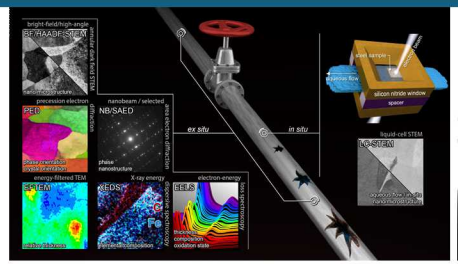
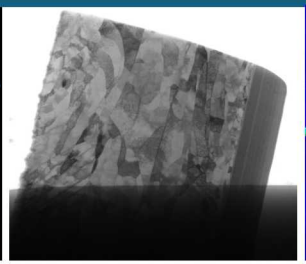
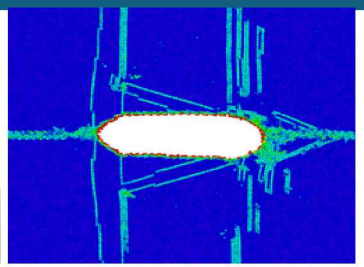
SAND2019-12654C

Pipeline corrosion research at Sandia National Laboratories:

From nanoscale science to structural engineering and piping applications







PRESENTED BY

Patrick D. Mattie, Manager
Structural and Thermal Analysis
Sandia National Laboratories

WITH

[1]Katie Jungjohann, PhD, [1]Remi Dingreville, PhD, and
[2]Michael Starr, PhD
[1]Center for Integrated Nanotechnologies
[2]Structural and Thermal Analysis
P.O. Box 5800 – MS0748
Albuquerque, NM, 87185

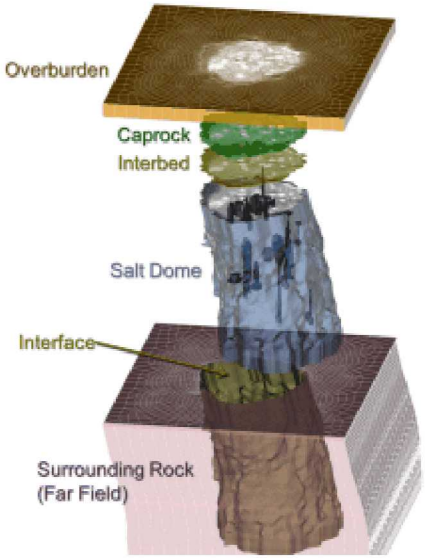
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

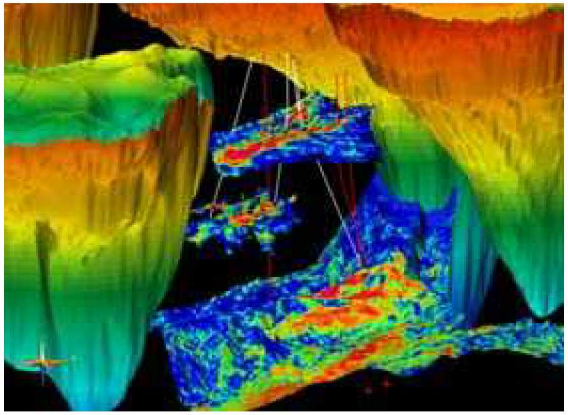
Sandia National Laboratories is a multidisciplinary national laboratory

SNL is a federally-funded research and development center with a mission of:

- anticipating and resolving emerging national security challenges
- innovating and discovering new technologies to strengthen the nation's technological superiority
- creating value through products and services that solve important national security challenges
- informing the national debate where technology policy is critical to preserving security and freedom throughout our world

Sandia supports the creation of a secure energy future for the U.S.



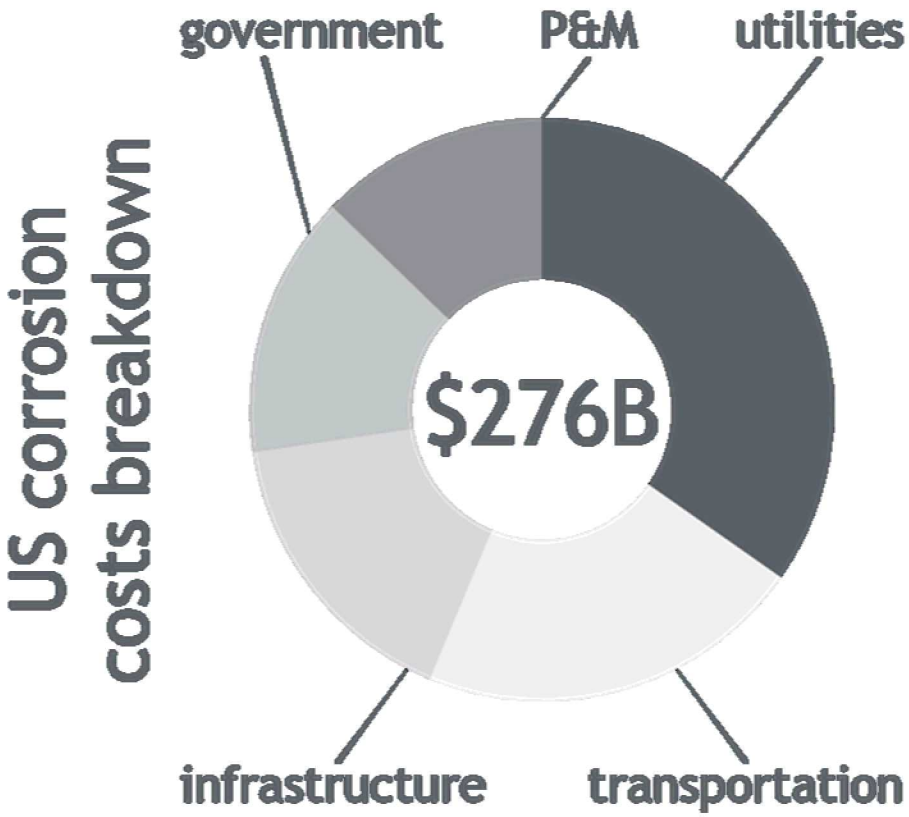


Salt wellbore simulation

Sandia's primary mission is ensuring the U.S. nuclear arsenal is safe, secure, reliable, and can fully support our nation's deterrence policy. Additionally, Sandia uses its capabilities to enable an uninterrupted and enduring supply of energy from domestic sources, and to assure the reliability and resiliency of the associated energy infrastructure. The capabilities that Sandia leverages span:

1. Characterization, sensing, and imaging,
2. Modeling and simulation,
3. Drilling technology,
4. Materials design, and
5. Robotics.

Corrosion Costs are Extreme for US Economics



240,000 broken water mains per year

1 in 3 bridges in the US rated as structurally deficient or functionally obsolete

Aim to develop technologies to modernize oil and gas infrastructure in support of efficiency and safety

Knowledge gaps associated with materials response to oil and gas is a barrier in developing the future of pipeline technologies.

1. **ADVANCED MATERIALS:**
Materials enabling transport of natural gas along with critical fuels and fluids.

2. **PIPELINE INSPECTION AND REPAIR:**
Technologies improving pipeline inspection and mitigate leaks and pipe anomalies.

3. **DATA SCIENCE AND MANAGEMENT:**
Tools employing data to identify pipeline integrity concerns and predict inspection intervals and failure.

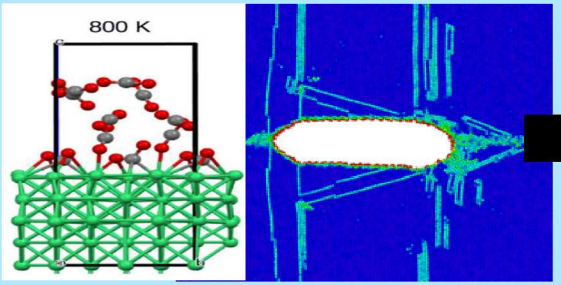
How do we bridge phenomena to capability?

