Mechatronic Orrery
(Technical Paper)

Ethical Considerations for Lunar and Martian Colonization
(STS Paper)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Organizations around the world are developing the spacecraft needed to once again land on the moon and make the first manned interplanetary mission to Mars. With this will come an expansion of the knowledge and perceived importance of our solar system and the planets and moons that make it up. Additionally, a host of new ethical problems and considerations will be encountered by the people and organizations that are involved in spaceflight and potential colonization missions.

Orreries are mechanical models of the Solar System that represent the positions and motions of the planets and moons. A mechanical arm can be turned so the correct speed and position of the planets can be shown. Traditional orreries are created with complicated gear ratios and lever arms stemming from a concentric shaft (Williams, 2016). The complication to this design is that you cannot look into the future very far, unless you plan on spinning the gears hundreds and thousands of times, which will be time consuming. Traditional orreries are also inefficient and will lose accuracy as you continue to spin the planet because of imperfections with gears. The purpose of this capstone design which is to create a mechatronic orrery is to demonstrate in a unique and fun way, the positions of the earth and moon, relative to the sun. This project will create a more versatile and aesthetically pleasing and accurate model of the Earth, Moon and Sun than traditional gear driven orreries. This will help people visualize the movement of these heavenly bodies in relation to each other and how their movements determine things like seasons, moon phases, eclipses and so on

Understanding the nature of unknown lands or bodies has been a focus of the lives of many people over the course of human history. Exploration and Colonization of unknown lands has been conducted since the dawn of human civilization. This urge for exploration and colonization has been the result of many factors whether they be the pursuit of wealth and resources, prestige, technological advancement, or pure curiosity (Elvis, 2021). However, the history of such adventures is one riddled with conflict between groups of people and nations, the destruction of native populations, and exploitation of slaves and workers among other destructive practices. Space travel and the development of the technology that made it possible saw the development of the V1 and V2 rockets used by Nazi Germany to bomb civilian targets as well as nuclear weapon carrying long range and intercontinental ballistic missiles that now put the extinction of human civilization a real possibility for the first time in history (Eramian, 2020). Furthermore, this may only be the beginning of space travel technology being used for destructive purposes (Deudney, 2022). This moment in space travel development and history provides an important opportunity to examine and subsequently develop ethical principles to guide interplanetary space travel and technological development with a particular focus on reducing conflicts between nations or other groups as a result of Lunar or Martian colonization (Sullivan,2016). This is especially important, for example, due to the geographic concentration of suitable area for colonization and easy to access resources (Badescu, 2010). The purpose of creating the STS research paper is to investigate the ethical and moral challenges associated with spaceflight and the development of related technologies and create a framework in which to approach these challenges.

Technical

The final capstone design will consist of a sun and an earth and moon that will rotate around the sun. The sun itself will not be a traditional sun in that it will be more aesthetically pleasing rather than an accurate representation. However, the sun will contain a lighting fixture that will shine light on the earth as well as the moon. As the earth rotates, the light will show how the seasons are made relative to the earth's atmosphere. As the light shines on the moon, it will show a rough estimation of how the phases of the moon are created. There will also be an electronic display that will show the phase of the moon as well as the date and the position of the earth. The orrery will have two modes. One mode is where the orrery will rotate on its own at a constant space, showing how the earth and moon are revolving around each other and the sun. The second mode will involve the user input in which a user can put in a date, and the orrery will automatically rotate to show the earth and moon's position at that time. It will also be able to indicate the next eclipse, as well as other events regarding the lunar cycle.

The Technical project will extensively employ two types of rapid prototyping that are essential to modern mechanical engineering: 3D printing and laser cutting. 3D printing is an additive process where an object is created by laying down successive layers of material until the object is created (Robertson, 2021). Extremely complex geometries can be sliced into thin layers and quickly built from the bottom up. Laser cutting is a fabrication process that, "uses a thin, focused, laser beam to cut and etch materials into custom designs, patterns, and shapes as specified by a designer" (Obudho, 2019). Using these methods allows us to quickly build parts with complex geometries and precise features while constantly iterating on our design.

Mechanical orreries, while very breathtaking, reflect traditional mechanical engineering principles, producing precise motion using gears and other mechanical components. With the emergence of cheaper electronic components, most notably microcontrollers, over the past couple of decades, antique mechanisms have been increasingly replaced by mechatronic systems. A mechatronic system is characterized by one or more sensors feeding information to a microcontroller, which is controlling the actuation of a motor. Mechatronic systems improve upon antique mechanisms by simplifying the creation of complex mechanical motions. Our mechatronic orrery will allow us to improve upon antique mechatronic orrery designs by allowing user input. The user will input a date, and the orrery will display the position of the earth and moon in their orbits on that date. This can only be accomplished using servo motors. Servo motors use a closed-loop control system to "allow for precise control in terms of angular position, acceleration, and velocity" (Lavaa, 2021).

