INVESTIGATION OF USING ICEPHOBIC COATINGS ON A CABLE STAYED BRIDGE

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Outline

- Icing problem
- Veterans’ Glass City Skyway Bridge and Icing
- Anti/de-icing technologies and selection
- University of Toledo testing facilities
- Coating testing indoor and outdoor
- Other Anti-/de-icing Techniques
- Real time monitoring system(Dashboard) and sensor development
- Conclusions

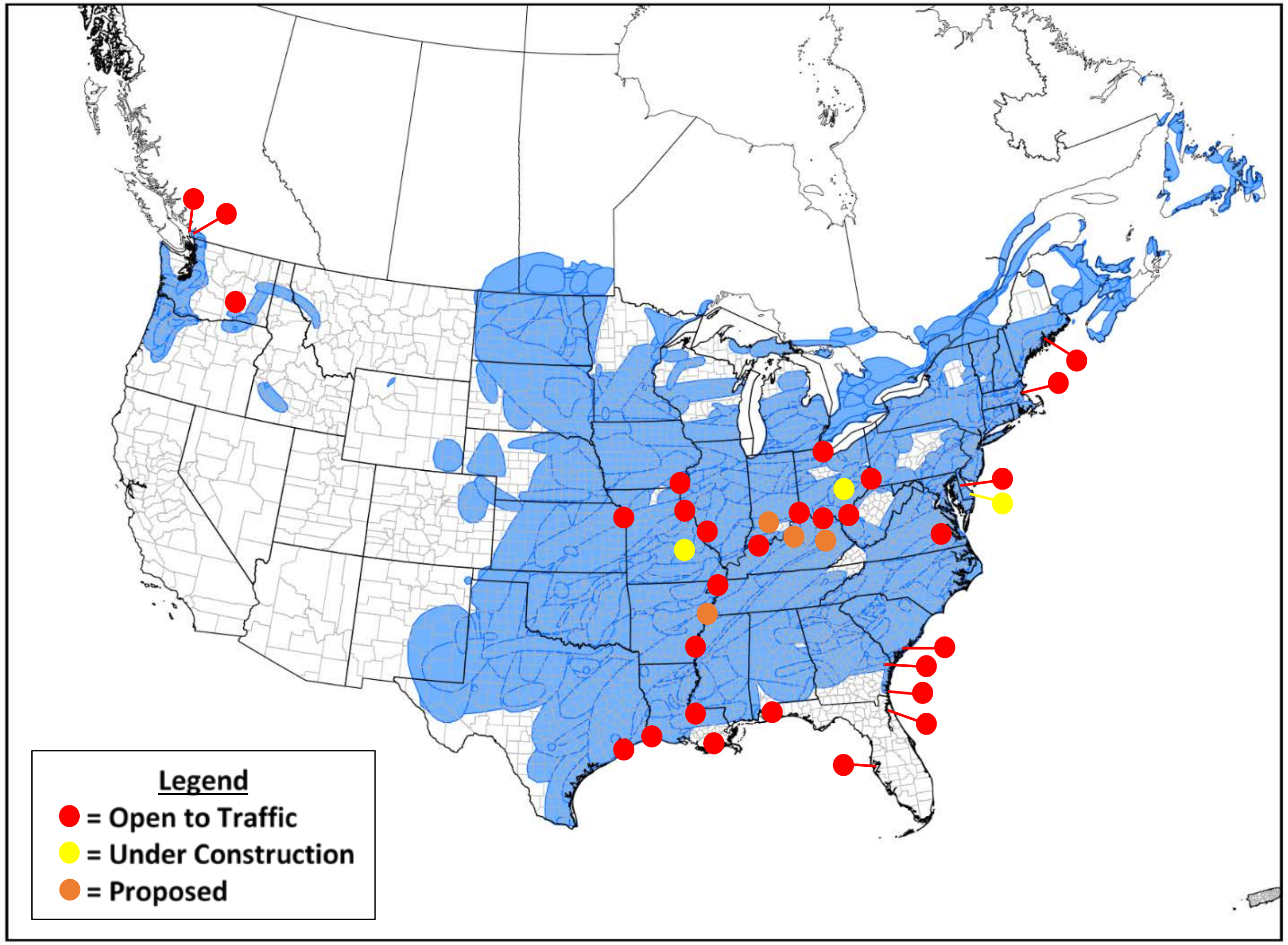
Icing problem

Ice accumulation on the east side of VGCS

Ice accumulation pattern on VGCS stays

Ice shed from the stays

Icing problem



Cable stayed bridges in the United States and lower tier of Canada and map of footprints of damaging ice storms (1946-2014)

