Undergraduate Thesis Prospectus

Satellite-Guided Truck Parking

(technical research project in Aerospace Engineering)

The Satellite Constellation Controversy

(sociotechnical research project)

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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General Research Problem

How can satellites improve efficiency and productivity?

Satellites are essential for telecommunications, and GPS data supports air, ground, and marine transport. Satellite data is also used to improve agricultural efficiency, monitor climate change, protect ecosystems and conservation efforts, improve access to public health, and assist in search and rescue operations (Canadian Space Agency, 2020). Weather disasters, which cost billions of dollars in property damage and claim many lives annually, can be predicted using information from satellites (Hertzfeld & Williamson, 2002). According to Hertzfeld and Williamson, Earth observations from satellites have "a huge and significant impact on the economy." Yet low Earth orbit (LEO) is now cluttered with space debris, complicating space missions (Lehoucq, 2020). Light pollution from satellites obscures astronomical observations and may even prevent detection of an incoming asteroid.

Satellite-Guided Truck Parking

How can semi-truck drivers have real-time access to truck parking information in Virginia?

Project Overview

The project will integrate and apply air, space, and terrestrial resources to enhance semi-truck parking in Virginia. The technical advisor is Professor Chris Goyne of the Mechanical and Aerospace Engineering Department. The collaborators for this project are 11 students enrolled in Spacecraft Design.

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, since there is no centralized system to locate vacancies and relay information to truck drivers effectively, parking stations often become overcrowded. This leads drowsy and fatigued truck drivers to either illegally park along the highway or continue driving in search of an available space, endangering themselves and other drivers on the road. For this technical research project, the goal is to develop a space-based solution for remote sensing of trucks and parking spots in Virginia and to propose a systems architecture to process parking data and disseminate it to truck drivers.

The team reached out to the Eastern Transportation Coalition, the I-81 Corridor Coalition, the 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. Interviews with the first three of the listed organizations have already been conducted. 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.

State of the Art and Shortcomings

Despite 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, the team conducted research on state-of-the-art solutions and developments. Crowd-sourced tracking apps as well as in-ground detectors with cameras for additional monitoring are commercially available solutions, yet they 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).

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 (pavement) to install the sensors. On-site cameras are currently the most favorable solution. However, this 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 pre-existing solutions, we have determined that the solution needs to have high data-collection frequency and should be widely applicable to avoid the installation of sensors or cameras at every parking location in the state.

Proposed Solution

The team decided that the proposed solution should incorporate a constellation of satellites in Low Earth Orbit (LEO). A space-based approach offers the advantageous capability of being globally applicable, 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 at each truck stop. The exact quantity of constituent satellites and their orbital parameters will be determined throughout the remainder of the solution development process. An additional solution requirement developed by the team is to update parking availability data every thirty minutes.

The end result of this project will be a concept for an integrated system capable of tracking and monitoring truck parking throughout Virginia while updating truck drivers with near-real-time information.

The Satellite Constellation Controversy

How are critics and advocates of satellite constellations advancing their respective agendas?

Satellite constellations can provide global or near-global coverage for navigation (e.g., GPS), communications (Iridium, Starlink), and Earth observation (PlanetLabs). From the 1980s until the late 2010s, constellations only consisted of several dozen satellites (International Astronomical Union, 2020). Starlink, a new constellation, is SpaceX's project to assemble a network of over 40,000 satellites in LEO to support global internet access (Sheetz, 2020). SpaceX claims Starlink will bring internet access to 3.3 billion people who are still offline (O'Callaghan, 2019). However, this ambitious plan has been subject to opposition from critics because of the increase in space debris and light pollution. Before the Starlink project began in 2018, less than 9,000 satellites had been sent into orbit since Sputnik 1 (1957), of which only about 1,000 were still operating in LEO (Datta, 2020). By late 2020, SpaceX had launched over 900 Starlink satellites. Other companies are following SpaceX's lead: Boeing, OneWeb, Telesat, and Kuiper Systems (a subsidiary of Amazon) all plan to launch their own internet constellations with thousands of satellites each.

According to SpaceX, the satellite internet business is targeting a $1 trillion potential market (Sheetz, 2020). Answering critics, Elon Musk has said "potentially helping billions of economically disadvantaged people is the greater good" (O'Callaghan, 2019). Nevertheless, SpaceX is striving to reduce the albedo (reflectiveness) of future satellites by testing a non-reflective coating and a solar shade (Ralph, 2020). Since GPS constellations are in medium Earth orbit (MEO) and thus appear dimmer in the night sky, they do not cause light pollution. The now defunct Iridium constellation produced bright flares of reflected sunlight that were visible in

daylight because of its satellites' high reflectivity. But because Iridium had fewer than 100 satellites, it was much less controversial.

The American Astronomical Society (AAS) and the International Astronomical Union (IAU) oppose large satellite constellations (Gough, 2020). According to Gallizzi, Scardia, and Maris (2020), satellite trails ruin astronomers' long-exposure photographs and the irradiation of satellite communications interferes with observations in other wavelengths. Such interference can also obscure asteroids and comets.

Satellite operators warn that growing constellations may make collisions inevitable and render certain orbits unusable (Lehoucq, 2020). As the risk of collisions increases, the cost of space insurance will rise. Some companies are leaving the LEO launch market. The managing director of Assure Space, a space insurance underwriter, believes space insurers will eventually stop insuring LEO satellites: "there is too much risk and too little being done about mitigating space debris or managing space traffic globally" (Johnson, 2020). Launch service providers (LSPs), including United Launch Alliance (ULA) and Northrop Grumman, will face rising launch costs for space insurance and collision avoidance systems (Ailor, 2010).

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