Hydrogen Embrittlement and Pipeline Integrity

Michael Khonsari
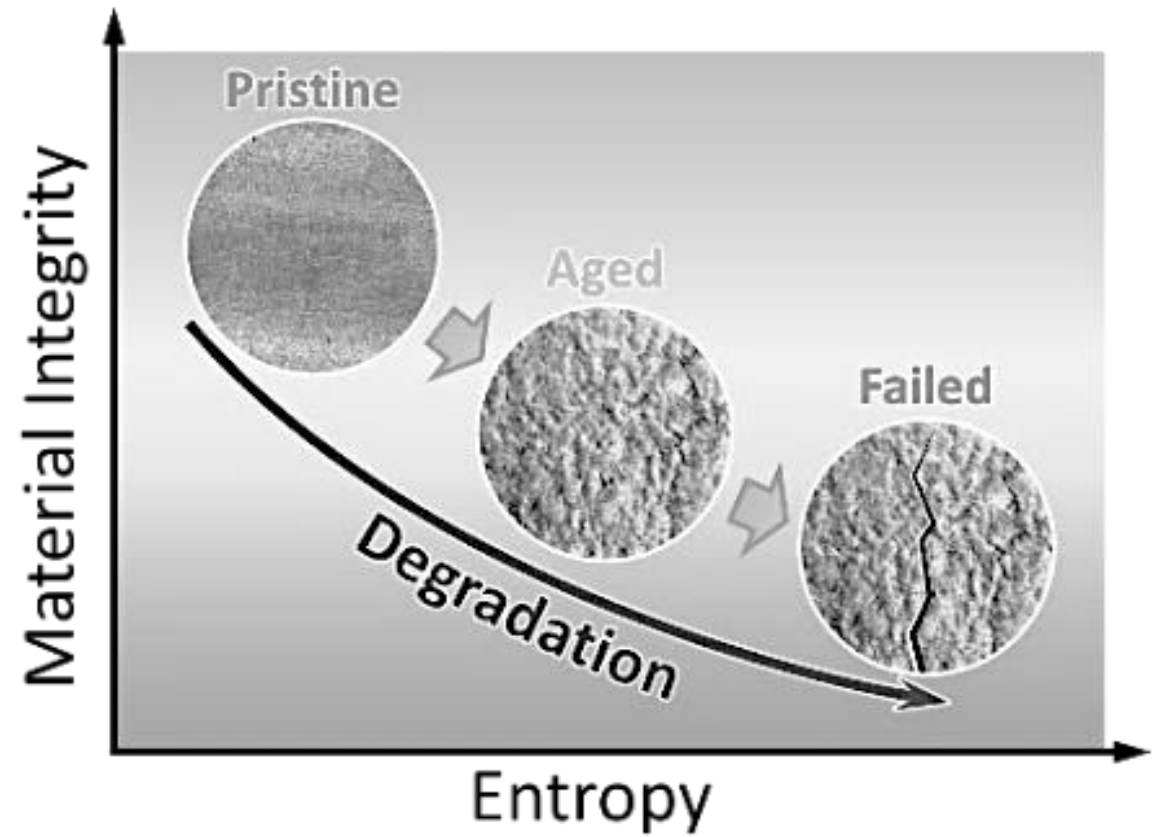**Dow Chemical Endowed Chair and**
Professor of Mechanical Engineering
Director, NSF Center for Innovations in Structural Integrity Assurance (CISIA)
Director, Center for Rotating Machinery (CeRoM)
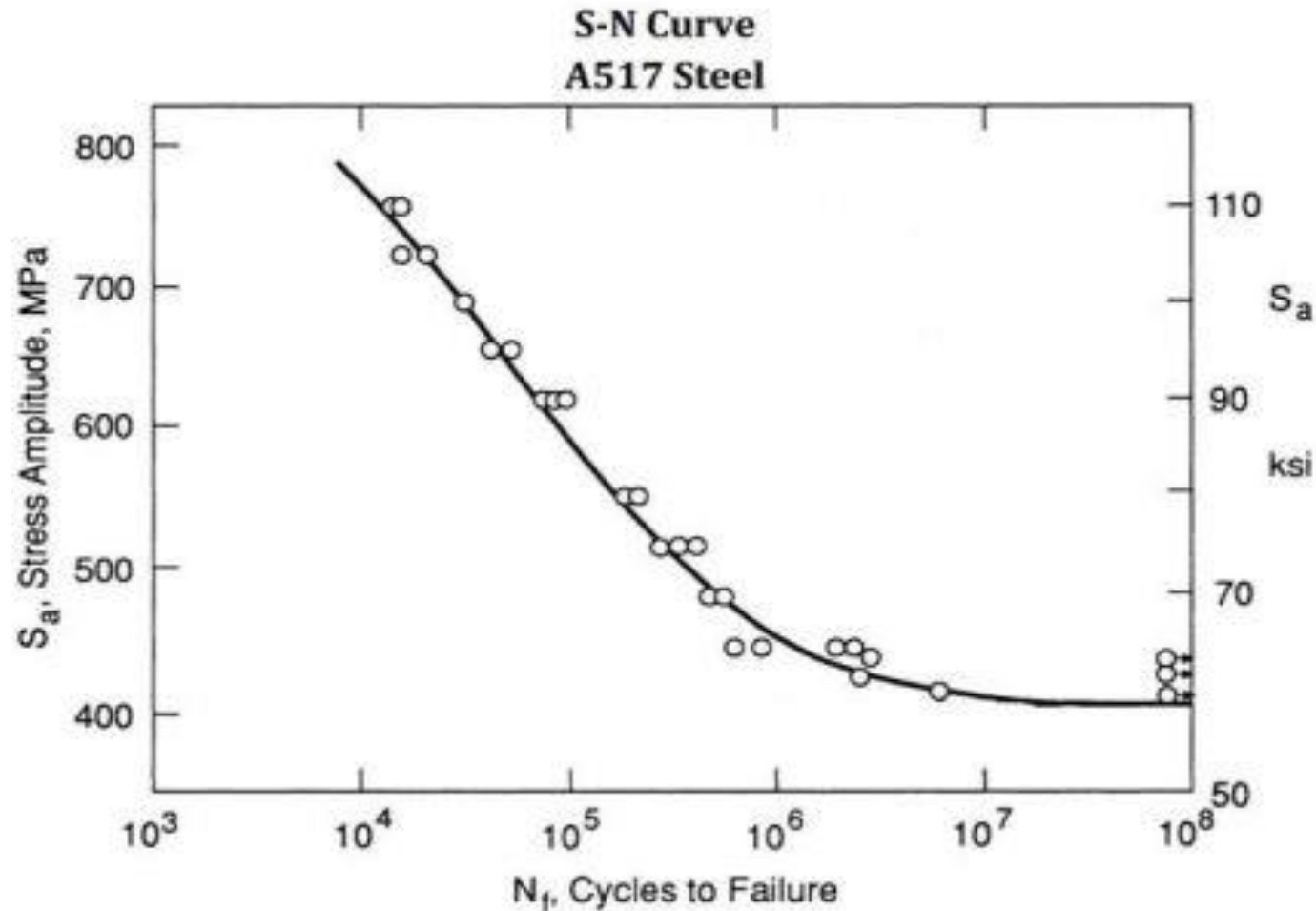**Louisiana State University**

