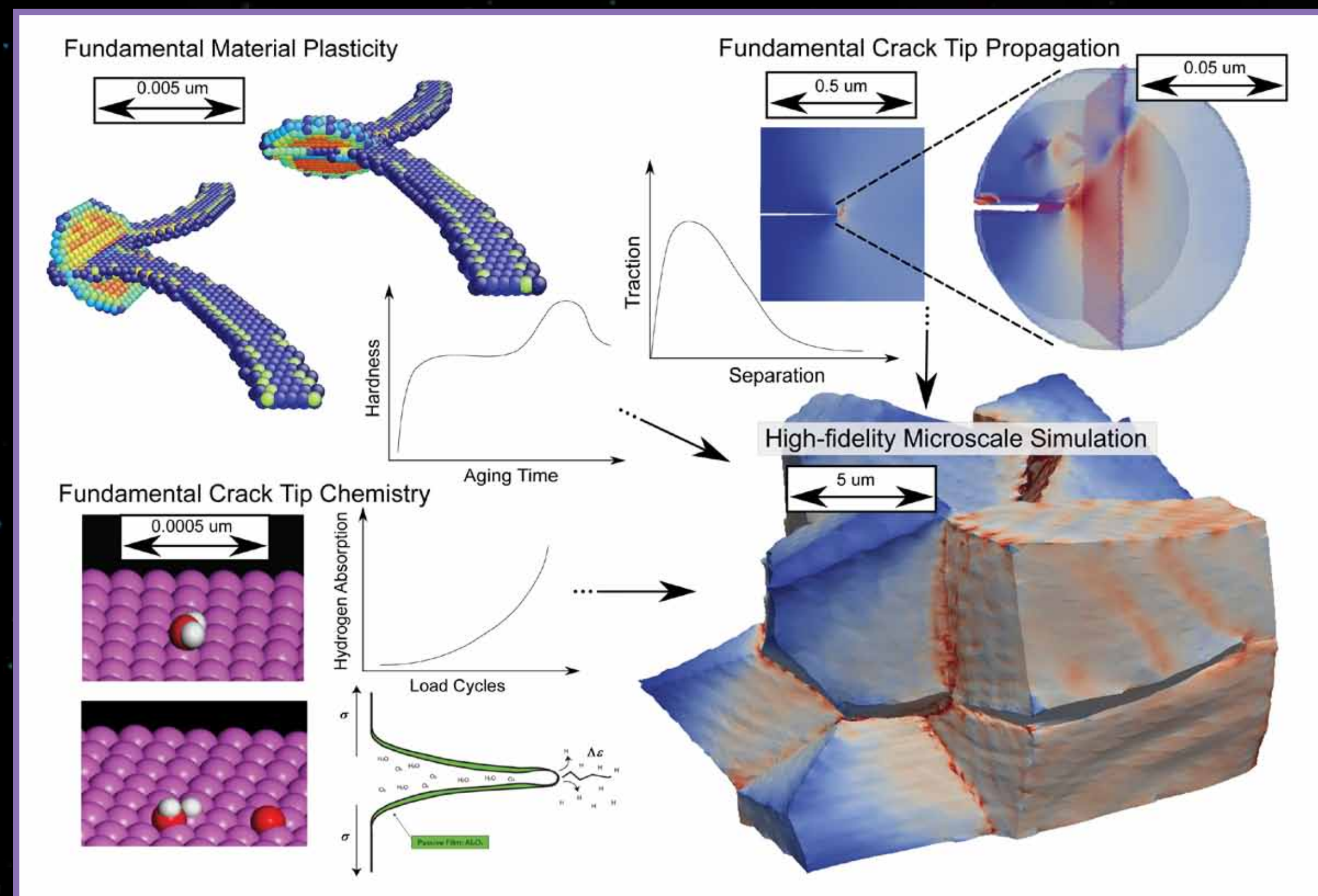
