Articulating the Ethics Concerning Space Exploration and Colonization

Samarth Venkatesh Halyal

Department of Engineering and Computer Science, California State University Fullerton

CPSC 548: Professional, Ethical and Legal Issues for Software Engineers

Dr. Michael D. Falkow

December 11, 2022

Table of Contents

Articulating the Ethics Concerning Space Exploration and Colonization

Throughout the years, humanity has developed from the Industrial to the Information era. But with recent growth in rocket and thruster technologies, we are beginning to step into the space age. With the advent of space exploration and colonization plans, there will be conflicts in ethics within humans and the entire solar system. This paper will discuss the ethical limits of the current laws on earth when applied to space-colonized societies. The consequentialist approach starts seeming prominent over the rules-based approach in bringing about a workable ethical theory in space. According to Seth D. Baum (2016), most thinkers and experts in the area criticize the consequentialist form of ethics, one of the most prominent and widely supported forms (p. 1).

Although these explorations are constant nowadays or voyages that may not be compared to actual exploration that happened in the 1950s and 1960s, Earlier explorers date back to the 1600s when astronomers and scientists such as Galileo and Kepler began their observations. Kepler, in his work "Dissertatio cum Nuncio Sidereo" meaning *Conversation with the Starry Messenger,* stated to Galileo:

> "There will certainly be no lack of human pioneers when we have mastered the art of flight. Who would have guessed that navigation across the vast ocean is less dangerous and quieter than in the narrow, threatening gulfs of the Adriatic, the Baltic, or the British straits? Let us create vessels and sails appropriate for the heavenly ether, and there will be plenty of people unafraid of the barren wastes. In the meantime, we shall prepare, for the brave sky-travelers, maps of the celestial bodies—I shall do it for the Moon and you, Galileo, for Jupiter." (Koestler 1968, 378)

Advancements in space exploration will lead to space colonization, which, although it has advantages in the far future, will deplete the resources on earth soon. The energy generated to sustain one person in space for colonization is enormous. Comparing that to a couple of hundred thousand people requires an even more tremendous amount of energy. Maintaining this kind of power can be disastrous with the technologies in hand. A set of rules should guide these decisions.

Method

Research Questions

Research question 1: How the dominance of developed countries and technological advancements over resourceful areas in outer space will affect the developing and underdeveloped countries primarily related to resource consumption and utilization from space and the earth—at the same time solving many long-running wars and conflicts between countries due to the abundant availability of raw materials from outer space. Discussion on this question will help design a modified ethical theory for space derived from the rules and laws on earth.

Research Question 2: How do ethics concerning technologies involving communication bandwidths affect various space explorations?

Research Question 3: Things like space debris, Heavy mining, and Warming planets artificially using fusion reactions can cause a shift in the equilibrium of gravity. Such acts cause discrepancies in the balance maintained in our solar system. What is the consequentialist approach to saving the solar system?

Research Design and Approach

I will be doing a SWOT analysis on the strengths, weaknesses, opportunities, and threats involving the technologies involved in space technology and colonization. I will also be talking

about different ethical theories revolving around these developments regarding technology and speak in terms of a consequentialist about the morality involved in the decision-making in such endeavors. For this paper, I will refer to the works of various prominent authors who have done significant studies on space. I will also be conducting interviews with people in space research and getting to know their thoughts about the ethics revolving around space exploration. We will conclude our study by implementing different ethical principles to determine the extent of the impact of space technology on human civilization and the ecosystem in general.

Discussion

Let's start by discussing the first research question about how developed countries' technologies influence or impact developing or underdeveloped countries regarding resource mining. I will divide the question into two sections; the first section explains the pros and cons of resource mining from space on the entire world, also how it impacts outer space, and the second section gives analogies of current laws and rules on earth that may need to be modified to fit the scenarios in space. “Resources” in this and further discussion refer to all energy-generating resources like Uranium, Hydrogen, Nitrogen, Silicon, et cetera, and related ores.