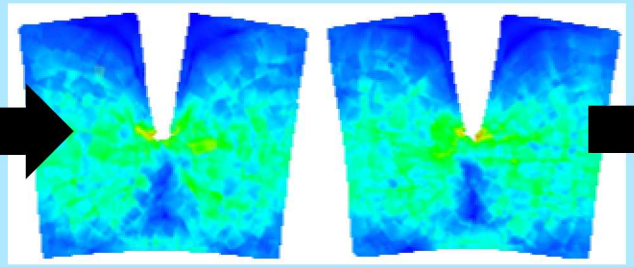
PREDICTIVE MODELING AND SIMULATION

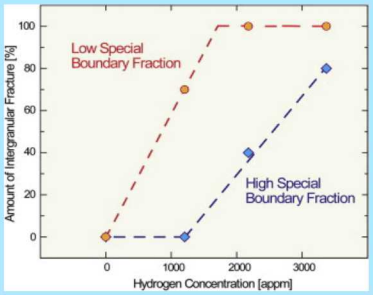
Atomistic simulations
Reactive pathways, nanoscale mechanisms

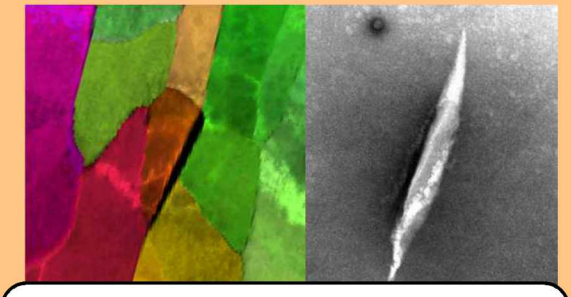
Grain-level framework
Localized fracture corrosion processes

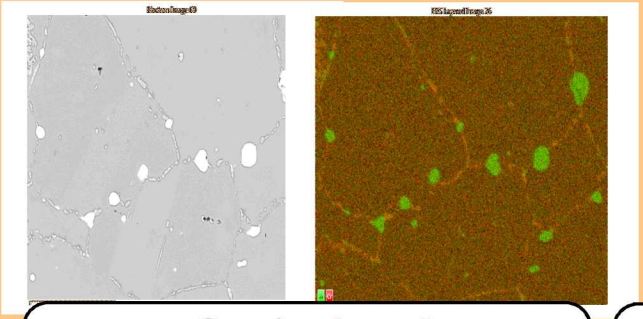
Fracture model
Environmental fracture performance

