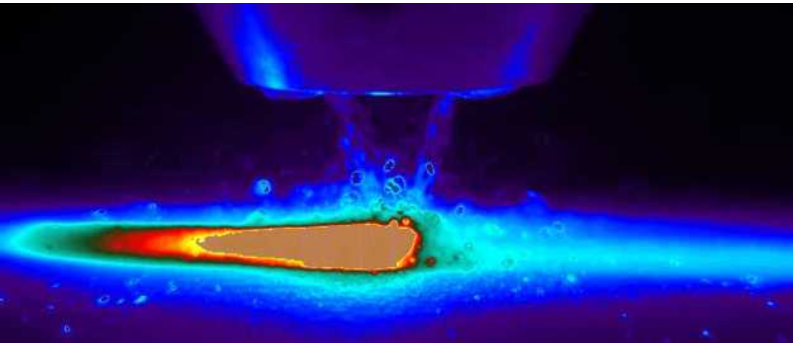
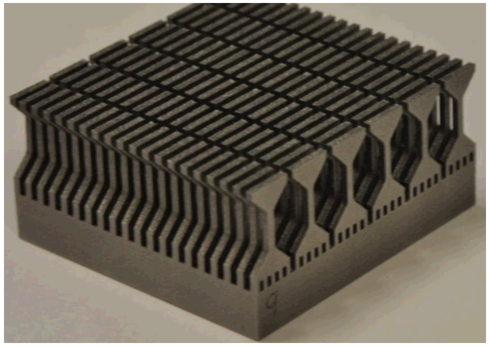
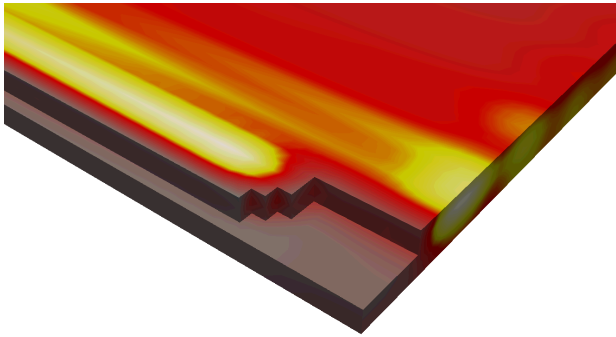
SAND2018-2695PE





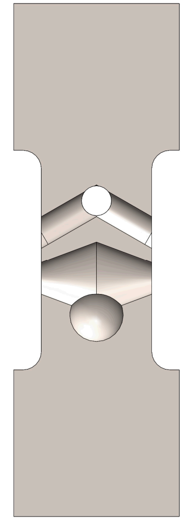


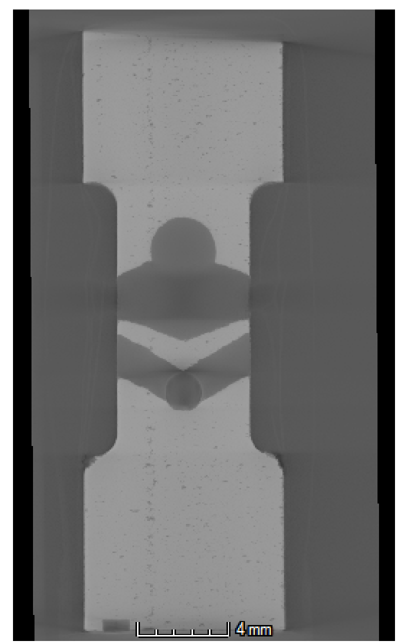
The 3rd Sandia Fracture Challenge – Team R Approach

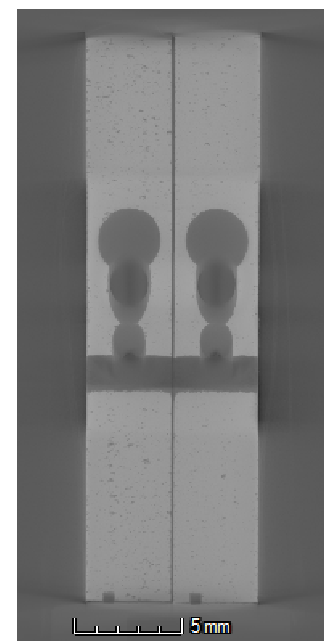
Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.