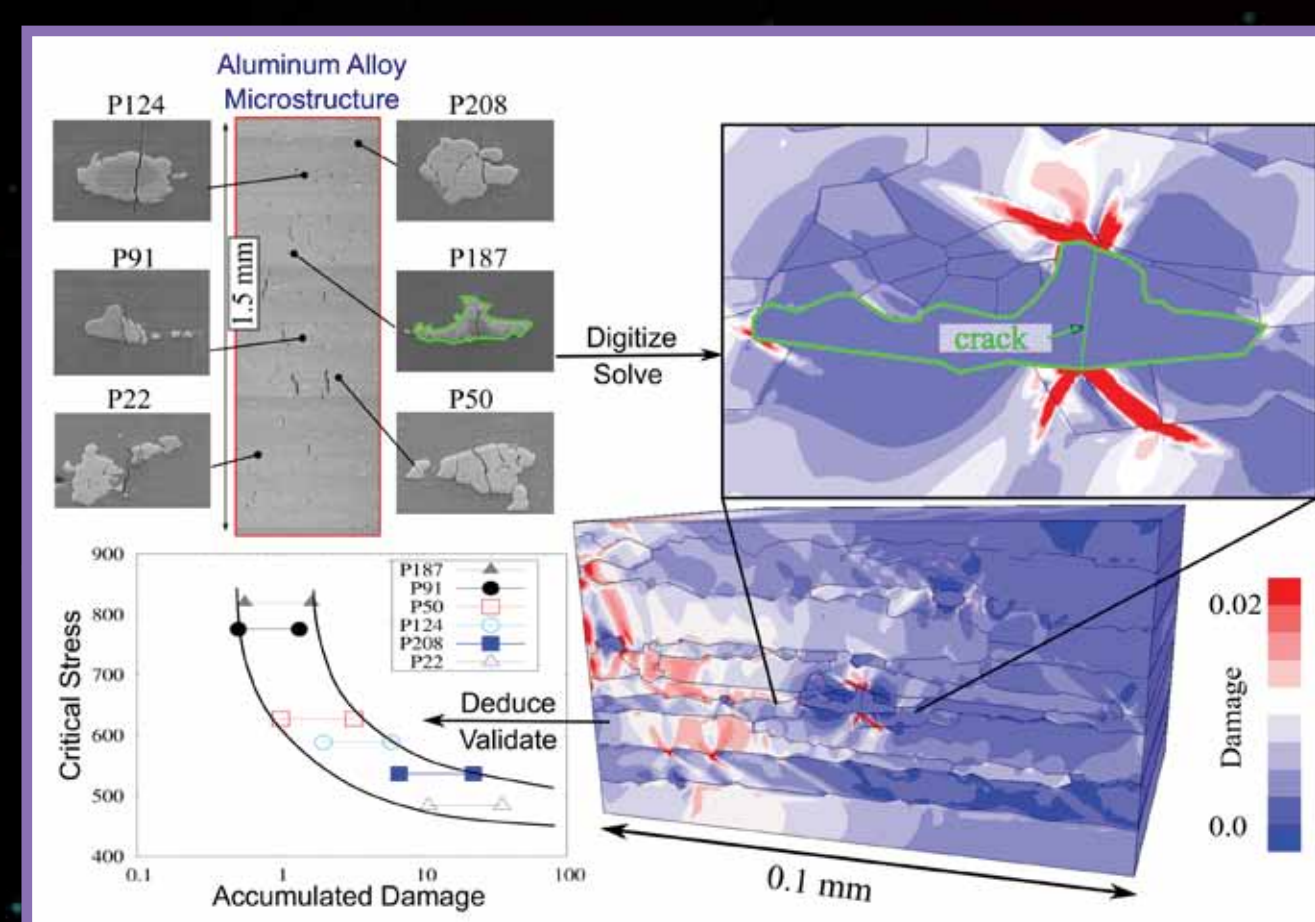


