GEORGE MASON UNIVERSITY
OLD DOMINION UNIVERSITY
VIRGINIA SPACE GRANT CONSORTIUM
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
UNIVERSITY OF VIRGINIA
MITRE PRODUCT

MITRE'S UNIVERSITY INNOVATION EXCHANGE FOR SPACE

Using Space Research to Address Enterprise-Wide Problems

MITRE | SOLVING PROBLEMS FOR A SAFER WORLD™

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January 2021

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McLean, VA

EXECUTIVE SUMMARY

The Commonwealth of Virginia has several key needs addressed with space-based remote sensing data. The Commonwealth has many experts in remote sensing observations, data analysis, and data archival and dissemination working in independent groups on a range of research topics. Our thesis is that information from data sources can be more efficiently exploited to support real time decision making by problem stakeholders. While the title of our study includes 'space' we envision the use of space, airborne, terrestrial, maritime sensors, and a variety of data sources (e.g., weather, traffic reports) to support these problems. Our goal is to obtain necessary data from information sources associated with a given problem ('problem-centric') and integrate this data into a single process for data mining and exploitation. We anticipate improvement in the timeliness and effectiveness of actions taken by stakeholders, based on the exploitation of those data. Given the proliferation of remote sensing capabilities, information sources, and information technology enablers such as the internet-of-things, this is a logical next step for an Information Based Economy, such as the Commonwealth.

Based on this vision, MITRE is collaborating with four Virginia universities and the Virginia Space Grant Consortium to make high impac contributions to the Commonwealth. Taking advantage of existing capabilities and investments, we are leveraging current activities such as Virginia Research Investment Committee-Funded Virginia Small Sat Data Consortium, the Virginia Open Data Cube (VODC), and the work of other state and federal entities to provide efficient access to data to address problems in the Commonwealth.

MITRE's University Innovation Exchange (UIX) for Space brings these groups together to analyze Virginia's remote sensing needs and the resources available in five problem areas:

- Solar power generation efficiency – Stability and efficiency of the electric grid, the most important aspects for the energy infrastructure.

- Transportation efficiency – Congestion on Virginia roadways that costs billions of dollars and causes needless loss of life as well as affects Virginians' quality of life.

- Flooding prediction and response – Impacts of flooding, sea-level rise, and land subsidence all affect the near and far-term economic growth and development of Virginia coastal regions.

- Water body monitoring – A large portion of rivers are unmonitored and unassessed. Virginia's water pollution problem requires extensive monitoring to understand how to prevent environmental damage.

- Wildfire prevention and response – Assessing wildfire risk in the wilderness / urban interface is a major challenge and area of concern for wildfire danger—with the potential for massive loss of personal property and infrastructure.

This report documents our first phase of work. During this phase, the UIX Space Team identified and documented the information needed to address these problems, to determine if existing information sources are sufficient to provide that data and, if not, determine what is required and design a plan to obtain and populate the relevant data into the VODC, as means of integrating information for subsequent action. As a result of a purposeful and repeatable process of defining each problem area, the team has identified necessary approaches and viable solutions, a process to collaboratively address the problems, and next steps to work toward solutions. Key recommendations include:

- Solar power generation – Develop innovative data-driven technical products to control power connection to the electrical grid or to local battery storage. This is done by monitoring real time cloud obscuration of solar panels. Maximizing connection to the grid and minimizing battery storage time can create small improvements in power efficiency, which if used at a large scale, can be compelling. This can be done by combining space information resources and ground-based in-situ sensors around a solar farm, or in medium-sized solar generation systems on building rooftops.

- Transportation – Identify and integrate multiple information resources (space, air, terrestrial, maritime) to develop real time situational awareness of roadways for drivers and develop transportation routing efficiency enhancements based on this information.

- Flooding prediction and response – Create actionable options for use by emergency managers for better pre-storm assessment of potential flooding areas, from onset, duration, and impacts. Use space based electro-optic data for more timely information on flooding extents, shortening response and recovery times, and improving situational awareness.

- Water body monitoring/health – Use space, airborne and in-situ monitoring to provide timely and actionable data that support wide-area algae bloom detection.

- Wildfire prevention – Utilize space-based (Landsat) multispectral data, publicly-available land use and weather data to support land analyses that improve timely fire danger monitoring and prediction.

ACKNOWLEDGMENTS

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1 MITRE – VIRGINIA UNIVERSITY INNOVATION EXCHANGE

1.1 OVERVIEW

MITRE's University Innovation Exchange (UIX) is a partnership among participating Virginia public universities and the Virginia Space Grant Consortium (VSGC).

As an operator of federally funded research and development centers, MITRE takes an enterprise-wide perspective to deliver innovative solutions to meet the government's most critical needs. Each participating university has deep expertise in specific areas. Together, MITRE + Universities + VSGC = UIX. The role of UIX is to address enterprise-wide significant problems using deep expertise from Virginia universities. For each of the problems addressed, while a given university has the lead for that problem, *the entire team brings its best experts for the given problem*. We truly work as a single team.

1.2 WHY VIRGINIA?

The Commonwealth of Virginia has significant environmental, security, infrastructure, and public issues that could be addressed if the right data tools, sensor data, and subject matter expertise were identified and applied. The Commonwealth has many experts in remote sensing observations, data analysis, and data archival and dissemination, working in independent groups on a range of research topics. The Commonwealth Research and Technology Strategic Roadmap [1] highlights the focus areas of research for the Commonwealth of Virginia. This work aligns with that roadmap.

1.3 UIX FOR SPACE

1.3.1 GOALS

UIX-Space is working toward the following goals:

- Bringing groups together to analyze Virginia's remote sensing needs and the resources available
- Identifying government and industry partners as well as funding agents who have interest in this information
- Documenting findings and proposing a path forward to ensure the required information is easily available to those who need it

1.3.2 PROBLEM/RESEARCH AREAS

This paper covers research related to five key problem areas:

- Solar power generation efficiency
- Transportation efficiency
- Flooding prediction and response
- Water body health
- Wildfire prevention and response

The UIX-Space team addressing these research areas consists of MITRE experts working with George Mason University (GMU), with a focus on solar power generation; Virginia Tech (VT),

1.3.3 OTHER COLLABORATORS/STAKEHOLDERS

The UIX-Space Team has engaged with many collaborators and stakeholders for each of the five problems.

A complete listing of stakeholders and their contact information may be found in 0.

2 UIX-SPACE VIRGINIA PROBLEM STATEMENTS

2.1 SOLAR POWER GENERATION EFFICIENCY

2.1.1 PROBLEM SCOPE

Electric grid stability and efficiency are the most important aspects for the energy infrastructure. Renewables such as solar and wind contribute significantly to the instability of the grid. A higher degree of grid stability relies on proactive planning and stable energy generation. This planning influences grid configuration for specific time intervals.

Renewables such as solar are inherently unstable and depend on ever-changing cloud cover. Solar farms cannot guarantee the level of energy generated will be constant throughout longer time intervals (such as morning, noon, afternoon). Hence, the full utilization of solar energy is handicapped by cloud cover changing in real-time and the requirement for grid stability.

Using solar farms, Dominion Energy currently generates approximately 1.5 gigawatts (GW) and will bring an additional approximately 5 GW to the grid within the next two-three years. Because this amount becomes substantial, the increased demand is a challenge to grid stability.

2.1.2 CHALLENGES

Numerous challenges and gaps exist in this problem area, including:

- Utilization of solar farms is planned a day ahead at a lower level and at longer time intervals than optimal due to changing weather conditions and low confidence of estimated insolation levels. This planning excludes the best-case scenario and takes under consideration unplanned large variation in available energy level and uncertainty of its duration.
- Large battery farms are placed at solar farms to act as filters to mitigate this problem. They store an excess of energy supply when clouds are absent and supplement energy supply deficiency when clouds come over the area. Battery farms are very useful and will always be needed, but they are expensive and require maintenance.
- Additionally, between 10 to 20 percent of generated energy is wasted on energy conversion for storage and discharge in/from batteries. The efficiency of the conversion depends on numerous factors (e.g., temperature) and will worsen over time for older batteries.

2.1.3 APPROACH TO A SOLUTION

Considerable savings can be achieved by predicting utilization levels over a shorter period and online. This can be accomplished by utilizing cloud cover analysis and feedback from ground sensors. The goal is to (1) shorten the proactive planning period to smaller than one-hour time intervals, (2) provide a more accurate estimate of insolation levels and corresponding time intervals at solar farm locations, and (3) automate the entire process.

More accurate estimate of insolation levels and their durations will allow for setting a higher utilization level of solar energy supply provided to the power grid by individual solar farms. This is due to having higher certainty of insolation levels and time intervals. Accurate information about insolation and time intervals can be obtained through near real-time analysis and fusion of information from (1) National Aeronautics and Space Administration (NASA)/National Oceanic and Atmospheric Administration (NOAA) satellite images and (2) distributed low-cost ground sensors.

For a grid with 6.5 GW solar-battery farms, an increase in efficiency by just one percent will result in savings of 65 megawatts. This is a substantial savings; however, we believe higher efficiency can be achieved. In addition, battery farms can be scaled to a smaller size. Because this solution is in the class of high-return-on-investment, a small investment will result in a large financial benefit.

Current NASA/NOAA satellite images provide wide area coverage at respectful resolution covering Virginia and North Carolina. Images include visible and infrared spectrum, are available for free, and are provided in near real-time.

Image analysis will determine cloud cover shape, ground registered location, cloud class/density, cloud cover motion, and forward estimated ground coverage for smaller than one-hour time intervals. Images and subsequent image analysis will be obtained and executed in the near real-time (a few minutes). Low-cost ground sensors distributed in the vicinity of solar farms (10-20-mile radius) will provide feedback verification of insolation levels and enable short-term accurate predictions.

Figure 1 below depicts the broad concept of operations for improving solar power generation efficiency.

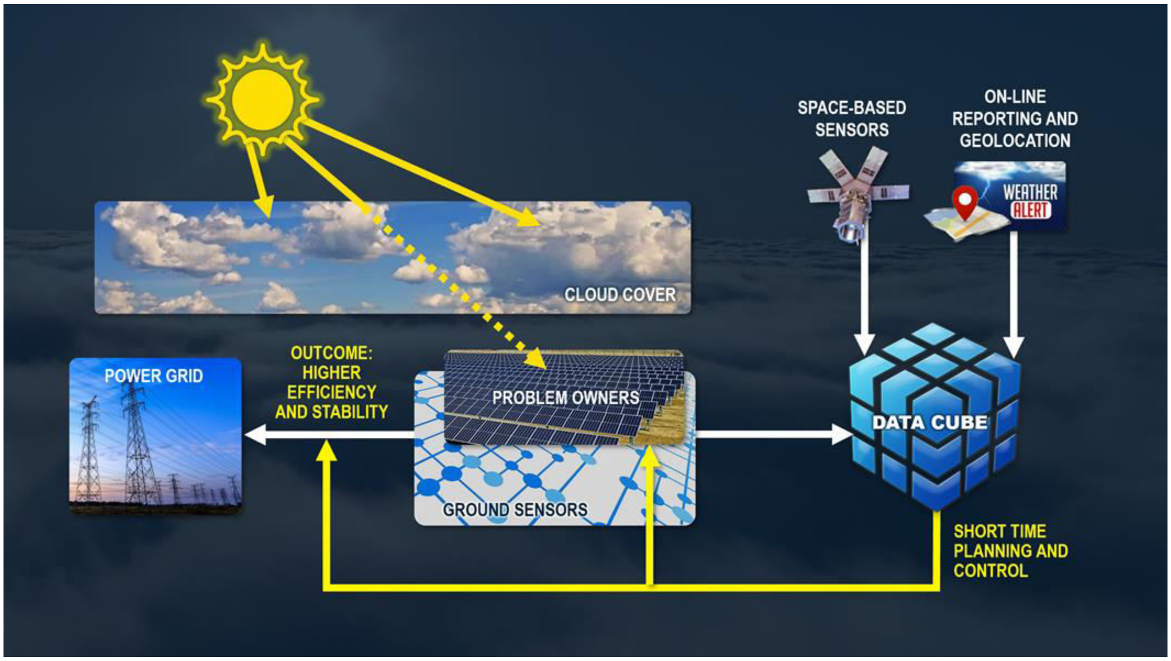

Figure 1. Solar Power Generation Efficiency Improvement, Concept of Operations

2.2 TRANSPORTATION EFFICIENCY

2.2.1 PROBLEM SCOPE

Transportation is key to Virginia's quality of life and economic development. Each year approximately $500 billion in goods are shipped into or out of Virginia [2]. The transportation system includes roads, rail, air, and sea. On a day-to-day basis, the public is most exposed to the road system, because it forms the backbone for commuting and commerce. Unfortunately, congestion on our roadways is increasing.

This congestion costs Virginia drivers close to $5 billion each year, due to lost time and increased fuel consumption. In addition, from 2014 to 2018, almost 4,000 people died in traffic accidents within Virginia. Beyond this needless loss of life, the economic cost to Virginia of traffic crashes was $6.4 billion in 2018 [2]. At the same time, the use of our road system is changing. Two percent of passenger vehicles in Virginia are currently electric. In 2040 this is expected to increase to 46 percent [2]. In addition, urban air mobility and autonomous vehicles are expected to play an increasing role in passenger transportation in the future. It is therefore imperative that we improve the efficiency and safety of our transportation system while considering new and emerging technology. This will save lives, save money, and improve our quality of life.

This is a national problem but one that particularly affects the Commonwealth of Virginia. Road congestion is particularly prevalent in Northern Virginia and the Hampton Roads areas. The I-95 and I-81 corridors within Virginia are national transportation arteries that also suffer from congestion problems.

2.2.2 CHALLENGES

Numerous gaps in data exist and create challenges in this area, including:

- Real-time weather data to improve roadway safety – In-vehicle and smart-phone-based satellite navigation devices will notify drivers of congested traffic, roadway incidents, detours, and road maintenance and closures. However, no real-time weather information exists that is integrated into the data streams delivered to these navigation devices.
- Remote-sensing-enhanced non-destructive evaluation of roadway infrastructure – Regular inspection and monitoring of roadway infrastructure is required for all bridges, tunnels, roadways, signs, lighting, and stormwater management structures. This inspection helps ensure structural integrity, anticipate repairs, and plan for infrastructure replacement. Inspection usually involves non-destructive evaluation techniques that are labor intensive and often require lane closures that can lead to traffic congestion.
- Emergency incident management and maintenance monitoring via air- and space-based platforms – Emergency incidents and unscheduled roadway maintenance can occur at any time and at any location within the roadway system. Unfortunately, Virginia Department of Transportation traffic cameras are located at fixed locations. Therefore, for much of the highway system, unless a manned aircraft or helicopter is immediately available nearby, the management of emergency incidents and the monitoring of unscheduled roadway maintenance must be performed via observation by personnel on the ground. This limits the temporal and spatial coverage of the incident and results in management decisions that are not fully informed.

2.2.3 APPROACH TO A SOLUTION

The MITRE-UIX-Space team will develop innovative data-driven technical products to improve transportation efficiency within the Commonwealth of Virginia. We will identify and integrate multiple information resources (space, air, terrestrial, maritime) to develop innovative transportation efficiency enhancements.

Safety improvements in throughput will be required in the 2020s. Integration of multi-modal/ multi-domain transportation systems in an automated systematic approach provides greater throughput and efficiency while preserving safety of operations.

Figure 2 below depicts the broad concept of operations for improving transportation efficiency.

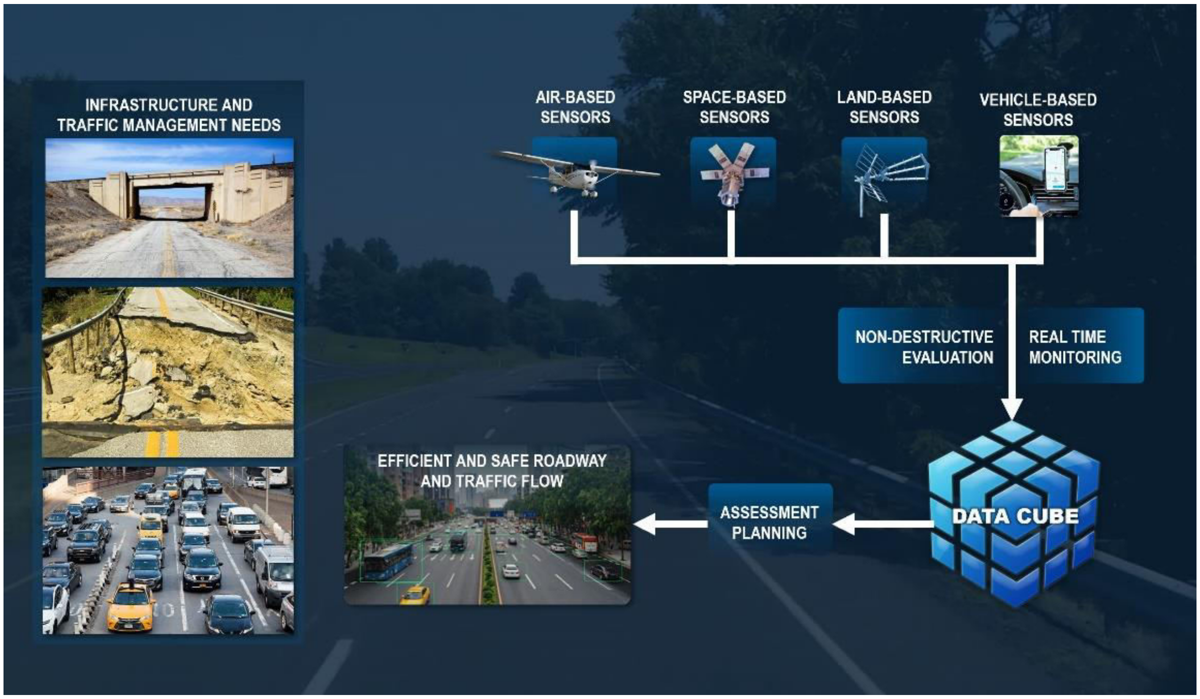

Figure 2. Transportation Efficiency Improvement, Concept of Operations

2.3 FLOODING PREDICTION AND RESPONSE

2.3.1 PROBLEM SCOPE

Virginia is home to a large Department of Defense footprint as well as major economic and population centers in its coastal regions. Coastal resiliency is a major issue in the Hampton Roads region. The impacts of flooding, sea-level rise, and land subsidence all affect the near and far-term economic growth and development of the region.

Much of Hampton Roads faces risk of flooding from coastal storms; higher tides due to rising seas; increasing intensity, duration, and frequency of precipitation; insufficient or aging stormwater infrastructure systems in a low coastal plain; and the combined impacts from all these factors. Municipalities, university researchers, and consultants are actively seeking better and new data to predict, plan for, respond to, and recover from these events.

The current state of flood information remains exceedingly siloed, limiting a wide variety of analyses. Flood prediction model outputs typically remain within dedicated webmap servers. Earth observation (EO) data are similarly stovepiped and require significant data processing. Small Unmanned Aerial Systems (sUAS) and citizen observations are not shared widely, lacking a platform and curation. Individual municipalities and the Planning District Commission have undertaken various analyses and products but are oftentimes not aligned or comprehensive. Urban flooding from extreme rainfall stormwater runoff remains an ad hoc process, focusing on currently known problem areas rather than a comprehensive assessment (and approached in patchwork fashion by cities across the region).

2.3.2 CHALLENGES

Numerous challenges and gaps exist in this space, including:

- Better forecasting/modeling of near-term weather-related consequences, such as flooding, and farther-term impacts of sea-level rise and land subsidence, all require increased data sets with varying degrees of temporal and spatial resolution.
- This project would leverage current activities such as the Virginia Research Investment Fund that is funded by the Virginia Small Sat Data Consortium (VSDC),[1] the Virginia Open Data Cube (VODC),[2] and the work of other entities such as the Commonwealth Center for Recurrent Flooding Resilience[3] and the ODU Institute for Coastal Adaptation and Resilience,[4] to provide the platform and user community for such data sets.
- Spatial and temporal factors continue to present major challenges to flood preparedness, response, and recovery. Forecasters and emergency managers focus on timely flood inundation forecasts to manage evacuation and deploy a response. First, antecedent conditions such as precursor rainfall events and soil moisture are known to affect flooding in urban and rural areas alike, yet these data are seldom explicitly included in flood forecasts. Second, at the height of flooding, observational data is lacking to record the inundation events, with limited real-time water-level sensors and ad hoc reporting. This situation heightens the need for damage assessment in the immediate aftermath and recording features such as flood-water heights on buildings, wrack lines, or other damages. Essentially, models and incidental reports are relied upon to answer the question, “What just flooded?” Further, flood forecast models seldom report important characteristics of flooding that could improve modeling and damage assessment, such as duration of the flood, timing of onset and abatement, or lingering flood water impacts on transportation and accessibility.

2.3.3 APPROACH TO A SOLUTION

Increased monitoring is required to assess all Virginia water bodies. Remote sensing offers an efficient method to monitor water bodies at a range of scales and in challenging environmental conditions. It can help assess water quality, drought, flooding, and pollution.

The potential for federal, state, and industry funding is very real (some funded activities already exist), given the significant impact on the current and future operations, sustainment, and location of major centers of economic growth.

