Virginia CubeSat Constellation Mission
(Technical Project)
Where Space Science Would be According to Stanley Kubrick
(STS Project)

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

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The Virginia CubeSat Constellation Mission is a project conducted by four Virginia universities: University of Virginia (UVA), Old Dominion University (ODU), Virginia Tech (VT), and Hampton University (HU). Three nano-satellites, each 10 centimeters cubed, deployed into orbit to obtain measurements of the properties of Earth's atmosphere (Hope, 2019). The three CubeSats launched on April 17, 2019, and on July 3, 2019, the CubeSats deployed from the International Space Station (Samarrai, 2019). The technical aspect of this thesis is to focus on fixing the communication systems between the ground station and the Libertas CubeSat deployed by UVA. The research motivation behind the CubeSat mission is to obtain atmospheric data as the satellite deorbits. Because communications are down between the satellite and the ground station, it is impossible to receive the data the University launched the satellite to receive. Secondary objectives are to finalize licensing with the Wallops Flight Facility in order to establish testing procedures and provide hands-on spacecraft design experience to undergraduate students.

The STS aspect of this thesis will look deep into the film, *2001: A Space Odyssey* and investigate how it predicted where space technology should be as opposed to where it actually is now. The film came out in 1968 and depicts technologies and missions beyond what people at the time had even begun to imagine. It starts out with its own version of the dawn of man, showing hominids waking up to find an alien monolith that somehow inspires them to use bones as weapons thus beginning the age of invention and innovation. The film then jumps millions of years into the future to the year 2001 where people now go on business trips to the moon and are able to travel all the way to Jupiter (Kubrick, 1968). Technologies depicted in this film such as an international space station orbiting the Earth and Artificial Intelligence (AI) did not exist at the time, and some still do not exist. This research will attempt to understand how the film inspired future technologies and understand why space engineering has not yet reached the level of advancement the film promised by the year, 2001. These two topics, while both space-related, are loosely coupled. One focuses on a specific mission conducted by UVA and other Virginia universities. The other attempts to understand a concept unrelated to the specific technical project at hand but that is still related to space exploration. Figure 1 below gives the timeline of the technical project in the form of a Gantt chart.

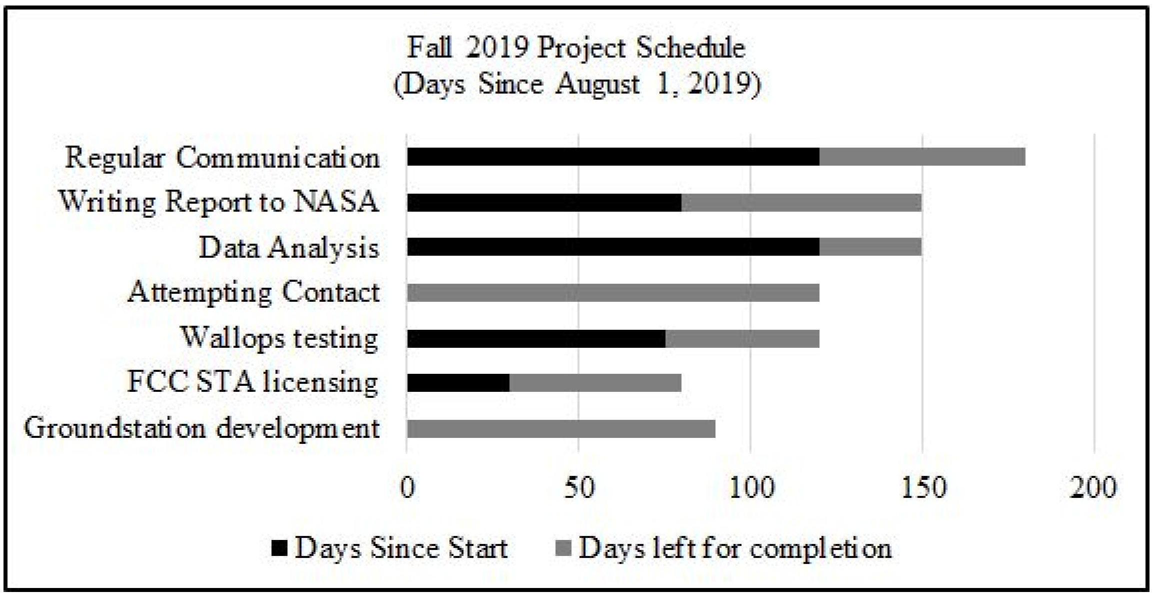

Figure 1: *Fall 2019 project schedule*: Days left for completion (Pollard, 2019)

