Prospectus

Developing a Novel System for the Tracking and Management of Truck Parking
(Technical Topic)

Investigating the Sociotechnical Forces and Outcomes of Space Exploration Through the Lens of Actor Network Theory
(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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An Introduction to the Complications of Truck Parking

Long-haul truck parking has remained a predominant and unsolved issue in the transportation industry. In a survey analysis conducted by the American Transportation Research Institute (ATRI), truck drivers identified parking as the second most critical issue they face on a daily basis (ATRI, 2018). The core of the issue stems from the fact that truck drivers are legally prevented from driving for more than a total of 11 hours after they have been off duty for at least 10 consecutive hours (FMCSA, 2015). Some drivers are forced to exceed this legal limit due to inadequate availability of parking spots at designated truck stops along the interstate. This leads drowsy and fatigued truck drivers to either illegally park along the highway or continue driving in search of an available space, ultimately endangering themselves and other drivers on the road in both cases (Boris et al., 2017). It is increasingly evident that parking availability is a root cause for a significant proportion of accidents involving long-haul trucks. Research has shown that roughly 31% of fatal and non-stationary truck accidents have been due to driver fatigue, highlighting the importance of tracking and managing truck parking to reduce the frequency of these accidents (Garber et al., 2004).

Given that much of the issue is derived from human decision making (truck drivers, company executives, local regulations, etc.), the inadequacy of truck parking can in a sense be viewed as a sociotechnical problem in and of itself, making it an incredibly complex issue to resolve through the means of technology alone. In an interview with Andy Alden, the executive director of the I-81 Corridor Coalition, it was made clear that solution developers have encountered challenges with implementing solutions that are simultaneously user-friendly to truck drivers, economical for stakeholders, and acceptable for localities and legislators (Alden, 2020). It is therefore necessary to consider the social implications of any technological solution that this research supports.

In its most general form, the overarching research question that this paper intends to address is: How can space exploration be leveraged to improve sociotechnical interactions on Earth? The technical aspect of this research serves to address the manner in which long-haul truck parking can be tracked and managed, and to propose the necessary system architecture in order to do so with a heavy emphasis on space-based approaches. The sociotechnical aspect of this research serves to identify and analyze the sociotechnical forces and outcomes of past space exploration efforts within the framework of actor network theory.

The Use of Space Technology to Track and Manage Truck Parking

The inadequate management of long-haul truck parking has led to illegal parking and overcrowding of truck stops, causing traffic and safety issues along major interstate highways across the US. Truck drivers must adhere to legal requirements regarding maximum vehicle operation time, and parking is expected to occur at waypoints and designated locations. However, as there is no centralized system to locate vacancies and relay that information to truck drivers effectively, parking stations often become overcrowded. The availability of truck parking is unpredictable and subject to several circumstantial factors, some as trivial as the day of the week (Torrey et al., 2007). Any proposed solution must be versatile enough to overcome these irregular circumstances.

The aim of this technical research project is to develop a space-based solution to conduct remote sensing of trucks and parking spots in Virginia, and to propose a systems architecture to process the relevant parking data and disseminate it to truck drivers in a non-intrusive manner.

We have conducted interviews with the Eastern Transportation Coalition, I-81 Corridor Coalition, Owner-Operator Independent Drivers Association, and the American Transportation Research Institute to gather a better understanding of the fundamentals of the problem, as well as to gain insight regarding pre-existing solutions. These discussions emphasized the common theme that the truck parking problem is largely a result of a lack of initiative and interest from the government and the general population despite its importance to roadway safety. Thus, it falls into the hands of independent research groups to explore this problem. As this problem extends beyond the borders of Virginia, a comprehensive solution will take broader cooperation and awareness in order to be successfully implemented. Despite the aforementioned bureaucratic limitations, several organizations have attempted to remedy the truck parking problem in localized areas using different data collection and management techniques. As part of the literature review process, we conducted research on state-of-the-art solutions and developments. Crowd-sourced tracking apps as well as “detectors installed in the ground, and video cameras for additional monitoring” with truck detecting algorithms (see Figure 1 below) are solutions that are commercially available, yet all of these solutions exhibit major inefficiencies (I-95 Corridor Coalition, 2009). Mobile-phone-based tracking apps require truck drivers to input and update current parking data, posing the likely possibility of producing flawed data due to drivers without access to the app and an unreliable user base (Woodrooffe, 2016).