The Norfolk and Virginia Beach Joint Land Use Study (JLUS) is near completion and focuses on flooding as the main encroachment to bases within the area. Other JLUS studies in the region also consider flooding as an encroachment. Many projects have been identified, and localities are actively seeking support for implementation. Additionally, Norfolk, Virginia Beach, and

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[1] VADataHub.org

[2] Data4VA.org

[3] floodingresiliency.org, a partnership of ODU, Virginia Institute of Marine Science, and William & Mary Law School’s Virginia Coastal Policy Center

[4] oduicar.org

Hampton have independently developed multi-pronged resilience plans. These plans detail infrastructure improvements reaching into the billions. However, increasing access to data or combining data in novel ways may, at a lower cost, inform additional planning, reduce losses (both in productivity and in property) from flooding, and increase response and recovery time. Further open access to data fosters innovation activities in the region already ongoing with the support of organizations such as RISE and the Open Seas Technology Hub.

Additionally, flood mapping should identify the enhanced risk and cumulative impact of urban imperviousness in runoff forecasts, better depict the effects of antecedent soil moisture and precursor rainfall events, and factor the consequences of flooding on response and recovery (e.g., transportation and other infrastructure impacts).

We should ensure effective deployment of water-level sensor networks to identify impactful flooding (roads, development, and critical infrastructure) across multiple and combined flood events (extreme rainfall, storm surges, backflow/tailwater, and ground-water table inundation).

Geographic Information System (GIS) combined with EO may improve pre-identification of extreme rainfall, tidal backflow/tailwater, and verification of flooding from satellite observations. In addition, in situ monitoring on buoys is rapidly expanding and improving through data transmission to satellites. This along with other data sources should be archived in an easily accessible platform to optimize its impact.

Figure 3 below depicts the broad concept of operations for improving flooding prediction and response.

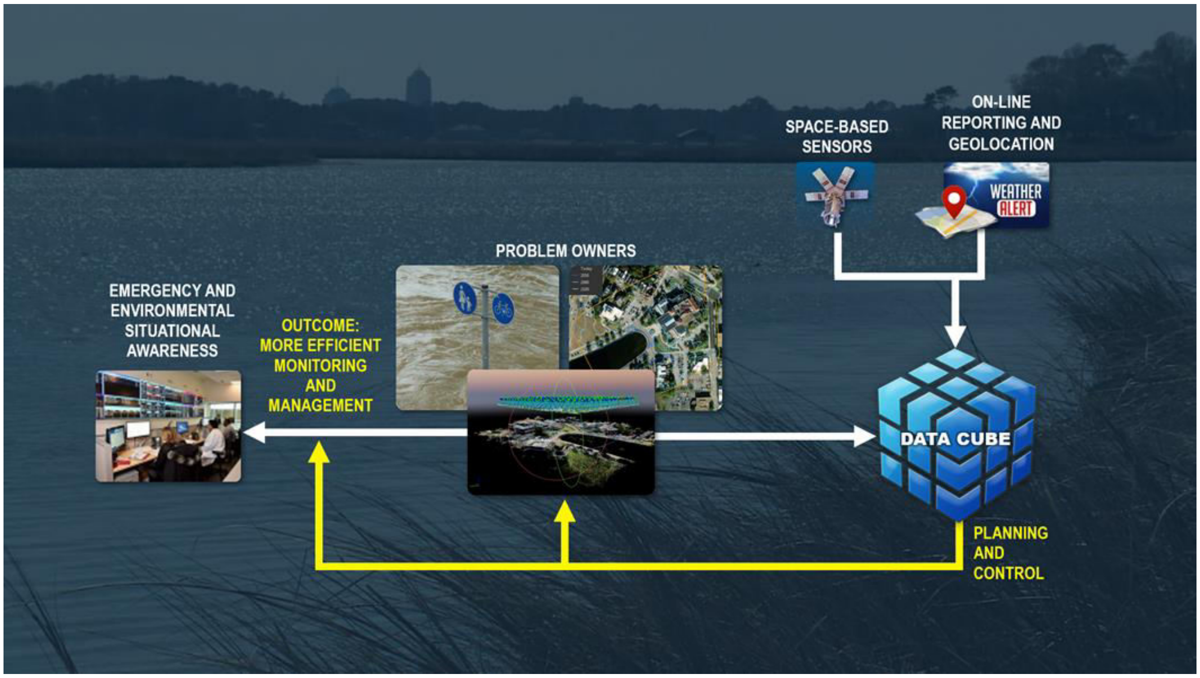

Figure 3. Improved Flooding Prediction & Response, Concept of Operations

2.4 WATER BODY HEALTH AND MONITORING

2.4.1 PROBLEM SCOPE

According to the most recent (2018) Water Quality Assessment Report by Virginia's Department of Environmental Quality [3], only 21 percent of Virginia's river miles are assessed. Of those, 16 percent (75 percent of the total) are designated as impaired. Most of those have control plans for improvement, but increased monitoring is required particularly for the nearly 80 percent of unmonitored river miles. Remote sensing cannot fully meet the needs, but it can be a major help, particularly in viewing hard-to-reach areas. Like many states, Virginia has a large pollution problem and thus requires extensive monitoring as a tool to prevent environmental damage.

2.4.2 CHALLENGES

We need data that are continuous over various scales. Remote sensing offers an efficient method to monitor rivers at a range of scales and in challenging environmental conditions. We also need high accuracy, high resolution data, to detect small changes between surveys and to monitor small rivers that may not be easily visible in satellite data analysis. In addition, we lack the ability to monitor stream flow and how streams contribute to rivers and lakes.

2.4.3 APPROACH TO A SOLUTION

Remote sensing via current satellite measurements combined with new measurements has the potential to increase the number of rivers monitored, at a range of scales and in challenging environmental conditions. Radar images and GIS techniques can provide, for example, elevation changes and water-flow paths. A ground-satellite system that autonomously detects pollution events and focuses on optimal times, such as just after a storm, would be needed to minimize human intervention. Sophisticated ground and flight software would be required. This software, the sensors, and the satellite would have to be designed.

The MITRE-UIX Space team will be considering an observatory designed for a specific region that utilizes wavelengths chosen to address that region's specific needs, has a favorable orbit for that region, and optimizes data storage and transmission to observations from that region.

Figure 4 depicts the broad concept of operations for improving river and lake health.

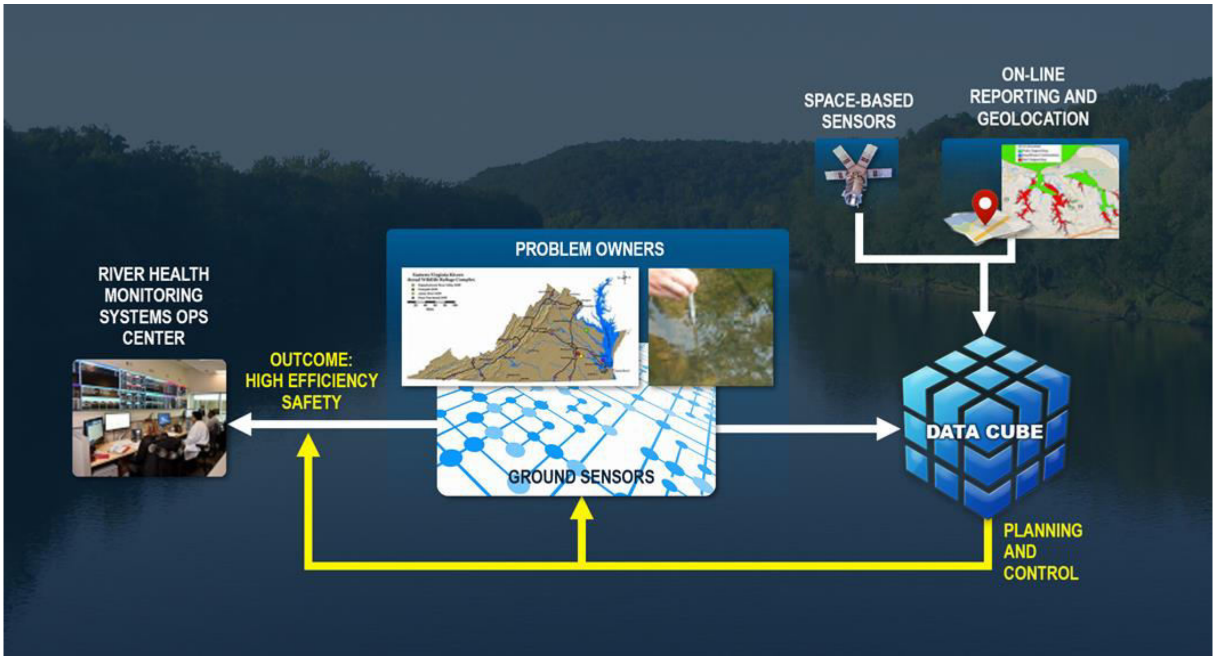

Figure 4. River and Lake Health Improvement, Concept of Operations

2.5 WILDFIRE PREVENTION AND RESPONSE

2.5.1 PROBLEM SCOPE

Assessing wildfire risk in the wilderness urban interface (WUI) is a major challenge and an area of major concern for wildfire danger. Wildfires that occur in the WUI often have potential to cause massive loss of personal property and infrastructure. Many of the current wildfire risk analysis tools are not specifically suited to the WUI; however, some of the improvements to the Fire Susceptibility Index (FSI) have made it a strong candidate to analyzing fire risk near urban areas. This work expands a decision support tool by designing a new method of assessing this risk by fusing Landsat and other remote sensing data, and other publicly-available land use and weather data using the VODC to result in global land analyses that improve fire danger monitoring and prediction.

2.5.2 CHALLENGES

The FSI is a type of geospatial data that models wildfire risk based on remote sensing data. The main fire risk analysis tool, the National Fire Danger Rating System (NFDRS), is intended for use on broad-scale applications and requires a broad array of data such as weather, the plant growth period, and ground-based observations, requiring an intensive labor process. The weather and plant growth period directly affect the light reflectance gathered by the satellite, meaning that the FSI does not have to directly account for these factors, and the remote sensing data has a spatial resolution of 30 meters, allowing for higher resolution and broad regional coverage. However, this analysis is not intended to replace the NFDRS but to add an accessible real-time analysis to allow wildfire management agencies, state and local governments, companies, and individuals to better allocate their resources. Once the FSI is properly implemented, it will allow for a much lower-labor-cost fire-risk analysis tool.

2.5.3 APPROACH TO A SOLUTION

If executed well, wildfire assessment can result in better-informed land management and insurance decisions and a reduction in the impact of wildfires.

Processing and regression analysis of these data sets produce a regional FSI in which the user can see the most likely areas, to tens-of-meters resolution, for fires to start. New capabilities that this effort will produce include increased resolution and timelines, new data feeds, additional sensors and platforms using a custom design optimization approach, scaling to global coverage, and artificial intelligence/machine learning-enabled predictive analytics. An FSI expansion like this could result in public/private partnerships to investigate predictions such as insurance risk protection, residential and commercial construction, targeted blackouts, and fire prevention. Indeed, individual land and homeowners could also benefit from risk-reduction incentives, subscriptions, and data sharing.

Other markets such as public/non-governmental organizations, the U.S. Forestry Service, state emergency services, municipalities, and HAM radio could also avail themselves of these capabilities. Other potential applications might include pipeline monitoring, topsoil erosion, Light Detection and Ranging (LIDAR) data, U.S. Geological Survey work, water quality, 5G/6G, etc.

Figure 5 depicts the broad concept of operations for improving wildfire risk analysis.

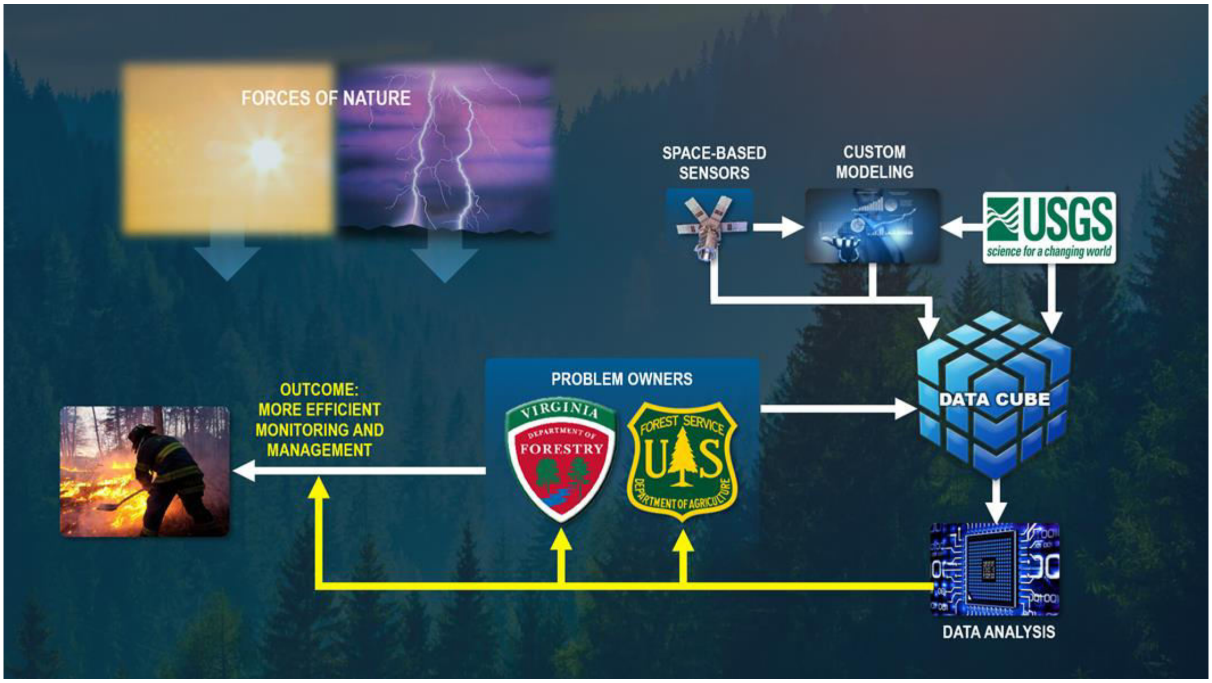

Figure 5. Improving Wildfire Risk Analysis: Prevention and Response

3 UIX IDEATION PROCESS TO ADDRESS PROBLEMS

To be able to accurately describe the current problems in the Commonwealth, the UIX-Space Team convened a series of guided discussions (‘ideations’) with and among the relevant stakeholders. These discussions were held on-line and had participation that included state, local, federal, private, and academic institutions. Numerically, these events included 20-30 persons associated with a given problem and lasted two-three hours. The outcome of these discussions was a consistent set of problem descriptions, key areas to be addressed for each problem (such as available data sources). Appendix C provides a fuller description of these events and the associated products.

3.1 SOLAR POWER GENERATION EFFICIENCY

Based on discussions and voting results from the workshop with other industry leaders, the data-centric approach to the increase in efficiency of solar power generation has been identified as the important area for applied research resulting in imminent results. In addition to solar power generation, the prediction of peak power demand has been identified as the dual use of this data-centric approach.

3.2 TRANSPORTATION EFFICIENCY

Given the results of this study and the completed workshop, the issue of real-time weather data to improve roadway safety will be the focus of the MITRE UIX-Space Initiative for transportation efficiency. Therefore, based on the results summarized in this report, the primary recommendation is the establishment of a pilot project to demonstrate the feasibility of coupling real-time weather observations with navigation, to improve roadway safety and efficiency in the Commonwealth of Virginia. This pilot will serve as a capability demonstration in preparation for a larger research and development program.

3.3 FLOODING PREDICTION AND RESPONSE MONITORING

Given the results of the workshop, the issues of improved flood prediction and usability of flood prediction products is the focus of the initiative for flooding. The ideation process resulted in the agreement to establish an approach to integrate data, usable tools, and information for flood prediction, response, and recovery. This could serve as a capability demonstration and stepping-stone in preparation for a larger research and development program.

3.4 WATER BODY MONITORING

The ideation session involved ways to leverage remote sensing capabilities for monitoring the Virginia Water Resources while considering data fusion approaches. Stakeholders who attended the workshop voted on the most pressing problems. The three most- voted-for problems were 1) small streams ignored but key to maintaining water quality (small unmonitored, unseen waterways); 2) lack of monitoring modeling to supplement the measured data; and 3) 'episodicity,' large episodic events that cannot be managed from space-based data. Several key considerations to address the "Small Streams" problem were developed. Among these, the group voted that critical problems in the monitoring of small critical unmonitored waterways call for technology, spatially distributed monitoring data, and data from episodic events (e.g., flashfloods, hurricanes) across the landscape unit. The group concluded that the problems associated with modelling (specifically soil moisture) and technology to monitor simpler water systems are most likely feasible to be solved.

3.5 WILDFIRE PREVENTION

The Ideation session agenda had several key discussion points, including 1) defining the problem statement, 2) clarifying Ideas and Solution Opportunities, and 3) prioritization of ideas. VT presented a summary of the current Wildfire Risk Analysis program at VT, including details of the problem, the implementation of algorithms to assess this risk, initial results, and implementation of algorithms on the Data Cube. Based on this presentation, the group identified this problem statement involved ways to leverage static and dynamic data sources, analytic tools, and fire-related models to improve current wildfire risk assessment, prediction, and response recovery.

4 PROPOSED SOLUTIONS/NEXT STEPS

Based on these discussions, the UIX-Space Team has identified a set of 'pilot projects' that should be conducted as a next phase of work. All pilot projects address the key aspects, needs, limitations and opportunities associated with a given problem at an appropriate scale to discern viability of the approach with a less expensive and shorter timeline. Based on success for these pilots, the next phase of work will be to implement our solution(s) at a large scale. Several themes have emerged that are shared by each of the five projects, including:

- Making use of available information sources, sensors, data to the greatest extent possible. Only if necessary, develop new information sources, sensors, or datasets. The key theme of the UIX-Space work is that of information integration, rather than development.

- Designing technical approaches for information management that are recurring across the five problem areas, such as through the use of the Open Data Cube system developed separately by VT and ODU. This system becomes a recurring element in all five problem areas. In this way, we can make better use of data that apply to multiple problem areas, such as space-based weather systems, and make better use of a library of algorithms that can be used to exploit the data in the data cube.
- Designing technical approaches for sensing and communications that can be used in multiple problem areas. For example, the use of Internet-of-things (IoT) sensors for in-situ monitoring of cloud cover around a solar farm, or for the use of monitoring river health, or for detecting flooding, moisture content in forests or weather information for traffic management is compelling. A modular design that can be reused for these various applications is envisioned.

The following describes the UIX-Space Teams' recommended pilot projects. Full detailed reports of these pilot projects can be found in Appendix D.

4.1 SOLAR POWER GENERATION EFFICIENCY PILOT PROJECT

In the first phase of solution implementation, we will establish a small development and test station where developed techniques and algorithms will be tested for efficiency and accuracy in a realistic setup and under changing conditions. The station of two small solar panels and controllable variable load will be divided into two sections, one applying currently used approach and the second the newly proposed approach. Several distributed low-cost sensors will be placed and networked wirelessly around the test station location to provide feedback to the cloud analysis part of the system. We will also work on derivative applications where short-term prediction of cloud cover and solar flux intensity may positively impact local area supply-demand management, including mitigation of peak power demand. This includes urban areas with solar roofs and individual office and industrial buildings.

4.2 TRANSPORTATION EFFICIENCY PILOT PROJECT

We aim to achieve integration of multi-modal, multi-domain transportation systems in an automated systematic approach, which obtains greater throughput/efficiency while preserving safety of operations. An example would be dynamic management of I-95 and I-81 and associated connectors. We also need to consider future systems, such as 'urban mobility systems' (i.e., flying cars) that operate both on the ground and in the air. We must be able to answer the key question of how they can efficiently and safely integrate into operations.

Additionally, we will consider how best to integrate existing and required assets. This will involve utilizing new technologies including space-based sensing, Internet of Things systems such as Waze, traffic cameras, UASs, ship transponders (Automatic Identification System), autonomous vehicle, beacons, etc. The merger of these data using a multi-modal/multi-domain platform will be required to show viability of the approach.

4.3 FLOODING PREDICTION AND RESPONSE MONITORING PILOT PROJECT

The growing UAS community would benefit from collaboration and joint/co-production of knowledge (including the private sector, NASA, Space Grant, community colleges, and ODU academics). sUAS for flood mapping could be developed as a "hackathon" participatory event to enhance Catch-the-King or expand on ODU's Blue Line Project with Norfolk.

