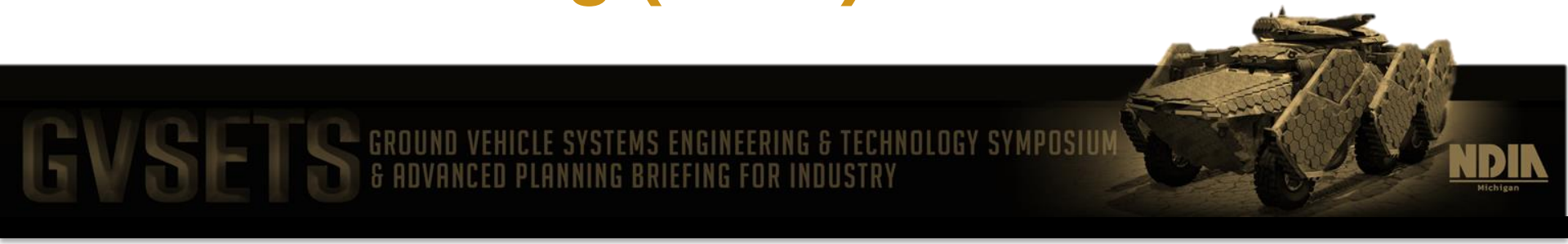
Advanced Materials & Manufacturing (AAM)



Improve LiDAR Performance with UV Durable Hydrophobic Coatings

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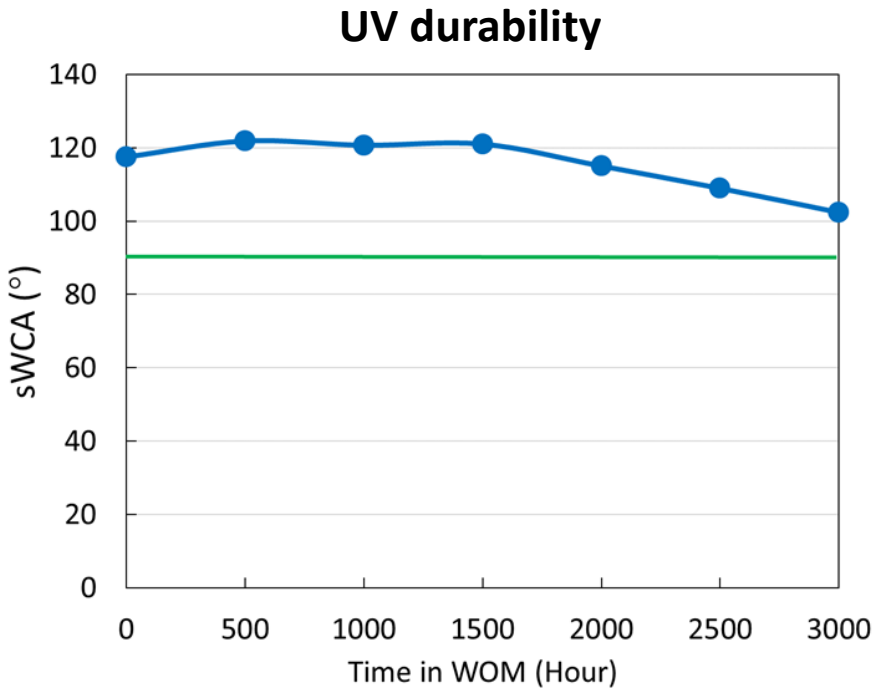
- LiDAR sensors used in autonomous driving solutions
  - Require both a clean and dry sensor screen to operate safely

- Current automatic cleaning system
  - Fluid-jet or ultrasonic vibration to remove debris accumulation
  - Air blow or heating elements to keep the sensor screen dry

UV Durable Hydrophobic (UVH) Coatings

- UV durable hydrophobic self-cleaning coating on sensor screen
  - Reduce the active cleaning cycles and minimize cleaning fluids or energy consumption
  - Repel rain, snow, mud, bug, and other fluids or contaminations on the screen, prevent information distortion during driving
  - Performance permanence