Impact of Technological advancements by Developed Countries

In today’s world, technologically advanced countries such as Australia, China, the United States, Japan, et cetera can explore far away distances in outer space as well as sustain themselves in space more efficiently compared to developing countries and underdeveloped countries that still may have a long way to reach the domain of space. This is mainly because their technologically advanced systems and proficient manpower constantly innovate in the space race. The day is not long before resources in space shall be mined and brought to earth. Space is abundant with minerals and ores that are very scarce on earth and shall be a critical

component in many devices, processes, and experiments. But numerous hurdles lie before this idea of mining from space, the primary one being the plethora of resources on earth that will be consumed to begin the expedition of mining in outer space, which outnumbers the possible profit from the resources mined and brought back to earth. This includes the available resources on earth and some that need to be mined, like uranium 232. Calculating the energy required in such expeditions is enormous and shall deplete the earth of resources it originally had. Apart from this, a lot of energy is required to sustain one person in space, which will require more resources like hydrogen and oxygen from earth and fuel resources summing up to a huge quantity of resource depletion from earth to even reach the bounds of unexplored space. Say, at some point, we achieve this feat of creating a self-sustaining energy source; then, the next task would be to handle such power. Any mistake during handling will lead to catastrophic scenarios. The technologies on earth do not meet this requirement of containing such an energy source. The next step would be to reach the Asteroid belts between the orbits of Mars and Jupiter in our solar system, which are quite far from earth. These are believed to have a high concentration of minerals and ores that may be paramount. Reaching this region is problematic, considering the distance and fuel required to travel and return. Considering if we even reach this point, sustaining the astronauts and spaceships here is a task of much higher priority. This will again consume huge amounts of energy to create an environment using nuclear fuels.

The problems that may arise hereafter may be the ones that disturb the equilibrium of space and gravity itself. Mining on Asteroids will require huge explosions and reactions. Suppose these asteroids are impacted with energy larger than they can withstand. In that case, they may lose the orbit and hit other heavenly objects that may cause havoc in space that may be

unrecoverable. The technologies that need to be designed to help aid these mining need to follow a set of ethical grounds to what may happen if they fail during the mission.

Modified Rules guiding these developments

The first ethical right that needs the most attention is property rights which are also believed by many as the foundation of all rights. Although the earth has specific rules and regulations concerning property rights, and is almost the same no matter what country you live in. On Earth, the rights of property go by saying that land or property of some kind belongs to an X person if the person owns it by value or heritage and with the respective documentation. Talking specifically about the U.S. Constitution. The fifth amendment states that

> "No person shall be ... deprived of life, liberty or property without due process of law; nor shall private property be taken for public use, without just compensation."(U.S. Const. amend. V).

This includes the rights of possession, the right to control, the right to exclude, the right to derive income, and the right to disposition. But do these basic rights on earth hold in space?

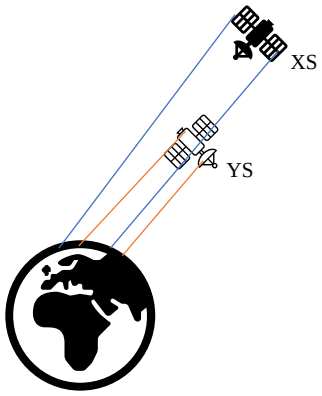
The experience from the Astronauts' visit to the International Space Station (ISS) for a long duration will likely prepare templates for managing humanity in space. Different governance arrangements are made to venture the complex international operations, which work on several levels. In 1998 in Washington, Intergovernmental Agreement (IGA) was signed, leading to ISS's creation. Later there were four memoranda of understanding (MOU) signed by NASA and other partner states for various implementation agreements (Newman, 2016). The IGA is a structure of rules which can be considered for framing law since it considers specific details for general questions. At the same time, it refers to more specific questions, such as crew

management, to regulating documents on the matter specifically established for the Space Station. (Sgrosso 2004, 65).

