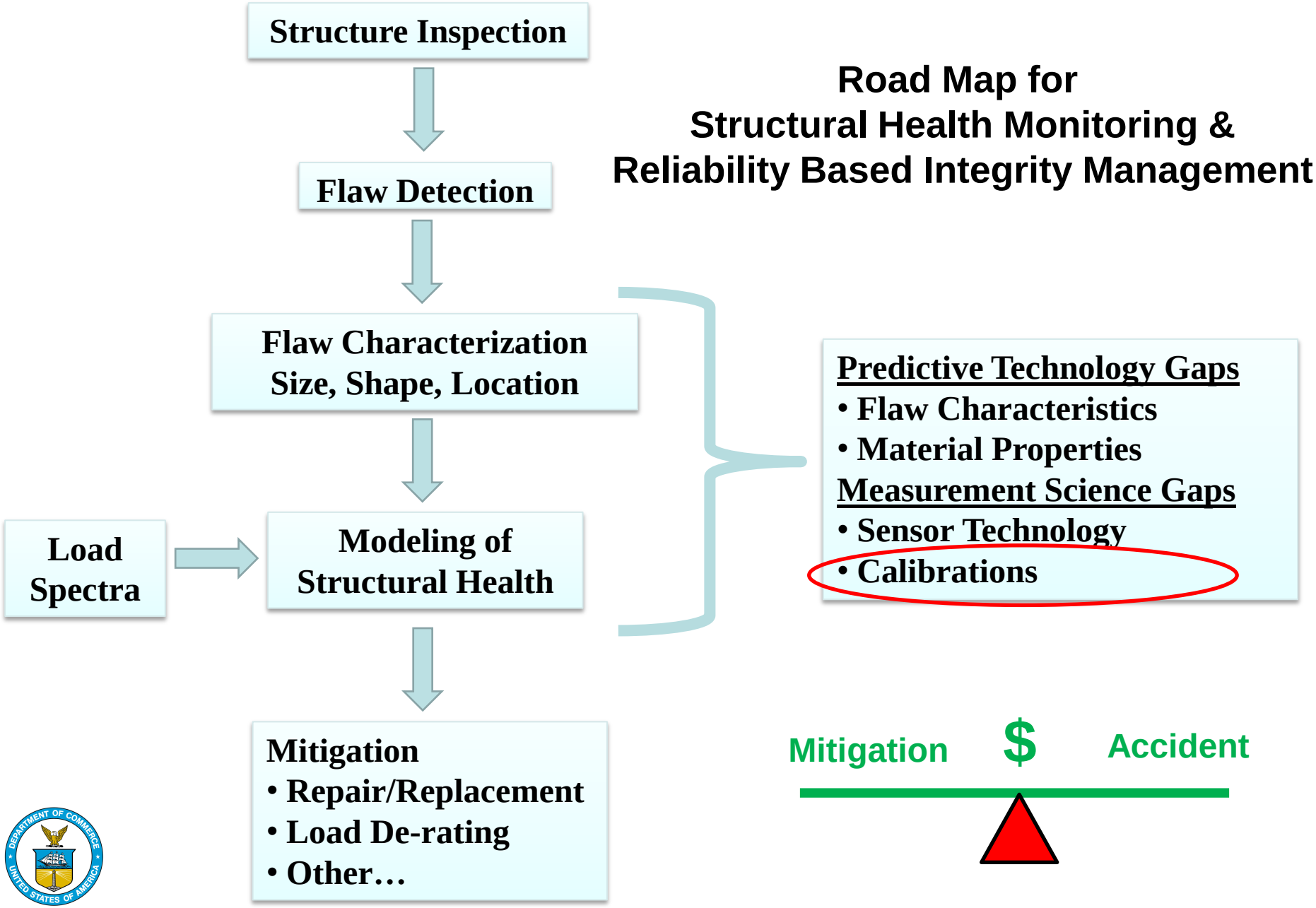
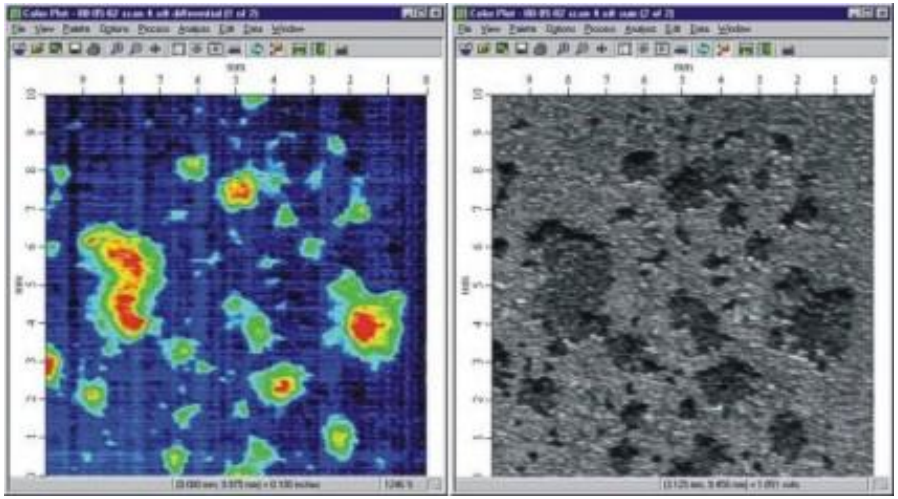
NIST Standard Reference Material Development for NDE Calibration & Failure Artifact Repository