Example: Sandia Fracture Challenge

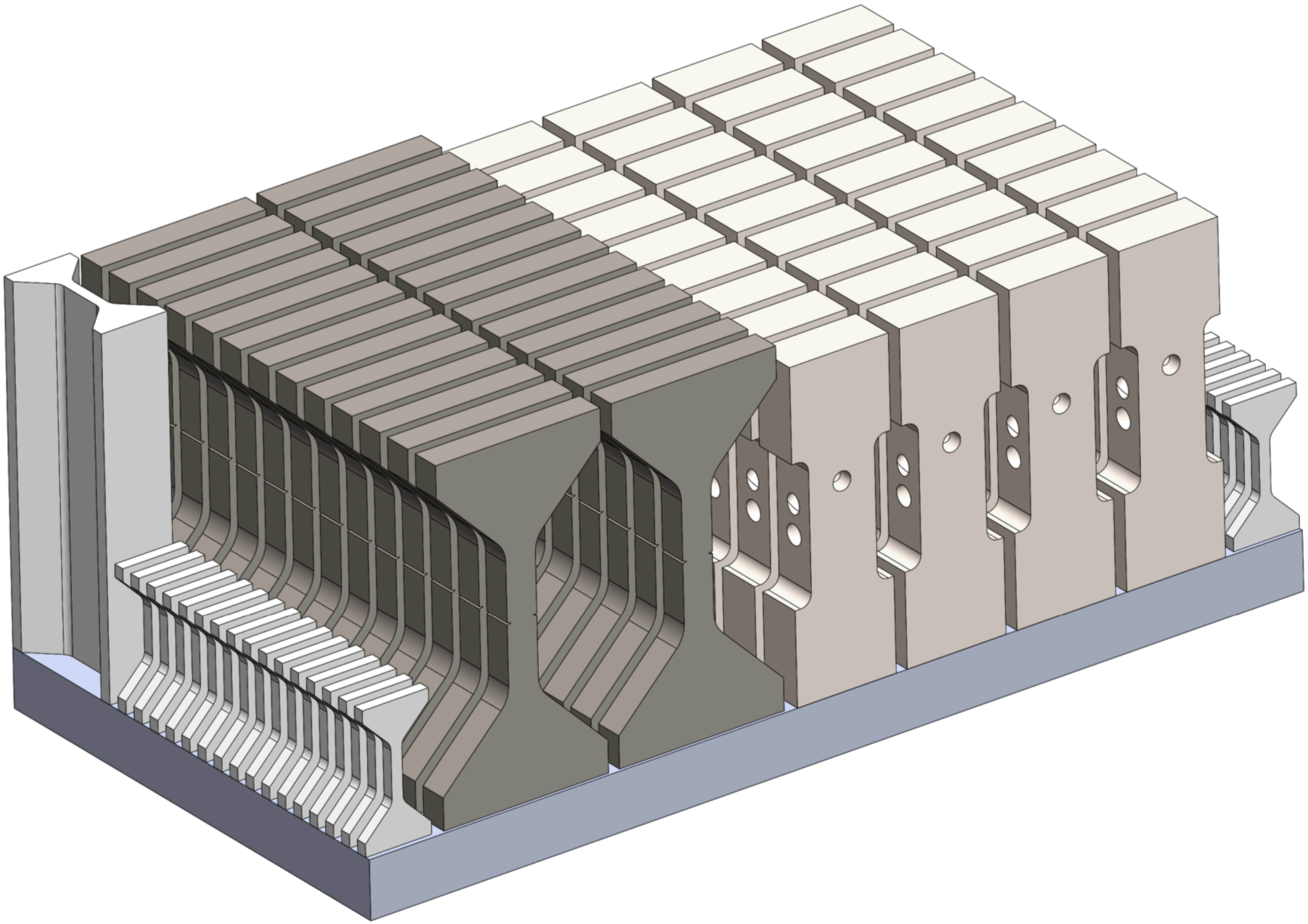
- 316L Stainless Steel LPBF Part
- Complex geometry with internal channels and spherical cavity
- Loaded in tension
- Given CT data along with smooth tension and notched tension data
- Challenge Questions:
  - Force at four different displacements
  - Force and log strain at four points on front face
  - Total force-displacement curve
  - Force and log strain along four horizontal lines on front face
  - Images of front surface at crack initiation and complete failure