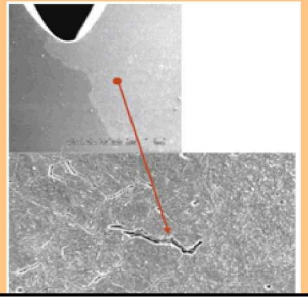












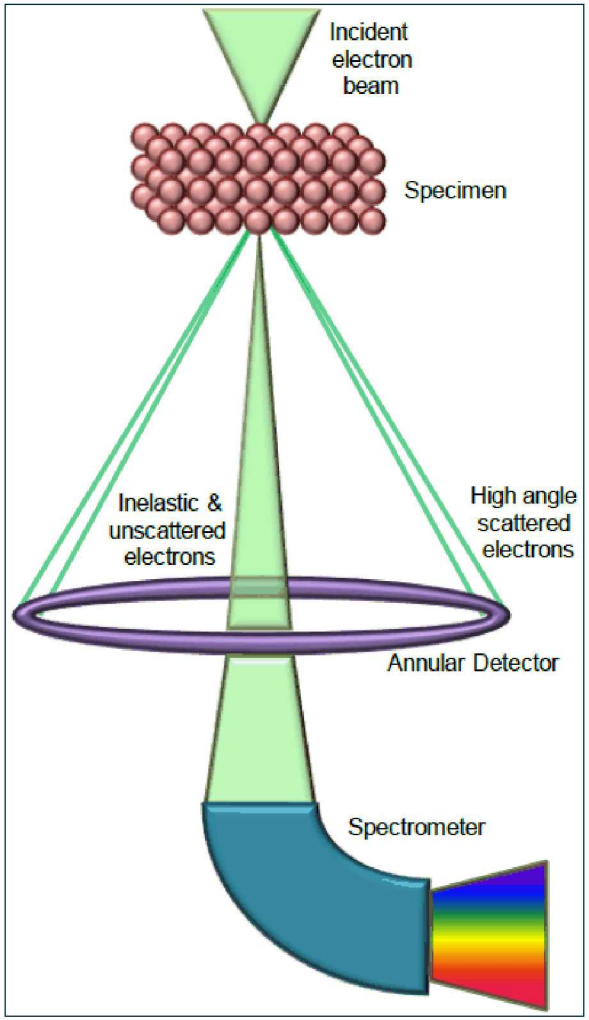
Nanoscale characterization & testing

Grain-level characterization & testing

Macroscale testing

EXPERIMENTAL DISCOVERY AND VALIDATION

Characterization: In-Situ Transmission Electron Microscopy



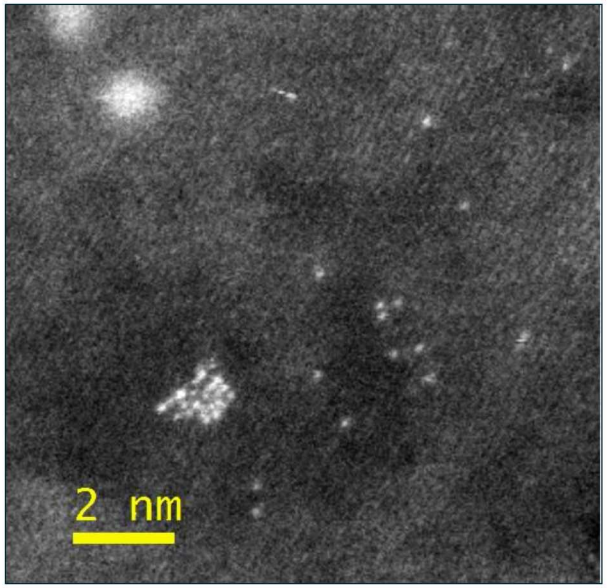
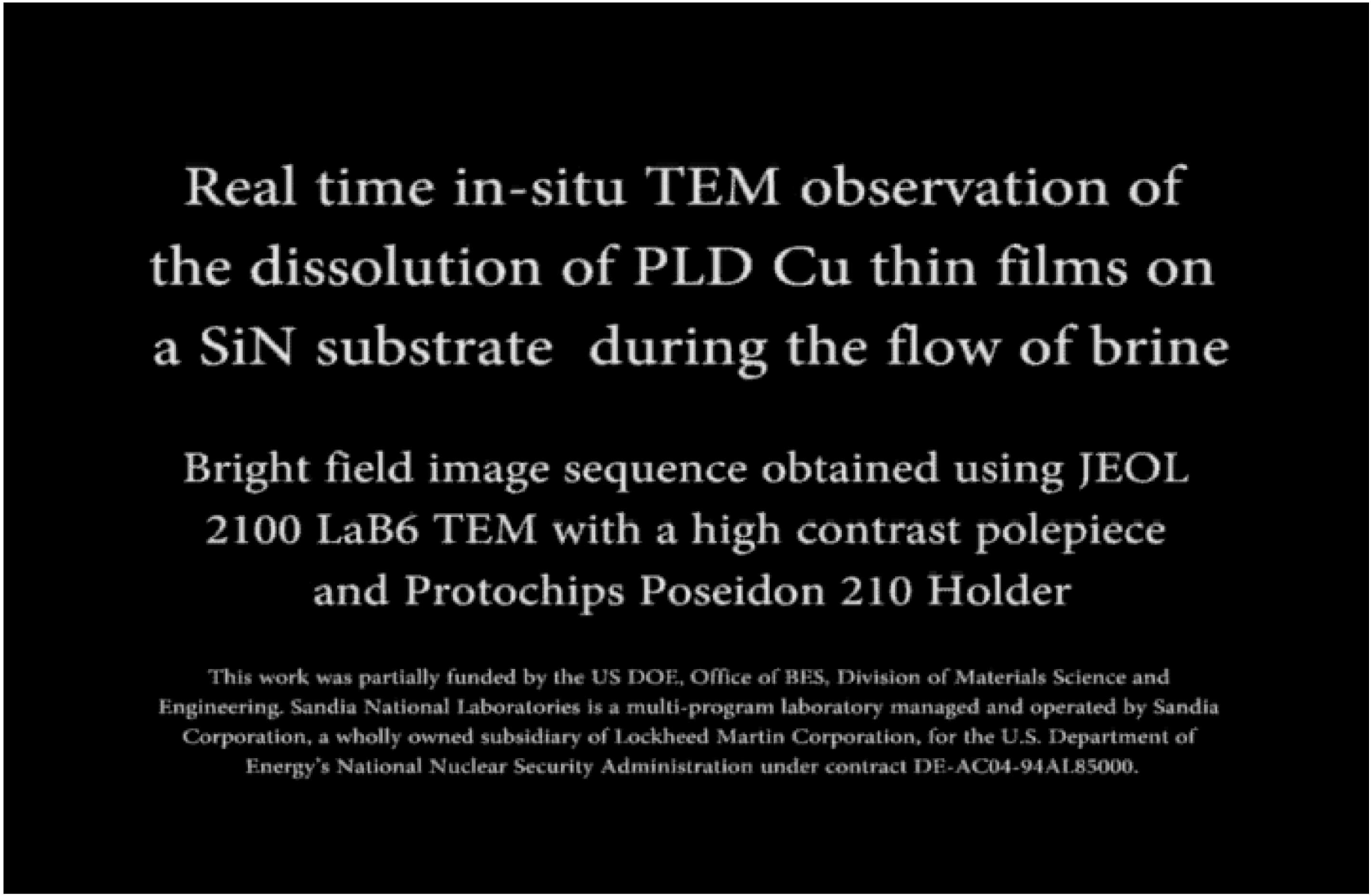
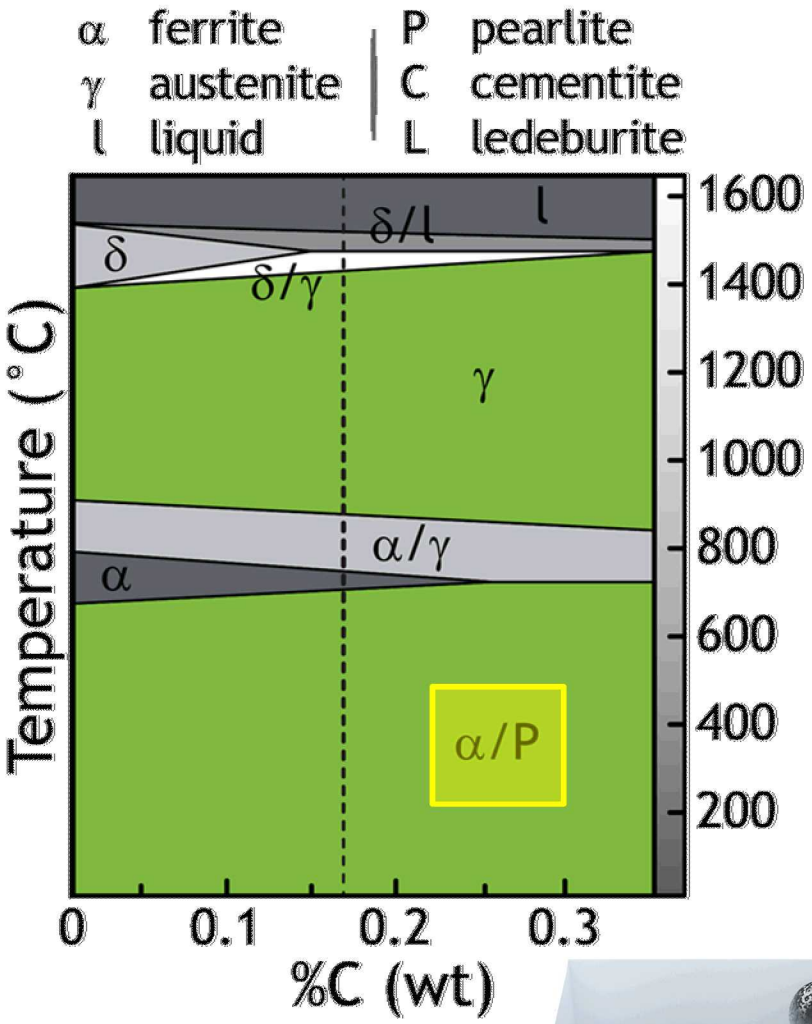


