



Virginia Center *for* Transportation  
**INNOVATION**  
& **RESEARCH**

*We bring innovation to transportation.*

---

# **Structural Health Monitoring in Virginia**

Bernie Kassner, Ph.D., P.E.

Southeast Bridge Preservation Partnership Meeting

April 14, 2015

# Projects

- Delta Frame Bridge
  - + Reconstruction Monitoring
  - + Fatigue Monitoring
- Varina-Enon Bridge
  - + Segmental Joint Monitoring
- Ancillary Structures
  - + Vibration Monitoring





845'

Maury River

Kerrs Creek

64

64

64

64

64



155'

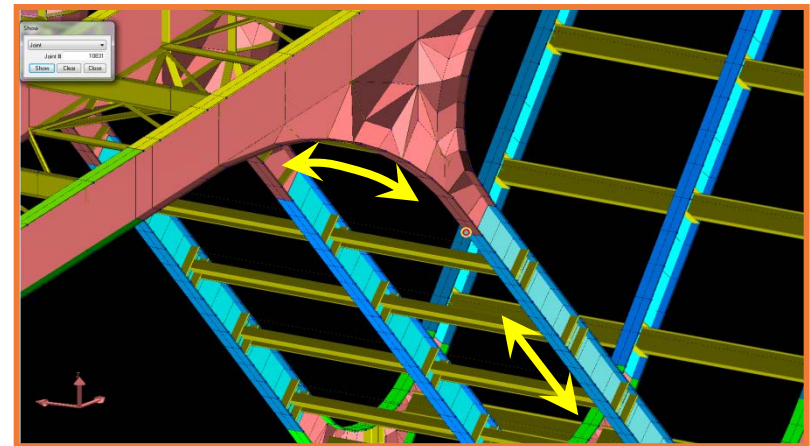
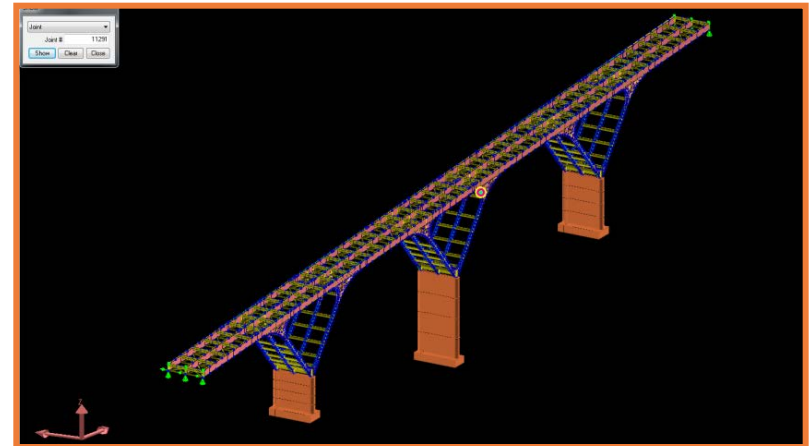
# Delta Frame Bridge Reconstruction

- Background
  - + Original design in 1969
  - + Constructed in 1976
  - + Fatigue problems discovered in late '80's
  - + Retrofits done in 1992
  - + Additional retrofits recommended in 2009
  - + 2013 TIGER grant awarded



# Delta Frame Bridge Reconstruction

- Motivation for Monitoring
  - + Concrete deck replacement
  - + Complex structure
  - + Modeling showed areas of large stresses / movements
  - + Monitoring needed during construction

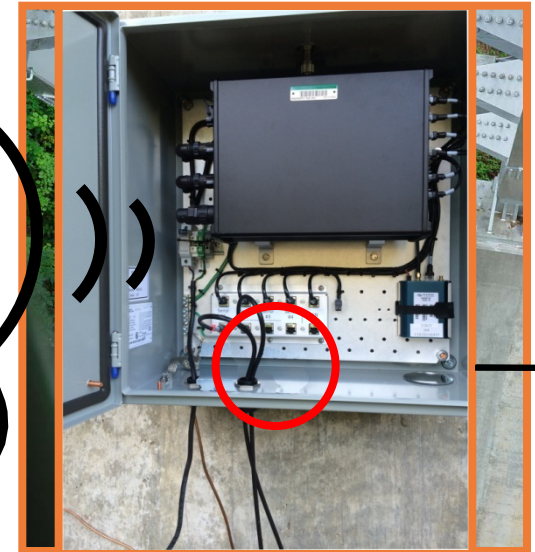


by permission of Whitman, Requardt, and Associates, LLP



# Delta Frame Bridge Reconstruction

- Instrumentation:  
SENSR CX-1
  - + Acceleration in 3 directions
  - + Rotations in 2 directions
  - + Temperature
  - + Range of 750 ft
  - + Data collected remotely
  - + System is power-hungry



# Delta Frame Bridge Reconstruction

- Monitoring
  - + Continuous throughout each phase
  - + Alert can be sent if threshold limits are exceeded
  - + Video observation of construction activity
  - + Possible continued monitoring after completion