Additionally, specific options for remote sensing in this problem area include:

- NASA Soil Moisture Active Passive can characterize antecedent soil moisture with high temporal resolution.
- Sentinel 1B SAR (Specific Absorption Rate) can capture flood waters and is not affected by cloud cover. Although affected by high noise in urban developed areas, with LIDAR for terrain analysis, spurious flood water detections can be removed from areas by shadow/SAR illumination modeling.
- sUAS can be deployed in a testbed approach at key areas of concern to validate GIS/Remote Sensing data. sUAS have been employed in the area already for King Tide model verification and a few times for wind tides in Back Bay and tropical storm flooding in Norfolk. sUAS is also amenable to professionalization across jurisdictions and a growing user community, with potential to crowdsource also growing with the availability of online Federal Aviation Administration permitting support.
- Foster the nascent innovation sector to develop solutions to flooding (and other resilience-related) problems in Coastal Virginia.
- A refined map of regional flood susceptibility would provide emergency managers and planners with decision support. Such maps could identify multiple flood predictive sources and vulnerabilities applicable in different event scenarios (e.g., storm surges, extreme rainfall, tidal flooding, and combined events.)
- An integrated approach using operational models (NOAA SLOSH, Virginia Institute for Marine Science SCHISM, United States Geological Survey [USGS], National Hydrologic Model, and ODU Delft-3D) and EOs with the VODC would be able to identify flood forecast errors and uncertainties (spatial and temporal), especially all-important omission errors.
- A refined map that inventories flooding for an actual event (or series of events) would also guide expansion or integration of a flood sensor network.
- A Flood Hub for flood-related vulnerabilities could be developed, with contents including flood maps, tools, verification data, and model inputs.
- Urban flood vulnerability from extreme rainfall and stormwater could be comprehensively approached with GIS/RS (Geographic Information Systems and Remote Sensing) modeling, such as a synoptic "Blue Spot" mapping project to screen potential current and future road flooding (linking Sentinel 1B, water sensor networks, and sUAS). The increasing extent and frequency of tidal flooding is also amenable to the same approach to modeling and observational validation.

Such options would provide emergency managers a better pre-storm assessment of the flooding, from onset, duration, and impacts. Use of EO data would provide more timely information on flooding extents, shortening response and recovery times, and improving situational awareness. Planners would be able to use more widely available future flooding information, particularly for tidal and extreme rainfall events.

4.4 WATER BODY MONITORING PILOT PROJECT

Numerous assets exist for the monitoring of water health. One of the most widely used is NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on the Tera and Aqua satellites. Our research will examine how well instruments such as MODIS address Virginia's specific needs and what requirements remain unaddressed.

Our goal is to develop a requirements list for river, lake, and stream remote sensing. What geophysical information is required? What spatial and temporal resolution? What assets exist to meet these needs? What new assets are needed? What technology is needed? Answering these questions is a top priority.

4.5 WILDFIRE PREVENTION AND RESPONSE PILOT PROJECT

Landsat satellites acquire moderate-resolution, multispectral measurements globally. To maximize the utility of current and near-future SmallSat remote sensing capabilities, the UIX-Space team proposes efficient use and seamless fusion of Landsat multispectral data, other remote sensing data, and other publicly available land-use data, to result in global land analyses that improve fire danger monitoring.

Specifically, the effort develops remote sensing data fusion for monitoring and characterizing rapidly changing agriculture and forest cover change and the progression of fire scars. The result will be multi-sensor methods based on increased temporal-spatial coverage and measurement spectral diversity that advance the virtual constellation paradigm for mid-resolution land imaging.

The remote sensing data fusion analysis is being developed in a GIS on the VT Advanced Research Computing and prior to implementation on VODC. A total of eight data sources will be fused to identify high-risk patches of wildland at the Landsat 30m ground sample distance. The final product will be a tool that will be tested and refined to automatically refresh when new data becomes available, allowing for new algorithm development, at which point it could be implemented in a production environment.

5 CONCLUSIONS AND NEXT STEPS

The UIX-Space Team has completed this first phase of work and has done the necessary due diligence to characterize important problems, identify the key stakeholders and their information needs and identify technical approaches for pilot projects to show the viability of our approach. The data-centric theme of UIX overlays all of these problems and represents a new paradigm for addressing problems in the Commonwealth. We intend to socialize our findings with our stakeholders and Virginia Government officials to take the next steps.

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Appendix A CONTACTS

A.1 COLLABORATORS

NAME	PHONE	EMAIL	ORGANIZATION NAME	TITLE/POSITION	QUALIFICATIONS/FOCUS AREAS
Dr. Piotr (Peter) Pachowicz	(703) 582-0638	ppach@gmu.edu	George Mason University (GMU)	Associate Professor, Electrical and Computer Engineering Dept.	Dr. Pachowicz helps with leading activities in CubeSats, SatCom, SpaceCom, and Intelligent Systems at the Volgenau School of Engineering as a Principal of the Space Systems Lab. CubeSat areas of interest include small-factor satellite bus design and engineering, resilient satellite architectures, rad-hard embedded software, and coordination in SmallSat mega-constellations for near real-time Earth observations and surveillance. Communications' interests orient toward practical aspects including design of low-noise RX antennas, signal and data fusion, signal intelligence, and custom hardware and software. Building GMU's CubeSat/ SatCom/SpaceCom infrastructure that will support data transmissions from spacecrafts on their flight to the moon, moon relays, stations, and landers, as well as Low Earth Orbit, Medium Earth Orbit, and Geostationary Orbit satellites.
Dr. Scott M. Bailey		baileys@exchange.vt.edu	Virginia Tech (VT)	Professor, Dept. of Electrical and Computer Engineering, and Director of the Center for Space Sciences and Engineering	Dr. Bailey is an expert in the use of space-based remote sensing systems for the probing of the Earth's atmosphere and to understand the impacts of solar variability and atmospheric coupling. Current leadership roles in satellite, sounding rocket, and balloon flight experiments for National Aeronautics and Space Administration (NASA).
Dr. Christopher Goyne	(434) 982-5355	goyne@virginia.edu	University of Virginia (UVA)	Associate Professor of Mechanical and Aerospace Engineering, and Director of the Aerospace Research Laboratory at UVA	Dr. Goyne has 25 years of research experience in aerospace engineering, including CubeSat development, high-speed propulsion, sensor development, and ground and flight testing of aerospace technology. Founded the UVA CubeSat Laboratory and was a co-I and technical lead for the Virginia CubeSat Constellation Mission. Published and presented his research through 150+ international journal articles, conference publications, patents, and reports and invited presentations. Associate Fellow of the American Institute of Aeronautics and Astronautics. Currently Chair of the Virginia Space Grant Consortium (VSGC) Advisory Council and

					member of the VSGC Small Sat Working Group. Serves on the Virginia Governor's Aerospace Advisory Council.
Dr. Jeffrey Fox	(434) 297-6093	jjf5x@virginia.edu	University of Virginia (UVA)	Director of Research Development	Dr. Jeff Fox is the Director of Research Development with the University of Virginia's School of Engineering and Applied Science. Jeff has been assisting the UVA Principal Investigator, Chris Goyne, on the UIX-Space project.
David Bowles		dbowles@odu.edu	Old Dominion University (ODU)	Executive Director, Virginia Institute for Spaceflight and Autonomy	Dr. David E. Bowles is the first Executive Director of the recently established Virginia Institute for Spaceflight and Autonomy (VISA) at ODU. Located on the Eastern Shore, VISA is chartered to grow the entrepreneurial ecosystems for spaceflight and autonomy in the Commonwealth through industry, academic and governmental partnerships, leveraging the expanding space facilities and growing capability to support advances in satellites and autonomous systems, the sensors they carry, and the data they produce. Prior to his appointment at ODU, Dr. Bowles was at NASA's Langley Research Center in Hampton, Virginia for 39 years, and served as Center Director from 2015 until his retirement in 2019. Dr. Bowles is active in the aerospace and local communities as an Associate Fellow of the American Institute for Aeronautics and Astronautics and currently serves on the Boards of the Eastern Shore Community College, the National Institute of Aerospace, the Virginia Unmanned Systems Center at Center for Innovate Technology (CIT), and the Virginia Aerospace Business Association.
Dr. Brentha Thurairajah	(540) 231-0656	brenthat@vt.edu	Virginia Tech (VT)	Research Scientist in the Center for Space Science and Engineering Research	Dr. Brentha Thurairajah is a research assistant professor at the Center for Space Science and Engineering at VT. Brentha's interests are remote sensing, data analysis, and modelling of the aeronomy of the middle and upper atmosphere, with an emphasis on understanding the dynamics of the whole atmosphere.
Dr. Jonathan Black	(540) 231-0037	jonathan.black@vt.edu	Virginia Tech (VT)	Professor Co-Director, Space@VT	Dr. Jonathan Black is a Professor in the Crofton Department of Aerospace and Ocean Engineering at VT, Co-Director of the Center for Space Science and Engineering Research (Space@VT), the Director of the Aerospace and Ocean Systems Laboratory within the Ted and Karyn Hume Center for National Security and Technology, and the Northrop Grumman Senior Faculty Fellow in C4ISR. Prior to joining VT, Dr. Black served as a faculty member in the Aeronautics and Astronautics department at the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, where he was the founding Director of the Center for Space

					Research and Assurance. Dr. Black's research interests include space and atmospheric vehicle dynamics, linear and nonlinear control theory, autonomous vehicle design, structures, structural dynamics, advanced sensing technologies, space systems engineering, and novel orbit analysis for a wide variety of military and intelligence applications including large lightweight space structures, micro Unmanned Aerial Vehicle (UAV) development, and task-able satellites.
Dr. Leon Harding	(540) 231-2928	lkharding@vt.edu	Virginia Tech (VT)	Research Associate Professor, Aerospace and Ocean Systems Lab	Dr. Leon Harding is a Research Associate Professor in the Ted and Karyn Hume Center for National Security and Technology and in the Center for Space Science and Engineering Research (Space@VT), at VT. Dr. Harding has a background in astronomy and astrophysics, as well as astronomical ground, airborne and space instrumentation, and spacecraft design, and pursues active research in these areas. Before VT, Dr. Harding was a Technologist in the NASA Jet Propulsion Laboratory (JPL) and remains a JPL Affiliate as part of the NASA Roman Space Telescope program.

Afroze Mohammed	571-858-3007	afroze@vt.edu	Virginia Tech (VT)	Associate Director for Strategic Alliances, Office of Economic Development	Afroze Mohammed is Associate Director of Strategic Alliances and based at the Virginia Tech Research Center in Arlington. Her role focuses on building strong partnerships between Virginia Tech and companies in metropolitan Washington, D.C., with the goal of fostering greater collaboration in research endeavors, entrepreneurial activities, and economic development. Afroze is active in economic development and industry groups in the National Capital Region. Afroze works closely with the Virginia Tech's Space@VT center and is responsible for organizing Virginia Tech's involvement in the MITRE University Innovation Exchange (UIX). She helped shape the UIX for Space initiative.
Mary Sandy	(757) 868-7602	msandy@odu.edu	Virginia Space Grant Consortium	Director	Mary Sandy is Director of the Virginia Space Grant Consortium, a consortium of NASA Centers, Virginia universities, state agencies and other organizations with an interest in Aerospace and related STEM fields. VSGC manages state, regional and national programs and partnerships related to Aerospace and STEM education, workforce development and research. She has more than 40 years experience in managing programs in the aerospace sector. Sandy previously served as NASA's Public Affairs Officer for Aeronautics and Space Technology at NASA Headquarters and as the Head of the Office of Public Services at NASA Langley Research Center.

A.2 ATTENDEES FROM WEBINARS

NAME	ORGANIZATION NAME	WEBINAR ATTENDED
Afroze Mohammed	VT	Solar, Transportation, River Health
Anastosios Golnas	Department of Energy	Solar
Andre Eanes	Secure Futures	Solar
Andy Alden	VT Transportation Institute	Transportation
Anne Philips	Commonwealth of VA Special Asst. Resilience	Flooding
Ashley Gordon	Hampton Roads Planning District Commission (HRPDC)	Flooding
Ben McFarland	HRPDC	Flooding
Brentha Thurairajah	VT	River Health
Carlos Rivero	VA State Government	Wildfire Prevention
Cathy Pennington	MITRE	Solar
Chris Carter	VSGC	Transportation, River Health
Chris Goyne	UVA	Solar, Transportation, Flooding
Chris Hill	MITRE	Transportation
Cindy J	VEDEQ	River Health
Cully Hession	VT	River Health
Daniel Boudreau	RISE +	Flooding
Daniel McLaughlin	VT	River Health
David Borges	NASA	Flooding
David Bowles	ODU, VISA	Solar
David Fritz	MITRE	Solar
David Ihrie	CIT	Solar, Wildfire Prevention

Debra Zides	MITRE	Solar, Transportation, River Health, Flooding, Wildfire Prevention
Doug Marcy	NOAA	Flooding
Durelle Scott	VT	River Health
Elsa Katz	World Bank	Solar
Erin Sutton	City of Virginia Beach Emergency Management	Flooding
Giovanna Casalino	MITRE	Transportation, River Health, Wildfire Prevention
Halea Fowler	VT	River Health
Hosein Foroutan	VT	Wildfire Prevention
Ian Kelley	VT	River Health
Ilkay Altintas	University of California San Diego	Wildfire Prevention
James Beckley	Addison-Evans WP & Lab Facility	River Health
Jane Walker	VT	River Health
Jeff Fox	UVA	Transportation, River Health, Wildfire Prevention
Jeff Orrock	National Weather Service - WFO	Flooding
Jennifer Whytlaw	ODU	Flooding
Jerree Grimes	Joint Base Eustis-Langley (JBEL)	Flooding
John Bateman	Northern Neck Planning District Commission	Flooding
Jon Goodall	UVA	Flooding
Jonathan Black	VT	Wildfire Prevention
Julian Hoffman	MITRE	Transportation
Kate Berman	MITRE	Transportation
Katharine Bond	Dominion Energy	Solar
Keith Vangraafeiland	ESRI	Flooding
Kelly Wilson	ODU	River Health
Ken Jurman	DMME.virginia.gov	Solar
Kenton Ross	NASA Development	Wildfire Prevention
Kevin McGuire	VT	River Health

Kevin Sterne	VT	Wildfire Prevention
Kyle Spencer	City of Norfolk Resilience	Flooding
Larry Goldstein	Transportation Research Board, NAS	Transportation
Laura McKay	DEQ	River Health
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Leon Harding	VT	Wildfire Prevention
Liling Huang	GMU	Solar
Loretta Keleman	NASA Langley Ops	Flooding
Louise Salinas	ODU	Wildfire Prevention
Manoo Shirzaei	VT	River Health, Wildfire Prevention
Mary Carson Stiff	Wetlands Watch	Flooding
Mary Sandy	VSGC	Solar, Transportation, River Health ,Flooding
Michael Balazs	MITRE	River Health
Michael Recchia	MITRE	Solar
Mike Dutter	National Weather Service - WFO	Flooding
Mohamadreza Banihashemi	FHWA (Federal Highway Administration), Turner-Fairbank Highway Research Center	Transportation
Nathaniel Wright	VT	Wildfire Prevention
Navid Tahvildari	ODFU	Flooding
Nicholas McLoota	MITRE	Wildfire Prevention
Olivia Blackmon	MITRE	Solar, Transportation, River Health
Paul Robinson	Rise Resilience	Flooding
Pavle Bujanovic	FHWA, Turner-Fairbank Highway Research Center	Transportation
Peter Sforza	VT	Wildfire Prevention
Piotr Pachowicz	GMU	Solar, Wildfire Prevention
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Rebecca Unruh	National Park Service	Wildfire Prevention

Reilly Henson	VT	Wildfire Prevention
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Rob Case	MITRE	River Health
Robbie Coates	Va. Dept of Emergency Mgt.	Flooding
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Robert Weiss	VT	Flooding
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Vickie Connors	VCU	River Health
Whitney Katchmark	Hampton Roads Planning District Commission	Flooding
Yang Shao	VT	Flooding

Appendix B ABBREVIATIONS AND ACRONYMS

Term	Definition
CIT	Center for Innovate Technology
DLS	drone-based laser scanning
EO	Earth orbit
FHWA	Federal Highway Administration
FSI	Fire Susceptibility Index
GIS	Geographic Information System
GMU	George Mason University
GW	gigawatt
HRPDC	Hampton Roads Planning District Commission
ITK	Innovation Toolkit
JLUS	Joint Land Use Study
LIDAR	Light Detection and Ranging
MDE	Major Design Experience
MODIS	Moderate Resolution Imaging Spectroradiometer
MW	megawatt
NASA	National Aeronautics and Space Administration
NFDRS	National Fire Danger Rating System
NOAA	National Oceanic and Atmospheric Administration
NOVEC	Northern Virginia Electric Cooperative
ODU	Old Dominion University
PDC	Planning District Commission
POC	Point of Contact
SAR	Specific Absorption Rate
SfM	structure-from-motion
SME	subject matter expert
UAS	Unmanned Aerial System
sUAS	Small Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UIX	University Innovation Exchange
USGS	United States Geological Survey
UVA	University of Virginia
VIMS	Virginia Institute for Marine Science

VISA	Virginia Institute for Spaceflight and Autonomy
VODC	Virginia Open Data Cube
VSCG	Virginia Space Grant Consortium
VT	Virginia Tech
WUI	Wilderness urban interface

Appendix C POST WORKSHOP REPORTS

C.1 SOLAR POWER GENERATION EFFICIENCY

Post Workshop Report

9/17/2020

Improving Solar Power Efficiency and Stability Workshop

MITRE-UIX Space

Peter W. Pachowicz (ppach@gmu.edu)

GMU

A workshop on Improving Solar Power Efficiency and Stability was held on September 10, 2020 in an on-line format. The workshop was organized under MITRE-UIX Space initiative (University Innovation Exchange - UIX) involving MITRE, four universities in Virginia (GMU, ODU, UVA, VT), and VSGC. There were 29 participants representing federal and state governments, industry, non-profit organizations, and academia.

The MITRE-UIX initiative aims at solving several larger-scale problems typical for the Commonwealth of Virginia, utilizing data-centric approach, human assets, and an infrastructure investment that is already in place. The workshop goal was to discuss and identify the most important aspects that will contribute to the efficiency improvement of solar power generation and demand management.

Workshop agenda included: Welcome and roll call, Introduction, Problem framing, Brainstorming session, Prioritizing session, and Wrap-up. Scott Kordella, Director of Space Systems at MITRE, moderated the workshop. The workshop began with a welcome, roll call, and an introduction to MITRE-UIX initiative by Scott Kordella. Peter Pachowicz, Associate Professor at George Mason University, followed with an introduction to selected problem areas of solar energy generation and demand management exploiting existing space assets, ground sensor networks, data fusion, data-centric analysis, and predictive decision support. Potential financial and environmental benefits were introduced as well. Deb Zides, Principal Program Manager at MITRE, led the participants through the MITRE Ideation Process. The goals of this process were (1) to identify key problems within the area of solar energy and (2) to prioritize the targeted problems for research and development. This discussion involved all workshop participants and resulted in developed workshop materials for further analysis and guidance toward future projects. The workshop was wrapped up with a thank-you and concluding statements given by Scott Kordella and Peter Pachowicz.

At first, the group discussion formulated a list of problem statements as perceived from a stakeholder perspective. The list includes 22 entries listed below:

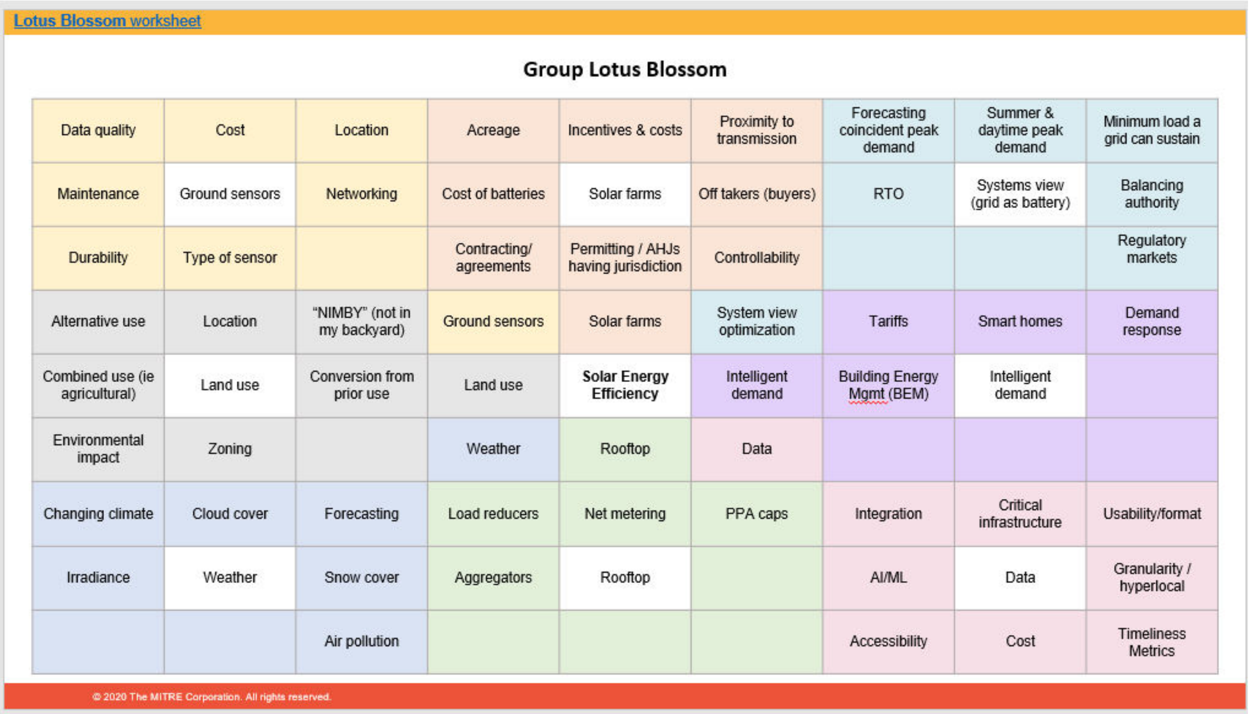
1. Higher degree of electric grid stability relies on proactive planning and stable energy sources.
2. This planning influences grid configuration for specific time intervals.
3. Renewables such solar are inherently unstable – depend on ever changing cloud cover.
4. Solar farms cannot guarantee that the level of energy generated will be constant throughout longer periods of time.
5. Efficiency of solar energy generation and stability of the power grid.
6. Intelligent demand adjustment for energy.