Hydrogen embrittlement and fatigue

How is fatigue analysis done today and what is the state-of-the-art?

- There are different types of loading
- Different operating condition conditions
- Each require a specific type of testing apparatus

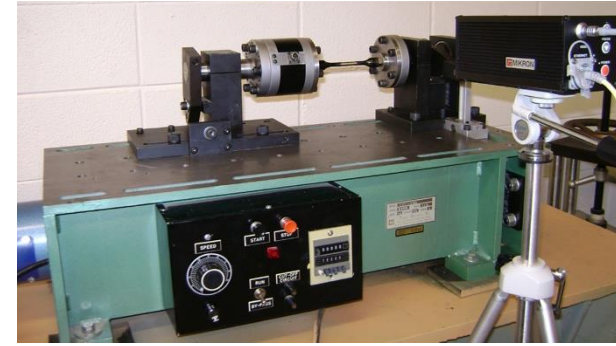# Current Practice: Stress-cycle (S-N) curve

S-N Curve
A517 Steel

- Typically push-pull tests
- Constant stress amplitude
- No information for different type of loading
- No information on combined loading
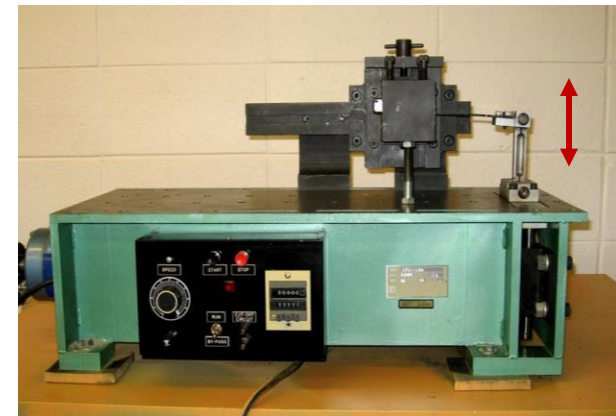- No information for predicting looming failure