As discussed earlier, the technological advancements of developed countries like China will allow them to dominate the larger region of asteroid belts and closer regions to the sun to make the most out of the resources found in space. However, this can be guided by a new and modified ethical system for outer space. The resources can be divided based on the necessity of those resources and their availability in the country. Although this system seems tedious and complex to be followed, looking at it with a consequentialist view of ethical reasoning seems to work in many aspects. Many countries still on the verge of making such a feat shall hope for asteroid mining opportunities in the future. Following this approach to moral behavior will benefit human civilization in numerous ways. Mainly the long-running wars and conflicts between countries regarding petroleum and other resources will end. Since everyone is obliged to use the resources when they can venture out into space, everyone can become self-sustaining in terms of resources. If the resources are brought to earth, the abundance of the resources will bring down the cost of those resources. All these ideas of a better future can be judged by employing a more understandable form of consequentialist ethics named Utilitarian ethics. Utilitarian ethics have two forms based on whether ethics applies The Principle of Utility to individual actions or moral rules. We call them Act Utilitarianism and Rule Utilitarianism (The Internet Encyclopedia of Philosophy, n.d.).

Eventually, in the future, when space exploration becomes a common trait of all living beings, newer laws will need to be enforced, which should be contained within its unified constitution. A Unified constitution is a must because there is one space, and everything belongs to this space, every guideline should be followed equally regardless of caste, creed, or

nationality. This Space Constitution shall hold the articles and parts concerning modified rules that are a conglomeration of every constitution belonging to different countries. It will have trials for every crime that could be committed in regions that are not on earth since crimes are an



unavoidable trait of us humans. This concern can be better understood from the role of June Harris, aka (Dr. Smith) who was a career criminal and a stowaway on the 24th colony mission who stole her sister's identity to get into a classified mission and did unethical adventures for her selfish benefits, shown in the Netflix show "*Lost in Space*" (Allen, Sazama & Sharpless, 2018). Utilitarian grounds can be applied to omit the risks that have been proven from a small number of such missions that have failed and concentrate on the significant moral gain from such excavations. Since most of the failed missions were probably unavoidable and can be morally defended (Graves R. P, 2016).

Ethics concerning technologies involving bandwidths affecting various space explorations

Bandwidths used for communication with satellites and space crafts are a major concern in the space industry. Say you are a space company X that wants to communicate with the satellite that you have launched (say) XS, and there is another company Y that wants to communicate with its satellite YS. Then the bandwidth you use should not interfere with or attenuate the signal sent by Y. RADAR, and GCS (Ground Control Systems) take a lot of effort to minimize this using the current technology. But still, even with today's advanced technologies, it cannot be guaranteed that such interference will not happen. One tiny mistake and there can be catastrophic effects on the orbiting objects. It should be the responsibility of any company designing these interfaces to ensure they do not affect the communication signal at any level.

Although most companies and organizations will base their decisions using the ethical theory of Subjective Relativism, that one must follow those means and rules that benefit themselves, we are more concerned about the effects on the entire ecosystem of space, not individuals. For these purposes, I will follow the consequentialist perspective to discuss this case. The theory that will explain how the software and related technologies need to be implemented to minimize the risk of causing any conflicts is the Social Contract Theory. The urge that there should be a social contract signed by everyone in general regarding their nationality is of prime significance. Because such decisions should be guided by an entity that decides what is wrong and right by keeping everyone's benefit in mind. Although Kantianism seems to work here, there could be scenarios where a single rule cannot be applied to judge the outcome, or it may so happen that some rules have conflicts with each other. On the other hand, a Social Contract will consolidate as a Space Constitution established and maintained by an organization whose authority shall be created solely for space explorations and colonization.