7. Cannot tell a solar farm to deliver x amount of power at a certain time (like other utilities).
8. Demand is variable (time of day, season, etc.).
9. Power is variable (random nature of clouds, time of day, etc.).
10. Batteries are expensive (but getting cheaper).
11. Cannot treat solar as dispensable today because scheduling is not ready.
12. Need to take a "systems" view to optimize – opportunity to reconceptualize role of the grid as "battery"
13. Systems view for climate trend impacts (trends – precipitation levels), historical trends.
14. Improved understanding of cloud cover could improve grid (as a battery) – cloudy = less peak demand at customer level (correlation – data could be brought into the data cube).
15. Daytime summer hours – peak typically.
16. Peak demand $ carried over for ~ 11 months due to intervals (cost to end users).
17. Land use – how much acreage required? Land attributes (location, ideal weather conditions).
18. Correctly forecasting solar – so few ground sensors available/accessible to enable projecting demands/peaks/etc.
19. No government's policy to ensure sensors (radiance data) installed w/rooftop solar panel systems (NY has a micro network that VA may be able to replicate?).
20. Ground sensors require significant maintenance (cost $) today.
21. Quality data is expensive (acquisition & sustainment).
22. Revenue model impacts.

Next, the group defined an extended list of potential stakeholders which include:

- Energy production and transmission companies (utilities)
- Building management
- Local demand planners
- Balancing authorities (entities generation & demand)
- Utility companies
- Solar developers
- Commercial customers (peak demand shaving)
- End users especially with tariff impact (commercial entities - universities/hospitals/etc.)
- Technical subject matter experts (SMEs)
- State Clean energy goal POCs (100 percent clean-energy economy)
- Meteorologists
- National Weather Service/NOAA model POCs
- Owners/investors of solar farms

Problem framing was followed by defining most critical areas of solar energy efficiency. These areas are color coded on Figure C-1 **Error! Reference source not found.**and include Ground sensors, Solar farms, System view optimization, Intelligent demand, Data, Rooftop, Weather, and Land use. More detailed analysis within each area was developed.



Lotus Blossom worksheet

Group Lotus Blossom

Data quality	Cost	Location	Acreage	Incentives & costs	Proximity to transmission	Forecasting coincident peak demand	Summer & daytime peak demand	Minimum load a grid can sustain
Maintenance	Ground sensors	Networking	Cost of batteries	Solar farms	Off takers (buyers)	RTO	Systems view (grid as battery)	Balancing authority
Durability	Type of sensor		Contracting/ agreements	Permitting / AHJs having jurisdiction	Controllability			Regulatory markets
Alternative use	Location	"NIMBY" (not in my backyard)	Ground sensors	Solar farms	System view optimization	Tariffs	Smart homes	Demand response
Combined use (ie agricultural)	Land use	Conversion from prior use	Land use	**Solar Energy Efficiency**	Intelligent demand	Building Energy Mgmt (BEM)	Intelligent demand	
Environmental impact	Zoning		Weather	Rooftop	Data			
Changing climate	Cloud cover	Forecasting	Load reducers	Net metering	PPA caps	Integration	Critical infrastructure	Usability/format
Irradiance	Weather	Snow cover	Aggregators	Rooftop		AI/ML	Data	Granularity / hyperlocal
		Air pollution				Accessibility	Cost	Timeliness Metrics

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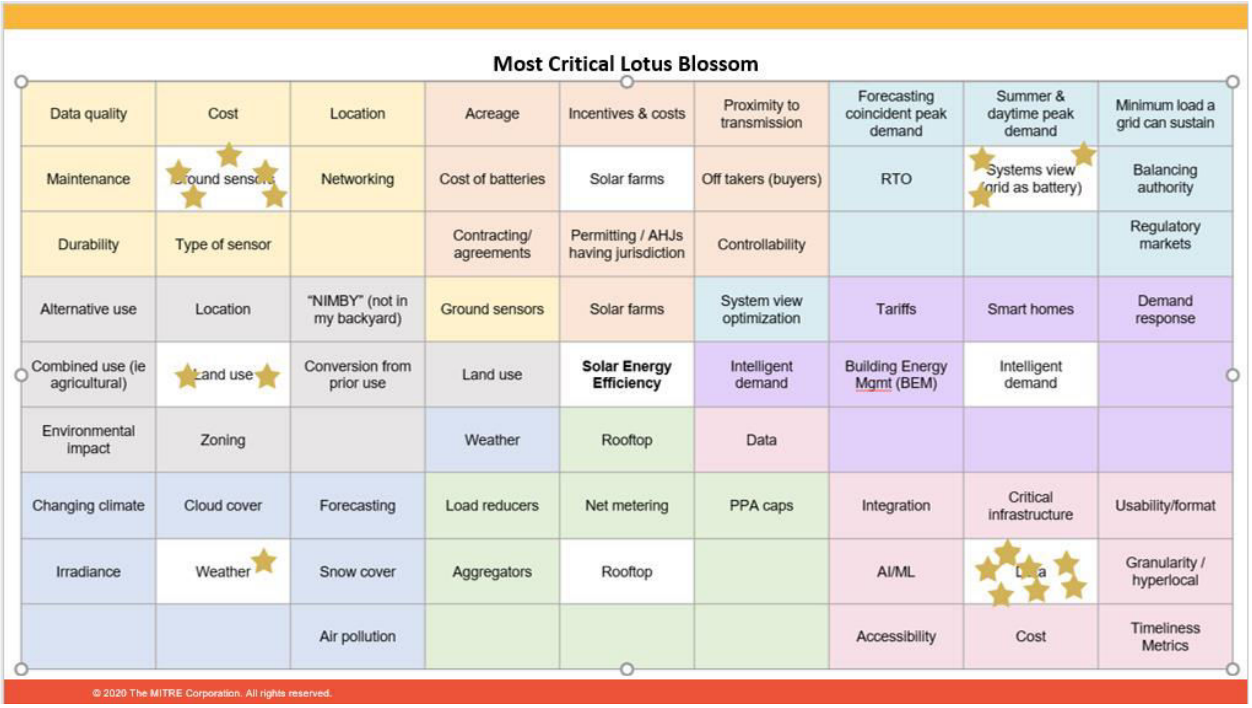
Figure C-1. Developed Problem Framing Canvas for Increasing Efficiency of Solar Energy



Most Critical Lotus Blossom

Data quality	Cost	Location	Acreage	Incentives & costs	Proximity to transmission	Forecasting coincident peak demand	Summer & daytime peak demand	Minimum load a grid can sustain
Maintenance	Ground sensors ★★★★★	Networking	Cost of batteries	Solar farms	Off takers (buyers)	RTO	Systems view (grid as battery) ★★★	Balancing authority
Durability	Type of sensor		Contracting/ agreements	Permitting / AHJs having jurisdiction	Controllability			Regulatory markets
Alternative use	Location	"NIMBY" (not in my backyard)	Ground sensors	Solar farms	System view optimization	Tariffs	Smart homes	Demand response
Combined use (ie agricultural)	Land use ★★	Conversion from prior use	Land use	**Solar Energy Efficiency**	Intelligent demand	Building Energy Mgmt (BEM)	Intelligent demand	
Environmental impact	Zoning		Weather	Rooftop	Data			
Changing climate	Cloud cover	Forecasting	Load reducers	Net metering	PPA caps	Integration	Critical infrastructure	Usability/format
Irradiance	Weather ★	Snow cover	Aggregators	Rooftop		AI/ML	Data ★★★★★★	Granularity / hyperlocal
		Air pollution				Accessibility	Cost	Timeliness Metrics

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Figure C-2. Results of the "Most Critical" Problem Framing Canvas with Voting Results

The group followed with a vote to identify priorities. Results of voting are showed in Figure C-2 and Figure C-3. In the "Most Critical" category (Fig. C-2), participants highlighted a need to address (1) availability and processing of data, (2) availability of ground sensor network providing quality data, and (3) a system view focused on the prediction of peak power demand. In the category of "Most Likely" to be solved within a shorter period of time (Fig. C-3) the group highlighted (1) availability and processing of data, (2) improvement in weather forecast, and (3) availability of ground sensor network providing quality data.

Most Likely Lotus Blossom

Data quality	Cost	Location	Acreage	Incentives & costs	Proximity to transmission	Forecasting coincident peak demand	Summer & daytime peak demand	Minimum load a grid can sustain
Maintenance	Ground sensors	Networking	Cost of batteries	Solar farms	Off takers (buyers)	RTO	Systems view (grid as battery)	Balancing authority
Durability	Type of sensor		Contracting/ agreements	Permitting / AHJs having jurisdiction	Controllability			Regulatory markets
Alternative use	Location	"NIMBY" (not in my backyard)	Ground sensors	Solar farms	System view optimization	Tariffs	Smart homes	Demand response
Combined use (ie agricultural)	Land use	Conversion from prior use	Land use	**Solar Energy Efficiency**	Intelligent demand	Building Energy Mgmt (BEM)	Intelligent demand	
Environmental impact	Zoning		Weather	Rooftop	Data			
Changing climate	Cloud cover	Forecasting	Load reducers	Net metering	PPA caps	Integration	Critical infrastructure	Usability/format
Irradiance	Weather	Snow cover	Aggregators	Rooftop		AI/ML	Data	Granularity / hyperlocal
		Air pollution				Accessibility	Cost	Timeliness Metrics

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Figure C-3. Results of the "Most Likely" Problem Framing Canvas with Voting Results

Table C-1. Summary of voting results

	SUBPROBLEM	VOTES ON "MOST CRITICAL" TO BE SOLVED	VOTES ON "MOST LIKELY" TO BE SOLVED
1	Availability and processing of data	7	8
2	Availability of ground sensor network providing quality data	5	3
3	Improvement in weather forecast	1	4
4	A system view focused on the prediction of peak power demand	3	1

Table C-1 shows a summary of voting results. It is very interesting to note that the first two subproblems strongly relate to each other. Hence, the availability and processing of data, in practice, includes the availability of ground sensor network in addition to satellite images; they both influence the improvement of weather prediction. It is also important to note there is a growing interest in a secondary application: the prediction of peak power demand, where substantial savings can be reach for energy customers.

Conclusions: The workshop provided very valuable feedback. Based on discussions and the voting results, the data-centric approach to the increase in efficiency of solar power generation has been identified as the important area for applied research resulting in imminent results. In addition to solar power generation, the prediction of peak power demand has been identified as the dual use of this data-centric approach with the use of the same data products and analytical tools.

C.2 TRANSPORTATION EFFICIENCY

Post Workshop Report

9/3/20

Improving Transportation Efficiency Workshop

MITRE UIX-Space

C.P. Goyne (goyne@virginia.edu)

UVA

A workshop on Improving Transportation Efficiency was held on August 20, 2020, 10:00 am – 12:30 pm, and was hosted by MITRE and the UVA as part of the MITRE – Virginia UIX, Virginia UIX Space Initiative. There were 25 participants present at the workshop that represented eight organizations (MITRE, UVA, VT, ODU, GMU, Virginia Transportation Research Council, VSGC, Federal Highway Administration, and National Academy of Sciences). The workshop goals were to "conduct a structured brainstorming discussion around important problems in Virginia with stakeholders" and to examine, with respect to transportation efficiency, "what is being done now, what needs to be done to improve the outcomes, and what are the opportunities to leverage the UIX-Space vision."[5]

The agenda began with a welcome and roll call by Scott Kordella, Director of Space Systems, MITRE; an agenda review by Chris Goyne, Associate Professor of Mechanical and Aerospace Engineering, UVA; an overview of the Virginia UIX-Space Initiative by Scott Kordella; and an introduction to Improving Transportation Efficiency by Chris Goyne. Deb Zides, Principal Program Manager, MITRE, then led the group through the MITRE Ideation Process. The meeting wrapped up with a thank-you and concluding statements from Scott Kordella and Chris Goyne.

Leading up to the event, the workshop organizer, Chris Goyne, undertook a process of initial problem refinement and solution formulation, to develop a scope for the workshop. This included initial engagement with transportation SMEs at the UVA, ODU, and Virginia Transportation Research Council. This initial engagement identified two transportation problems related to traffic operations and one related to infrastructure. These problems included 1) real-time weather data to improve roadway safety, 2) emergency incident management and unscheduled maintenance monitoring via air- and space-based platforms, and 3) remote-sensing-enhanced non-destructive evaluation of roadway infrastructure. The purpose of the workshop was to use MITRE's Innovation Toolkit (ITK) ideation process to examine these problems further and identify additional problems through group exercises in problem framing, brainstorming, and consensus building.

After considerable discussion and deliberation that was guided by the MITRE ITK Problem Framing Canvas (see **Error! Reference source not found.**), the group agreed on the following problem statement:

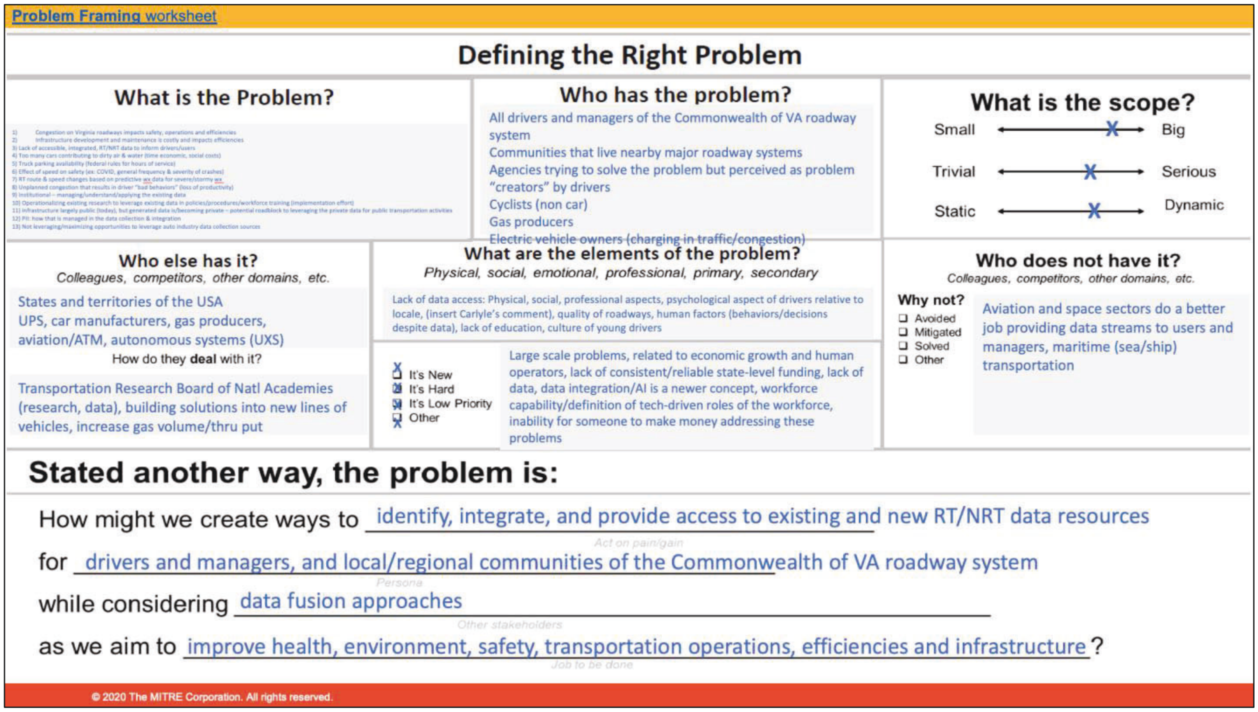
How might we create ways to identify, integrate, and provide access to existing and new real-time and near-real-time data resources for roadway system users and managers, and local and regional communities within the Commonwealth of VA, while considering data fusion approaches, as we aim to improve health, environment and safety, and transportation operation, efficiency, and infrastructure.

---

[5] "Virginia UIX-Space Initiative Overview" slides, Improving Transportation Efficiency Workshop, MITRE UIX-Space, August 20, 2020.

The participants identified a total of 12 subproblems that fall under this problem statement. They are listed in the "What is the Problem" window in the Problem Framing Canvas in Figure C-1 and are repeated here:

1. Congestion on Virginia roadways impacts safety, operations, and efficiencies.
2. Infrastructure development and maintenance is costly and impacts efficiencies.
3. Lack of accessible, integrated, real-time and near-real-time data to inform drivers/users.
4. Too many cars contributing to dirty air and water (time economic, social costs).
5. Truck parking availability (federal rules for hours of service).
6. Effect of speed on safety (e.g., COVID-19, general frequency and severity of crashes).
7. Real-time route and speed changes based on predictive weather data for severe/stormy weather.
8. Unplanned congestion that results in driver "bad behaviors" (loss of productivity).
9. Institutional (connecting data analytics and the organizational response), managing/understand/applying the existing data.
10. Operationalizing existing research to leverage existing data in policies/procedures/workforce training (implementation effort).
11. Infrastructure largely public (today), but generated data is/becoming private – potential roadblock to leveraging the private data for public transportation activities, how that is managed in the data collection and integration?
12. Not maximizing opportunities to leverage auto industry data collection sources.



Problem Framing worksheet

Defining the Right Problem

What is the Problem?

1) Congestion on Virginia roadways impacts safety, operations and efficiencies
2) Infrastructure development and maintenance is costly and impacts efficiencies
3) Lack of accessible, integrated, RT/NRT data to inform drivers/users
4) Too many cars contributing to dirty air & water (time economic, social costs)
5) Truck parking availability (federal rules for hours of service)
6) Effect of speed on safety (ex: COVID, general frequency & severity of crashes)
7) RT route & speed changes based on predictive wx data for severe/stormy wx
8) Unplanned congestion that results in driver "bad behaviors" (loss of productivity)
9) Institutional – managing/understand/applying the existing data
10) Operationalizing existing research to leverage existing data in policies/procedures/workforce training (implementation effort)
11) Infrastructure largely public (today), but generated data is/becoming private – potential roadblock to leveraging the private data for public transportation activities
12) PII: how that is managed in the data collection & integration
13) Not leveraging/maximizing opportunities to leverage auto industry data collection sources

Who has the problem?

All drivers and managers of the Commonwealth of VA roadway system
Communities that live nearby major roadway systems
Agencies trying to solve the problem but perceived as problem "creators" by drivers
Cyclists (non car)
Gas producers
Electric vehicle owners (charging in traffic/congestion)

What is the scope?

Small ←——X—→ Big
Trivial ←——X——→ Serious
Static ←——X——→ Dynamic

Who else has it?
Colleagues, competitors, other domains, etc.

States and territories of the USA
UPS, car manufacturers, gas producers, aviation/ATM, autonomous systems (UXS)

How do they **deal** with it?

Transportation Research Board of Natl Academies (research, data), building solutions into new lines of vehicles, increase gas volume/thru put

What are the elements of the problem?
Physical, social, emotional, professional, primary, secondary

Lack of data access: Physical, social, professional aspects, psychological aspect of drivers relative to locale, (insert Carlyle's comment), quality of roadways, human factors (behaviors/decisions despite data), lack of education, culture of young drivers

☒ It's New
☒ It's Hard
☒ It's Low Priority
☒ Other

Large scale problems, related to economic growth and human operators, lack of consistent/reliable state-level funding, lack of data, data integration/AI is a newer concept, workforce capability/definition of tech-driven roles of the workforce, inability for someone to make money addressing these problems

Who does not have it?
Colleagues, competitors, other domains, etc.

Why not?
☐ Avoided
☐ Mitigated
☐ Solved
☐ Other

Aviation and space sectors do a better job providing data streams to users and managers, maritime (sea/ship) transportation

Stated another way, the problem is:

How might we create ways to identify, integrate, and provide access to existing and new RT/NRT data resources
Act on pain/gain
for drivers and managers, and local/regional communities of the Commonwealth of VA roadway system
Persona
while considering data fusion approaches
Other stakeholders
as we aim to improve health, environment, safety, transportation operations, efficiencies and infrastructure?
Job to be done

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Figure C-4. Completed Problem Framing Canvas from the MITRE UIX-Space Improving Transportation Efficiency Workshop

The Problem framing activity was followed by a Clarity of Ideas structured brainstorming session to enable the group of participants to examine a subset of the above 12 subproblems. This process used the MITRE ITK Lotus Blossom Canvas as the focal point for the discussion and the completed canvas is shown in Figure C-5. This canvas was then used to develop a consensus on prioritization of opportunities. The consensus was developed through group votes on problems that were considered the most critical and problems that were considered the most feasible, and the most likely, to be solved. The results of the Lotus Blossom Canvas voting by the group, together with the identified priorities of the subproblems, are shown in Table C-2.

