



Engineer Research and Development Center

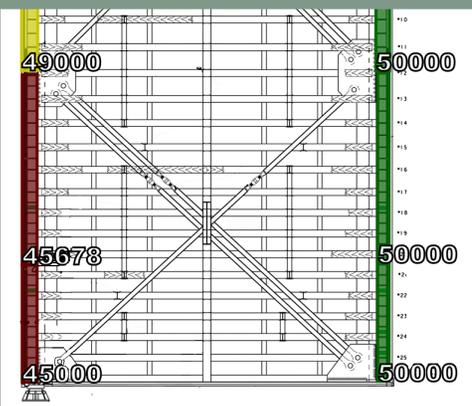
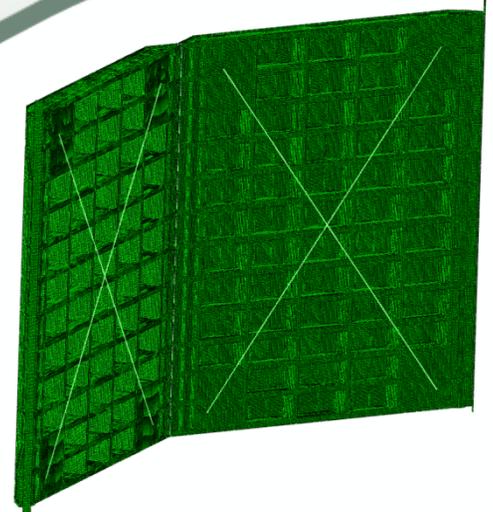
# Lock Gate Condition Automated Decision Support System

## SMART Gate 2.0

Matthew D. Smith, PE, PhD

ERDC

10 February 2015



US Army Corps of Engineers®

# SMART Gate 2.0

- Early warning system
  - Automated detection
    - Leading to catastrophic conditions
    - Useful to field
    - Quick to implement (within current capabilities)
    - Traffic light type signals for lock operator
    - LOMA implementation
  - Data-portal for post-warning decision support
  - Affordable
  - Incorporate structural and mechanical systems
  - Design guidance and specifications for existing and new gates



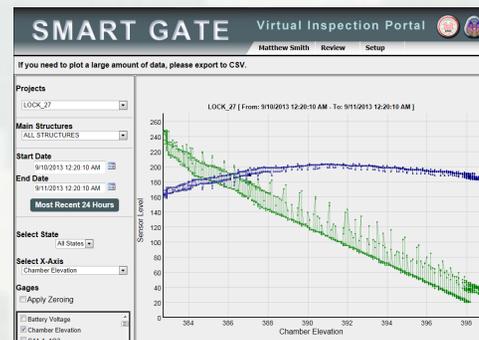
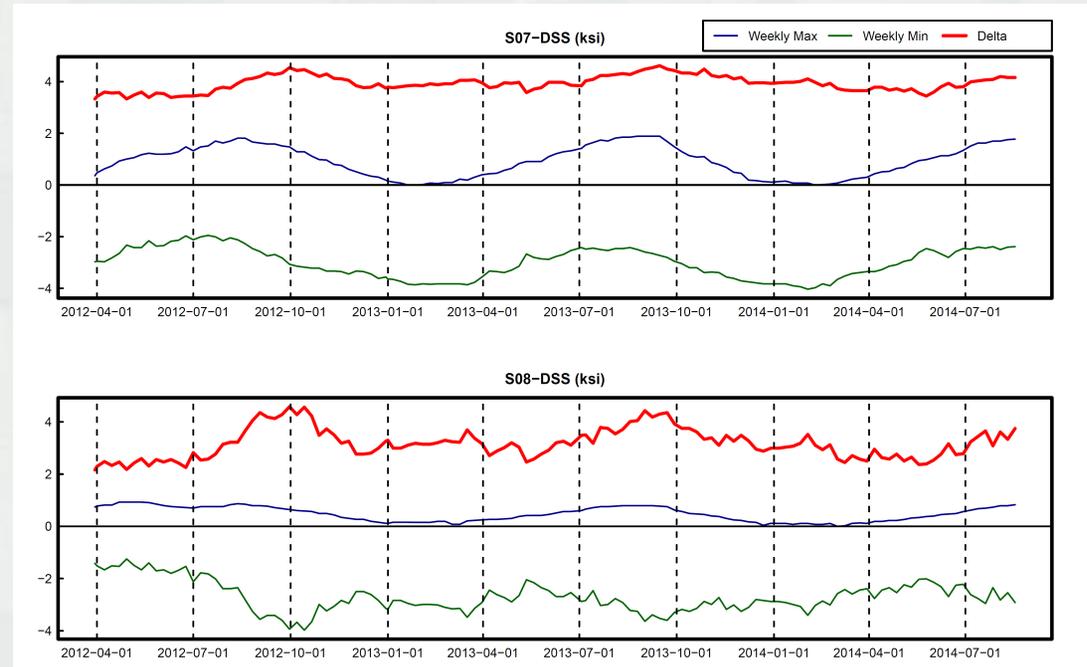
BUILDING STRONG®

