September 4, 2014

Ohio Department of Transportation
Research Section
Office of Statewide Planning & Research
1980 W. Broad Street – Mail Stop 3280
Columbus, OH 43223
Research@dot.state.oh.us

RE: Veteran’s Glass City Skyway Ice Dashboard Implementation Proposal

Dear Research Section:

The University of Toledo (UT) is pleased to submit the subject proposal. We feel the implementation of the icing dashboard and associated sensors through the winters of ‘14-‘15 and ‘15-‘16 will assist ODOT in effectively managing icing events during that period and develop a system which will help ODOT anticipate icing events in the future and eliminate the need for ODOT personnel to go in harm’s way to verify the presence of ice on the stay cables.

As detailed in part 1 of the proposal, the University of Toledo - Intermodal Transportation Institute and the University of Cincinnati Infrastructure Institute will migrate the dashboard to District 2 and insure fully functionality of the dashboard over this period. Part 2 of the proposal addresses the development and deployment of ice presence, state and thickness sensors. The budget request for this work is $263,171 and the work is scheduled to be completed between October 1, 2014 and August 30, 2016.

We appreciate the opportunity to assist ODOT in this important work. If you have any questions or need further information, please contact Brenda McKinley, Associate Director, Research & Sponsored Programs (419-530-2844 or researchadmin.mc@utoledo.edu) for any administrative questions or Dr. Douglas Nims (419) 530-8122, Douglas.Nims@utoledo.edu for any questions regarding technical aspects of this proposal.

Sincerely,

Richard Martinko, P.E.
Director – University Transportation Center

William S. Messer, Jr., Ph.D.
Vice President for Research
Veteran’s Glass City Skyway Ice Dashboard Implementation

Bridge No. LUC-280-0283

A Proposal
Presented to

The Ohio Department of Transportation

Proposing Agency:
The University of Toledo University Transportation Center

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Implementation Background

The Veteran’s Glass City Skyway (VGCS) is a large cable-stayed bridge in Toledo, Ohio. It went into service in the summer of 2007. Under some winter conditions, ice forms on the stay cables. Ice accumulation can be up to approximately 3/4” thick and ice conforms to the cylindrical shape of the stay sheath. As the stays warm, they shed the ice in curved sheets that fall up to two hundred and fifty feet to the roadway. Due to their aerodynamic shape, these sheets can be blown across several lanes of the bridge deck and sometimes off of the bridge into the river. The falling ice sheets could present a potential hazard to the travelling public.

The Ohio Department of Transportation manages these icing events by closing lanes or the bridge as appropriate. To assist the operators in making these decisions, a real-time icing monitor, referred to as the “ice dashboard” was developed and a local icing weather station was installed on the VGCS. The dashboard integrates the local sensor information, regional weather and historical icing behavior of the bridge in a graphical manner that puts key information for managing icing events at the operators’ fingertips. Since its inception, ODOT operations has routinely used the dashboard to aid in making decisions about managing icing events.

The dashboard has been in service, hosted at the University of Cincinnati, since the winter of 2010-2011. The capabilities of the dashboard have been continuously upgraded since it was originally deployed. Thermistors to measure the stay temperature and a dedicated camera to monitor icing were added prior to the winter of 2012-2013. Prior to the winter of 2013-2014, a weather tower with an icing detector, tipping rain bucket, leaf wetness sensor and a sunshine indicator was installed.

There are two immediate issues with the present dashboard and sensor suite:

i. The dashboard has been transferred to the district in a stand-alone configuration. This has several implementation shortcomings from an operational perspective: ODOT needs to gain familiarity with the IT aspects of operating the dashboard and the current configuration does not have the interconnectivity, ability to grow as weather events occur, and transparency and flexibility to make it as robust as ODOT desires.

ii. The sensor suite cannot directly detect the presence and state of ice on the stay.

In the long-run, to be effective in aiding the operators to make better decisions about managing icing events, the dashboard must be used and become a part of the culture of protecting the traveling public in an icing event. In addition, it must be hosted in an economical manner.

This proposal is divided into two parts. Part 1 addresses the implementation of the dashboard. Part 2 addresses the implementation of an ice presence and state sensor and a thickness sensor.
Part 1: Implementation

1.0 Implementation Objectives

The objective of this proposal is to locate and configure the dashboard app to maximize the utility to the operators of the VGCS. It is desired to do this as quickly as possible while maintaining the functionality of the dashboard through the upcoming winters of 2014-2015 and 2015-2016. District 2 has defined the requirements that the dashboard meet at the end of this project.

