# Colonial Pipeline Company

# Practical Experience on Addressing the Assessment & Management of Dents

**USDOT PHMSA 2018 R&D Forum**
**Baltimore, MD**
**September 11, 2018**

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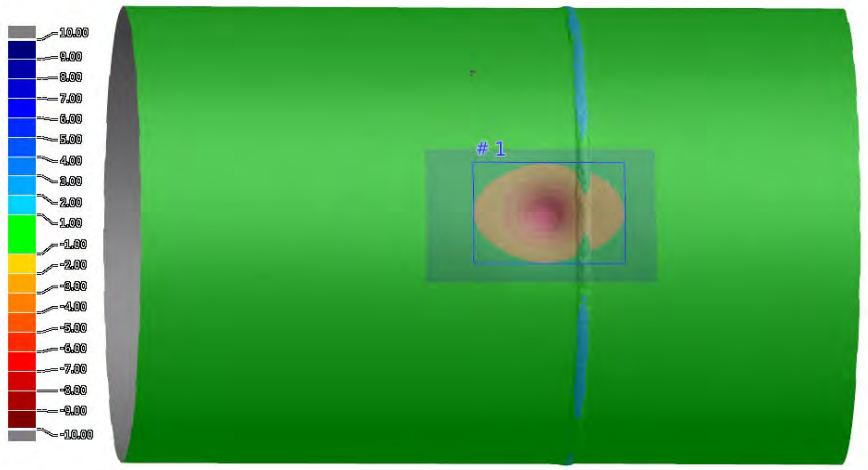
# Research Objective

- Improve our understanding of dent fatigue to develop appropriate inspection, response/repair, and P&M technologies, strategies and programs
- Adjust operations to reduce cyclic fatigue on system
- Apply R&D results to evaluate and prioritize dents and deformations that represent a potential for failure




# Hazardous Liquids Final Rule

- Liquids industry petitioned to allow for an industry recognized engineering analysis to determine those dents that are non-injurious and require no further investigation
- Engineering analysis accepted for cracks, not dents

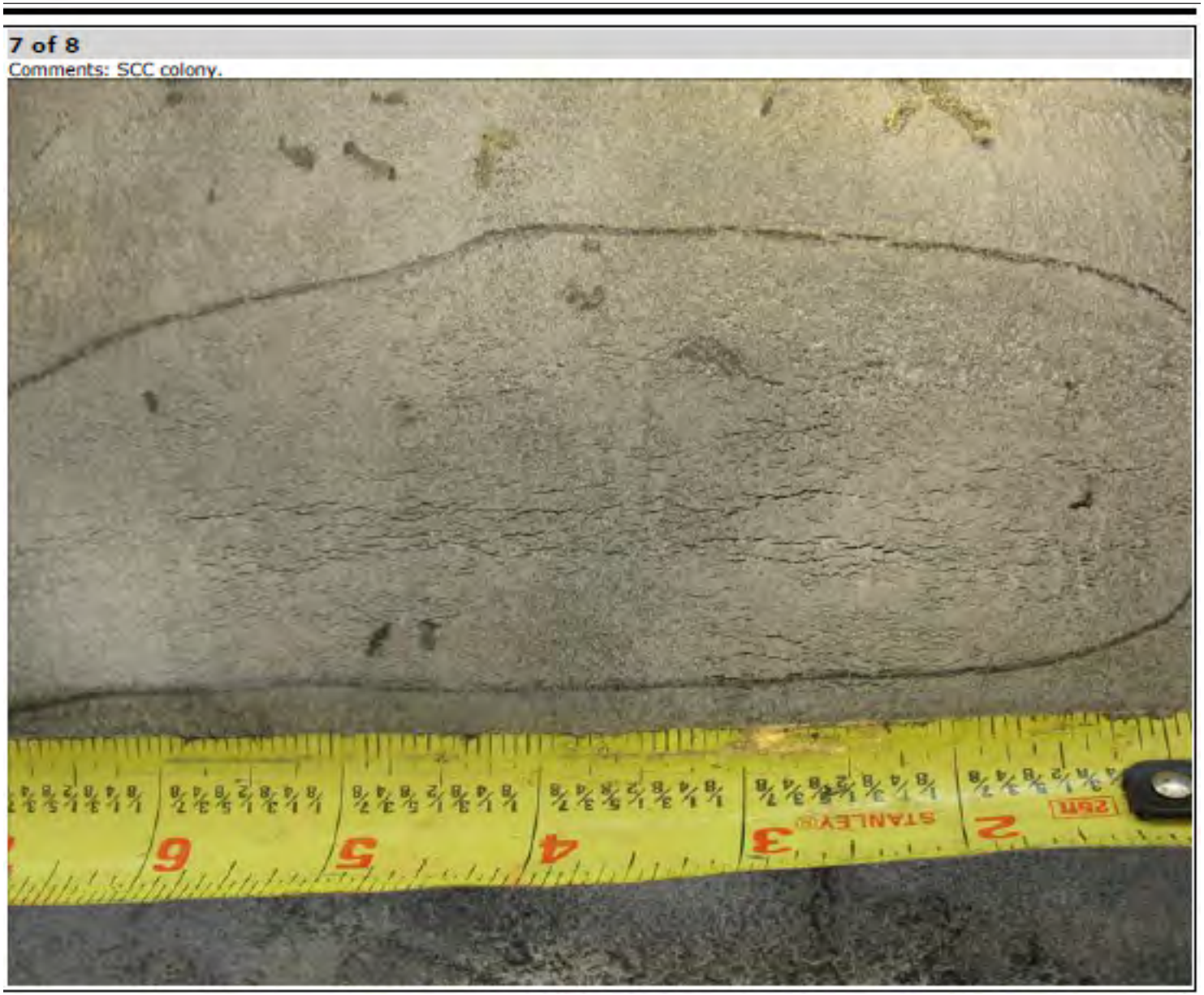
notify the appropriate PHMSA Region Director when unable to inspect infrastructure impacted by extreme weather within 72 hours; 2) PHMSA is allowing a specified engineering critical assessment (ECA) to extend the repair deadline with regard to SCC and SSWC but not for dents;

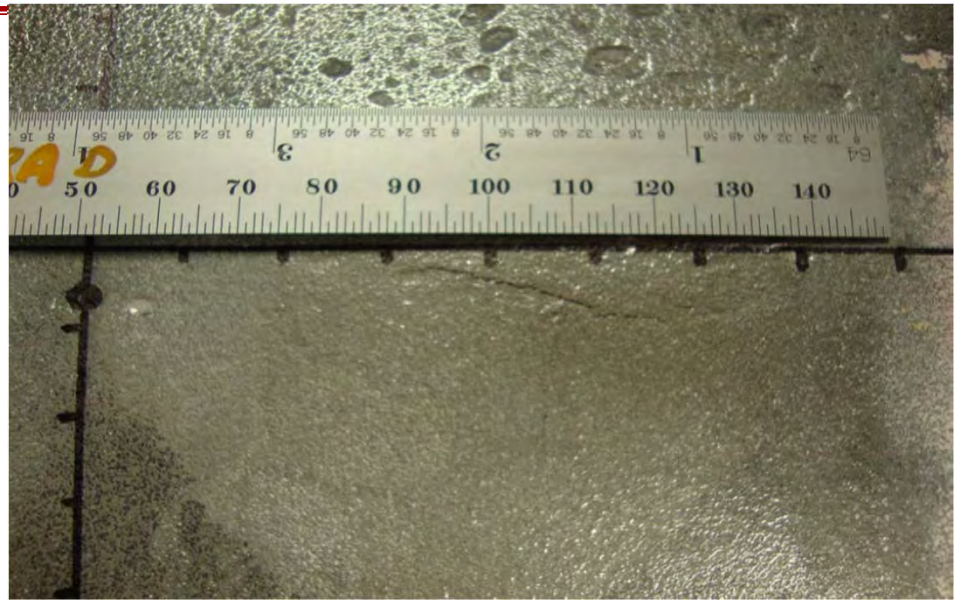
- With Final Rule pending, what are options?
- What tools are available for managing shallow dents?