Non-standardized data formats	Integration into backend platform	Modularity (MOSA)	Resolution/scale	Image processing from existing sources	AI (artificial intelligence) applicability	Truck crash & clearing sites quickly	Prestaging drones on-site & livestream back to ops centers	Drone policies limit overflight access
Human factors	**RT weather data stream**	Leverage existing wx data platforms (apps)		**Infrastructure non destructive eval (NDE)**		How to use/integrate existing land-based sensors	**Unscheduled MX & incident mgmt**	Feedback/lessons learned from past data to enable advisories
actionable	Data fusion w/disparate data sources	Surface temperature application				Data prediction	How to leverage data to predict & respond faster	
Remote sensing using commercial imaging update timelines	Cloud cover	Ie, Sentinal 2B (non-visual imagery)	**RT weather data stream**	**Infrastructure non destructive eval (NDE)**	**Unscheduled MX & incident mgmt**	Open data sources	private	public
	Truck tracking & parking mgmt	Remote sensing (Look at where trucks are parking illegally today) to determine new parking requirements	**Truck tracking & parking mgmt**	**ID, integrate, access to RT/NRT data resources**	**Data source**	vehicles	**Data source**	UAV
	CVO system integration for truck drivers	Training drivers to share information	**Policies**	**User (UX)**	**Data access**	Resolution/scale of data sources	Commercial satellite imagery	Predictive analytics sources
policies	procedures	Workforce	Human factors	Education & driving culture		Architecture	infrastructure	PII
Liability, laws	**Policies**			**User (UX)**		Fusing sources	**Data access**	Access to gov't data sources
						Data use agreements between platforms	Data size (bandwidth for access)	

Figure C-5. Completed Lotus Blossom Canvas from Clarity of Ideas Brainstorming session of the MITRE UIX-Space Improving Transportation Efficiency Workshop

Table C-2. Consensus of the MITRE UIX-Space Improving Transportation Efficiency Workshop participants as indicated by votes on subproblems identified in the completed Lotus Blossom Canvas

PRIORITY	SUBPROBLEM	VOTES ON MOST CRITICAL PROBLEM	VOTES ON MOST FEASIBLE/LIKELY TO BE SOLVED
1	Real-time weather data to improve roadway safety	5	6
2	Remote-sensing-enhanced non-destructive evaluation of roadway infrastructure	3	1
3	Effective use and interpretation of multiple data sources using open data and predictive analytics. Developed to connect analytics and the organizational response.	2	3
4	Management and tracking of truck parking	1	0
5	Emergency incident management and unscheduled maintenance monitoring via air- and space-based platforms	0	2

Error! Reference source not found. depicts that five subproblems received votes on being critical and feasible in terms of being solved. While each subproblem is important in its own way, the subproblem of real-time weather data to improve roadway safety is deemed as Priority #1, as it was viewed as the most critical and the most likely to be solved. The number of votes for this subproblem were significantly higher than the others for both vote categories.

To provide more detail on the solution to this weather related problem, it was proposed during the workshop that by combining real-time weather products from NOAA (Doppler radar, Goes-R, land-based weather stations) with real-time traffic reporting (Waze, INRIX, Google Traffic, etc.) and roadway condition information (Virginia Department of Transportation weather stations and traffic cameras), drivers could be more informed about road conditions so as to choose an alternate route or adapt their driving style for the expected conditions ahead. Real-time advisories, independent of in-person roadway observations, could be provided in relation to roadway impacts of rain, flooding, wind, snow, ice, and fog. The satellite navigation devices could also provide speed and vehicle separation recommendations based on anticipated traffic and roadway surface conditions ahead. By providing drivers (and automated vehicles) with an additional data stream, the safety of our roadways could be improved.

Given the results of the workshop, the issue of real-time weather data to improve roadway safety will be the focus of the MITRE UIX-Space Initiative for transportation efficiency. Therefore, based on the results summarized in this report:

The primary recommendation from the MITRE UIX-Space transportation workshop is the establishment of a pilot project to demonstrate the feasibility of real-time weather data to improve roadway safety in the Commonwealth of Virginia.

This pilot will serve as a capability demonstration in preparation for a larger research and development program.

The following post-workshop action items are pending or have been completed to advance this new focal issue:

1. Thank you email sent to workshop participants (completed)
2. Share summary of workshop results with workshop participants (via this document)
3. Continue engagement with key stakeholders to seek support and advocacy
4. Engage with MITRE and UIX-Space team to plan next steps
5. Develop structure for a suitable pilot project to demonstrate feasibility of real-time weather data project
6. Seek sponsor funding to support solution execution for real-time weather data project

C.3 FLOODING PREDICTION AND RESPONSE MONITORING

Post Workshop Report

September 10, 2020

MITRE UIX-Space Initiative

Tom Allen (tallen@odu.edu)

Emily Steinhilber (esteinhi@odu.edu)

David Bowles (dbowles@odu.edu)

ODU

The workshop on *Flooding Prediction, Response, and Recovery*[1] was held on August 27, 2020, 9:00 am – 12:00 pm via ZoomGov, and was hosted by MITRE and Old Dominion University and the Virginia Institute for Space Flight Autonomy as part of the MITRE – Virginia UIX, Virginia UIX Space Initiative. Forty-one participants attended from over 20 organizations including MITRE, ODU, UVA, VT, Virginia Institute for Marine Science (VIMS), GMU, VSGC, Virginia Department of Emergency Management (VDEM), the Office of the Governor, NASA, Joint Base Eustis-Langley, City of Virginia Beach, Hampton Roads Planning District Commission (PDC), Northern Neck PDC, Accomack County, NOAA OCM, NOAA NWS, RISE, Wetlands Watch, GZA RISE Team, FloodMapp RISE Team, and Esri.

The workshop goals were to "conduct a structured brainstorming discussion around important problems in Virginia with stakeholders" and to examine, with respect to transportation efficiency "what is being done now, what needs to be done to improve the outcomes, and what are the opportunities to leverage the UIX-Space vision."[6]

The agenda kicked off with a welcome and roll call by Scott Kordella, Director of Space Systems, MITRE; an agenda review by Tom Allen, Professor of Geography, ODU; and the scope and process for the workshop ideation process led by Deb Zides, Principal Program Manager, MITRE. The bulk of the workshop focused on defining the problem, identifying stakeholders, and beginning a process for solutions to develop. The meeting wrapped up with a thank-you and concluding statements from Scott Kordella, Tom Allen, and David Bowles.

Leading up to the event, the workshop conveners, Tom Allen, Emily Steinhilber, and David Bowles, undertook a process of initial problem definition, refinement, and solution formulation, to frame the discussion. Planning discussions of the organizing team, select key stakeholders, and MITRE developed and refined a list of potential attendees. This initial preparation also identified two coastal flooding problems related to flood emergency management (i.e., preparedness and response focus) and one related to hazard resilience (mitigation and recovery). These facets of the coastal flooding problem were captured in a provisional problem framing statement. The workshop participants next followed the MITRE ideation tools process to examine these problems further and identify additional problems through group exercises in problem framing, brainstorming, and consensus building.

Problem Ideation and Ownership

After considerable discussion and deliberation that was guided by the MITRE Problem Framing Canvas (**Error! Reference source not found.**), the group agreed on the following problem statement:

> *How might we create ways to improve data/data access in order to better predict, respond, and address risk (mitigate, minimize), and adapt to impacts of flooding for local government/community, emergency managers, and planners while considering residents, urban-regional planning, public health, business enterprises, and citizens as we aim to reduce risk and improve resilience to flood events with sea level rise and climate change?*

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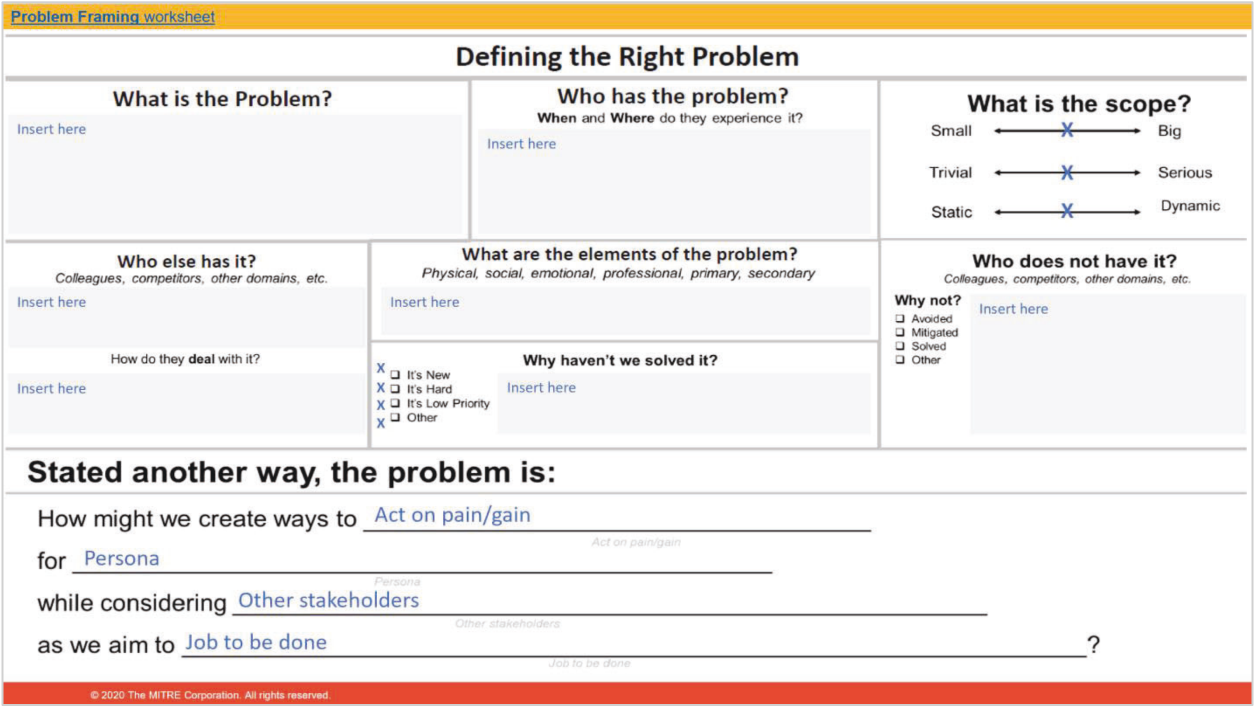
[6] "Virginia UIX-Space Initiative Overview" slides, Flooding Prediction, Response and Recovery, MITRE UIX-Space, August 27, 2020.



Problem Framing worksheet

Defining the Right Problem

What is the Problem?
Insert here

Who has the problem?
When and **Where** do they experience it?
Insert here

What is the scope?
Small ←—X—→ Big
Trivial ←—X—→ Serious
Static ←—X—→ Dynamic

Who else has it?
Colleagues, competitors, other domains, etc.
Insert here
How do they **deal** with it?
Insert here

What are the elements of the problem?
Physical, social, emotional, professional, primary, secondary
Insert here

Why haven't we solved it?
X ☐ It's New
X ☐ It's Hard
X ☐ It's Low Priority
X ☐ Other
Insert here

Who does not have it?
Colleagues, competitors, other domains, etc.
Why not?
☐ Avoided
☐ Mitigated
☐ Solved
☐ Other
Insert here

Stated another way, the problem is:

How might we create ways to Act on pain/gain (Act on pain/gain)
for Persona (Persona)
while considering Other stakeholders (Other stakeholders)
as we aim to Job to be done (Job to be done)?

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Figure C-6. The Problem Framing Canvas ideation tool from the MITRE UIX-Space Flooding Prediction, Response, and Recovery Workshop used to frame/refine the problem and stakeholders

The participants identified a total of 20 subproblems that fall under this problem statement. This long list was drawn from tabulation in the "*What is the Problem*" window of the Problem Framing Canvas in Figure C-6 and are repeated here:

1. Pre-flood damage estimates are needed for preparing response, evacuation, and recovery.
2. During and after a flood event, what has flooded, what roads are impassable, and what damages incurred?
3. How much debris has been generated? Pollution released? Or public health risks arisen?
4. Lack of modeling: combine flooding sources/joint flooding modeling prediction; extreme rainfall, riverine influences, etc. causing the overall picture (land use, precipitation, sea rise, etc.) – future water level predictions, etc.
5. Hyper-local weather.
6. Flooding in Hampton Roads; modeling data lacking; not uniform; hydrologic activity, infrastructure impacts on flooding (traffic backup, facility damage).
7. Compound flooding – combined rainfall/coastal flooding/riverine (NOAA National Weather Service model); shortcomings in the coastal zone for very heavy rainfall – rainfall prediction critical; resolution temporal/spatial scale; "hindcast" better – but need the data for forecast.
8. Hazard characterization (above); information flow, communication, what other relevant activities on-going (i.e., the other additional elements).
9. Limitations w/data – who and what are at risk; not having the underlying attributes (i.e., high-wind damage).

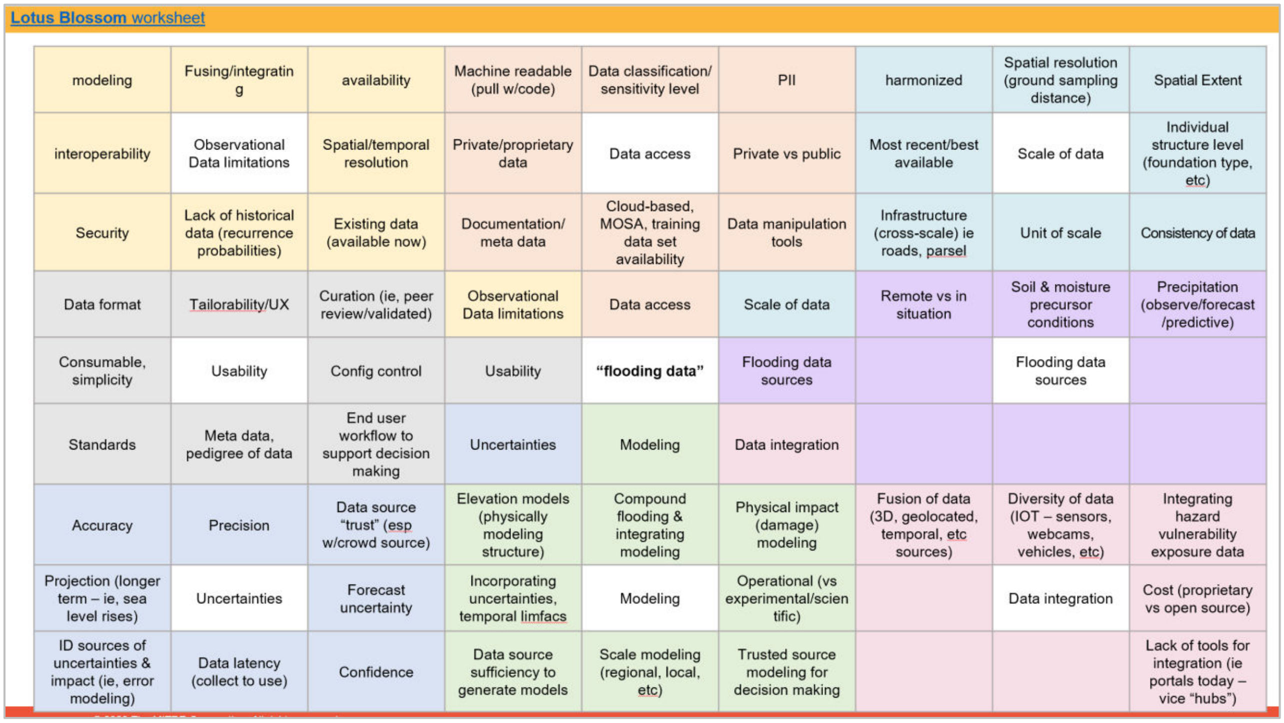
10. At risk/vulnerable populations & structures – need to have more data for those.
11. Need somewhere for the storm water to go – where is that water going to be stored in the system?
12. Real-time monitoring/control to get most capacity out of existing structure.
13. Long-term temporal aspect needs to take into consideration (not fighting the same battle over & over) – what those future impacts will be to enable long-term resilience.
14. Extreme events (flooding/damage/hurricanes): quantification of damage to structure/infrastructure; especially in urban settings need to take into account build-up topography in urban settings to better quantify damages (modeling using bare-earth digital elevation).
15. Property damage as increased: where does perspective, “We know this area is prone to flood, but we will build anyway” – building restrictions/zoning & insurance aspects? (adaptation & mitigation)
16. What are the assets predisposed to damage?
17. Are we looking at the plans in communities to understand impacts to the models in the out years? (vision versus potential) “ecohydrology” concern
18. Insurability: when land becomes uninsurable, it becomes untaxable – municipalities loss of money.
19. When do you make the decision to relocate communities? Can’t manage all the water. How do you quantify? Risk? Insurance company perspectives.
20. Lack of adoption geospatial standards – ongoing work to try to provide input, but government/private/academia lack standards – fusion of multiple data sets to support state/local decision making.

Among the numerous dimensions of the problem, our workshop then deliberated and arrived at a consensus by voting to rank the top challenges. The top three problem areas were 1) during and after a flood event, determining what has flooded, what roads are impassable, and what damages have occurred; 2) there remains a lack of modeling of compound (combined) source flood predictions (encompassing extreme rainfall, riverine, and coastal surges and tides); and 3) lack of adoption of geospatial standards and related protocols limits the potential fusion of multiple data sources to support state and local decision-making.

As for the implications of the problem, participants also deliberated on *problem ownership* and management. Among 19 noted problem owners, the workshop attendees gravitated toward three key groups: 1) local municipalities and state government agencies responsible for urban and regional planning and coastal management; 2) emergency managers (broadly, including emergency services and public safety agencies and personnel); and 3) residents of flood-prone areas.

Brainstorming Problem Criticality and Feasibility

The Problem framing activity was followed by a Clarity of Ideas Brainstorming session to enable the group of participants to examine a subset of the above 20 subproblems. This process used the MITRE Lotus Blossom Canvas as the focal point for the discussion and the completed canvas is shown in **Error! Reference source not found.**. This canvas was then used to develop a consensus on prioritization of opportunities. The consensus was developed through participant votes on problems that were considered the *most critical* and secondly, problems that were considered the *most feasible* and most likely to be solved. The results of the Lotus Blossom Canvas voting by the group, together with the identified priorities of the subproblems, are shown in **Error! Reference source not found.**.



Lotus Blossom worksheet

modeling	Fusing/integrating	availability	Machine readable (pull w/code)	Data classification/ sensitivity level	PII	harmonized	Spatial resolution (ground sampling distance)	Spatial Extent
interoperability	Observational Data limitations	Spatial/temporal resolution	Private/proprietary data	Data access	Private vs public	Most recent/best available	Scale of data	Individual structure level (foundation type, etc)
Security	Lack of historical data (recurrence probabilities)	Existing data (available now)	Documentation/ meta data	Cloud-based, MOSA, training data set availability	Data manipulation tools	Infrastructure (cross-scale) ie roads, parsel	Unit of scale	Consistency of data
Data format	Tailorability/UX	Curation (ie, peer review/validated)	Observational Data limitations	Data access	Scale of data	Remote vs in situation	Soil & moisture precursor conditions	Precipitation (observe/forecast /predictive)
Consumable, simplicity	Usability	Config control	Usability	**“flooding data”**	Flooding data sources		Flooding data sources	
Standards	Meta data, pedigree of data	End user workflow to support decision making	Uncertainties	Modeling	Data integration			
Accuracy	Precision	Data source “trust” (esp w/crowd source)	Elevation models (physically modeling structure)	Compound flooding & integrating modeling	Physical impact (damage) modeling	Fusion of data (3D, geolocated, temporal, etc sources)	Diversity of data (IOT – sensors, webcams, vehicles, etc)	Integrating hazard vulnerability exposure data
Projection (longer term – ie, sea level rises)	Uncertainties	Forecast uncertainty	Incorporating uncertainties, temporal limfacs	Modeling	Operational (vs experimental/scientific)		Data integration	Cost (proprietary vs open source)
ID sources of uncertainties & impact (ie, error modeling)	Data latency (collect to use)	Confidence	Data source sufficiency to generate models	Scale modeling (regional, local, etc)	Trusted source modeling for decision making			Lack of tools for integration (ie portals today – vice “hubs”)

Figure C-7. Completed Lotus Blossom Canvas from Clarity of Ideas Brainstorming session of the MITRE UIX-Space Flooding Prediction, Response, and Recovery Workshop

Table C-3. Completed Lotus Blossom Canvas from Clarity of Ideas Brainstorming session of the MITRE UIX-Space Flooding Prediction, Response, and Recovery Workshop

PRIORITY	SUBPROBLEM	VOTES ON MOST CRITICAL PROBLEM	VOTES ON MOST FEASIBLE/LIKELY TO BE SOLVED
1	Data integration	8	11
2	Flood prediction uncertainties	7	2
3	Usability	3	13
4	Observational data limitations	7	4
5	Scale of data	4	4
6	Data access	2	2

Table C-3 **Error! Reference source not found.**depicts that six subproblems received votes on being critical and feasible in terms of being solved. While each subproblem is important in its own way, the subproblem of data integration to improve coastal flooding prediction, response, and recovery was deemed as Priority #1, given its criticality and feasibility to be improved. The number of votes for this subproblem were significantly higher than the others for both vote categories overall. Nonetheless, while deemed lower criticality, through the ideation process, the group also highlighted the feasibility of improving the usability of flooding prediction products.

