Prospectus

Low Risk Cubesat Design Using Amateur Radio Frequencies

(Technical Topic)

An Investigation of the Mars Surveyor '98 Failures

(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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Socio-Technical Problem

During the Last decade a new class of small satellites known as CubeSats have become common projects for industry, government, and academia. These Satellites are extremely low cost to build, compared to traditional satellites, and can be designed and built in as little as nine months (National Aeronautics and Space Administration [NASA],2017). Some universities have begun to take advantage of this and have launched cubesats both to perform research and to educate engineering students. The University of Virginia launched its first CubeSat, Libertas, in April of 2019 as a part of the Virginia Cubesat Constellation (VCC), which is composed of three cubesats from Virginia universities. However, as of October 2019, two-way radio contact has not been made with any of three satellites. This result is not uncommon for cubesat missions, which have failure rates around 34%, and especially university missions, which have a failure approaching 50% (Swartwout, 2013).

The current reliability of university cubesats presents several issues and if these are not addressed universities may be unable to continue to launch them. The largest issue is the loss of funding sources. Most university missions are for research or educational purposes and are therefore funded by external sources through grants. If the failure rate does not substantially improve, funding sources may move on to other mission types. Nonfunctional cubesats could also pose a danger to other space missions in the form of space debris. While most cubesats are deployed in low earth orbit (LEO) and will deorbit in less than a years, some may remain in orbit for decades (Clark, 2015). Even the possibility of danger to other spacecraft may force regulators to limit the number of cubesats which can be launched or require even more strict, and expensive, validation procedures.

In order to improve reliability of the UVA cubesat program I will help design and build a 1U cubesat which has the ability to reliably communicate with multiple ground stations. The satellite will be designed with an amateur radio license to allow for it to communicate with a variety of ground stations to aid with troubleshooting. However, a strictly technical solution will not fully address the problem of cubesat reliability. Cubesat missions of today show many similarities to the NASA program management style of "Fast, Better, Cheaper" (FBC) which focused on a reduction of mission cost, having very specific mission objectives, and shorter mission timelines. This management style had both successes, such as in Mars pathfinder, but also several failures, such as the Mars Surveyor '98 program (NASA, n.d.). The relationship of this project management style to the mission outcome, and especially failure, will need to be better understood if we hope to increase the reliability of university cubesats.

In order to decrease cubesat mission failure both social and technical aspects must be addressed. In the following prospectus I will propose a cubesat project which will help the University of Virginia develop reliable communication capabilities with a satellite in low earth orbit. I will then use actor network theory to analyze the failures of the Mars Surveyor '98 program and how improper recruitment of actors by network builders can lead to project failure.

Technical problem

Reducing the cost of space missions has long been a goal of governments, academic institutions, and private businesses. In an effort to lower the cost and shorten the timeline of satellite development California Polytechnic Institute and Stanford University introduced CubeSats in the late 1990s. Cubesats are a class of picosatellite which have standardized dimensions counted in "Units" and use a universal deployment mechanism known as a P-POD (California Polytechnic Institute, 2014). Most university cubesat missions are 1U spacecraft and have the external dimensions of 10x10x10cm. These standards set forth a design process for a simple satellite with low mass with several advantages that make these satellites appealing to universities.

The primary drivers for the adoption of cubesats is the reduction in cost and, theoretically, an improvement in reliability. The standardized dimensions have allowed for businesses to develop components that can easily be integrated into a satellite project without forcing a team to design a custom component. These parts are referred to as “Commercial off the Shelf” and can offer lower cost and higher reliability than custom parts. Costs are further reduced by the low mass and the standardized deployer. This allows the cubesats to be easily integrated and launched as secondary payloads to larger missions (NASA, 2017). Several government agencies including the Air Force, NASA, and the National Reconnaissance Office will even allow for research or educational cubesats to be added to their missions for a reduced or free launch cost. Finally, the simple design of cubesats, compared to traditional satellites, has allowed for a compressed design schedule, which allows for universities to use cubesats as capstone projects.

In a joint effort with the Virginia Space Grant consortium, Old Dominion University, Hampton University, and Virginia Tech, the University of Virginia helped develop the Virginia Cubesat Constellation (VCC). A Constellation is a collection of multiple individual satellites that work together to perform a mission. The VCC consisted of three 1U cubesats which aimed to develop a more accurate model of atmospheric density and was launched in April of 2019. However, none of the universities were able to reliably make two-way radio contact with their cubesats after they were deployed from the International Space Station (Samarrai, 2019). Troubleshooting this problem was made more difficult by the restrictions placed by the FCC license currently in use by the team. The experimental classification limits who and from where communications with the satellite can be established (Federal Communications Commission, 2013) Never establishing communications with cubesats is not uncommon with university led projects, which have 20% chance of never establishing contact if they make it to orbit (Langer and Bouwmeester, 2016).

Because of the low orbital altitude of university cubesat missions they have low lifespans before deorbiting and burning up in the atmosphere. When a cubesat is deployed from the International Space Station, it may have a lifespan of only a few months (Clark, 2015). Establishing communications quickly with any cubesat is an essential part of mission success. Developing a cubesat which can reliably communicate with ground stations will allow for the UVA satellite program to continue to expand.

In order to address the issues with cubesat reliability I will help design and build a 1U cubesat which uses an amateur radio license and emphasizes low risk. Using an amateur radio will allow for a broader range of people to communicate with the satellite and allow for easier troubleshooting if contact is not made at time of deployment. It will also allow the public to become involved with the mission and become better informed as to the capabilities of cubesats. This mission will prove that UVA is capable of developing cubesats and will pave the way for more complex missions in the future.

