

# ***Structural Metallic Materials for Aerospace Applications***

***Rollie Dutton, Dennis M. Dimiduk,  
and Chris Woodward***

**Materials and Manufacturing Directorate  
Air Force Research Laboratory**



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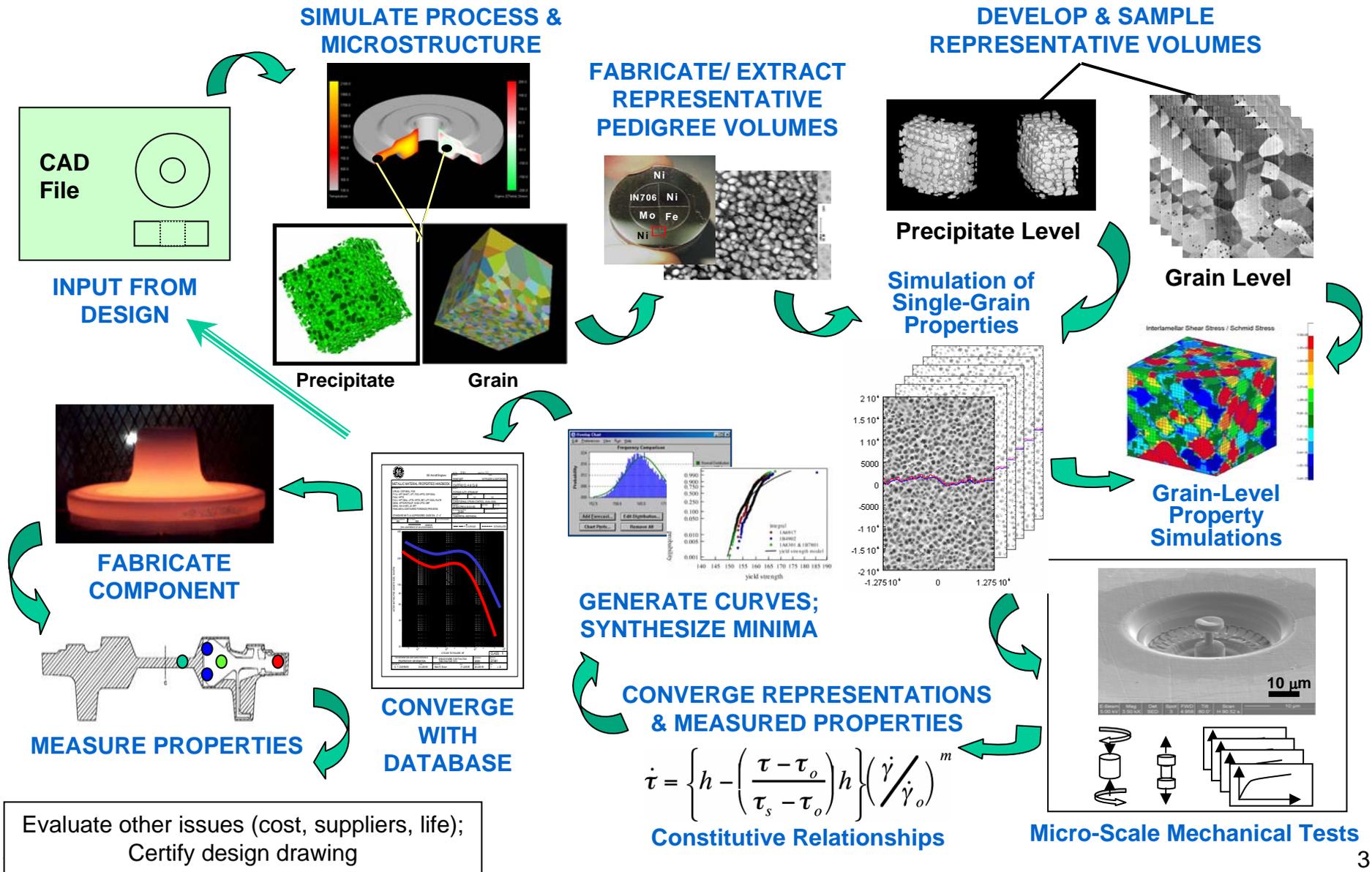
***Steve Wax***





