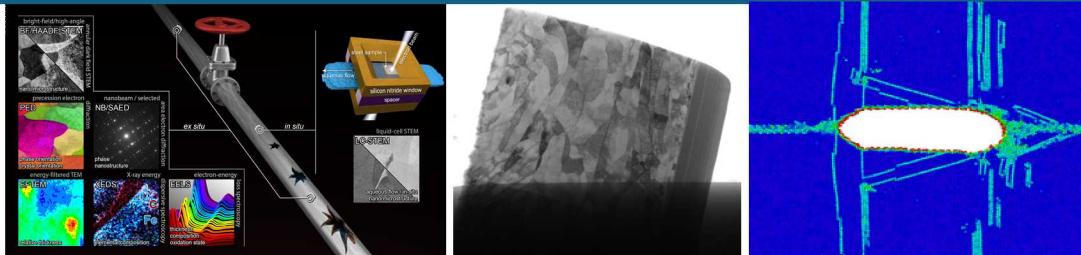


Pipeline corrosion research at Sandia National Laboratories: From nanoscale science to structural engineering and piping applications



PRESENTED BY

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WITH

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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.

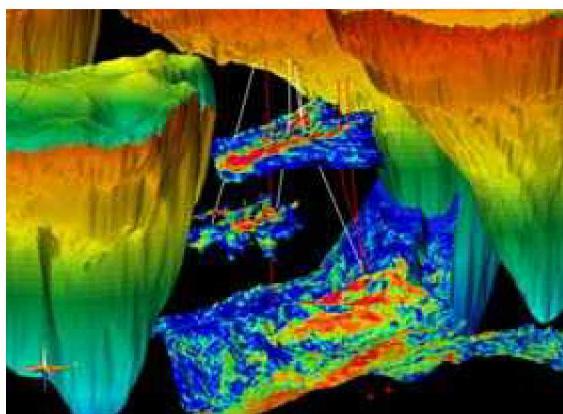
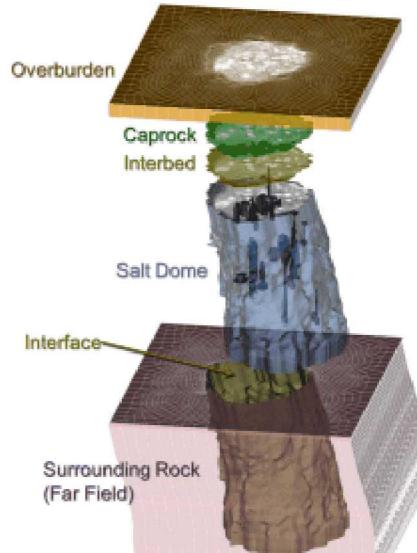
Sandia National Laboratories is a multidisciplinary national laboratory



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.

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

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

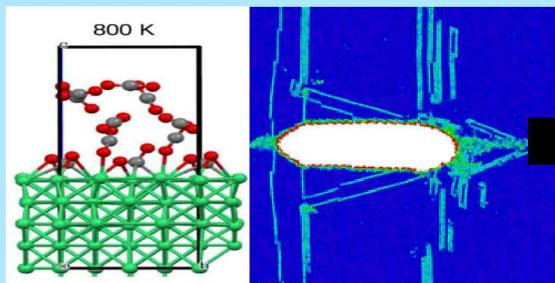
Tools employing data to identify pipeline integrity concerns and predict inspection intervals and failure.

How do we bridge phenomena to capability?

PREDICTIVE MODELING AND SIMULATION

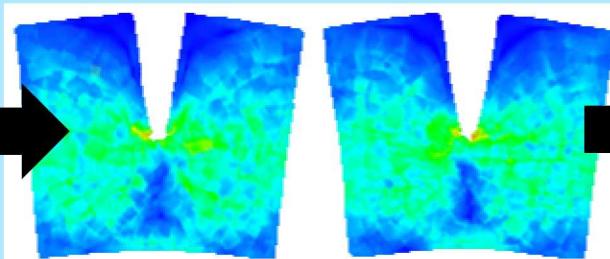
Atomistic simulations

Reactive pathways,
nanoscale mechanisms



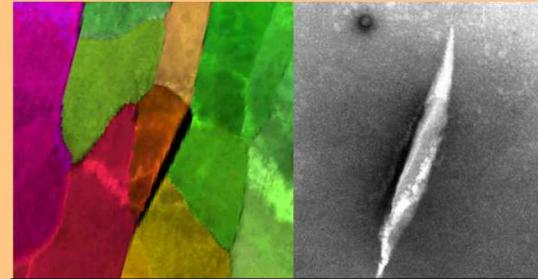
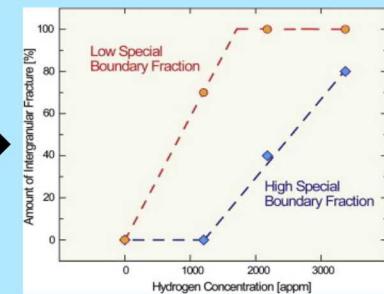
Grain-level framework