In an interview with Aniket Kelkar, who is a space enthusiast and experienced engineer in space technologies at ISRO (Indian Space Research Organization), I learned many facts regarding how technologies are paramount when we talk about space exploration. Space is dangerous; getting stuck in space with nowhere to go is horrific. NASA and other agencies take the most care that there is always a connection between ground and space shuttles in missions. Any human error in the software or technologies implemented within the spaceships can cause great financial loss to the countries. Each mission costs millions of taxpayers' money and may also cause danger to astronauts' lives. If the software and technology involved do not meet certain guidelines authorized by Quality Assurance, then what measures need to be taken by justice authorities have been guided by Supreme Court and the Constitution itself. This does not

hold in space when colonization becomes a common trait. Because most tools that are created on earth have not been tested in space. They may have completely different behavior based on the conditions. These may require a modification in the procedures adopted by manufacturing industries. Newer quality assurance procedures need to be developed that will guide the technologies built-in space. Failing to do so shall result in a failed ecosystem following colonization. This is mainly connected to the electronics and communications industry as they should help facilitate all the missions successfully without communication disruption.

An example of the adverse effects caused by the malfunction with mission flights can be better understood from the 1978's Cosmos 954, a nuclear-powered Soviet spy satellite, which fell from space, scattering radioactive debris across a wide area in Canada. Although this was not a typical example of a communication hazard I am discussing now, it shows how serious it can be a precursor if proper measures are not taken (Alexander, 1984). A typical example of a communication mishap can be explained through the Phobos 1 spacecraft launched in 1998 by the Soviet Union to study the moons of Mars and land a probe near them. On the 2nd of September 1998, scientists at the space research organization lost contact with the satellite. An Investigation team was set up to investigate this case, and later investigation revealed that the latest software uploaded on August 29th was missing a character in the command sequence. This command could only be controlled from the earth, leading to the thrusters' shutdown. The communication loss happens when it goes off orbit and cannot get the sun's rays to keep it in power mode. It was also a fact that the operating system installed on this probe did not account for such mistakes and thus sealed the spacecraft's fate (National Aeronautics and Space Administration, 2020). Likewise, in 2016 a similar case can be seen with Japan's Hitomi X-ray satellite with a fault in the uploaded command that let it orbit uncontrollably around the earth's

orbit. Japan's Hitomi left a significant amount of Space Debris after this flight (Muerhoff, 2018). In the following sections, we will discuss the havoc caused by Space Debris.

We will be concluding this section by saying that a social contract in place would be required to guide the principles required to design and deploy technologies and software that adhere to the need for a robust system that follows ethical reasoning to account for the failure that may follow in case of any unplanned changes. The contract should follow a consequentialist perspective to maintain and enforce laws and rules that work for the betterment of society. An entity or government should govern this constitution and ensure everyone acts according to the social contract. This government should also make sure that it does not lead to function in a dictatorial fashion.

Our Universe and Beyond

The last question we discuss in this paper will be how human interventions in space, like space debris, mining, explosions, and nuclear reactions, will benefit, at the same time, start a chain reaction and affect the equilibrium in space. The butterfly effect may raise new issues in space or even destroy a solar system. Our forefathers have designed a robust system called constitutions and laws that govern our worlds. Much thinking goes into creating impartial guidelines that work toward the benefit of all individuals in that country. Will we, the current generation, be able to create a system that may work for the use of the entire universe?

As discussed earlier, space debris is a significant issue even at this point and can be found everywhere in near-earth orbits. Most satellites and spacecraft launched from earth and don't return to the earth turn into space debris once they stop functioning and are out of the control of the ground control systems. This debris is the by-product of human-developed technologies. A ton of work has been put forth not to let the technologies that end up in space become space

debris. Companies like SpaceX and Blue Origin are constantly working on technologies to mitigate the possibility of reducing space debris. Spaceflights are being designed that come back to earth with minimal fuel without getting stuck in space. Although there is an effort put in to minimize Space debris, it cannot be guaranteed that some mission X will not lead to the creation of one. Space Debris started even before the early stages of space exploration, with humans developing ejecta and being thrown into space. These were the nuclear test byproducts from tests like the Pascal B Test for the Plumbbob nuclear tests that were thrown at a very high speed during the atomic explosions that ended up in space as debris. Later explorations like Sputnik 1 have added to this debris formation in outer space.