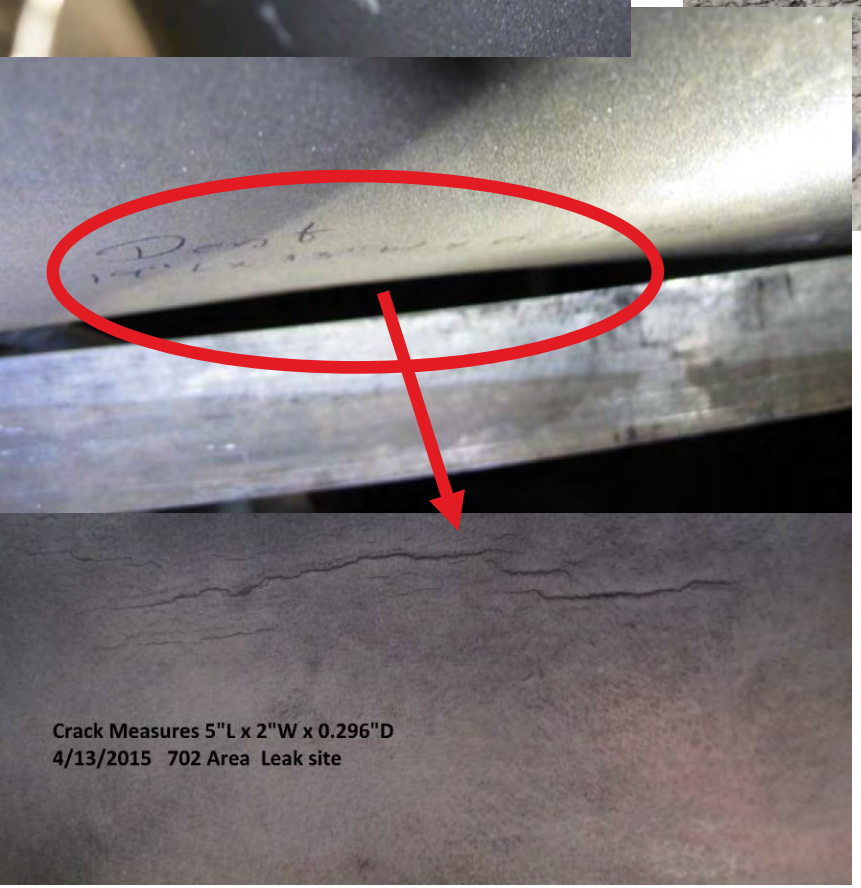
# NTSB Recommendation

- P-17-1: *Work with pipeline trade and standards organizations to modify the pipeline dent acceptance criteria to account for all the factors that lead to pipe failures caused by dents, and promulgate regulations to require the new criteria be incorporated into integrity management programs*
- Regulations are not vague
- Support for revised/alternate response criteria
- Addressing the shallow dents that require response
- Resource allocation to true threats – improving pipeline safety

# Pipeline Inspection & Repairs





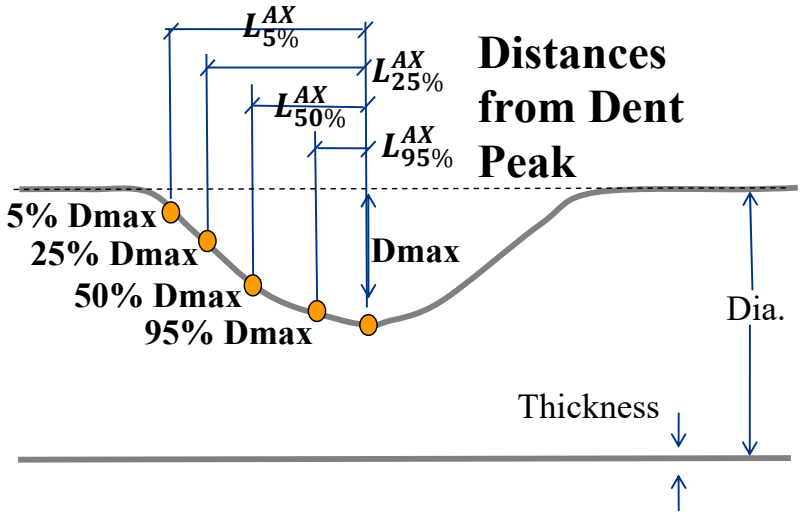

Crack Measures 5"L x 2"W x 0.296"D
4/13/2015 702 Area Leak site


13-Jan-2016 1742 UTC | 30.929653, -90.829407
2005 LA-432, Greensburg, LA 70441, USA
line 1 leak (Felixville)
Line 1

# Key Outcomes of Dent Fatigue Research

- Dent shape parameter (not depth!)
  - Incorporated into pipeline operator ILI specifications
  - Sets a standard for dent/deformation ILI reporting requirements
  - Used in Level 1, 2, 3 analysis