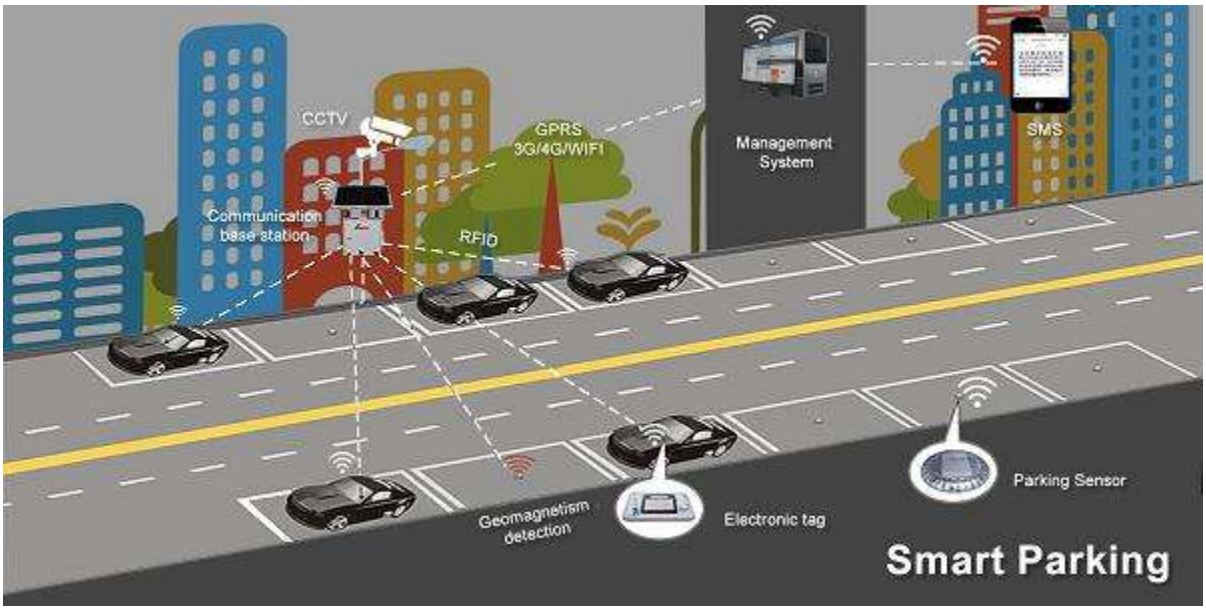

Figure 1. Example of a sensor-based parking system with video cameras to demonstrate the inefficiency of this design. (Image from: Research N Reports, 2018)

In an interview with the I-81 Corridor Coalition, the use of in-ground sensors was discouraged due to the Virginia Department of Transportation's (VDOT) apprehension to damage the existing infrastructure - the pavement - to install the sensors. On-site cameras are currently the most favorable solution. However, this still requires the installation of a camera at every parking site and the establishment of a communications network between them (Morris, 2017). Through the interviews conducted and research on pre-existing solutions, we have determined that a successful solution must: have adequate spatial and temporal resolution, be inexpensive, be reliable in adverse conditions, and avoid the modification of pre-existing physical infrastructure.

Taking into account the success criteria, we decided that the proposed solution should incorporate a constellation of satellites (see Figure 2 on the next page) in Low Earth Orbit (LEO). A space-based approach offers the advantageous capability of being globally scalable, thus facilitating the acquisition of truck parking data at nearly any location and time. Additionally, a satellite constellation would not necessitate the modification of any pre-existing infrastructure or the construction of new infrastructure on the ground at each truck stop.

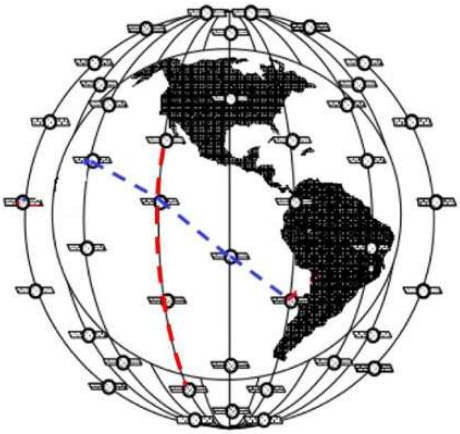

Figure 2. A depiction of a satellite constellation (Image from: Vergoossen et al., 2020)

Land Info's Worldview-4 satellite imagery platform offers a 30cm resolution and can collect up to 680,000 km^2 per day, which is more than sufficient to quantify truck parking availability along I-81 ("Worldview-4 30cm Global", (n.d.)). The exact quantity of constituent satellites and orbital parameter values remain to be determined throughout the remainder of the solution development process. After brainstorming ways in which to develop a more specific temporal resolution target, it was decided that the constellation should be able to update parking availability data every thirty minutes.