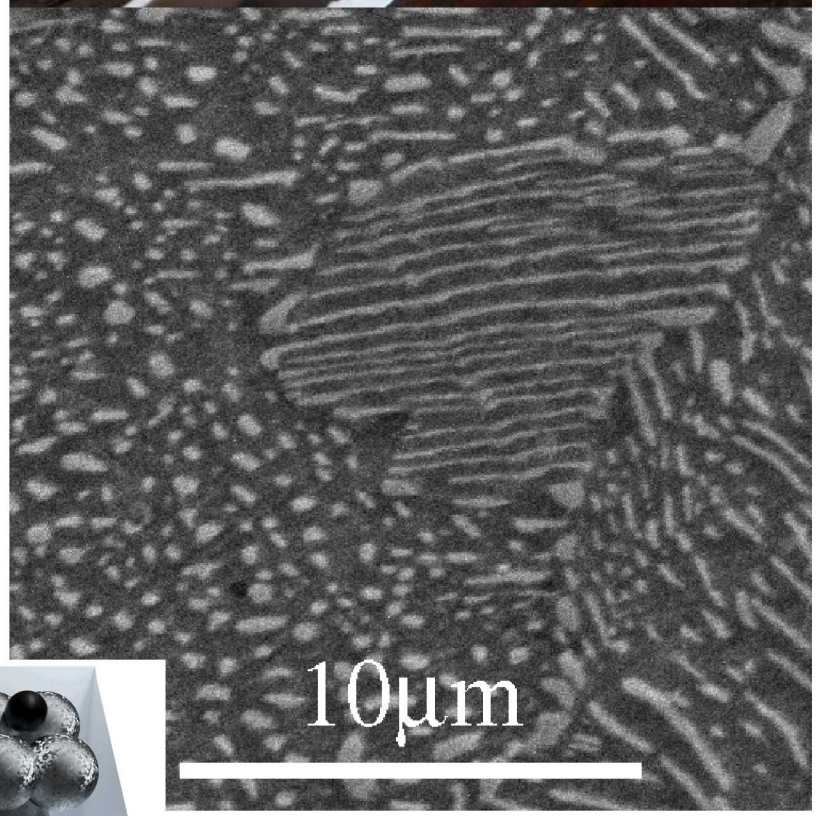
Image by P. Voyles Group

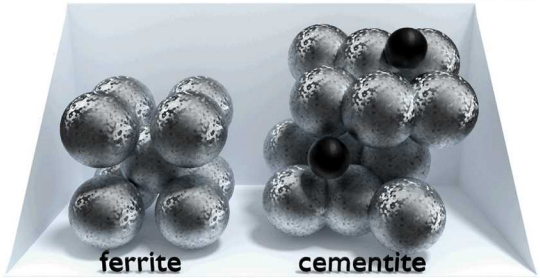
Corrosion of a Cu Thin Film



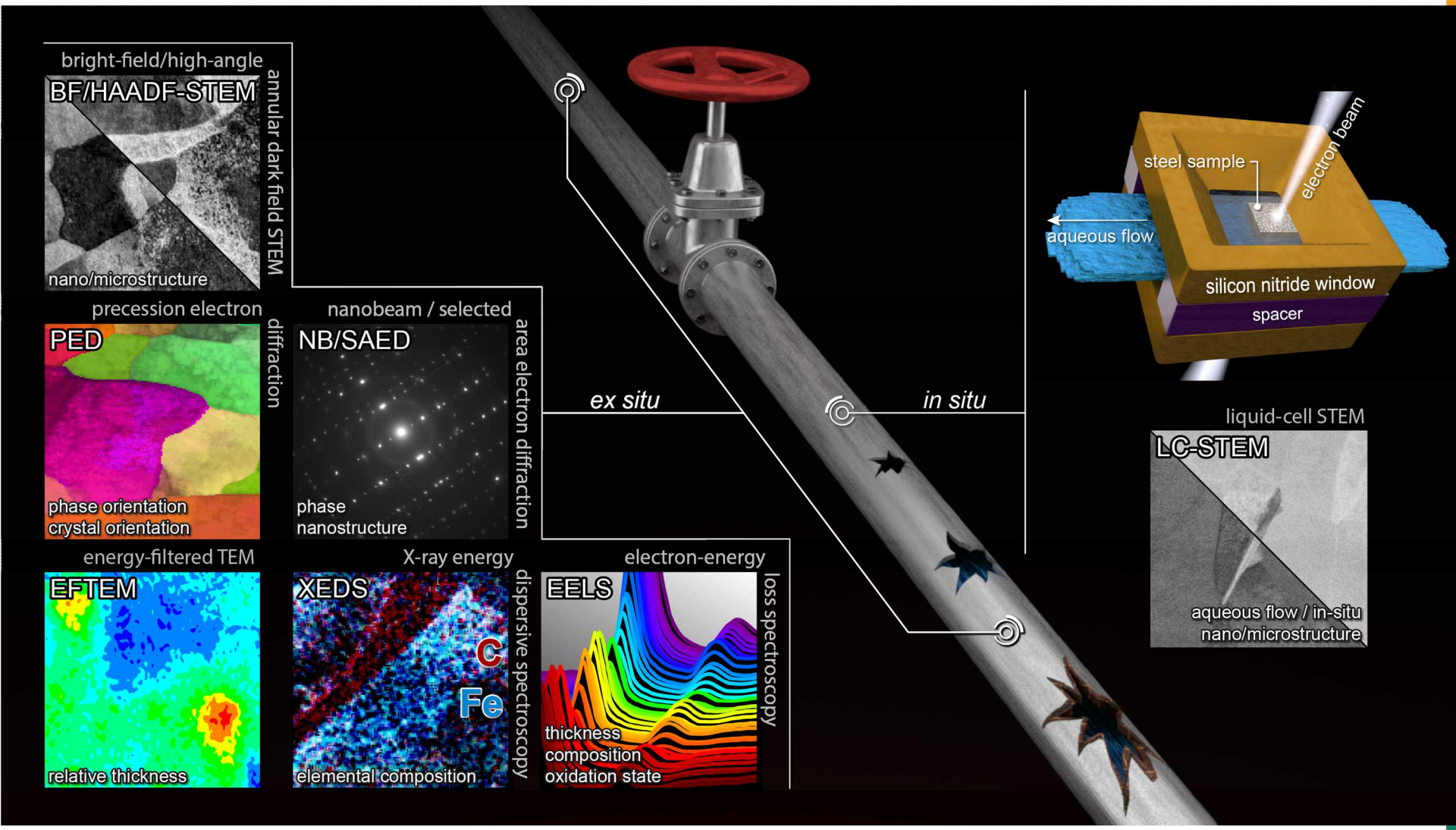
Low-Carbon Steel





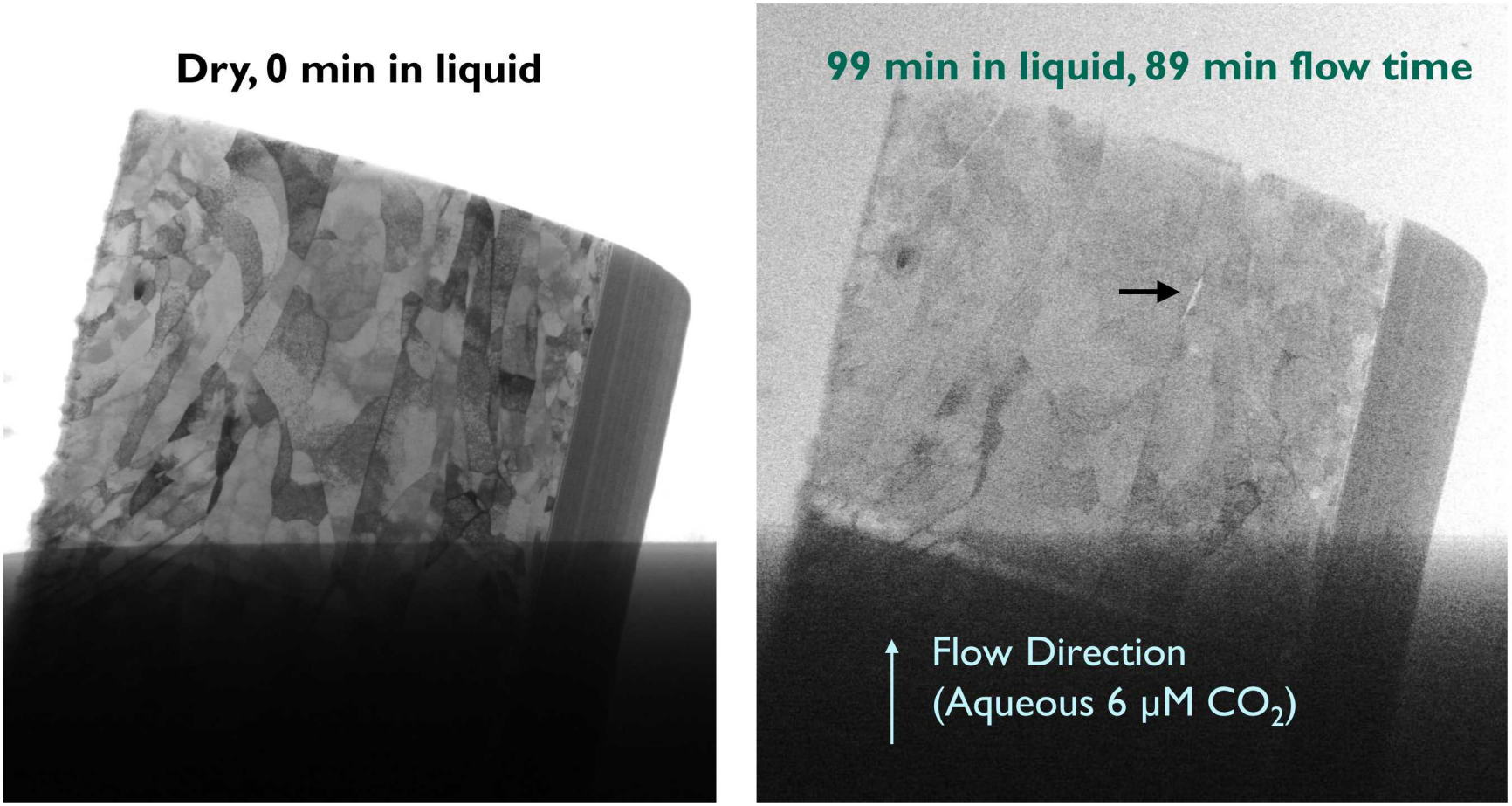


Complete Characterization of the Low-Carbon Steel



Hayden et al., 2019, npj Mater. Degrad. **3**(1), 17.

