Thesis Project Portfolio

Economic Analysis for In-Situ Resource Utilization on Mars in Support of the Generation of Rocket Fuel and Potable Water

(Technical Report)

Analyzing Apollo Program Failures and Their Applications to Future Mars Missions

(STS Research Paper)

An Undergraduate Thesis

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In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Sociotechnical Synthesis

(Executive Summary)

Analyzing Areas of Possible Cost Cutting for Manned Mars Missions

Captain Picard puts it best, “Space, the final frontier… to boldly go where no one has gone before!” In our quest to continue exploring things beyond Earth, Mars serves as the next stepping stone to branching out into this final frontier in terms of manned missions. Both of my projects focused on improving the viability of a manned Mars mission mostly through cutting costs. My technical project, in collaboration with my team, designed a rocket fuel plant on Mars that would produce enough methane and liquid oxygen for a return trip to Earth in one mission cycle. My STS researched focused on reviewing the Apollo program and its shortcomings so that those mistakes would not be made when planning and carrying out said manned Mars missions.

The technical portion of my thesis produced designs for a rocket fuel plant on Mars. As putting things into space is expensive, specifically about $10,000 per pound, my group sought to determine whether or not sending this rocket fuel plant to Mars would have been economically advantageous compared to shipping rocket fuel. This was accomplished by utilizing the cold Martian environment as a heat sink, its atmosphere as a carbon dioxide source, and the ice on Mars as a source of water. Water was electrolyzed to produce oxygen and hydrogen in which hydrogen was used to react with carbon dioxide to make methane with water as a byproduct. As there are many unknowns with a Mars mission, my group determined a few economic outcomes for the rocket fuel plant. If only one cycle is considered and the water byproduct is not needed, our process costed about $100,000,000 more than just shipping rocket fuel. However, if water is considered then there are possible savings up to $225,000,000. If two cycles of generating rocket

fuel is considered without water, about $552,000,000 could be saved. If both water and two cycles is considered, about $1,200,000,000 could be saved.

In my STS research, I compared the Apollo program to possible plans for Mars missions. In particular, I focused on the shortcomings, failures, and scrapped missions of the Apollo program in my research. The findings of this research culminated in a few major points. The first major point is that the safety culture relating to the missions has to be risk adverse. While the Lunar missions were able to save astronauts from some failures, a Mars mission will not have such liberties. Furthermore, planning ahead is absolutely important. While the Apollo missions were planned in advance, the later missions were scrapped due to budget constraints and initial failures in the program. Finally, the first mission must be successful for a Mars program to continue. The cost of a Mars mission is magnitudes higher than that of a Lunar mission, meaning that there likely won't be any second chances if the mission fails. It is also worth noting that during my research I realized there is still much more to do on the Moon in terms of research, so currently it is more advantageous to go to the Moon. This is currently happening with the planning of the Artemis program which also plans to test Mars mission equipment in the later half.

As both projects handled roughly the same subject matter, I was able to dedicate more time to deeper analysis overall of a Mars mission. Furthermore, as the two didn't have exactly the same subject matter, the overall knowledge learned from both projects was greater than that if I had only done one of them. The overlap from the projects did help me understand that a manned Mars mission maybe closer than we expected in terms of technology, the limiting factor in this case is money. In terms of STS themes, the project as a whole exemplified ethics and professional responsibility. These missions have many moving parts which requires each

engineer to constantly be making the “right decision” even if it is a hard one, and to always focus on safety. While many engineers are working on these projects, it is absolutely necessary for each of these engineers to have a vested interest and maintain their professional responsibility to the mission for it to be successful.

I would like to acknowledge both Professor Eric Anderson and Professor Ronald Unnerstall of the Chemical Engineering Department at UVA for their help and expertise on designing the technical portion of my project.

Why Space Related Projects?

Ever since I was young, I have always been fascinated by space. From Star Trek, Star Wars, the lesser-known Babylon 5 series, and all the shows from the Science and Discovery channel the absolute scale of space paired with all the unknowns was interesting. Learning how large the universe was and how insignificant I was comparatively was rather cool than intimidating as it is to most people. Pushing the limits is something I also love, and space one of those final frontiers we’re still pushing today. While I wanted to be an astronaut when I was younger, I realized that it was extremely unlikely and was put down about it by my advisors in elementary school. Therefore, even though it may be too late for me to try and be an astronaut, I’d still like to contribute in some form to helping further humanities journey to interplanetary travel and maybe even interstellar travel.