To elaborate briefly on these priorities, the *data integration* problem dimension was viewed as feasible for the potential to integrate or combine, if not fuse, disparate geolocated data (e.g., flood model forecasts with in situ sensors, earth observations, and crowdsourced or other public data.) In addition, integrated data sources could improve modeling of compound flood events, capture precursor extreme rainfall or antecedent soil moisture conditions and detailed, high-resolution impervious surface cover. Earth observations and citizen science or crowd-sourced data alike could also yield data for model verification and validation. Uncertainties in flood forecasting also received great attention, yet feasible solutions to improve upon this were relatively lower ranked. On the contrary, *usability* of flood forecasting was viewed as a highly feasible area of opportunity. While lower ranked in criticality, the group was attracted to vote for the feasibility of customizing *user-centric* flood forecasts, *tailoring* products to suit individual user or agency needs, and developing *training or workflows* that might build capacity to use flood predictions and enable decision-making.

Further Efforts Toward Common Operational Picture

The workshop attendees represented a wide range of expertise, skills, and specializations, ranging from basic science and engineering, to operational flood forecasting, to decision-making for emergency management and long-range urban and regional planning. Given the breadth, the workshop necessarily included discussions on taxonomy, jargon, and the overall lexicon of flood hazards and resilience. We captured a “parking lot” of such concepts that merit future consideration and could promote improved flood resilience across disciplines and professions. Three recommendations in this wrap-up phase were 1) wherever possible, adopt, use, and create (when necessary) data standards, to include metadata; 2) carefully and explicitly identify terms of reference or taxonomy (we arrived a preference for the use of the concepts mitigation, adaptation, and risk reduction); and 3) promote more integrative ideas for risk reduction strategies overall.

Given the results of the workshop, the issues of improved flood prediction and usability of flood prediction products will be the focus of the MITRE UIX-Space Initiative for flooding. Therefore, based on the results summarized in this report:

The primary recommendation from the MITRE UIX-Space flooding workshop is the establishment of a pilot project to demonstrate the feasibility of innovative data integration and usable tools and information for flood prediction, response, and recovery.

This pilot could serve as a capability demonstration and stepping-stone in preparation for a larger research and development program.

The following post-workshop action items are pending or have been completed to advance this new focal issue:

1. Thank you email sent to workshop participants (completed).
2. Share summary of workshop results with workshop participants (this document)
3. Continue engagement with key stakeholders to seek support and advocacy
4. Engage with MITRE and UIX-Space team to plan next steps
5. Develop structure for a suitable pilot project to demonstrate feasibility of real-time weather data project
6. Seek sponsor funding to support solution execution for real-time weather data project

C.4 WATER BODY MONITORING

Virginia UIX Space Initiative Virtual Discussion on River Health

Workshop Report

18 Nov 2020

Scott Bailey (baileys@vt.edu)

Brentha Thurairajah (brenthat@vt.edu), VT

A workshop on monitoring of water resources in the Commonwealth of Virginia was held on September 18, 2020. This virtual workshop organized under MITRE-UIX Space initiative was attended by stakeholders from several institutions including VT, UVA, Virginia Department of Environmental Quality, and Chesterfield County Utilities.

Scott Kordella from MITRE introduced the UIX-Space initiative. He conveyed that the goal of the brainstorming discussion around important problems in Virginia was to address (1) what is being done now?, (2) what needs to be done to improve the outcome?, and (3) what are the opportunities to leverage the UIX-Space vision? Based on prior discussions with several stakeholders, Scott Bailey from VT presented a summary of the why we need a unique Virginia remote sensing program and what we need to measure. Debra Zides from MITRE stated the (draft) problem statement as "*How might we create ways to leverage remote sensing capabilities for monitoring the Virginia Water Resources while considering data fusion approaches as we aim to improve the environment in the Commonwealth of Virginia?"*

Based on Scott Bailey presentation, Debra Zides listed the problems in monitoring Virginia river health as follows:

1. Harmful Algae blooms
2. Temperature (athermal pollution blooms)
3. Pollution into rivers
4. Swamps and streams
5. Water quality (drinkability, swim-ability)
6. Lack of physical waterway access (private property, roads)
7. Lack of insight into "bulk flow" of dumping into waterways (daily point source vice episodic)
8. Persistent hot spots (requires larger scale view of the system)
9. Water quantity – velocity of the water/discharge, water coverage
10. Flooding & connection to the flood planes
11. Lack of monitoring modeling to supplement the measured data
12. Ground water quality cannot be sensed but can be understood from the surface nutrient levels
13. New pathogens, bacteria in the water – lack of deployed sensors (netted sensor grids)
14. Need to parameterize the models
15. Cost of direct water sensing methods (i.e., sediment)
16. Cloudy conditions impact overhead sensor observability (vice on-demand UAVs)
17. Timeliness of overpasses (i.e., LANDSAT only passes once every 20 days) – problem time scale
18. "Episodicity" – agricultural nutrients will get into the waterways (i.e., hurricane rainfall) – large episodic events that cannot be managed from space-based data
19. Small streams ignored but key to maintaining water quality (small unmonitored, unseen waterways)

20. Impervious surface coverage only used at local level – scale to larger coverage by integrating with additional data (state overflight data)
21. Land use/land coverage change over time
22. Spatially-specific information at the time it is occurring is needed (see water quality changes at "x" instance when needed, load/discharge rates)

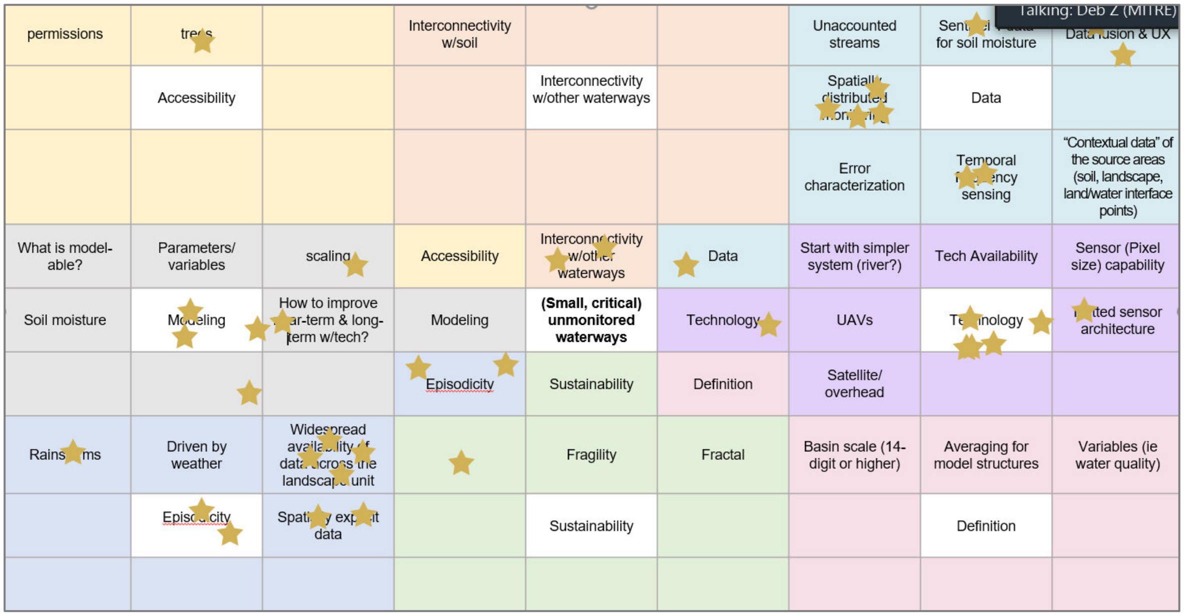
Participants voted on the most pressing problems. The three most voted problems in decreasing ranking order were 1) **small streams** ignored but key to maintaining water quality (small unmonitored, unseen waterways); 2) lack of monitoring **modeling** to supplement the measured data; and 3) '**episodicity'** – large episodic events that cannot be managed from space-based data.

The key consideration to address the "Small Streams" problem was developed using a Lotus Blossom canvas, as shown in Figure C-8.

permissions	trees		Interconnectivity w/soil			Unaccounted streams	Sentinel 1 data for soil moisture	Data fusion & UX
	Accessibility			Interconnectivity w/other waterways		Spatially distributed monitoring	Data	
						Error characterization	Temporal frequency sensing	"Contextual data" of the source areas (soil, landscape, land/water interface points)
What is model-able?	Parameters/ variables	scaling	Accessibility	Interconnectivity w/other waterways	Data	Start with simpler system (river?)	Tech Availability	Sensor (Pixel size) capability
Soil moisture	Modeling	How to improve near-term & long-term w/tech?	Modeling	**(Small, critical) unmonitored waterways**	Technology	UAVs	Technology	Netted sensor architecture
			Episodicity	Sustainability	Definition	Satellite/ overhead		
Rainstorms	Driven by weather	Widespread availability of data across the landscape unit		Fragility	Fractal	Basin scale (14-digit or higher)	Averaging for model structures	Variables (ie water quality)
	Episodicity	Spatially explicit data		Sustainability			Definition	

Figure C-8. Lotus blossom ideation of key considerations to address the problem of small, critical unmonitored waterways

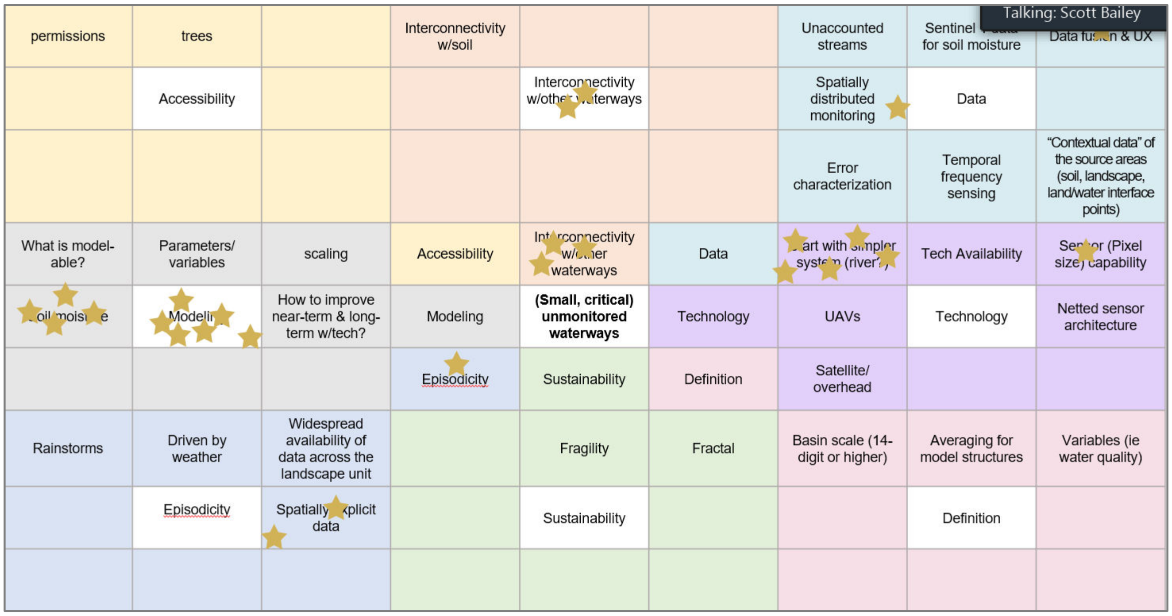
The group voted to identify the most critical consideration to solve and the most likely/feasible to be solved. Figure C-9 and Figure C-10 show the voting results for most critical and most likely to be solved, respectively. Table C-4 summarizes the voting results of the top three subproblems that were voted most critical. Table C-5 summarizes the voting results of the top three subproblems that were voted most likely/feasible to be solved.



Talking: Deb Z (MITRE)

permissions	trees		Interconnectivity w/soil			Unaccounted streams	Sentinel [illegible] data for soil moisture	Data fusion & UX
	Accessibility			Interconnectivity w/other waterways		Spatially distributed monitoring	Data	
						Error characterization	Temporal frequency sensing	"Contextual data" of the source areas (soil, landscape, land/water interface points)
What is model-able?	Parameters/ variables	scaling	Accessibility	Interconnectivity w/other waterways	Data	Start with simpler system (river?)	Tech Availability	Sensor (Pixel size) capability
Soil moisture	Modeling	How to improve near-term & long-term w/tech?	Modeling	**(Small, critical) unmonitored waterways**	Technology	UAVs	Technology	Netted sensor architecture
			Episodicity	Sustainability	Definition	Satellite/ overhead		
Rainstorms	Driven by weather	Widespread availability of data across the landscape unit		Fragility	Fractal	Basin scale (14-digit or higher)	Averaging for model structures	Variables (ie water quality)
	Episodicity	Spatially explicit data		Sustainability			Definition	

Figure C-9. Voting results from the most critical problems to be solved



Talking: Scott Bailey

permissions	trees		Interconnectivity w/soil			Unaccounted streams	Sentinel [illegible] for soil moisture	Data fusion & UX
	Accessibility			Interconnectivity w/other waterways		Spatially distributed monitoring	Data	
						Error characterization	Temporal frequency sensing	"Contextual data" of the source areas (soil, landscape, land/water interface points)
What is model-able?	Parameters/ variables	scaling	Accessibility	Interconnectivity w/other waterways	Data	Start with simpler system (river?)	Tech Availability	Sensor (Pixel size) capability
Soil moisture	Modeling	How to improve near-term & long-term w/tech?	Modeling	**(Small, critical) unmonitored waterways**	Technology	UAVs	Technology	Netted sensor architecture
			Episodicity	Sustainability	Definition	Satellite/ overhead		
Rainstorms	Driven by weather	Widespread availability of data across the landscape unit		Fragility	Fractal	Basin scale (14-digit or higher)	Averaging for model structures	Variables (ie water quality)
	Episodicity	Spatially explicit data		Sustainability			Definition	

Figure C-10. Voting results from the most likely problems to be solved

Table C-4. Voting results of the top three subproblems voted most critical

	SUBPROBLEM	NUMBER OF VOTES (MOST CRITICAL)
1	Episodicity: Widespread availability of data across the landscape unit	4
2	Data: Spatially distributed monitoring	4
3	Technology	4

Table C-5. Voting results of the top three subproblems voted most likely to be solved

	SUBPROBLEM	NUMBER OF VOTES (LIKELY TO BE SOLVED)
1	Modeling	6
2	Technology- start with simpler system (e.g., river)	5
3	Modeling-Soil moisture	4

Conclusions

The group of stakeholders concluded that one of the most pressing problems in monitoring of river health in Virginia is the monitoring of small water waterways. The group voted that critical problems in the monitoring of small critical unmonitored waterways is the need for technology, spatially distributed monitoring data, and data from episodic events (e.g., flashfloods, hurricanes) across the landscape unit. The group concluded that the problems associated with modeling (specifically soil moisture) and technology to monitor simpler water systems are most likely and feasible to be solved.

C.5 WILDFIRE PREVENTION

Virginia UIX Space Initiative Virtual Discussion on Wildfire Prevention

Workshop Report

27 Oct 2020

Jonathan Black (jonathan.black@vt.edu)

Leon Harding (lkharding@vt.edu), VT

The workshop on Wildfire Prevention was held on October 27, 2020, 1:00 p.m. – 3:00 p.m. via Zoom, and was hosted by MITRE, VT, and ODU as part of the MITRE Virginia UIX Space Initiative. Twenty-two participants attended from over 10 organizations including MITRE, VT, UVA, ODU, VA State Government, Center for Innovative Technology, NASA DEVELOP, GMU, National Parks Service, and the University of California San Diego.

Debra Zides from MITRE introduced the UIX-Space initiative and was the Ideation Facilitator for the workshop. The Ideation session agenda included several key discussion points, including (1) Defining the problem statement, (2) Clarifying Ideas and Solution Opportunities, and (3) Prioritization of ideas. Dr. Leon Harding from VT presented a summary of current Wildfire Risk Analysis program at VT, including details of the problem, the implementation of algorithms to assess this risk, initial results, and implementation of algorithms on the Data Cube. Based on this presentation, and in-depth discussion from all parties present, Debra Zides defined the (draft) problem statement as "*How might we create ways to leverage static & dynamic data sources (including remote sensing capabilities) in combination with powerful analytical tools for*

Wilderness Urban Interface (WUI) regions, rural communities, and non-populated areas (aka total coverage), while considering fire-related models (the Fire Susceptibility Index [FSI]), as we aim to improve current wildfire risk assessment, prediction, planning, mitigation, response recovery techniques (incl beyond the fire event itself) in the Commonwealth of Virginia?" Key problems that were identified regarding Wildfire Prevention were identified as follows:

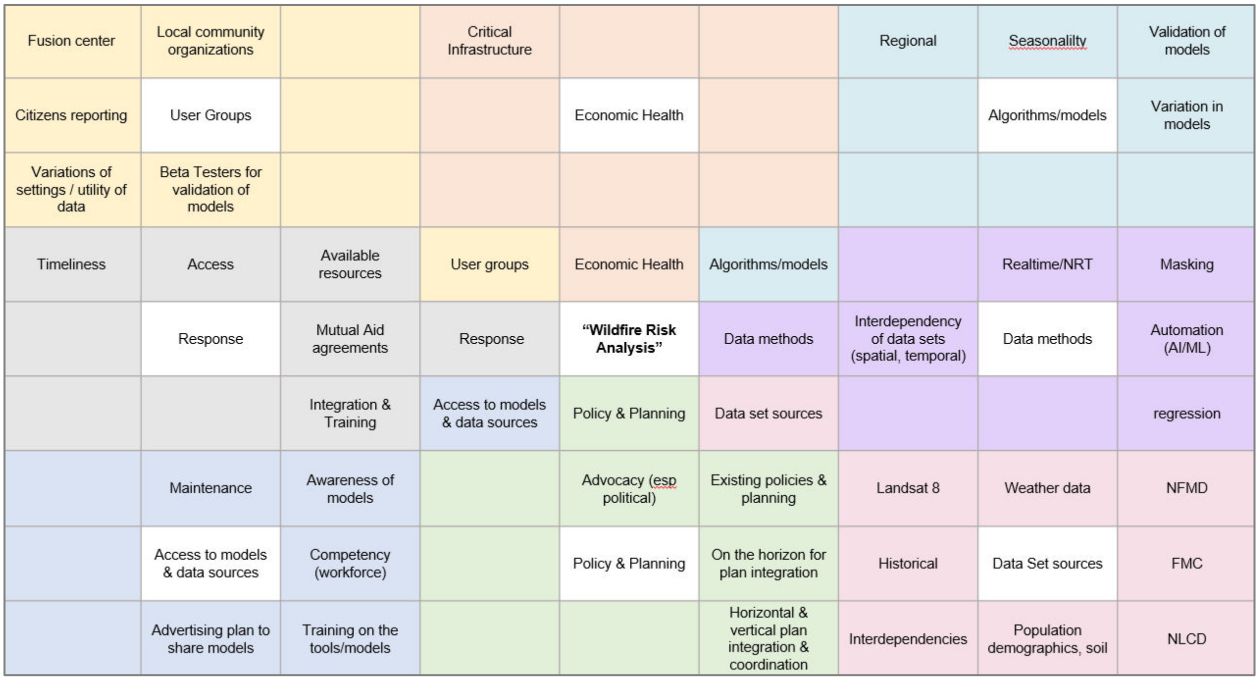
1. Assessing wildfire risk in the WUI is a major challenge and a major concern for wildfire danger
2. Wildfires that occur in WUI can cause massive loss in property and infrastructure and have greatest danger to property and life
3. The WUI requires small scale trends to properly capture the wildfire risk in these areas
4. Current tools are not well suited to the WUI and are hindered by 2 factors:
    - They are broad scale, look at trends over large areas and do not focus on small scale trends
    - They are labor and data intensive
5. Timely notification from risk to ignition to fire (responders, homeowners)
6. WUI – not just the greatest loss, but where humans are and do things – greatest risk of fire starting in an unnatural way
7. How to plan to use the land; intelligently for long-term preparedness & day-to-day activities (defensible space around structures)
8. Predicting/warning land management/scaping activities (unintended consequences of risky [flammable] activities)
9. Hazard planning & modeling: interrelationships with other (campfire, incendiaries, smoking, etc.)
10. WUI diverse landscape – not everything burns the same; separating systemic/causal with near-term
11. Foresight of climate change – how it impacts wildfire risk
12. Large communities affected (more than just the burning area smoke transport & health effects) i.e., CA offshore & came back inland
13. Burning toxicity natural versus manmade – impact to crops, animals, structures, etc.
14. Data: better data sets to inform where the housing developments/human populations (census data not necessarily sufficient for daytime/commuting populations)
15. No "one size fits all" fire model; need to understand which model/data to use; multiple models w/different data – aka context, locale (math versus inputs)
16. Data driven vs. context-driven models
17. Awareness & access to the "right" fire models for different regions (i.e., local models capturing the local physics of the area) – model effectivity
18. Bringing together the experts for the models to collaborate
19. Submodels (i.e., wind, terrain inputs)

