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

Public Understanding of Space: Differences between the Apollo and Contemporary Eras through a Co-Production Framework
(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Kevin Fletcher
Fall, 2020

Technical Project Team Members

Isaac Burkhalter,
Andrew Curtin,
Cooper Dzema,
Shane Eilers,
Jalen Granville,
Dorothea LeBeau,
Colin Purcell,
Bailey Roe,
Khamal Saunders,
Anisha Sharma,
Naja Tyree

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

Introduction

With $1.8 billion budgeted each year for the maintenance and operation of the vast transportation infrastructure network in Virginia, the Virginia Department of Transportation (VDOT) must be diligent in where it chooses to allocate funds. VDOT is responsible for the condition of 130,000 lane miles and 21,000 bridges and large culverts with an available allocation of $800 million and $25 million as of 2019 (Virginia Department of Transportation, 2019). Current performance levels include over 44,000 lane miles with a deficient rating and 739 poor rated and 4040 “on the cusp” rated structures (Virginia Department of Transportation, 2019). Where a deficient rating means that the road pavement conditions are drivable but are deteriorating, and a poor rating means that a component of the structure must be monitored and maintenance is required. Due to the large number of poor rated lane miles and structures the allocation of funds has been centered on the replacement of poor infrastructure with the measure of success based on the number of poor rated lane miles and structures in Virginia. As a result, the number of poor rated lane miles and structures has decreased but at the cost of the deterioration of the overall roadway transportation inventory in Virginia. The objective of the proposed technical project is to promote a proactive solution that provides reliable high frequency, high resolution, and timely coverage data through the pairing of current ground systems with air and space systems.

On a different note, public understanding of engineering problems and capabilities, such as the progressive deterioration of Virginia roadway infrastructure, is limited by many social and technical factors. In order to better understand how public understanding of technical problems and innovations is influenced by various actors, a co-production framework will be used to analyze how the relation between space exploration and the public understanding of space has

changed over the last sixty years. Actors to be considered initially and narrowed down based on relative influence over the public's understanding of space include political, economic, societal, scientific, and cultural actors. The STS research paper proposal will focus on the differences in the public understanding of space during the Apollo missions in the 1960's and that of modern day surrounding the upcoming Artemis missions.

Technical Topic

Currently VDOT monitors the condition of most Virginia roadways through a contractor, Fugro-Roadware Inc., using vehicles equipped with several cameras for gathering data on road conditions, such as cracks, roughness, rutting, and potholes (Vlacich, 2018). These vehicles drive on roadways throughout the year and drive on all roadways comprising of the Interstate and Primary systems and 20% of the roadways comprising the Secondary system (Vlacich, 2018). Where the Interstate, Primary, and Secondary systems consist of 5,500, 22,700, and 100,600 lane miles, respectively (Virginia Department of Transportation, 2019). As a result, the sufficiency rating of the lane miles for the Secondary system is 60% whereas the Interstate and Primary systems have sufficiency ratings of 90% and 85% (Virginia Department of Transportation, 2019). The reason for a lower deficiency rating in the Secondary system has to do with the manner in which VDOT determines which roadways to allocate funding for maintenance. VDOT awards contracts for road paving and maintenance for the upcoming year based on current road quality data. Funding is allocated based on a variety of factors, including ride quality, pavement condition, and traffic volume (Virginia Department of Transportation, 2019, October 18). The combination of a more frequent road condition data stream and higher volume of traffic usually results in the Interstate and Primary systems taking precedent over the Secondary system, this contributes to the overall deterioration of the Virginia roadway system. Another contribution is

that the allocation of these funds is primarily put towards the repair of deficient roadways instead of towards a combination of both deficient and sufficient roadways.

A similar procedure is in place for the evaluation of structures. Federal law requires that all structures be inspected every 2 years and every year if given a poor rating (Gee et al, 2017, June 6). The allocation of funds for poor structures is much worse than for roadways. In 2019 VDOT stated that they allocated all funding to address poor rated structures which accounted for only 4% of all structures under their supervision (Virginia Department of Transportation, 2019). Although it is easier to detect deficient structures and roadways, many issues crop up as a result of this methodology. These issues include the cost of replacement being greater than available funds and much greater than if rehabilitation were prioritized earlier. These inspections are carried out by workers, for whom it takes longer to replace and repave than to repair and patch up structures and roadways, resulting in inefficient uses of labor and traffic delays. There are many rehabilitation methods, such as crack sealing, which depending on the road conditions and timing of sealing can result in the life extension of infrastructure at a fraction of the cost and maintenance duration (Mousa et al, 2019).