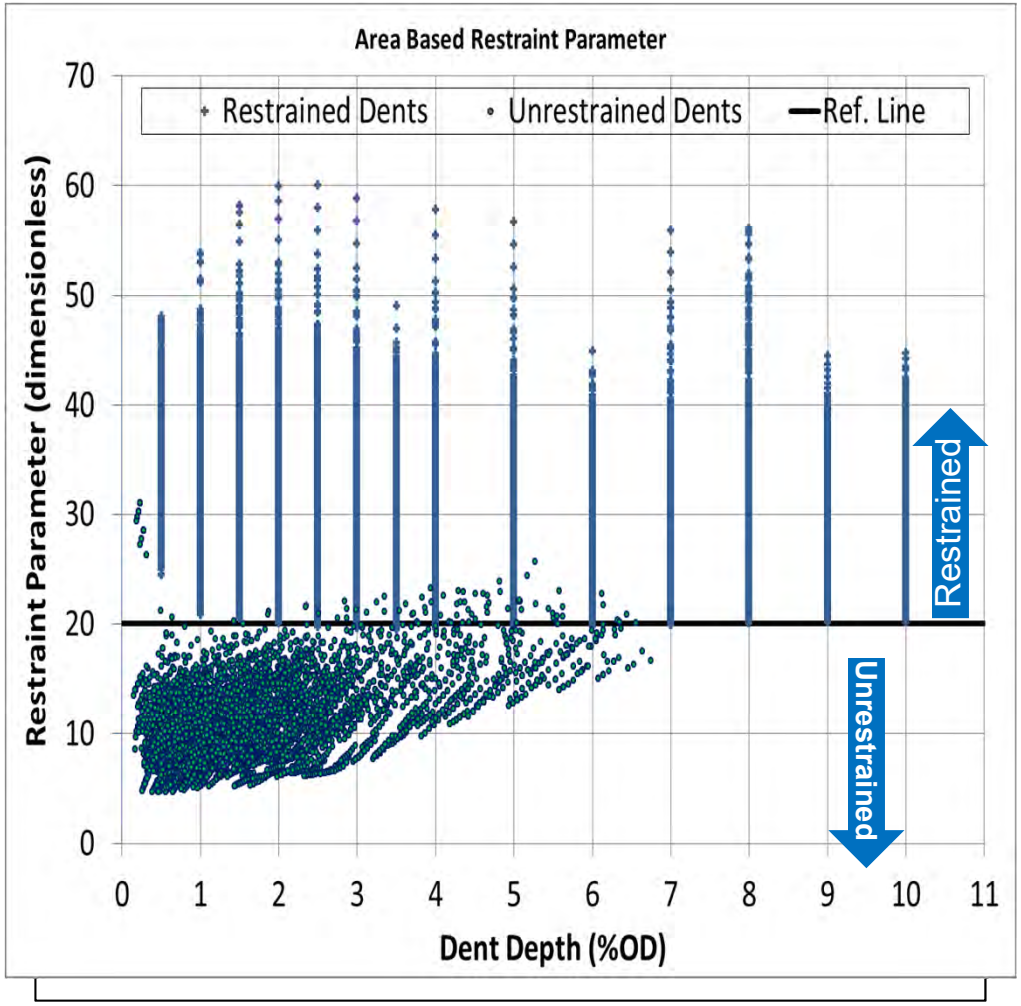
PRCI Dent Shape Parameter Specification



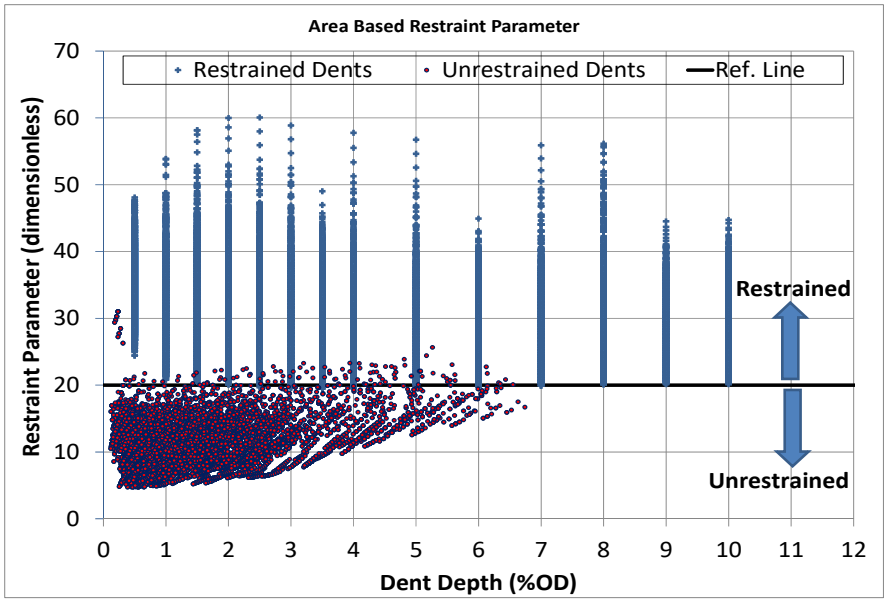

- PRCI MD 4-9 Technical Note
- Develop shape parameter using characteristic lengths measured across the dent profile
- Use calculated shape parameters, pipe grade, and SCADA data to rank shape severity (L1) and /or fatigue severity (L2)
- L3 – full FEA; complex shapes

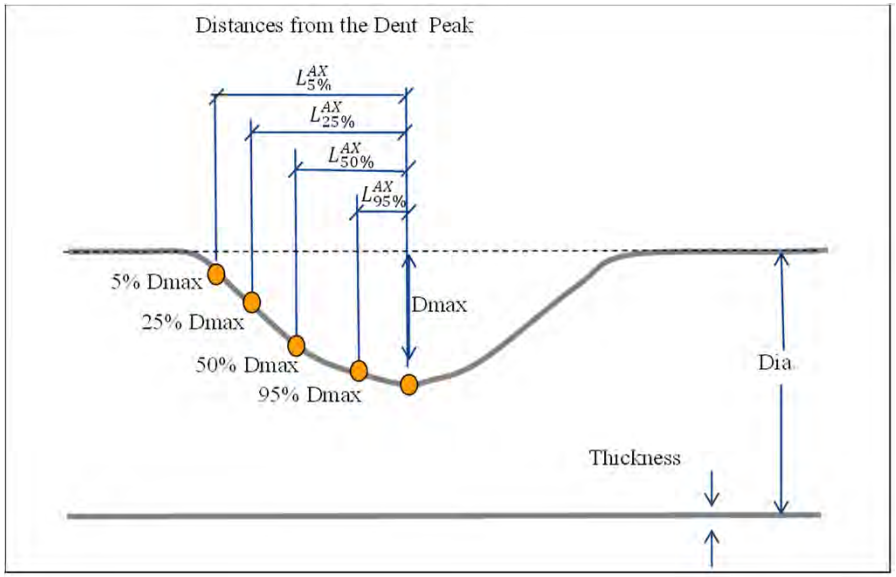
# Key Outcomes of Dent Fatigue Research

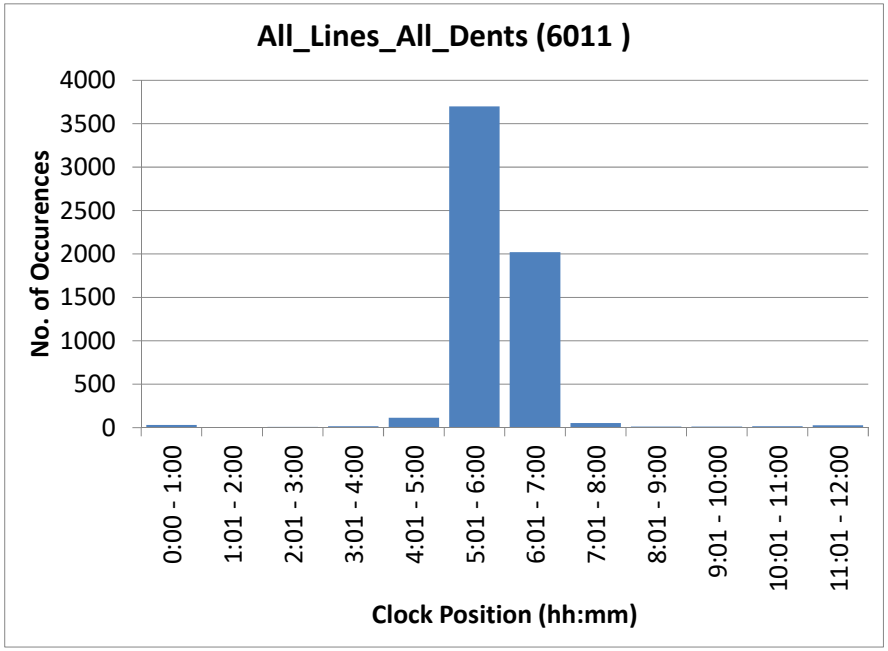
- **Dent restraint parameter – restrained vs. unrestrained affects fatigue life**
  - **Restrained – longer life**
  - **Unrestrained – reduced life**
  - **Bottom-side dents have higher restraint potential**
  - **Previously excavated dents: restrained and unrestrained**