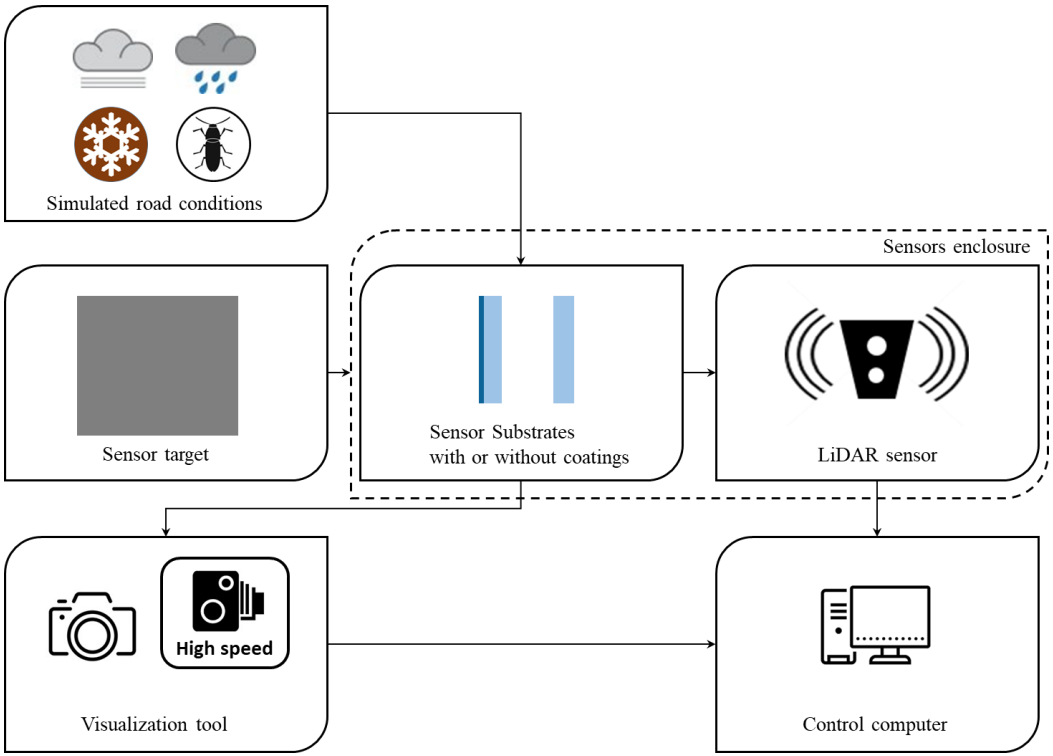


Weather-O-Meter (WOM) ASTM test

Water contact angle ≥ 90° after 3000 hours

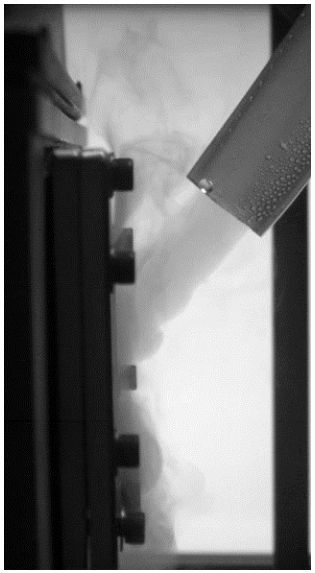
Evaluating UVH Coatings for LiDAR

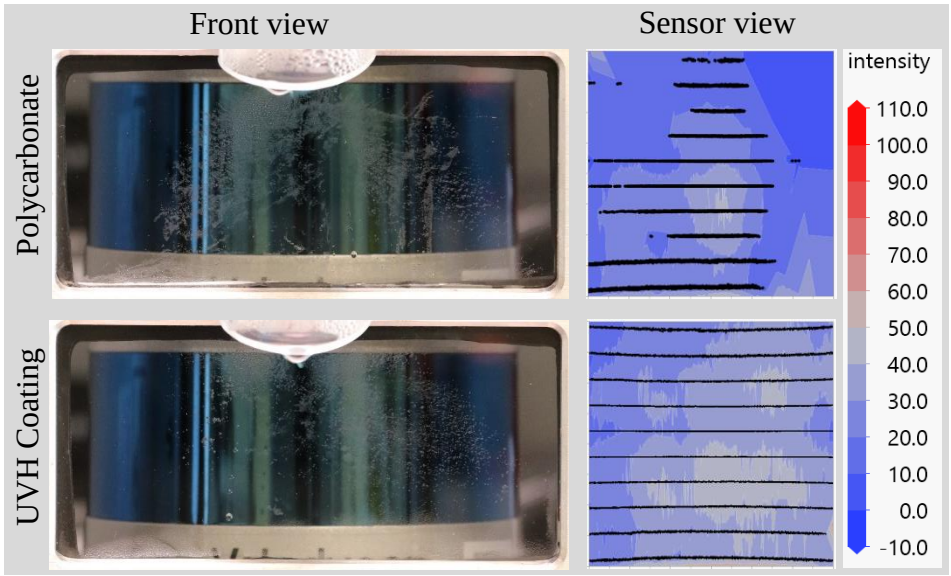
- Study fluid effects, debris and dirt cleanability on UVH coated substrate
- Evaluation of LiDAR sensor performance with simulated road conditions
  - Target detection intensity (%)
  - Returned laser dot number

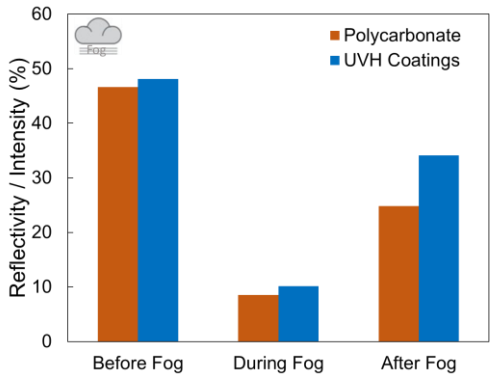


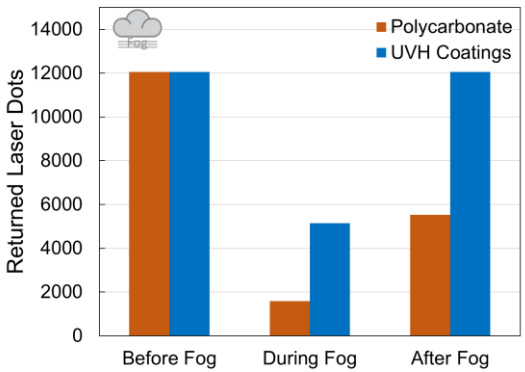
Block Diagram of the Lab Sensor Testbed with simulated road conditions