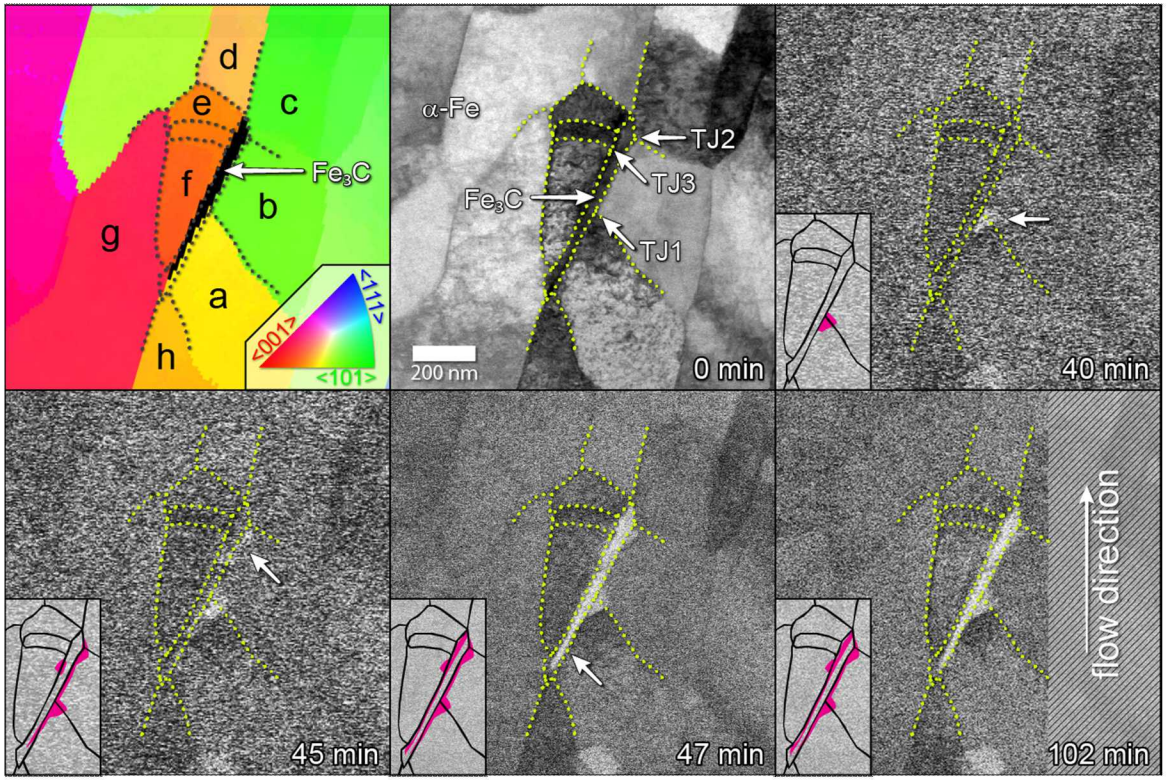
In-situ Corrosion of Low-Carbon Steel

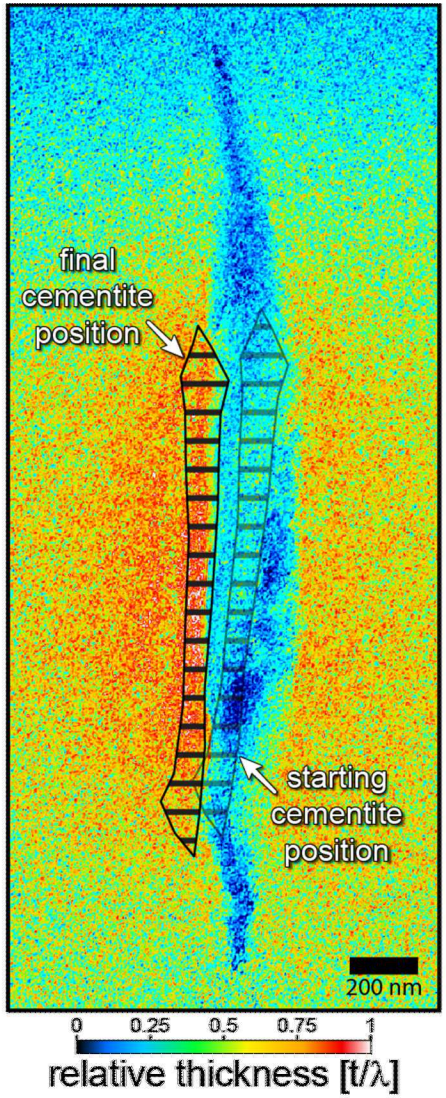


Hayden et al., 2019, npj Mater. Degrad. **3**(1), 17.

Determining Localized Corrosion Initiation Site

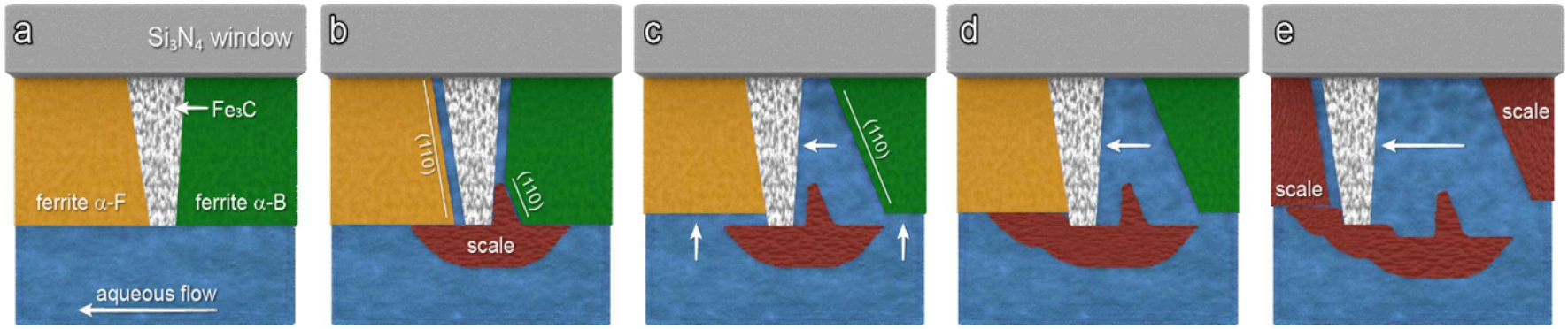
Hayden et al., 2019, npj Mater. Degrad. **3**(1), 17.





Localized corrosion started at a triple junction of three grains in the microstructure, a cementite grain intersecting two ferrite grains.

