2021 NSF CYBER-PHYSICAL SYSTEMS PRINCIPAL INVESTIGATORS' MEETING

# CPS:: Mobile Automated Rovers Fly-by *(MARS-Fly)* for Bridge Network Resiliency

Nasim Uddin (PI), Mohammad R. Haider (CO-PI)
The University of Alabama at Birmingham

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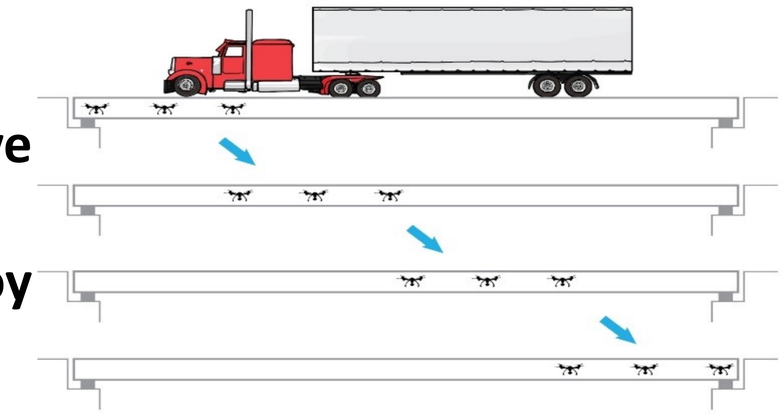
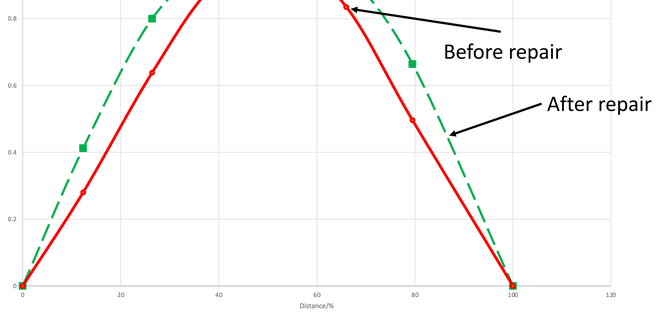
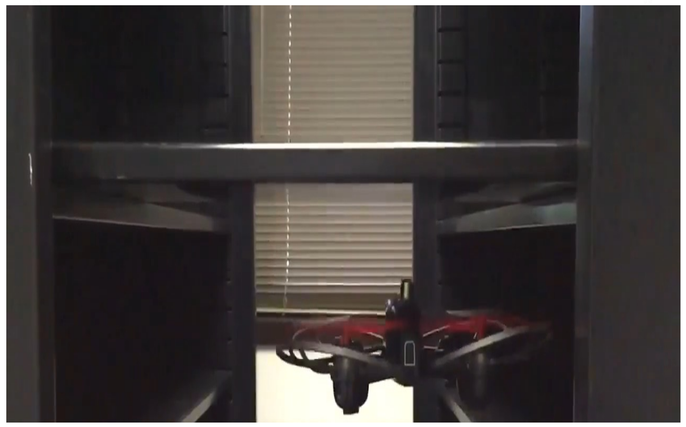
## Redeployable Accelerometers

- **Bridges are generally large so it's not always possible to have enough accelerometers to cover the entire bridge simultaneously.**
- **Our concept is to mount the accelerometers on drones and redeploy them along the bridge to build up a picture of its condition.**






Bridge repair



Drone sensor with perching mechanism

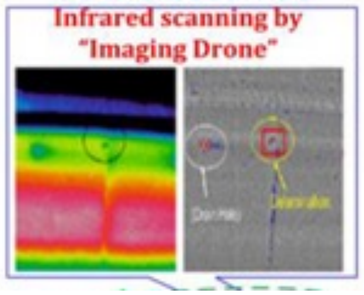
## Real Time Bridge Weigh-In-Motion

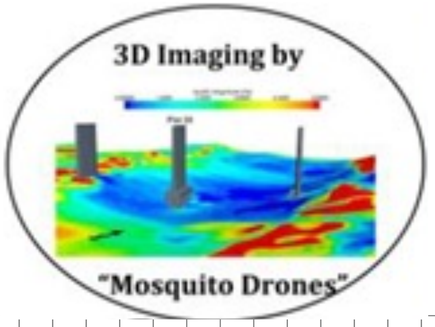
- **New Bridge weigh-in-Motion (B-WIM) algorithm allows to calculate the truck weight in less than 5 sec using sensors data**

| Item | Static weight | Calculated weight | Error (%) |
|---|---|---|---|
| Axle-1 | 66700 | 65046 | -2.54 |
| Axles 2+3 | 94800 | 95005 | +0.22 |
| GVW | 161500 | 160051 | -0.90 |