Design of Ultra-Durable Materials for Future Aerospace Vehicles



Crack tip chemistry simulations predict the dissociation of water on crack surfaces. Material plasticity simulations predict dislocation-precipitate interactions. Crack propagation simulations predict atomic separation models. The multiple simulations, at various time and length scales, inform micro-scale simulations for improved fidelity in engineering applications. *Rob Kelly, University of Virginia; Derek Warner, Cornell University*



Hypothesis testing and validation of the simulation framework are done by replicating observed microstructures and computing fields that cannot be measured. *Jacob Hochhalter, NASA/Langley*

Extreme structural requirements of future aerospace vehicles motivate the development of new, ultra-durable materials and game-changing methodologies for material certification and sustainment. Computational simulations spanning many orders of magnitude in length and time scales—from the nanoscale of underlying damage processes to the larger scales of continuum cracks—are being developed to support these requirements. Results of these simulations are used to deduce key aspects of material response to loads and environments, including:

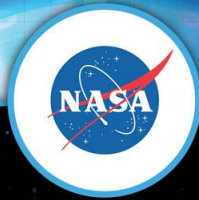
- The microstructural mechanics that govern metal fatigue crack initiation and growth
- The variety and complexity of the dislocation-precipitate interactions that underpin plastic behavior and damage evolution
- The energetic principles that govern the interaction of water with crack surfaces within a structural component
- The mechanics of grain boundary separation

Modeling the physics behind these metal fatigue behaviors is extremely complex, and requires intensive, high-fidelity simulations. The knowledge gained through these simulations, however, is forming the keystone for advanced material design and will enable development of more capable, reliable structures for aerospace vehicles.

Jacob Hochhalter, Edward Glaessgen, NASA Langley Research Center



The following presentation slides support the poster and may be used as backup in discussions.



Design of Ultra-Durable Materials for Future Aerospace Vehicles

Jacob D. Hochhalter, NASA Langley
Edward H. Glaessgen, NASA Langley

Topics



- I. Understanding and predicting the distribution of fatigue behavior
- II. Designing ultra-durable materials to meet uniquely-high demands

Developing fundamental concepts that will enable future aeronautics and space exploration alike