Virginia CubeSat Constellation Mission

The Virginia CubeSat Constellation Mission consists of three satellites, Libertas, Aeternitas, and Ceres, deployed from the International Space Station via the NanoRacks CubeSat Deployer (NRCSD). The purpose of this mission was to launch these CubeSats into Low Earth Orbit (LEO) in order to record position, altitude, and attitude information that can be used to create and test atmospheric models as the satellites deorbit. Orbital predictions depend on the drag the satellite will experience, which depends on the density of the atmosphere. It is important to increase the accuracy of atmospheric density models because they can help improve current orbital predictions, predict the time and location of reentry for orbital debris, and prevent orbital collisions (Dunne, Puckette, & Wilson, 2019). The lifespan of these satellites is about one to two years before they burn up in the Earth's atmosphere (Chin, J. et al.,2017). Despite its deployment, the Libertas satellite, UVA's CubeSat, has a few issues that need to be worked out before it can be deemed a properly working mission.

One issue is that UVA needs to finalize licensing with the Wallops Flight Facility, a rocket launch site in Wattsville, Virginia that supports science and exploration missions for the National Aeronautics and Space Administration (NASA) and other Federal agencies, in order to establish testing procedures with them. In addition, communication between the Libertas satellite and the ground station located at UVA has not been working. VT was able to get a reading from UVA's CubeSat, but that is the extent of the three ground stations's ability to communicate with the satellite. So far, UVA has been unable to obtain a reading from its own satellite. Communication is important because the purpose of the satellite is to get readings regarding the Earth's atmosphere, and without the ability to communicate, the data will be lost.

This research project will implement design elements in order to fix the communications system. Along with fixing the communication between the ground station and the satellite, this research project will entail obtaining licensing for the satellite, providing a hands-on spacecraft design experience for undergraduate students, and hopefully encourage funding for future projects conducted by the department of Mechanical and Aerospace Engineering (MAE) at UVA. Researchers will approach the problem using the Space Mission Engineering (SME)

Process definition of mission parameters and refinement of requirements so as to meet the objectives of the mission in a timely manner at minimum cost and risk (Microcosm, 2011). Using this process, the mission is expected to be low-cost, low-risk, and near-term with sufficient performance such that the customer, the Virginia Space Grant Consortium and NASA in this case, are willing and anxious to proceed to build the system (Goyne, 2019). Figure 2 below depicts the SME Process.

Steps
Define Objectives and Constraints 1. Define the Broad (Qualitative) Objectives and Constraints 2. Define the Principal Players 3. Define the Program Timescale 4. Estimate the Quantitative Needs, Requirements, and Constraints
Define Alternative Mission Concepts or Designs 5. Define Alternative Mission Architectures 6. Define Alternative Mission Concepts 7. Define the Likely System Drivers and Key Requirements
Evaluate the Alternative Mission Concepts 8. Conduct Performance Assessments and System Trades 9. Evaluate Mission Utility 10. Define the Baseline Mission Concept and Architecture 11. Revise the Quantitative Requirements and Constraints 12. Iterate and Explore Other Alternatives
Define and Allocate System Requirements 13. Define System Requirements 14. Allocate the Requirements to System Elements

Figure 2: *The SME process*: Refinements and requirements (Microcosm, 2011).

Software courtesy of space-track.org will also be used to obtain two-line element (TLE) sets, lists of orbital elements of an Earth-orbiting object for a given point in time. These TLEs can then be used to create pass schedules of the CubeSat's orbit which tell when the spacecraft passes over the horizon (Space-track.org, n.d.). The technical advisor for this research is

Professor Christopher Goyne in the department of Mechanical and Aerospace Engineering at UVA, and the research team members attempting to redesign the communication system are Joseph Brink, Cameron Greer, Connor Hsiang, Margaret Pollard, and Connor Segal, all of whom are fourth-year students majoring in aerospace engineering at UVA's School of Engineering and Applied Science (SEAS). The time frame is two semesters as it is a part of the Spacecraft Design I and Spacecraft Design II Capstone classes.

Where Space Science Should be According to Stanley Kubrick

The purpose of this STS research project is to understand the intersection of science and art. Specifically, it will investigate how the film, *2001: A Space Odyssey,* predicted the future of space technology and understand why science has, in some ways, failed to meet its expectations. The influence of art on science is important to investigate as the two have always gone hand-in-hand. For instance, Leonardo da Vinci was drawing sketches of airplanes 400 years before the Wright Brothers flew the first plane in 1903 (Jakab, 2013). Before an invention can come to fruition, it has to be conceptualized by imaginative minds. Therefore, it is necessary to look at how *2001: A Space Odyssey* inspired the mathematically inclined to materialize the technologies the film's creators thought up to create the spectacle in their science fiction epic. The purpose of this research project is to understand how art, science, and technology intersect. Also, it will attempt to understand how a classic film like 2001: A Space Odyssey inspired years of technological advancements and continues to do so.