To improve the stand-alone dashboard, ODOT has requested an upgrade to the stand-alone system to revert it back to a web-based app to be hosted on ODOT servers in District 2. In particular, ODOT has requested a software app meeting the following requirements:

1. The entire system to be server-based, either on a virtual server or actual hardware.
2. Automation of the services on the system (rather than manually starting it up).
3. Ability to have multiple people access the system at the same time.
4. Utilize ODOT’s mail system to send notification emails.
5. Have the build documentation, software licenses, and system requirements provided to ODOT.
6. Users would be able to utilize a web browser on their computer to access the system.

At the end of this implementation proposal, ODOT should have a flexible functional tool for assisting in the management of icing events on the VGCS. This will provide a solid foundation for determining the how to operate and maintain the dashboard functionality most important to ODOT in the long term.

1.1 Implementation Work plan:

The tasks necessary to achieve the objectives in a manner that insures the desired functionality are described below. Basically, it is envisioned that the dashboard will be restored to full functionality and hosted by the University of Cincinnati in the winter of 2014-2015. Then in the spring of 2015 work to migrate the dashboard to ODOT servers will begin. The migration should be complete by the beginning of winter 2015-2016. In the winter of 2015-2016, the dashboard will be operated out of D02 and mirrored by UC. This will facilitate debugging and ensure functionality throughout that winter.

Charles Ryerson and Kathy Jones of the U.S. Army Cold Regions Research and Engineering Laboratory and Ted Zoli of HNTB have agreed to consult at no cost on the implementation of the dashboard. This is an expression of the national significance of the work.
Task 1.1 – Revive and reinstate the icing monitor website hosting and maintenance at UCII labs.

For the coming weather season, University of Cincinnati Infrastructure Institute (UCII) will reinstate the VGCS Icing Monitor on its servers (with its associated webpage and automated alarm system). The stand-alone system in ODOT DO2 will be turned off in order to avoid datalogger conflicts. This will provide several advantages:

• It will allow UCII researchers to revive the web based monitor platform, which is currently not operational.

• This configuration is necessary for continued development by UCII researchers in order to migrate the application software to ODOT servers in a methodical manner as described below in Task 1.3.

• It will give ODOT the multi-user, web browser-based access as they had before in past seasons and provide a stable monitor platform complete with backups for the coming weather season.

Task 1.2 - Undertake the software modifications necessary to migrate the monitor to an ODOT virtual server based system.

Under this task UCII researchers would work with ODOT IT officials to make the modifications necessary to transition the icing monitor software to either virtual or physical hardware on the ODOT network. The basic functionality of the monitor will remain the same as originally making use of weather data from sensors located at the bridge, RWIS and local airports. The airport data will be obtained from Weather Underground. The web application will be configured, as it was before, to have a single username and password logon and will allow up to 12 simultaneous users.

The existing software, developed in a Linux environment, needs to be modified to operate under the Windows OS preferred by ODOT. The software will also be modified to meet/fit the hardware and software specifications, as listed below, which have been discussed with IT personnel in ODOT DO2. It is assumed that up to a dozen users could be active at a time.

Hardware Specifications:

Processor: Dual core or more, > 2GHz
RAM: > 6GB
System Type: 64-bit
Gigabit connectivity between servers.
Network access to the Internet

The hardware configuration should consist of 3 machines running inside the ODOT network (one running the database and LoggerNet, one serving as a database (DB) backup/hot
spare, and one serving as a web server). Additional machines could be brought up as web servers in the event a large number of users need to be serviced. The database machine must have at least the hardware specifications as listed above. The Web and Backup machines can have less RAM. This proposal assumes ODOT will provide these 3 machines and any other hardware that ODOT requires for hosting the website.

Note that the Python, MySQL, and PHP packages are open source and do not require any licensing or fees. This proposal assumes that use by ODOT is in compliance with the end user licensing agreements for these packages. The LoggerNet software will be purchased by UCII and provided to ODOT as part of this proposal. For any software purchased, the licensing documentation will be given to ODOT. This proposal assumes ODOT will provide all necessary Windows 7 Enterprise software and any other software that ODOT requires for hosting the website.

Note that no other hardware or software specifications or requirements have been discussed nor considered in this proposal; further, no internal ODOT IT policies or requirements have been discussed nor considered in this proposal or its budget.