Localized
fracture corrosion processes

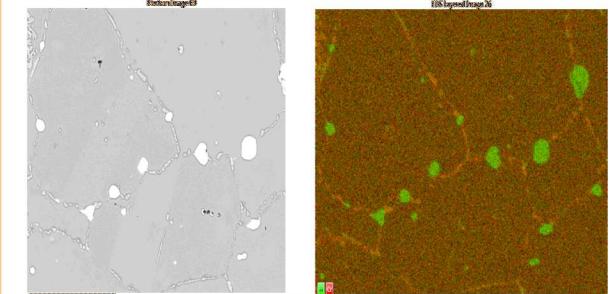


Fracture model

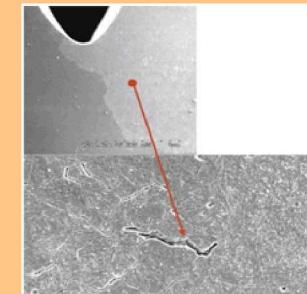
Environmental
fracture performance



Nanoscale characterization & testing



Grain-level characterization & testing



Macroscale testing

EXPERIMENTAL DISCOVERY AND VALIDATION

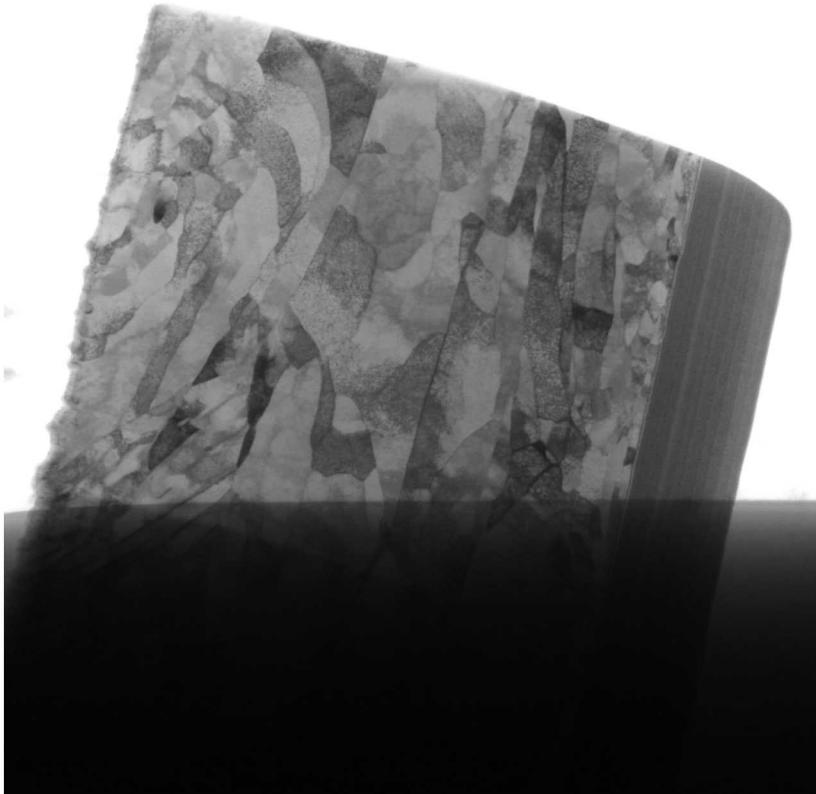
Real time in-situ TEM observation of the dissolution of PLD Cu thin films on a SiN substrate during the flow of brine

Bright field image sequence obtained using JEOL 2100 LaB6 TEM with a high contrast polepiece and Protochips Poseidon 210 Holder

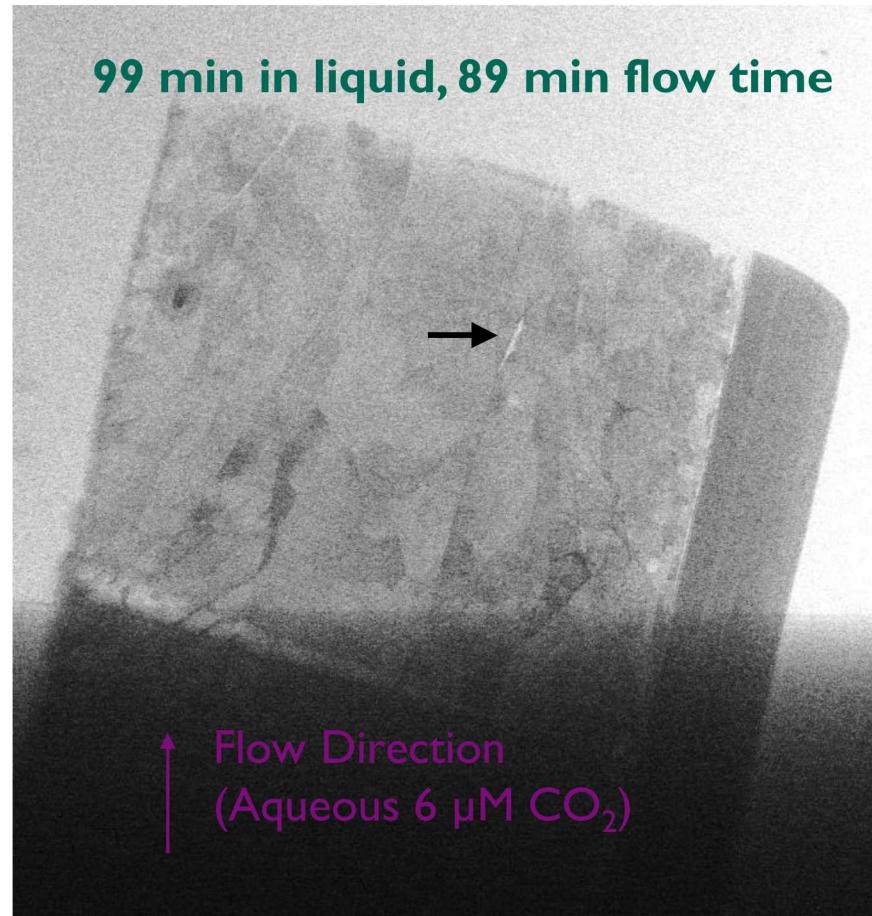
This work was partially funded by the US DOE, Office of BES, Division of Materials Science and Engineering. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

