Utilization of Real-Time Weather Data to Improve Roadway Safety
(Technical Paper)

Societal Implications of Satellite Data Retrieval
(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

Mici Cummings
Spring, 2021

Technical Project Team Members
Arianna Asquini, Ian Davis, Kyle Ebanks, Rikia Freeman, Raeann Giannattasio, Allen Lang, Pranav Sridhar, Elias Topp, Ethan Vicario, and Avery Walker

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

Signature Mici Cummings Date May 4, 2021
Mici Cummings

Approved _____ Date _____
Christopher Goyne, Department of Mechanical and Aerospace Engineering

Approved H Rogers Date May 4, 2021
Hannah Rogers, Department of Engineering and Society

Introduction

Imagine having the ability to prevent twenty-one percent of traffic accidents across the United States. According to the United States Department of Transportation's Federal Highway Administration, twenty-one percent of traffic accidents are associated with weather conditions (Federal Highway Administration, 2016). Utilizing real-time weather data to ensure roadway safety is essential to reduce these avertible calamities. Satellites are the primary method of receiving information regarding climate conditions. The National Oceanic and Atmospheric Administration (NOAA) currently utilizes a Geostationary Operational Environmental Satellite (GOES) to secure weather data (US Department of Commerce, NOAA, National Weather Service, 2016). Understanding satellite data and how this data is collected is the first step to discovering a solution for weather-related accidents. Noting the correlation between temperature, precipitation, and other components is involved when analyzing the climate (*Climate data monitoring | National Oceanic and Atmospheric Administration*, 2019). Once this knowledge is obtained, steps will be taken to discover if the current capabilities of satellites are sufficient for reducing roadway disasters or if an alternative solution is required. Within these steps, the accuracy of the data will have to be determined. NOAA conducts frequent quality checks for their devices, and their data is updated often as well (*How do weather observations become climate data? | NOAA Climate.gov*, 2018). Examining this topic further will be crucial for this technical project. The technical portion of this proposal will focus on researching current methods of obtaining weather data in order to formulate a new solution to decrease roadway disasters.

The implications of satellite data retrieval are the focus of the second portion of this prospectus. How this data is attained and what it means for society is essential in discovering

further ways of improvement. Moreover, on average, the lifespan for weather satellites is ten years (Werner, 2018). These satellites are then rendered useless, so where do they go? Creating satellites with short lifespans could be more efficient, since this would be less expensive over time (Werner, 2018). However, if these satellites are not returned to Earth to burn in the atmosphere, then they are left in space, retreating farther and farther from Earth (*Where Do Old Satellites Go When They Die? | NASA Space Place – NASA Science for Kids*, 2019). Further looking into what space debris means for society is imperative in identifying methods of amending this issue. Thus, the second topic of this proposal will discuss the implications of space debris and possible solutions.

Technical Prospectus

Weather conditions strongly affect the safety of the roadway system, particularly snow and rain. Since drivers do not always take precautions when it comes to road conditions, there is a higher chance of accidents during inclement or even slightly less ideal weather. Currently, in-vehicle and smart-phone-based satellite navigation devices do not integrate real-time weather information. Interestingly, many aviation satellite navigation devices do have this capability because weather variations are a greater risk to planes than ground vehicles, creating a higher demand for technology in aircraft than cars.

The Mitre Corporation (MITRE) has enlisted this research team to create a spacecraft that would improve roadway safety in relation to weather. In order to solve the problem of reducing roadway accidents due to weather, there are three key elements that are researched for literature review: weather safety and human factors, weather data collection, and data delivery. A discovery when researching weather satellites is that the National Oceanic and Atmospheric Administration (NOAA) primarily utilizes doppler radar, satellite data, and supercomputers to

monitor weather conditions (*6 tools our meteorologists use to forecast the weather | National Oceanic and Atmospheric Administration*, 2017). The NOAA satellites relay the data they collect to receivers back on Earth (*How Bits and Bytes of Data Become a Forecast | NOAA National Environmental Satellite, Data, and Information Service (NESDIS)*, 2019). This data is then processed using supercomputers to create weather forecasts. In fact, one of the primary locations for these supercomputers is in Reston, Virginia. The aforementioned data discovered during literature review will be useful in forming an improved technology or concept.