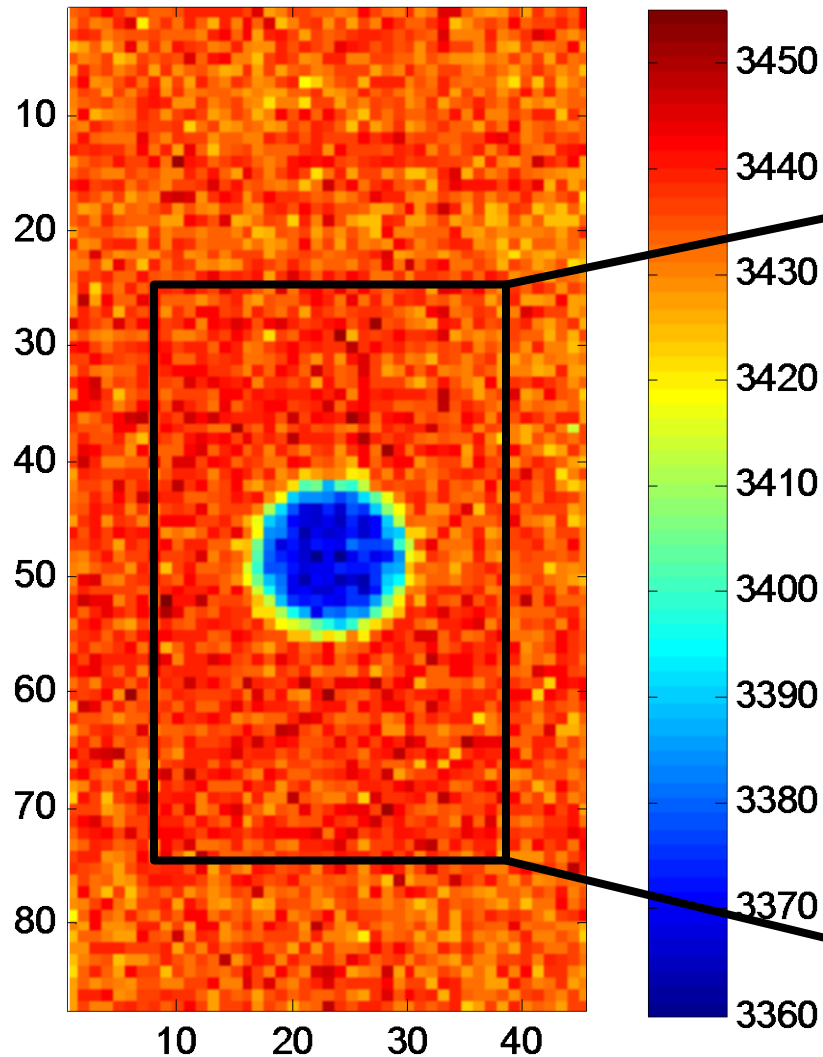
# Delta Frame Bridge Fatigue

- Thermoelastic Stress Analysis (TSA)
  - + Detection of fatigue cracks
  - + Relies on principle of thermoelasticity:
$$\Delta T_{tE} = -KT\Delta(\sigma_1 + \sigma_2)$$
  - + Uses low-cost IR camera
  - + Some signal processing is required