Fog Effect on LiDAR



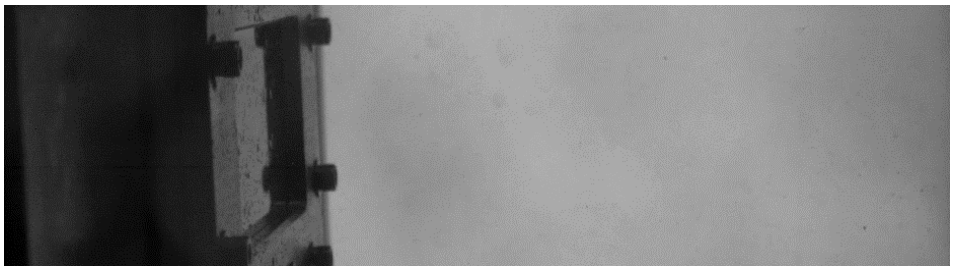


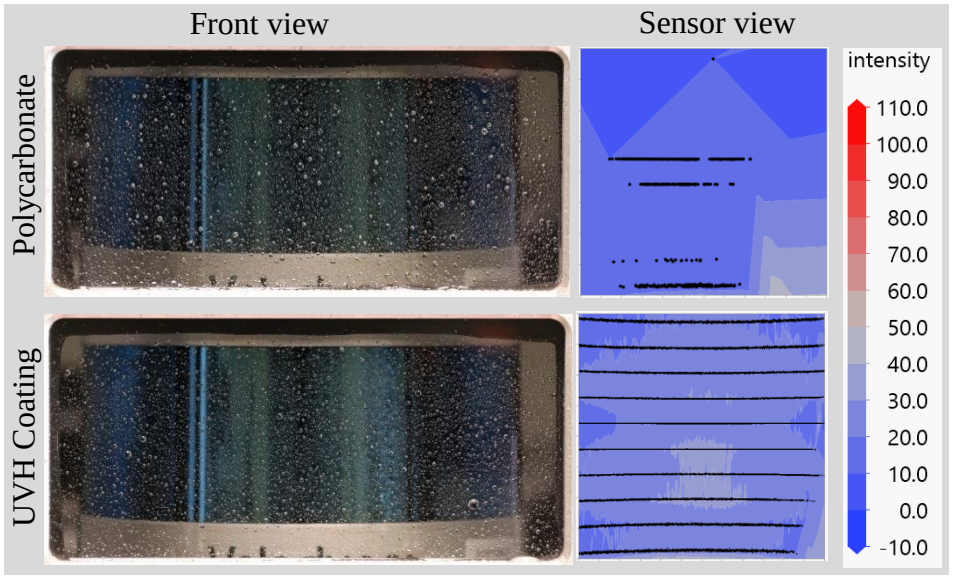




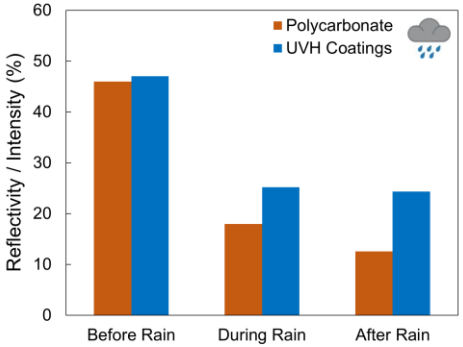
- Fog accumulated on the sensor substrate will reduce both target detection intensity and returned laser dots
- UVH coating showed higher recovery of the detection intensity and returned laser dots after the fog condition stopped