**ERDC**

*Innovative solutions for a safer, better world*

# Early SMART Gate 1.0

- 5 Lock Projects
  - ▶ Greenup
  - ▶ The Dalles
  - ▶ Bonneville
  - ▶ Meldahl
  - ▶ Lock 27 (St. Louis)
- Engineering Focus
- Instrumentation Monitoring
- Manual Alarms
- Web-Portal:  
<http://smartgate.erdcdren.mil>
- NWP using this to help decide not to dewater Bonneville in FY15



# Lessons Learned

## Structural Monitoring and Analysis in Real-Time (SMART)

Version 1.0	Version 2.0
Many Sensors (>200)	Few Sensors (<120)
No Detection Targets	Carefully Selected Targets
\$600k+ per Chamber	Goal of <\$250k per Chamber
No Automated Decision Support	Automated Event Detection using FEM
Easy Data Access and Plots via Website <a href="https://smartgatedev.usace.army.mil">https://smartgatedev.usace.army.mil</a>	Same Web Access with Plotting + LOMA Warning Traffic Lights
Manual Alarms (email & text)	Auto and Manual Alarms (email & text)
No Elec/Mechanical Sensors	Incorporated Elec/Mech. Sensors

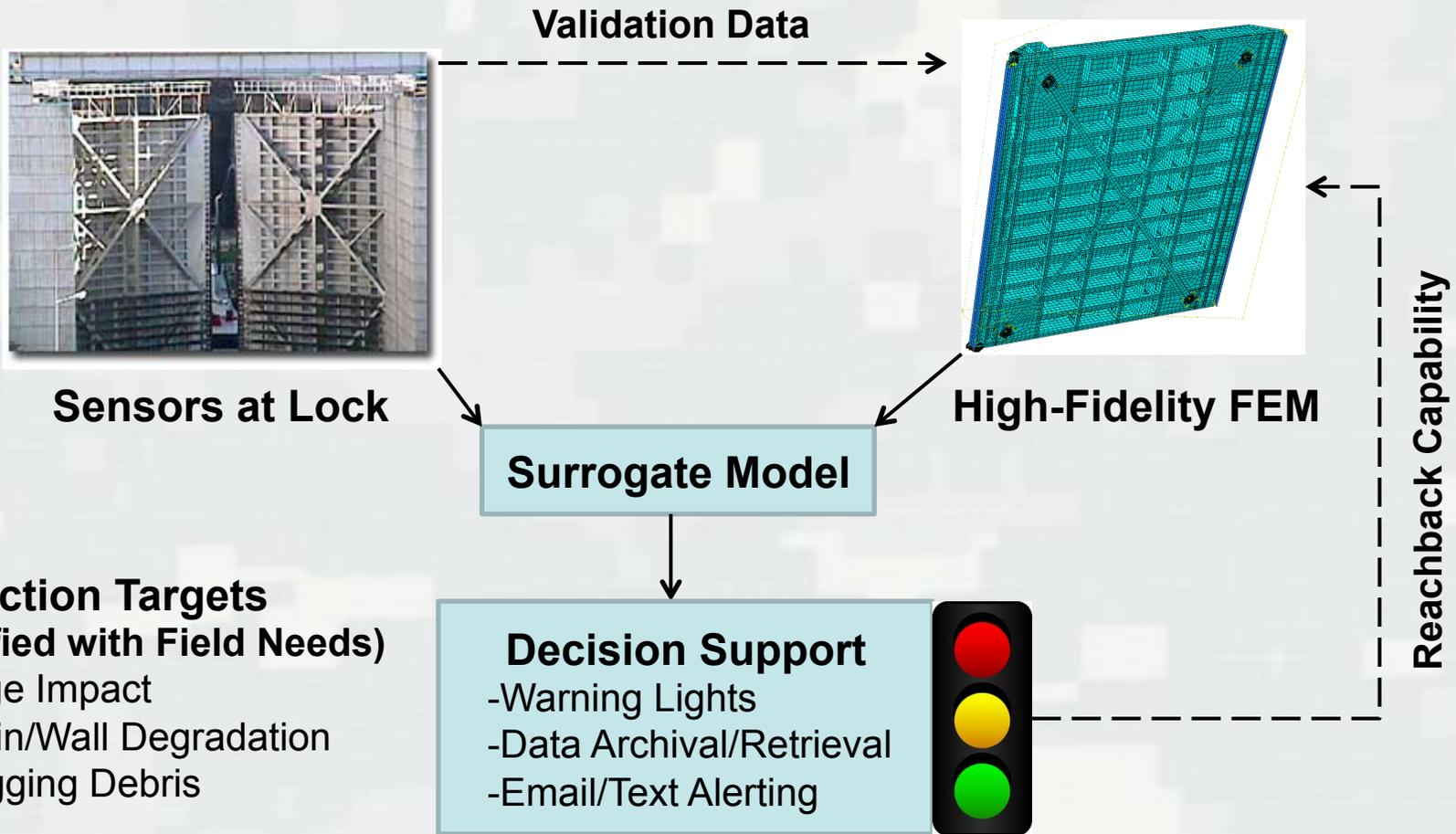


BUILDING STRONG®



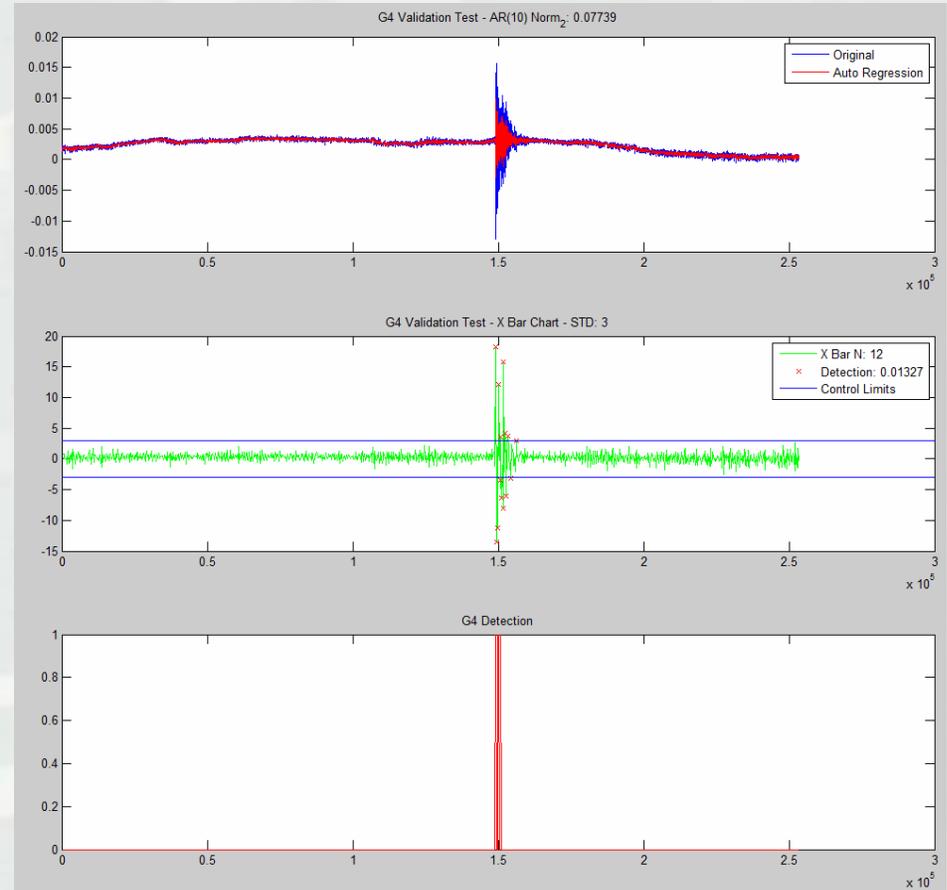
*Innovative solutions for a safer, better world*