Mechanism of Localized Corrosion in Low-Carbon Steel

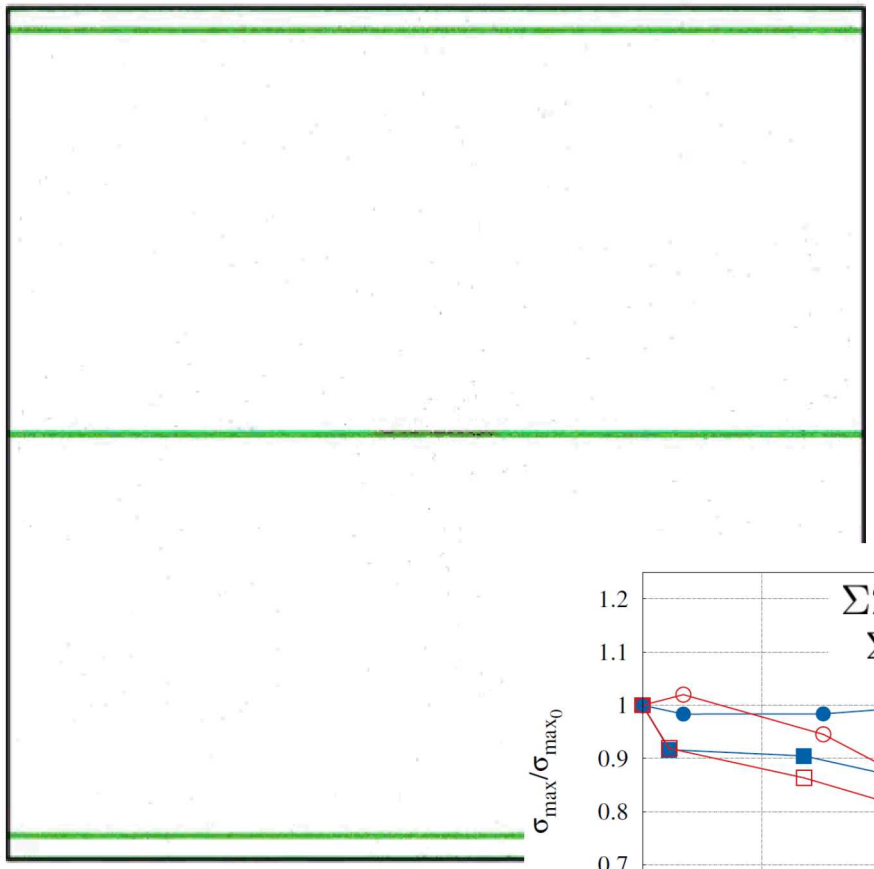


Hayden et al., 2019, npj Mater. Degrad. **3**(1), 17.

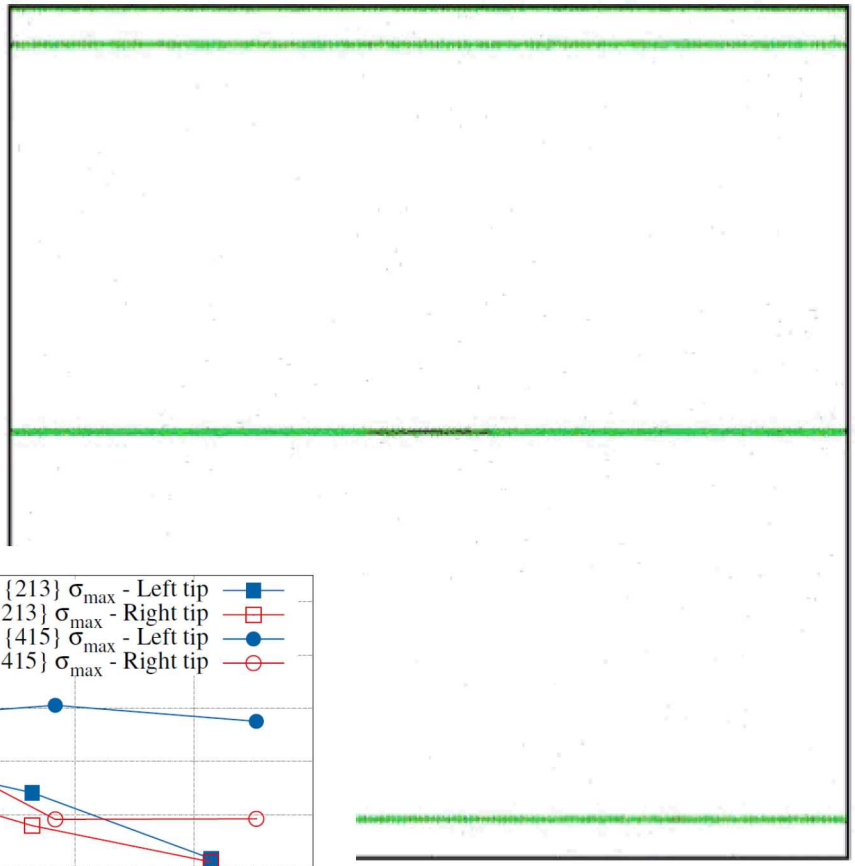
Data can inform models of microstructural features in materials that are most susceptible to high-rate corrosion mechanisms that cause failure.

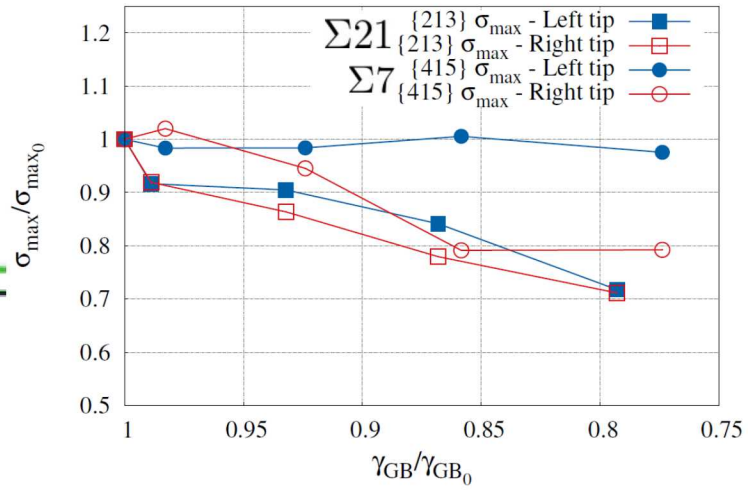
Intergranular fracture due to hydrogen embrittlement