As stated earlier, the film includes technologies such as an earth orbiting international space station and AI. The international space station depicted in the movie orbits the Earth and is used as a layover stop for the one of the character's trip to the moon. While the first rudimentary space station was constructed in 1969 by linking two Russian Soyuz vehicles in space, construction on the International Space Station that is used today did not begin until 1998, 30 years after the film's release (U.S. National Laboratory, 2019). Figures 3 and 4 below are the space station depicted in the film, *2001: A Space Odyssey* and the actual ISS astronauts from multiple countries use today, respectively.

Figure 3: *2001: A Space Odyssey*: International space station (A.M.P.A.S., 1968)

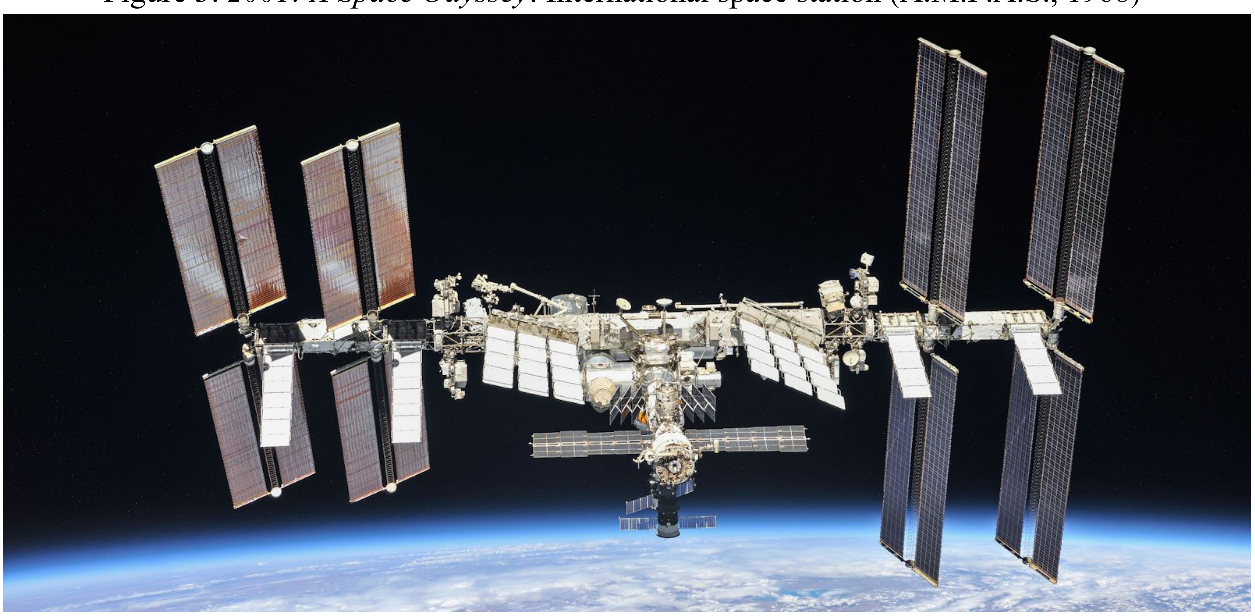

Figure 4: *ISS*: The largest and most complex international construction (NASA, 2018)

Similarly, the film came out in 1968, but the first AI was not completed until 1969 (Fuge, 2018). Therefore, the film put AI into society's consciousness before it even existed for public use. The AI in the film, HAL, closely resembles AIs like Amazon's Alexa. This type of device is common in any household now; however, in the film, it was used for high caliber situations such as operating a spacecraft on its way to Jupiter. In contrast, the film also predicted technological advancements that scientists have yet to achieve even by the year 2019. Namely, the main storyline of two scientists on their way to Jupiter is still a fantasy in the modern world (Kubrick, 1968). Today, the world's best engineers are still figuring out how to send humans to Mars and back, so the ability to send a manned spacecraft to Jupiter is still incredibly theoretical and will most likely be for years. This begs the question: with the technology engineers have been able to develop, why have space scientists not been able to achieve advancements like what films like *2001: A Space Odyssey* promised they would have by this year?