Veterans' Glass City Skyway Bridge

- Veterans' Glass City Skyway (VGCS) is a large single pylon cable stayed bridge in Toledo, Ohio, USA with a main span of 375m
- Stay sheaths are brushed stainless steel
- Three lanes of traffic in each direction with average daily traffic count of 50,000
- Owned and operated by the Ohio Department of Transportation (ODOT) and opened to traffic in 2007

Veterans' Glass City Skyway Bridge

Veterans' Glass City Skyway

Veterans' Glass City Skyway's illuminated glass pylon

Veterans' Glass City Skyway Bridge and icing

VGCS Icing Event History

Ice Event	Ice Accretion	Ice Shedding Trigger	Ice Persistence (Days)	No. of Lanes Closed	Damaged Vehicles
Dec 2007	Freezing rain, fog	Rain with temperature above freezing	2	2	Yes
Mar 2008	Snow, rain, fog	Sun with temperature above freezing	1	2	Yes
Dec 2008	Snow, fog; freezing rain, fog	Rain, gusty winds and temperatures above freezing	7	2	No
Jan 2009	Freezing rain, fog	Gusty winds, temperature above freezing	10	1	No
Feb 2011	Freezing rain, clear	Light wind, overcast, and temperature above freezing	4	All	No
Jan 2015	Freezing rain, snow	Gusty winds and overcast, remaining ice sublimated/melted following day when air temperature was above freezing	4	All	No

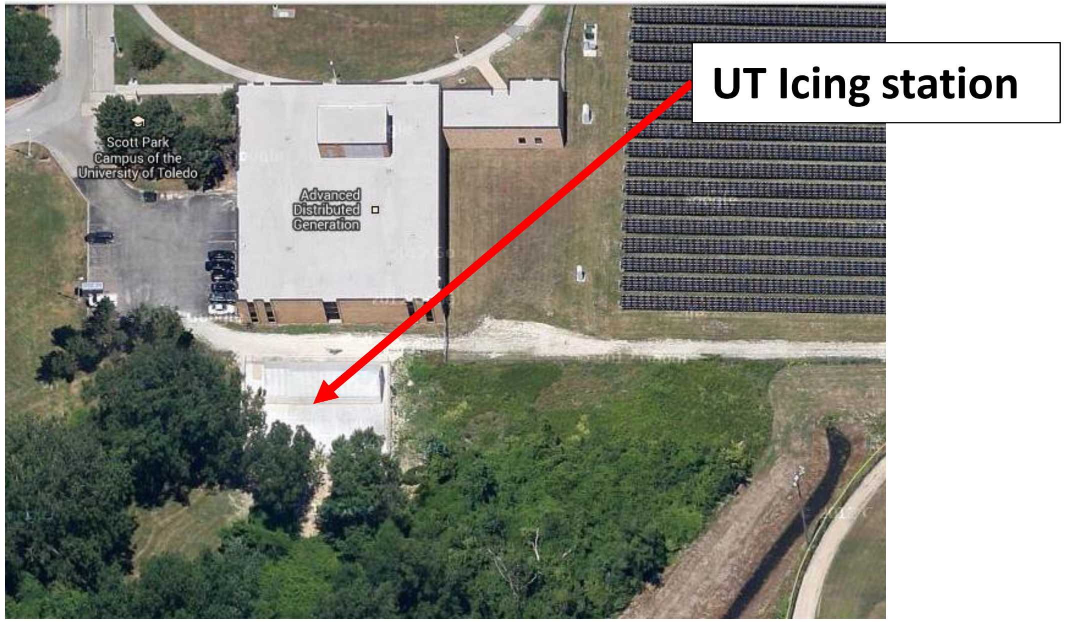
Anti/de-icing technologies

- Broad investigation was conducted to review all the identified anti/de-icing technologies
- Selection of the tested technologies was based on efficiency, cost, and environmental friendliness of each technique
- Three technologies selected
  - icephobic coatings
  - chemicals
  - internal heating
- This study focuses on testing several icephobic coatings