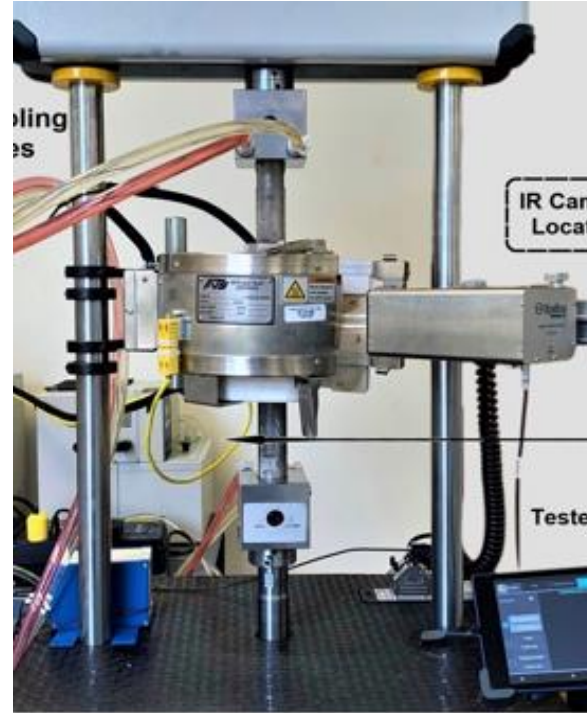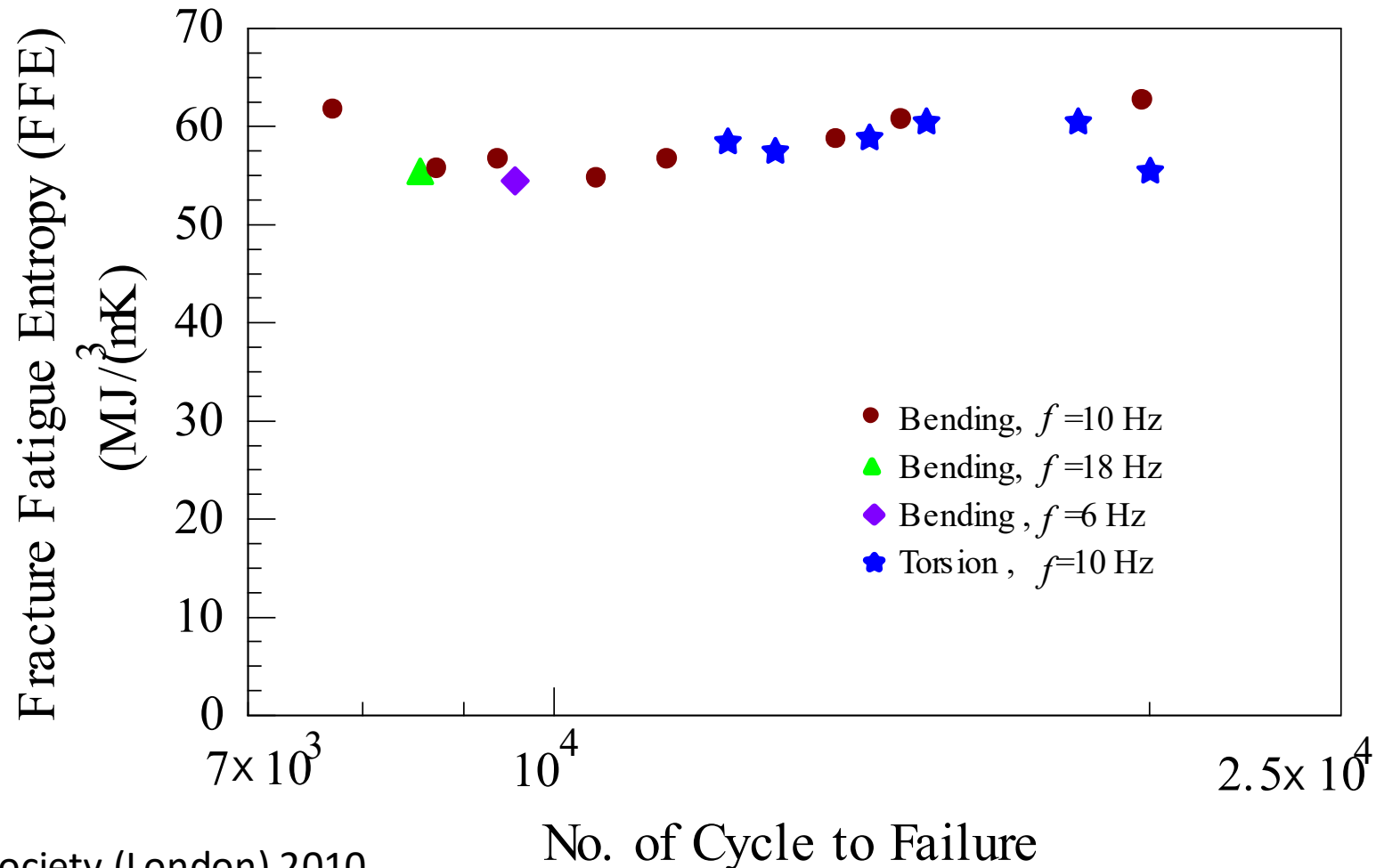# How to evaluate material integrity due to cyclic pressure