These system requirements have been discuss with ODOT District 2. District 2 has confirmed the existing hardware infrastructure will accommodate the three virtual servers needed for implementation. And, the operating systems will be covered by ODOT’s licensing agreements.

**Task 1.3 - Migrate software to ODOT servers piecewise while mirroring on UC servers to ensure reliable operation.**

After this coming winter (and before the next winter), it is anticipated that the software developed and debugged on UCII servers under Task 3, would be migrated over to ODOT servers in a piecewise manner to ensure its working order and reliable operation.

At the completion of this task all of the functionality (and associated software) of the dashboard will be operating on the ODOT DO2 server system. UCII will monitor the system for correct and reliable operation during the piece-wise transition through the end of the contract. UCII will also conduct all necessary software maintenance, excluding ODOT specific software, through the end of the contract. UCII will be available on an hourly rate basis after the completion of this proposed contract period for additional maintenance and upgrade activities. As an alternative, ODOT may opt to extend this contract via Task 6 as they see fit.

Note that:

- All migration, troubleshooting, and maintenance would require VPN or a port forwarded in the firewall to access the ODOT machine(s) to provide UCII researchers remote access.
Researchers will need an ODOT mail account set up in order to handle transmission of icing alerts. The current system sends notifications via Gmail.

During the software development and migration activities listed under Tasks 3 and 4, UCI will run the web application on our servers next winter to guarantee uninterrupted icing detection.

It is anticipated that Tasks 1.3 and 1.4 will take several months to complete. As a result, the icing monitor will not be completely migrated and fully operational on ODOT servers until after the coming 2014-15 weather season. During the coming season, the monitor would be available as outlined in Task 1 on UCII servers.

Task 1.4 – Develop and deliver build documentation for the software package.

The research team will develop and formally submit a project final report complete with executive summary at the completion of the contract. This report will fully describe the activities undertaken on the project as required of all ODOT research projects. It will include documentation of the software migration. Note that no other internal ODOT IT policies or requirements regarding software documentation have been discussed nor considered in this proposal or its budget.

The final report will included a recommendation or options with projected costs for the operation of the dashboard for the five years after the end of this project.

1.2 Alternate Implementation Option

As a potential alternate to ODOT hosting the monitor, the research team was asked to consider continuing to host the monitor. The research team is prepared to continue operation and maintenance of the monitor (including hardware and software components) for an extended period of time as needed by ODOT while IT issues are ironed out or as otherwise necessary. This task would include management and maintenance of the backend software to collect data from the bridge site, database software for archival of all data records, and frontend software to manage the website and graphical user interface. It will also include hosting of the website on UCII servers and maintenance of the automated alarm system. This task is NOT included in the associated budget but would cost $36,000/year and would require an appropriate change to the end date of the contract.

1.3 Benefits of Implementation

The operators of the VGCS need to make difficult operating decisions concerning lane and bridge closure to protect the public during a hectic time under the adverse conditions of an icing event. To make these decisions, they need to know the icing state of the stays. Is ice accumulating? Is existing ice a hazard to fall? When? The proposed implementation of the
dashboard has immediate and long-term benefits for helping ODOT protect the public and ODOT personnel.

Restoring the full functionality of the dashboard protects the public and ODOT staff and facilitates internal communication in ODOT concerning the state of icing. To protect ODOT personnel, the determination of the icing state of the stays should be able to be made with a minimum of manual observation of the stays. Each manual observation puts ODOT personnel in live traffic during icy conditions. By integrating the regional weather, sensors on the bridge, historical icing behavior and displaying the information in a user-friendly format, the dashboard makes it possible for the operators to make more accurate decisions while minimizing the exposure of ODOT personnel to traffic. During the winters the dashboard has been functional, the D02 highway administrator has routinely followed the dashboard throughout icing events. This has helped the administrator understand the progress of an event and communicate effectively with the shift supervisors.

This migration will put the dashboard directly under ODOT control. Historically, there have been approximately two damaging icing events in the vicinity of the VGCS each year. This means ODOT needs to have a long term strategy for collecting and understanding the information necessary to manage these events. Moving the dashboard to ODOT servers and building it in to the ODOT culture is a reasonable part of that strategy.

In the long term, it will help ODOT to manage icing events if
i. The dashboard remains fully functional
ii. Changes in software and maintenance/upgrade of hardware occur periodically as necessary when the input sources change and the hardware ages.
iii. The dashboard algorithms can be improved as the bridge experiences more icing events. The dashboard with the local sensors on the bridge has not yet experienced a major icing event. When this event occurs, the dashboard algorithm will have improved performance if revised to reflect the new knowledge.