STS Topic

Through which ethical lens should the key decision makers that lead humanity's exploration of the Moon and Mars look use to make decisions that lead to the greatest benefit for humanity? How we undergo this unprecedented mission in a way that future generations look back with pride at our choices rather than regret? The history of exploration and colonization is looked upon by contemporary academics with regret and criticism and the future for space travel is looked upon similarly by some. One scholar wrote that "The history of neoliberal and capitalist policies here on earth depicts unwavering evidence that privatization and commodification of space will have the propensity to elicit poor ethical practices" (Segobaetso, 2018) while other scholars, like McElroy Jr. recognize the risk for unethical behavior but find

wildly different potential sources of this risk. If the past demonstrates a general unethical trend when human civilization encounters new land and resources, how can we enter into interplanetary colonization in a novel way that supports ethical behavior and minimizes conflict?

One on end, Space Travel is very different from, say, the colonization of the Americas by European colonial powers because there are no humans already living in these places to fight or infect with disease. Additionally, productive economic work on the Moon or Mars would likely be much less dependent on cheap labor which is one economic factor that contributed to the enslavement and death of millions through the Trans-Atlantic Slave Trade. These facts provide that colonization of another world may be more ethical than the colonization of the Americas by European powers in some ways, however, history has demonstrated another side to this coin. Wernher Von Braun, who is widely considered the father of modern rocketry and the Apollo Program, made technical strides in rocket technology in Nazi Germany before and during WW2. In fact, he built many of his rockets using slave laborers from the Dora Mittelbau concentration camp with over 20,000 laborers dying in the process with the produced rockets going on to kill civilians (Tzvi, 2021). Von Braun justified this by saying "My refusal to join the party would have meant that I would have to abandon the work of my life. Therefore, I decided to join. My membership in the party did not involve any political activities…", (Eramian, 2020). The justification that Von Braun used placed the importance of the development of this breakthrough technology above the importance of peace, human life, and human dignity. One scholar characterizes the ethical code that leads to such actions when he wrote that Von Braun's horrendous actions do not make him a standout in the Nazi regime because he was one of thousands of officials accepting the discarding of so much human life. Instead, the scholar writes that the problem arises from "his technocratic amorality, his single-minded obsession with his

technical dreams, that is so disturbing. If the human race is to survive its own rapidly advancing technology in the twenty-first century and beyond, scientists and engineers will have to take moral and political responsibility for their actions-something Wernher von Braun and his colleagues signally failed to do" (Neufeld, 2002). This writing points to the ethical challenge of space travel, a particularly scientific and technology-based action, as being one of understanding and prioritizing the ethical, social, and political implications of such technological development since it is not achieved in a socio-political vacuum. One scholar builds on this history to address the uniqueness of space travel and colonization in an ethical context when he writes that the novel nature of space as an environment means that "'space demands a somewhat different [ethical] philosophy" (Galliott, 2015). Therefore, an understanding of the foundations of current space travel technology coupled with significant analysis of the socio-political environment and its actors is required to understand potential ethical concerns and develop a suitable ethical code to minimize conflicts between groups. It is important to note the hopefulness of some scholar on the feasibility of space travel and colonization leading to increased unification of humanity, so this paper will work to explore the mechanisms through which this can be achieved (Odom, 2019).

STS Methodologies

STS Research Question: What ethical principles must be used to guide interplanetary space travel, colonization, and technological development in order to minimize conflicts between nations or other groups as a result of Lunar or Martian colonization.

To answer this research question, I will use the Technological Momentum framework to understand how space travel and colonization technologies have developed and will develop as a

result of the social context of the present day (Nye, 2006). In Particular, I will gather sources that spread light upon the underlying social, economic, and political influences that will affect the directions of development of space travel technology and colonization. I will also use the Deontology framework to understand the broader sense of purpose and destiny that guide many of the actors contributing to space travel. Sources that contribute to an understanding of the broader meaning and purpose of individuals involved in this project will contribute to developing a foundation of understanding for the current ethics around the project of space travel and colonization. Additionally, this research question will be answered through the usage of Ethical analysis to evaluate the moral and ethical decisions behind existing technology that is developed or being developed for space travel and colonization. Then, Policy Analysis will be used to examine how powerful groups that will likely be key decision players in the colonization of the Moon and Mars are planning on cooperating through international agreements as well as internal laws.

Conclusion

This technical project seeks to design and manufacture a mechatronic orrery which will not only provide aesthetic benefits over traditional benefits, but also functional ones. Through the use of mechatronic devices such as motors and complex electronics and coding, this project will produce a fully programable model of the Sun-Earth-Moon that will not only be able to accurately model the movement of these three celestial bodies, but provide functionality to change the speed of these movements or even "jump" accurately to the celestial positions of these bodies on any given date between 1500-2500 AD. With a easy to use electrical interface, visitors to the display will be able to control the movement of this orrery to learn more about our

solar system and the bodies within it along with the power of mechatronics over some forms of traditional machinery

On a similar note of space travel, this paper explores the leading ethical questions and decisions that will be made in the project of space exploration and the colonization of the Moon and Mars. Through this, a refined ethical code or understanding of the ethical situation will be created as to guide decision makers in this project to make choices that minimize human conflict, whether that be between groups or nations. Space travel and colonization is, in many ways, similar to previous human experiences of exploration and colonization, but also offers unique characteristics that will necessitate a deep understanding of humanity's history, the present socio-political circumstances guiding current technology development, and the unique environment of space, the Moon, and Mars in order to act in ways that will ethically stand the test of time.

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