Axial Tension-Compression Torsion

Torsion

Rotating Bending

Bending

LSU Discovery of a new material property

A tool to reliably forecast materials life-expectancy

Bending Test of Stainless Steel 304

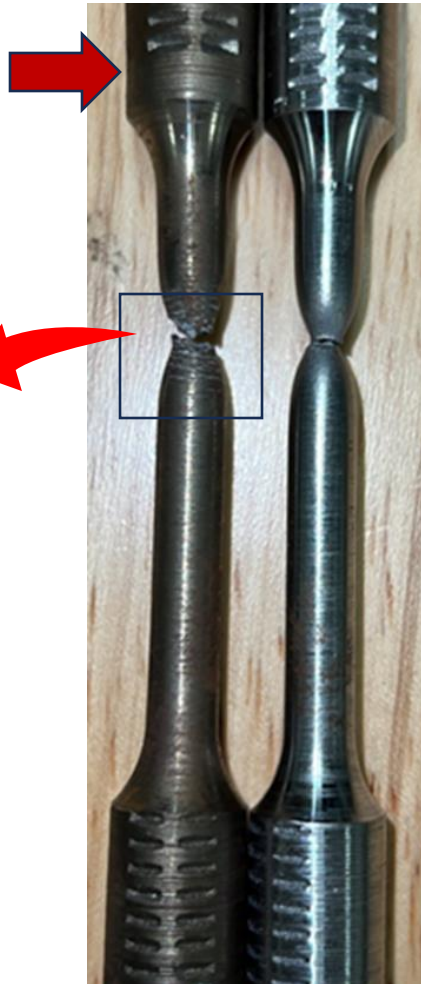Machine is running until it reaches to 90% of life and then stopped by FPU based on FFE concept