# SMART Gate 2.0



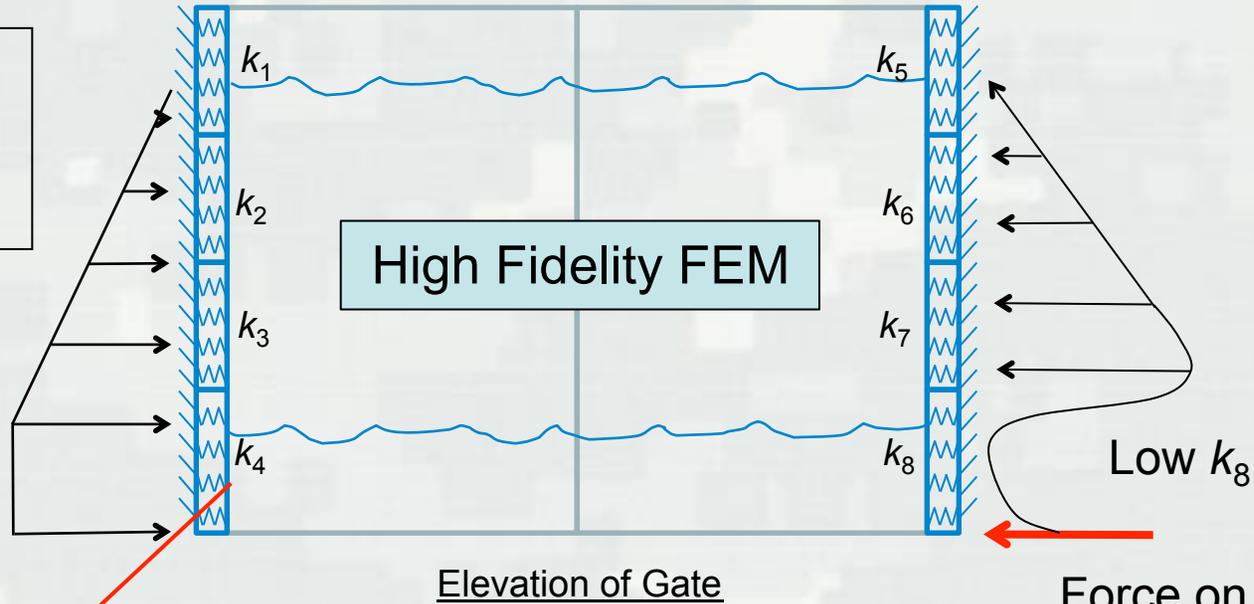
# Condition Monitoring Targets

- Three Initial Targets Developed with Field (District Ops and Eng) PDT
  - Lock Gate Barge Impact
  - Degrading Quoin-to-Wall Contact
  - Dragging/Trapped Debris
- Barge impact
  - Test acceleration vs. learned thresholds
  - Combined with LOMA can determine parties responsible for repairs
  - Algorithms developed with actual barge impact data