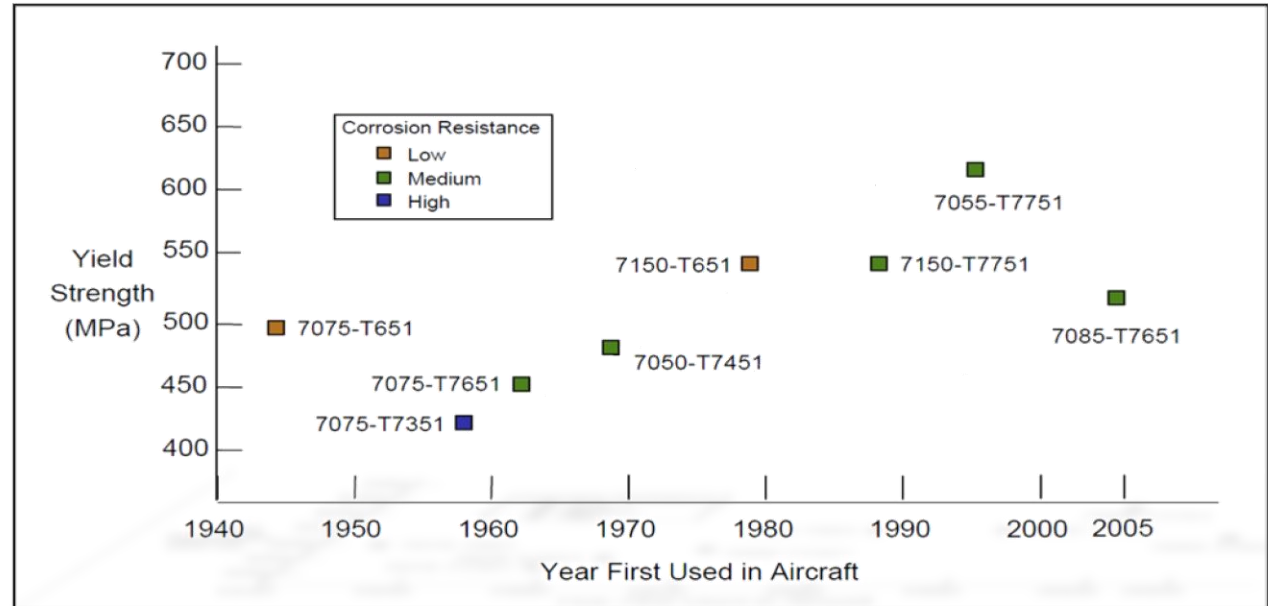


Materials Design Today

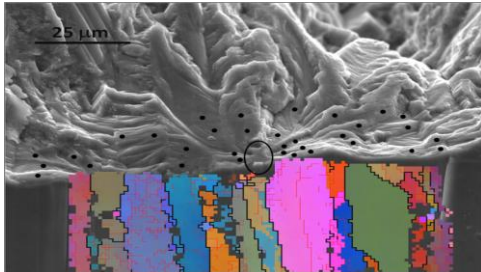
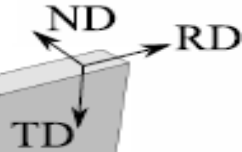


Material improvements driven by empiricism

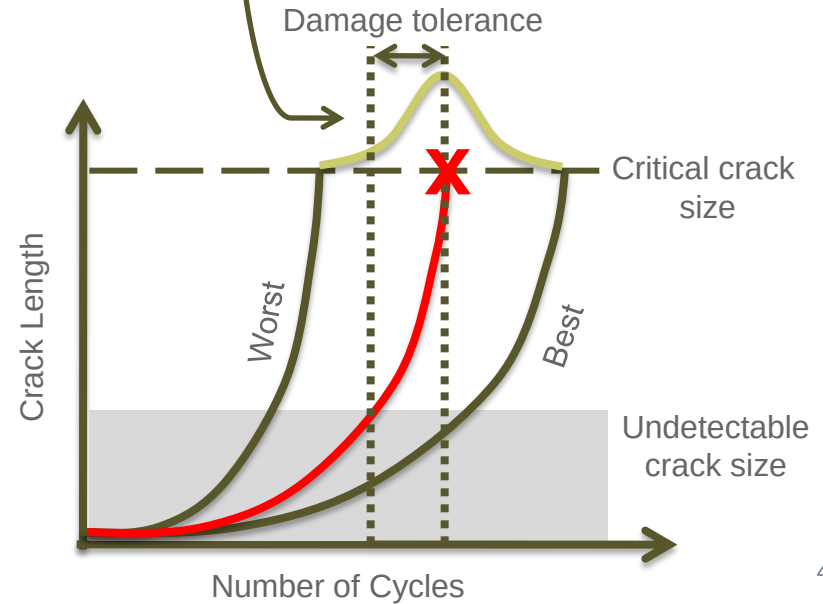
Material development using an empirical approach has proven effective, but slow