Given the many challenges that VDOT faces in the maintenance of the roadway infrastructure under its supervision, the need for new solutions and technologies is apparent. With the guidance of MITRE, this project will look into the applicability of airborne and space-based systems in conjunction with ground systems towards the non-destructive evaluation of roadway infrastructure. Potential solutions that are being investigated include drones, satellites, ground systems, and combinations of these systems. Given the refinement of the problem statement to the need for a proactive evaluation and maintenance of roadway infrastructure, several solution capabilities were determined. These capabilities include coverage area,

frequency and resolution of data streams, ability to collect multiple data streams, and the ability to effectively utilize resources and logistics.

Currently there are scattered sensors in various sections of the VDOT infrastructure network with the capabilities of providing limited data on road and bridge conditions, these sensors are found more frequently in bridges and similar structures. Due to the low quality of sensor readings, more extensive inspection is required and done through the manual operation of more precise sensors which are expensive and result in noticeable traffic delays. With regard to drones, there have been studies conducted through the Michigan Department of Transportation that have yielded promising results supporting the capability of UAV's to precisely detect road irregularities (Brooks et al, n.d.). According to UVA professor Devin Harris, drones are a feasible means of determining defects in roadways, but especially for bridges. A paper he contributed to described the ability of drones to capture multiple data streams using various equipment including thermal, infrared, vibrational, optical, and LiDAR among several other payload systems (Ahlborn et al, n.d.). The issue with drones is the limited coverage area due to the Virginia requirement of them needing to be operated manually, versus autonomously, and legislation over the operation of drones in public areas.

A study was done for the detection of potholes in Staunton, Virginia using a COSMO-SkyMed satellite and was able to accurately detect the presence of potholes in the surveyed area (Hoppe et al, 2016). The advantage of satellites is their ability to cover a large area on a single pass, yet there are concerns over the achievable resolution within the available budget and the lack of being able to provide multiple data streams. Other considerations include the use of accelerometers and gyroscopes in cellphones while driving to obtain vibrational data, although this data stream is limited by the reliability of this data (Sattar et al, 2018). The final potential

solution to be considered by this group is the utilization of MobilEye and Tesla sensor and camera data from their autonomous vehicles, although this would require industrial partnership. All of these potential solutions will be further investigated by the capstone team in order to determine the best combination of systems to achieve the objective of proactive roadway transportation operation and maintenance. The current timeline includes identifying a feasible solution with desired data streams to be presented to MITRE at the end of the Fall semester.

STS Topic

The exploration of space has always captivated the mind of Americans since the launch of Sputnik 1 and the American response of the launch of Explorer 1. The successful launch of Sputnik 1 marked the beginning of the space race between the US and USSR culminating in the ultimate goal of being the first to land a human on the Moon and return them safely back to Earth. Despite the common image at the time of the United States rocketry program lagging behind that of the Soviets after the launch of Sputnik 1, American scientists had been preparing satellites for orbit for several years prior. This development was aided primarily by the contribution of former Nazi rocket experts, such as Werner Von Braun (Holzwarth, 2018, September 20). The shock of the American public at the launch of Sputnik and multiple early failures of American launches cemented the image of the United States trailing the Soviet Union and made possible the intervention of political actors to frame the issue as a means of determining the scientific superiority of the United States over that of the Soviet Union (Johnson, 1961).

The actions of Werner Von Braun in 1958, presenting a plan to land on the Moon within a decade to the American public, sparked scientific curiosity. This curiosity inspired several novels and television series about space exploration, such as Star Trek (Hersch, 2011). This trend

culminated in the role of American libraries to educate the American public and encourage further research into the field of space exploration (Spencer, 2016). The actions of President John F. Kennedy were also crucial to the framing of the space race as a competition to get the first human to the Moon as the only acceptable measure of success. President Kennedy did this through his historic speech to a joint session of Congress on May 25, 1961 when he stated "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth." In an effort to catch up and overtake the Soviet Union in an area where the United States held a slight advantage, landing on the Moon (Krasnozhon et al, 2019). As a result, the Apollo project saw an influx of funding and societal support that swung public opinion such that the space race became a symbol of national prestige. So much so that President Kennedy actually shielded the Apollo program from the 1963 tax cuts and diverted funds from other projects to Apollo (Gisler et al, 2008). However, after Apollo 11 landed on the moon on July 16, 1969 the American public lost interest in space and federal funding for the Apollo project dropped to less than 1% of the federal budget due to the growing need to fund the Vietnam War (Krasnozhon et al, 2019). Since Apollo 17 landed on the Moon in December of 1972 no other human has stepped foot on the Moon.