In-situ corrosion observation of low-carbon steel

Dry, 0 min in liquid



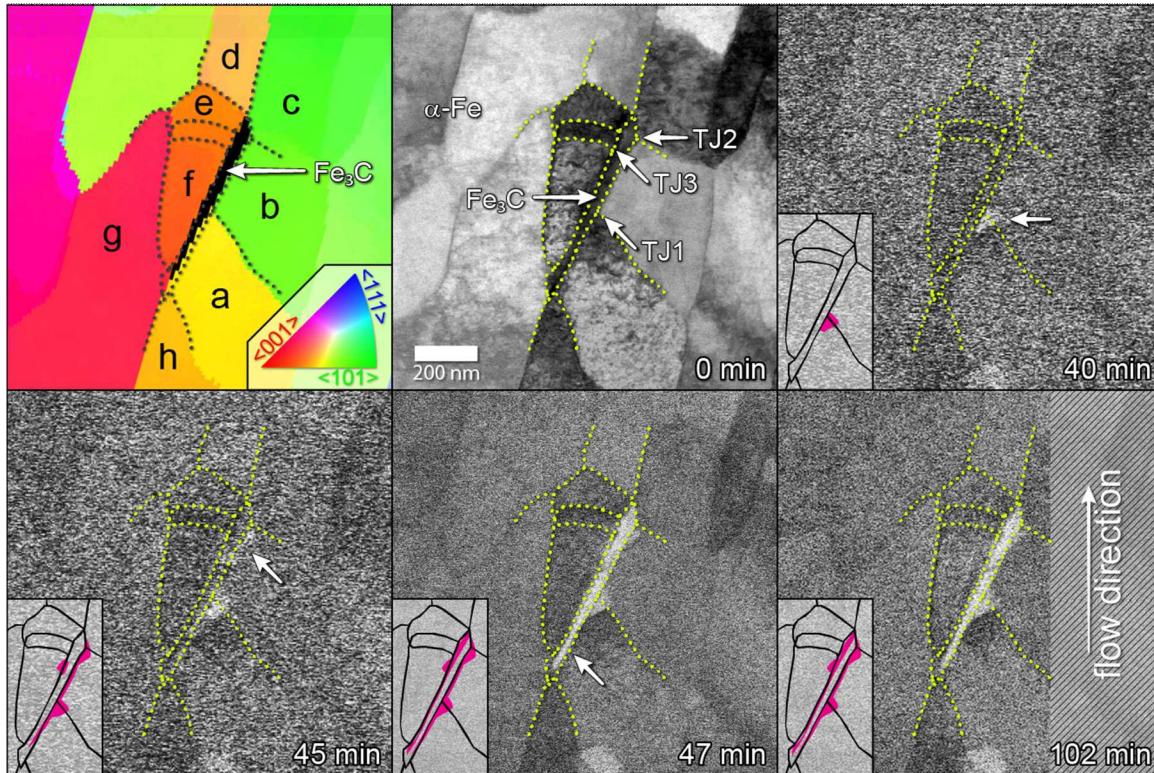
99 min in liquid, 89 min flow time



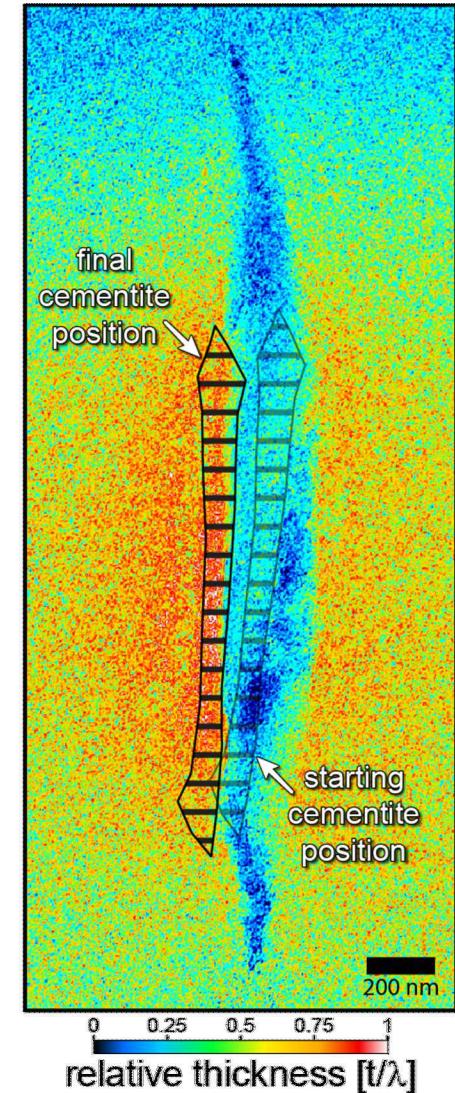
Hayden et al., 2018, in review

Determining localized corrosion initiation site

Hayden et al., 2018, in review



Localized corrosion started at a triple junction of three grains in the