The present proposal lays the foundation for meeting these long term needs by getting the operation and control of the dashboard into the hands of the ODOT personnel to whom its function is most critical.

1.4 Implementation Budget and Justification

The attached budget is laid out so the expenses related to implementation are covered in the main body of the budget. The dashboard software was developed by UCII and consistent with this the main expense in the implementation is labor by UCII. UT personnel will provide support and on site observation to validate the performance of the dashboard throughout the winters. A detailed breakdown of the UCII budget is proved in the appendix.
The PI and Co-PIs (Profs. Nims, Helmicki, Hunt, Ng and Talaga) will play key roles in managing the research effort. They will be responsible for directing the activities of the other research organizations as well as the UT-UTC research personnel. Prof. Nims will manage and coordinate the research direction, participate in interpreting the results, lead in communicating with ODOT officials, etc.

The primary implementation research staff consisting of 1 TBN graduate student will assist in conducting all software development, testing, migration and report preparation.

$3,000 is included in the implementation budget to cover travel to and from Toledo, OH, as well as to cover the cost of overnight stays during the periods of intensive field operations and the meetings. Based on previous experiences, it is estimated that the average cost for travel (van rental, food, hotel, etc.) is roughly $1000 per day. Three one-night trips have been budgeted. This travel may also/alternatively include trips to ODOT Headquarters in Columbus, OH for technical meetings with IT personnel there.

$5,600 is budgeted for expendable supplies needed to conduct the software development portion of the research, including:

- Software and storage media for data, development, etc., based on experience, totaling $2,500.
- Maintenance and upkeep of existing UCII lab equipment (data loggers and accessories for the monitor, servers, etc.), based on experience, $2,500.
- Purchase of Campbell Scientific LoggerNet 4.2.1 for Windows, $600.

The implementation budget estimates assume that ODOT will provide all hardware and Windows software as well as remote access needs as outlined above. Finally, note that any costs associated with the optional alternate implementation are NOT included in these budget tables. Any extended hosting of the icing monitor system at UCII beyond this proposal would lead to additional costs. Similarly, any additional requirements on or changes to software, hardware, access, or documentation beyond this proposal would lead to additional costs.
1.5 Implementation Schedule

![Implementation Schedule Diagram]

**Figure 1: VGCS Ice Prevention or Removal - Dashboard Migration and Senior Development and Deployment**
Part 2: Ice Presence, State and Thickness Sensors Implementation

2.0 Sensor Implementation Objective

The objective of the sensor development is to develop and deploy sensors to measure the ice presence, state and thickness on the VGCS.

The state of the ice is the temperature and wetness of the ice as well as the flow of water between the ice and the sheath. This flow of water is a precursor of imminent ice shedding. The presence of liquid water breaks the bond between the ice and the stay surface. If the ice is thin (less than ¼ inch), the surface adhesion is enough to hold the ice in place. Therefore, thin ice simply melts and runs down the stays. This was observed several times in March of 2011. If the ice is thicker than ¼ inch, it can rotate off the stay and shed. A resistance based ice presence and state sensor that mounted directly on the stay has been developed, tested in the laboratory and tested outdoors at the UT Scott Park Icing Facility. It has been tested on both the VGCS sheath specimens and HDPE specimens. This sensor is ready for a trial deployment on the VGCS.

Optical and ultrasonic based thickness sensors have been researched and experimented with in the laboratory and at the Scott Park Icing Facility. Both have been found to perform satisfactorily. They are ready for deployment on the bridge. Deployment of the optical sensor is believed to be more advantageous because of its broader capabilities.

2.1 Sensor Implementation Tasks

These tasks address the need to develop and deploy sensors that measure the state, thickness and persistence of ice on the stays.

Charles Ryerson and Kathy Jones of the U.S. Army Cold Regions Research and Engineering Laboratory and Ted Zoli of HNTB have agreed to consult at no cost on the sensor implementation.

Task 2.1 – Deploy the ice presence and state sensor of the VGCS for the winter of 2014-2015.

Four sensors would be mounted on the stay near the icing weather station. Depending on cost and available connections the data would be collected manually or via an internet connection. Because the Goodrich Ice Detector already deployed on the VGCS, detects the accretion of ice, manual collection of data is not as problematic as it may first appear. The system could be on a continuous loop through a data logger and the data need only be recovered when icing occurs.
Task 2.2 – Carry out laboratory and field station tests on the icing presence and state sensors.