Presently, preparations are underway for the Artemis missions, sister missions to the Apollo missions that will return Americans to the Moon with a goal of landing the first woman on the lunar surface. Unlike during the space race there is very little political backing of a lunar mission in the near future. The issue lies in the commitment of administrations to space exploration across terms and across parties. In 2005 President Bush pushed for a return to the Moon with the constellation project, in 2010 President Obama pushed for a mission to Mars, and in 2019 President Trump pushed for the return to the Moon by 2024, which has been viewed as

overly optimistic by both Democrats and Republicans (Patel, n.d.). Despite the lack of federal funding for NASA, there has still been strong public support for space exploration, specifically voyaging to Mars thanks to the emergence of several private space companies such as Space-X, Blue Origin, Relativity Space, and Virgin Galactic.

Commercial space companies are driving the public understanding of space. One of the most visible trends in media is the success and effectiveness of Space-X. Through the ability of the Falcon-9 first stage and fairing to be reused on multiple launches the price point of launches has been significantly reduced (SpaceX, 2020). The rise of private spaceflight took off under the Obama administration through un-crewed ISS resupply missions on behalf of NASA by Space-X and what at the time was Orbital ATK (Wall, 2017). This movement has resulted in a shift in contracts being awarded to private spaceflight companies such as Space-X, Blue Origin, Dynetics, and others to develop and operate both supply missions and landers for potential lunar missions.

Other significant developments include the growing movement towards small satellite packages, such as CubeSats, that are cost effective and do not result in space debris from decommissioned satellites. The emergence of space tourism and the potential to fly civilians into low Earth orbit has provided another likely means of revenue for the space industry. Two other factors contributing to public understanding are the formation of the United States Space Force by President Trump in 2019 and the signing of the Artemis Accords in 2020 by multiple countries including the United States that promotes the ability for astronauts to mine and process local lunar materials (NASA, 2020).

Analysis of the differences in public understanding of space between the Apollo era and modern day will be conducted through the use of a co-production framework. Co-production is

the analysis of the process through which societies develop states of knowledge that form their understanding of the world (Jasanoff, n.d.). There are two branches of co-production, the constitutive, which focuses on the "emergence of new facts, systems, and systems of thought" and the interactional, which focuses on knowledge conflicts between the natural and social within a society (Jasanoff, n.d.). The strength of co-production is the ability to determine the progression of states of knowledge between two separate points in time and understanding the factors that lead to the states of knowledge that societies adopt. Another strength is the consideration of both the impact of external actors on society as well as the impact of society on those external actors as time progresses. Limitations include the discernment of the contribution of each individual factor on societal states of knowledge and the difficulty of co-production being applied to current states of knowledge as they are still being developed.

The importance of using co-production to understand the evolution of the public understanding of space is that the investigated actors and states of knowledge are not particular to just space. The importance of studying the ability of actors to change public perception on space allows for a better understanding of how these actors promote these changes and the motivations behind them. Once the role of the actor on public perception is determined further analysis can dive into the impact of public perception on the societal and technological growth being evaluated. This allows for a better understanding of how crucial the acceptance and desires of individuals play in shaping the avenues through which technological innovation is prioritized and expanded. The momentary understanding of the tug-of-war between society and technology is more apparent as a result.

Research Question and Methods

Research Question: How has the modern state of the public understanding of space changed since the Apollo era?

To answer this question, the co-production framework will be used. The methods that will be used to collect and organize the supporting research for this answer are a combination of documentary research and discourse analysis. Beginning with background, context of both the economic and political states and developments of significance during the Apollo and modern eras will be researched further. Through the analysis of the construction of societal states of space knowledge in both eras, using available literature and data, the contribution of political and economic actors will be evaluated in the context of the individual era. From this analysis, a single actor having the greatest impact on the public understanding of space during each era will be chosen and more extensively researched through the guidance of the interactional co-production framework. This framework will likely describe the extent to which political actors dominated the public understanding of space during the Apollo era, similar to how economic actors are determining public understanding of space currently.

Conclusion

The technical portion of this paper covers an investigation of the potential of a system consisting of ground, air, and space-based devices to aid in the non-destructive evaluation of Virginia's roadway infrastructure. With an emphasis on proactive monitoring and detection of infrastructure irregularities such that infrastructure rehabilitation occurs in place of replacement. This capstone team will research and determine a viable system concept that will allow for more efficient allocation of VDOT funds and both extend the lifetime and increase the quality of

Virginia roadway infrastructure. As of now, this solution is leaning towards a vast ground system, and potentially a constellation of CubeSats, with multiple data streams that inform the deployment of UAVs so that a more extensive inspection can be conducted, though this is a preliminary concept and further research and development is required.