The Biggest risk from this is to the human-crewed spacecrafts. All space debris travels at a high momentum and will not slow down ever due to zero friction in space which can cause damage to the space objects. One of the most significant concerns is if they hit the international space station, the primary docking place for all other space flights. The risk is not just monetary but also to the life of astronauts. What ethical guidelines need to be enforced has already been discussed earlier. Still, one thing that needs to be clarified is that the term ‘astronaut’ identifies all legal statuses of travelers to deep space. Everyone who categorizes themselves as colonists, scientists, or engineers is now legally termed an astronaut. This uniformity of conceptual foundation upon which the notion of equality lies before the governance systems says that earthly laws can be extended to “space travelers”.

Space debris also risks other heavenly objects, like moons, planets, and asteroids. The impact of space debris can change the path of these objects or lead to colliding with other things in space, eventually reversing the balance maintained in orbits. But many thinkers and scientists

argue over whether to treat space as the environment. If it should be done so, it should be regulated under specific environmental conditions. From Reiman's (2009) perspective,

> "Space at large should not enjoy a moral status equal to Earth" (ibid., 86).
>
> "In many ways, Earth, with its unique, abundant life, is special. There is nothing quite like it in the Solar System" (ibid.)

Although this is a significant point to be discussed, our existence is slippery and should not be risked by ignoring the universe. Our actions should be relevant to sustain this universe and us. Reiman further says:

> "humans' actions towards their surroundings will continue to affect people whether we live on Earth or in space" (2009, 86).

Furthermore, asteroid mining, explosions on mars, and nuclear tests in space again threaten the balance in space. Mars acts as a milestone to reach the long-term goal of farther space. Carl Sagan's theories of warm mars were because of the interactions between methane, carbon-di-oxide, and hydrogen. The current technologies that can be implemented to bring this condition back on mars and make it habitable must be used under extreme care. Failing to do so shall result in catastrophic effects on mars. These technologies, mainly concerned with small nuclear fusion explosions to warm up Mars, are to be designed by developers and managers who should understand the ethics of outer space. Ferrando (2016) notes that there is an urgency to reflect on large-scale ethical implications, socio-political challenges, and technological preconditions of space migration.

If this urgency is not met, then the percussions can be perilous, change in the orbits and orbiting momentums, destruction of planets, and expansion or contraction of equilibrium are some of the hazards. Technologies should ensure they are not built on obsolete ideas and

hypotheses. Do developers need to take into consideration who is affected? Am I treating other human beings with respect? Would my decision hold up to public scrutiny? How will those who are least empowered be affected? Are my acts worthy of an ideal professional? These questions can be looked at from the point of view of Virtue Ethics. We must acquire, through practice, those derivative, emotional, and social skills that enable us to put our general understanding of well-being into practice in ways that are suitable to each other. This belief goes back to the time of Aristotle when he conceded this idea in his works of Nicomachean Ethics. According to Aristotle, ethical theory is distinct from theoretical science. As a result, its methodology must match its subject matter of good action and acknowledge that many generalizations can only be applied to most cases in this field (Aristotle, 2014).

Future space technologies plan to rely heavily on robotics and artificial intelligence to assist human teams of astronauts. Robots may be able to perform maintenance and repairs on existing space stations as well as assist scientists in collecting and analyzing data. Even with modern space technology, commercial space travel remains a sci-fi concept. Nevertheless, companies like Blue Origin and Virgin Galactic, founded by Jeff Bezos and Richard Branson, aim to accomplish this shortly. Virgin Galactica has already taken at least 600 deposits for passengers booked on the first commercial flight scheduled for a few years from now. Establishing colonies on other planets will likely play a significant role in future space technology. These extraterrestrial territories are the new frontier of imagination, from 3D-printed homes on Mars to outposts with nuclear power supplies. It is even predicted that something similar will exist by 2030, according to NASA. One theory like Aristotle's Nicomachean Ethics to explain the guidelines to be rules for such explorations is a matter of reasoning. A Consequentialist theory to explain it all is a near-impossible task as of now but pioneering such a

social contract that enforces rules and laws is a doable task. This contract should also encompass all the conflicts that arise when establishing modified rules in outer space. A conglomeration of Utilitarian ethics, Social Contract theory, Virtue ethics, and deontological aspects of Kantianism from the viewpoints of the second formulation that humans should treat others not as means but as ends to means; seem to be wise guidelines to enforce.