Dash Weeks
David McColskey
Mark Richards
Ross Rentz
Ken Talley

Road Map for Structural Health Monitoring & Reliability Based Integrity Management

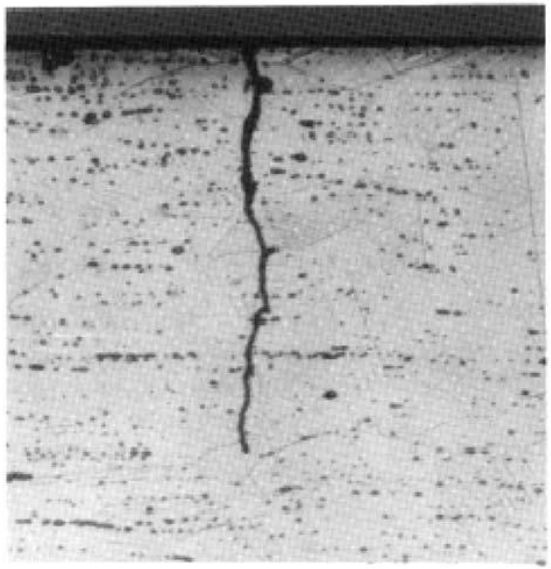




Corrosion Pitting [1]

Corrosion Fatigue [2]

SCC [3]



Fatigue Crack [3]

[1] Laser Techniques Company, LLC
[2] The Hendrix Group, Inc
[3] Technical Manual T.O. 33B-1-1

Reference Standards are available but PRCI has identified the need for NIST Traceability

SRM Program

Calibration Services

Failure Analysis
Fatigue & Fracture
NDE Measurements
Microstructure Analysis
Test Method Development
International Collaborations

A Core concept in metrology is “traceability” where the result of a measurement is related to references through an unbroken chain of comparisons all having stated uncertainties.

NDE Quality Management:

- Probability of Detection (PoD)
- Accuracy
- Precision or Repeatability
- Reliability or Reproducibility
- Traceability

The concept of measurement traceability is central to NIST's mission

NIST SRM PROGRAM

NIST supplies industry, academia, government, and other users with over 1300 reference materials of the highest quality and metrological value.

NIST Standard Reference Material® (SRM) - A CRM issued by NIST that also meets additional NIST-specific certification criteria and is issued with a certificate or certificate of analysis that reports the results of its characterizations and provides information regarding the appropriate use(s) of the material (NIST SP 260-136).