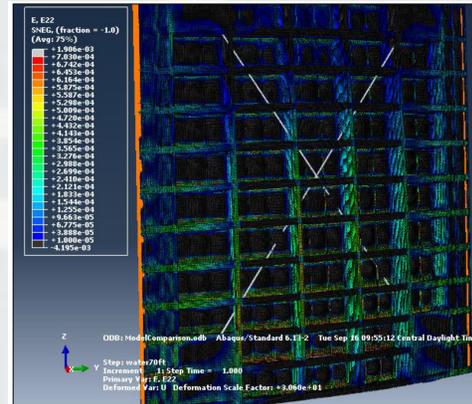


# Condition Monitoring Targets

Degrading  
Quoin-to-Wall  
Contact



Contact  
coefficients

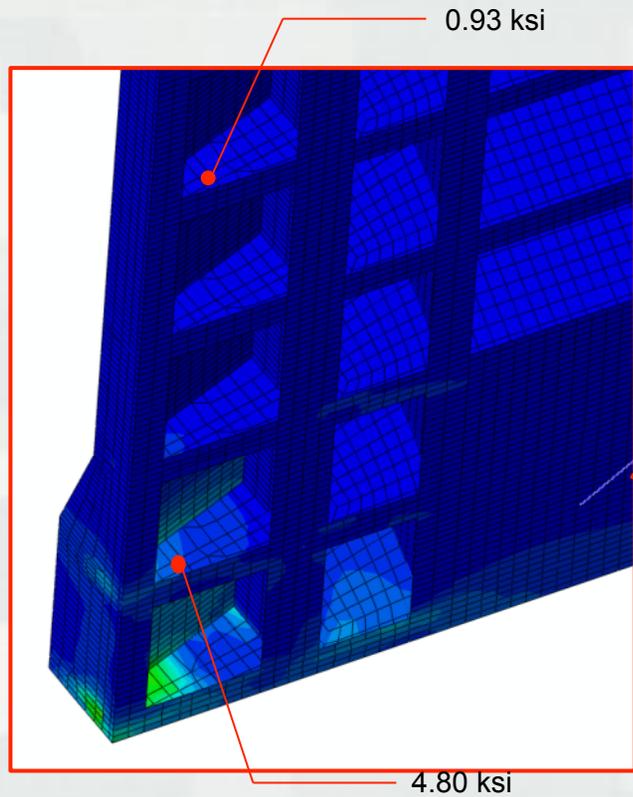


BUILDING STRONG®

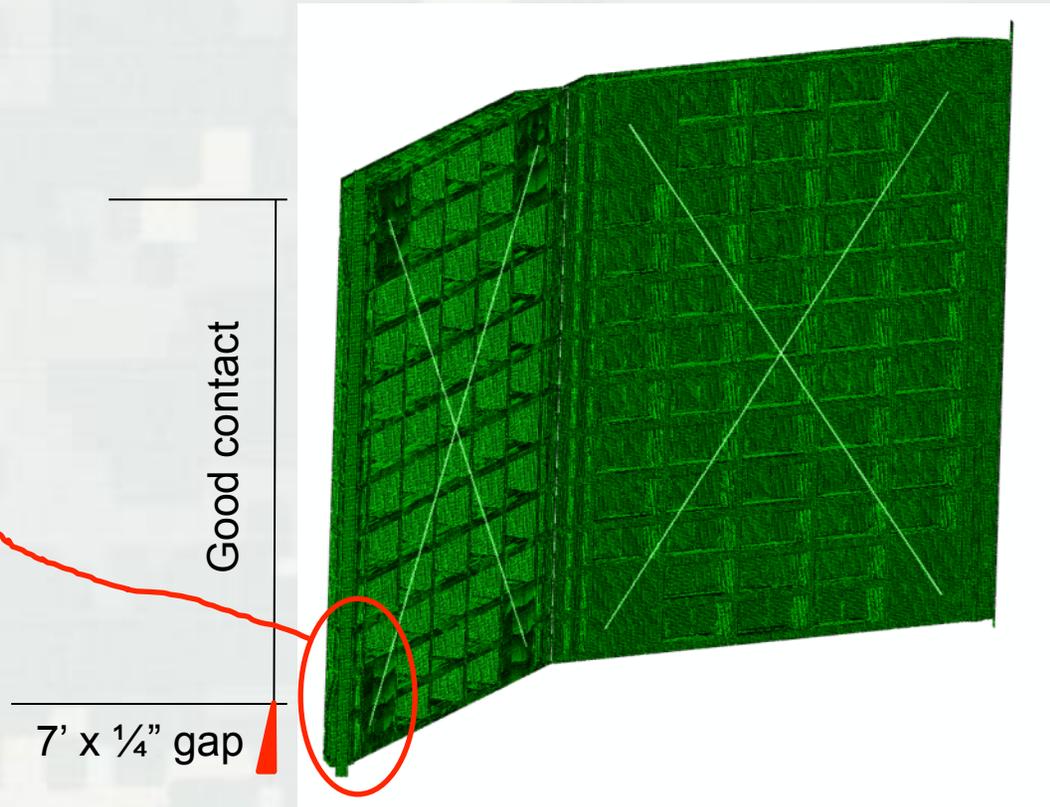