STS Problem

In the early 1990s NASA began to shift from a project management style focused solely on mission success to one which was referred to as “Faster, Better, Cheaper” (FBC) by NASA administrator Dan Goldin. The basic tenants of FBC included putting more emphasis on mission cost and schedule, focusing on numerous smaller missions, and utilizing new advanced technologies (NASA, n.d.). Under FBC NASA had several great successes, such as the Mars Pathfinder, but also several embarrassing failures. One such failure was the Mars Surveyor '98 program, which consisted of the Mars Climate Orbiter (MCO), the Mars Polar Lander (MPL), and Deep Space 2 impactors. The three missions were sent to Mars during the same transfer window in two separate launches with the MPL and Deep Space 2 launching together. All three of the missions successfully launched and made the trip to Mars but then suffered issues which resulted in complete failure.

The failure of the Mars '98 missions has often been considered to be caused by mistakes in the design and validation of the spacecraft. The MPL had a sensor to detect when the landing legs touched the Martian surface, but the sensor could also send out a "landed" signal when the lander was still airborne. If the computer received this false signal then it would cut off the landing rockets and the MPL would fall from the sky. The Deep Impact 2 mission consisted of two impact landers which would test landing on Mars without using parachutes, landing rockets, or airbags. However, the landers were never fully tested is a realistic impact landing, so the failure mode is not certain (Jet Propulsion Laboratory, 2000). Finally, the Mars Climate Orbiter is an often-cited example of a failed unit conversion. Software controlling the rocket burn that would put the probe into orbit around Mars used imperial units while the agreement with the contractor who made it specified metric units. The incorrect burn put the orbiter too low in the Martian atmosphere and it either burned up or was flung out of Martian orbit (Lilley, 2009). However, addressing only the technical mistakes of these missions does not allow for consideration of the effect that FBC had on these projects and how it could have contributed to their failure.

This project management style is mirrored by today’s cubesat missions, which place heavy emphasis on low mission costs and compressed development timelines. If the effect of the FBC style project management is ignored we won’t gain full understanding of how this management style can lead to project failure, as is the case of the Mars Surveyor ’98 program. To understand this relationship, I will use Actor Network Theory to study how the network builder managed translation of the Mars ’98 missions. Actor Network Theory is method for studying technological development which focuses on the relationships of power in heterogeneous networks. These networks are made up of different actors which can be human or non-human entities. The network builder, in this case the project manager, recruits actors into a network to work towards a common goal. Translation is the process of forming and maintaining an actor network. It involves a network builder identifying a problem which an actor network can solve, recruiting actors to fill certain roles, and securing them in those roles.

Conclusion

This paper will consist of a technical report and an STS research paper that will revolve around improving space missions that emphasize budgetary and timeline constraints. The technical report will consist of a design for a new of cubesat which will be capable of communicating with ground stations from low earth orbit. The cubesat will be designed with risk mitigation in mind and will use amateur radio frequencies to allow for easier troubleshooting. The STS research portion of this paper will investigate the Mars Surveyor ’98 mission by using actor network theory to analyze why the project failed.

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California Polytechnic State University, San Luis Obispo. (2014). *CubeSat Design Specification*. Retrieved from https://static1.squarespace.com/static/5418c831e4b0fa4ecac1bacd/t/56e9b62337013b6c063a655a/1458157095454/cds_rev13_final2.pdf

Clark, S. (2015, July 30). NASA: Tracking cubesats is easy, but many stay in orbit too long. *Spaceflight Now*. Retrieved from https://spaceflightnow.com/2015/07/30/nasa-tracking-cubesats-is-easy-but-many-stay-in-orbit-too-long/

Federal Communications Commission. (2013). *Guidance on Obtaining Licenses for Small Satellites*. Retrieved from https://docs.fcc.gov/public/attachments/DA-13-445A1.pdf

Jet Propulsion Laboratory. (2000). *Report on the loss of mars polar lander / deep space 2*. Retrieved from https://spaceflight.nasa.gov/spacenews/releases/2000/mpl/mpl_report_1.pdf

Langer, M., & Bouwmeester, J. (2016). *Reliability of CubeSats—Statistical Data, Developers' Beliefs and the Way Forward*, 30th Annual AIAA/USU Conference on Small Satellites, Logan, UT, 2016.

Lilley, S. (2009). Lost in translation. *System Failure Case Studies*. 3(05). Retrieved from https://sma.nasa.gov/docs/default-source/safety-messages/safetymessage-2009-08-01-themarsclimateorbitermishap.pdf?sfvrsn=eaa1ef8_4

National Aeronautics and Space Administration. (2017). Cubesat 101: Basic concepts and processes for first-time cubesat developers. Retrieved from https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf

National Aeronautics and Space Administration. (n.d.) *NASA FBD task final report*. Retrieved from https://mars.jpl.nasa.gov/msp98/misc/fbctask.pdf

Samarrai, F. (2019). UVA ‘cubesat’ deployed; students seek contact from ground station. *UVA Today*. Retrieved from https://news.virginia.edu/content/uva-cubesat-deployed-students-seek-contact-ground-station

Swartwout, M (2013). The first one hundred cubesats: A statistical look. *Journal of Small Satellites*. 2(2), 213-233