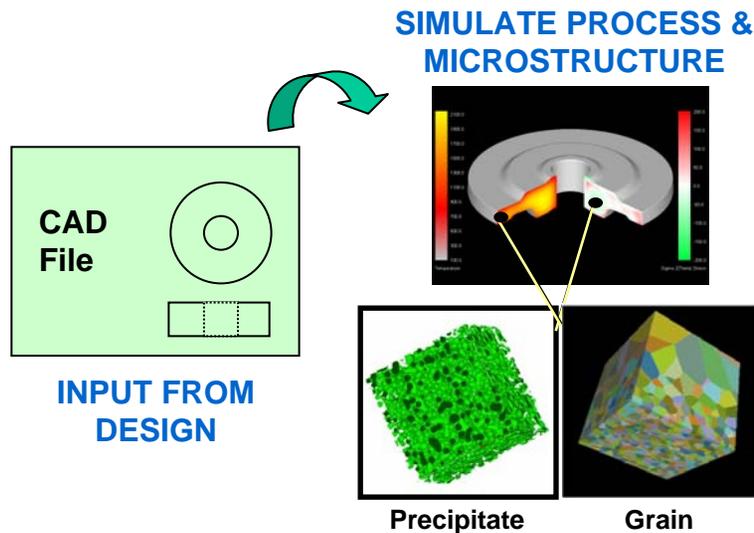


# Accelerated Insertion of Materials Tools & Methodology New Material





# Areas Requiring Further Study



## Multiscale Process Models for Microstructure Evolution:

- Methods spanning:
  - Length: dendrites  $\rightarrow$  tertiary  $\gamma'$
  - Time: solidification  $\rightarrow$  in-service lifetimes
- Linking time scales for grain growth and phase/constituent evolution
- Grain boundary constituent precipitation and growth
- *Interfacial thermodynamics and kinetics with realistic chemistries*
- Efficient representations and numerical schemes



## Areas Requiring Further Work



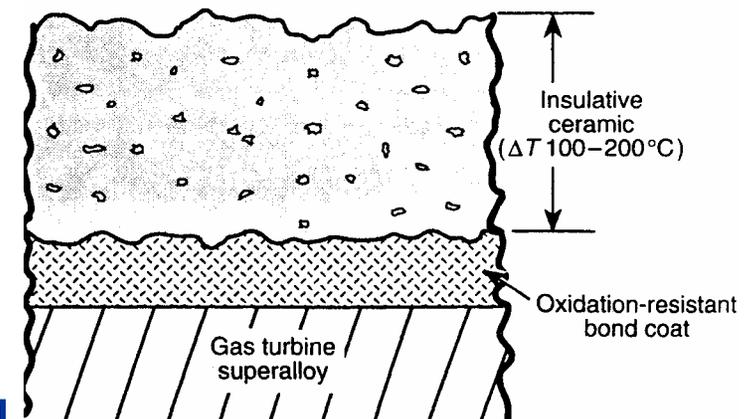
# Require an experimental/modeling rapid assessment tool for the thermodynamics/kinetics of *metal-metal interfaces*

- Complexity ranges from:
  - Crystalline planar faults (stacking faults, APB's,...)
  - Coherent interfacial boundaries (e.g. Ni-Al  $\gamma$ - $\gamma'$ )
  - Incoherent interfacial boundaries
  - Grain boundaries
- High T, complex chemistries
  - structure, energy
  - thermal expansion
  - time dependent properties
  - environmental effects (hot corrosion)

***Need similar tool for metal-oxide interfaces***

Zirconia thermal barrier coatings

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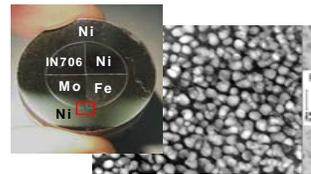
# Areas Requiring Further Work



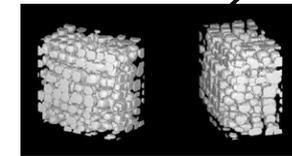
## Composition & Constitution of Alloys

- Methods for rapid & robust evaluation of multi-component phase diagrams ( $O(n^2)$  or better for models)
- Techniques for micro-structural *kinetics*

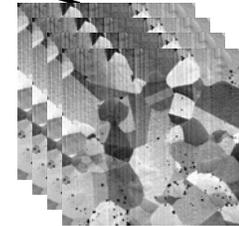
FABRICATE/ EXTRACT  
REPRESENTATIVE  
PEDIGREE VOLUMES



DEVELOP & SAMPLE  
REPRESENTATIVE VOLUMES



Precipitate Level



Grain Level

## Define & Sample Representative Volumes

- High fidelity, efficient material structure representation
  - Automated interpretation, analysis of large data sets: texture, shape, size distribution, inter-grain correlation
  - Generalized *representation across material classes*
  - *Rare events: deviations far from the mean*