**ERDC**

*Innovative solutions for a safer, better world*

# Condition Monitoring Targets



Change in Stress from  
Wall Gap



Global Model

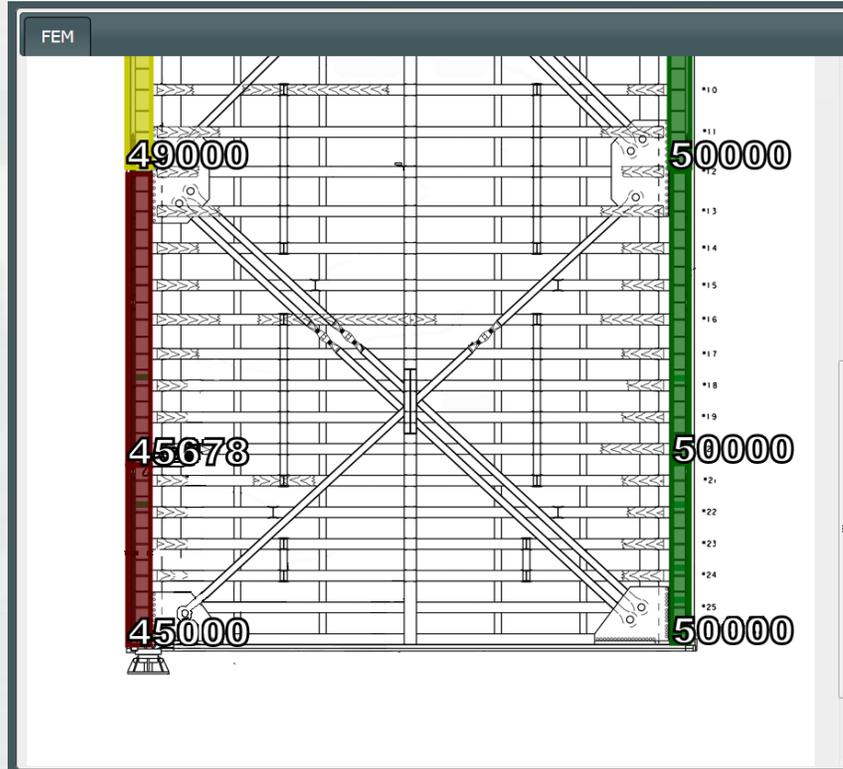


BUILDING STRONG®

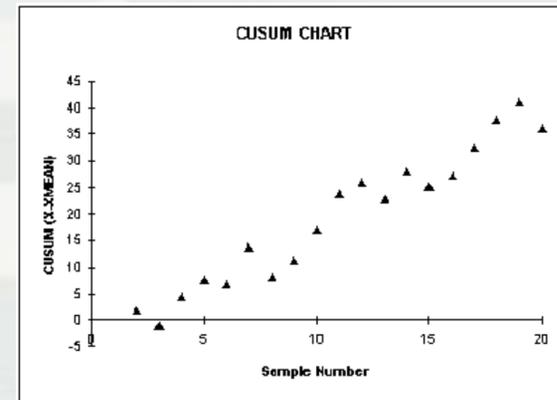
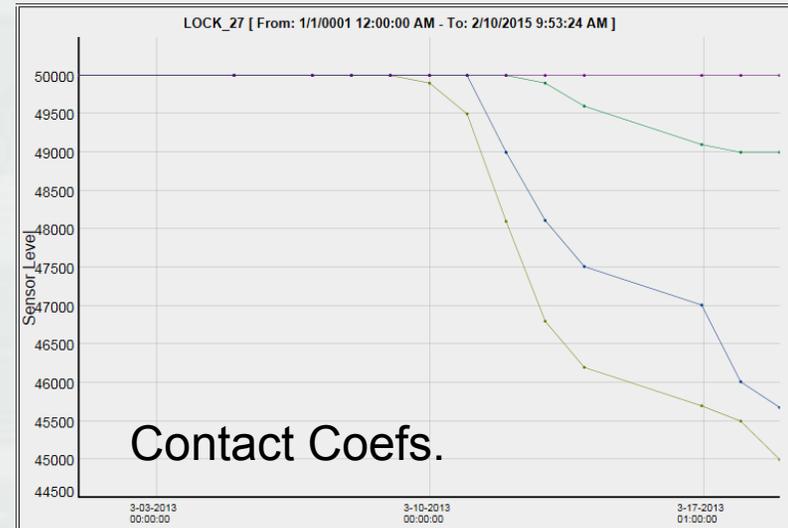