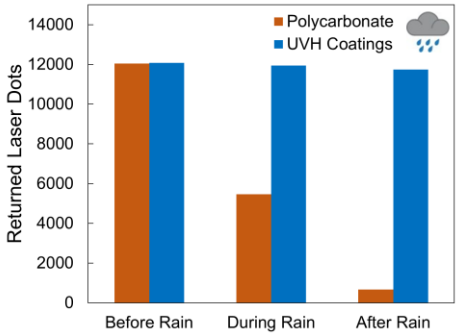
Light Rain on LiDAR



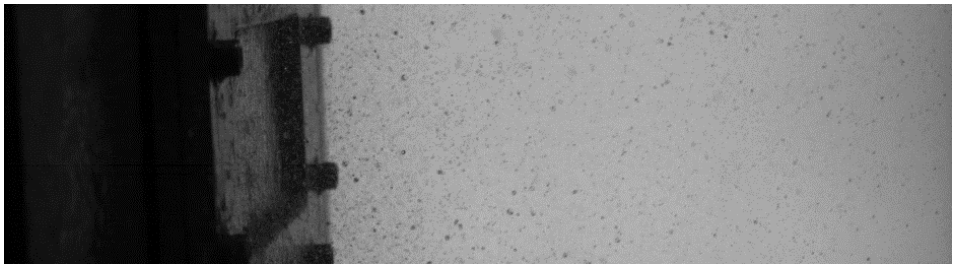


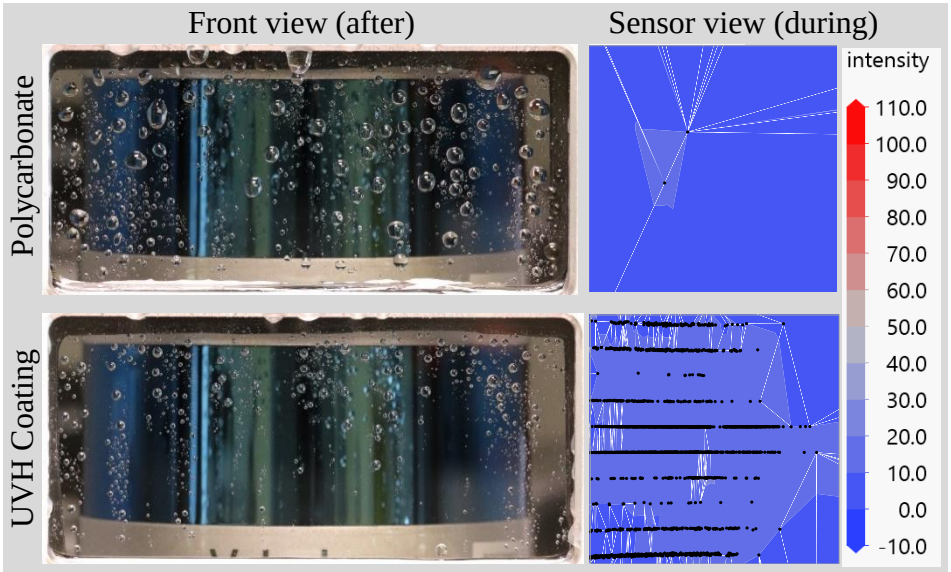
- Light rain droplet accumulated on the sensor substrate will reduce both target detection intensity and returned laser dots
- UVH coating minimized the water droplets, improved LiDAR sensor detection intensity and returned laser dots