# Areas Requiring Further Work



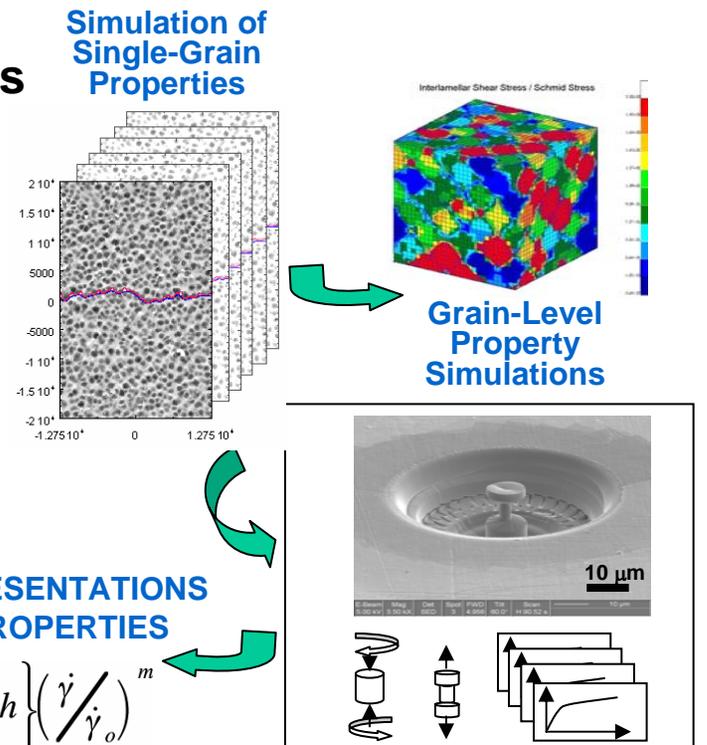
## Exploring Single & Multi-Grain Properties

- Structure-sensitive constitutive descriptions of “hierarchical fidelity”
- Structure-sensitive material flow rules (kinetic descriptions of plasticity)
  - *time-dependent* property descriptors (creep, fatigue, crack-growth)
  - *environmental effects* (chemical attack, oxidation, hydrogen, etc.)
  - emphasis on *portability* across material classes
  - direct link to structure representations (previous chart)
- Rapid, *statistically relevant* micro-scale mechanical testing
  - temperature and strain rate variations
  - multiaxial stress states
- *Direct links* to stochastic and probabilistic life management methods
- Efficient numerical and computational schemes

CONVERGE REPRESENTATIONS  
& MEASURED PROPERTIES

$$\dot{\tau} = \left\{ h - \left( \frac{\tau - \tau_o}{\tau_s - \tau_o} \right) h \right\} \left( \frac{\dot{\gamma}}{\dot{\gamma}_o} \right)^m$$

Constitutive Relationships





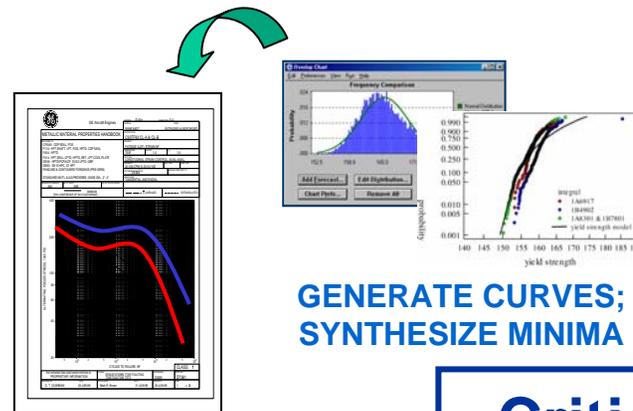
# Interface with Industry



## Mapping results to industrial partners

End users of these tools: industrial component- designers

- Work developed under previous charts must be linked to these engineering requirements
  - Procedures must conform to industrial environment, practice and constraints
  - Critical to engineering certification and use



CONVERGE  
WITH  
DATABASE

GENERATE CURVES;  
SYNTHESIZE MINIMA

**Critical role for industrial  
partners to define and  
police this interface**



# Must Address Full Breadth of Component Requirements



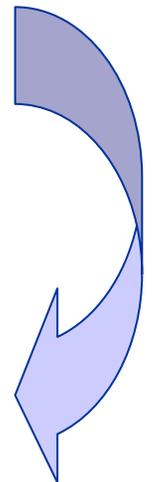
## Requirements for Turbine Engine Disks:

- **Ultimate Tensile Strength**
- **0.2 % Yield Strength**
- **Tensile Ductility**
- **Notch Strength**
- **Burst Margin**      **DARPA - AIM**
- **Creep**
- **Rupture**
- **Rupture Ductilities**
- **Continuous Cycling LCF**
- **Hold Time LCF**
- **Continuous Cycling Crack Growth**
- **Hold Time Crack Growth**
- **Superplasticity**
- **Flow Stresses**
- **Abnormal Grain Growth Resistance**
- **Gamma Prime Solvus**
- **Carbide(s) Solvus**
- **Density**