NIST SRMs are provided when:
(1) A measurement problem has been identified for which a Certified Reference Material from NIST has been determined to be the most effective means for providing the required measurement accuracy, traceability, or both
(2) Industry-wide reference materials or standards for commerce not otherwise available are needed from a neutral supplier
(3) Continuing availability of a highly characterized material from a common source is important to science or industry.

http://www.nist.gov/srm/

Consumable vs. Durable SRMs

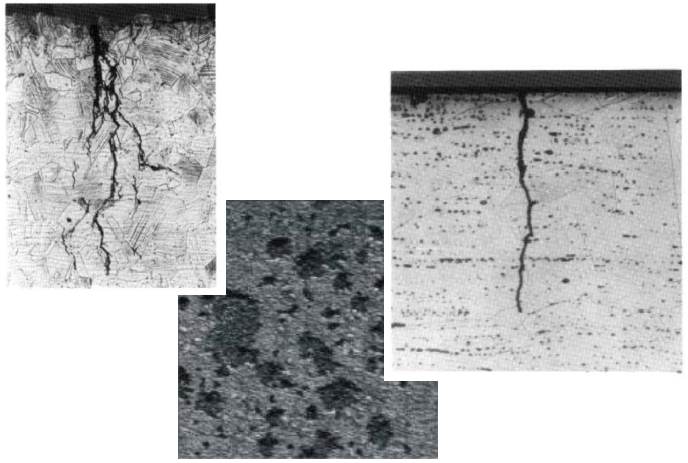
- Chemicals
- Charpy Specimens

Consumable ~ Expensive

- Gage Blocks
- Mass

Durable ~ Uncertainty Issues

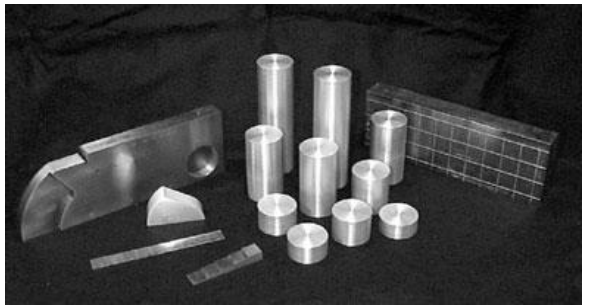
Calibration Services: NIST provides Calibration Services using well-characterized, stable and predictable measurement processes on instruments that are suitable as reference or transfer standards.



- Physical standards representing the actual measurand

- Application of the measurements is extremely complex and available standards don't meet all the needs

- NIST and Industry collaborations are necessary to ensure that conditions are relevant
  - Temperature
  - Stress/Strain History
  - Coatings
  - Materials
  - Physical Access



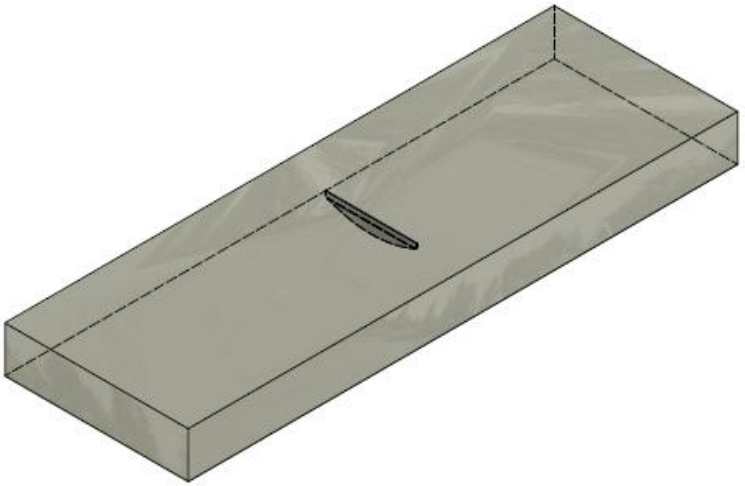
Lots of commercial variations

Standards supporting PRCI Research Programs

- Fatigue Crack Standards
- Corrosion Standards
  - External Surface Corrosion
  - Internal Surface Corrosion
  - Corrosion Fatigue Cracks
  - Stress-Corrosion Cracks
- Mechanical Damage & Shape Tolerances

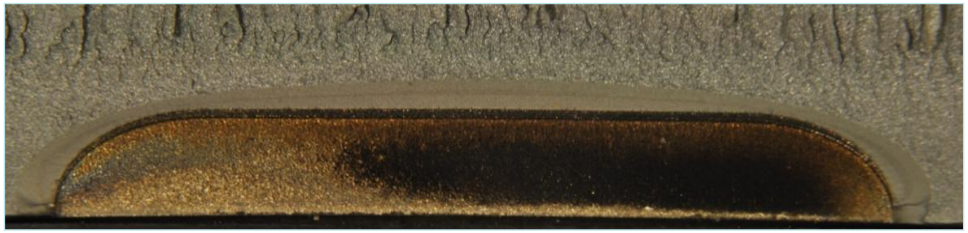
Artificial Corrosion Reference (Applus RTD)