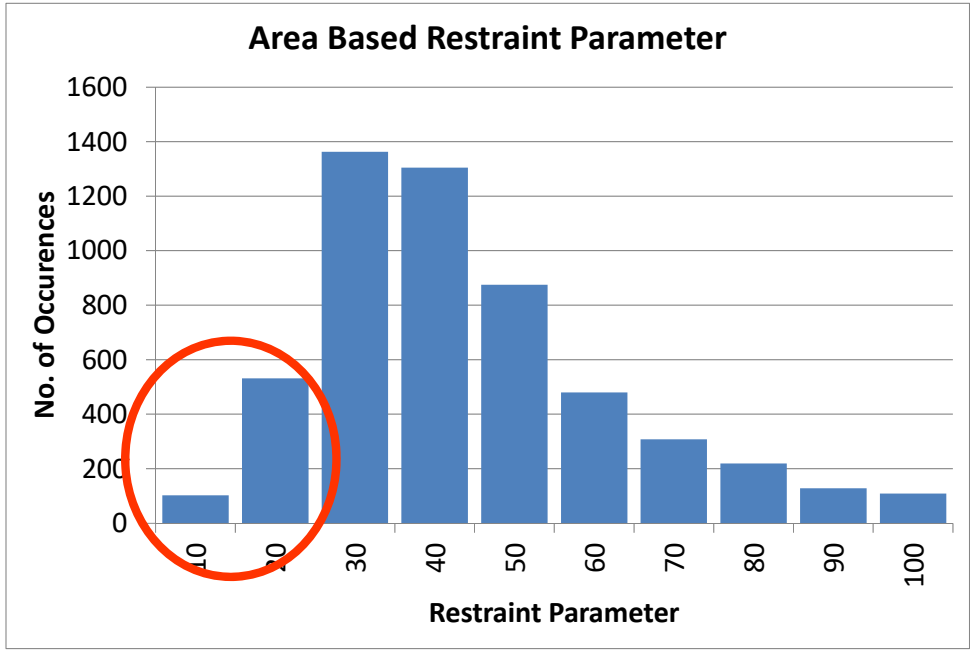


# Analysis of Restraint Condition



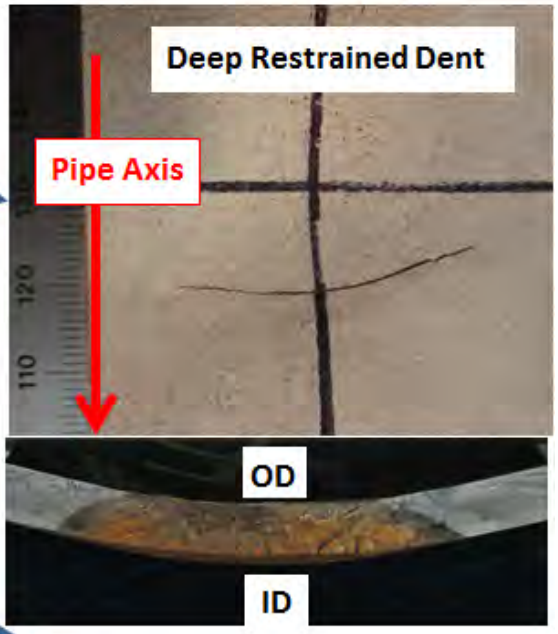



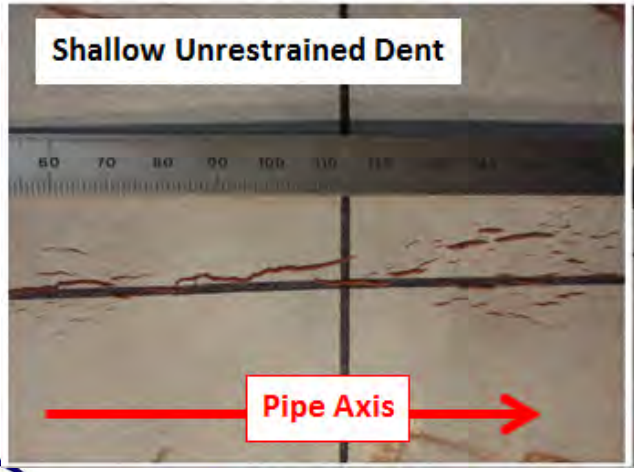



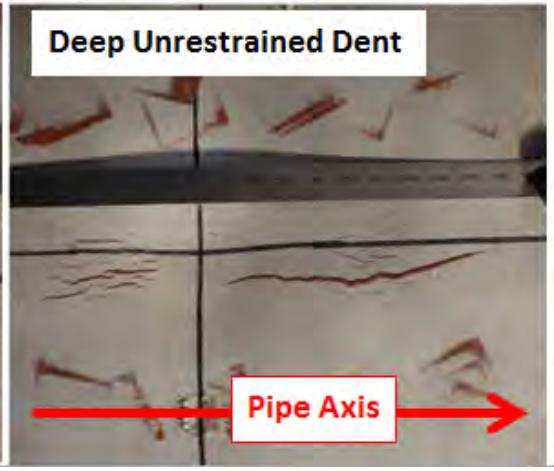
# Key Outcomes of Dent Fatigue Research

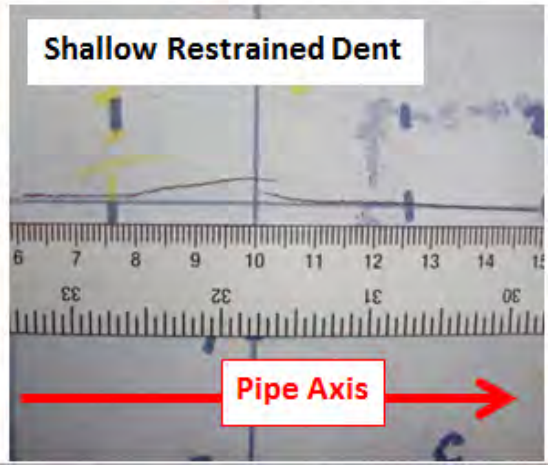
## Dent Fatigue Crack Location, Orientation and Surface

| Dent Type | Depth | Shape | Crack Location | Orientation |
|---|---|---|---|---|
| Restrained | Deep (> 5%) | Blunt or Sharp | Axial Shoulder (one or both) ID Initiation | Circumf. |
| Restrained | Shallow (≤ 2%) | Blunt or Sharp | Center of dent ID Initiation | Axial |
| UnRestrained | Deep (> 1.5%) | Blunt or Sharp | Axial Shoulder OD Initiation | Axial (Multiple) |
| UnRestrained | Shallow (≤ 1.5%) | Blunt | Center of dent OD Initiation | Axial (Multiple) |
| | | Sharp | Axial Shoulder OD Initiation | Axial (Multiple) |