microstructure, a cementite grain intersecting two ferrite grains. Data can inform models of microstructural features in materials that are most susceptible to high-rate corrosion mechanisms that cause failure.



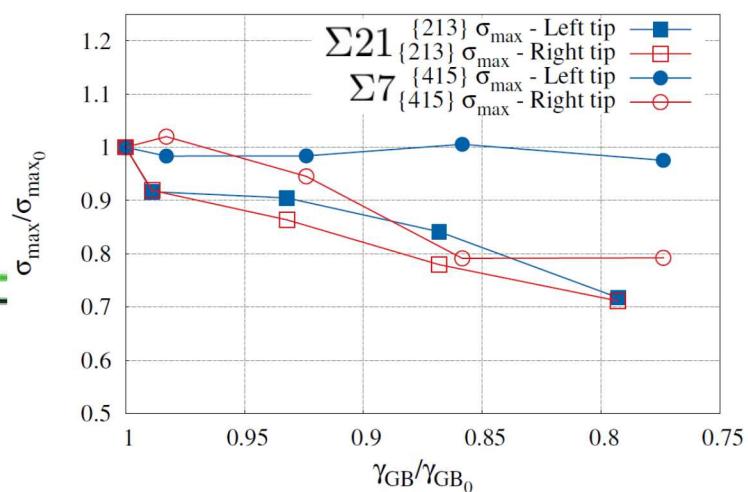
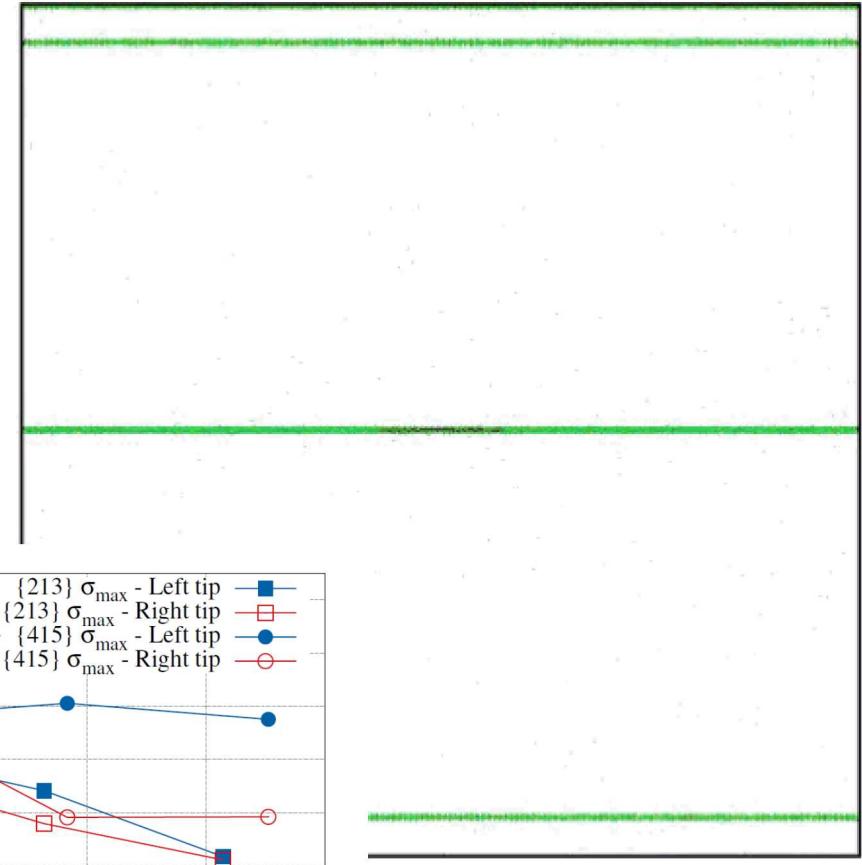
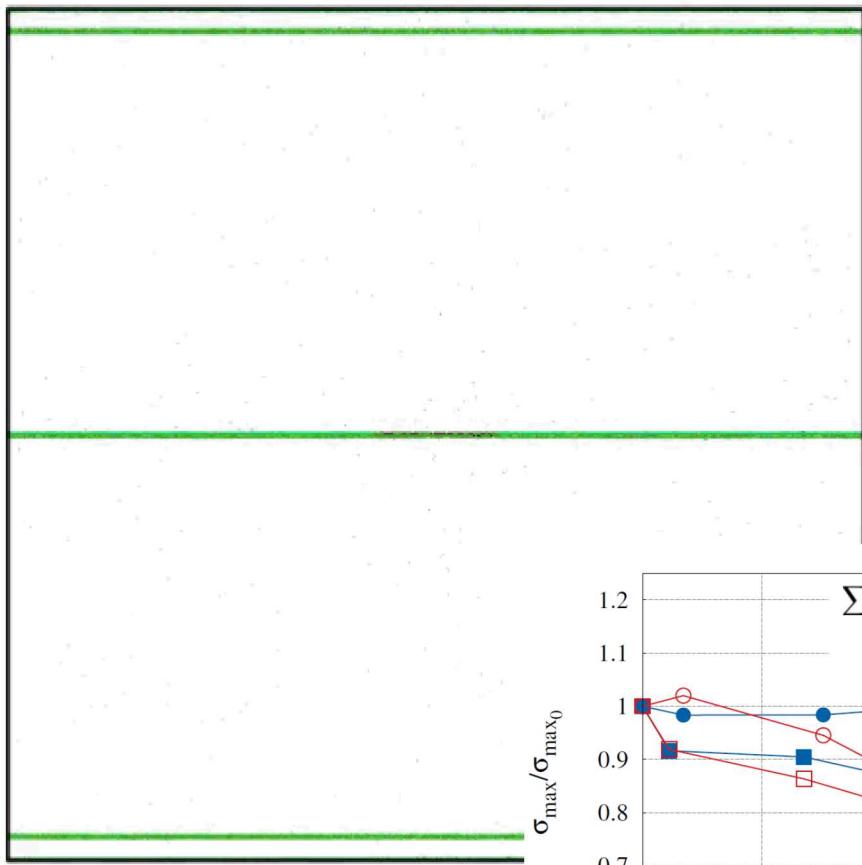
Intergranular fracture due to hydrogen embrittlement