Icing events on the bridge are rare. It has been demonstrated that icing events can be simulated at the field station. Tests would be carried out there through the winter to assess the performance of the sensors. Laboratory tests and developmental work will be carried out based on the field tests.

Task 2.3 – Deploy either the optical or ultrasonic thickness sensor on the bridge.

The optical sensor is the simplest and most versatile. Therefore, it is the preferred sensor for deployment.

For the optical sensor, the camera and illuminating laser would be mounted on the existing icing weather tower. An optical target would be mounted on the stay. No attachment to the stay is anticipated to be necessary in the long run. However, an attachment is useful for validation purposes in the initial trials.

As with the presence and state sensor, data would be collected through a manual data logger or via the web.

Task 2.4 – Carry out laboratory and field station tests on both the optical and ultrasonic thickness sensors using the VGCS specimens.

The experimental versions of both sensors have been built and would be used throughout the winter on simulated icing events. For the ultrasonic sensors the testing will primarily be addressed at clarifying the operating envelope. For the optical sensor, the task is primarily aimed at identifying the distances over which it can be accurate. It is expected that the optical sensors will be able to look at several stays and be accurate when the camera is over 30 feet from the stay.

Task 2.5 – Integrate the ice presence and state sensor and the thickness sensor into the dashboard.

In the field testing in 2014-2015, if practical, UCII would assist in getting the data from the new sensors to the internet. This would eliminate the need to have a manual data collection system on the bridge for these sensors.

If the field testing in the winter of 2014-2015 validates the performance of the sensors, they will be permanently deployed and integrated into the dashboard in the winter of 2015-2016. UCII would assist in upgrading the sensor installation and interfacing. They will also make the data from the ice presence and state sensor and the thickness sensor available on the web or through a server to UT. The new sensors would be incorporated into the ice accretion and shedding algorithms in the dashboard.
Task 2.6 – Write Final Report

Sections of the final report will discuss the implementation of the sensors, their operating envelops, behavior in the lab and field trials and the integration into the dashboard algorithms.

2.2 Icing Presence and Sensor Specifications and Warranty

If the sensors perform as anticipated during the field and experimental station testing during the winter of 2014-2015, the deployed sensors will have the following specifications.

The ice presence and state sensor will be able to detect whether the water in contact with the sensor is ice or liquid. It will be able to detect the temperature of the solid or liquid water in contact with the sensor with 1 degree centigrade. It will be able to detect the presence of water at the interface between the ice and the sheath.

The optical thickness sensor will be able to detect the thickness of ice or snow on the stay to within 0.10 inch when the camera and illuminating laser are up to 30 feet from the stay.

The sensors will be under warranty for one year from installation

2.3 Benefits of Sensor Implementation

The water flowing between the ice and the sheath is an indicator that shedding may be imminent. The thickness of the ice on the stay determines whether the ice sheds or melts in place. Since the ice persists on the stays, its thickness varies throughout an icing event. Some of the ice melts or sublimates. Sometimes, additional precipitation increases the thickness of the ice. In some instances, an ice-snow sandwich with the potential of shedding has collected on the stays.

These circumstances suggest that sensors that measure the state and presence and the thickness of the ice would provide valuable information to the VGCS operators. Because no commercial sensors that generally fulfills these needs is available, no such sensors were procured to be installed on the local weather tower. Therefore, the existing local weather station on the bridge does not directly report the presence and state of ice on the stay nor does it directly report the thickness of the ice.

The research team has made progress developing sensors that meet these needs. The presence and state sensor mounts directly to the stay and detects the presence of water under the ice and the persistence of the ice. The thickness sensor measures the thickness of the ice layer. Installing these sensors and incorporating their input into the dashboard will improve the utility of the dashboard to the bridge operators.
2.4 Sensor Implementation Budget and Justification

The attached budget is laid out so the expenses related to sensor implementation are included in the other expenses portion of the budget. The work will be primarily carried out at UT. UT is well positioned to do this work because they have an icing wind tunnel, laboratories in which icing work is conducted and an icing experiment station with full scale specimens of the VGCS stays. The proximity of UT to the VGCS makes the climate very similar and makes it easy to collect data manually from a datalogger if required.

The ODOT share of the budget is $55,276.83 and the UT cost share is $57,273.86 for a total budget of $112,550.69. The cost share comes primarily from academic year effort by Drs. Ng and Nims and under recovery of F & A on the subcontractor contract (There is no F & A charged by UT on the UC subcontract.). An overview of the ODOT share of the expenses is provided below.