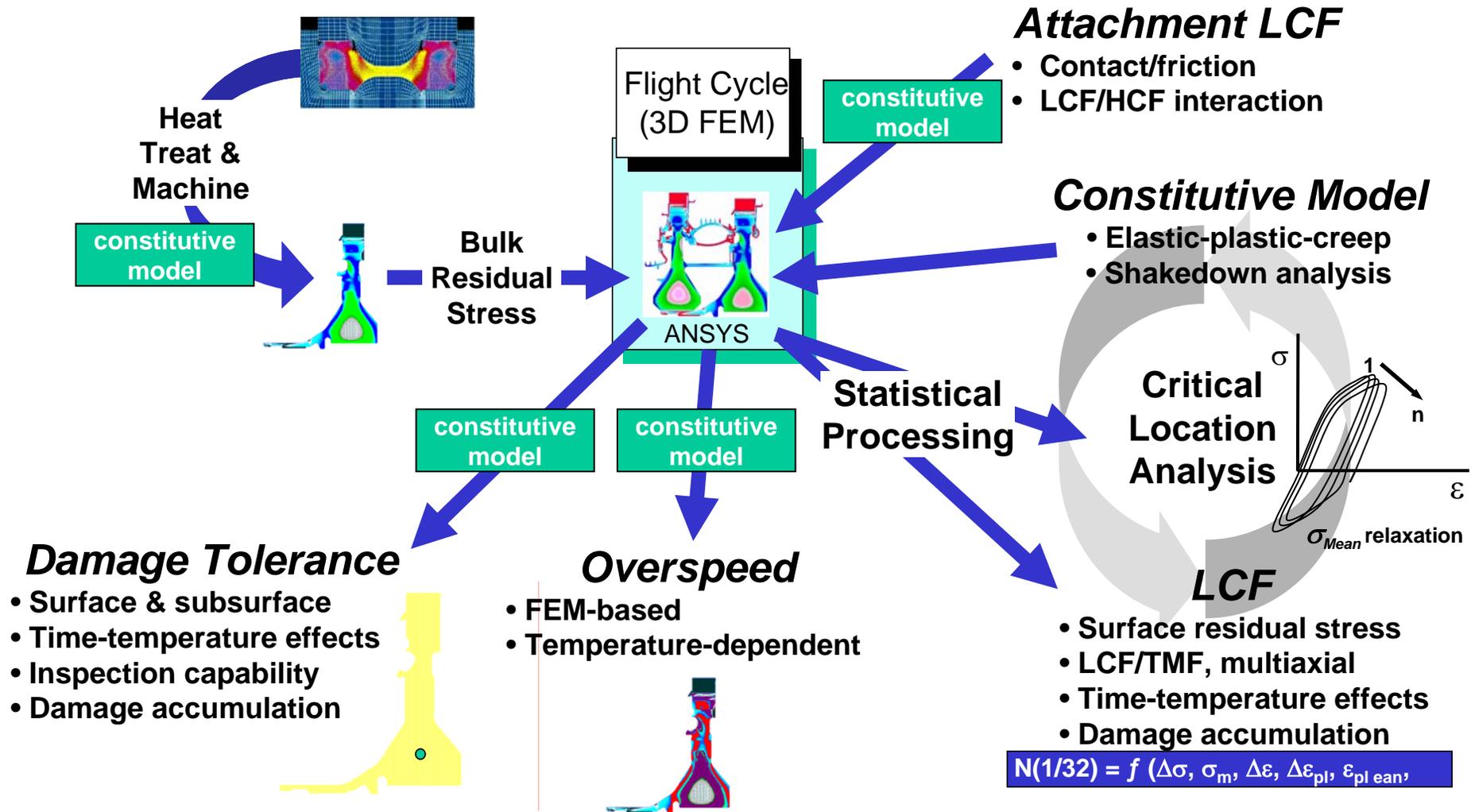
- **TIP**
- **Structural Stability**
- **Exposed Behavior**
- **Defect Sensitivity**
- **Defect Content**
- **Grain Size**
- **Gamma Prime Size**
- **Segregation /Effects**
- **Inspectibility**
- **Quench Crack Resistance**
- **Multi-source Capability**
- **Low Costs--Elemental and Processing**
- **Weldability**
- **Machinability**
- **Machined Surface Behavior**
- **Residual Stresses**
- **Cost Reduction Potential**
- **Size/Volume Scaling Effects**

*The Issues That Often Determine Success or Failure*





# Longer-Range Challenge: Structure-Sensitive Design Life-Prediction



**Structure-Sensitive Constitutive Representations are the Key to Success**



**See you at the breakout!**



# Hypothesis Focusing In-House Research