In 2019, Anne McClain, a NASA astronaut, was alleged to hack the bank account of her ex-wife, summer McClain to access sensitive data for personal reasons from a computer aboard the space station. One might assume that hacking a satellite is a near-impossible task, but it is not that difficult. Since modern satellites and spacecraft are completely software-operated, they can easily be manipulated. All these facts make it clear why space ethics is an urgent matter. Consider this situation in an even far apart galaxy that cannot be reached as easily as reaching the space station. When space exploration becomes more pronounced in the near future, such cases might cause conflicts in denser populated civilizations in space, making it very hard for jurisdiction to bring the culprit to law. A system of contracts that works as decentralized law enforcement needs to be designed, which should maintain peace no matter which point of civilization commits infringement. Some science fiction movies and television shows have shown a time patrol group that travels to the point of crime with space-time teleportation. Scientists have proven such feats at laboratories at the atomic level using superposition principles and quantum computing. However, such systems will take still a millennium to exist or even come to a practical sense. Hence, an urgent step would be to create a decentralized system of social contract or constitution that I discussed earlier that handles such cases.

Discussing further, although we have met a certain threshold in our technological advancements to venture out into space, the question still arises whether we should do it in an

ethical sense. Risks are criminal and financial and have psychological and medical effects on mankind. Most astronauts who are sent out to space are trained to a great extent to endure that harsh outer space. Even with today's technologies, we cannot minimize the harm space can cause to the human body, which is adapted to live on earth with a certain amount of gravity. The central nervous system is mainly affected by long exposure and could have many psychological effects. Although most scientists believe that our bodies can evolve after certain generations of living in space, are we willing to pay that cost to explore space? Or are we just some species pointed out by many thinkers and philosophers as parasites on earth, just a species living back dead hosts(earth)? Colonizing planets is not a far thought today; with multiple drones and rovers to send to mars to examine the atmosphere, companies are taking leaps into making it a reality. Ethically these technologies are not tested on the surface of mars or, in the literal case, in space, so are we to be trusted with something that is never tested in some environment that brings about new risks to humanity traveling to space? To consolidate all these questions, there is an example of a story that happened in 1976 when two soviet cosmonauts were sent on a mission to the Salyut 5 space station. The last dedicated military space station in the program/ the commander and flight engineer boarded the Soyuz 21 spaceflight, beginning a mission that was supposed to last 66 days. But after just 49 days, the mission ended abruptly when the astronauts reported something dangerous aboard the space station. They reported a nauseous chemical smell. Ground systems scrambled to get the astronauts back to earth. Soon after the landing, a replacement group boarded the flight with breathing equipment. With the concept, a fluid leak could have filled the station with this dangerous smell. But after a thorough inspection, they found no odor, gas, or technical issue on the flight. Subsequent reports of psychological problems in the Soyuz crew made NASA conclude that the odor was just a hallucination caused due to long hours,

exhaustion, and a harsh alien environment. The human body is an amazing machine, but it's not meant to live in space. Although G-suits and other technological advancements are made to enhance the body's capability. According to some, keeping the body sustained on the trust of these technologies may not be ethical, as seen in the example of Soyuz astronauts. The integrity of the technologies used is paramount, and they should be documented and guided according to a set of rules designed for space exploration. Eliminating boundary conditions like the psychological aspects of each astronaut is wrong.

On the contrary utilitarian analysts may say that the scope for better and trusted technologies that have been tested thoroughly should be implemented. All basis and thinking can lead to the theory of social contract that should be implemented as precisely and detailed as our constitutions have been. Eventually, there can be conflicts that have not been mapped in this contract that should be resolved ethically.