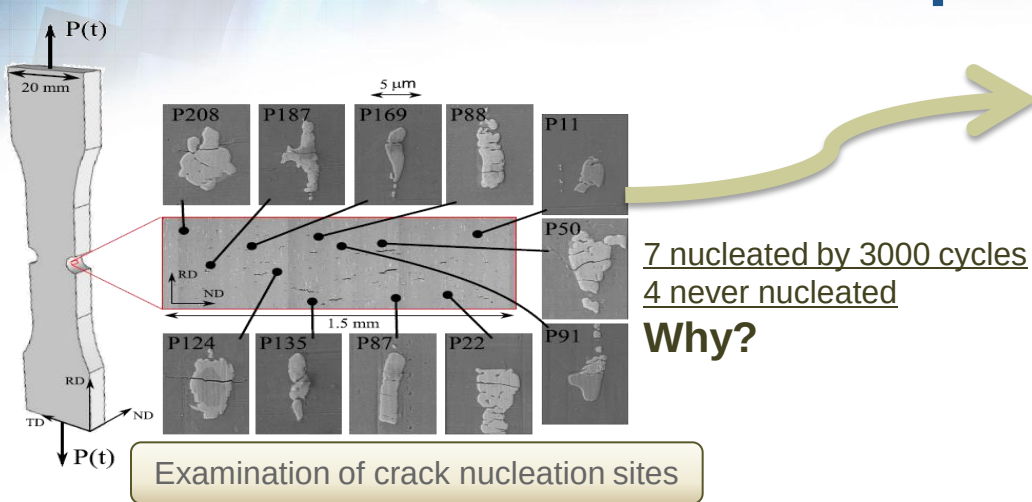
Fatigue Behavior Prediction Today



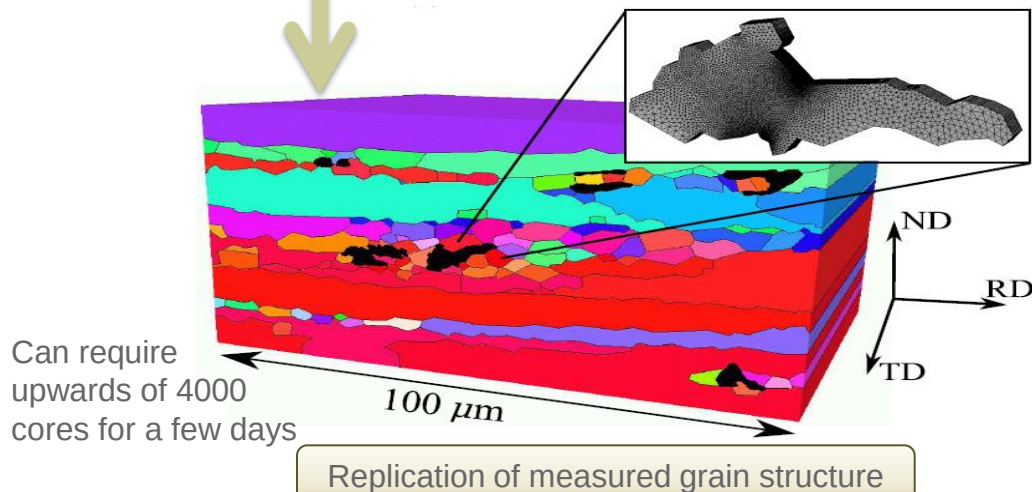
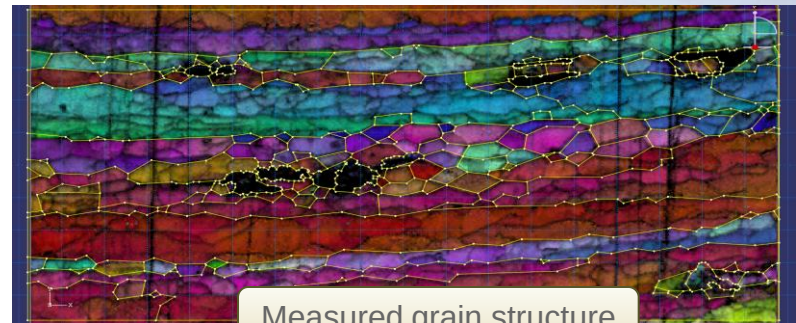
We lack models that
describe **observed**
variability in behavior