{213} STGB

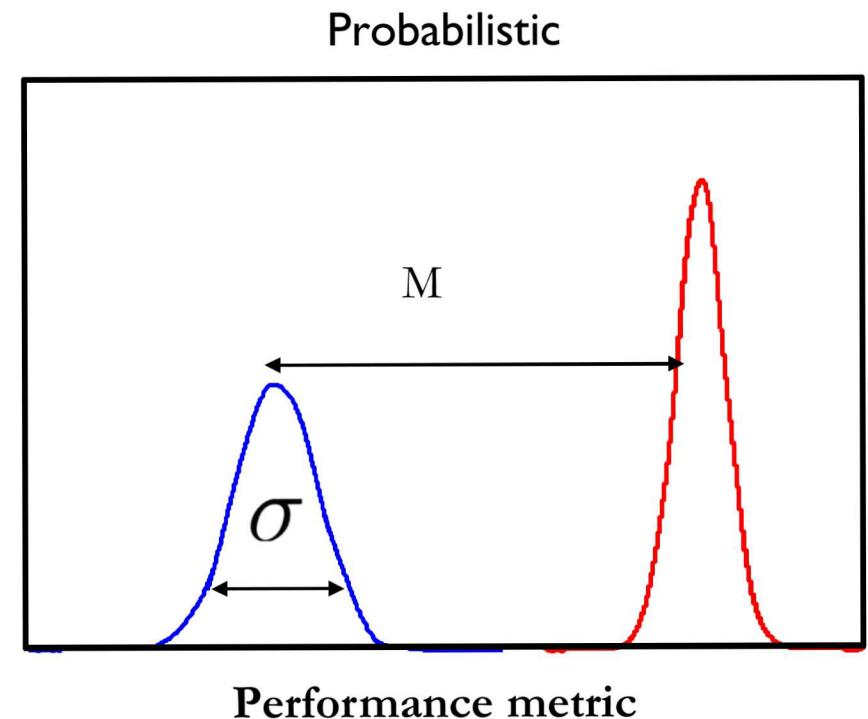
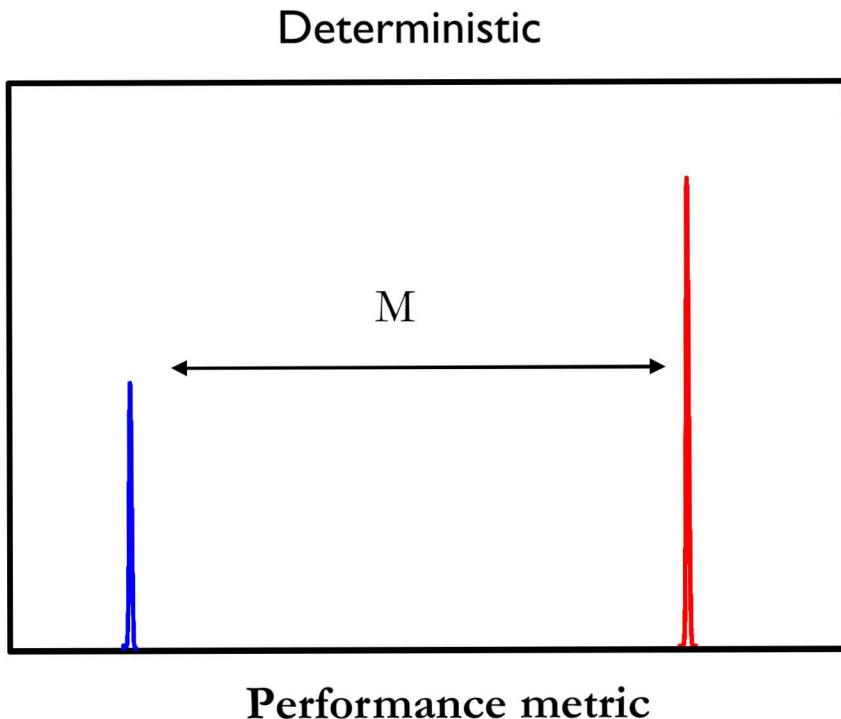
$\Sigma 21$