The reliance on satellite communication, imaging, and navigation to alleviate the mismanagement of truck parking is a complementary example of the benefits of space exploration in an industry which is beyond the scope of the sociotechnical analysis. This relationship highlights the broader implications and benefits of space technology, and how several Earth-based problems could potentially be better addressed by space-based solutions.

Exploring the Sociotechnical Actors of Space Exploration

Global positioning system (GPS), memory foam, cordless vacuums, complementary metal oxide semiconductor (CMOS) image sensors – these are a handful of the countless examples of technologies that the National Aeronautics and Space Administration (NASA) has coined "NASA spinoffs" (Sarah, 2018). NASA spinoffs are technologies that are brought about as a result of the exploration of space through NASA, either directly or indirectly. Many of these technologies have opened new doors within pre-existing industries, and many have led to the

creation of entirely new industries. These technologies are a microcosm of the tangible benefits of space exploration, and they have become so prevalent in the commercial sector that companies often turn to space technology to address problems on Earth. While it is important to consider the tangible benefits of space exploration, it is equally as important to consider the intangible outcomes and their corresponding impetuses.

In the context of this research, "space exploration" refers to any human or technological incursion in space beyond the boundaries of Earth's atmosphere. For the purposes of conciseness, this research will only focus on space exploration conducted by organizations and entities based in the United States (US). Two space programs will be investigated through this study: NASA's Apollo program and SpaceX's Starlink program. The Apollo program is representative of the traditional view of space exploration – the demonstration of engineering prowess to achieve the unprecedented goal set forth by the federal government of placing a man on the Moon (Grossman, 2009). On the other hand, the Starlink program is a commercial endeavor that aims to provide global high-speed internet access to mobile phone users via 42,000 satellites located at LEO. As different as these two initiatives may be, they both offer a unique perspective regarding who and what the relevant sociotechnical forces and outcomes of space exploration are through the lens of Bruno Latour's actor network theory. In the framework of ANT, social determinism and technological determinism are allowed to coexist in a vast network of heterogeneous social and technological actors (Latour, 1992). ANT allows nonhuman actors to assume the role of human actors, and vice versa, which in effect levels the playing field and is conducive to a more holistic and unbiased analysis. The three core principles of ANT are agnosticism, generalized symmetry, and free association (Tabak, 2015). The principle of agnosticism prompts the researcher to abandon any pre-existing, popular assumptions of the network, and to perceive the entire system with arbitrary interpretation. Doing so invites the possibility of producing novel ideas rather than expounding upon old beliefs. Generalized symmetry supports the idea that all actors are to be treated equally, and their analyses should thus be conducted in an identical manner. The principle of free association serves to eliminate distinction between natural and social forces, and to perceive them both as results of the behavior of the network as a whole. The aim of this work is to analyze the Apollo and Starlink programs by identifying the relevant actors, how they interact, and what outcomes they produce.

At surface level, the Apollo program was a pivotal US initiative in the Space Race characterized by ambition and ingenuity. However, the Apollo program represented far more than a collection of brilliant astronauts, engineers, and NASA officials – it represented democracy in stark contrast to communism. The Space Race was simply a microcosm of a much larger conflict between the US and the Soviet Union. This conflict is notoriously known as the Cold War. Tensions were high between the two nations, and was further escalated by the threat of nuclear warfare. The inevitability of mutually assured destruction led the US and the Soviet Union to pursue other avenues in order to gain an upper hand, and both nations ultimately turned to space. The first major victory in the Space Race was claimed by the Soviet Union in 1957 when they were the first to place a satellite, Sputnik I, into orbit. The Soviets also took a second victory by being the first to launch an astronaut beyond the boundaries of Earth's atmosphere. After both the US and the Soviet Union claimed other minor victories in the Space Race, it became very clear that the true champion would be the first nation to land a man on the moon. Landing a man on the Moon was viewed as a national victory on a monumental scale, and it would highlight the victor as the most technologically advanced nation in the world. The motivation behind John F. Kennedy's message in his famous "man on the Moon" speech was truly to "best the Soviet Union and show the world the strength of a free society" (Chaikin, 2007). The issue for both the US and the Soviets was that the technology necessary to propel people to the Moon did not yet exist. Therefore, the accelerated development of space technology in the Space Race was warranted by government action and nationalism in the context of a war between political ideologies. A primary unintended, yet positive, consequence of Apollo 11's success was the rapid emergence of an entirely new and inspired generation of scientists, technologists, engineers, and mathematicians ("Benefits Stemming from Space Exploration", 2013). The increase in STEM education, along with trend shifts in the communications industry and environmental activism that resulted from the Apollo program will be further analyzed in this work. This analysis will indicate the manner in which the political rhetoric of Apollo engendered technological advancement, which set in motion a perpetual interplay between social influences and technology.