University of Toledo testing facilities

University of Toledo testing facilities

UT Icing Experiment Station



UT Icing experiment station

Three specimens with different orientations

Indoor coating testing

- Three icephobic coatings were tested:
  (1) Aliphatic petroleum distillates with proprietary additives
  (2) Epoxy polymers, silicate mesh with new melt-point-depressants
  (3) Fluorocarbon polymer and aliphatic, moisture-cure, three-part polyurethane
- Air speed was 8.8 m/s and the temperature was -5.5°C
- Misting system to simulate freezing rain
- Three nozzle sizes (40, 42, and 50 microns) to simulate different rain drop sizes
- Test also done for uncoated specimen at the same conditions

Indoor coating testing

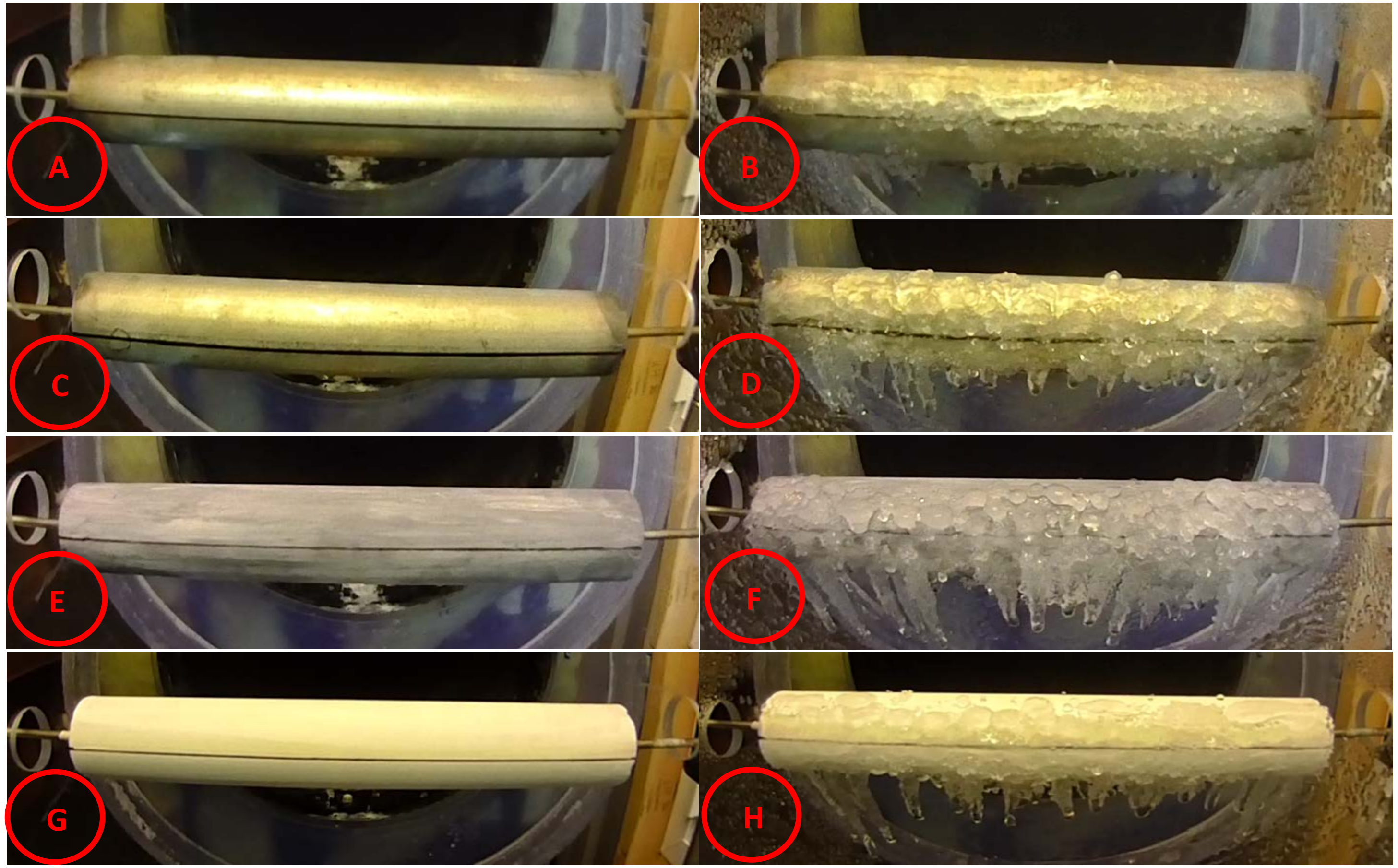
0:00 min | 10:00 min

Uncoated

Aliphatic petroleum distillates with proprietary additives

Epoxy polymers, silicate mesh with new melt-point-depressants

Fluorocarbon polymer and aliphatic, moisture-cure, three-part polyurethane



Indoor coating testing

Ice thickness comparison of ice-phobic coatings and droplet sizes

Coating / Drop size	None	Aliphatic petroleum distillates with proprietary additives	Epoxy polymers, silicate mesh with new melt-point-depressants	Fluorocarbon polymer and aliphatic, moisture-cure, three-part polyurethane
40 micron	6.5 mm	10.0 mm	10.0 mm	8.0 mm
42 micron	5.5 mm	6.5 mm	6.5 mm	9.5 mm
50 micron	5.0 mm	6.5 mm	5.5 mm	9.5 mm

Outdoor coating testing

Aliphatic petroleum distillates with proprietary additives was selected

Aliphatic petroleum distillates with proprietary additives sprayed on half of the specimen

Water droplets due to icephobic coating

Other anti/de-icing techniques

Thermal de-icing/anti-icing (internal heating)

- VGCS stays are hollow with the structural elements occupying 50% of the internal volume
- Internal heating experiments were conducted with 70,000 BTU forced air as a heat source
- Tried as de-icing and as anti-icing technique

Other anti/de-icing techniques

Thermal de-icing/anti-icing (internal heating)