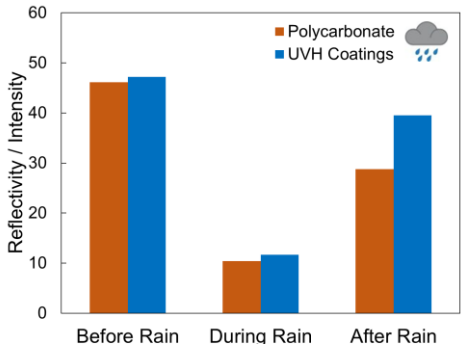


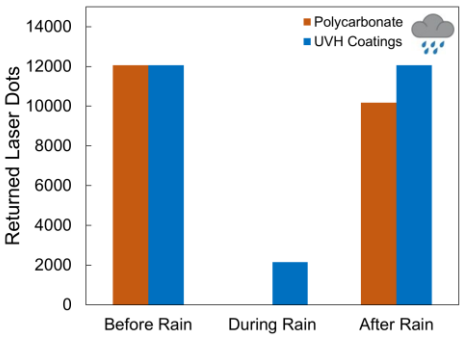
Heavy Rain on LiDAR

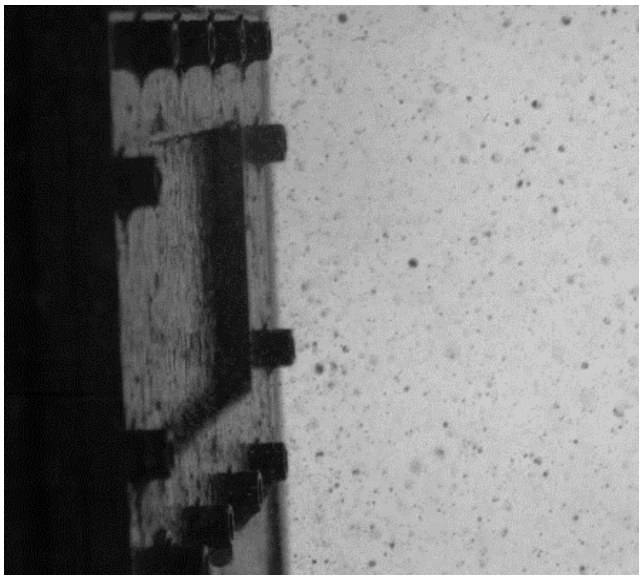


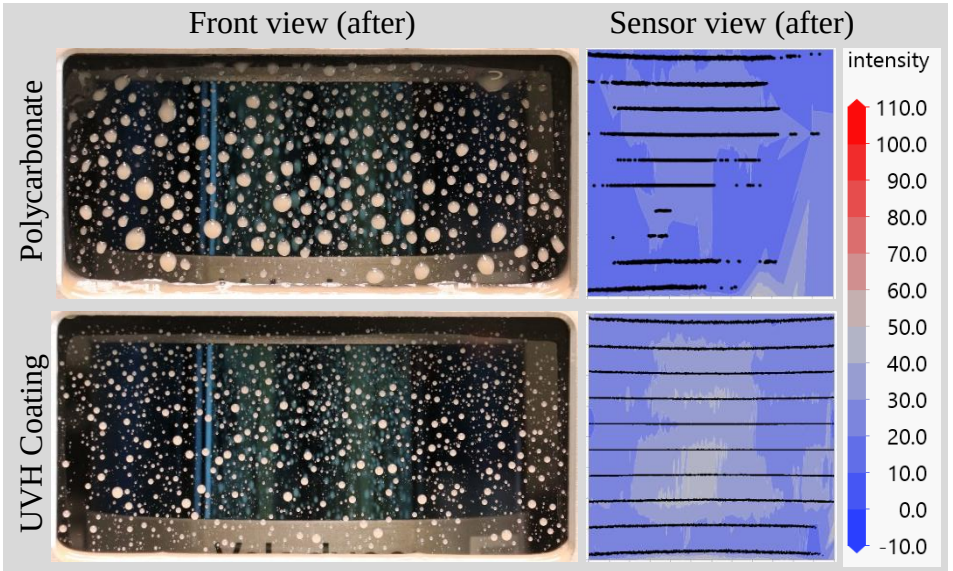


- Under heavy rain the LiDAR sensor without UVH coating lost almost all return signals from the target
- UVH coating can repel some water droplets, improve the sensor detection and