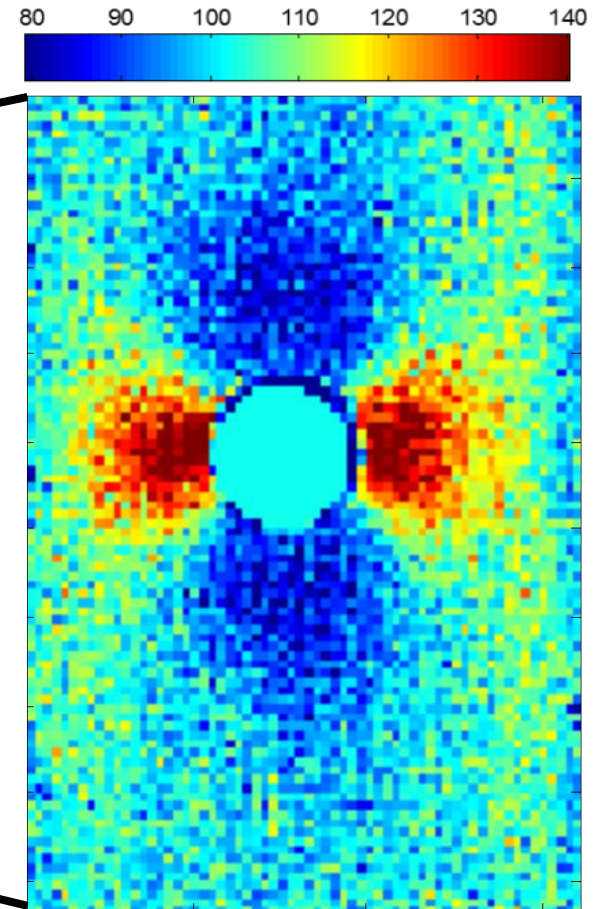


# Delta Frame Bridge Fatigue

Raw Data



Thermoelastic Response



# Delta Frame Bridge Fatigue

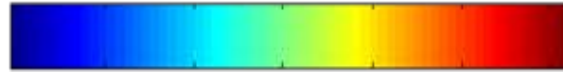
Gross Stress: 14 ksi

50 60 70 80



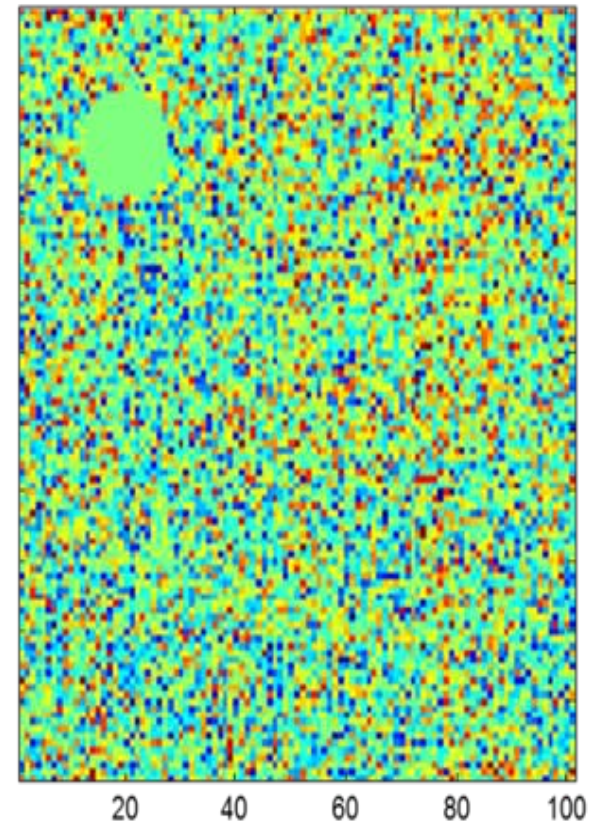
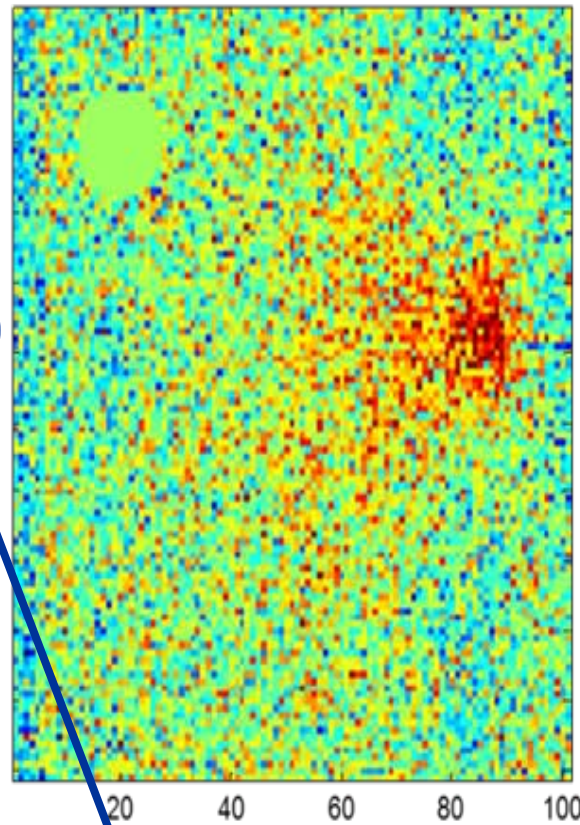
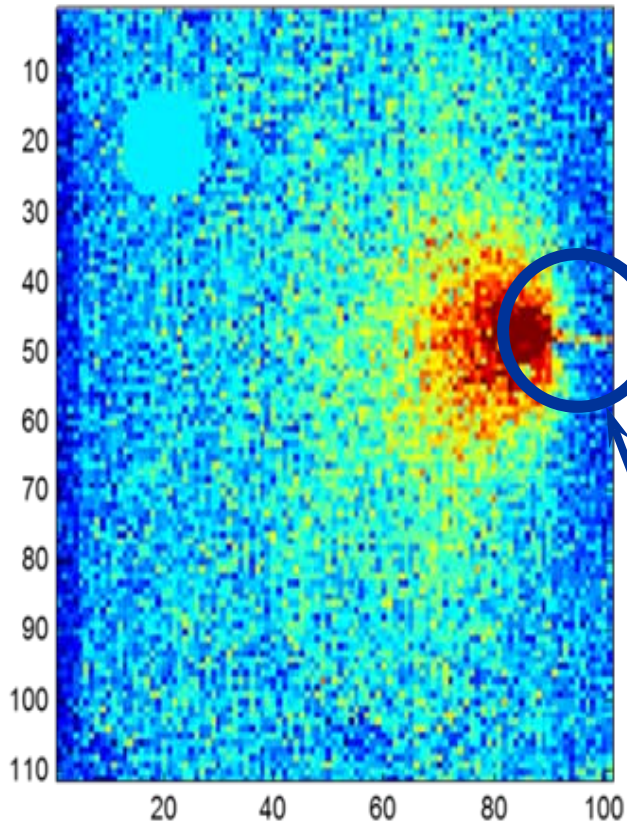
Gross Stress: 10 ksi

20 22 24 26 28 30 32



Gross Stress: 5 ksi

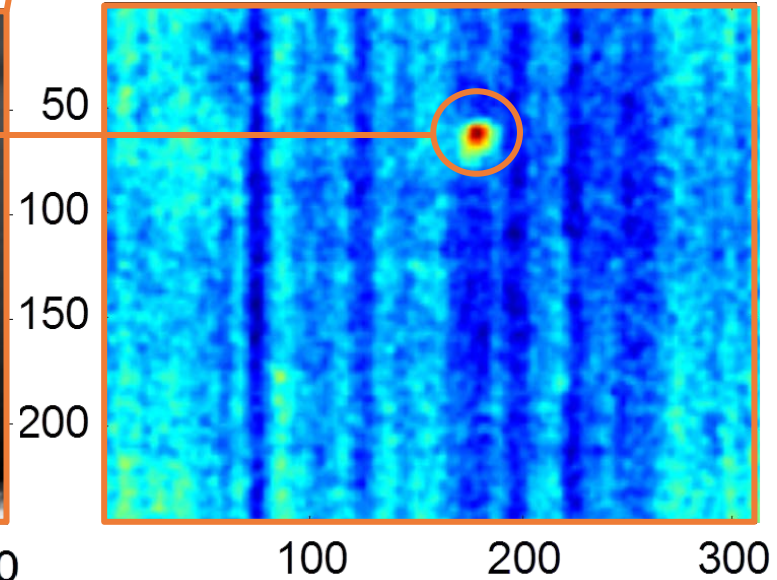
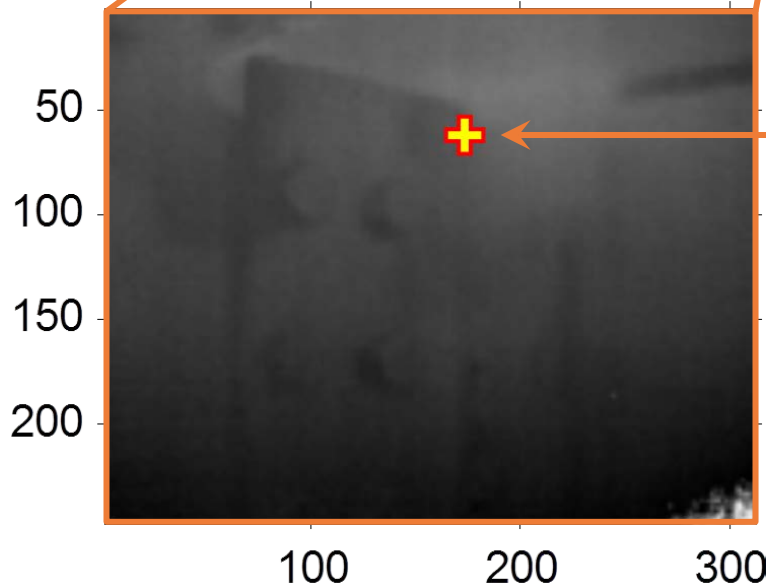
12 13 14 15 16