Microstructure-Replication Modeling



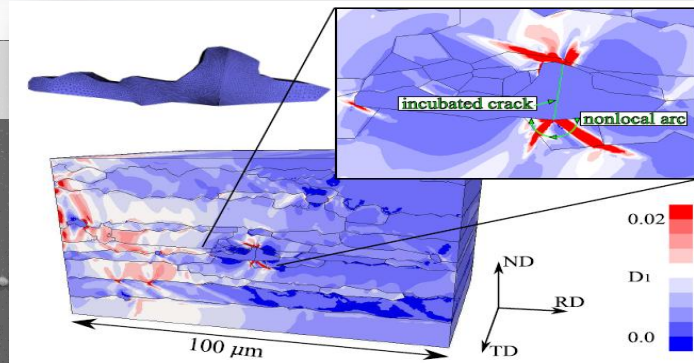
HPC enables simulation of microstructural mechanics: necessary to develop models that describe observed variability



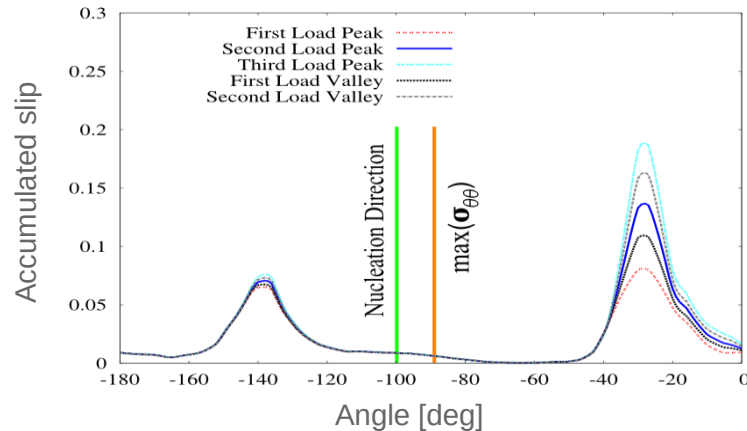
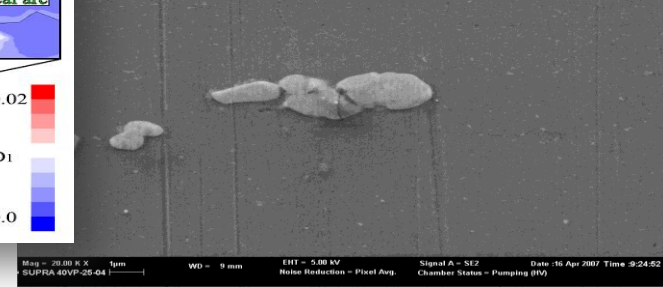
Computing Fields We Cannot Measure