20. Need for case studies/demo of how fire models can be effective for different stages/phases of emergency response
21. Two types/strengths of models: fusible & coupled models (long-term climate)
22. Weather extremes in regions drives local impacts (investigate from science perspective)
23. Data resolution (higher – from overhead sensors)
24. Models able to digest the new data / data sources
25. Policy aspect – need to work with the local policy makers in areas that will be impacted by the wildfires – especially the disconnected plans, i.e., "plan integration"
26. Communities need to revise planning based on predictions from the models
27. Impact of natural fire suppression on the wildfire data
28. Analyzing beyond the wildfire itself – i.e., Post-fire hazards (landslides, mud slides)
29. From FSI: how much energy is it going to take (given a source) to light on fire? Able to drill down to the WUI level & ask the energy question

By considering the above list, the group identified who/what might be most affected by these problems:

1. First responders
2. Land managers
3. Local state/federal officials
4. Regional/local planning offices
5. Economic developers
6. Insurance industry
7. Infrastructure managers (railroads, critical infrastructure facilities, utilities)
8. Private landowners
9. Ecosystem/biodiversity impact related organizations
10. Homeland Security
11. Land Trust owners/managers (farming, natural habitat)
12. Researchers/academia/industry modeling wildfires
13. Data providers (especially new providers who can address east coast challenges such as cloud cover)
14. Homeowner Associations (HOAs)
15. AI/ML community to inform the models (analytics)

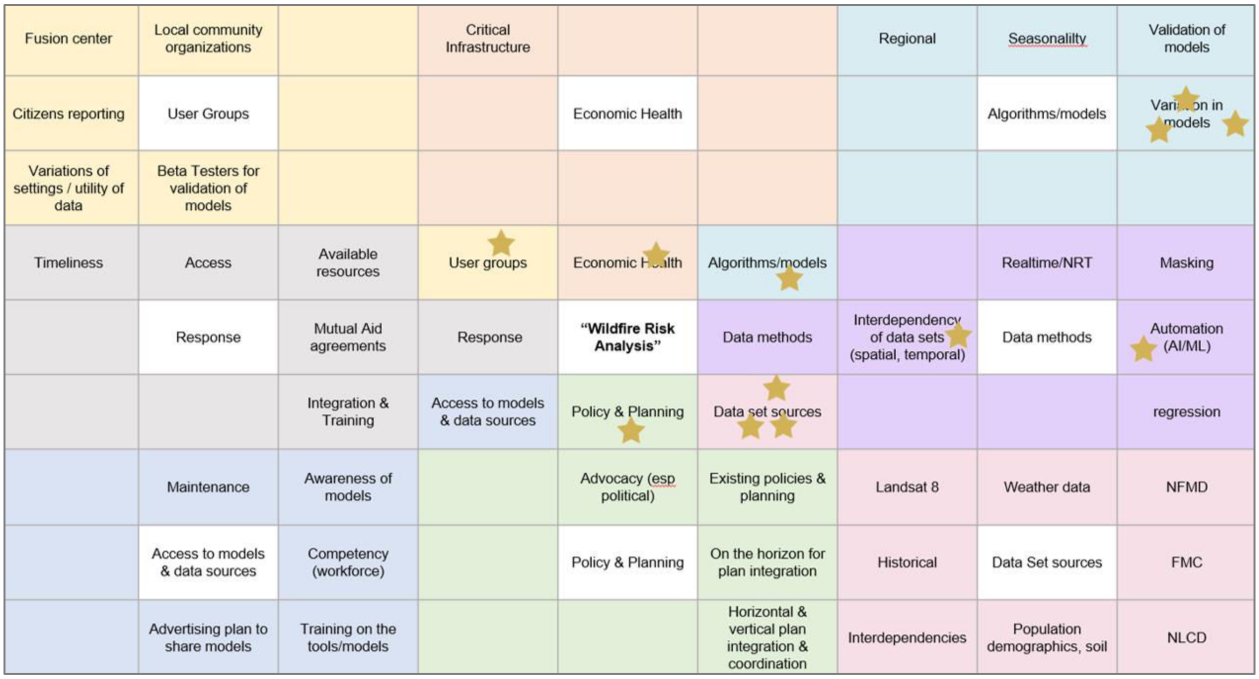
Key considerations to address the Wildfire Prevention were developed using the Lotus Blossom method, as shown in Figure C-11.



Fusion center	Local community organizations		Critical Infrastructure			Regional	Seasonalilty	Validation of models
Citizens reporting	User Groups			Economic Health			Algorithms/models	Variation in models
Variations of settings / utility of data	Beta Testers for validation of models							
Timeliness	Access	Available resources	User groups	Economic Health	Algorithms/models		Realtime/NRT	Masking
	Response	Mutual Aid agreements	Response	**"Wildfire Risk Analysis"**	Data methods	Interdependency of data sets (spatial, temporal)	Data methods	Automation (AI/ML)
		Integration & Training	Access to models & data sources	Policy & Planning	Data set sources			regression
	Maintenance	Awareness of models		Advocacy (esp political)	Existing policies & planning	Landsat 8	Weather data	NFMD
	Access to models & data sources	Competency (workforce)		Policy & Planning	On the horizon for plan integration	Historical	Data Set sources	FMC
	Advertising plan to share models	Training on the tools/models			Horizontal & vertical plan integration & coordination	Interdependencies	Population demographics, soil	NLCD

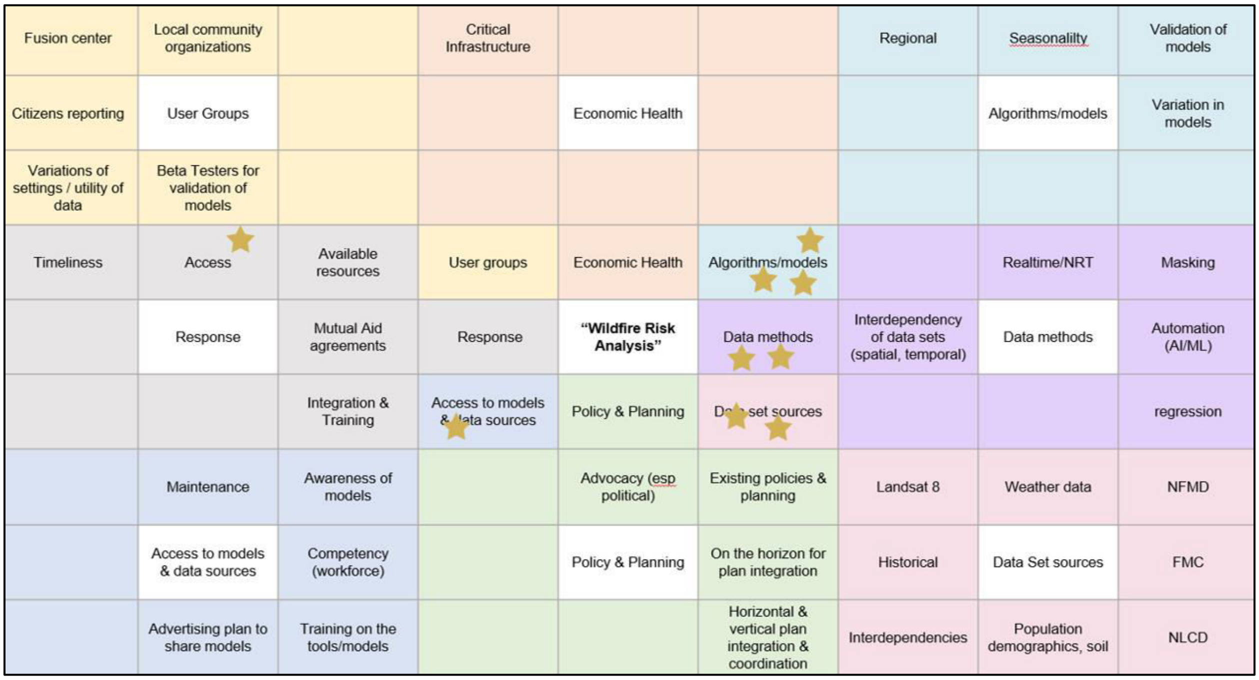
Figure C-11. Lotus blossom ideation of key considerations regarding Wildfire Prevention

The group then voted on the most critical considerations (Figure C-12) as well as identifying most likely or feasible to be achieved (Figure C-13):



Fusion center	Local community organizations		Critical Infrastructure			Regional	Seasonalilty	Validation of models
Citizens reporting	User Groups			Economic Health			Algorithms/models	Variation in models ★★★
Variations of settings / utility of data	Beta Testers for validation of models							
Timeliness	Access	Available resources	User groups ★	Economic Health ★	Algorithms/models ★		Realtime/NRT	Masking
	Response	Mutual Aid agreements	Response	**"Wildfire Risk Analysis"**	Data methods	Interdependency of data sets (spatial, temporal) ★	Data methods	Automation (AI/ML) ★
		Integration & Training	Access to models & data sources	Policy & Planning ★	Data set sources ★★★			regression
	Maintenance	Awareness of models		Advocacy (esp political)	Existing policies & planning	Landsat 8	Weather data	NFMD
	Access to models & data sources	Competency (workforce)		Policy & Planning	On the horizon for plan integration	Historical	Data Set sources	FMC
	Advertising plan to share models	Training on the tools/models			Horizontal & vertical plan integration & coordination	Interdependencies	Population demographics, soil	NLCD

Figure C-12. Lotus blossom ideation of critical considerations regarding Wildfire Prevention



Fusion center	Local community organizations		Critical Infrastructure			Regional	Seasonalilty	Validation of models
Citizens reporting	User Groups			Economic Health			Algorithms/models	Variation in models
Variations of settings / utility of data	Beta Testers for validation of models							
Timeliness	Access ★	Available resources	User groups	Economic Health	Algorithms/models ★★★		Realtime/NRT	Masking
	Response	Mutual Aid agreements	Response	**“Wildfire Risk Analysis”**	Data methods ★★	Interdependency of data sets (spatial, temporal)	Data methods	Automation (AI/ML)
		Integration & Training	Access to models & data sources ★	Policy & Planning	Data set sources ★★			regression
	Maintenance	Awareness of models		Advocacy (esp political)	Existing policies & planning	Landsat 8	Weather data	NFMD
	Access to models & data sources	Competency (workforce)		Policy & Planning	On the horizon for plan integration	Historical	Data Set sources	FMC
	Advertising plan to share models	Training on the tools/models			Horizontal & vertical plan integration & coordination	Interdependencies	Population demographics, soil	NLCD

Figure C-13. Lotus blossom ideation of most likely/feasible considerations regarding Wildfire Prevention

Conclusions

The group was successful in framing the problem of Wildfire Prevention by achieving consensus on the purpose of the program, defining the scope of initial activities and what defining a pathway to program completion. The group also identified a series of ideas via the Lotus Blossom method that were assessed for priority and viability. These ideas were then voted on to identify the most critical to solve, as well as the most likely/feasible to solve in the short term. These are shown in Table C-6 below:

Table C-6. Completed Lotus Blossom Canvas for Wildfire Prevention Critical/Likely

COMPLETED LOTUS BLOSSOM CANVAS FOR WILDFIRE PREVENTION CRITICAL/LIKELY		
Problem	**Critical votes**	**Likely/feasible votes**
Data set sources	**3**	**2**
Variation in models	**3**	**--**
Interdependency of data sets (spatial/temporal)	**1**	**--**
Automation (AI/ML)	**1**	**--**
Algorithms/models	**1**	**3**
Economic health	**1**	**--**
User groups	**1**	**--**
Policy & planning	**1**	**--**
Access to models & data sources	**--**	**1**
Access	**--**	**1**
Data methods	**--**	**2**

Several of the collaborators, including NIST, were unable to attend the working group. The follow-up is therefore to send the report out to the entire invite list to add to the above Table C-6, then create working groups to move out on proposing solutions to the identified problems.

Appendix D PROPOSED PILOT PROJECTS

D.1 SOLAR POWER GENERATION EFFICIENCY

Improving Solar Power Generation Efficiency and Stability

Peter W. Pachowicz (ppach@gmu.edu, 703-582-0638)

Volgenau School of Engineering

GMU

SUMMARY

As part of the MITRE-UIX Space initiative, this effort will provide preliminary design and targeted early prototyping of selected system modules for the solar power generation and demand management. These system components are part of a large-scale project where MITRE, four Virginia universities (GMU, VT, UVA, ODU), and VSGC work together to improve the Virginia State infrastructure.

This project aims at increasing efficiency of solar energy generation and demand planning by employing smart technologies over an existing power infrastructure. Analysis of cloud cover and ground verification of irradiation levels will contribute to accurate solar flux prediction over significantly shorter time periods (five-ten minutes) at solar farm locations. Developed technology will allow for generation of more energy from an existing solar farm, size/cost reduction of associated battery farm, and an inherited land conservation. Hence, this project is in a class of high return-on-investment initiatives.

The approach relies on a fusion of NOAA GOES-R satellite products and distributed ground sensory data to provide improved prediction and timing of cloud coverage. A group of low-cost ground ‘in-situ’ sensors will be distributed around a solar farm and form two rings of ~10-20 miles radius. These ground sensors will be networked to the DataCube (an existing computing cloud infrastructure) through 3G/4G telecom networks and satellite IoT links where network ground coverage is poor or missing. An estimation and feedback verification of irradiation levels over short time intervals will be executed automatically and distributed from the DataCube to problem owners. Targeted problem owners are solar farms. However, we also identified secondary beneficiaries such as building management and local energy distribution companies.

Proposed work will focus on three listed below aspects of the system which were identified during a workshop held on September 10, 2020. Workshop participants included representatives from federal and state government, industry, non-profit organizations, and academia.

1) Distributed network of in-situ self-powered sensors providing quality data.

We aim at the design of a plug-and-play, low-cost, and low-bandwidth architecture that will allow for sensor reconfiguration depending on chosen application, such as an estimation of solar irradiance, estimation of particle density for forest fire management, detection of water contamination, estimation of traffic congestion, etc. Networking will include terrestrial and satellite IoT/MoM options.

2) Specification and selection of satellite images and algorithms for cloud cover analysis.

Technical specification of image subset from NOAA GOES-R satellite product including algorithms necessary for implementing a system for cloud cover analysis. Definition of an image resolution, processing, and analysis processes with the purpose of predicting solar power generation level at solar farms, solar-on-roof locations, and peak power management for large office and industrial sites.

3) ‘Pico-scale’ ground test station for algorithm evaluation.

Design of a self-powered test station capable of comparing two algorithms against each other for evaluation of solar farm efficiency. The station will mirror solar farm infrastructure, including battery farm, control system, controllable variable load simulating power grid, and data collection unit.

This project will follow system engineering practice and provide a preliminary design of the above-mentioned products. We will conduct a targeted prototyping effort to evaluate selected designs and components. Evaluation methods and metrics will be developed as well. In summary, this project will lay down grounds for a much larger effort leading toward a full-scale implementation of an integrated multifaceted smart infrastructure.

Period of performance: 6-12 months

D.2 TRANSPORTATION EFFICIENCY

Whitepaper Proposal

Transportation Efficiency Pilot Program

Christopher Goyne, Venkataraman Lakshmi and B. Brian Park

University of Virginia

Scott Kordella and Liv Blackmon, MITRE

Period of Performance: December 1, 2020 – November 30, 2021

Introduction

Transportation is key to the quality of life and economic development across the United States. In Virginia, for example, approximately $500 billion in goods are shipped into or out of the Commonwealth each year.[1] The transportation system includes roads, rail, air and sea. On a day-to-day basis, the public is most exposed to the road system because it forms the backbone for commuting and commerce. Unfortunately, congestion on our roadways is increasing. This congestion costs Virginia drivers close to $5 billion each year due to lost time and increased fuel consumption.[7] Further, from 2014 to 2018, almost 4,000 people died in traffic accidents within Virginia. At the same time, the use of our road system is changing. While two percent of passenger vehicles in Virginia are currently electric, the electric fleet is expected to increase to a share of 46 percent by 2040.[1] In addition, autonomous vehicles are expected to play an increasing role in passenger surface transportation in the future. Further, UAM vehicle use will also increase in the future, and this may result in new ways in which surface and air modes of transportation intersect. It is therefore imperative that we improve the efficiency and safety of

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[7] “Virginia Transportation By The Numbers: Meeting the State’s Need for Safe, Smooth and Efficient Mobility,” TRIP, A National Transportation Research Nonprofit, February 2020.

our transportation system within Virginia and the United States, while considering new and emerging technologies. This will save lives, save money, and improve our quality of life.

The efficiency and safety of our roadways is a national issue, but one that particularly affects the Commonwealth of Virginia. Road congestion is particularly prevalent in Northern Virginia and the Hampton Roads areas. In addition, the I-95 and I-81 corridors within Virginia are national transportation arteries that also suffer from congestion problems. Fortunately, Virginia is well positioned to find solutions to these problems, due to a significant number of relevant research centers and subject matter experts across the Commonwealth. These include the University of Virginia Center for Transportation Studies, Old Dominion University Transportation Research Institute, Virginia Tech Transportation Research Institute, Virginia Transportation Research Council (VTRC), the Commonwealth Center for Advanced Logistics Systems, and MITRE. By coupling this expertise with that of the MITRE UIX-Space, we will be able to develop innovative, data-driven technical products to improve transportation efficiency and safety within Virginia. This will be achieved by identifying and integrating multiple information resources (space, air, terrestrial, and vehicle) to develop innovative transportation solutions.

On August 20, 2020, MITRE and the UVA hosted a workshop on Improving Transportation Efficiency. There were 25 participants present at the workshop that represented MITRE, UVA, VT, ODU, GMU, Virginia Transportation Research Council, VSGC, Federal Highway Administration, and National Academy of Sciences. Using the MITRE Ideation Process, the workshop attendees identified 12 important problems in transportation that ranged from traffic operations inefficiencies through to roadway infrastructure deterioration. However, real-time weather data was identified as a key resource to improve roadway safety and efficiency. This concept was deemed as the most critical problem and the most likely to be solved.

The primary recommendation from the workshop was the establishment of a pilot project to demonstrate the feasibility of coupling real-time weather observations with vehicle navigation in order to improve roadway safety and efficiency in the Commonwealth of Virginia.

Problem

Our road transportation system has a significant impact on climate change. Globally, 72% of greenhouse gas (GHG) emissions come from road vehicles.[8] This climate change is resulting in more extreme weather events and these events are, in turn, having a greater impact on traffic safety and efficiency, and on roadway maintenance and life expectancy.[9] As the efficiency of the roadways are reduced, GHC emissions will further increase. In-vehicle and smart phone-based satellite navigation devices currently notify a driver of congested traffic, roadway incidents, detours, and road maintenance and closures. However, there is no real-time weather information that is integrated into the data streams that are delivered to these navigation devices. By combining real-time weather products from NOAA (Doppler radar, GOES-R, land-based weather stations, NCEP/NOAA real-time weather forecasts) with real-time traffic reporting (Waze, INRIX, Google Traffic, etc.) and roadway condition information (Virginia Department of Transportation weather stations and traffic cameras), drivers could be better informed about road conditions so as to choose an alternate route or adapt their driving style for the expected conditions ahead. Real-time advisories and route modifications, independent of in-person roadway observations, could be provided in relation to roadway impacts of rain, flooding, wind, snow, ice, fog, and smoke. The satellite navigation devices could also provide speed and vehicle separation recommendations based on anticipated traffic and roadway surface

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[8] World Resources Institute, Everything You Need to Know About the Fastest Growing Source of Global Emissions: Transport, Wang, S. and Ge, M., October 16, 2019

[9] United States Environmental Protection Agency, Climate Impacts on Transportation, downloaded 10/6/20.

conditions ahead. By providing drivers (and automated vehicles) with an additional data stream, the safety of our roadways could be improved.

It is proposed here to conduct a pilot study to further engage the MITRE, UVA, and UIX-Space team in order to conduct a pilot project to demonstrate the feasibility of using real-time and predicted weather data to improve roadway safety and efficiency. This will enable the team to generate preliminary data to demonstrate effectiveness and utility of the solution, and to seek federal and state funding to support solution execution at a larger scale. In addition, we will engage key expertise within Australian universities, government, and industry, to promote U.S.-Australia technical exchange and accelerate our efforts toward improving roadway safety and efficiency. As discussed below, this proposed work is well aligned with MITRE corporate strategy initiatives and the MITRE Innovation Program.

Objectives

The specific objectives of the pilot program will be to:

1. Assess the relationship between weather events and traffic accidents and incidents in the Commonwealth of Virginia by examining publicly available historical weather and traffic databases.
2. Identify relevant weather data sources and develop automated decision-making approaches to make available actionable information for roadway users and managers.
3. Examine ways in which roadway use and management recommendations can be safely and effectively delivered to end users in a way that maximizes compliance and effectiveness.
4. Through traffic modelling and simulation, quantify the ability of a real-time and predicted weather data solution to reduce adverse effects of weather on roadway efficiency and safety.
5. Synthesize research results for a proposal for a larger research program with the goal of technology transition to industry and large-scale deployment of the solution.