Fatigue Crack (FC) SRM



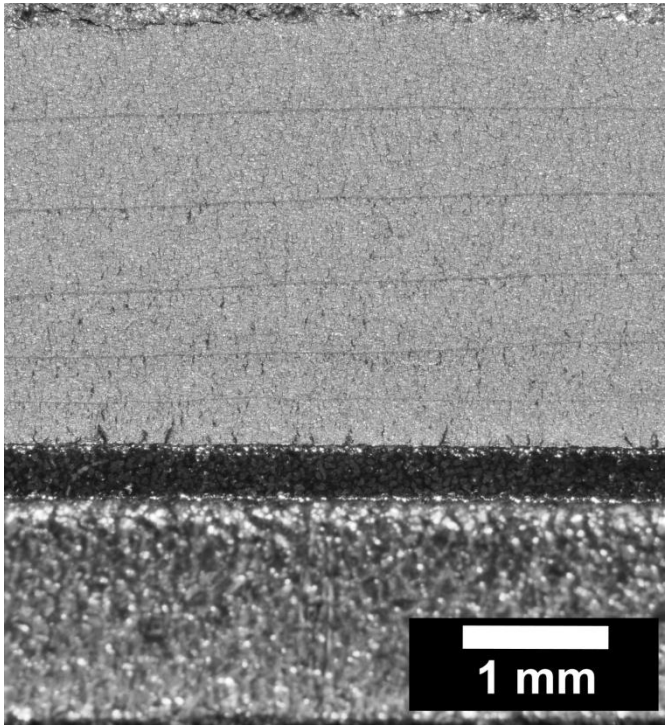
- Machine plates of relevant materials
- EDM surface notch to prescribed dimensions
- Propagate fatigue crack
- Machine surface to remove EDM remnants
- NDE measurement of fatigue crack
- Liberate fatigue crack and optically verify geometric dimensions

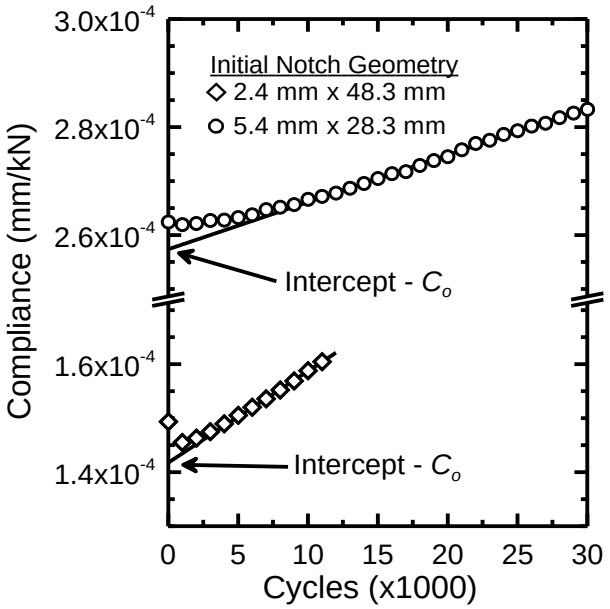
Fatigue Cracking Developed for Fracture Mechanics Study on girth welds of X100 Linepipe (Curved Wide Plate Testing)