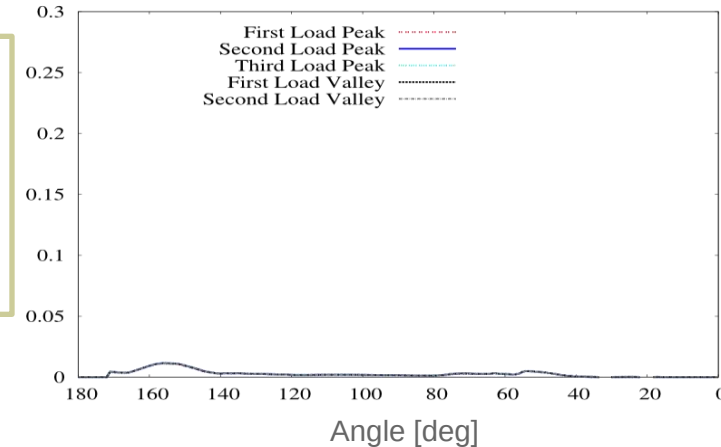
Nucleated



Did Not Nucleate



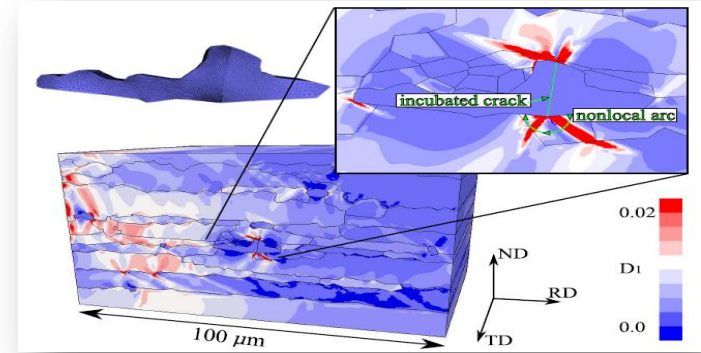
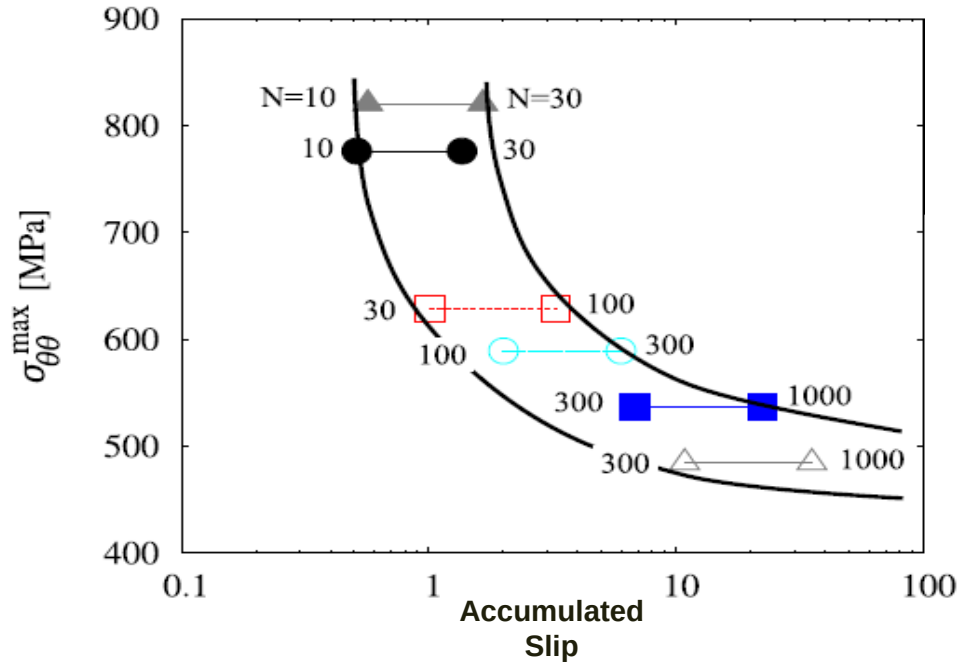
HPC simulation results revealed why some particles nucleate cracks, while others do not