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<td></td>
</tr>
</tbody>
</table>

The PI and Co-PIs (Profs. Nims and Ng) will play key roles in managing the sensor implementation effort. They will be responsible for directing the activities of the other research organizations as well as the UT-UTC research personnel. Prof. Nims will manage and coordinate the research direction, participate in interpreting the results, lead in communicating with ODOT officials, etc.

The primary implementation research staff consisting of 2 TBN graduate students who will assist development, testing, report preparation.

$490 is budgeted for expendable supplies
2.5 Sensor Implementation Schedule

![Dashboard Migration and Sensor Development and Deployment](image)

- Task 2.1: Support Sensor Deployment
- Task 2.2: Deploy Ice Presence and State Sensor
- Task 2.3: Icing Experiment Station Ice Sensor
- Task 2.4: Deploy Ice Thickness Sensor
- Task 2.5: Icing Experiment Station Thickness Sensor
- Task 2.6: Integrate Sensors into Dashboard
- Task 2.7: Write report.
- Quarterly reports

Original Schedule
Actual Progress
Current Schedule
Ice Prevention or Removal on the Veteran’s Glass City Skyway Cables

Upgrade of Icing Monitor for ODOT District 2

Bridge No. LUC-280-0283

A Proposal
Presented to

University of Toledo
and
Ohio Department of Transportation

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September 2014
1. Project Background and Implementation Goals

The Veterans' Glass City Skyway (VGCS), is a cable-stayed type bridge with a single pylon and two spans 612'-6" (200 m) on each side of the pylon. Its stainless steel sheathing offers aesthetic and life cycle cost advantages over other materials; however, there have also been other unexpected results. Specifically, ice accumulates on the stays, which presents safety issues for the motorists traveling below. When this occurs, the department must close lanes in each direction until the ice is gone.

Working with the University of Toledo and a team of weather experts, the University of Cincinnati Infrastructure Institute (UCII) developed a web application to track weather and icing conditions and act as an icefall dashboard warning-alert system. This application takes the form of a dashboard populated with weather data from various sources including:

1. Four nearby RWIS stations,
2. Two nearby Toledo airports in Toledo, and
3. A suite of sensors installed at the VGCS bridge site.

This weather data is archived off as well as processed thru a series of algorithms designed to gage the potential for ice accretion and shedding. The results of this processing are displayed on the dashboard in a user friendly manner. Transportation officials are also notified automatically via email of any important status changes.

The dashboard was initially implemented in January of 2011 and has undergone several upgrades and modifications as lessons were learned by the team. Several icing events were successfully captured and monitored, and the immediate determination of ice conditions present at and/or nearby the bridge have been useful to ODOT DO2 officials in order to make decisions about any responses necessary to manage the structure during severe weather events.

The dashboard is shown below in Figures 1a and 1b. Current icing conditions are summarized in an easy-to-read speedometer style gauge. The last 48 hours of states or conditions are also shown below the gauge in a ticker. A Report button can be used by officials to report weather to a blog found on the History tab. The dashboard also summarizes the status of connections to the various data sources. Additional tabs in the application allow access to a map-based view of the data (Figure 1b) as well as access to historical data and application documentation.

![Figure 1a: VGCS Ice Monitor Dashboard Web application.](image-url)
The basic software process involves users to UCII through custom, multiple users. The system’s back-end software, responsible for connecting to the data sources and collecting, cleansing and processing the input data via the icing algorithms. The raw weather data and key processed icing variables are then passed on to be stored/archived in the database. The front-end software operates the graphical user interface displaying the system status (as per Figure 1) and allowing users to interface with the data through functions like plotting, exporting, etc.

UCII operated and maintained this icing system on its lab servers in Cincinnati, OH from Jan 2011 thru April 2014. Under this arrangement the application was available to ODOT via a custom, password protected, website and accessible by web browser anytime, anywhere. Multiple users could sign on simultaneously and interact with the system.

The existing contract ended in June 2014. In order to transition operation of the application to ODOT, UCII developed a local, stand-alone monitor for the VGCS bridge which was installed...
on a dedicated PC housed in ODOT District 2 offices. This monitor includes the software and functionality necessary for all three aspects of the monitor’s operation discussed above (backend, database, and front-end). This standalone system was installed at the ODOT DO2 Northwoods facility in early June 2014. The standalone system has some substantial limitations compared to the web application originally hosted at UCII:

1. It can only be used on the dedicated PC by one user at a time,
2. The standalone PC must remain powered and connected to the internet, and running in good condition in order for the icing monitor to be maintained operational. Interruptions in power or connectivity could lead to spurious monitor status reporting.
3. The standalone system is not robust to API or FTP changes in bridge or weather data from Weather Underground or outgoing email warnings via SMTP.
4. The standalone system does not incorporate automated system and data backups.