*Innovative solutions for a safer, better world*

# Condition Monitoring Targets



SMART Gate Wall  
Contact Condition



BUILDING STRONG®

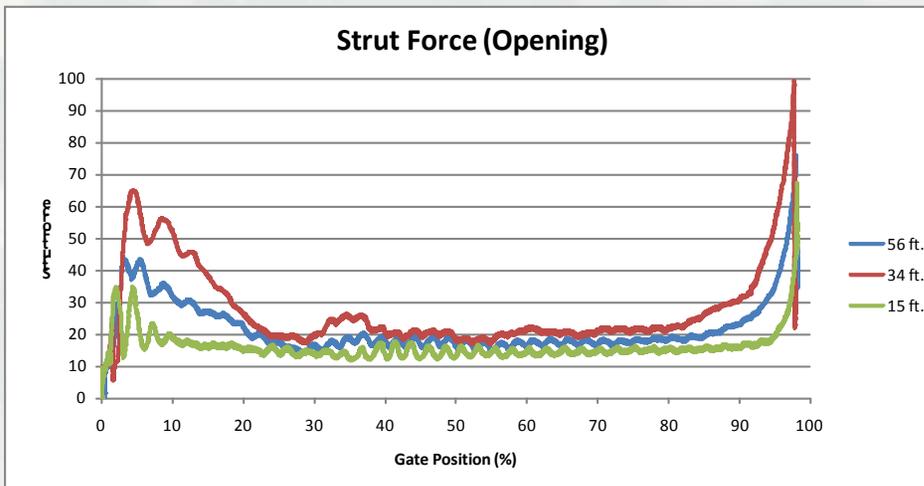
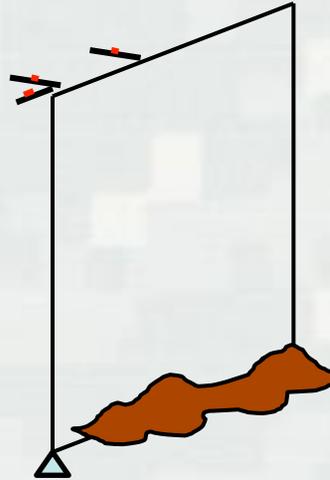
**ERDC**

*Innovative solutions for a safer, better world*

Image Ref: <http://lorien.ncl.ac.uk/ming/spc/spc8.htm>

# Condition Monitoring Targets

- Dragging/Trapped Debris
  - Forces in anchors and struts indicate dragging
  - Response surface model
  - Statistical process control
  - Scale Model V&V