Computing Fields We Cannot Measure

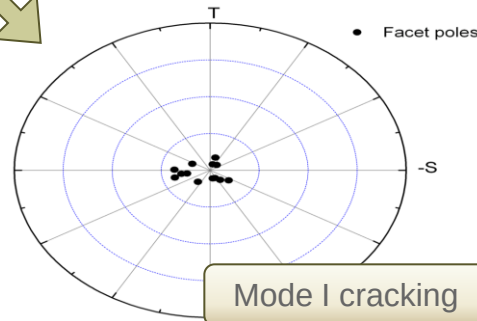
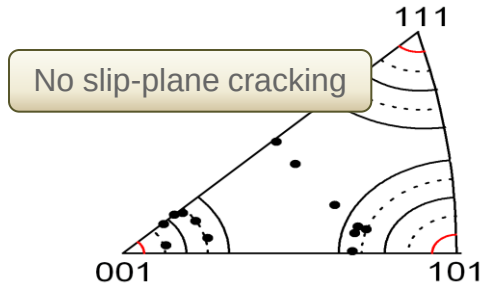
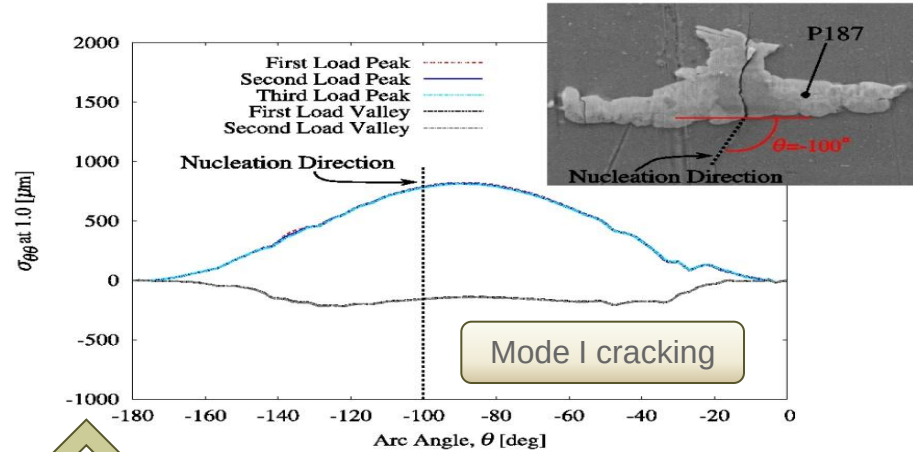
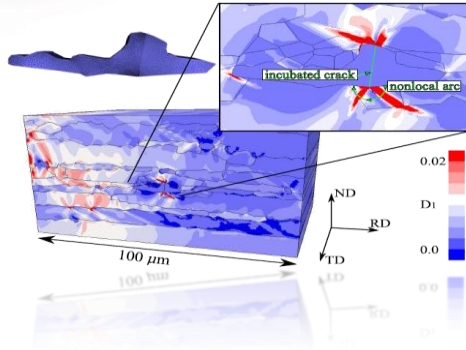


Why? The stress required to drive nucleation reduces with accumulation of slip



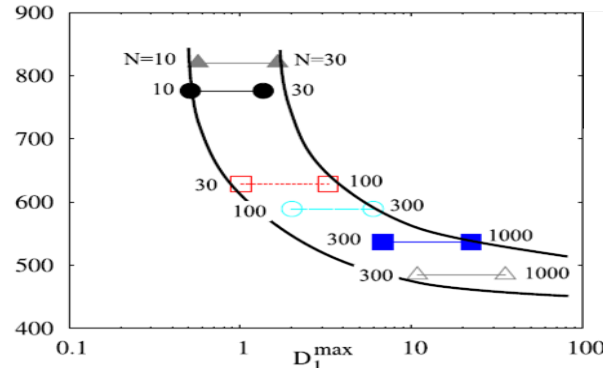
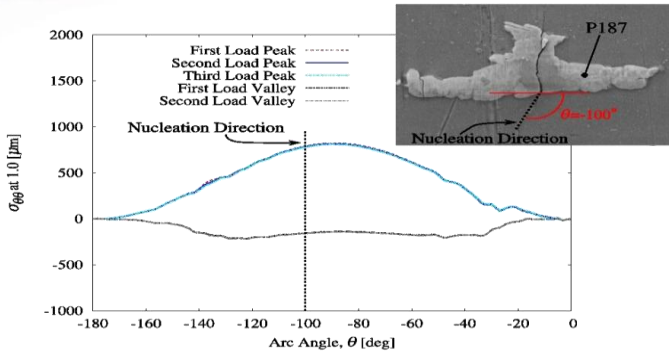
HPC simulation of several microstructures led to a model that describes observed variability

Validating Computed Results



Comparing simulation results with recent measurements provides validation and corrects errors in previous models

Improving Fatigue Predictions Tomorrow



Modeling the mechanics that underpin **observed variability** enables design of ultra-durable materials