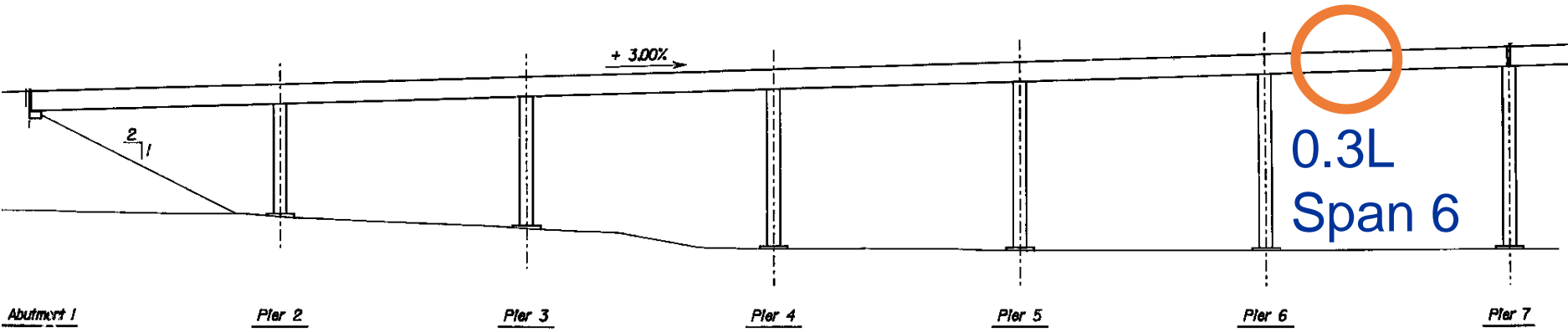
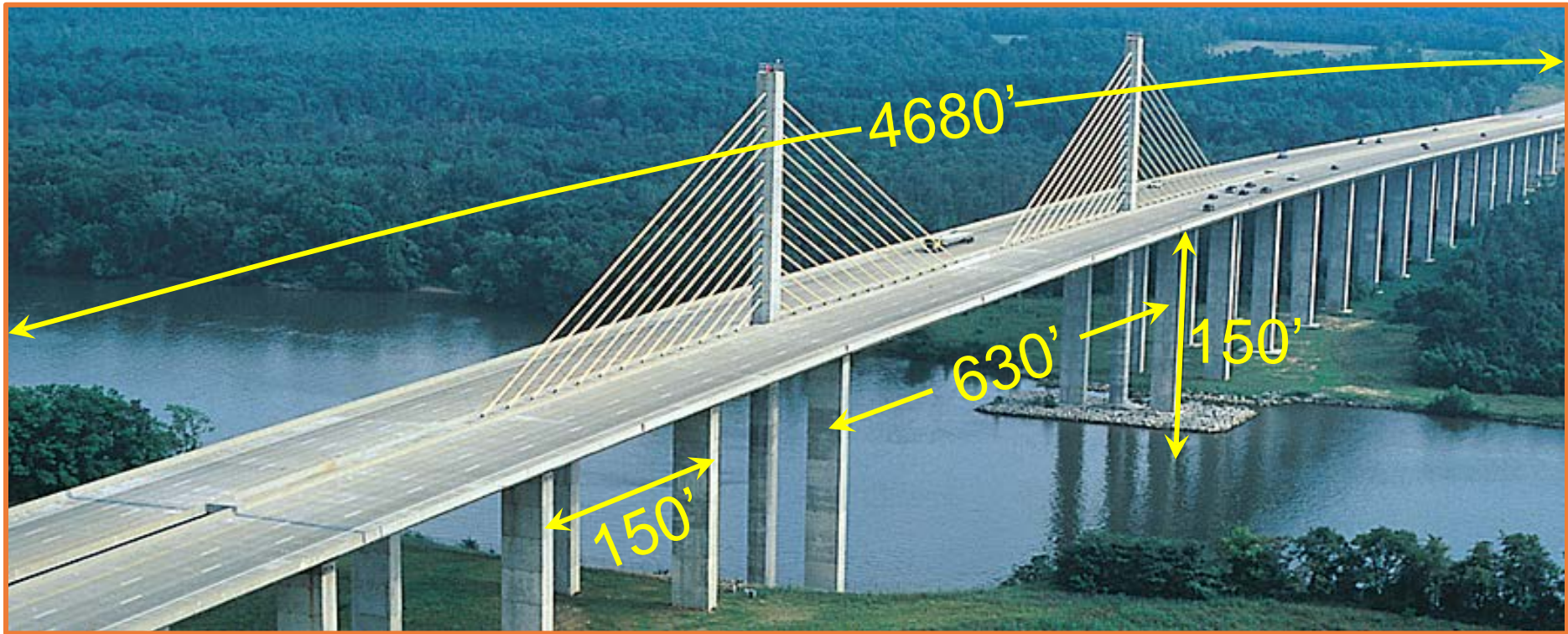
Crack



