the potential revenue is certainly great. Beyond just minerals and ores, Mars is also home to other deposits of resources that are not found on earth.

Deuterium (an isotope of Hydrogen) is in great abundance on Mars compared to Earth, and it is being used in fusion reactors here on earth<sup>34</sup>. The payout for Deuterium is \$10,000 per kilogram which is nowhere near the price of precious metals such as gold, but is worth more than tens times the value of silver<sup>35</sup>. Furthermore, the price of Deuterium may rise and an incentive to capture it from Mars may also begin to rise. The high cost of transport may keep the price high despite supplies of it increasing. With nuclear energy being a major clean energy source the demand for nuclear energy may increase in the future as countries begin transitioning away from fossil fuels. There are currently 440 nuclear power reactors in the world and there are currently 50 more that are under construction<sup>36</sup>. The sustained growth of these nuclear power plants opens the potential of the market for Deuterium to rise greatly. However, there are great barriers associated with any operations that try to bring Martian materials back to Earth.

The costs of launching and bringing back materials is a major barrier to making the import of the resources from Mars possible. The costs of payloads is extremely high and just to send a pound into Earth's orbit cost \$10,000<sup>37</sup>. The cost for a payload for a trip to Mars can be projected to be significantly more. If the technology can reach a point where the costs can be reduced, then the potential for a profitable mining and resource extraction enterprise will be achievable. Despite the shortcomings of resource extraction methods as a source of income, there is a small potential for commercial profit.

A popular form of wedding rings are meteorite rings. Many of these rings sell for thousands of dollars. A Martian meteorite ring that was custom made is currently on sale for \$29,000<sup>38</sup>. This opens the possibility of bringing small amounts of Martian rock or minerals back

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<sup>33</sup>Grieve, R. A., and V. L. Masaitis. "The Economic Potential of Terrestrial Impact Craters." *International Geology Review* 36, no. 2 (1994): 105–51. <https://doi.org/10.1080/00206819409465452>.

<sup>34</sup>Zurbin, Robert. "The Case for Colonizing Mars." National Space Society, August 1996. <https://space.nss.org/the-case-for-colonizing-mars-by-robert-zubrin/>.

<sup>35</sup> Ibid

<sup>36</sup>"Plans for New Nuclear Reactors Worldwide - World Nuclear Association." World Nuclear Association , March 2021. <https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx>.

<sup>37</sup>Dunbar, Brian. "Advanced Space Transportation Program Fact Sheet." NASA. NASA. Accessed May 1, 2021. <https://www.nasa.gov/centers/marshall/news/background/facts/astp.html>.

<sup>38</sup>"Meteorite Engagement Ring from Mars: Custom Engagement Rings." Abby Sparks Jewelry, April 15, 2020. <https://www.abbysparks.com/custom-jewelry/the-black-beauty-yellow-gold-diamond-engagement-ring/>.

to the Earth and fitting them for potential use in rare space jewelry. The scarcity of these minerals is what gives them their value on Earth. Since the technological capabilities of bringing back large amounts of Martian resources is not currently possible their scarcity can be used as an advantage. Nevertheless, the evaluation of resource extraction from Mars seems to be a much smaller market than a commercial enterprise would desire. A more practical use of these materials, with the current technological limitations, would be scientific research.

Until there is technology capable to lessen the cost of interplanetary commerce the reality of Mars resources extraction is not possible. The market of Mars jewelry is not widely tested and investment into consumer surveys might help to develop a wiser estimation of its value. There is not enough data to make a clear estimation for the amount of money that can be generated for Martian jewelry. The value of the minerals and other resources on Mars and the asteroids near Mars can surpass a trillion dollars<sup>39</sup>. However, there are challenges that make interspace commerce extremely expensive. In addition, to the high cost of sending a single payload, Mars and Earth only every so often are oriented in such a way that the distance between them is the shortest. Therefore, interspace commerce with Mars' resources with current technologies is unreliable and not profitable.

### **Intellectual Property Exports**

In addition to the export of material goods like rare minerals or Deuterium, the settlement of Mars presents significant opportunities to make money off technological developments or other intellectual property. Perhaps the best example of this can be seen in the private space launch sector. Companies like SpaceX, Blue Origin and Northrop Grumman have won large government contracts to launch military payloads into space.<sup>40</sup> Furthermore, NASA has selected SpaceX to conduct a variety of space launches for them. These include SpaceX's Crew Dragon, which will bring astronauts and supplies to the ISS or the use of the Falcon Heavy to launch NASA's Griffin Mission 1 lunar lander.<sup>41</sup> Innovations in life support, agriculture, in-situ resource utilization, energy, radiation shielding and the many other capabilities necessary to sustain a Mars colony are likely to also have financially lucrative applications on Earth.<sup>43</sup> One example of this can be seen in Solar Electric Propulsion systems which are already used in many

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<sup>39</sup> Wong, Andrew. "Space Mining Could Become a Real Thing - and It Could Be Worth Trillions." CNBC. CNBC, May 15, 2018. <https://www.cnbc.com/2018/05/15/mining-asteroids-could-be-worth-trillions-of-dollars.html>.