{213} STGB Σ21

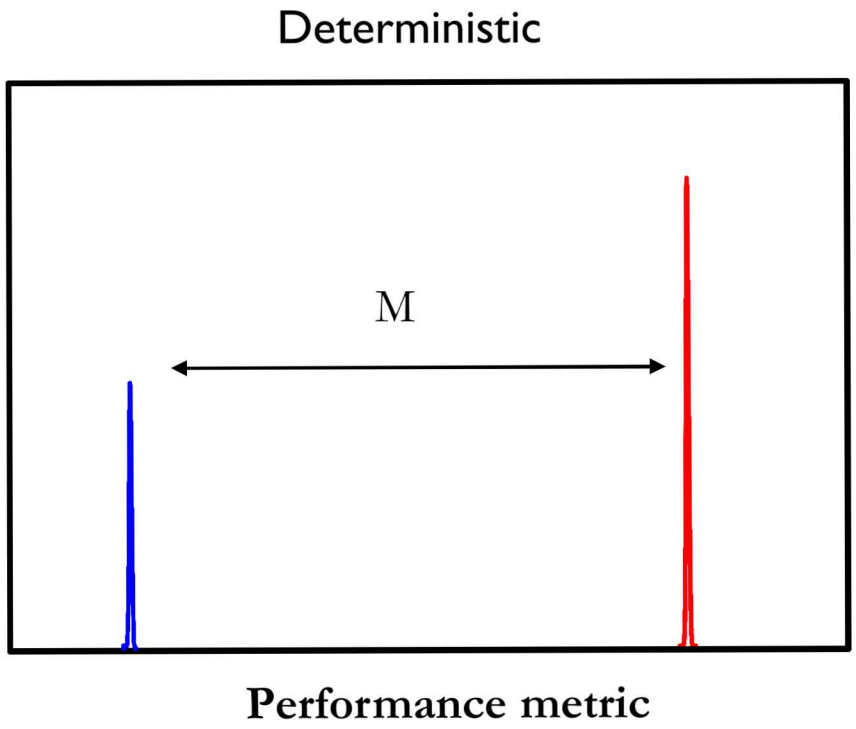


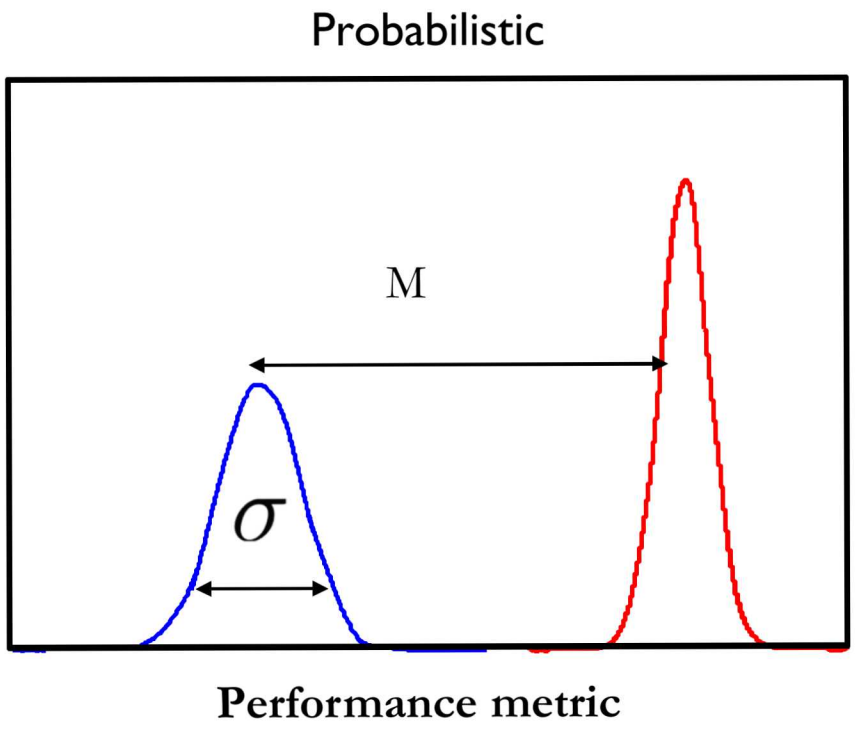
{415} STGB Σ7





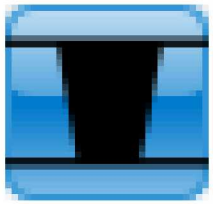
Evaluating the risk through a probabilistic approach