# Delta Frame Bridge Fatigue

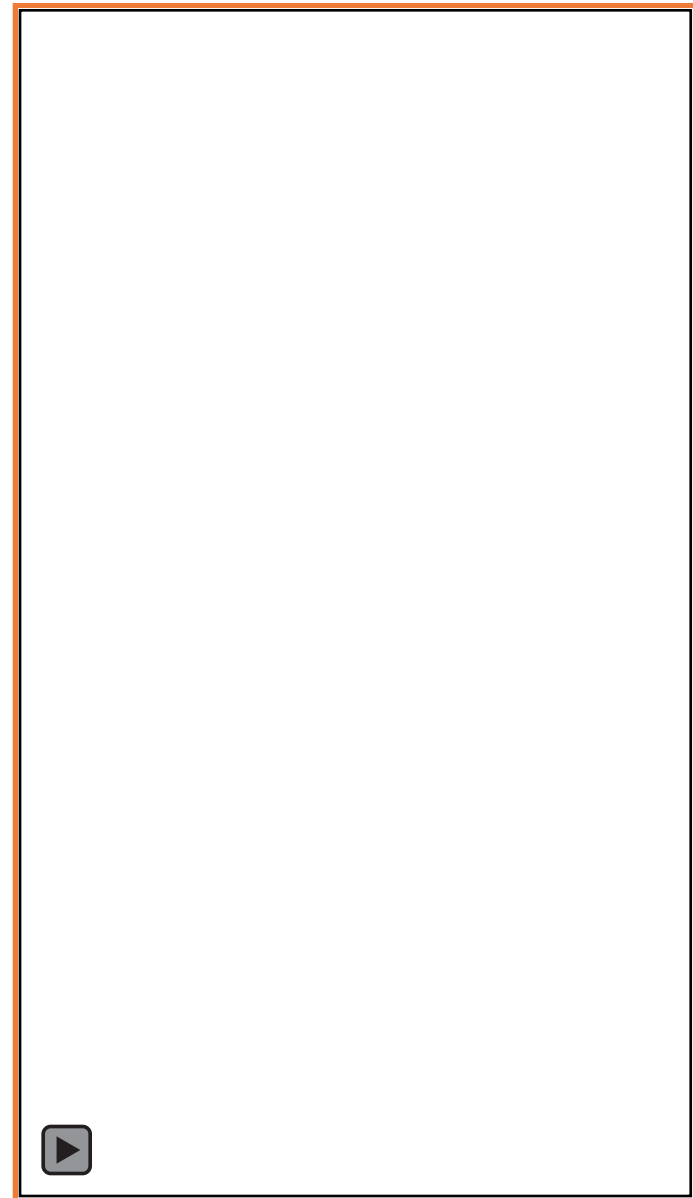


# Varina-Enon Bridge Joint Monitoring



# Varina-Enon Bridge Joint Monitoring

- Visual Inspection
  - + June 2012
  - + Observed 1/16-in. joint opening under normal traffic
  - + 103°F
- Load Test
  - + 294 kip live load
  - + Recorded 1/64-in. opening
  - + 85°F