# Mobile Automated RoverS Fly-By (MARS-FLY) for Bridge Network Resiliency

**A. The Bridge Vibration and the Vehicle vibration are collected Simultaneously**



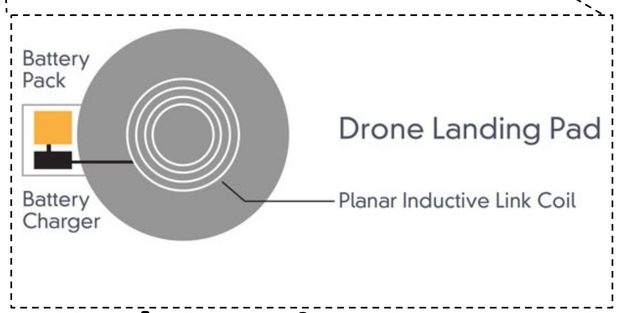




**B. Mosquito Drones Returns to the Vehicle and the Large Imaging Drone Fly To Inspect the Bridge**

**C. Imaging Drone Predict Delamination**



**Bridge Sensors Are Connected to Drone Landing Pad**




**Drone Pad Receive Energy From the Mosquito Drone to <u>AWAKE</u> the bridge Sensors**


**Mosquito Drone Charge and Collect the Short Burst of Sensors Data**

## Project Media

- https://www.youtube.com/watch?v=LFU3wlI2mY0
- https://www.facebook.com/UAB.edu/videos/1665057630234599/

## Project Impacts

Intellectual Merit: Remote powering of wireless sensors and data communication by UAVs through wireless power link for bridges in remote locations where the cost of installing electricity and a data acquisition system is cost prohibitive.

Broader Impact: Observe and control truckloads on bridges for the first time while creating an entirely new data-driven paradigm for more accurate health assessment of infrastructure systems.

MARS-Fly project has already generated **three Master's thesis** [Mohammed '17, Munot '19, Chavan '19], **three Ph.D. dissertations** [Elhattab '18, Mohammed '19, Tan'19], **ten journal papers** [Elhattab et al '17-'19; Mohammed et al '18-'19; Tan et al '17-'19], and **fifteen conference papers** [Elhattab et al '17-'19; Mohammed et al '17- '19; Tan et al '17-'19] submissions. Two 3MT awards. Few sample publications are listed in the next slide.