De-icing pattern in thermal test

Accumulated ice in anti-icing thermal test

Other anti/de-icing techniques

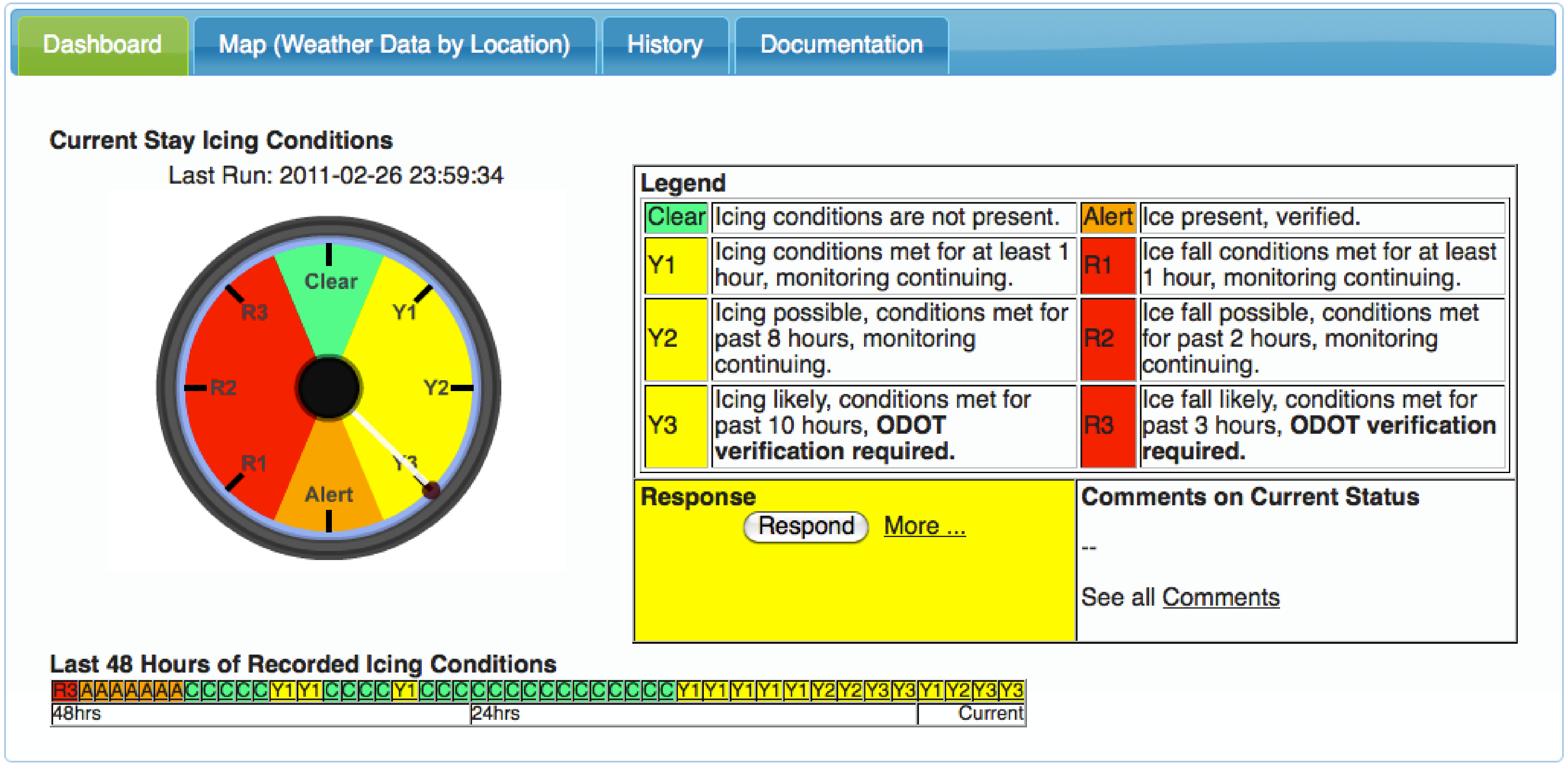
Fluid Chemical De-icer

- Material used was an organic-based fluid made of refined molasses carbohydrate: NaCl, $CaCl_2$, KCl, and $MgCl_2$
- De-icing and anti-icing experiments were conducted
- Did not prevent the ice from accumulating or remove existing ice

Real time monitoring system (Dashboard)

- Automated real time monitoring system built to observe the conditions on the bridge
- Dashboard shows data from the sensors on the bridge (stay temperature, ice accumulation, precipitation, solar radiation) and from local airports and Road Weather Information System (RWIS) stations
- Developed algorithm based on the weather data on the bridge that identifies ice accumulation, ice shedding, and clear conditions

Real time monitoring system(Dashboard)