<sup>40</sup> Sheetz, Michael. "SpaceX and ULA win billions in Pentagon rocket contracts, beating out Blue Origin, Northrop Grumman" CNBC. August 7, 2020. <https://www.cnbc.com/2020/08/07/spacex-and-ula-win-2022-pentagon-rocket-launch-contracts.html>

<sup>41</sup> Rincon, Paul. "Why Elon Musk's SpaceX is launching astronauts for Nasa." BBC. November 14, 2020. <https://www.bbc.com/news/science-environment-52818543>

<sup>42</sup> Proust, Jeff. "Astrobotic selects Falcon Heavy to launch NASA's VIPER lunar rover" Spacenews. April 13, 2021. <https://spacenews.com/astrobotic-selects-falcon-heavy-to-launch-nasas-viper-lunar-rover/>

<sup>43</sup> Carberry, Chris and Rick Zucker. "Is there a business case for Mars?" The Space Review. October 10, 2016. <https://www.thespacereview.com/article/3080/1>

commercial satellites.<sup>44</sup> Improvements in Solar Electric Propulsion for the purposes of supporting a Mars mission are also of interest to companies launching commercial satellites, who could increase the operational life cycle of their satellites.<sup>45</sup>

While revenue streams like tourism or raw material exports, that we have discussed previously, would require the development of a stable and permanent Mars settlement before they could come to fruition, intellectual property and technological innovation demonstrate how a Mars settlement could make money in the short run. In addition, the actual settlement of Mars is likely to bring a large number of new financially lucrative developments.

One of the more out of the box applications was Mars One's plan to create a 24/7 reality television out of their Mars colonists. This plan faced no shortage of ethical criticism and did not come to fruition.<sup>46</sup> However, the possibility Mars entertainment television that is broadcast back to Earth could present a legitimate source of revenue. While a 24/7 reality TV show might be excessively intrusive, a documentary about the first settlers on Mars and the journey would likely be extremely popular. In the long term, Mars might even develop unique sports that take advantage of the planet's lower force of gravity.

In his paper "The Economic Viability of Mars Colonization" Robert Zurbin argues that Mars settlers might be able to sustain themselves off the export of intellectual property. Zurbin draws an analogy to the settlement of the Americas, arguing that an extreme shortage of labor would drive a technological culture on Mars that could produce inventions that they could sell back to Mars.<sup>47</sup> Detractors argue that relying heavily on intellectual property faces large political risks. At the moment, it is unclear how you would enforce IP law on an inter-planetary scale and what recourse Mars settlers could have if people on Earth did not respect their copyrights. While these are still open questions, the success of companies like SpaceX, which drew significant attention from commercial and government actors for their cheaper Falcon rockets, have demonstrated that there is already a market on Earth for the technologies needed to settle Mars, presenting a viable path that a private Mars venture could make short term profits.

### **Public-Private-Partnerships**

This paper has so far focused on ways to generate revenue from private actors (tourism and media revenue) or from industrial ventures like extracting resources or collecting royalties on intellectual property. One avenue of funding that is becoming increasingly common in LEO spaceflight that has not been explored is that of public-private-partnerships (PPP). Put simply, a

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<sup>44</sup> "Solar Electric Propulsion" NASA Glenn Research Center. Accessed May 2, 2021. <https://www1.grc.nasa.gov/space/sep/>

<sup>45</sup> Ibid

<sup>46</sup> Erik Seedhouse. *Mars One: The Ultimate Reality TV Show?* Berlin: Springer, 2016.

<sup>47</sup> Zurbin, Robert. "The Economic Viability of Mars Colonization" <http://www.aleph.se/Trans/Tech/Space/mars.html>

PPP is a type of long-term contractual relationship between the government and one or more private actors. The OECD defines a public-private-partnership as “long term contractual arrangements between the government and a private partner whereby the latter delivers and funds public services using a capital asset, sharing the associated risks.”<sup>48</sup>

NASA has already been contracting a variety of private partners to develop the requisite technologies for cislunar, lunar, and Mars based operations for years.<sup>49</sup> One of the biggest and robust partnerships between NASA and the private sector can be seen in the operations of the ISS. Launched in 2005, the effort to transition from a wholly government-owned and operated cargo delivery system to the ISS to one primarily operated by the private sector is called the Commercial Orbital Transportation Services (COTS).<sup>50</sup> This program paved the way for the development of SpaceX’s Falcon 9 and Orbital’s Antares launch vehicles.<sup>51</sup>

One of the biggest successes of the COTS program was the tremendous cost savings it delivered. In 2010, NASA conducted a study to compare what it cost SpaceX and Orbital to develop their launch vehicles compared to what it would have cost NASA to develop comparable technology. The study found that NASA estimates for such a project would amount to almost \$4 billion while the reported cost to SpaceX was \$443 million, accounting for a cost savings of almost 89%.<sup>52</sup> Based on this experience, it is reasonable to assume that the continued utilization of PPP may significantly reduce the cost of reaching Mars.