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•Chavan, R. S. Multi-Hazard Modelling and Performance Assessment, MS in CCEE Department. 2018, University of Alabama at Birmingham
•Elhattab, A., N. Uddin, and E. OBrien, (2017a) Drive-by bridge damage monitoring using Bridge Displacement Profile Difference. Journal of Civil Structural Health Monitoring, 2016. 6(5): p. 839-850.
•Elhattab, A., Uddin, N. Eugene O'Brien, E. & Wang, Y.,. Field Verification for Drive-by Bridge Monitoring using Non-specialized Inspection Vehicle. in 26th ASNT Research Symposium. 2017a.
•Elhattab, A., N. Uddin, and E. OBrien. Identifying Localized Bridge Damage Using Frequency Domain Decomposition. In 26th ASNT Research Symposium. 2017b.
•Elhattab A. and Uddin, N. (2017b) "Drive-by Bridge Damage Monitoring: Concise Review", Civil Eng Res Journal, CERJ.MS.ID.555555 (2017), Volume 1 Issue 1 - July 2017
•Elhattab, A., Uddin, N., and OBrien, E., (2018) "Drive-By Bridge Frequency Identification under Operational Roadway Speeds Employing Frequency Independent Underdamped Pinning Stochastic Resonance (FI-UPSR)"; Journal Sensors; 2018, 18(12), 4207; https://doi.org/10.3390/s18124207
•Elhattab, A (2018). "Drive-By Bridge Damage Inspection and Monitoring, PhD Dissertation in CCEE Department. 2018, University of Alabama at Birmingham.
•Elhattab, A., Uddin, N., and OBrien, E., (2019) "Extraction of Bridge Fundamental Frequencies Utilizing a Smartphone MEMS Accelerometer"; Journal Sensors; 2019, 19(14), 3143; https://doi.org/10.3390/s19143143
•Elhattab A. and Uddin, N, Bridge Motoring Utilizing Smart Portable Sensors, 9th International Conference on Structural Health Monitoring of Intelligent Infrastructure, August 4–7, 2019, St. Louis, Missouri USA
•Mohammed, Y.M. and N. Uddin. Bridge Damage Detection using the Inverse Dynamics Optimization Algorithm. In 26th ASNT Research Symposium. 2017a.
•Mohammed, Y. and N. Uddin, Bridge Damage Detection using the Inverse Dynamics Optimization Algorithm. ASNT 26th Research Symposium Proceeding, 2017b.
•M. Yahya, N. Uddin, Field Verification for B-WIM System using Wireless Sensors. 27th ASNT Research Symposium, 2018, Orlando Florida, March 26, 2018a
•M. Yahya, N. Uddin, Passenger Vehicle Effect on the Truck Weight Calculations using B-WIM System. 27th ASNT Research Symposium, 2018, Orlando Florida, March 26, 2018b
•Yahya, N. Uddin, Bridge Resiliency during the Hurricanes. Proceedings of the joint ICVRAM ISUMA UNCERTAINTIES conference. Florianopolis, SC, Brazil, April 8-11, 2018c
•Mohammed, Y., and Uddin, N. "B-WIM System using Fewer Sensor", J. Transportation Management (2018) Volume 1, Issue 2, doi:10.24294/tm.v1i2.701
•Mohammed, Y., and Uddin, N. (2019a) "Acceleration-Based Bridge Weigh-in-Motion"; Journal of Bridge Structures 14(4): 131-138.
•Mohammed, Y., and Uddin, N. (2019b) "Moving Force Identification for Real-Time Bridge Weigh-In-Motion"; Journal of Bridge Structures; 14(4): 139-145.
•Mohammed, Y. and N. Uddin, Multihazard bridge connection. 9th International Conference on Structural Health Monitoring of Intelligent Infrastructure, August 4–7, 2019, St. Louis, Missouri USA
•Mohammed, Y.M., Cyber-Physical System for Monitoring and Controlling Loads, MS Thesis in CCEE Department. 2016, University of Alabama at Birmingham.
•Mohammed, Y.M., Bridge Safety against Multi-Hazard, PhD Dissertation in CCEE Department. 2019, University of Alabama at Birmingham.
•Munot, N. Rajendra (MS 2019) Scenario Modelling Algorithm to figure out the maximum daily response of the bridge, MS in CCEE Department. 2019, University of Alabama at Birmingham.
•Tan, C. and Uddin, N. (2017a) ""Drive-By" Bridge Frequency Based Monitoring Utilizing Wavelet Transform", Journal of Civil Structural Health Monitoring, November 2017, Volume 7, Issue 5, pp 615–62
•Tan, C., A. Elhattab, and N. Uddin, (2017b) "Drive-by'' bridge frequency-based monitoring utilizing wavelet transform. Journal of Civil Structural Health Monitoring, 2017a. 7(5): p. 615-625.
•Tan, C., A. Elhattab, and N. Uddin, Wavelet Based Damage Assessment and Localization for Bridge Structures ASNT 26th Research Symposium Proceeding, 2017.
•Tan, Chengjun, Nasim Uddin., and Ahmed Elhattab, "Utilizing Hilbert Transform to Assess the Bridge Health Condition Proceedings of the joint ICVRAM ISUMA UNCERTAINTIES conference. Florianopolis, SC, Brazil, April 8-11, 2018a
•Tan, Chengjun, Nasim Uddin., and Ahmed Elhattab, "Wavelet Based Damage Assessment and Localization for Bridge Structures. Proceedings of the 27th ASNT Research Symposium, 2018, Orlando Florida, March 26, 2018b
•Tan, C. and Uddin, N, Deep learning on structural crack detection, 9th International Conference on Structural Health Monitoring of Intelligent Infrastructure, August 4–7, 2019, St. Louis, Missouri USA
•Tan, Chengjun, Nasim Uddin, Eugene J. Obrien, Patrick J McGetrick, and Chul-Woo Kim (2019). "Extraction of Bridge Modal Parameters Using a Passing Vehicle Response." Journal of Bridge Engineering (ASCE). Accepted.