In response to these, ODOT has requested an upgrade to the standalone system to revert it back to a web application to be hosted on ODOT servers in DO2. In particular, ODOT has requested a software application meeting the following requirements:

1. The entire system to be server based, either on a virtual server or actual hardware.
2. Automation of the services on the system (rather than manually starting it up).
3. Ability to have multiple people access the system at the same time.
4. Utilize ODOT’s email system to send notifications.
5. Have the build documentation, software licenses, and system requirements provided to ODOT.
6. Users would utilize a web browser on their computer to access the system.

The tasks necessary to achieve these requirements are outlined in detail in the following section. The software, hardware, and access requirements needed to complete these tasks have been discussed with ODOT IT officials in District 2. In the scope of work below, it is assumed that the software, hardware, and access requirements can be met. Changes in these will require a change in scope and will be addressed as/if needed in an amendment to this proposal.

2. Scope of Work

Task 1 – Revive and reinstate the icing monitor website hosting and maintenance at UCII labs.

For the coming weather season, UCII will reinstate the VGCS Icing Monitor on its servers (with its associated webpage and automated alarm system) in Cincinnati. The standalone system in ODOT DO2 will be turned off in order to avoid any datalogger communications conflicts or data loss. This will provide several advantages:

- It will allow UCII researchers to revive the web based monitor platform, which is currently not operational.
- This configuration is necessary for continued development by UCII researchers in order to migrate the application software to ODOT servers in a methodical manner as described below in Task 3.
It will give ODOT the multi-user, web browser-based access as they had before in past seasons and provide a stable monitor platform complete with backups for the coming weather season.

**Task 2 - Undertake the software modifications necessary to migrate the monitor to an ODOT virtual server based system.**

Under this task UCII researchers would work with ODOT IT officials to make the modifications necessary to transition the icing monitor software to either virtual or physical hardware on the ODOT network. The basic functionality of the monitor as discussed briefly above under Figures 1 and 2 will remain the same making use of weather data from sensors located at the bridge, RWIS and local airports. The airport data will be obtained from Weather Underground. The web application will be configured, as it was before, to have a single username and password logon and will allow up to 12 simultaneous users.

The existing software, developed in a Linux environment, needs to be modified to operate under the Windows OS preferred by ODOT. The software will also be modified to meet/fit the hardware and software specifications, as listed below, which have been discussed with IT personnel in ODOT DO2. It is assumed that up to a dozen users could be active at a time.

**Hardware Specifications:**
- Processor: Dual core or more, > 2GHz
- RAM: > 6GB
- System Type: 64-bit
- Gigabit connectivity between servers.
- Network access to the Internet

**Software Specifications:**
- Campbell Scientific LoggerNet 4.2.1
- Python 2.7 (open source)
- MySQL >= 5.6 (open source)
- PHP >= 5.3, Apache >= 2.4 (open source)
- Operating Systems: Windows 7 Enterprise

The hardware configuration should consist of 3 machines running inside the ODOT network (one running the database and LoggerNet, one serving as a database (DB) backup/hot spare, and one serving as a web server). Additional machines could be brought up as web servers in the event a large number of users need to be serviced. The database machine must have at least the hardware specifications as listed above. The Web and Backup machines can have less RAM. This proposal assumes ODOT will provide these 3 machines and any other hardware that ODOT requires for hosting the website.

Note that the Python, MySQL, and PHP packages are open source and do not require any licensing or fees. The LoggerNet software will be purchased by UCII and provided to ODOT as part of this proposal. This proposal assumes ODOT will provide all necessary Windows 7 Enterprise software and any other software that ODOT requires for hosting the website.

Note that no other hardware or software specifications or requirements have been discussed nor considered in this proposal; further, no internal ODOT IT policies or requirements have been discussed nor considered in this proposal or its budget.
Task 3 - Migrate software to ODOT servers piecewise while mirroring on UC servers to ensure reliable operation.

After this coming winter (and before the next winter), it is anticipated that the software developed and debugged on UCII servers under Task 3, would be migrated over to ODOT servers in a piecewise manner to ensure its working order and reliable operation.