The Starlink program offers a valuable comparison to the Apollo program in that it is a commercial endeavor that provides technological advancement in direct response to a societal problem. A UN study showed that nearly 50% of the world's population has never used the

internet, and that only 10% of the surface area of the Earth is provided internet access via ground-based communication links (Harris, 2019). The implications of the successful implementation of Starlink are anticipated to be profound both positively and negatively. A negative implication is shown through astronomers' fears that the high quantity and low orbital altitude of Starlink satellites will distort astronomical images, and they are considering pursuing legal action to prevent the full implementation of the program (O'Callaghan, 2020). The human actors under consideration are Elon Musk, proponents, and opponents while the technical actors are reusable launch vehicles, satellites, and laser communication technology. The rationale of proponents and opponents will outline the potential outcomes under consideration as part of this work. Given that Starlink is a relatively new program and relevant data may be scarce, the implementation of GPS navigation technology will replace Starlink in this research should it be discovered that not enough data is available.

The two programs being studied in the sociotechnical portion of this research will provide insight regarding how development of space technology can be implemented to address problems on Earth. This insight will point to the potential consequences – both positive and negative – that can arise through the use of a satellite constellation to curb the issue of truck parking.

Qualifying, Quantifying, and Analyzing the Implications of Space Exploration

As the exploration of space has become more commonplace over the past few decades, and will continue to for the next several decades, it is important to consider why it is worthwhile despite the existence of a multitude of problems on Earth. The ultimate goal of this work is to answer the question: "how can space exploration be leveraged to improve sociotechnical interactions on Earth?" The answer to this question has the potential to reveal entirely new avenues through which Earth-based problems can be solved more effectively from outside Earth's atmosphere than within it. Steve Dick, one of NASA's previous chief historians, illustrates the importance of this study by stating that the "societal impact of spaceflight is in need of systematic scholarly examination" (Dick, 2007). Methods of primary evidence will include: interviews with NASA officials and engineers, interviews with members of the baby-boomer generation who have been directly affected by the Apollo program, interviews with proponents and opponents of Starlink, STEM education statistics for the 20th and 21st centuries,

time-based counts of patents and literature related to communications, and time-based counts of patents and literature related to sustainability and environmentalism. Collection methods of secondary evidence will include media accounts of the Apollo landings and Starlink launches, policy documents related to space exploration, and prior literature that substantiates the societal effects of space exploration.

Approximately 5 interviews will be conducted pertaining to the Apollo program, and 10 will be conducted pertaining to the Starlink program. Interviews pertaining to Starlink are greater in number to account for the lesser amount of documentation relevant to Starlink. The questions asked in each interview will be identical within each respective space program. These data collection methods will be exercised with the intention of providing a comprehensive view of the relevant social, technical, and political implications in question. Descriptive data analysis methods will include thematic analyses of trends found across all forms of evidence. More specifically, counts of positive and negative consequences of each program (hypothetical positive and negative consequences in the case of Starlink) will be taken, and further divided according to commonly mentioned words or ideas. Should the data indicate the emergence of a comparable amount of positive and negative consequences, consequential analysis will also be employed for further expansion in order to determine the relative impact of each consequence. Counts of patents and literature will be taken during the first half of December 2020. Policy documents, prior literature, and media accounts will be read and annotated in the latter half of December 2020. Interview questions will be formulated during the first week of January 2021 and they will also be based on the findings of the work completed in December 2020. Interviews will be conducted throughout the rest of January 2021. All data analysis methods will be carried out in February 2021.

Conclusion and Potential Impact

The culmination of this research will include a technical deliverable and a sociotechnical deliverable. The technical deliverable will be a formal proposal for a systems architecture and design of a satellite constellation to track and manage the availability of truck parking. The sociotechnical deliverable will be in the form of a thesis that investigates the sociotechnical forces and outcomes of space exploration through the lens of actor network theory. The completion of this research has potential to indicate possible approaches to implementing space

technology to solve Earth-based problems, while at the same time illustrating potential negative consequences and barriers that may occur as a result of the implementation. A greater understanding of space technology's role in the daily lives of its users will reveal the best manner in which to utilize and regulate its power. The expected results of this research are that the implications of space exploration are widely embedded in the fabric of US industries and sociopolitical beliefs, and that it can in many cases be utilized to solve ground-based problems in a more cost-effective and efficient manner than ground-based solutions.

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