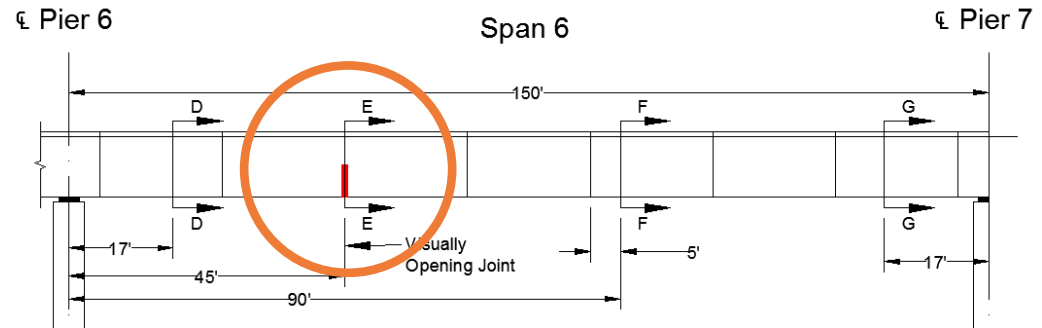


# Varina-Enon Bridge Joint Monitoring

- Long-term Instrumentation

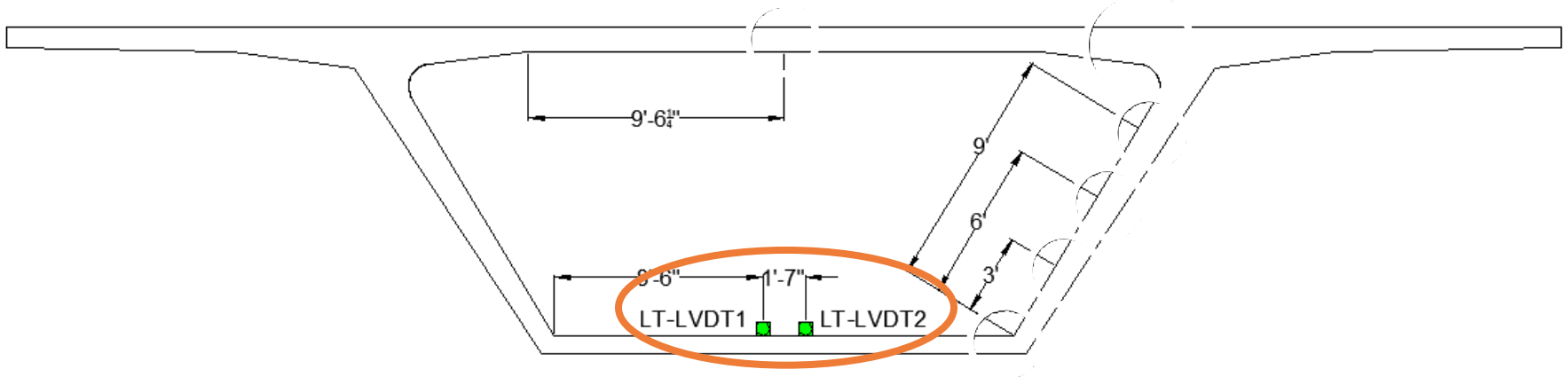
- +2 LVDTs monitoring joint opening

- +1 Strain transducer next to joint



- +24 Thermocouples measuring thermal gradient

- +1 Trigger strain transducer



# Varina-Enon Bridge Joint Monitoring

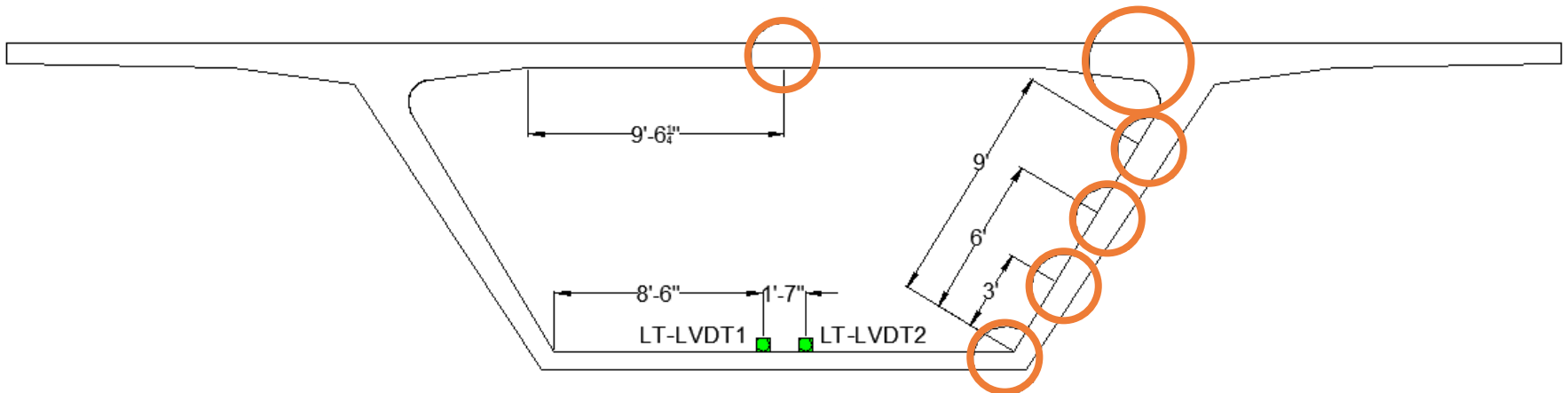
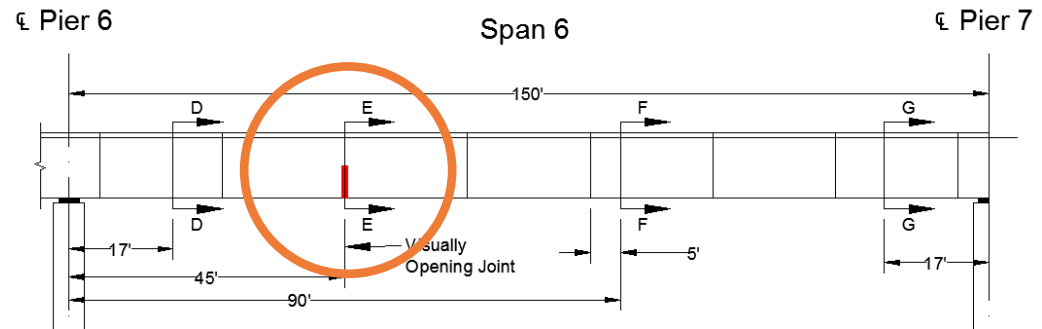
- Long-term Instrumentation

- +2 LVDTs monitoring joint opening

- +1 Strain transducer next to joint

- +24 Thermocouples measuring thermal gradient

- +1 Trigger strain transducer





# Varina-Enon Bridge Joint Monitoring

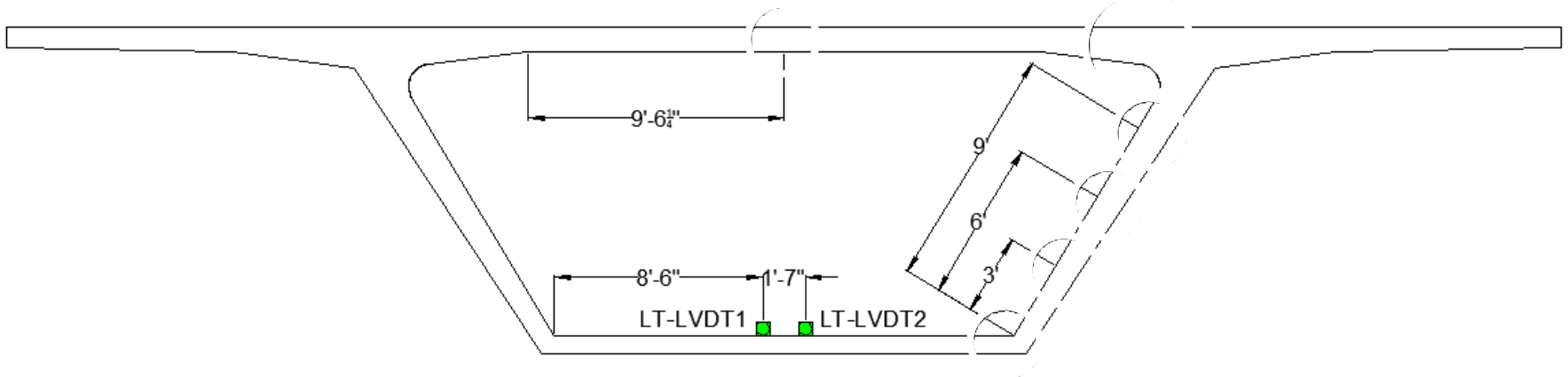
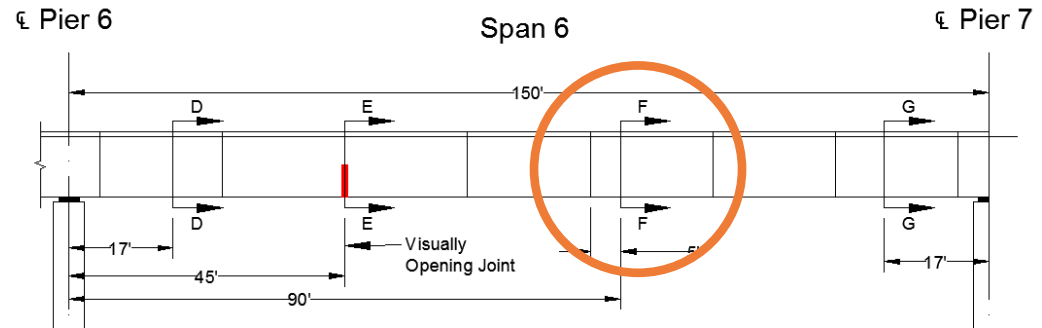
- Long-term Instrumentation