At the completion of this task all of the functionality (and associated software) as shown in the grey box in Figure 2 will be operating on the ODOT DO2 server system. UCII will monitor the system for correct and reliable operation during the piece-wise transition through the end of the contract. UCII will also conduct all necessary software maintenance, excluding ODOT specific software, through the end of the contract. UCII will be available on an hourly rate basis after the completion of this proposed contract period for additional maintenance and upgrade activities. As an alternative, ODOT may opt to extend this contract via Task 6 as they see fit.

Note that:

- All migration, troubleshooting, and maintenance would require VPN or a port forwarded in the firewall to access the ODOT machine(s) to provide UCII researchers remote access.
- Researchers will need an ODOT mail account set up in order to handle transmission of icing alerts. The current system sends notifications via Gmail.
- During the software development and migration activities listed under Tasks 3 and 4, UCII will run the web application on our servers next winter to guarantee uninterrupted icing detection.
- It is anticipated that Tasks 3 and 4 will take several months to complete. As a result, the icing monitor will not be completely migrated and fully operational on ODOT servers until after the coming 2014-15 weather season. During the coming season, the monitor would be available as outlined in Task 1 on UCII servers.

Task 4 – Develop and deliver documentation for the software package.

UCII shall work with the rest of the research team to develop and formally submit a project final report complete with executive summary at the completion of the contract. This report will fully describe the activities undertaken on the project as required of all ODOT research projects. It will include documentation of the software migration. Note that no other internal ODOT IT policies or requirements regarding software documentation have been discussed nor considered in this proposal or its budget.

Task 5 (Optional) – Host VGCS Icing Monitor at UCII for an extended period of time.

UCII is prepared to continue operation and maintenance of the monitor (including hardware and software components) for an extended period of time as needed by ODOT while IT issues are ironed out or as otherwise necessary. This task would include management and maintenance of the backend software to collect data from the bridge site, database software for archival of all data records, and frontend software to manage the website and graphical user interface. It will also include hosting of the website on UCII servers and maintenance of the automated alarm system. **This task is NOT included in the associated budget but would cost $36,000/year beyond the work outlined in Task 1 above and would require an appropriate change to the end date of the contract.**
Task 6 – Enhanced sensor installation and interfacing.

This task will run in support of University of Toledo’s Tasks 7-11 as outlined in Part 2 of its proposal. It will facilitate deployment of UT’s sensors on the bridge by making the data from the ice presence and state sensor and the ice thickness sensor available on the web or through a server to UT. This would eliminate the need to have a manually data collection system on the bridge for these sensors and allow the sensor information to subsequently be integrated into the Icing Monitor Dashboard.

3. Budget

The tables on the following pages represent the budget that has been estimated for the activities proposed herein. The budget estimates assume that ODOT will provide all hardware and Windows software and remote access needs as outlined in section 2 above. Finally, note that any costs associated with optional Task 5 are NOT included in these budget tables. Any extended hosting of the icing monitor system at UCII beyond this proposal would be additional costs. Similarly, any additional requirements on or changes to software, hardware, access, or documentation beyond this proposal would be additional cost.

The PI and Co-PIs (Profs. Helmicki, Hunt, and Talaga) will play key roles in managing the research effort. They will be responsible for directing the activities of the other research personnel as well as managing/ coordinatimg the research direction, interpreting results, communicating with ODOT officials, etc.

Note that UC does not accumulate salary expenditures based on labor hours. Our payroll system accumulates effort based on a percentage of FTE (full time equivalents).

The research staff consisting of 1 TBN graduate students will assist in conducting all software development, testing, and migration, and report preparation.

$3,000 is budgeted to cover travel to and from Toledo, OH, as well as to cover the cost of overnight stays during the periods of intensive field operations and the meetings. Based on previous experiences, it is estimated that the average cost for travel (van rental, food, hotel, etc) is roughly $1000 per day. Three one-night trips have been budgeted for. This travel may also/alternatively include trips to ODOT Headquarters in Columbus, OH for technical meetings with IT personnel there.

$5,600 is budgeted for expendable supplies needed to conduct the software development portion of the research, including:

- Software and storage media for data, development, etc., based on experience, totaling $2,500.
- Maintenance and upkeep of existing UCII lab equipment (data loggers and accessories for the monitor, servers, etc), based on experience, $2,500.
- Purchase of Campbell Scientific LoggerNet 4.2.1 for Windows, $600.