Remote Sensing Enhanced Non-Destructive Evaluation of Roadway Infrastructure
(Technical Paper)

Nuclear Fusion Energy: How Fear Could Affect the Development of Nuclear Fusion Reactors
(STS Paper)

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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

Roadways connect almost every building in the United States. Every business, home, institution, and facility are connected by roads except for a small few that are only accessible via the air or by trail. Roads and highways need to be maintained to keep drivers safe, but finding roads with poor conditions is a challenge. The state of Virginia has 57,867 miles of state maintained highways, all of which need to be inspected with the precision necessary to determine its condition (Roads/Bridges, 2015). Inspecting large areas of road frequently and closely is the best way to improve road conditions. How to inspect the roads to determine which areas should be fixed is the focus of the research portion of this capstone paper.

The STS portion of this capstone paper tackles a future problem rather than a current one. Energy production and global warming induced climate change are directly linked. Reducing the global carbon output is essential to slowing and stopping the greenhouse effect caused by fossil fuel emissions. Nuclear fusion will be a major key to this mission. Fusion is the process of combining smaller elements. This process powers our Sun and thus is the root of almost all of our energy supply, with the exception of geothermal technology. Nuclear fission is the opposite of fusion. Fission is the process of splitting larger elements and is the process that powers our current nuclear reactors and the first nuclear bombs. The public perception of risk regarding nuclear power has played a significant role in limiting its expansion in the US and the world, causing a continued reliance on fossil fuels. Fusion is expected to be more efficient, more reliable, and safer than fission. In the next 5 years, researchers are expected to complete and operate the first energy positive nuclear fusion reactor which will be a proof of concept for the future (Kimani, 2020). Grounded in the history of nuclear fission technology, how will public perception influence the future development of nuclear fusion reactors? This paper is intended to answer this question and find possible solutions for the successful implementation of nuclear fusion technology.

Technical Topic

There are over 57,000 miles of roadways that need to be maintained by the state of Virginia and the Virginia Department of Transportation (Roads/Bridges, 2015). These roadways are crucial for efficient transportation and the daily lives of the public. Currently, national regulations only enforce the inspection of roadways every five years and the inspection of bridges every two years (Gee, 2007). Current methods, such as Visual Inspection, Acoustical Techniques, and Infrared or Thermal Imaging of roadway infrastructure inspection are inefficient because they are accomplished by only using a variety of ground-based systems. These systems have many drawbacks as they result in traffic buildups, lane closures, and also require many individual vehicles (Vaghefi, 2012). Additionally, they all have limitations such as invalid assessment of interior infrastructure, inaccurate testing, and limited usage (McGuire, 2020, para. 1-3). To improve the inspection process, the solution should include remote-sensing enhanced nondestructive evaluation through the combination of state-of-the-art spacecraft and aircraft. A satellite could send data to VDOT and allow them to focus on maintaining worn roads instead of repairing broken roads. Locating roads that are deteriorating and proactively repairing them would create a more efficient system for the state's roadways that would be safer, cost less, require less labor, and cause fewer transportation infrastructure delays.

Bridge collapse is the most catastrophic consequence of negligent infrastructure maintenance. The death of 13 people in 2007 was caused by the collapse of an overpass on I-35W in Minnesota (Vezner, 2007). Although this collapse has led to reform in how infrastructure is inspected, those methods are now dated and could be improved to increase efficiency and decrease cost. Research indicates that as road conditions deteriorate, there are more collisions and accidents tend to be more severe (Alhasan, 2018). By sensing all transportation infrastructure continuously, it would be possible to identify which roads are deteriorating at faster rates and put more time and effort into these problematic areas.

Research indicates there are a variety of remote sensing options available with either drones or satellites that allow for remote sensing from air and space. A paper published by Devin Harris, a Civil Engineering Professor at the University of Virginia, and other contributors discusses the wide variety of sensors that is the focus of the technical project, including Synthetic Aperture Radar (SAR), Interferometric Synthetic Aperture Radar (InSAR) on satellites, and a sensor called Light Detection and Ranging (LIDAR) on drones (Ma, 2019). Another technique to assess infrastructure from space is three-dimensional optics, which is a technology that can provide depth and height information that cannot be obtained from only one image. Three-dimensional optics works by overlapping two images, taken from two different angles of an object, with at least 60% overlap when combined. In addition to satellites, there are also several types of Uninhabited Air Vehicles (UAVs) that could be used for evaluation of infrastructure, such as the tethered blimp, small imaging quadcopter, a micro quadcopter, and a hexacopter. The hexacopter would be the best choice for remotely sensing Virginia's road infrastructure as it needs to be able to carry more weight for the different kinds of sensors. However, it has a short flight time of 30 minutes.

Designing a system that will be able to see all the roads and bridges of Virginia and accurately determine which ones have damage will come with various challenges. Satellites are limited in what resolution they are able to detect, so current and affordable technology might not be within reach of the state government and an outside company may be required to fund the project. Drones are also limited by Virginia laws that require them to be manually piloted, which greatly decreases the range they can cover in a day. Camera systems installed in vehicles through companies like MobilEye and Tesla could provide intel into transportation infrastructure usage and quality, but it may be difficult to gain access to the data. The most effective solution the research team has decided upon is to design a system with an overarching satellite that collects information on all roadways daily with a few drones or UAVs that can be sent to analyze the problematic areas in more detail.