the total number of returned laser dots during the rain



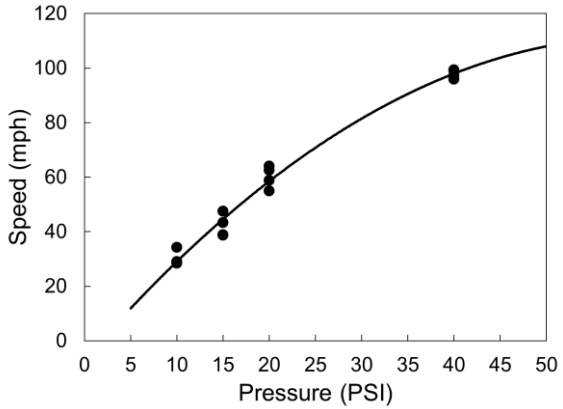


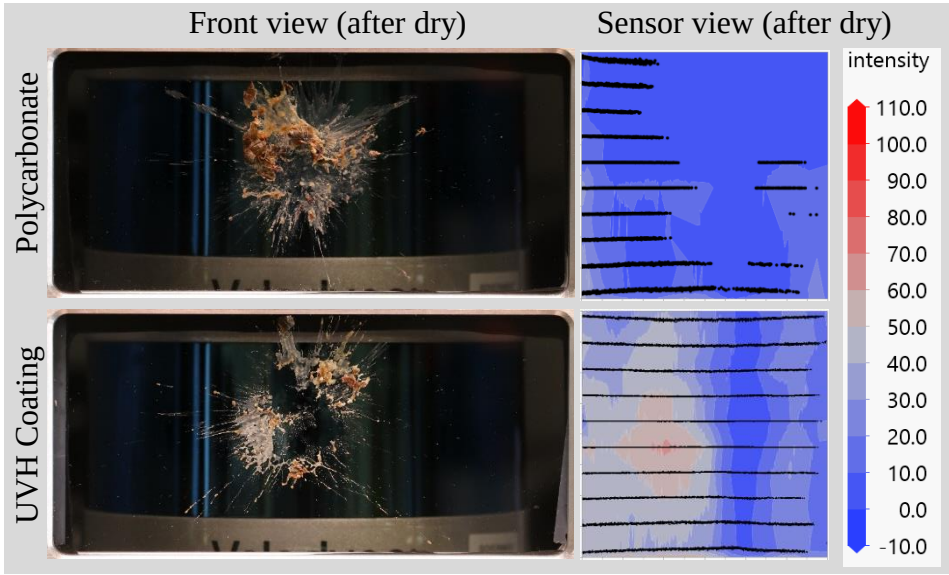




- A light mud mist that is to mimic the winter road condition was applied
- UVH coatings coated substrate
  - The mud droplets accumulated on the surface were much smaller
  - Higher detection intensity and signal strength