Conclusion

Through the procedure of SWOT, we have discussed the pros and cons of *Utilitarian ethics* and how it can be used to analyze the technological misconducts that may affect space exploration teams. We also discussed the *Social Contract Theory* to create a constitution that guides all space activities and how it should be developed, enforced, and maintained by a power above the individual constitutions and governments of different countries. We discussed the deontological aspects of *Kantianism* and its *Second Formulation* to realize the tiny gap between a social contract and a universal theory. Finally, we discussed how Virtue ethics could be used to decide the guidelines software and hardware developers need to bound to build systems as robust as required. We hereby conclude our study of ethics required by space exploration and colonization by stating that there is an urgency to design a Social Contract guiding the ethics that

must be practiced in space and on earth by all entities participating in such activities. This Contract shall encompass all the aspects of need-based consequentialist theories like Utilitarian, Kantian, and Virtue ethics. This shall be developed over the years and modified based on the specific cases encountered during all our Space Endeavors.

References

Alexander F. Cohent (1984). Cosmos 954 and the International Law of Satellite Accidents. *Yale Journal of International Law, 10(*78*)*, 78-91.

Allen I., Sazama M., & Sharpless B. (Directors), & Parker M., Stephens T., & Jenkins M. (Actors). (2018). *Lost in Space* [Series]. Retrieved from https://www.netflix.com

Aristotle. (2014). Cambridge texts in the history of philosophy: Aristotle: Nicomachean ethics (R. Crisp, Ed.; 2nd ed.). Cambridge University Press.

Baum, D. S. (2016). *The ethics of Outer Space: A consequentialist perspective*. Social Science Research Network. https://doi.org/10.1007/978-3-319-39827-3

Dunbar B. (2021). Space Debris and Human Spacecraft. National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/station/news/orbital_debris.html

Ferrando F. (2016). Why Space Migration Must Be Posthuman. In Schwartz, J. S. J., & Milligan, T. (Eds.), *The Ethics of Space Exploration* (pp. 239-249). Springer. https://doi.org/10.1007/978-3-319-39827-3

Graves R. P. (2016). *The Risks of Nuclear Powered Space Probes*. In Schwartz, J. S. J., & Milligan, T. (Eds.), *The Ethics of Space Exploration* (pp. 239-249). Springer. https://doi.org/10.1007/978-3-319-39827-3

Kelkar, A. (2022, September 26). Personal communication [Personal interview].

Koestler, A. (1968). The sleepwalkers: A history of man's changing vision of the universe. London: Pelican.

Muerhoff, M. (2018, February 1). Resilience and discovery in decades-long satellite collaboration. https://uwmadscience.news.wisc.edu/. https://uwmadscience.news.wisc.edu/astronomy/hitomi-satellite

National Aeronautics and Space Administration's High Energy Astrophysics Science Archive Research Center (2020). *Phobos 1* (J.D. Myers, Ed.). https://heasarc.gsfc.nasa.gov/docs/heasarc/missions/phobos1.html#instrumentation

Newman C. (2016). *'The Way to Eden': Environmental Legal and Ethical Values in Interplanetary Space Flight. The Ethics of Space Exploration* (pp. 221-237). Springer. https://doi.org/10.1007/978-3-319-39827-3

Reiman, S. (2009). Is space an environment? Space Policy, 25, 81–87.

Sagan C. (1971), *Long-Wavelength Ultraviolet Photoproduction of Amino Acids on the Primitive Earth*. *172*(3995), (pp. 417-420). Science. DOI: 10.1126/science.173.3995.417

Schwartz, J. S. J., & Milligan, T. (2016). *The Ethics of Space Exploration*. Springer. https://doi.org/10.1007/978-3-319-39827-3

Sgrosso, G.C. (2004). *Legal aspects of the astronaut in extravehicular activity and the "space tourist". In ECSL, ESA, UNESCO Joint Symposium on the Legal and ethical framework for astronauts in space sojourns* (pp.79–81). [Online]. Paris: UNESCO. Available at: http://unesdoc.unesco.org/images/0013/001397/139752m.pdf. Accessed November 7, 2022.

The Internet Encyclopedia of Philosophy (n.d.) *Act and Rule Utilitarianism* https://iep.utm.edu/util-a-r/

U.S. Const. amend. V.