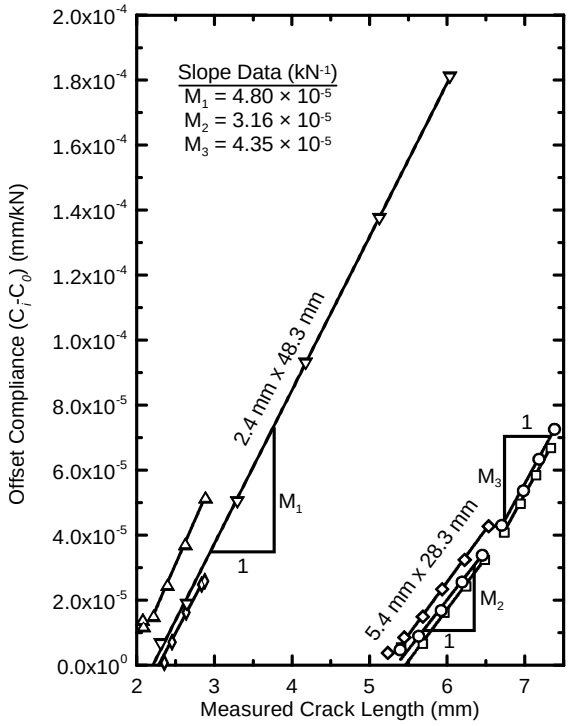


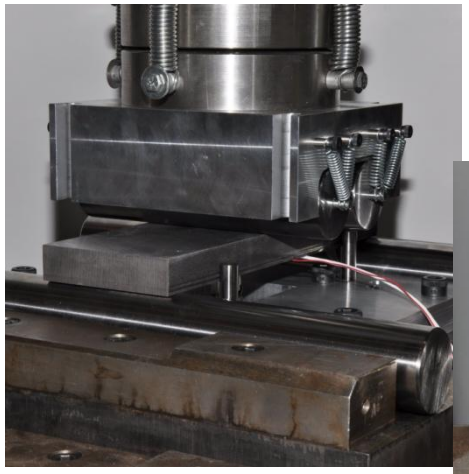
Detail showing EDM notch, fatigue crack and fracture surface

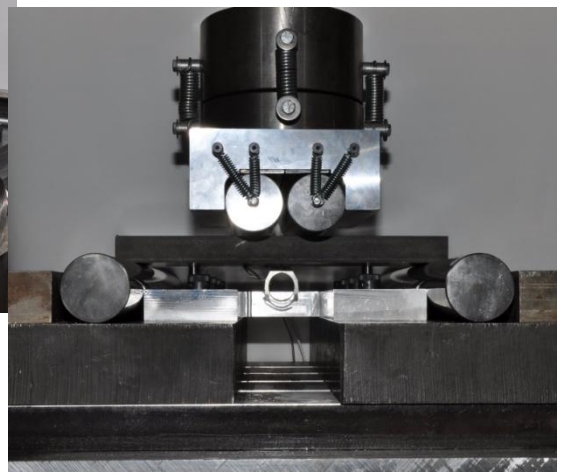
Photo of fatigue crack surface detailing fatigue marker bands used for optical verification of in-situ crack length prediction during crack growth

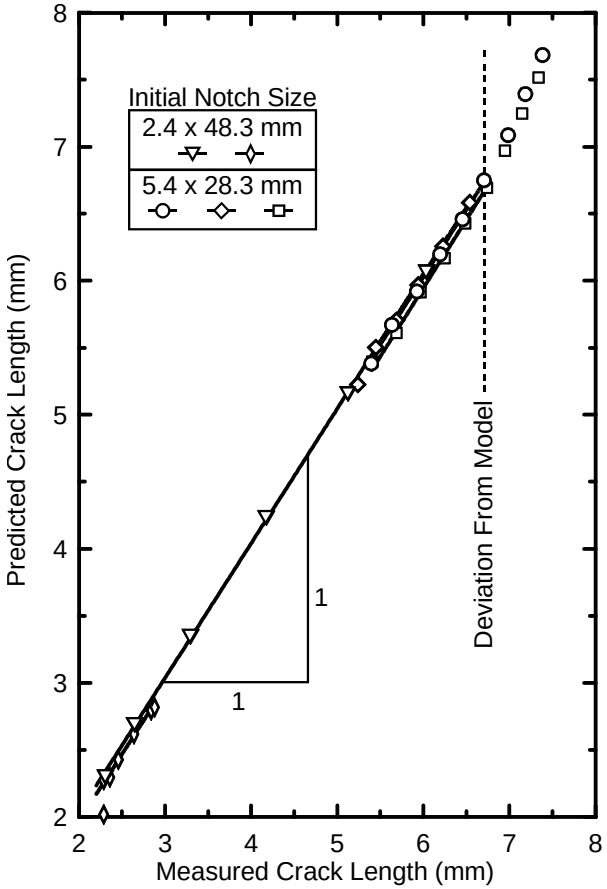



Initial Notch Geometry
2.4 mm x 48.3 mm
5.4 mm x 28.3 mm
Intercept - C_o
Intercept - C_o
Compliance (mm/kN)
Cycles (x1000)