Effect of Bug on LiDAR Signal





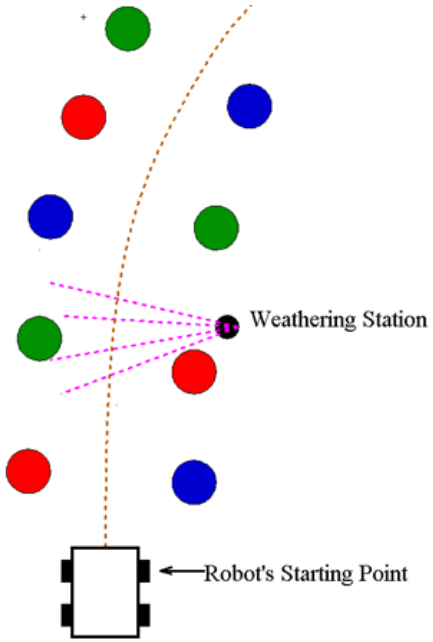
- A bug launching setup was developed to mimic bug conditions on the summer road
- UVH coatings coated substrate
  - The majority of the bug can be removed after drying or blowing with compressed air
  - Higher detection intensity and signal strength

Mobile Testbed – Collaboration with NDSU

- Collaborated with Professor Majura Selekwa and the Mechatronics and Robotics Laboratory at North Dakota State University (NDSU)

- Constructed a robotic vehicle equipped with LiDAR and other perception sensors

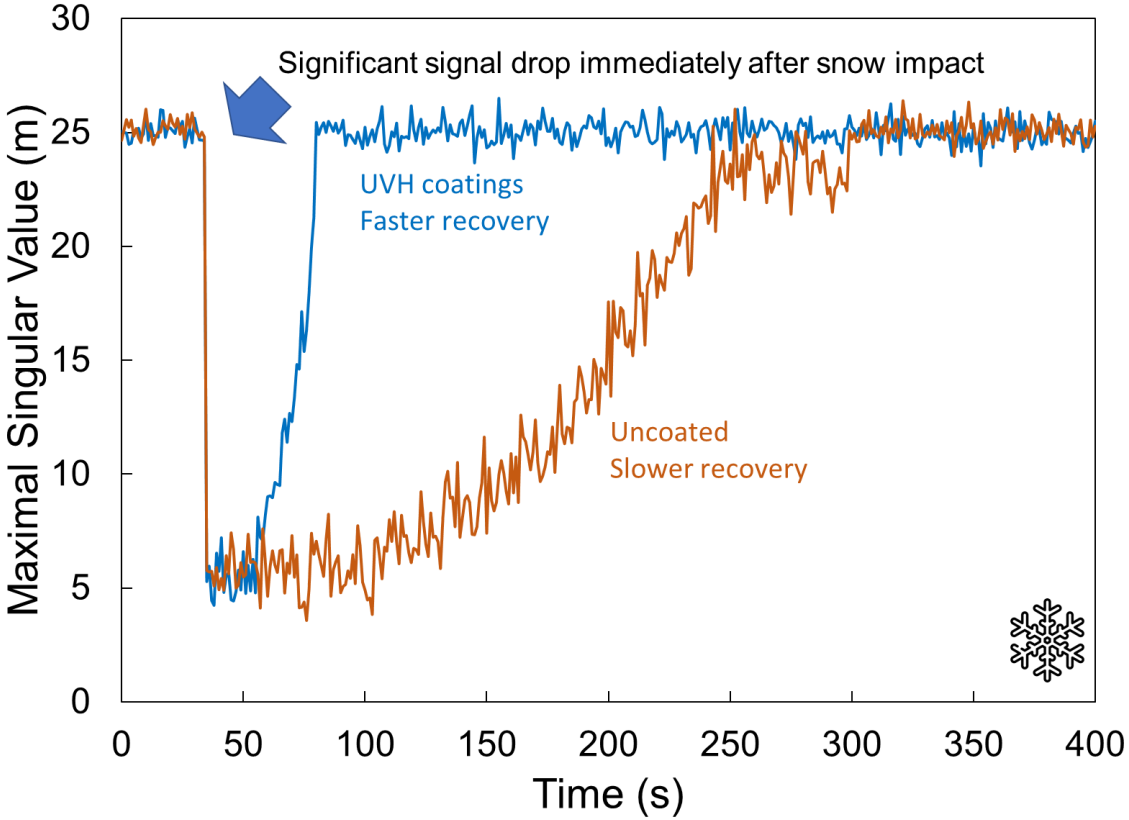
- Evaluated different simulated environmental effects on LiDAR sensor