The STS portion of this paper explores the factors that impact the public understanding of space in the Apollo era and the reason for a different current state of the public understanding of space. The public perception of space was heavily dominated by the political actors of the 1960's through the politicization of the space race and the framing of being the first to land a man on the moon as the defining symbol of American society at the time. Similarly, modern perception of space by the public is largely a result of the growth of the private and commercial space industries and the economic actors that comprise these industries. Understanding of the influence of actors over the public understanding of space extends itself into understanding similar social programs of importance and can serve to provide the means for critical thought for what the public understanding of space might look like in the near future.

References

Ahlborn, T. M., Harris, D. K., Vaghefi, K., & Oats, R. C. (n.d.). *An Evaluation of Commercially Available Remote Sensors for Assessing Highway Bridge Condition*. 73.

Brooks, C., Dobson, R., Banach, D., Oommen, T., Mukherjee, A., Havens, T., Ahborn, T., Bhat, C., Zhao, S., Lyu, Q., & Marion, N. (n.d.). *Final Report, No. SPR-1674*. 164.

Gee, K., & Henderson, G. (2017, June 6). *Highway Bridge Inspections* [Text]. US Department of Transportation; United States Department of Transportation. /testimony/highway-bridge-inspections

Gisler, M., & Sornette, D. (2008). 'Bubbles in Society'—The Example of the United States Apollo Program. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1139807

Hersch, M. H. (2011). Return of the Lost Spaceman: America's Astronauts in Popular Culture, 1959-2006. *Journal of Popular Culture*, *44*(1), 73.

Holzwarth, L. (2018, September 20). 20 Successes and Failures of the American Space Program in the 1960s. *HistoryCollection.com*. https://historycollection.com/20-successes-and-failures-of-the-american-space-program-in-the-1960s/

Hoppe, E., Bruckno, B., Campbell, E., Acton, S., Vaccari, A., Stuecheli, M., Bohane, A., Falorni, G., & Morgan, J. (2016). *Transportation Infrastructure Monitoring Using Satellite Remote Sensing* (pp. 185–198). https://doi.org/10.1002/9781119318583.ch14

Jasanoff, S. (n.d.). Ordering knowledge, ordering society. Retrieved November 2, 2020, from http://sheilajasanoff.stsprogram.org/wp-content/uploads/S.-Jasanoff-States-of-Knowledge-Ch.-2-Ordering-Knowledge-Ordering-Society.pdf

Krasnozhon, L., & Maye, W. (2019). *Economic History of the Relationship Between Congress and NASA: A Case Study of the Apollo Program: Volume 3* (pp. 103–116). https://doi.org/10.1007/978-3-030-11313-1_7

Lyndon B. Johnson (1961). Memorandum for the President, "Evaluation of Space Program". Retrieved November 2, 2020, from https://history.nasa.gov/Apollomon/apollo2.pdf

Mousa, M., Elseifi, M., Gaspard, K., Zhang, Z., & Free, K. (2019). *Challenges and solutions for crack sealing in asphalt pavements | Roads & Bridges*. https://www.roadsbridges.com/challenges-and-solutions-crack-sealing-asphalt-pavements

NASA. (2020). The Artemis Accords. Retrieved November 2, 2020, from https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf

Patel, N. V. (n.d.). *We need to shield the US space program from election cycle chaos*. MIT Technology Review. Retrieved November 2, 2020, from https://www.technologyreview.com/2020/10/05/1009377/shield-us-space-program-from-election-cycle-chaos-trump-biden-artemis/

Sattar, S., Li, S., & Chapman, M. (2018). Road Surface Monitoring Using Smartphone Sensors: A Review. *Sensors (Basel, Switzerland)*, *18*(11). https://doi.org/10.3390/s18113845

SpaceX. (2020). *SpaceX - Falcon 9*. https://www.spacex.com/vehicles/falcon-9/

Spencer, B. (2016). The Book and the Rocket: The Symbiotic Relationship between American Public Libraries and the Space Program, 1950-2015. *Information & Culture*, *51*(4), 550–582. https://doi.org/10.7560/IC51405

Virginia Department of Transportation. (2019). *Maintenance and Operations Comprehensive Review – 2019*. 107.

Virginia Department of Transportation. (2019, October 18). *Pavement Treatment—Asphalt—Info | Virginia Department of Transportation*. http://www.virginiadot.org/info/pavement_treatment_asphalt.asp

Vlacich, B. (2018). *State of the Pavement 2018*. 91.

Wall, M. (2017). *President Obama's Space Legacy: Mars, Private Spaceflight and More*. Space.Com. Retrieved November 2, 2020, from https://www.space.com/35394-president-obama-spaceflight-exploration-legacy.html