Some areas for improvements over the current technology are considered to further analyze how to ameliorate this issue. First, there are currently no satellites observing real-time road conditions for snow cover, ice, or flooding. Second, current solutions are fleet-based, rather than focused on individual drivers. Third, timelines in communicating observations to drivers should be looked into further.

This Capstone team proposes to create a solution by implementing remote-sensing through the use of a CubeSat. This CubeSat would monitor on-road accumulation of precipitation on roads and calculate average speed changes to provide users with in-application weather warnings. It would include real-time delays and alternatives. Placing this device in Geostationary Earth Orbit (GEO) will allow for consistent imaging and data collection over a particular area. By comparing real-time observations of inhabitants in a locality as well as ground-based sensors in the vicinity, the team will verify if the rain accumulation detected by the satellite created is correct. This experimentation will be a source of confirmation for whether the satellite is effective. Furthermore, the team plans to integrate data from popular navigation applications with that collected from their satellite. Through the incorporation of applications that are widely used by the public—such as Waze, Google Maps, and Apple Maps—this

innovation will have the ability to contribute to a large population.

STS Prospectus

Weather data is vastly important for society, as it provides inhabitants with the ability to judge future actions, such as evacuation. Satellites become relevant here because they are useful for seeing cloud cover and measuring Earth's surface temperature (*How do scientists use radar and satellites to observe and predict weather?*, 2016). The ability to predict weather based on these features is incredible, though the accuracy of the data should be considered. First, the speed of the satellite should be the same as that of Earth's rotation to be most effective. Thus, the satellite is able to view the same place on Earth throughout its rotation (*How do scientists use radar and satellites to observe and predict weather?*, 2016). Two types of satellites are used to collect weather data: geostationary satellites and polar-orbiting satellites. Geostationary satellites are utilized to predict weather and other climatic events, whereas polar-orbiting satellites collect environmental data for precipitation, sea surface temperatures, and humidity, among other items (*Satellite Data | National Centers for Environmental Information (NCEI) formerly known as National Climatic Data Center (NCDC)*, 2010). Additionally, the aforementioned GOES satellites that the United States utilizes have a 5-channel imager to detect visible and infrared reflected and emitted solar radiation, allowing them to detect numerous weather conditions, such as atmospheric temperature, winds, moisture, and cloud cover (Natural Resources Canada, 2015). Moreover, NOAA's doppler radar systems track weather formation that is produced in a map-like format (US Department of Commerce, NOAA, National Weather Service, 2020). This NOAA weather prediction system narrows down to 0.5 degrees resolution, which is about a 55-kilometer square area, presenting a re-analysis of past data as well as forecasted weather (*Model Datasets | National Centers for Environmental Information (NCEI) formerly known as National*

Climatic Data Center (NCDC), 2011). NOAA environmental data is updated at least once per day, tracking air temperature, evaporation, precipitation, sky cover, clouds, sunshine, water, weather type—rain, sleet, hail, thunder, et cetera—and wind (National Centers for Environmental Information (NCEI), 2020). Climate information is often available only as raw observations or in the form of tables, graphs, or written summaries, which is difficult for users who are not well-versed in climate science to fully interpret. NOAA's National Climatic Data Center does work with other sectors to determine the effect of weather conditions on transportation (*NOAA's National Climatic Data Center Sectoral Engagement Fact Sheet*, n.d.). The current collection of weather data appears both holistic and accurate.