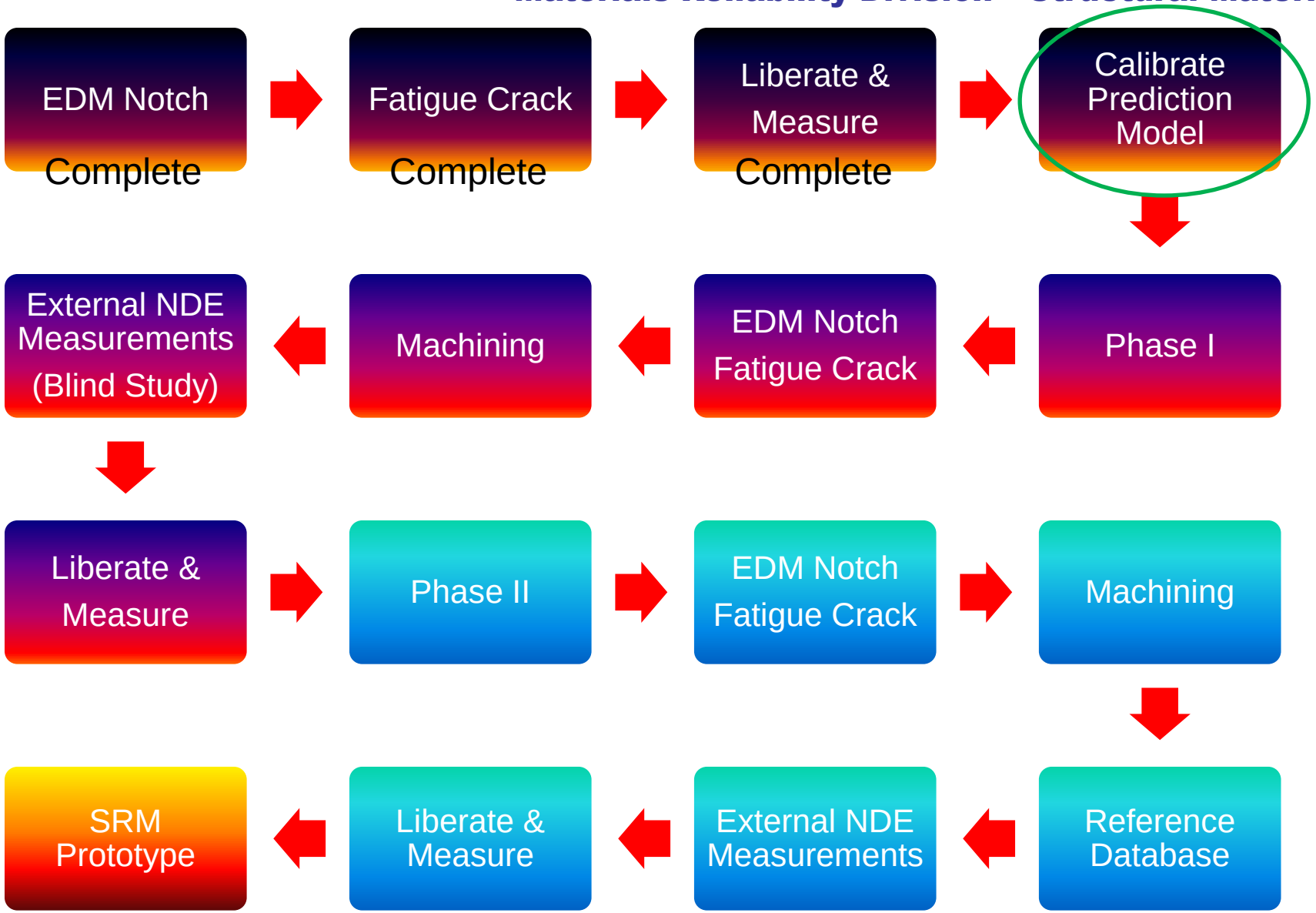

Slope Data (kN^{-1})
M_1 = 4.80 × 10^{-5}
M_2 = 3.16 × 10^{-5}
M_3 = 4.35 × 10^{-5}
2.4 mm x 48.3 mm
5.4 mm x 28.3 mm
Offset Compliance (C_i-C_o) (mm/kN)
Measured Crack Length (mm)