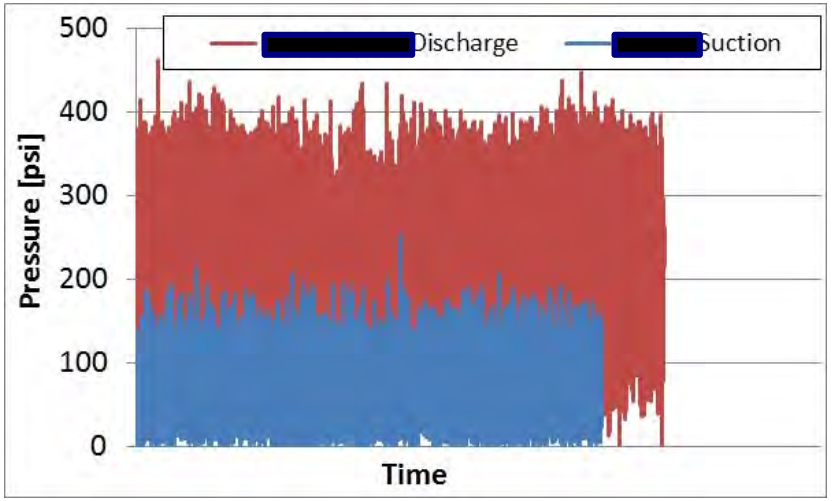



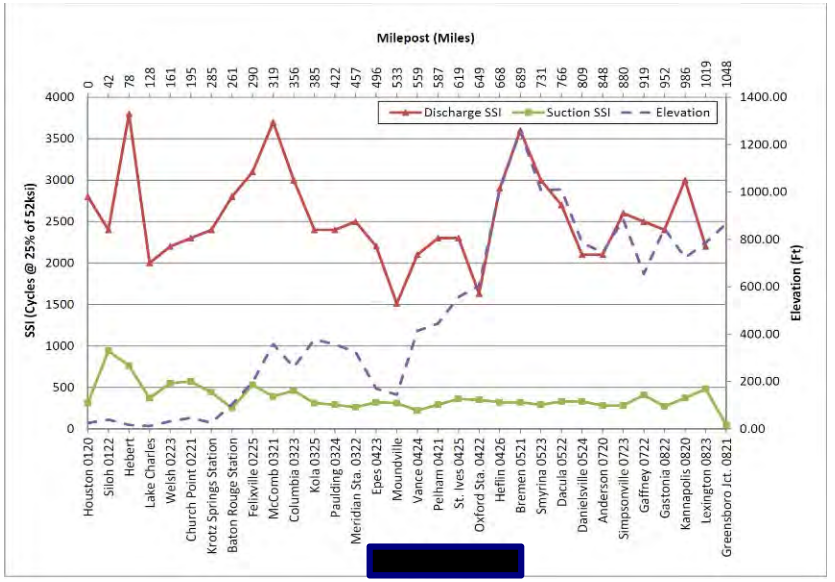



# Key Outcomes of Dent Fatigue Research

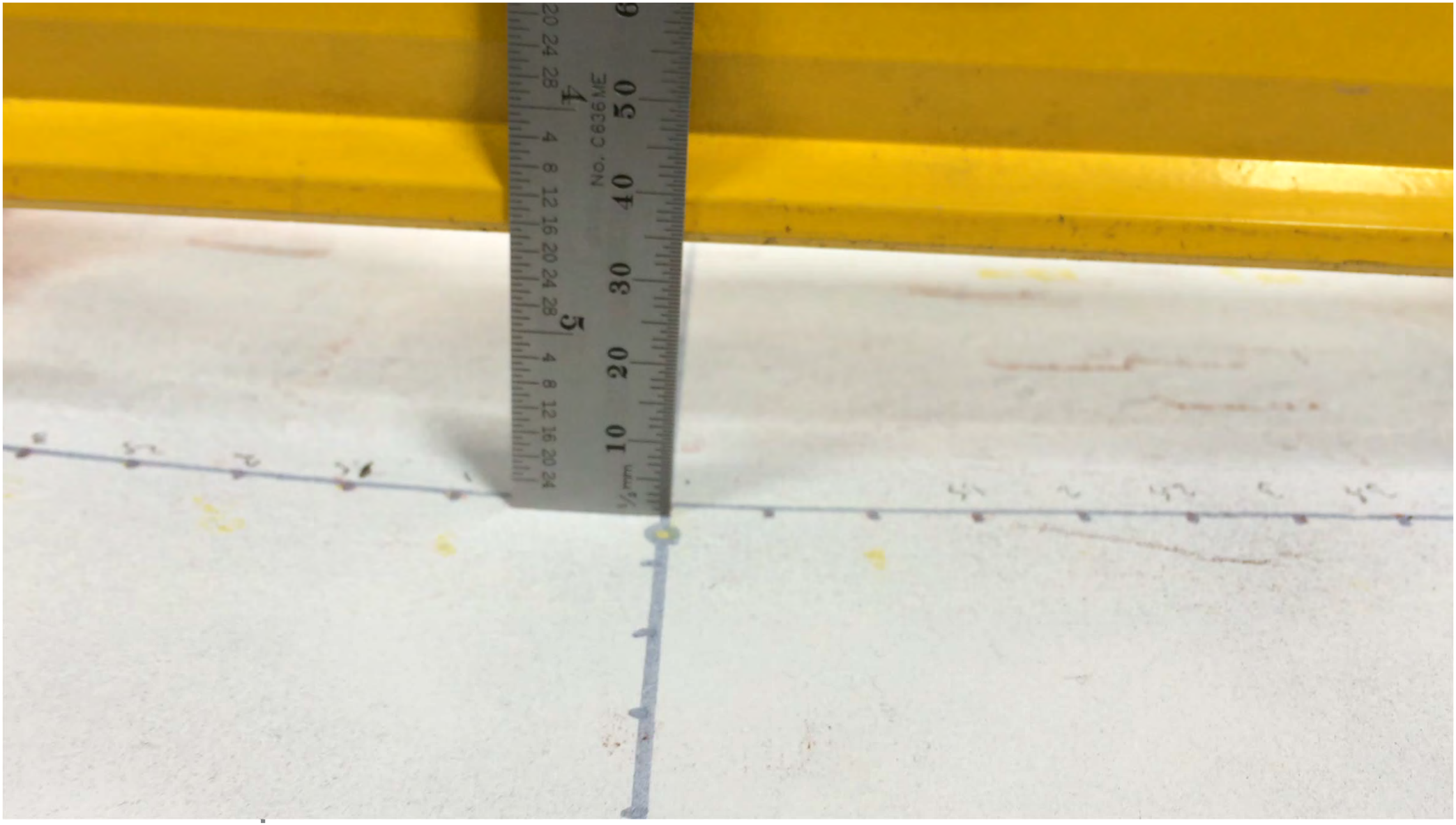
## Pressure Cycle Management

- # of cycles and magnitude of cycling loading influence dent fatigue failure
- Pressure attenuation – discharge vs. suction
- Liquids operations vs natural gas
- Pressure cycling references in regulations
  - *Absent in PHMSA Proposed Final Rule (49CFR §195)*
  - *Included in PHMSA Advisory for natural gas lines (ADB 2016-0131)*