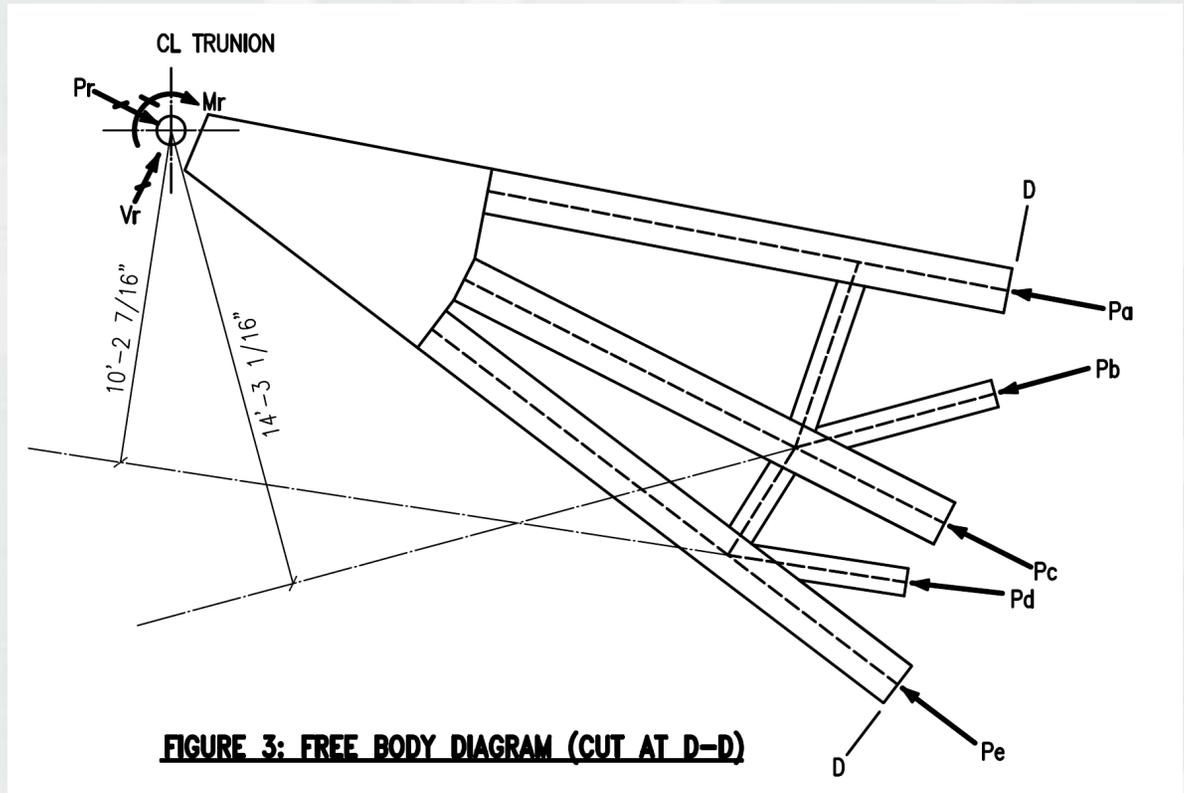
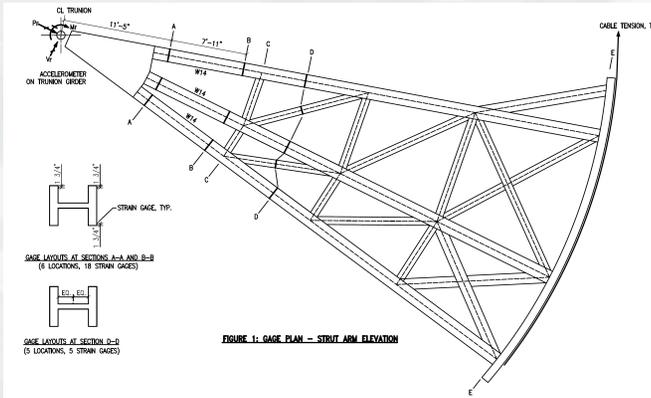
BUILDING STRONG®



*Innovative solutions for a safer, better world*

Image Ref: SHM Course Notes, Los Alamos Dynamics, <http://www.la-dynamics.com/>

# Tainter Gate Trunnion Friction



BUILDING STRONG®

**ERDC**

*Innovative solutions for a safer, better world*

# Value

- Early detection of conditions leading to catastrophic failure
- Framework for added capabilities from R&D
- System framework applicable to other infrastructure (Spillway Gates, Bridges, etc.)
- Possible tie to Asset Management and Maintenance Management
  - ▶ Automated and accurate condition assessment
  - ▶ Predict remaining life
  - ▶ Repair alternative simulations



# Lock Projects and Schedule

## Participating Lock Projects

- Development Site: Lock 27, St. Louis District
- Demonstration (Pilot) Site: Racine, Huntington District

## Schedule

- FY15: Demonstration of SMART Gate 2.0: Racine Lock May-June
- FY15 and Beyond: Adding Capabilities through new sensor types, new detection targets, improved reliability, interrelationship between inspection and SHM, integration into asset management, ...