{415} STGB

$\Sigma 7$

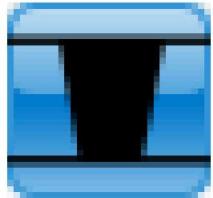


Evaluating the risk through a probabilistic approach

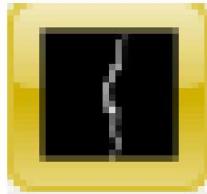


Concept of Probabilistic Fracture Mechanics (PFM) for piping systems

Weld



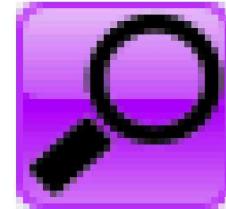
Cracks



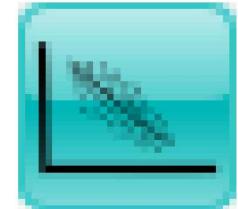
**Operating
Conditions**



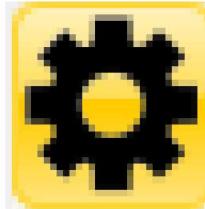
**Inspection/
Mitigation**



Probabilistic

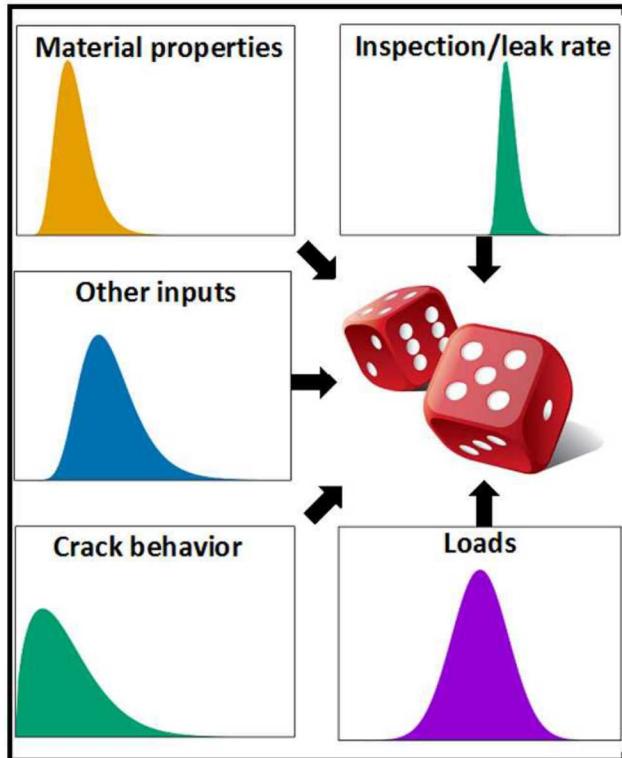


Decision making

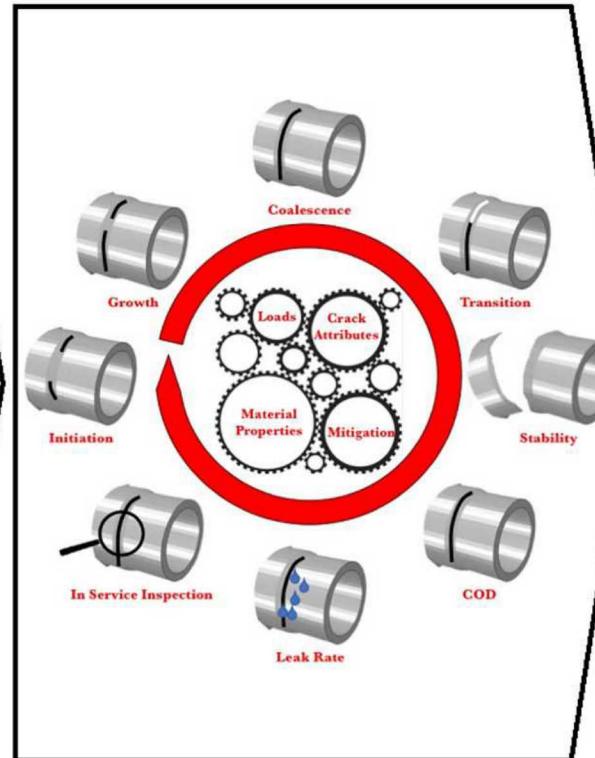


Holistic stress corrosion cracking capability for assessment of structural integrity of piping systems