PPP are able to solve major problems for both the government and private actors when it comes to space exploration. The US government has an interest in continuing to invest in human spaceflight for a variety of reasons. One 2009 National Research Council report argued that the US civil space program has been “integral to achieve goals significant to the nation.” They cite a variety of reasons, from national security to providing clean energy to improving the US’s international standing.<sup>53</sup> Private actors are, in turn, able to provide services cheaper than the government and have security knowing that there is a paycheck waiting for them once they deliver.

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<sup>48</sup> “Recommendation of the Council on Principles for Public Governance of Public-Private Partnerships.” OECD. May 2012. <https://www.oecd.org/governance/budgeting/PPP-Recommendation.pdf>

<sup>49</sup> “NASA Announces Partners to Advance ‘Tipping Point’ Technologies for the Moon, Mars.” NASA. October 14, 2020. [https://www.nasa.gov/directorates/spacetech/solicitations/tipping\\_points](https://www.nasa.gov/directorates/spacetech/solicitations/tipping_points)

<sup>50</sup> “Commercial Orbital Transportation Services (COTS)” NASA. Accessed May 2, 2021. <https://www.nasa.gov/commercial-orbital-transportation-services-cots>

<sup>51</sup> Miller, Charles, Alan Whilhite, Dave Chevront, Rob Kelso, Howard McCurdy, Edgar Zapata. “Economic Assessment and Systems Analysis of an Evolvable Lunar Architecture that Leverages Commercial Space Capabilities and Public-Private-Partnerships.” NextGen Space LLC. July 13, 2015.

<sup>52</sup> Ibid.

<sup>53</sup> National Research Council, *America’s Future in Space: Aligning The Civil Space Program With National Needs*, The National Academies Press, Washington, D.C., 2009, p. 59.

Despite these advantages, PPPs do carry significant disadvantages and risks. One of the biggest, especially in a long-term project like Mars exploration or settlement are political risks from shifting political administrations. As new Congresses and Presidents are elected, new space policies are promulgated. This instability would likely dissuade investors from entering into such a long term and risky contract with the US Government to reach and/or settle Mars. Furthermore, collaboration with the government would not change the underlying reality that successfully settling or even landing a crewed mission on Mars would be incredibly risky and difficult financially and technologically.

To address these challenges, one paper discussing the settlement of the Moon suggests the development of an “International Lunar Authority” to mitigate the business risks associated with PPP acquisition strategies. Drawing on examples like CERN, the transnational European nuclear research organization, they argue that developing a transnational lunar authority to manage settling the Moon could mitigate many of the risks inherent to PPP.<sup>54</sup> A similar authority may similarly prove effective for Mars settlement by bringing together international actors and providing a stable, long term mandate.

In spite of these challenges, our research suggests that PPP will likely be one of the few viable ways for commercial actors to earn profit on the road to Mars settlement. As we have discussed, most of the traditional propositions for making money from settling Mars are impractical, uncertain or require massive time horizons. At present, one of the major sources of revenue for companies like SpaceX or Blue Origin is executing government contracts, demonstrating the value of PPP in LEO or lunar spaceflight. In fact, in April of 2021, NASA announced that it had awarded SpaceX a \$2.89 billion dollar contract to land astronauts on the Moon as a part of the Artemis program,<sup>55</sup> showcasing how PPP will likely become a bigger part of NASA’s overall strategy.

## **Conclusion**

“Why should a man climb Everest? Because it is there”

-George Mallory

This paper has examined the costs of a crewed mission and eventual settlement of Mars as well as several avenues from which profit could be generated from a Mars settlement. We argue that the high investment required for any kind of Mars mission would heavily outweigh any revenue that could be generated for years, if not decades. However, if technological advances continue to reduce the cost of interstellar travel, the prospect of space tourism, resource

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<sup>54</sup> Ibid.

<sup>55</sup> “As Artemis Moves Forward, NASA Picks SpaceX to Land Next Americans on Moon” NASA. April 16, 2021. <https://www.nasa.gov/press-release/as-artemis-moves-forward-nasa-picks-spacex-to-land-next-americans-on-moon>

and intellectual property exports could eventually lead to Mars settlement that is self-sufficient or even profitable.

Our research only considers private, profit oriented avenues for funding a Mars mission. We have not considered non-traditional funding schemes such as crowdfunding. At present, any serious attempt to put humans on Mars would require substantive investment by the government through the form of public-private-partnerships. Ultimately, it is worth considering if a business case for Mars is even required. For almost all of human existence, people have explored not for logical, profit driven reasons, but simply out of a desire to explore. While a mission to Mars may not yet be commercially viable in the short term, it is possible that investors may choose to back the project for reasons other than the generation of profit. When considering a task so monumental and emotional as settling Mars, using a traditional profit driven framework may not be the most useful. As our research finds, settling Mars is likely of limited economic value, especially in the short run, which raises a serious question of whether a business case for Mars is even required. There are many good reasons to explore and settle Mars but the profit incentive may ultimately not be one.