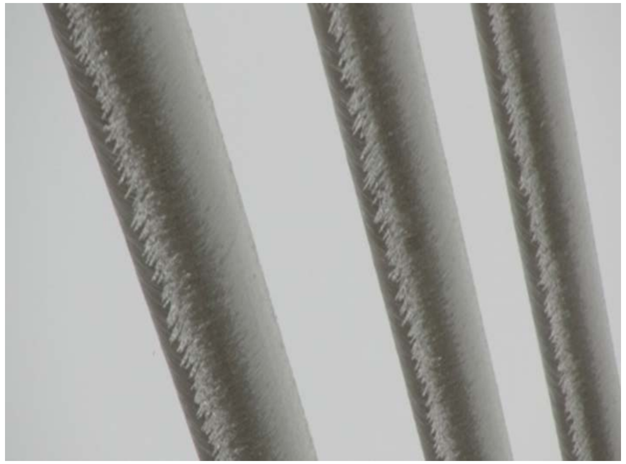


Screenshot of dashboard tab of the monitoring system

Sensor development

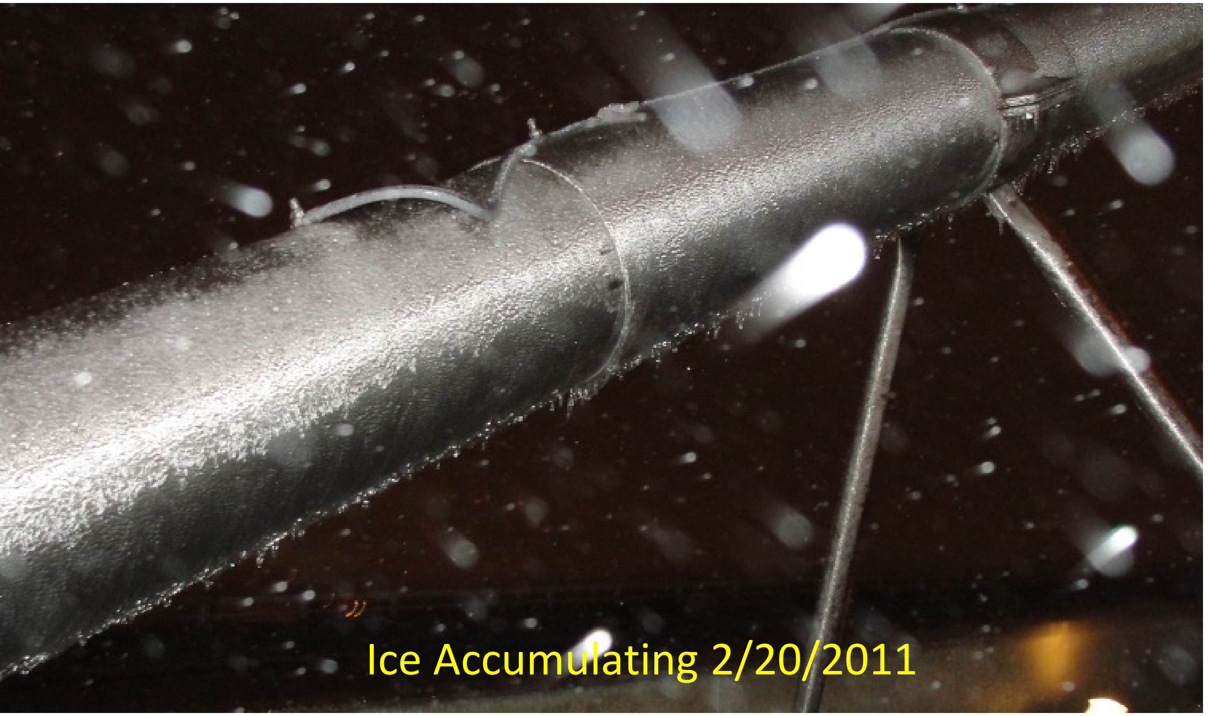
- Two new sensors developed: ice presence and state sensor and ice thickness sensor
- ***Ice presence and state sensor***: resistance based sensor used in conjunction with a thermocouple to detect whether water is present on the stay and if it is liquid or ice
- ***Optical ice thickness sensor***: measures thickness of the ice on the stay with a laser and camera
- These sensors have been tested successfully in the lab and field and will be deployed on the VGCS in winter 2015

Conclusions



- None of the anti-/de-icing techniques were appropriate on the bridge
  - did not prevent icing
  - high cost
  - altered aesthetic features of the stays
  - environmental concerns
- Developed automated real-time monitoring system to obtain the current condition of the stays
- Developed new sensors for ice accumulation and thickness
  - ice presence and state sensor
  - ice thickness sensor

Thank You
Questions?



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