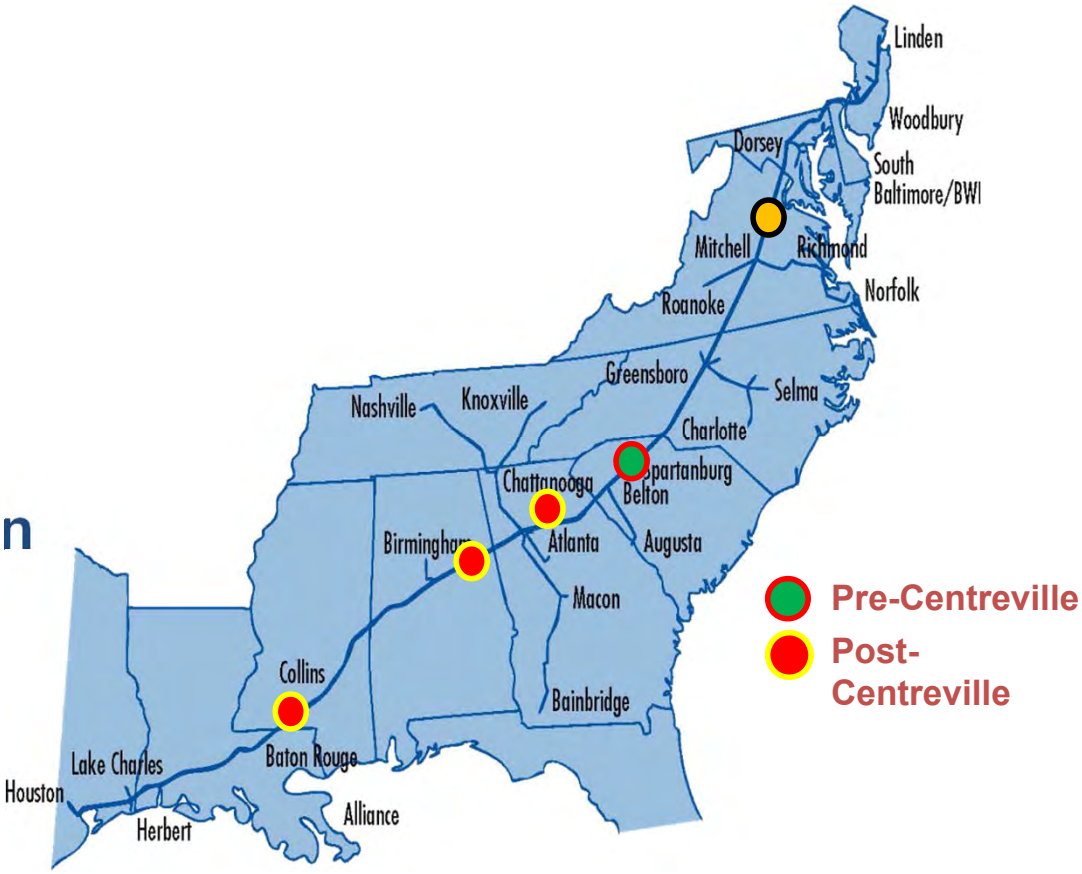



# Full-scale Testing of Dent Sample



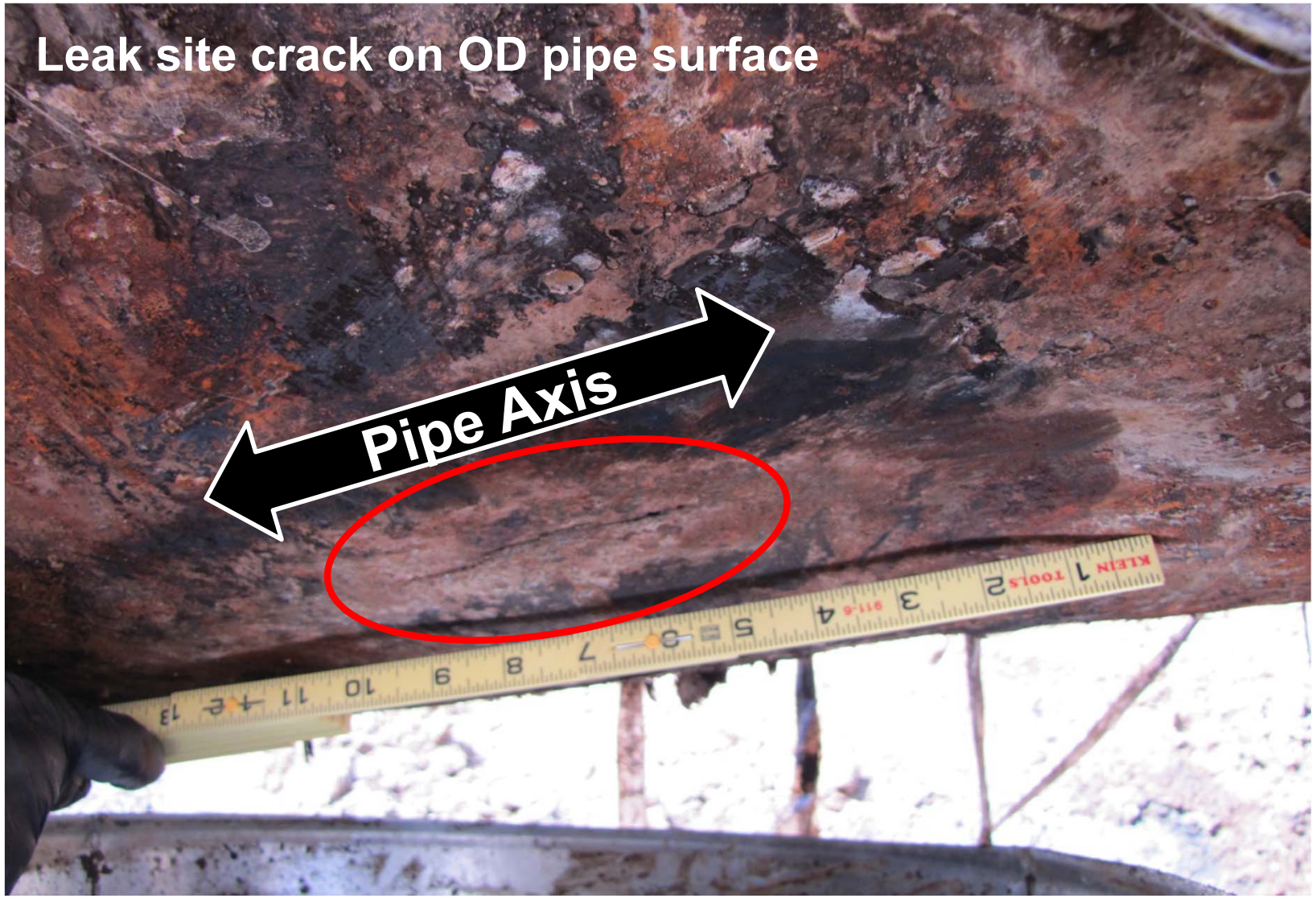
# Effects of Dent Shape

- Leak Differences
  - Manufacturer
  - Date of Install
  - Pipe Diameter
  - Coating Type
  - Product Type
  - Distance to Pump Station
  - Terrain
  - Soil Type
  - Moisture Content
  - Indenter Cause

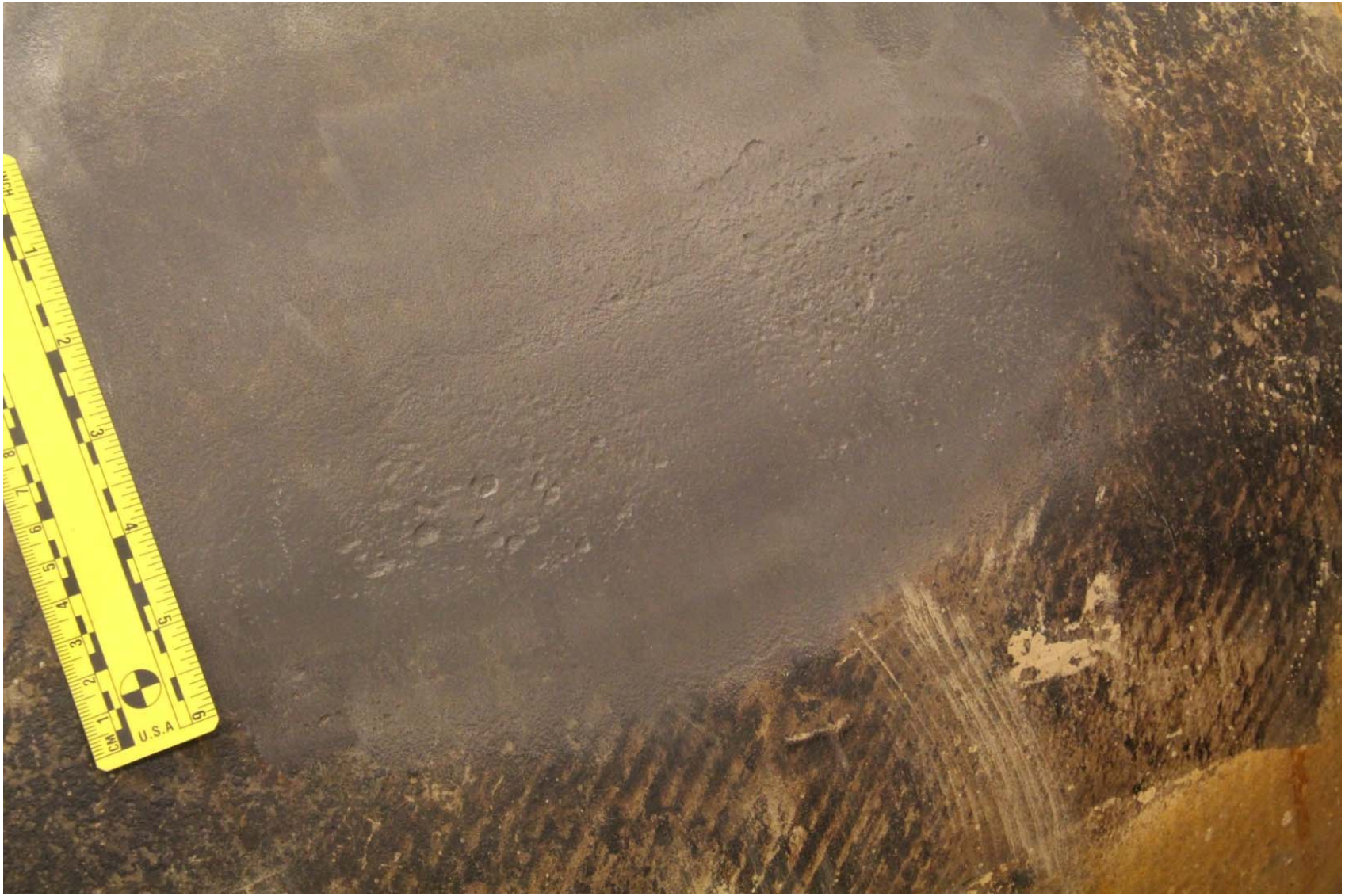



- Leak Similarities
  - Shallow Bottom Side Dents
  - High D/t Pipe

# NTSB Accident Investigation – Centreville, VA

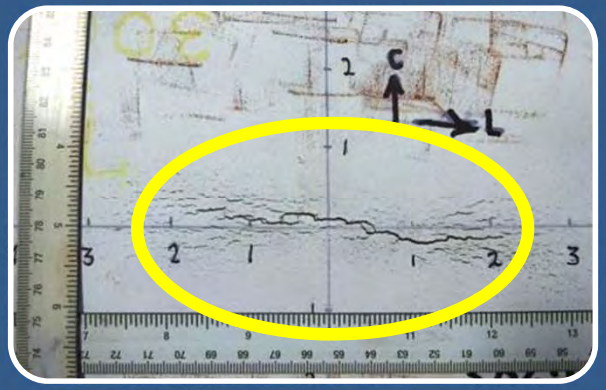


# Fatigue Testing of Uncracked Dent Sample



# Effects of Dent Shape

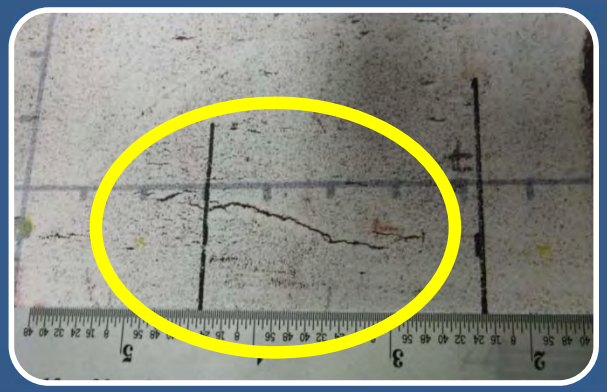
## 3rd Dent (Fatigue Test)



- Fabricated dent
  24” indenter, 1.1% deep
- Smooth dent profile
- 90 psi to 540 psi
- Unrestrained dent
- Center of dent axis

- **455k cycles to failure**

## Un-cracked Dent (Fatigue Test)



- In-service, bottom-side dent: 1.6% deep
- Smooth dent profile
- 90 psi to 365psi*
- Previously dug and remediated (2002)
- Restrained & unrestrained
- Near dent peak

