Prospectus

Truck Parking Management Using Space-based Solution
(Technical Topic)

The Dangers and Politics of Space Debris
(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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Introduction

My technical project this year is to investigate space-based solutions for the collection of data on truck parking. Truck parking shortages and inefficiencies cause roads to be more dangerous and potential solutions and management techniques both require extensive data collection on parking behaviors and conditions. Most data collection methods to-date are ground based and not widely applicable. Therefore, the ultimate goal for this project is to conclude with deploying multiple small spacecraft with sensors to track changes in truck parking several times a day. The use of space-based solutions such as this by private companies, in this case MITRE, is a rapidly expanding field. I want to explore this expansion of commercial satellite deployment and how it is affecting the issue of space debris and orbit pollution. There are millions of pieces of space debris in Low Earth Orbit (LEO) and most of it can reach speeds of 18,000 mph, posing a serious risk to all our satellite infrastructure and any future human spaceflight missions (Keeter, 2018). Efforts in the past to manage and confront the issue by different people and entities have resulted in doing things such as tracking the debris, but there has never been a concerted effort to solve the issue itself. Now that there are more actors in the space industry with hundreds of companies of varying sizes able to launch satellites, not just major governments, I want to investigate how the issue of space debris is evolving. On one hand, more satellites are expected to be launched which could cause the issue to increase in severity. On the other hand, more parties involved and increasing interest in space from the financial sector might mean that cooperation or technical solutions may proliferate in order to preserve everyone’s ability to use space and satellites to run our global infrastructure.

Technical Topic

The poor management of freight truck parking has led to illegal parking and overcrowding, causing traffic and safety issues along major interstate highways in Virginia. Truckers 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 truckers effectively, parking stations often become overcrowded. This leads drowsy truckers to either illegally park on the highway or continue driving in search of an available space, endangering themselves and other vehicles on the road. For the purposes of this capstone project, the aim is to develop a space-based solution to conduct remote sensing of trucks and parking spots, and then construct a systems architecture to process the data and disseminate it to truckers in a non-intrusive way. We have partnered with the MITRE Corporation under the mentorship of Dr. Cj Rieser and Dr. Michael A. Balazs, as well as our technical advisor Professor Chris Goyne, to investigate and tackle this problem.

The team has reached out to the Eastern Transportation Coalition, I-81 Corridor Coalition, Owner-Operated 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. Interviews with the first three organizations have already been conducted by other members of the technical project team, and the common theme driving the truck parking problem is the 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 more cooperation and awareness of the issue to implement.

Despite limitations, past organizations have attempted to remedy the truck parking problem in localized areas using different data collection and management techniques. As part of the process, the team 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 all solutions that are currently commercially available; however, all these solutions have major inefficiencies (I-95 Corridor Coalition, 2009). Tracking apps require truckers to input and update current data, a method with obvious drawbacks as drivers without access to the app and unreliable users can lead to flawed data (Woodrooffe, 2016).

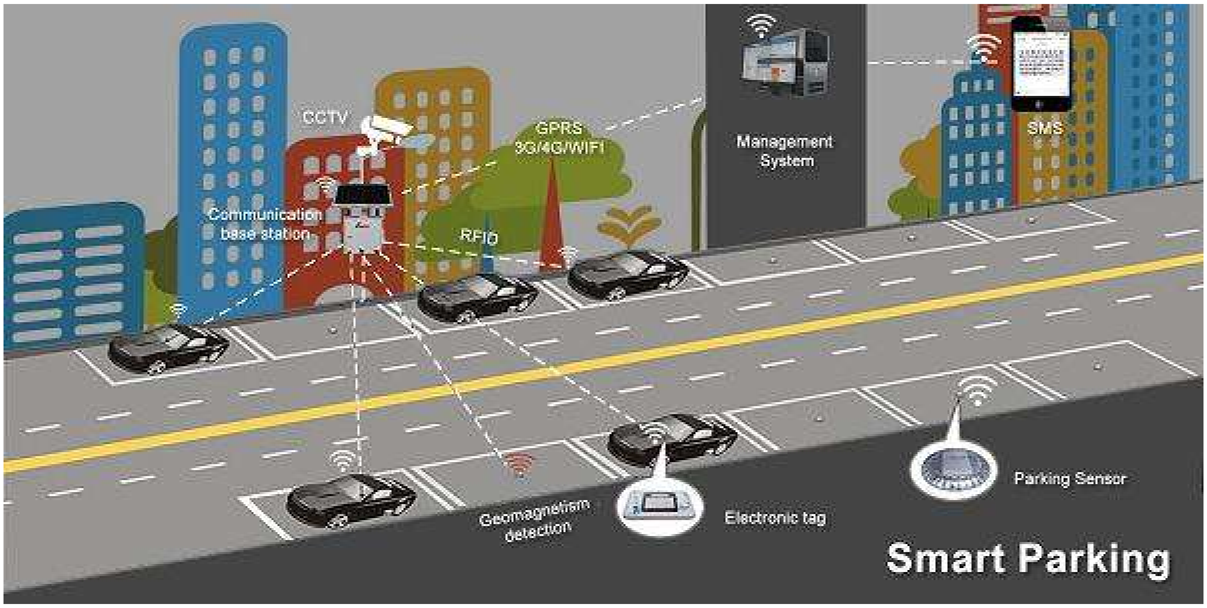

Figure 1: Example of a sensor based parking system with video cameras to demonstrate the inefficiency of this design. (Research N Reports, 2018)