This thesis will approach its research using actor-network theory (ANT). ANT provides a socio-technical approach to analyze concepts that help track the chain of decisions and power relationships through which actors gradually agree upon, going from an idea to its realization. There is a process of constant negotiation, compromises, and conflicts during the implementation of whatever plan they are developing. Their aim is to stabilize the relationships surrounding the project. In this theory, actors can be people or anything that has influence (Jolivet & Heiskanen, 2009). In the case of this project, the actors are the film, 2001: A Space Odyssey, the film's creators, Stanley Kubrik and Arthur C. Clarke, film watchers, the public, policy makers, engineers, and advancements in technology. An illustration of this network is depicted below in figure 5.

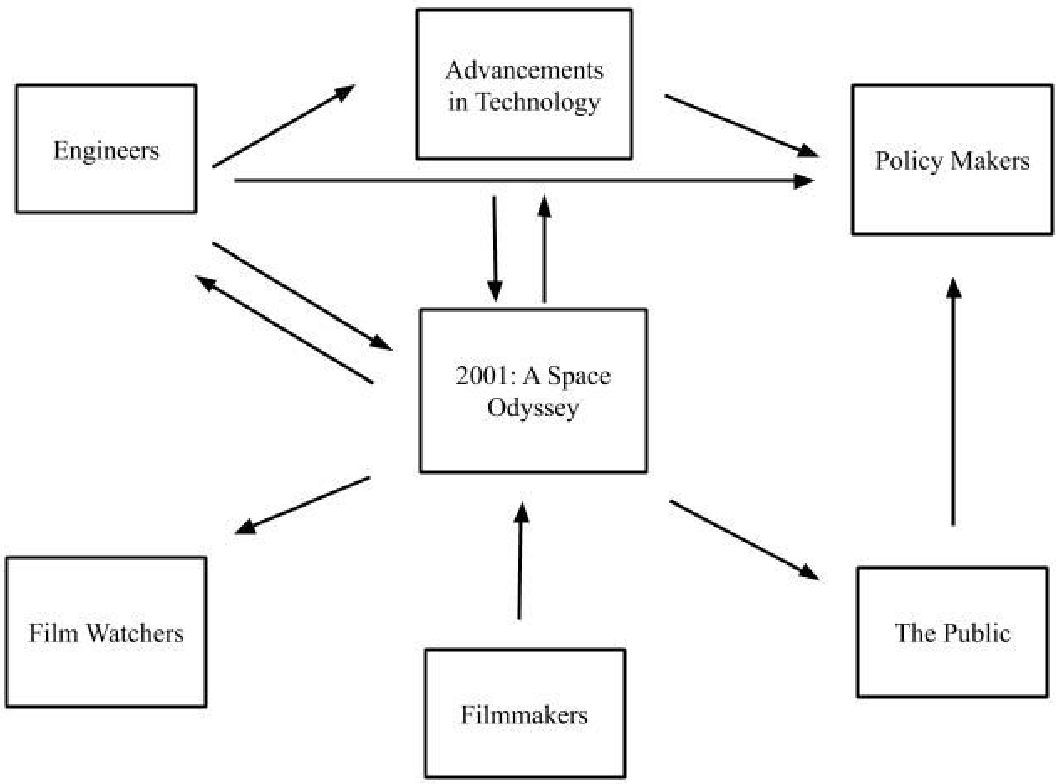

Figure 5: *STS framework*: Interaction of *2001: A Space Odyssey* and the actors it influences (Pollard, 2019)

As depicted above, the filmmakers were inspired by existing technologies and in turn, inspired engineers to develop future technologies through the film, *2001: A Space Odyssey*. The film itself influences the general public, including film watchers and policy makers. Therefore, this model highlights the negotiation between filmmakers, engineers, and the public.

This research project will employ methods such as surveys and interviews with aerospace engineers and those studying it, and published journals and articles will be used in order to discover why modern day space scientists have yet to explore places beyond the moon, such as Mars and Jupiter. In addition, *2001: A Space Odyssey* will be analyzed to see what technologies the film promised society by the year 2001 and see how well its predictions hold up in the year 2019. The anticipated and hoped-for outcome is that there is a correlation between the technology the film imagined and current technological advancements that exist in addition to those that are being developed, proving that art and science are not separate but instead go hand-in-hand. This part of the thesis will take the form of a scholarly research paper as it attempts to prove that these concepts intersect.

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Microcosm. (2011) Figure 2: *The SME process*: Refinements and requirements

NASA. (2018) Figure 4: *ISS*: The largest and most complex international construction

Pollard, M. (2019) Figure 1: *Fall 2019 project schedule*: Days left for completion

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