Initial Notch Size
2.4 x 48.3 mm
5.4 x 28.3 mm
Deviation From Model
Predicted Crack Length (mm)
Measured Crack Length (mm)

Machine off EDM Notch Remnants


EDM Notch Complete
Fatigue Crack Complete
Liberate & Measure Complete
Calibrate Prediction Model
Phase I
EDM Notch Fatigue Crack
Machining
External NDE Measurements (Blind Study)
Liberate & Measure
Phase II
EDM Notch Fatigue Crack
Machining
Reference Database
External NDE Measurements
Liberate & Measure
SRM Prototype

Fatigue Crack Standard Development

Phase I (External Blind Study)

- Davis NDE
- JENTEK Sensors
- Olympus NDT

Phase II+

- Add Collaborators
- Include PoD
- Include Resolution/Accuracy
- Include Repeatability/Reproducibility
- Change Flaw Geometries
- Add Pipeline Sections

NIST has very high confidence in producing fatigue-flawed pipe sections. This plate SRM is possible because of extensive fatigue-flaw growth experience in welded pipes.

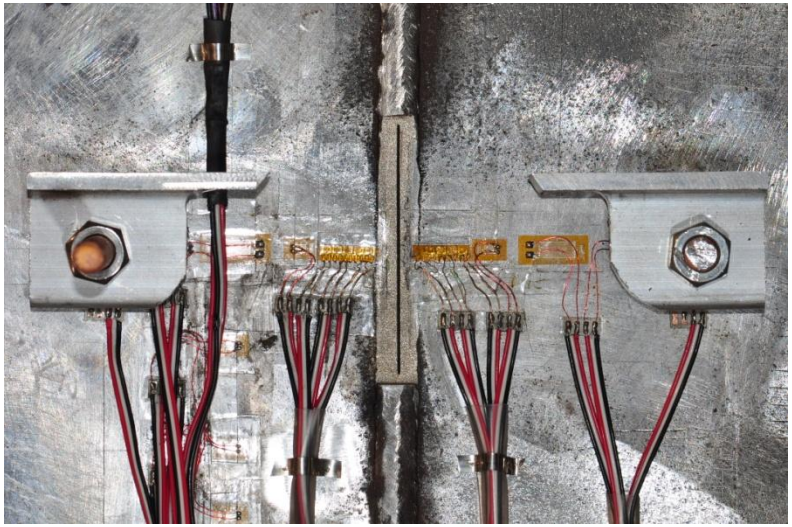


Plate steel is being used first since it's the simplest – if we can't measure or calibrate to a known flaw in plate steel – we'll have no confidence in pipe, through coatings, at temperature, in the field nor under various stress/strain histories.

Progress and Limitations:

Encouraging proof of concept

Competition and collaboration with programs

Reference doesn't fit the traditional NIST SRM model so a lot of work still remains for statistical purposes as well as collaborations for relevancy.

We have a bigger vision for relevancy…..

We have a vision of a National Center dedicated to Reliability Based Integrity Management. A comprehensive facility that accommodates all facets of structural health monitoring for the pipeline/infrastructure industry. It starts with calibrations, without which all measurements are qualitative. Qualitative measurements cost the industry millions of dollars in accidents or unnecessary mitigation.

- Industrial partnerships
- Neutral & Non-profit
- Measurement science research
- Sensor/system development
- Calibrations
- Failure analysis
- Library of in-service material and component flaws

Section of San Bruno Pipe

NIST is proposing a national center for pipeline and infrastructure defects where components with failure artifacts will be collected from various sources in the industry.

Modeled after the EPRI NDE Center

ILI Standards

- Mechanical Damage
- Corrosion
- Cracks

Questions?

Comments?

Collaborators?