- +2 LVDTs monitoring joint opening

- +1 Strain transducer next to joint

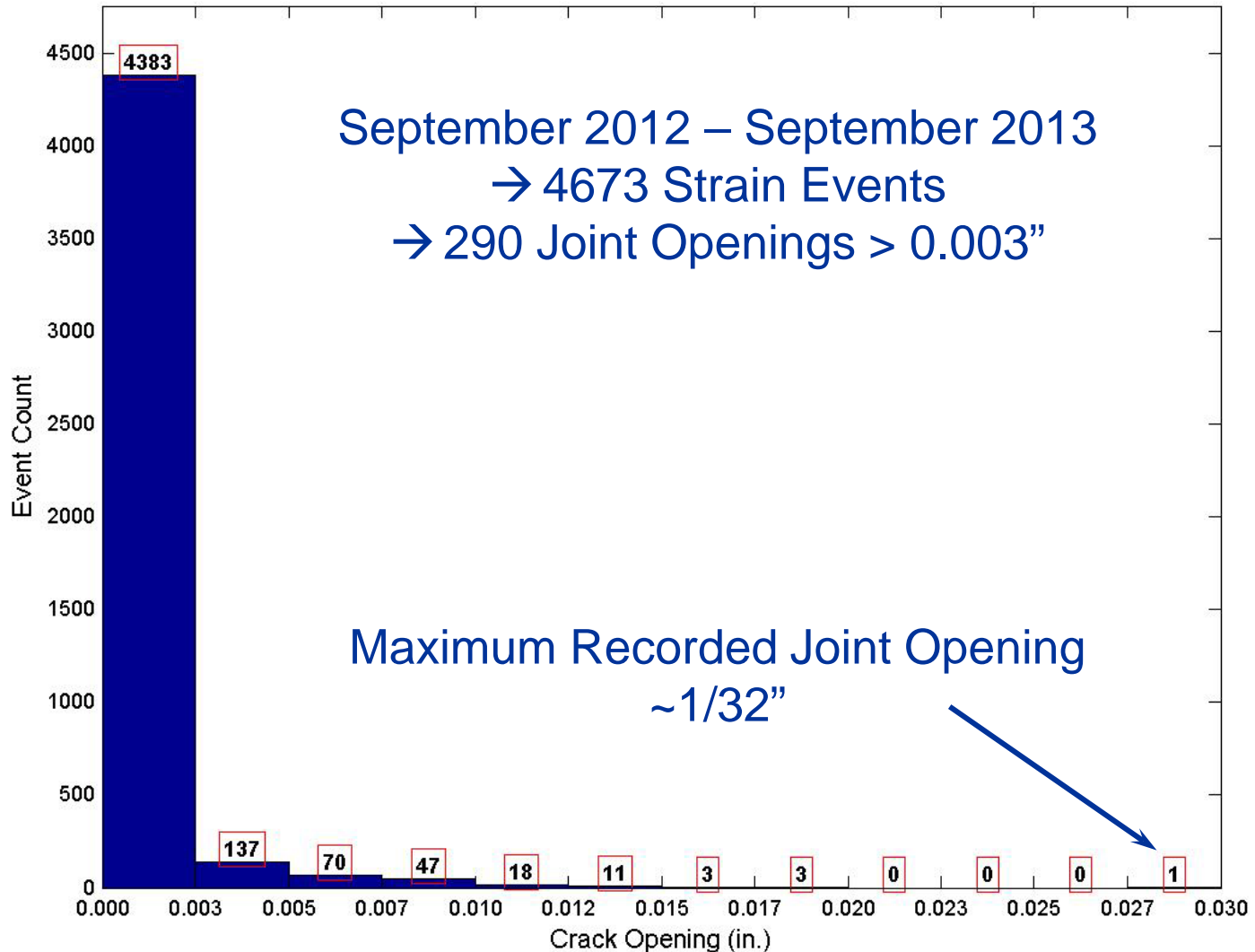
- +24 Thermocouples measuring thermal gradient