- **108k cycles to failure**

## Leak Site (failed in-service)

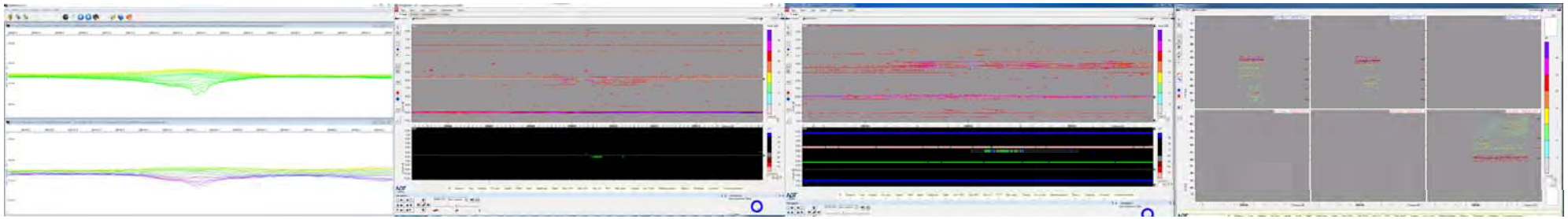
- In-service, bottom-side dent: 1.6% deep
- Complex shape
- 365 psi max
- Previously dug and remediated (1994)
- Restrained & unrestrained
- Near dent peak

- **12k cycles to failure**

# Integrating Multiple ILI Tool Runs

- Typical mainline data set
  - 3+ MFL\DEF\INS
  - 1 UT crack tool run
- All data is integrated and odometers generated for all historic tool runs
  - Previous tool runs are reviewed in conjunction with most current tool run
  - Prior dig data is integrated - allows for tool validation prior to digging
  - All dents are manually reviewed in raw data (recall DRRPM)

| 1 | ANOMALYID | AF | ENDORC | ODO2015 | CRACK2014 | COMBO201 | ORCPC | Altstation | USWELD | DSWEL | RIENTA | JOINTLENG | VENDORNOTES | PTHPER | LENGTH | WIDTH | INTEX | ERF | STREA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 303979 | | 0 | BND 1569 | 1318103.480 | 1317752.332 | 1321965.134 | | 1105597.6 | 13.6 | 13.5 | 12:11 | 27.1 | | | 80.88 | | | | |
| 303980 | | 5 | B-16142 | 1318103.590 | 1317752.442 | 1321965.244 | | 1105597.71 | | | | | 39.8 D -0.7ø Left 3.7ø Up | | | | | | |
| 303981 | | 7 | AGM | 1318106.200 | 1317755.052 | 1321967.854 | | 1105600.32 | 16.344 | 10.677 | : | | | | | | | | |
| 303982 | 2B-1318111.723-2016-51 | 16 | crack field | 1318111.723 | 1317761 | 1321973 | | 1105606 | 21.842 | 5.121 | 6:24 | 26.963 | Associated With Dent ID 4901644 | 8.32451 | 4.60 | 2.51 | ext | | |
| 303983 | | 7 | DENT | 1318111.872 | 1317760.724 | 1321973.526 | | 1105606.15 | 22.041 | 4.98 | 6:00 | | | | | | | | |
| 303984 | | 2 | DENT | 1318112.083 | 1317760.935 | 1321973.737 | | 1105606.36 | 22.283 | 4.782 | 6:00 | | DENT | | | | | | |
| 303985 | | 16 | dent | 1318112.096 | 1317760.948 | 1321973.75 | | 1105606 | 22.215 | 4.748 | 6:12 | 26.963 | Associated With Crack Field ID 4901645 | | 12.03 | 6.70 | | | |
| 303986 | | 5 | D-4579 | 1318112.153 | 1317761.005 | 1321973.807 | | 1105606.06 | 22.309 | 4.921 | | | 1.1% Dent at 6:00 | 1.107 | 14.96 | | | | |
| 303987 | | 16 | weld | 1318116.844 | 1317765.721 | 1321978.646 | | 1105611 | | | | 40.322 | | | | | | | |



# Integrating Multiple ILI Tool Runs

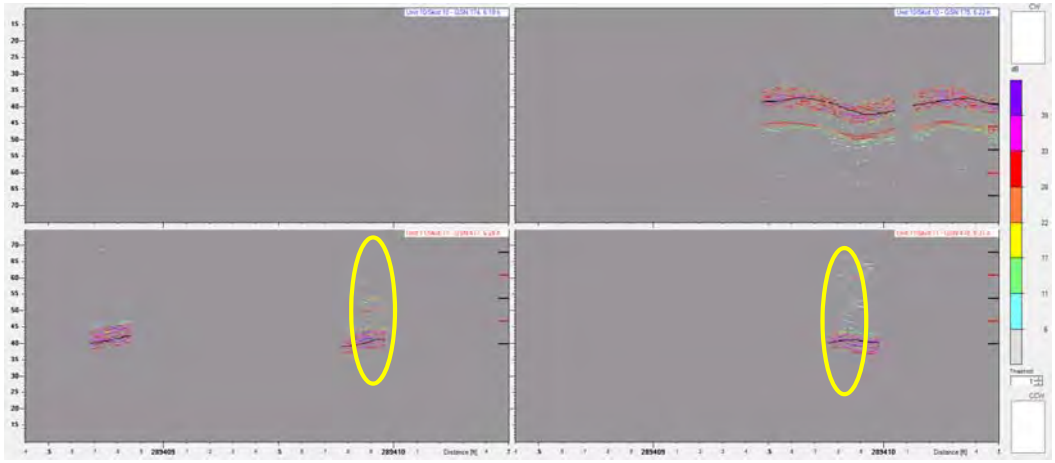
- Reporting thresholds
  - Deformation reporting specifications
    - 1% Deformations
    - False positive challenges <1%
  - Crack reporting specifications
    - Any dent with a crack field reported
    - Limitations with UT tool detection within deformation
      - Continuing to improve process
      - PRCI MD 1-13
    - Crack data is integrated and reviewed for feature proximity to deformations
    - Crack location and orientation now considered
- Continual review and analysis of crack raw data as data becomes available or is refreshed
  - This review is documented and integrated into the DRRPM
    - DRRPM scores are updated

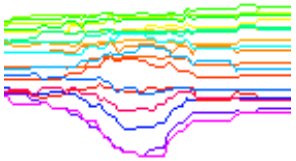
# Integrating Multiple ILI Tool Runs

Looking for the unreported\below threshold

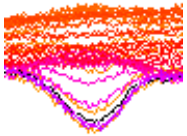
**2014 UT ILI**

- Single reflector only
- Only CCW
- Not seen on skip
- Weak signal





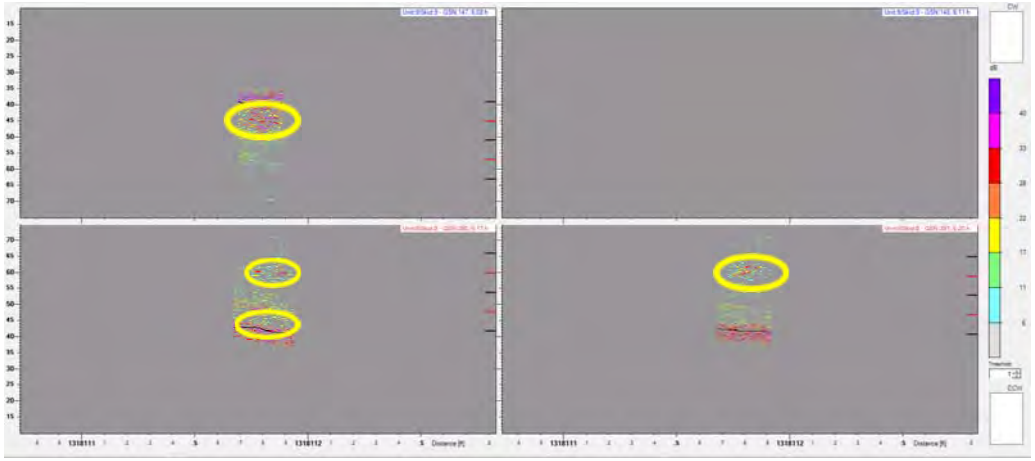
2003 DEF

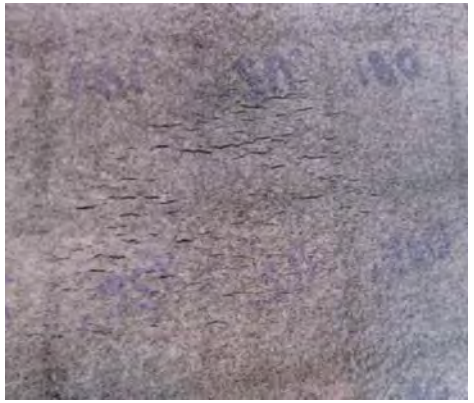


2013 DEF

**2015 UT ILI**

- Multiple reflectors present
- CW\CCW
- Seen on ultrasonic skip
- Strong signal
- Called crack by ILI