Running the machine again to see how much life is remaining
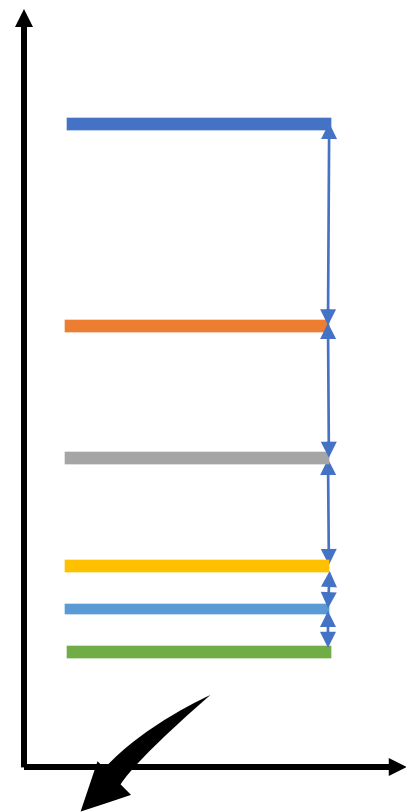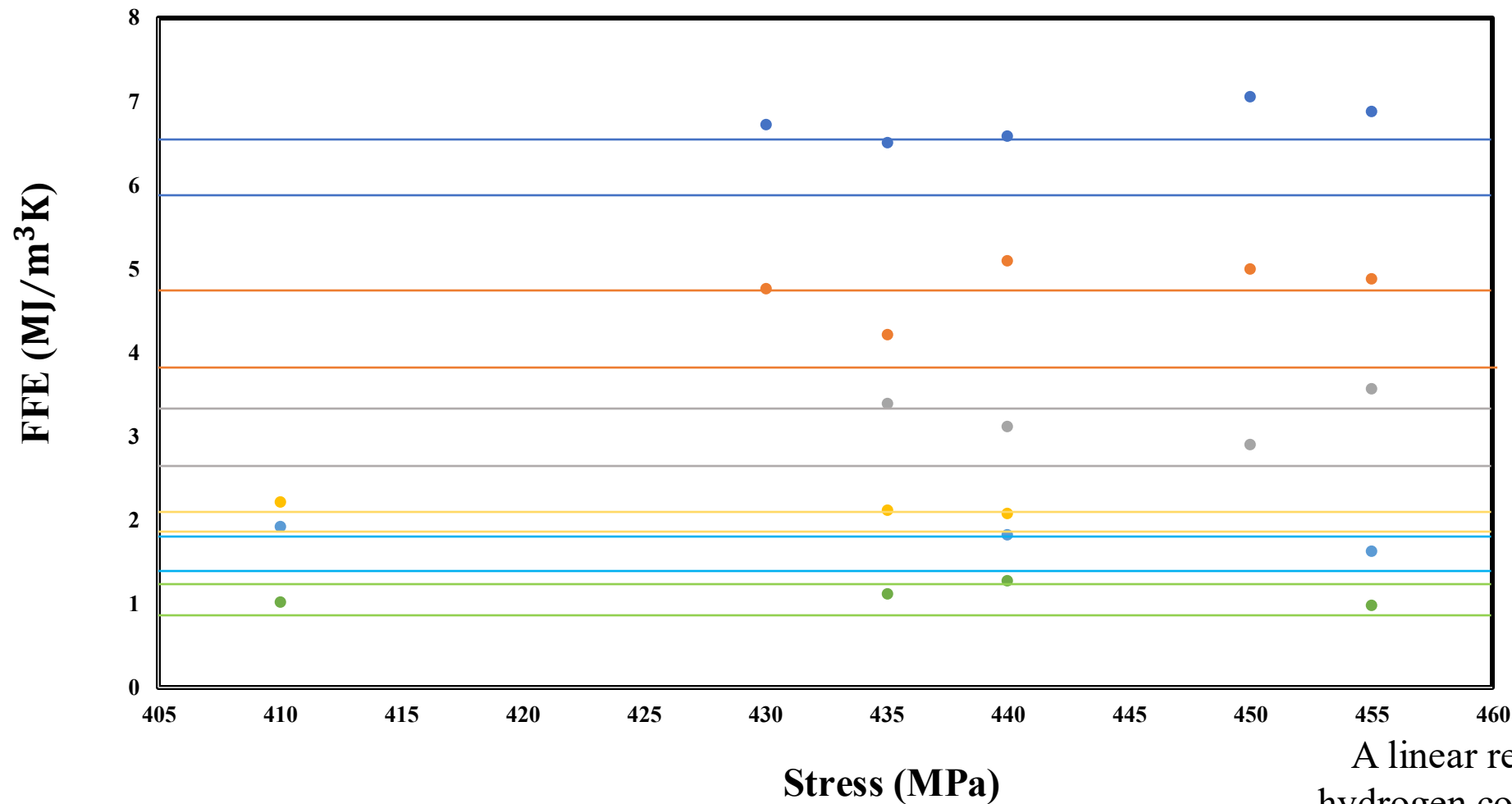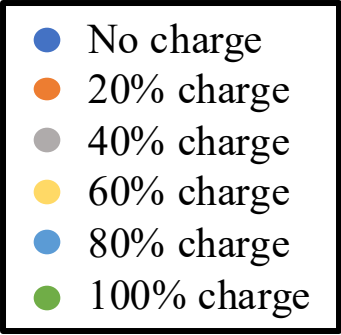
Piping Material A182 F22 Low Alloy Steel

Charged with Hydrogen

Unpublished results

Results: Hydrogen causes significant drop in FFE capacity

Unpublished results

A linear relation between hydrogen content and drop in FFE is NOT observed

Summary

- Hydrogen embrittlement is a serious material integrity problem
- Causes failure at much lower number of cycles allowed by design
- This is a problem in hydrogen pipelines and storage devices
- Existing theories in defining the underlying mechanism are contradictory
- The concept of Fracture Fatigue Entropy (FFE) provides a path forward for prediction and detection of looming failure
- Research is needed to take advantage of this concept for evaluating remaining useful life

Thank you for your attention