Prospectus

Amateur Radio CubeSat
(Technical Topic)

The Interaction of Private and Public Space Agencies
(STS Topic)

By

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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

Launched into orbit off the International Space Station (ISS) in July 2019, UVA's CubeSat Libretas is part of a three satellite constellation. The goal of this project is to study orbital decay and the effect of a drag brake (Sandy, 2019). However, the UVA ground station has failed to make contact with Libretas, meaning that the data gathered cannot be accessed or studied (Segal, Brink, Greer, Hsiang, & Pollard, 2019). This could be due to a problem with the ground station, a problem with the satellite, or a result of the limited frame in which communications could be established. A broader consequence of this issue is that without this project being successful, UVA is less likely to receive future funding on similar space design projects or acclaim within the CubeSat community. To address this technical problem, we propose designing a CubeSat that operates on amateur radio frequencies that can establish two-way communication with the UVA ground station. Additionally, data from the satellite could be accessed by the Amateur Radio Community and used for experimentation. This would confirm the working capabilities of the UVA ground station and bring acclaim to UVA within the CubeSat community. The satellite would be launched to the ISS and then into Low Earth Orbit, where it would fly for about two years.

Upon researching the process to launch a satellite to the ISS, the increasing privatization of space travel became apparent. Although it is one of five agencies supporting the ISS, NASA currently does not directly resupply the station. Instead NASA relies entirely on two private companies, SpaceX and Northrop Grumman, to accomplish this (Shi, 2016). Therefore, our designed satellite would travel privately to the ISS as opposed to being transported by a public government agency. This one example of privatization indicates a larger shift across the entire

space exploration industry. Since launching to the ISS is an essential step in getting our satellite into orbit, it is important to understand how this would happen and the outside companies involved. Additionally, a more complete understanding of the current policies and relevant organizations involved in space travel is necessary to successfully navigate the narrow field of space exploration.

To effectively establish communication with a CubeSat launched to and off of the International Space Station, both technical and social factors must be considered. Our technical project will design a CubeSat operating on amateur radio frequencies with the goal of sending and receiving signals to and from the UVA ground station. To further understand the social factors involved in launching a satellite to the ISS, my STS project will examine NASA's standing as a main force within the space exploration realm and how it is working to maintain this status. In order to counteract the potential struggles associated with older public organizations, such as a slow bureaucratic leadership system, NASA is employing newer companies, like SpaceX, to continue its momentum forward.

Technical Project

CubeSats are light, compact nanosatellites that are intended for Low Earth Orbit and typically serve purposes or conduct experiments that work on a miniature level. Over 2,000 CubeSats have been launched since 1998, many by university student groups, demonstrating the relative ease with which they are constructed and put into orbit (Toorian, Diaz, & Lee, 2008). Because they normally consist of off-the-shelf components and can be customized to fit a variety of projects, CubeSats are popular for amateur radio uses (Estela, Canales, & Coloma, 2019). The Amateur Radio Community, a large group of hobbyists who have a fascination with radio

communication, operates on non-commercial frequencies for the purpose of experimentation, communication, radiosport, and other related topics (Berg, 1989).

In April 2019, with funding from the Virginia Space Grant Consortium and in partnership with Virginia Tech and Old Dominion University, the University of Virginia launched three CubeSats to the International Space Station. UVA's satellite is named Libertas, after the Roman goddess of individual liberties represented on the back of the Virginia State Seal. On July 3rd, 2019, in an exciting culmination of many years of work, the three satellites were deployed into orbit (Sandy, 2019). The goals of this project are to gather data on atmospheric properties and to study orbital decay and the effect of a drag brake on the decay of a satellite. This data could be used to avoid orbital collisions and predict deorbit times and locations of reentry for a variety of satellites (Segal et al., 2019).

Unfortunately, the UVA ground station has yet to successfully send or receive any communication with Libertas. This could be due to a problem with the UVA ground station or the CubeSat itself. At the ground level, some potential complications include an antenna rotor calibration issue or the inability of the radio antenna to simultaneously send and receive data due to incorrect timing of sequencer relays. Additionally, Libertas can only be contacted when it passes overhead, and the project is only licensed to transmit on a frequency of 401.04 MHz, making communication with the satellite very narrowly accessible regardless of problems with the antenna. Without established communication, Libertas cannot collect data and therefore cannot complete its goals. Since the three CubeSats are designed to burn up when reentering Earth's atmosphere, Libertas will remain in orbit for a maximum of two years (Segal, et al.,

2019). This creates a strict time frame in which two-way communication has the potential to be established.