Mobile Testbed – Collaboration with NDSU

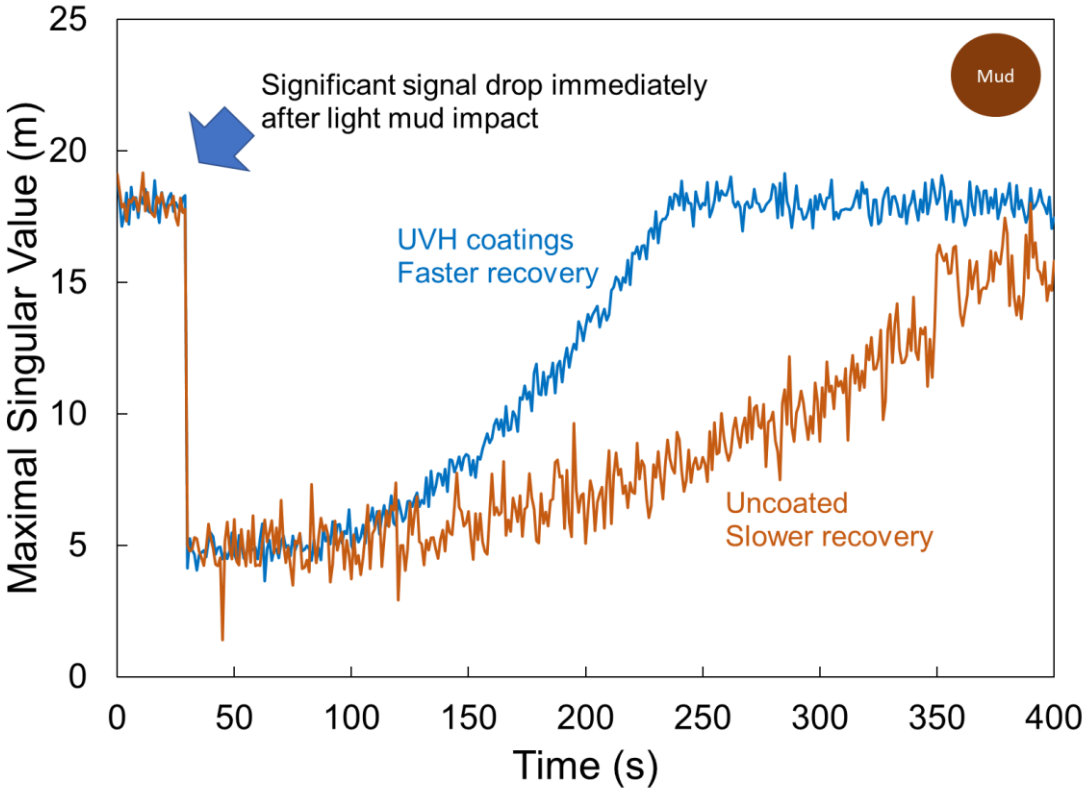
- Running the robot in an area with artificial obstacles
- Different simulated environmental conditions (Snow, Mud, etc.)

Effects of Heavy Snow on LiDAR Signal



- Complete recovery after < 1 min with UVH coatings
- Complete recovery after ~ 4 min without UVH coatings

Effects of Light mud on LiDAR Signal



- Complete recovery after > 3 min with UVH coatings
- Complete recovery after > 6 min without UVH coatings

- UV durable Hydrophobic (UVH) coatings were developed and evaluated for LiDAR sensor
  - High optical transmission, good wear durability and excellent UV durability
  - Simulated weathering conditions (fog, rain, snow, mud, and bug) with static lab testbed and mobile testbed
- UVH coated substrate performance
  - Prevent dust and dirt from sticking to the lens surface
  - Repel or minimize the water droplets during rain
  - Recover from the weather effects faster than the uncoated substrates
- Improve the effectiveness and efficiency of the LiDAR sensor and provides a key improvement in safety for autonomous vehicles

ACKNOLEDGEMENT

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