**UVA Amateur Radio CubeSat Mission**
(Technical Paper)

**The Effects of Advanced Ceramic materials on the Recycling Industry**
(STS Paper)

A **Thesis Prospectus Submitted to the**

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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
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# Introduction

Recycling and the push to move to space are, while somewhat related, two engineering issues humanity is facing. At the current rate of consumption of natural, nonrenewable resources humanity will end up losing access to some of our natural resources in the next decade (Collins, n.d.). Many of these resources we take for granted and will not be around forever. Of the solutions to this encroaching problem, recycling materials and looking for new horizons are some of the seemingly more attainable ideas. With the push for returning to the Moon and successfully leading an expedition to Mars in the next decade (Nodjimbadem, n.d.), there will be an increase in the amount of dangerous materials used to create the vehicles to get us there. Unfortunately, many of the materials used for these missions will be very dangerous if not reused or disposed of in a specialized manner ("Working with Silica, Fact Sheet," n.d.). In particular, the ceramic material currently being tested and researched for the protection of engine components in rockets and other aerospace vehicles are quite dangerous to the environment. Having worked with these materials and knowing the precautions taken to interact with them, it is obvious to me and other researchers that materials like these should never end up in the environment ("TOXNET," n.d.). Most, if not all, of the ceramic material in labs that work towards high temperature engine applications are incredibly dangerous to human life ("Working with Silica, Fact Sheet," n.d.). Additionally, high temperature ceramic materials are not widely available, which will end up controlling our dependency on recycling different materials (Rossner, 2011). One possible solution to this growing problem of resource dependency is too look towards space. While the STS portion of this proposal will focus on the recycling of different ceramic materials and the problems facing that practice, the technical portion of this paper will focus on the UVA Amateur Radio CubeSat Mission as a demonstration of UVA's ability to perform space missions and research.

## Capstone topic

The goal of this technical team of the UVA Spacecraft Design capstone class is to design and implement an amateur radio cube satellite. Our primary mission objective is to make a satellite system that is able to reliably communicate with both the UVA ground station and other amateur ground stations around the world. This mission will be accomplished at a low cost and with low risk so as to assure mission success. One of the goals of this mission is to create a long-term operational satellite to show the spacecraft engineering prowess of the UVA mechanical and aerospace engineering department. This spacecraft will have a communications radio operating on an amateur radio frequency with the corresponding license at the most basic design. There are plans to implement a beaconing radio to perform atmospheric measurements between the satellite and the ground station as well as an idea to implement a low power camera to take pictures and communicate said pictures of the earth as the satellite passes over.

The team will touch base with both the Amateur Radio Society and the Virginia Space Grant Consortium. The VSGS has funded the previous cube satellite missions created at UVA, and has a vested interest in the design and implementation of spacecraft missions at a university level ("2019-2020 Virginia Space Grant Consortiums' Undergraduate and Graduate STEM Research Scholarships and Fellowships," n.d.). Additionally, the Amateur Radio Society has presented interest in having an experimental radio onboard a satellite and. The team will be contacting the society in search of funding for the mission, and in return the team will send up the experimental radio and give the society access to perform different experiments on their own and in relation with UVA.

At the time of this proposal, the satellite has completed the necessary first steps in the space mission engineering process. There have been multiple concepts put forth and through risk analysis and system trades the final design has been finalized. The steps taken in the next three years will be concept design, component selection, and assembly before deciding on a launch date.

This mission also gives UVA students a chance to perform experiments with radio transmissions and learn how satellite-based radio transmission works. The UVA CubeSat team is already working on establishing communications with the Libertas, a satellite already in orbit. Once the UVA ground station is finalized, experimenting with communication will become much more streamlined and available to other students. Overall this mission will lead to the betterment of student understanding of both spacecraft mission design and radio communications. The amateur radio cube satellite mission will also show the ability of the Mechanical and Aerospace departments to successful design and implement space missions.

## STS Topic

Recycling is the main focus of the STS research paper, specifically in the field of rare earth metal ceramics. Recycling of inorganic solids is a major problem facing society, as it is one of the few sectors that does not have a set system (Kamiya, Mori, Kojima, Sasai, & Itoh, 2007). Many ceramic materials used in applications, such as transistors, heat shielding, coatings, and heating elements, contain rare earth metals that are not only scarce, but harmful to the environment if left to degrade in the open. These materials still have use after the machine they are protecting has reached the end of its life, but in most cases, there is not a system in place to efficiently recycle them (Kamiya, Mori, Kojima, Sasai, & Itoh, 2007). One such selection of ceramic materials that still pose a major threat are thin film transistor liquid crystal displays (Lin, Chang, Chang, Lee, & Lin, 2019). These materials include indium and its oxides. While not intensely toxic, indium and indium oxides can still be dangerous and it is not fully understood in its toxicity. Indium is also relatively rare, appearing in only .1 parts per million of the earth's crust ("Indium—Element information, properties and uses | Periodic Table," n.d.). However even though these materials are not abundant, the recycling programs designed for them are not highly accessible by all the populace, and in some areas, there is no recycling available for more complicated technologies. Another example is seen in the photonic and semiconductor industry. In this industry, the primary component of the waste produced is sub-micron silicon powder (Lin & Bai, 2013). Silica causes major damage to the respiratory and nervous system and has been cited as a known respiratory carcinogen ("Working with Silica, Fact Sheet," n.d.). Silica is commonly used in everyday pottery for arts and crafts (Daigo, Kiyohara, Okada, Okamoto, & Goto, 2017). Due to this there is already some movement for recycling in silica, but it is not yet a solid effort to remove it from different water supplies that move directly to the sewer or remove it from remove it effectively from single stream recycling.