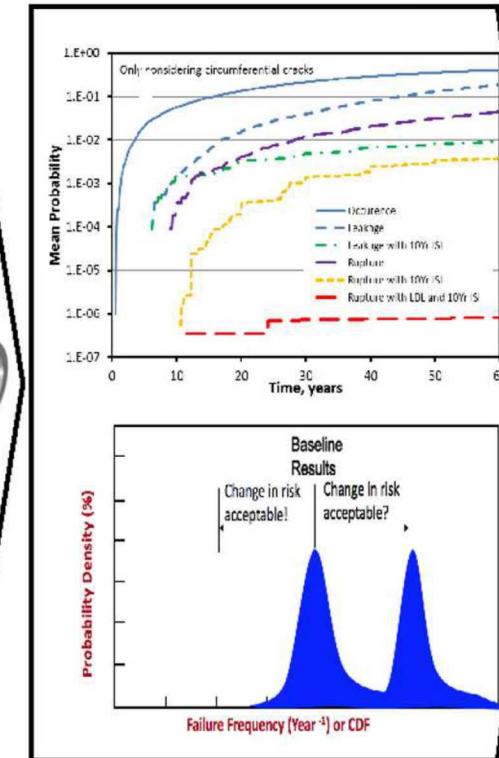
Probabilistic structure



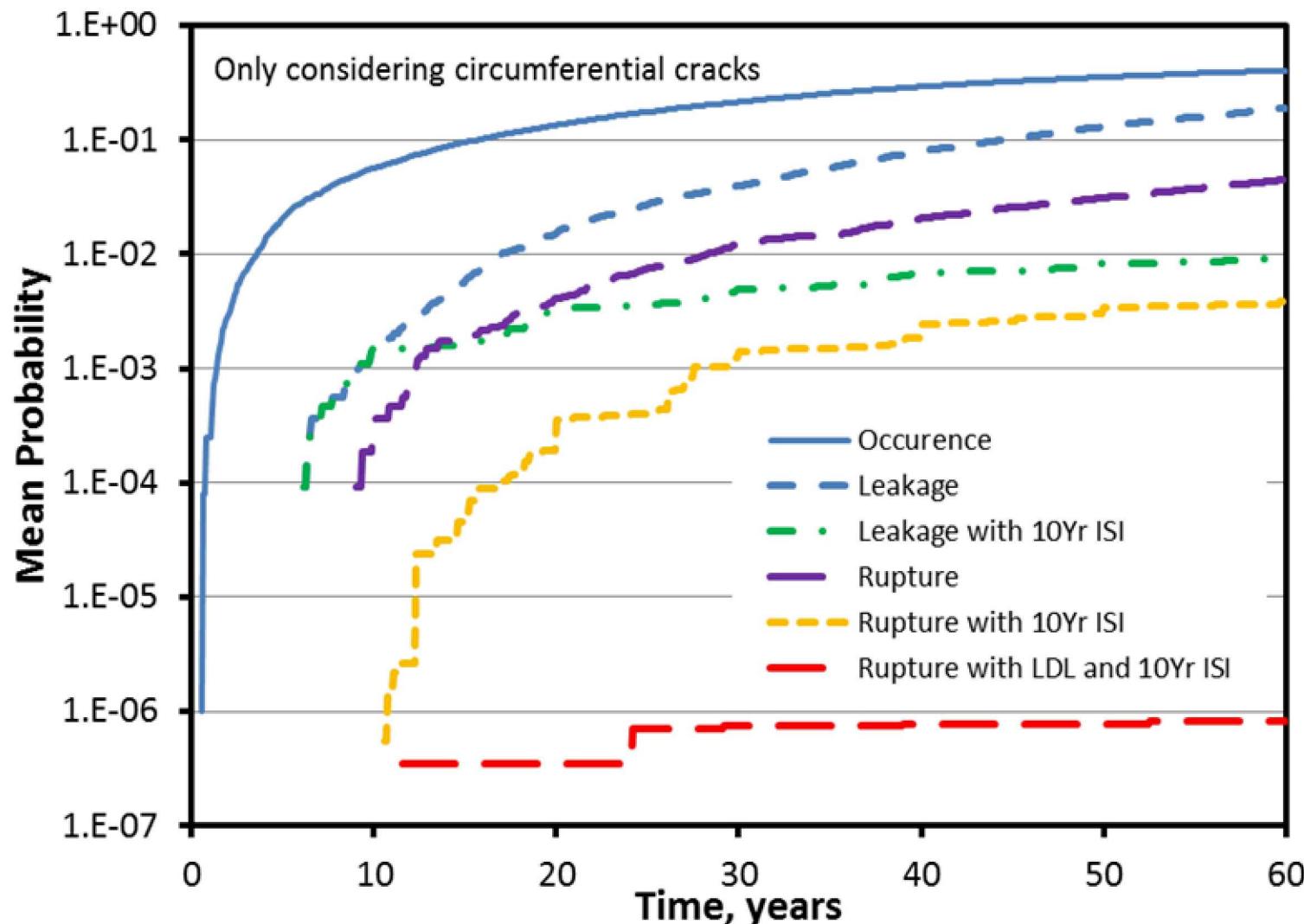
Deterministic Fracture Model