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). From interviews with the organizations listed, and research on current solutions, we have gathered that our solution needs to have a relatively high data collection frequency -knowing there was a space available hours ago is not useful - and should be widely applicable, avoiding the installation of sensors or cameras at every parking location in the state.

Due to the research and design emphasis of this project, there are minimal initial resource requirements necessary to complete this semester's tasks successfully. One requirement would be ample access to the stakeholders previously mentioned, as they provide firsthand accounts about where the problem lies and what solutions have been implemented in the past. Additionally, the mentorship of Dr. Cj Rieser and Dr. Michael A. Balazs provides valuable input on gaps in our team's knowledge and on possible shortcomings of proposed space-based solutions. The last resource requirement would be access to literature on the current state-of-the-art.

This capstone project is broken down into 12 tasks, the first three of which have been completed. The next three will be completed this fall semester, and the final six will be completed in the spring semester. The 11-member team has already presented its initial progress to MITRE and will present again at the end of the semester. My role on this team so far has been to research causes of the parking issues relating to space scarcity and costs associated with producing new spaces, and more recently refining the technical requirements of our solution.

STS Topic

The issue of space debris is a large scale one that poses a serious threat to our global technical infrastructure and subsequently our society. There is no international laws about the space debris management. We currently lose three to four satellites a year due to debris collisions, and debris has been projected to triple within 20 years (David, 2011). First, I want to briefly examine how the current method of tracking debris and establishing mitigation guidelines came about. Then

I will explore how the commercialization of the space industry and expansion of privatized launches right now is changing the finances and priority of the issue. Lastly, I want to know what emerging technologies are available to help us deal with the issue, who is motivated to develop them, and what their motivations are.

The issue of space debris did not begin with Sputnik, the first satellite launch, as both the main stage of its rocket and the satellite itself had both fallen out of orbit within months. In March of 1958 the US placed Vanguard 1 into medium Earth Orbit (MEO). It is no longer operational, yet it is expected to stay there for almost 200 more years (Hall, 2014). Just 13 years later in 1970 there was about 2,000 objects in orbit and 7,500 in 2000. (Witze, 2018) Today there are 25,000 objects being tracked by U.S. Space Command (Erwin, 2020). International guidelines have been written by both the United Nations Office for Outer Space Affairs (UNOOSA) and Inter-Agency Space Debris Coordination Committee (IADC) to help mitigate debris. The ESA reports increasing compliance to these guidelines, but it is far from universal (ESA, 2020). Only about 15-30% of objects launched into non-compliant orbits from 2008-2018 featured efforts to comply with measures by exiting at the end of service (ESA, 2020). Even then, only 5-20% did so successfully. Rocket body guideline compliance has been much higher with a roughly 70-75% successful compliance in 2017-2018 (ESA, 2020). Launches however are increasing much faster than compliance with mitigation measures. There were roughly 400 satellite launches a year from 2017-2019, (ESA, 2020) which is over four times the annual average from 2000-2010 (Witze, 2018). As a result, despite efforts at mitigation, space is getting more crowded. Figure 2 below, retrieved from the European Space Agency (ESA) shows the total area of objects in orbit over time. This figure clearly demonstrates how even with guidelines to combat debris, the issue has been steadily progressing for the worse. I would like to examine if any new technologies or mitigation methods are poised to change the observed trends.