As discussed earlier, satellites are not expected to be in orbit for longer than ten to fifteen years—and some may only last for five (Werner, 2018). Some manufacturers believe that satellites with shorter lifespans prove more effective when examining cost, since the satellites would tend to be smaller and easier to transport to space. Unfortunately, when these satellites are rendered useless, they either are returned to Earth to burn in the atmosphere upon re-entry or sent further into space, adding to the ever-growing space debris (*Where Do Old Satellites Go When They Die? | NASA Space Place – NASA Science for Kids*, 2019). Considering how useful weather data is for society to function, the long-term implications of utilizing ephemeral products could result in dangers for the future. Researching this topic further to discover initiatives being taken to meliorate disastrous prospects could prove ground-breaking.

The key framework that will be used to develop this concept is Technological Fix. The theory of Technological Fix comprises the utilization of technology to solve something with a deeper problem. Professor Byron P. Newberry discussed Technological Fix in his encyclopedia entry for the Encyclopedia of Science, Technology, and Ethics. He outlines how utilizing

technology as a quick solution to bigger problems can be dangerous. Furthermore, he questions if all situations can be solved using technology (Newberry, 2005). Technological fixes do not explore the root of the problem, which results in temporary fixes, rather than long-term solutions. Using technology to create a shortcut to a bigger problem is very apparent in the creation of the Great Pacific Garbage Patch (National Geographic Society, 2019). This collection of debris in the middle of the ocean is comparable to the Spacecraft Cemetery that was created for large spacecraft debris to be deposited—also in the middle of the ocean (*Where Do Old Satellites Go When They Die? | NASA Space Place – NASA Science for Kids*, 2019). This research paper will further delve into comparisons between these debris clusters as well as exploring how effective this Technological Fix is for society.

Wicked Problem Framing is another applicable framework to this problem of space debris. Wicked problems are inherently controversial and create differing opinions. Sustainability issues fall into this category of Wicked Problems quite often. Therefore, space debris and satellite disposal have the requirements to analyze from a Wicked Problem standpoint. Considering the effectiveness of the aforementioned Technological Fix, this research paper will also analyze this problem of space debris from a Wicked Problem Framing perspective.

Methodologies

Research Question: What are the societal implications of retrieving satellite weather data?

The main focus of this research paper is to discuss how inoperative satellites are handled. This discussion will require further research into implications of space debris and how to combat the issue. To accomplish this, researching the aforementioned "Spacecraft Cemetery" will be necessary (*Where Do Old Satellites Go When They Die? | NASA Space Place – NASA Science for Kids*, 2019). For comparison, studies will be conducted on the "Great Pacific Garbage Patch"

as well (National Geographic Society, 2019). These will be online sources and, ideally, contain as up-to-date information as possible. For this documentary research, keywords such as "space debris," "recyclable satellites," and "spacecraft re-entry" will be utilized. Wicked Problem Framing will also be a factor in this research process in order to organize the underlying causes of the space debris issue, since a Technological Fix alone will not be able to accomplish this task. Following intensive research on these topics, the writing process will begin for this research paper. The organization of this information will begin with background on why space debris is an issue. This will lead into discussing the theory of Technological Fix using research on the Spacecraft Cemetery and the Great Pacific Garbage Patch as well as considering Wicked Problem Framing. The proposed plan is to conclude the research paper with prospective ideas for improvement.

Conclusion

Discovering a method in which real-time weather data can be utilized to improve roadway safety is imperative for saving thousands of lives. This project intends to find or create this method using spacecraft to achieve the needs of the customer, MITRE. Currently, the plan is to develop a remote-sensing device that incorporates weather-related events with traffic patterns. This would create a combination of normal roadway safety precautions along with the equally important weather reports—which strongly affect roads.

The second proposed project in this prospectus discusses the implications of utilizing satellites to retrieve weather data. This research topic strives to learn how satellite data acquisition affects society, specifically through discussing the implications behind space debris and debris agglomeration on Earth. Delving into this topic will bring light to the issue of wasted

and non-recyclable products, allowing society to consider improvements upon current technologies to assuage environmental concerns.