In order to address the main problem with Libertas, the inability to establish communication, we propose designing a CubeSat operating on amateur radio frequencies with the main goal of reliably sending and receiving signals with the UVA ground station and the Amateur Radio Community. Similarly to Libertas, this proposed satellite will exist in Low Earth Orbit and ideally be constructed at a low cost, around $65,000, and with low-risk. To try and improve on the previous design, the new CubeSat is scheduled to fly over UVA at least four times a day, which increases the time period in which communication can be established. It should also have main antenna gain of at least 15 db and a minimum data transfer rate of 510 kB/s to optimize response time and probability. Beaconing, the continuous transmission of small pings, will be used to ensure there is a signal to be picked up by the ground station. To keep production costs low and ensure the functionality of individual parts of the CubeSat, off-the-shelf components will be used. By designing on amateur radio frequencies, we create a new community of users who can assist in testing the satellite once in orbit (Estela et al., 2019).

The first mark of success for this project will be designing a CubeSat that fits within the regulations required to be launched, such as size and weight constraints. Next, successful launch to and off of the ISS is necessary. Finally, if communication is established between our designed satellite and either an amateur radio hobbyist or the UVA ground station, this project will be an overall success.

STS Project

Founded in 1958, the National Aeronautics and Space Administration (NASA) is a federal agency focused on aeronautics and aerospace research. The organization flourished during the Space Race of the 1960s, competing against the Soviet Union to achieve spaceflight, build artificial satellites, and complete missions to the moon. Since then, NASA has led a number of space exploration efforts and is one of five agencies currently supporting the International Space Station (ISS) (Karafantis, 2014). Over the past 60 years, it has remained a source of technological pride and a cultural symbol of American innovation and progress. However, after the legalization of private space travel in 2004, there has been a rise of private space-oriented companies headed by billionaires, such as Elon Musk's SpaceX and Jeff Bezos's Blue Origin (Yuhas, 2019). These programs have been extremely successful, creating rockets and satellites and achieving goals previously accomplished only by public government organizations.

Some claim that NASA finds itself in a new space race. This time, it is competing with private companies to create reusable, manned rockets and explore deep-space (Yuhas, 2019). With NASA's funding decreasing, there seems to be a movement away from government space exploration. This could represent a cultural shift away from valuing scientific exploration or a decreased national interest in space travel. Already, NASA relies entirely on private companies to reach the ISS. Developed as a part of NASA's Commercial Resupply Services (CRS) program, SpaceX's Dragon was the first private spacecraft to supply the ISS, first taking the trip in 2012. It is also the only current spacecraft capable of returning cargo to Earth and has the

potential to carry up to seven passengers (Anderson, 2013). To some, this indicates NASA falling behind SpaceX as the leader of space exploration (Redd, 2019).

However, this argument fails to consider NASA's efforts to collaborate with the private companies. Through programs like the CRS, NASA is actively enlisting, not competing against, companies like SpaceX to work towards a common goal. By considering the public and private space sectors as independent, we fail to acknowledge the link between the groups. This partnership is key as it has allowed NASA to remain a relevant force in space science even with its limited funding and comparatively slow administrative processes. In addition to benefiting NASA, the technical support provided from the public sector to the private has been essential in enabling its success. To examine this mutually beneficial collaboration, I will further explore the CRS program that prompted the development of Dragon by SpaceX.

Using technological momentum as a framework, I will examine how NASA is fighting to maintain its presence and power in the field of space exploration. Developed by Thomas Hughes, the theory of technological momentum states that the relationship between technology and society is time-dependent and reciprocal (Hughes, 1994). System builders, like NASA, understand that having momentum can ensure durability and continued growth. However, these groups can also fall victim to reverse salients, components that develop insufficiently and prevent a system from reaching its goals (Hughes, 1994). For NASA, these components include old-fashioned rocket technologies and a slow bureaucratic leadership system. I will discuss how NASA's partnership with private companies is a response to its reverse salients and an attempt to remain on the forefront of space exploration while using its momentum and resources to assist the private realm in accomplishing their mutual goals.

Conclusion

The technical project is designing a CubeSat that operates on amateur radio frequencies and will be launched to and off of the International Space Station (ISS). The goal of this satellite is to establish two-way communication with the UVA ground station and send signals to the Amateur Radio Community. The STS research paper will examine the shift from public to private space travel, looking specifically at NASA's Commercial Resupply Services program that enlisted private corporations to resupply the ISS. Dragon, developed by SpaceX, was the first success from this program, and reached the ISS in 2012. I claim that NASA is not in competition with these private companies but instead has enlisted them to reach a common goal. The momentum of an established agency like NASA combined with the innovation and excitement of a newer company like SpaceX broadens the scope of what either group could accomplish alone. Since our designed CubeSat will require transportation to the ISS, it is essential that we fully understand the groups involved in getting it there and their relationship to each other.

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