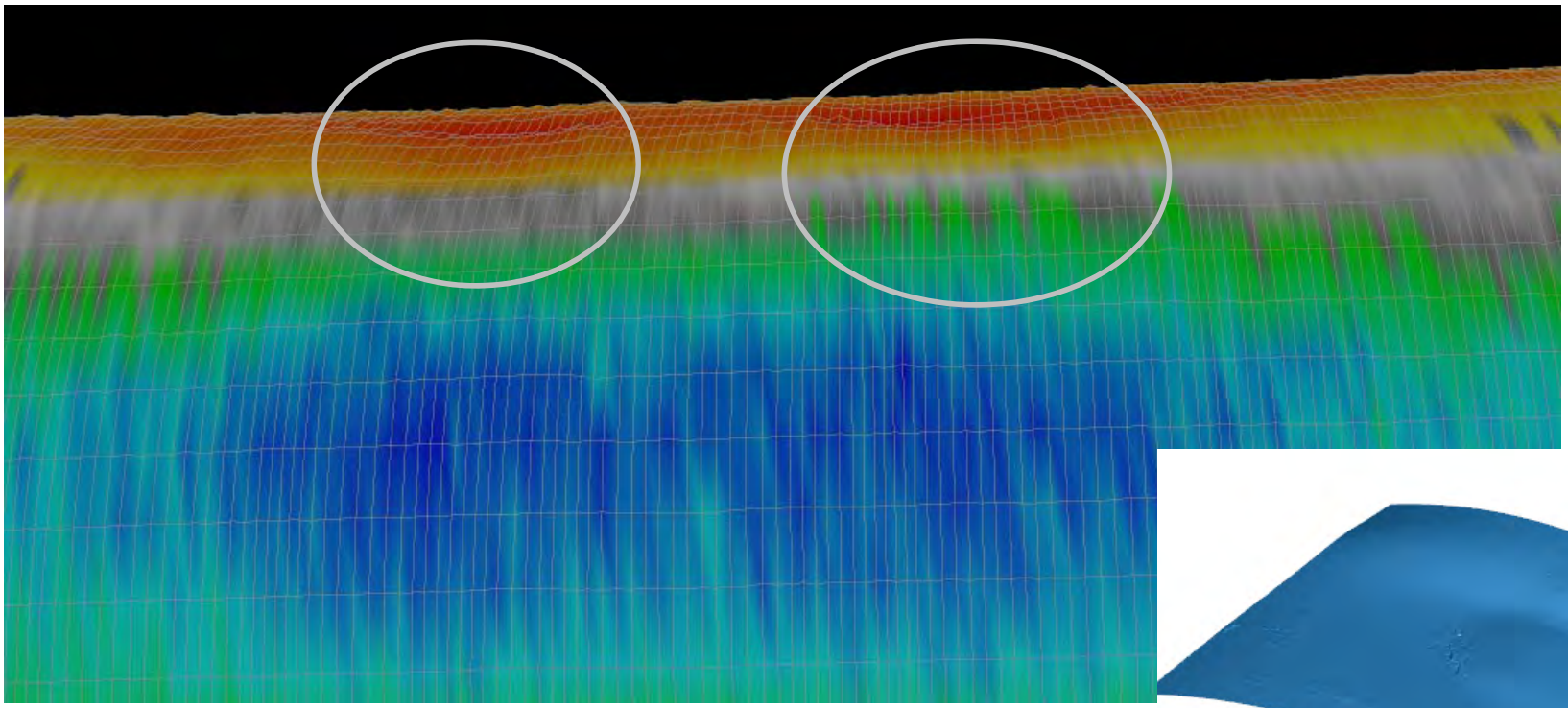


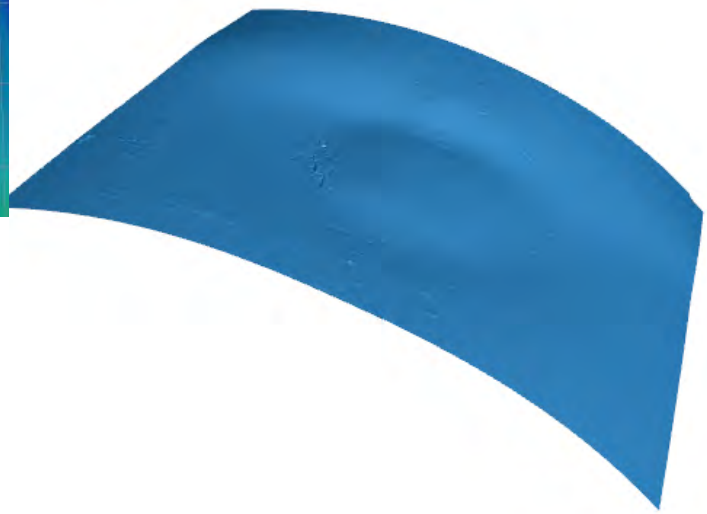
2016 Excavation

Reflectors

# Effects of Dent Shape

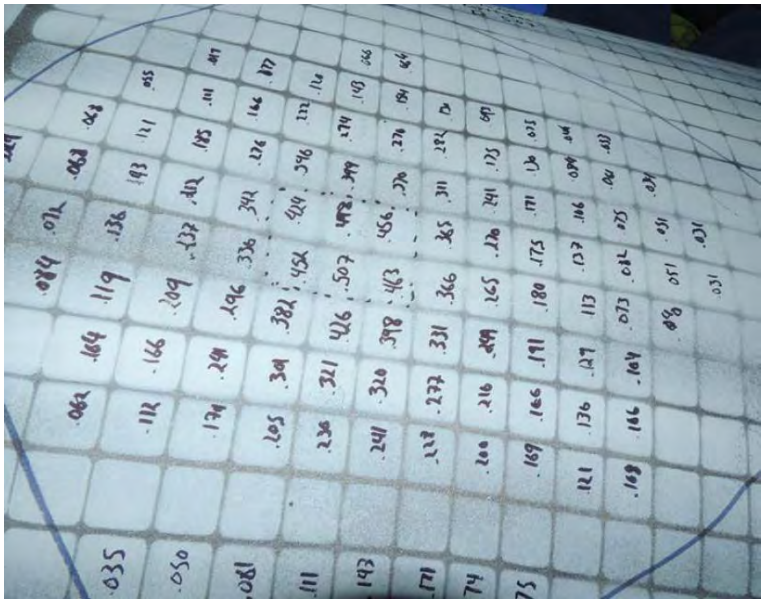
- Multi peak dents vs single peak

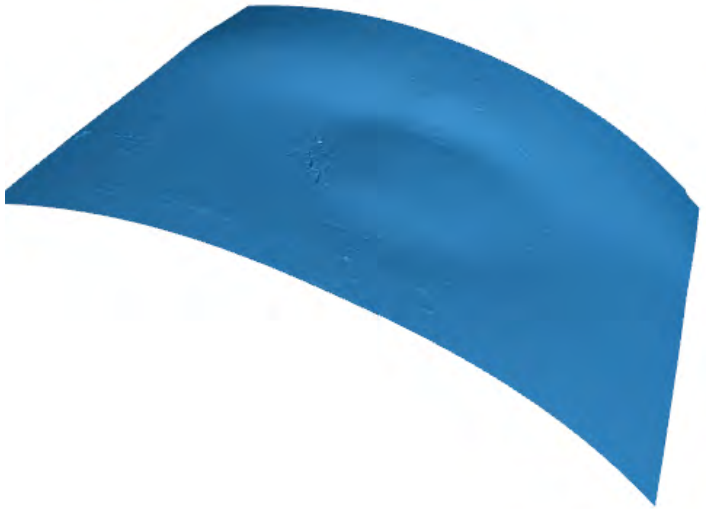




# NDE Methods – Dents and Cracks

- Document deformation profile in grid system
  - Minimum grid points
  - Deepest & most prominent locations
- Magnetic Particle dent and 12” surrounding
- Cracks are sized using shear wave or phased array – internal cracks
- If no findings during MP, shear wave or phased array
- 3D scan/profile
  - Compare to ILI – SP and RP
- NDE research
  - Multiple NDE vendors sizing cracks, destructive testing for confirmation
  - PRCI MD 1-13





# NDE Methods – Dents and Cracks