References

6 tools our meteorologists use to forecast the weather | National Oceanic and Atmospheric Administration. (2017). Noaa.Gov. https://www.noaa.gov/stories/6-tools-our-meteorologists-use-to-forecast-weather

Climate data monitoring | National Oceanic and Atmospheric Administration. (2019). Noaa.Gov. https://www.noaa.gov/education/resource-collections/climate/climate-data-monitoring

Federal Highway Administration. (2016). *How Do Weather Events Impact Roads? - FHWA Road Weather Management*. Dot.Gov. https://ops.fhwa.dot.gov/weather/q1_roadimpact.htm#:~:text=Weather%20Impacts%20on%20Safety,1%2C235%2C000%20%2D%20are%20weather%2Drelated

How Bits and Bytes of Data Become a Forecast | NOAA National Environmental Satellite, Data, and Information Service (NESDIS). (2019). Noaa.Gov. https://www.nesdis.noaa.gov/content/how-bits-and-bytes-data-become-forecast

How do scientists use radar and satellites to observe and predict weather? (2016, November 16). American Geosciences Institute. https://www.americangeosciences.org/education/k5geosource/content/weather/how-do-scientists-use-radar-satellites-to-observe-and-predict-weather

How do weather observations become climate data? | NOAA Climate.gov. (2018). Climate.Gov. https://www.climate.gov/maps-data/primer/processing-climate-data#:~:text=Data%20Processing%20Begins%20with%20Quality%20Control&text=Meteorologists%20at%20NCEI%20use%20computers,for%20consistency%20across%20a%20region

Model Datasets | National Centers for Environmental Information (NCEI) formerly known as

National Climatic Data Center (NCDC). (2011). Noaa.Gov. https://www.ncdc.noaa.gov/data-access/model-data/model-datasets

National Centers for Environmental Information (NCEI). (2020). *Daily Summaries Location Details: Virginia, FIPS:51 | Climate Data Online (CDO) | National Climatic Data Center (NCDC)*. Noaa.Gov; Climate Data Online (CDO). https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/FIPS:51/detail

National Geographic Society. (2019, July 5). *Great Pacific Garbage Patch*. National Geographic Society. https://www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/

Natural Resources Canada. (2015). *Weather Satellites/Sensors | Natural Resources Canada*. Nrcan.Gc.Ca. https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/remote-sensing-tutorials/satellites-sensors/weather-satellitessensors/9387

Newberry, B. (2005). Technological Fix. In *Encyclopedia of Science, Technology, and Ethics* (pp. 1901-1903). Detroit, MI: Macmillan Reference USA.

NOAA's National Climatic Data Center Sectoral Engagement Fact Sheet. (n.d.). Retrieved October 13, 2020, from https://www.ncdc.noaa.gov/sites/default/files/attachments/Transportation_Low%20Res.pdf

Satellite Data | National Centers for Environmental Information (NCEI) formerly known as National Climatic Data Center (NCDC). (2010). Noaa.Gov. https://www.ncdc.noaa.gov/data-access/satellite-data

US Department of Commerce, NOAA, National Weather Service. (2016). *Satellites*. Weather.Gov. https://www.weather.gov/about/satellites#:~:text=There%20are%20two%20types%20of%20weather%20satellites%3A%20polar%20orbiting%20and%20geostationary.&text=Polar%20orbiting%20satellites%20provide%20imagery,data%20over%20t

he%20entire%20Earth

US Department of Commerce, NOAA, National Weather Service. (2020). *NWS JetStream – Radar Images for GIS Software*. Weather.Gov. https://www.weather.gov/jetstream/gis

Werner, D. (2018, May 24). *SpaceCom Conference & Exposition*. SpaceNews. https://spacenews.com/ how-long-should-a-satellite-last/#:~:text=The%20U.S.%20Air%20Force%20wants,during%20an%20earlier%20keynote%20address

Where Do Old Satellites Go When They Die? | NASA Space Place – NASA Science for Kids. (2019). Nasa.Gov. https://spaceplace.nasa.gov/spacecraft-graveyard/en/