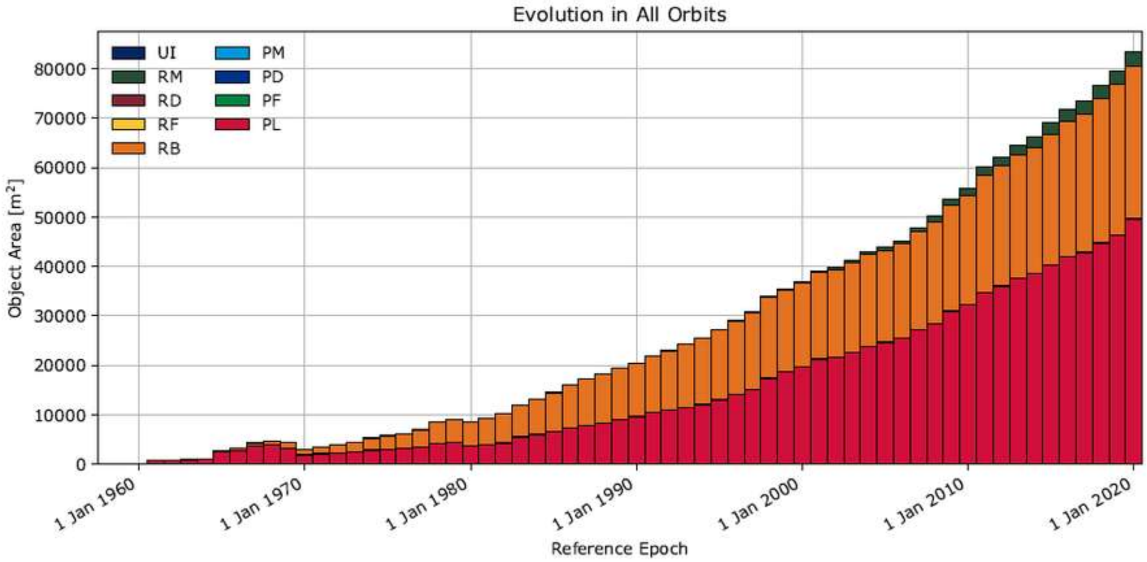

Figure 2: The total area that debris objects take up over time. "Red (PL) = Payload; Orange (RB) = Rocket Body; Dark Green (RM) = Rocket Mission Related Object."

There is a lot of money being spent on our space infrastructure and removing debris would be costly. Lots of computational cost and time is already spent on tracking objects in our orbit, but I will document all of the other competing solutions beginning to garner more attention. Andrew M. Bradley (2009) explores the risks to our satellite infrastructure over the next several decades with several different levels of compliance to debris mitigation guidelines. It argues that if the guidelines put in place by IADC and UNOOSA can be met within a few decades and anti-satellite (ASAT) weapon tests are kept to a minimum then risk will be tolerable (Bradley, 2009). Anti-satellite weapons testing is a key component of the issue because in these weapon tests satellites are destroyed. This leads to several fragments, which contribute to the problem much more seriously than an intact satellite. Unfortunately, these tests have taken place as recently as an instance by Russia on July 15, 2020. These actions were denounced, but similarly to other debris-mitigation guidelines there are no formal consequences to violation. This would suggest that efforts should be focused on forcing compliance with guidelines and tracking debris as it arises. Several other articles are about potential methods of actively removing space debris, contrary to the framework put forward by Bradley. In fact, the European Space Agency states that active debris removal is "necessary". A second peer-reviewed article "Active debris removal: Recent progress and current trends" describes the state of several of the most promising technologies to not just observe, but to actively remove debris at the time of publishing in 2013. The authors' closing recommendation is to carry out active debris removal in one instance and use it as a test case to evaluate financial viability of active removal overall (Bonnal, 2013). A third revisits the same exploration of current active removal technology much more recently. "Review of Active Space Debris Removal Methods" explore which technologies lead the field and how much more development is necessary for practical use. In the actual field, the ESA carried out an experimental active debris removal mission called Remove Debris. A satellite successfully deployed two smaller ten-centimeter (cm) cube satellites and removed them from orbit (ESA, 2020). An evaluation of this mission could help yield answers about active debris removal effectiveness and potential.

The ESA has also hired a private company to perform a non-experimental debris removal in 2025 (ESA, 2020). More details about this could lead to details about who is motivated to perform active debris removal and why. I plan to try to find more documentation on any research or missions pertaining to active debris removal as well. Using the gathered information I will evaluate to what extent we should use active debris removal and then explore what the best methods are.

To establish how much active debris removal we should use, I will need to weigh the amount of risk our satellites are in versus the estimated cost of active removal projects. Organizations are not going to fund active debris removal projects over other missions without thinking that debris removal is a necessity (Bonnal, 2013). I will start as recommended by Bonnal and use the Remove Debris mission as a case study. This will help me evaluate current technical and financial viability while keeping in mind that the technology is still in its infant stages. I then want to investigate private space companies' compliance with launch guidelines and attitude towards active debris removal. The private industry is where the massive increase in launches over the last 10 years has taken place. I therefore think how they respond to space debris and which solutions are in their best financial interest determine the future of the problem. Some companies see debris as an opportunity to receive funding from agencies for active debris removal, such as in the case of the ESA mission planned for 2025. Other companies want to make constellations of satellites that would greatly increase LEO traffic. In the end, I would like to make my recommendation of how many billions need to be spent and who needs to spend it in order to preserve our global satellite infrastructure.

Next Steps

If I can gather information on all planed debris removal projects, mitigation guideline compliance, and projected object launches I think I will have a clear picture that I can analyze freely. Understanding how many projects exist and how invested agencies and companies truly are in active debris removal will be especially important for my work. Studies on the risk such as those would allow me to evaluate the necessity of different solutions and how urgent the issue is. If all studies looking at the risks to our current infrastructure paint the issue as urgent then agencies may treat it with more respect. When I investigate compliance with guidelines, I would like to try to find the compliance of private companies specifically.

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3 interviews, any information from stakeholder websites