The US is one of the largest producers of electronic waste, and yet there is no mandatory recycling program for these materials (Kyle, 2014). In fact, there is no federal legislation on recycling whatsoever, leaving that legislation to state and city governments (US EPA, 2015). State legislation does not always ensure that recycling happens, or that it happens efficiently. In the case of glass, the US is not following the same trends as other countries. Most European countries have doubled or tripled their glass recycling over the last decade, while the US barely recycles thirty percent of the glass waste that is produced ("Why glass recycling in the US is broken," n.d.). The lack of motivation towards recycling can be attributed to the lack of education in the American school system about recycling and its importance and limitation, and the sluggish speed of the single stream recycling system most states use. Many products disposed into recycling systems are put there with good intentions, but if they contain food waste or simply cannot be recycled, these products can contaminate the entire batch. Single stream recycling ends up contaminating much of the recycling put in through the lack of education on what should be recycled (LeBlanc, n.d.). The lack of understanding and education leads to very inefficient cleaning methods that have not been updated in recent years in order to make the recycled materials clean enough to be used, not to mention sorted and bought back by companies ("Why glass recycling in the US is broken," n.d.). Another problem with the US's lack of recycling policy is that companies have to purchase recycled materials from the companies that clean, sort, and start the process the recycling into useful base materials ("Is what we're recycling actually getting recycled?," 2008). Purchasing recycled materials is not always incentivizing as the materials that have been recycled can be of lower quality or cost more than new materials since they have had so much time and energy put into them already. This monetization of the recycling due to the lack of US regulation creates problems in both directions of the business. Companies will not always want to purchase recycled materials since it isn't always economically viable, but recycling companies can charge people to take their recycling in the first place. There have been multiple examples of companies illegally storing recyclable materials rather than recycling them and turning a profit by charging people for taking them ("Is what we're recycling actually getting recycled?," 2008).

Much of the literature reviewed falls into two categories. The first category and the most accessible to most people is very high-level articles describing the shortcomings of the industry. The articles talk about the general ideas of the lack of materials and the predictions for the future. These articles are useful for the high-level interpretation of the problem being posed, but does not always offer useful or meaningful solutions. The second category is scientific articles on specific methods of recycling. This literature is useful for analyzing the current engineering attempt to efficiently recycle a massive variety of different materials. However, since there is a lag time between when papers are published and when the solutions are implemented, due to peer reviewing and multiple trials in order to solidify the solution as viable, there is little literature on the success or implementation of these scientific articles. In both of these fields, the only tackled materials are normally household, or established industry wastes. Due to this, there is very little direct literature on the recycling of high-tech ceramic materials used for thermal protection. This is partly due to the fact that these materials are not yet in mass production and the applications cannot be recycled yet or thrown out since most of them are experimental engines.

The theory to be applied to this problem is the social construction of technology (SCOT) (Kirsever, Karabulut, Toplan, & Toplan, 2015). SCOT is useful to see how societies views on different problems shape the technologies used to solve them.  (Klein & Kleinman, 2002). SCOT will be useful to understand how the social view of recycling in the united states influences the technologies and policies being created and used to try to push recycling forward. The main critique of SCOT in this case is it cannot describe how the technology will evolve, but how public perception will move it in a specific direction. The technology may still evolve without social influence, but SCOT will not be able to predict that evolution. Research into this topic will help shed light on the different systems working for and against recycling of all materials, but especially those that will become more and more prevalent as time and research goes on. Learning more about this societal view and letting people know about this lack of education will then create a societal push for more efficient recycling methods. With a better understanding of the societal view of recycling and reclaiming we will be able to propose possible solutions that will be accepted and carried out in order to secure a safer and healthier future.

## Research Question and Method

How will the US prepare for the safe recycling of ceramics in the future when they become more prevalent? The question posited by this proposal will be answered using different research methods. One research method is policy analysis. Using policy analysis, I will be able to see America's policies on recycling compared to the policies of other countries and even between states and cities within America. Policy analysis will eventually give insight into why the US has a lack of recycling policy currently, however it will require a serious look into many connected policies and political ideas (Browne, Coffey, Cook, Meiklejohn, & Palermo, 2018). Wicked problem framing is another potentially useful research method. This method will help to incorporate the different connections from seemingly unrelated issues to shed more light on why there is not as much of a drive for recycling of these materials. Additionally, wicked problem solving will aid in the understanding of the large societal impact that reforming a recycling system for even just a city would impose ("Wicked Problems: Problems Worth Solving—Wicked Problem," n.d.). These research methods will help to further define and understand this problem. Wicked problem solving will bring the different factors into light, and the analysis of different policies will help to give an idea of what other countries are working on as opposed to where we stand on these issues.

# Conclusion

## STS Topic

The current state of recycling in the US has many problems. Glass and ceramic recycling already face enough challenges due to single stream recycling not being a successful system (LeBlanc, n.d.). Ceramics contain very dangerous materials that are incredibly dangerous to life and the environment. The dangers of ceramic pollution are a problem that will start rearing up farther into the public eye as ceramics become more commonplace in not only thermal protection applications, but structural applications, art exhibitions, more electronic applications, and many others as the technology continues to progress. We as a nation need to be on the move with this problem by the time it starts affecting us so that we can deal with it effectively.

## Capstone Topic

The UVA Amateur Radio CubeSat will give UVA another chance to show how well we can engineer and implement a spacecraft into a useful and interesting space. This satellite will allow different members at UVA to perform atmospheric measurements using the beacon, perform radio science experiments using the communications radio, and send messages around the world using the radio as well. This mission will further cement University of Virginia's ability to have a competent and meaningful space program.

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