- +1 Trigger strain transducer



# Varina-Enon Bridge Joint Monitoring

- Long-term Results

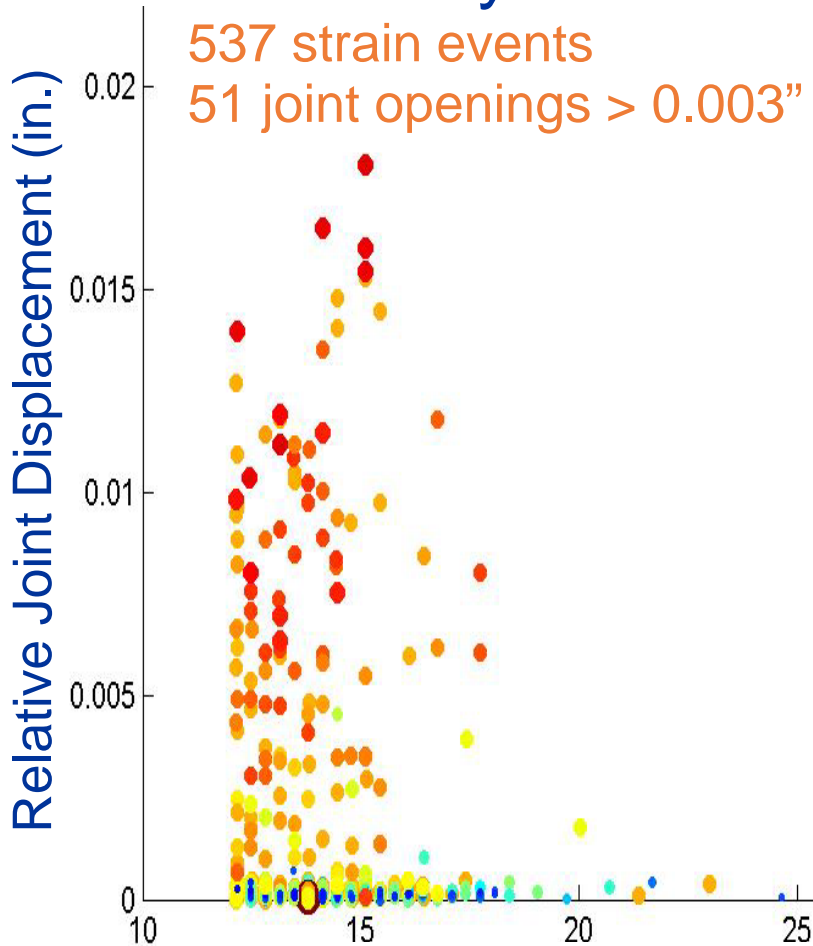


# Varina-Enon Bridge Joint Monitoring

- Long-term Results

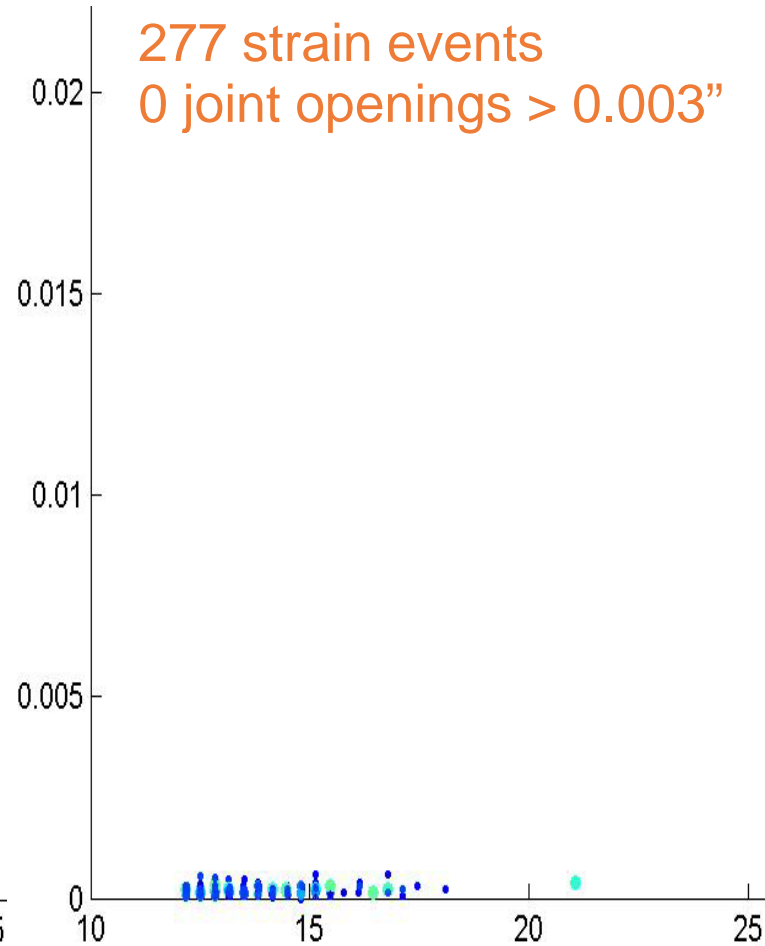
July

537 strain events  
51 joint openings > 0.003"



December

277 strain events  
0 joint openings > 0.003"



# Ancillary Structures Monitoring

- 32,300 structures in VA
  - + Luminaires
  - + Signs
  - + Traffic signals
  - + High mast lights
  - + Camera poles



# Ancillary Structures Monitoring

- 32,300 structures in VA
  - + Luminaires
  - + Signs
  - + Traffic signals
  - + High mast lights
  - + Camera poles
- Short-term monitoring



<http://www.sensr.com>



# Summary

- Delta Frame Bridge
  - + Reconstruction Monitoring
  - + Fatigue Monitoring



- Varina-Enon Bridge
  - + Segmental Joint Monitoring



- Ancillary Structures
  - + Vibration Monitoring



# Thank You!



## Special Thanks

- Thermoelastic Stress Analysis  
Dr. Steve Chase  
University of Virginia
- Varina-Enon Bridge  
Dr. Carin Roberts-Wollmann  
Virginia Tech  
Dr. Marc Maguire  
Utah State University

## Questions?