STS Topic

Nuclear power is often associated with images of massive cooling towers and radiation symbols that eventually devolve into mutation ridden animals and a steaming, barren landscape. This imagery associated with nuclear power is the product of a shared public fear, further reinforced with scary documentaries about horrible accidents and a cultural comic book obsession with 'toxic waste.' This negative public perception of nuclear power has affected and still affects the implementation of nuclear fission-based power plants in our energy supply. Nuclear fission is "a process where atoms split and release energy" (NUCLEAR, 2020). Today, nuclear fission reactors provide only 19.7% of the US total energy supply. While our nuclear electricity generation capacity has flatlined since 1990, our energy generation has increased by approximately 33% (EIA, 2020).

The risks often associated with nuclear energy does not match the numbers. Nuclear energy kills approximately 0.07 people per terwatt-hour of energy produced, while coal, natural gas, and oil kill 32.72, 24.62, and 18.43 people per terwatt-hour of energy produced, respectively. "Contrary to popular belief, nuclear power has saved lives by displacing fossil fuels" (Ritchie, 2020). The perceived risk from the immense devastation of a nuclear catastrophe skews the public mindset away from these numbers, and has inhibited the growth of the nuclear industry. This perception has resulted in countries turning to other sources of energy, such as non-renewables. Now, the development of nuclear fusion promises to revamp the nuclear industry. Nuclear fusion is the process of combining atoms of low atomic numbers, which is the same process that powers our Sun. Fusion is much harder to initialize than fission. The reaction requires large amounts of energy to start and to be maintained unlike fission, which is self-sustaining and must be closely controlled. As it takes a significant amount of energy to keep the reaction going, fusion is easy to stop in the event of a failure in the system by just stopping the addition of heat. This process is unlike fission, which requires neutrons and heat to be removed from the system to prevent a supercritical reaction, or "nuclear meltdown." Therefore, fusion is a much less dangerous method of energy production.

There is still a lot of research and engineering design to be done before nuclear fusion is a viable energy source. Currently, it takes more energy to maintain nuclear fusion than can be extracted, resulting in a net loss of energy. There are multiple projects involved with developing these technologies, the largest of which being ITER, which stands for the International Thermonuclear Experimental Reactor. This reactor is currently being assembled after 35 years of preparation and planning. The reactor is a tokamak, which is a doughnut shaped device consisting of large electromagnets that suspend superheated plasma. It will be the world's largest tokamak fusion device with an "estimated cost of about $24 billion and will be capable of generating about 500 MW of fusion energy starting as soon as 2025" (Kimani, 2020). This project is being funded by six different countries (US, Russia, China, India, Japan, and South Korea) and is a promising chance at achieving a net gain of energy from a nuclear fusion reaction. This paper will examine the past trends of nuclear fission based energy and public perception and understanding of nuclear technology to analyze the future reception of nuclear fusion. Due to the increasing danger and awareness of climate change and the potential of nuclear fusion to slow its progression, it is essential to ensure that the public perception of the risks of nuclear fusion does not impede its development and implementation.

Methods

Research Question: Due to the history of nuclear fission technology, how will public perception influence the future development of nuclear fusion reactors?

To answer my research question, this paper will use the Documentary Analysis, Literature Review, and Policy Analysis methodologies. Understanding the media that the public consumes about nuclear energy, the technical literature about the topic, and the relevant policies put into place will help answer this question and provide insight on what to do about it. This analysis will first explain nuclear power itself and outline the differences in process and safety between fission and fusion. It will then present the history of nuclear mishaps as well as influential media that has driven the perceived risk of nuclear technology. Next, there will be an inquiry into what policies and practices have been put into place regarding nuclear technology over the past few decades and draw conclusions about if they were the result of a perceived risk instead of objective decision-making. In this section conclusions will be formed about whether the perceived risk of nuclear power has led to a reduction in its use. Finally, possible courses of action to reduce, if not prevent, a perceived risk regarding newer nuclear-fusion based energy will be proposed.

Conclusion

The roadways of the US are the veins of our society. There is no system, business, operation, or person in our country that does not utilize some sort of roadway. Improving the way in which deteriorating roads are identified and examined will not only improve the roads but also the country. This project will develop a solution and design involving satellites and drones that will advance the way roads are maintained.

Nuclear fusion technology is the power source of the future. Unlike wind and solar, it has the power potential to open our civilization to a new level of energy consumption. However, the social perception of such technology cannot be ignored, due to past incidents involving nuclear processes. This final report will analyze both the public perception of nuclear energy in the past and multiple proposed solutions to reduce the perceived associated risks. Will the patterns of the past once again pull society away from a promising energy alternative? Or will the new mindset of solving climate change supersede fear? This paper will analyze these questions and attempt to draw conclusions and propose solutions for the future.

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