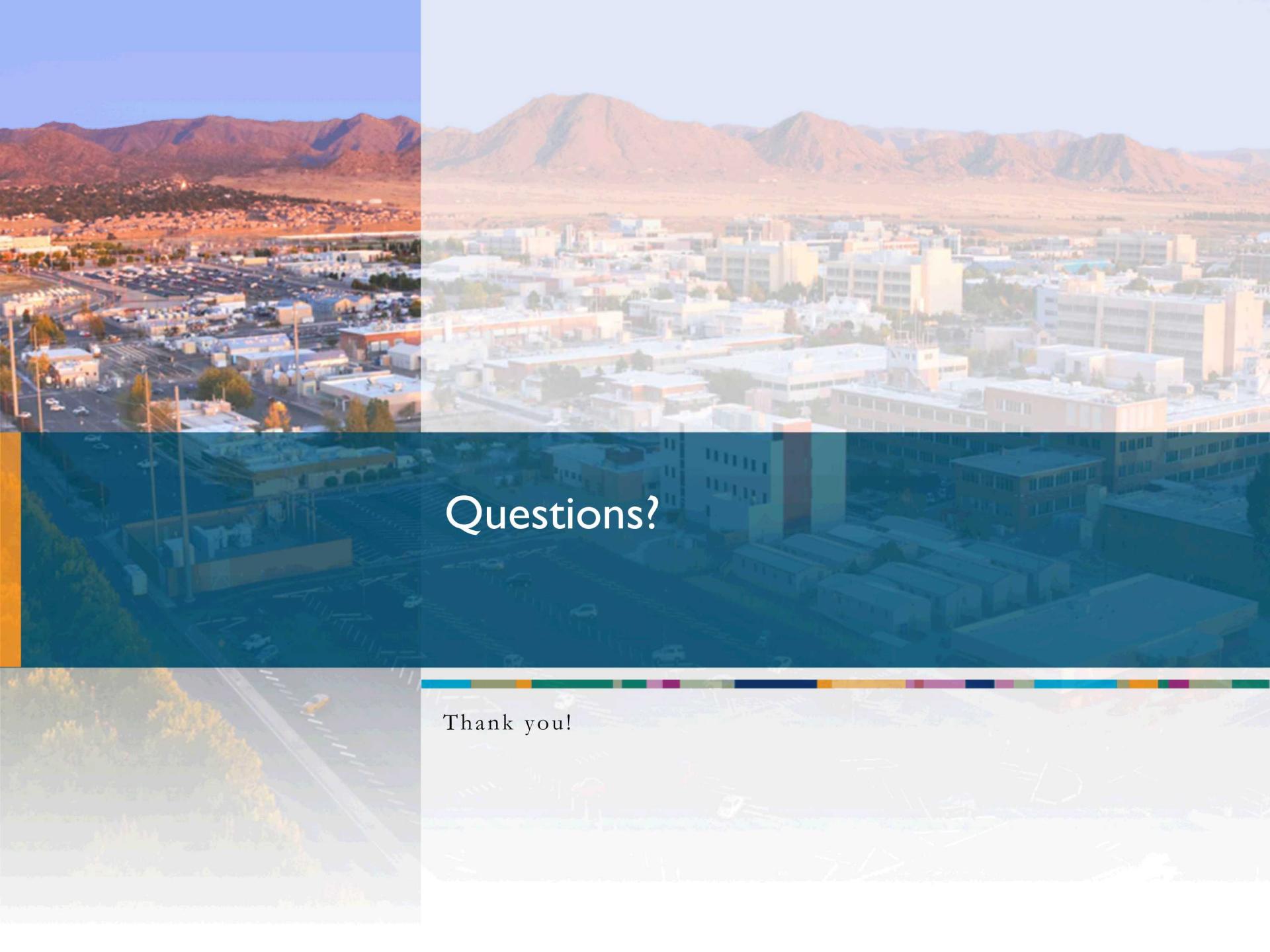


Probabilistic Risk Assessment



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





Questions?

Thank you!