Microstructure and defect informed predictions of damage tolerance and durability of materials and structures, including verification and uncertainty quantification

BORE

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## Approach

- Holistic framework to predict microstructurally sensitive fatigue crack initiation & propagation
- Applicable to a general class of structural

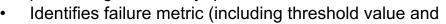
Manufacturing HEDM Experiment Predict Fatigue Behavior Cycles to Failure Uncertainty Microstructure Crystal Plasticity Model **Experimental Validation: Identifying Failure Metric:** Experiment Model  $\Delta \varepsilon = 1.2\%, R_{\varepsilon} = -1$ **Model Predictions** Probability 0.95 0.05 0.05 0.05 <sup>2</sup> (a) ▲Experimental data OF CONTRACTOR (%) Predicted life from 9 SEMs ange ( Log-normal mean of predicted life Bayesian Network  $10^{5}$  $10^{3}$  $10^{7}$  $10^{6}$  $10^{4}$  $10^{5}$ 10 Capturing short fatigu Cycles to failure Cycles to failure crack growth

Research Objective

Overall

Framework:

• Automates creation of crystal plasticity model for deformation, through identifying appropriate constitutive relationships, calibrating the model parameters, and performing uncertainty quantification



σ33 (MPa)

**Modeling Deformation** 

and Environmental

Damage: 对

uncertainty) through Bayesian network, using minimal test data

In situ HEDM experiments provides abundance of validation data at the appropriate length scale for each test

## **Potential Impact**

Next generation fatigue methods reduce the reliance on large-scale coupon testing, saving time and cost

polycrystals, loading scenarios, and environments

- (i) Develops statistically equivalent microstructures with manufacturing defects, (ii) Employs crystal plasticity for combined mechanical and environmental loading, (iii) Identifies fatigue failure through a Bayesian network, (iv) Validates the model via in situ high energy x-ray diffraction microscopy (HEDM) experiments, and (v) Scales to component analysis through hierarchical modeling
- Compared to classical approaches, proposed models account for: (i) manufacturing defects, (ii) microstructure variability, (iii) environmentally damage, and (iv) component features of similar length-scale as the material's microstructure
- High fidelity and precise models will reduce level of mission risk and reliably assess the safety of NASA spacecraft vehicles
- Project starts at TRL 1 and will finish at TRL 3