By achieving these objectives, the proposed team will be able to demonstrate the effectiveness and utility of the solution. This will enable project personnel to work with the MITRE UIX-Space team to seek federal and state funding to support solution execution at a larger scale.

Personnel and Collaborations

Table D-1 below lists the UVA personnel and roles for the proposed project. Due to the near-term start and limited period of performance of the project, we propose to include a research associate in the project rather a graduate student.

Table D-1. UVA Personnel and Roles

PERSONNEL	TITLE	ORGANIZATION	ROLE
Christopher Goyne	Associate Professor of Mechanical and Aerospace Engineering	University of Virginia	Principal Investigator, will manage the project and coordinate with MITRE
Venkataraman (Venkat) Lakshmi	Professor of Engineering Systems and Environment	University of Virginia	Co-Principal Investigator, will lead weather data and effects analysis
B. Brian Park	Professor of Engineering Systems and Environment	University of Virginia	Co-Principal Investigator, will provide guidance on traffic simulation and modelling tools
Reyadh AlBarakat	Research Associate	University of Virginia	Will conduct weather effects and roadway incident analysis, as well as traffic simulation

In order to promote US-Australia exchange and accelerate efforts to achieve the proposed project objectives, the project team will work with MITRE and the Australian Trade and Investment Commission (Austrade) to identify Australian academic, government, and industry collaborators. The proposed work is expected to make a significant contribution to Australian economic development due the increasing effects of climate change and extreme weather (thunderstorms, cyclones, flooding, fire, and dust storms) on Australian surface transportation.

Alignment with MITRE Strategic Initiatives

This propose work is well aligned with both MITRE corporate strategy initiatives and the objectives of the Aviation and Transportation area of the MITRE Innovation Program. First, this proposed project will contribute to building capabilities that are part of the Transportation Data Platform (SI-6: Scalable Platforms). Further, by applying aerospace solutions to surface transportation problems, we will be able to leverage current MITRE activities that support Strategic Initiative (SI) 2, Enabling Safe Operations Across the Air and Space Domains.

In terms of supporting the MITRE innovation strategy for the Aviation and Transportation area, the proposed work will support research objectives associated with surface transportation challenges (autonomous vehicles and traffic safety), climate change challenges (adapting to climate change and extreme weather), and cross-cutting challenge areas (resilient and safe systems-of-systems).

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D.3 FLOODING PREDICTION AND RESPONSE MONITORING

MITRE UIX-Space Pilot Study Concept for Coastal Flooding Prediction

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David Bowles (dbowles@odu.edu)

Guidance from the Flood Prediction, Response, and Recovery Workshop (August 2020)

Following the MITRE UIX-Space Coastal Flooding Workshop, discussions ensued around developing a strategic problem for pilot study with achievable progress in a near-term, tactical scale. Parameters for this problem selection included tackling the priority subproblem: 1) data integration, 2) reducing flood prediction uncertainties, and 3) building toward usability of produced information and decision-support products. Secondarily, a pilot study would demonstrate insofar as feasible, 1) adoption, use, and creation of data standards (including metadata); 2) carefully and explicitly identify terms of reference or taxonomy (e.g., concepts mitigation, adaptation and risk reduction); and 3) promote more integrative ideas for risk-reduction strategies overall.

Concept for a Pilot Study

A 12-month pilot study conducted by a multi-disciplinary team is conceptually developing that would combine expertise across remote sensing, GIS, hydrodynamic modeling, and flood hazard management. This project would integrate satellite and sUAS airborne data to augment existing digital elevation models (DEMs) for improved flood prediction, capture critical built environment infrastructure and thresholds (e.g., First Floor Elevations, or FFEs) and provide a range of analytical, operational and read-to-use geovisualizations of flood impacts for decision-maker input and risk communications. The project would focus on a community with demonstrable needs, such as Fort Eustis unit of Joint Base Eustis-Langley (JBEL) where a need has been identified by base command to identify flood risks and support preparedness operations. In addition, surrounding transportation networks that may affect or be affected by flooding (including road and railroad), evacuation and civilian or military personnel accessibility. As such, the project is poised to have impact on the preparedness, continuity of operation, recovery, and ability to absorb or adapt to flood risks. The project would have the synergistic benefits of bringing Geographic Information System (GIS), modeling, transportation, and UAV experts together with end users as collaborators. Students will be employed to assist data collection and trained in the technical analysis. The project would also solicit advisory contributions from faculty practitioners to develop future data inputs (e.g., natural and nature-based feature inventory such as wetlands and living shorelines) or personnel commuting and economic impacts (e.g., travel time and accessibility of impacted roads). Similar projects are in early conceptual or proposal stages at this time, including NOAA Effects of Sea Level Rise RFP, NSF Coastlines and PEople (CoPE), and a future RFP in FY 2022 by the U.S. Global Change Research Program's coastal resilience fund and the National Fish and Wildlife Federation (NFWF) resilience project funds. Hence, the project has the potential to pilot and prove concepts and capacity for a larger funded proposal. In addition, the DoD and ODU are members of the Chesapeake Watershed Ecosystems Studies Unit (CESU), which could provide a mechanism for non-competing funding in a follow-on larger implementation phase.

Rationale for Regional and Extramural Funding Potential

The local community expertise is well poised to address the problem given UAS capacity at NASA Langley Research Center as well as private sector entrepreneurial sector. The project would also leverage faculty expertise at ODU across the departments of Civil and Environmental Engineering, Geography Program, and Technical Communications that collaborate through the Institute for Coastal Adaptation and Resilience (ICAR) and the Commonwealth Center for Recurrent Flooding Resilience (CCRFR). Further, the project would enhance and expand upon a nascent effort of FFE data integration and classification by the HRPDC and a recent pilot study of building FFEs in the City of Newport News by ODU and VIMS sponsored by VDEM through a Federal Emergency Management Agency Hazard Mitigation Grant. We foresee this as a steppingstone for a broader, funded research to operations project that will expand data integration and capacity at regional military installations as well as interoperability of data and flood risk information between municipal government, HRPDC, and DoD.

D.4 WATER BODY MONITORING

Water Health & Drones Proposal to MITRE – Initial Ideas

November 13, 2020

Points of contact: Scott Bailey (baileys@vt.edu); W. Cully Hession (chession@vt.edu); Afroze Mohammed (afroze@vt.edu)

Summary

We propose to take the MITRE-sponsored UIX collaborations regarding water health to the next level. Leveraging off of existing drone-based instrumentation at VT and the ongoing MITRE-funded Major Design Experience, we will develop a multi-instrument drone-based sensor package to explore Virginia streams for the purpose of understanding their impact on river health and flooding. In the recent UIX water health ideation, it was concluded that important problems in the monitoring of small critical unmonitored waterways include the need for technology, spatially distributed monitoring data, and data from episodic events (e.g., flashfloods, hurricanes) across the landscape unit. Our proposed sensor package will yield technology that when implemented on a large scale, can address those needs.

The development would be conducted at VT in collaboration with the UIX team, and all data acquired would be integrated into the data cube. The study would take place over approximately 9-12 months and require about $100K funding. The results of this effort would confirm the feasibility of the technical approach at a small scale. A subsequent proposal would address the problem at a larger scale.

Background

A workshop on monitoring of water resources in the Commonwealth of Virginia was held on September 18, 2020. This virtual workshop organized under MITRE-UIX Space initiative was attended by stakeholders from several institutions including VT, UVA, Virginia Department of Environmental Quality, and Chesterfield County Utilities. The (draft) problem statement is “How might we create ways to leverage remote sensing capabilities for monitoring the Virginia Water Resources, while considering data fusion approaches as we aim to improve the environment in the Commonwealth of Virginia?”

Stakeholders who attended the workshop voted on the most pressing problems. The three most voted problems were 1) small streams ignored but key to maintaining water quality (small unmonitored, unseen waterways); 2) lack of monitoring and modeling to supplement measured data; and 3) ‘episodicity’ – large episodic events that cannot be managed from space-based data. Several key considerations to address the “Small Streams” problem were developed. Among these, the group voted that critical problems in the monitoring of small critical unmonitored waterways is the need for new sensor technology, spatially distributed monitoring data, and the need for data from episodic events (e.g., flashfloods, hurricanes) across the landscape unit. The group concluded that the problems associated with modelling (specifically soil moisture) and technology to monitor simpler water systems are the most likely and feasible to be solved.

Initial Project Concepts

The proposed funding from MITRE offers the opportunity to capitalize on existing programs and leverage the results of the investments MITRE has already made. VTG Professor W. Cully Hession leads a project which uses drone-based sensors for studies relating to flooding (described in the next section). This work ties in well with the UIX studies of flooding. We will add to that sensor package an instrument that can sense particulates and provide information on stream water composition. Such an instrument is already being studied by the MITRE-funded Major Design Experience (MDE) team within the Department of Electrical and Computer Engineering. The MDE instrument focuses on chlorophyll detection, but there is also information on other materials in the water. And while the goal of that project is to develop a drone-appropriate sensor, this first MDE is focusing more on demonstrating the sensor. Our proposal is to build a rugged version of that instrument, add emphasis on the non-chlorophyll information that the sensor provides, implement it on Dr. Hession’s drone system, and make observations at a number of streams in Virginia.

The requested funding would primarily be used to fund a graduate student, probably from the department of Biological Systems Engineering, who would perform much of the work and document the results. Some funds would be required for hardware purchases, and a small amount of funding would support a professional engineer who works with the student on design considerations best practices for deployed systems.

The goal would be to observe as many streams as possible so that the observations can be intercompared. It will be important to sample the streams multiple times and in particular after storms and large rainfalls. All data obtained would be archived in the data cube, as depicted in Figure D-1.

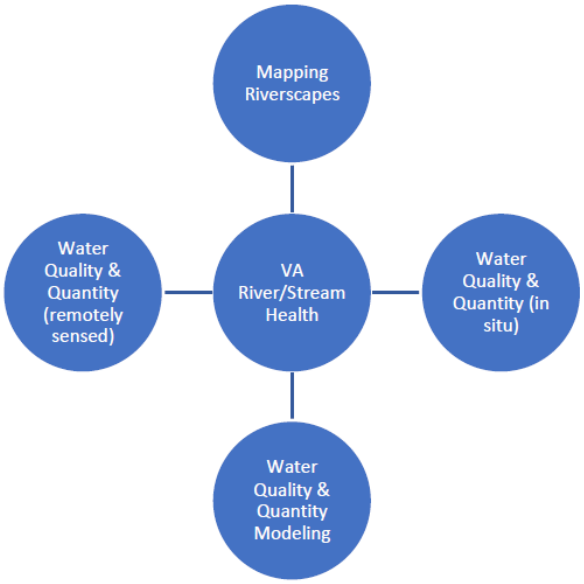

Figure D-1. Data Cube

While the proposed effort will be concentrated in the departments of Biological Systems Engineering and Electrical and Computer Engineering at VT, the interpretation of the results will include the wider UIX team and participants in the water health ideation. This project is cross cutting among two of the UIX core topics and so can be used to enhance the UIX collaborations.

Existing Drone-based Systems for Flooding Studies

We are currently using drone-based laser scanning (DLS) as well as structure-from-motion (SfM) photogrammetry to estimate floodplain roughness for improving 2D flood modeling.

- The current PhD student (Beth Pryor) leading this flood study recently published research from her undergraduate experience in the International Journal of Remote Sensing, "Investigating small unoccupied aerial systems (sUAS) multispectral imagery for total suspended solids and turbidity monitoring in small streams." We plan to expand her previous research in this area using our drones and payloads.
- We have done preliminary studies and are working on a publication where we compare three approaches to estimating roughness (Manning's *n*) for use in the 2D HEC-RAS model.
- While more research is needed, results show we can improve hydrodynamic modeling efforts using drone-based sensors. Flood modeling is becoming increasingly important for management and planning in response to climate change.
- The goal of ongoing research is to investigate how intra-seasonal, depth-dependent vegetation roughness influences flooding while also evaluating open access remotely sensed data quality for hydrodynamic modeling.

- In addition to utilizing DLS and SfM, we have a new multispectral camera that we plan to combine with high-resolution lidar data to improve vegetation mapping for use in roughness estimate and modeling.
- In a new project with NASA, we will have access to a hyperspectral camera that we can deploy with our drone. The initial study will be to obtain diurnal observations of forests for structure and functional trait analyses. However, both the multispectral and hyperspectral sensors can be used for monitoring water quality as well (e.g., turbidity, chlorophyll).
- To date, our drone-based data collection and modeling have been conducted at the Virginia Tech StREAM Lab (Stroubles Creek) and Catawba Sustainability Center (CSC, Catawba Creek), where we have extensive in-stream sensors for measuring flood extents and elevation, flow rates, and detailed velocity profiles (in the stream channel and floodplain). These data allow for calibration and or validation of our modeling efforts. We would likely install similar sensors in multiple streams for the MITRE project.

Equipment

- AeroVironment Vapor 35 – 30 lb drone, 5 lb payload, 35-45 min flight time
- YellowScan UAV Lidar System - Core System Mapper, integrated w/Vapor 35, multi-echo lidar sensor GNSS RTK, >450 pts/m2 @ 30 m flight height
- MicaSense Altum - Integrates a radiometric thermal camera with five high-resolution narrow bands, producing advanced thermal, multispectral, and high-resolution imagery in one flight for advanced analytics
- DJI Mavic Pro w/4k camera – for SfM imagery
- StREAM Lab - https://vtstreamlab.weebly.com/
  - Water quality monitoring (two locations along Stroubles Creek and one on Catawba Creek) – cond/temp/do/pH/turbidity
  - Stage monitoring (three locations, two @ StREAM Lab and one at Catawba Creek) – have one rating curve, working on another (for flow)
  - Velocity Probes (three locations)
  - Weather station (two locations, StREAM Lab and Catawba Creek)
  - Onsite permanent cameras (two locations), new deployable cameras (four)
  - Conductivity, temperature, and stage sensors @ four additional locations along Stroubles Creek to obtain more spatially explicit data related to water quality and quantity

Other Ideas Under Consideration

The above text describes our initial plan for the proposal, but we note that we are considering also projects involving in situ sampling of the streams to mirror what is being undertaken at the VT StREAM Lab (Stroubles Creek and Catawba Creek).

- Expanding our sensor networks on Stroubles Creek and Catawba Creek to truly be able to understand small stream water quantity and quality over time and space in “real time”
- BSE Sr Design project – Remote Water Sampling Drone (taking samples for return to lab)
- EE Sr Design project – Drone-based Laser Diffraction for Water Quality Analysis (in-situ measures)

D.5 WILDFIRE PREVENTION

Whitepaper Proposal

Wildfire Prediction & Prevention Pilot Program

Jonathan Black, Leon Harding, Zach Leffke

VT

Scott Kordella and Liv Blackmon, MITRE

Period of Performance: 1/1/2021 – 12/31/2021 (base), 1/1/2022 – 12/31/2022 (option)

Introduction

In 2020, there have been 308 forest fires in Virginia (almost one forest fire per day) that have damaged 5,200 acres, four homes, and 19 structures. Hundreds of other homes and structures have also been threatened by these fires. Therefore, wildfires in the WUI are one of the greatest threats to life and property. However, it is difficult to predict fire risk in the WUI; current wildfire risk assessment methods are broad-scale and look at trends over large areas. Assessing small scale trends is essential to predicting wildfire risk in the WUI.

The Fire Susceptibility Index (FSI)[10] is a strong candidate for a solution to this problem. The FSI is a type of geospatial data that models wildfire risk using remote sensing data. The FSI fuses a variety of datasets to model the wildfire risk but relies on Landsat remote sensing data to produce the most recent temporal analysis. The 30-meter spatial resolution of the Landsat satellite is the essential feature that enables the FSI to analyze small-scale trends in the WUI. The FSI uses a variety of data sources to compute the probability of ignition compared to a nominal, historical value. It is able to capture the changes in moisture content of plants with the Landsat remote sensing data, which is the primary factor in determining the physics of ignition.

The FSI will require the construction of a data lake to host the datasets; development of additional fusion, regressions, and predictive algorithms; and implementation on a cloud computing service. Potential future capabilities include expanding coverage, artificial intelligence/machine learning (AI/ML)-enabled predictive analytics.

Problem

Assessing wildfire risk in the WUI is a major challenge and an area of major concern for wildfire danger. The WUI is a loosely defined term, but we are using it here to represent the area where any man-made structure is in close proximity to any significant natural fuel source. If executed well, wildfire assessment can result in better-informed land management decisions, a reduction in the frequency and impact of wildfires, and enable advanced analytics to provide predictive capabilities. Wildfires that occur in the WUI often have potential to cause massive loss in terms of personal property and infrastructure. Many of the current wildfire risk analysis tools are not specifically suited to the WUI; however, some of the improvements to the FSI have made it a strong candidate to analyzing fire risk near urban areas. This work will expand a feasibility study

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[10] Swarvanu Dasgupta (2006) and Rebecca Unruh (2014).

[1] S. Dasgupta, J. J. Qu, and X. Hao, "Design of a susceptibility index for fire risk monitoring," *IEEE Geosci. Remote Sens. Lett.*, vol. 3, no. 1, pp. 140– 144, 2006.

[2] R. Unruh, "Data Fusion for Decision Support," Air Force Institute of Technology, 2014.

that developed an FSI-based decision support tool by designing a new method of assessing and analyzing this risk by fusing U.S. Landsat and other remote sensing data.

The FSI is a type of geospatial data that models wildfire risk based on remote sensing data. The main fire risk analysis tool, the National Fire Danger Rating System (NFDRS), is intended for use on broad-scale applications and requires a wider variety of data such as weather data, the plant growth period, and on-the-ground observations, requiring a more intensive labor process. The weather and plant growth period directly affect the light reflectance that is gathered by the satellite, meaning that the FSI does not require direct measurement of these factors, and the remote sensing data has a spatial resolution of 30 meters, allowing for more specific applications. However, this analysis is not intended to replace the NFDRS but to add an additional tool to allow Wildfire Management Agencies to better use their resources. Once the FSI is implemented in real time and validated with previous data, it will allow for a much lower-labor cost and more accessible fire risk analysis.

Approach & Objectives

Landsat satellites acquire moderate-resolution, global multispectral measurements globally. To maximize the utility of current and near-future small-sat remote sensing capabilities, the VT effort proposes efficient use and seamless fusion of Landsat multispectral data, other remote sensing data, and other publicly-available land use data, to result in global land analyses to improve fire danger monitoring. Specifically, the effort proposes to develop remote sensing data fusion for monitoring and characterizing rapidly changing agriculture and forest cover, and the progression of fire scars. The result will be multi-sensor methods based on increased temporal-spatial coverage and measurement spectral diversity that advance the virtual constellation paradigm for mid-resolution land imaging. The remote sensing data fusion analysis will be implemented in a GIS on the VT Advanced Research Computing. A total of eight data sources will be fused in a GIS to identify high-risk patches of wildland at the Landsat 30m ground sample distance. The final product will be a tool that will be tested and refined to automatically refresh when new data becomes available, allowing for new algorithm and predictive analytics development, at which point it could be implemented in a production environment.

Processing and regression analysis of these data sets produces a regional FSI in which the user can see the most likely regions for forest fires to start. Investment is required to augment current capabilities to:

- Build a comprehensive data lake that automatically accesses/downloads new data
- Port to cloud computing for broader access
- Develop new fusion, regression, and prediction algorithms
- Expand the current problem set

New capabilities that this effort could produce include increased resolution and timelines, new data feeds, additional sensors and platforms using the custom-design optimization approach above, scaling to global coverage, and AI/ML-enabled predictive analytics. An FSI expansion like this could result in public/private partnerships to investigate predictions such as insurance risk protection, residential and commercial construction, targeted blackouts, and fire prevention. Indeed, individual homeowners could also benefit from risk reduction incentives, subscriptions, and data sharing. Other markets such as public/NGOs, such as the U.S. Forestry service, state emergency services, municipalities, and HAM radio could also avail of these capabilities. Other potential applications might include pipeline monitoring, topsoil erosion, LIDAR data, USGS, water quality and 5G/6G.

Personnel and Collaborations

The table below lists the VT personnel and roles for the proposed project.

Table D-2. VT Personnel and Roles

PERSONNEL	TITLE	ORGANIZATION	ROLE
Jonathan Black	Professor, Crofton Dept. Aerospace and Ocean Engineering	VT	Principal Investigator, will manage the project and coordinate with MITRE
Leon Harding	Research Associate Professor, Hume Center / Space@VT	VT	Research Scientist, technical input, and supervision
Zach Leffke	Research Associate	VT	Research Associate, technical implementation
Undergraduate and Graduate students		VT	Implementation and analysis

Alignment with MITRE Strategic Initiatives

This proposed work is well aligned with both MITRE corporate strategy initiatives and the objectives of the Aerospace and Transportation and AI and ML areas of the MITRE Innovation Program, as well as the solutions-driven innovation and real-time technology approaches of MITRE Labs. Affiliated technical areas that will be leveraged as part of this work include modeling and simulation, concept development and exploration, and data mining and analytics.

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