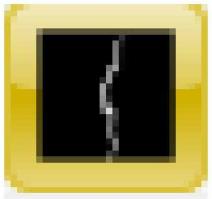


Concept of Probabilistic Fracture Mechanics (PFM) for piping systems

Weld

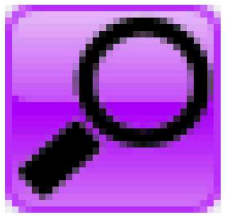


Cracks

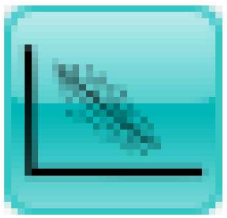


Operating Conditions

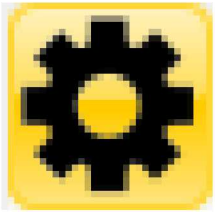
Inspection/ Mitigation



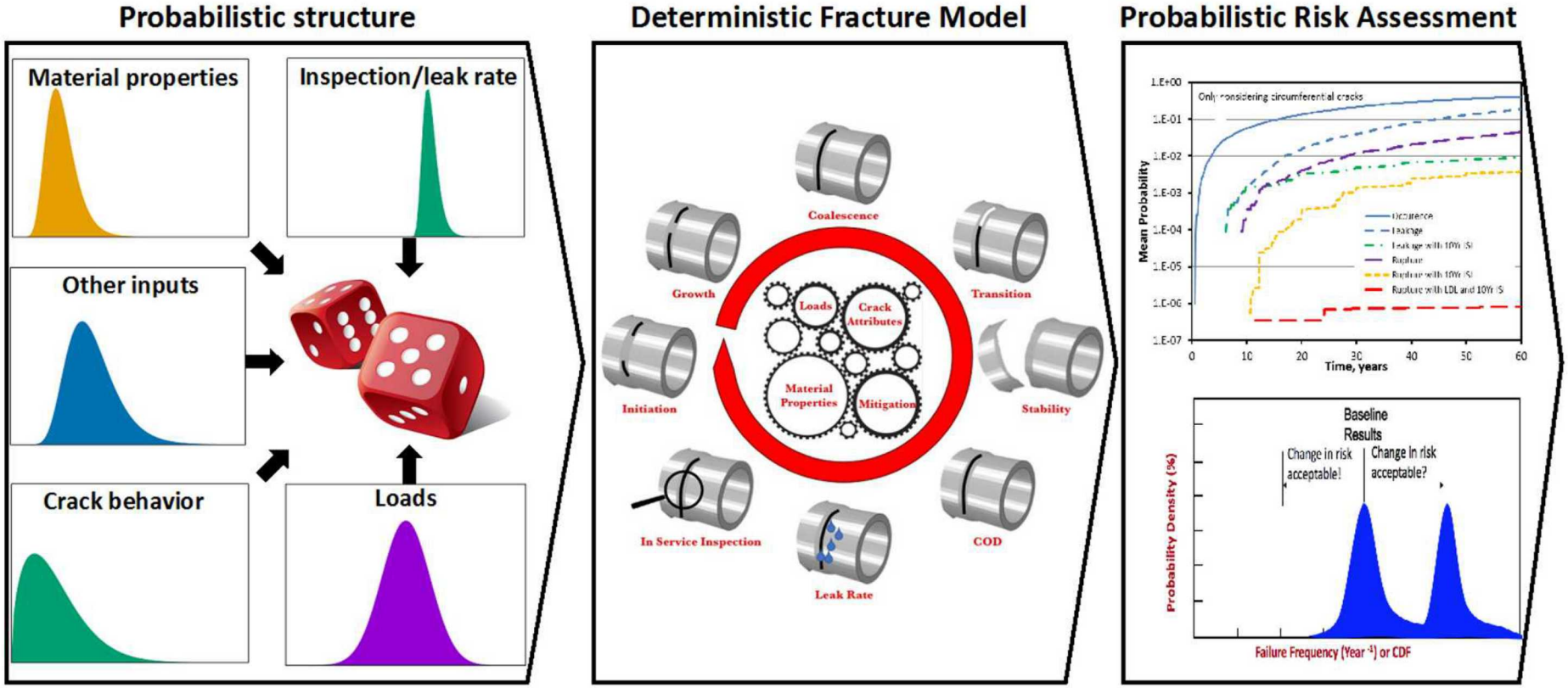
Probabilistic



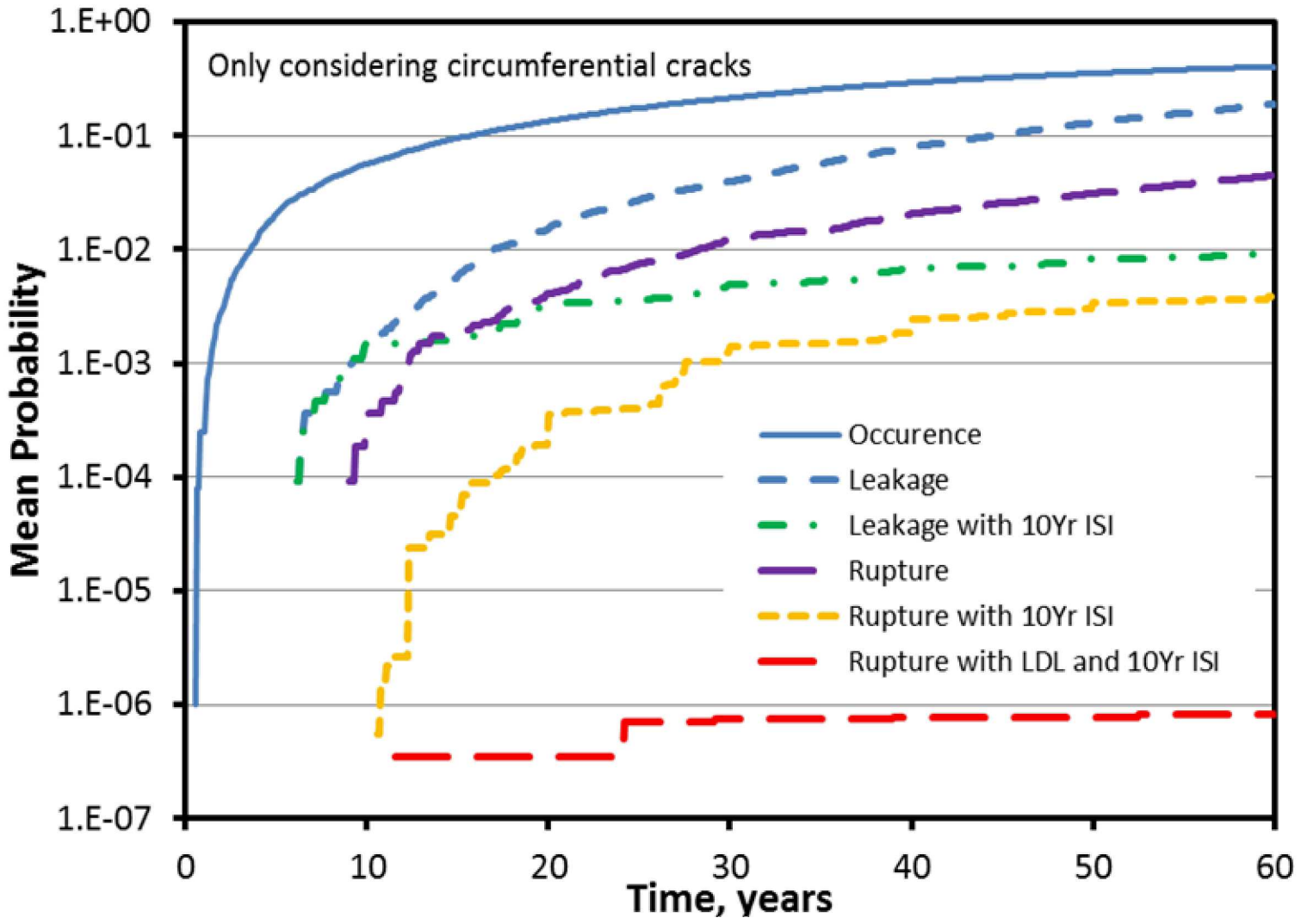
Decision making



Holistic stress corrosion cracking capability for assessment of structural integrity of piping systems



Holistic stress corrosion cracking capability for assessment of structural integrity of piping systems



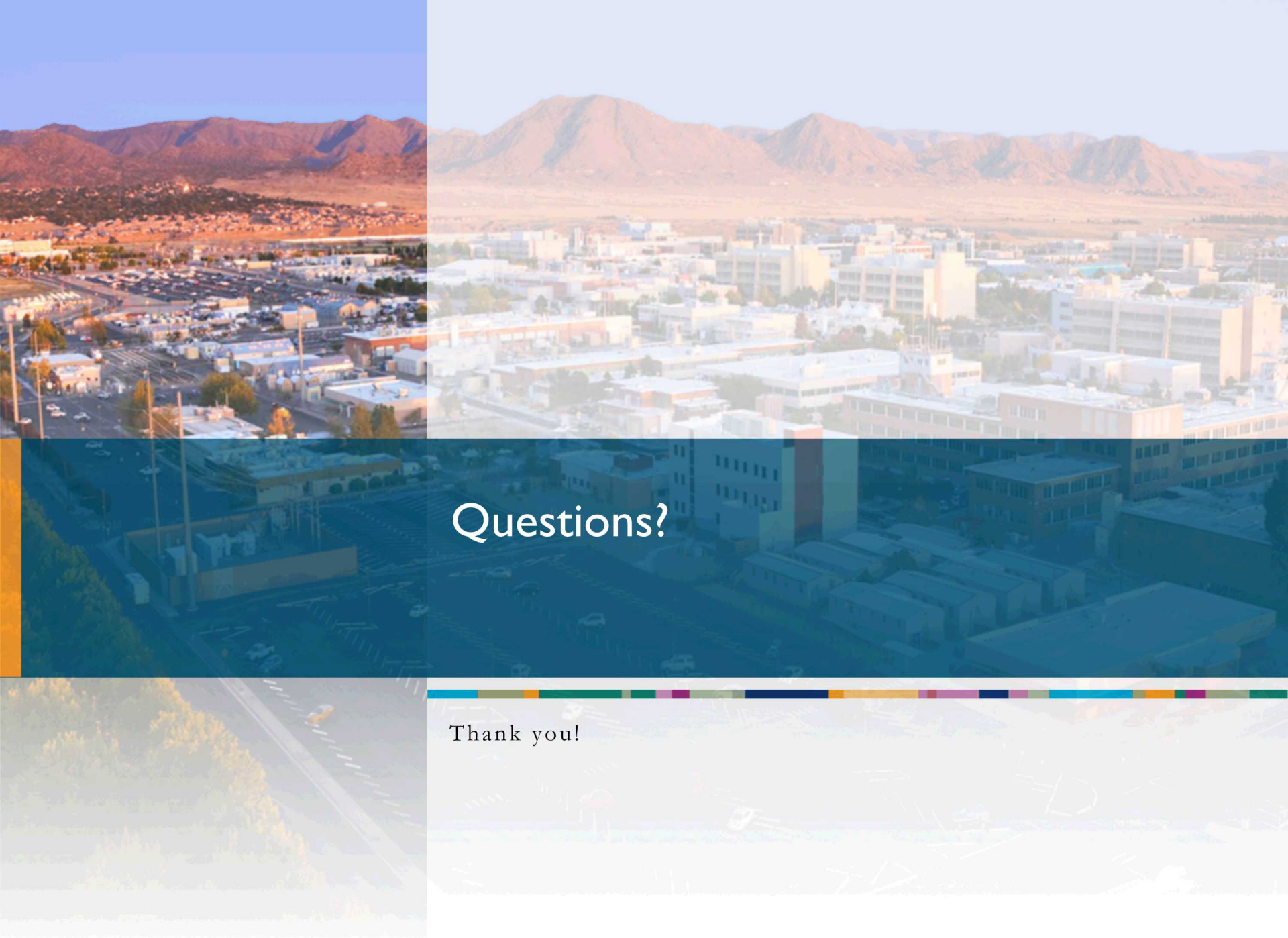
This presentation details the results from a recent pipeline corrosion initiation study

Research was conducted at the Center for Integrated Nanotechnologies (CINT) in support of oil and gas pipeline applications. CINT is a Department of Energy-funded nanoscience research facility that provides users from around the world with access to state of the art expertise and instrumentation in a collaborative, multidisciplinary environment with a focus on nanoscience integration.

CINT in numbers

Role of interface:

- 4 science thrusts
  - Nanomechanics
  - Nanophotonics & optical
  - Quantum nanomaterials
  - Soft, bio nanomaterials
- 2 facilities (SNL/LANL)
- 51 staff scientists
- 32+ postdocs and grad students
- 500+ users
- 200+ projects
- 250+ publications/year
- $0, no fee for pre-competitive research
- 100% full recovery cost for proprietary research



Questions?

Thank you!