Build Plate Part Layout



Predictive Approach

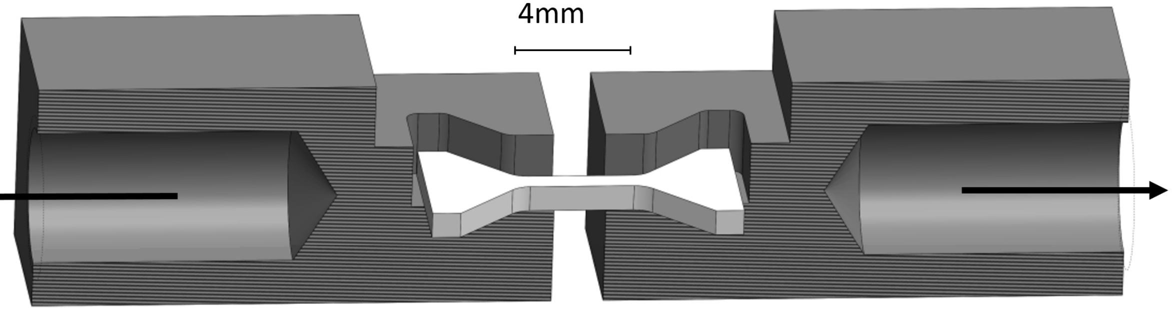
1. Fit robust plasticity model to calibration test data with porosity distributions as initial damage
2. Run many iterations of challenge geometry with many porosity distributions
3. Perform statistical analysis on results to enrich result distributions

- SNL/NM Team Members: John Emery, Joe Bishop, Judy Brown, Chris Hammetter, Spencer Grange, Kurtis Ford, Kyle Johnson
- Additional help from Kyle Karlson (SNL/CA)

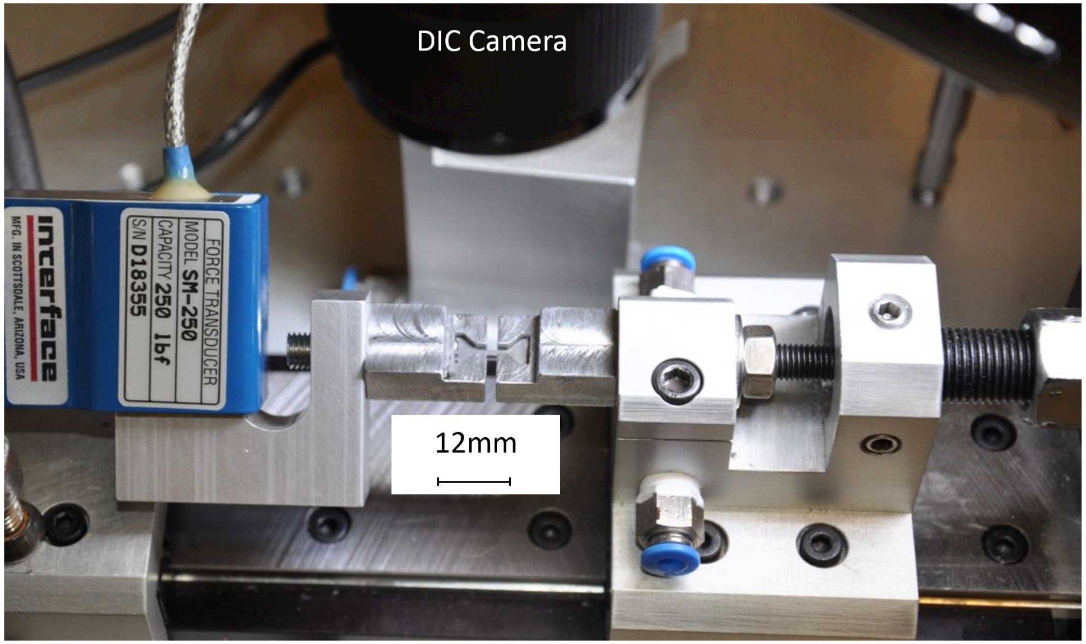
Tension Data Test Method

- Tension data tested using high-throughput techniques with DIC on top surface

a)

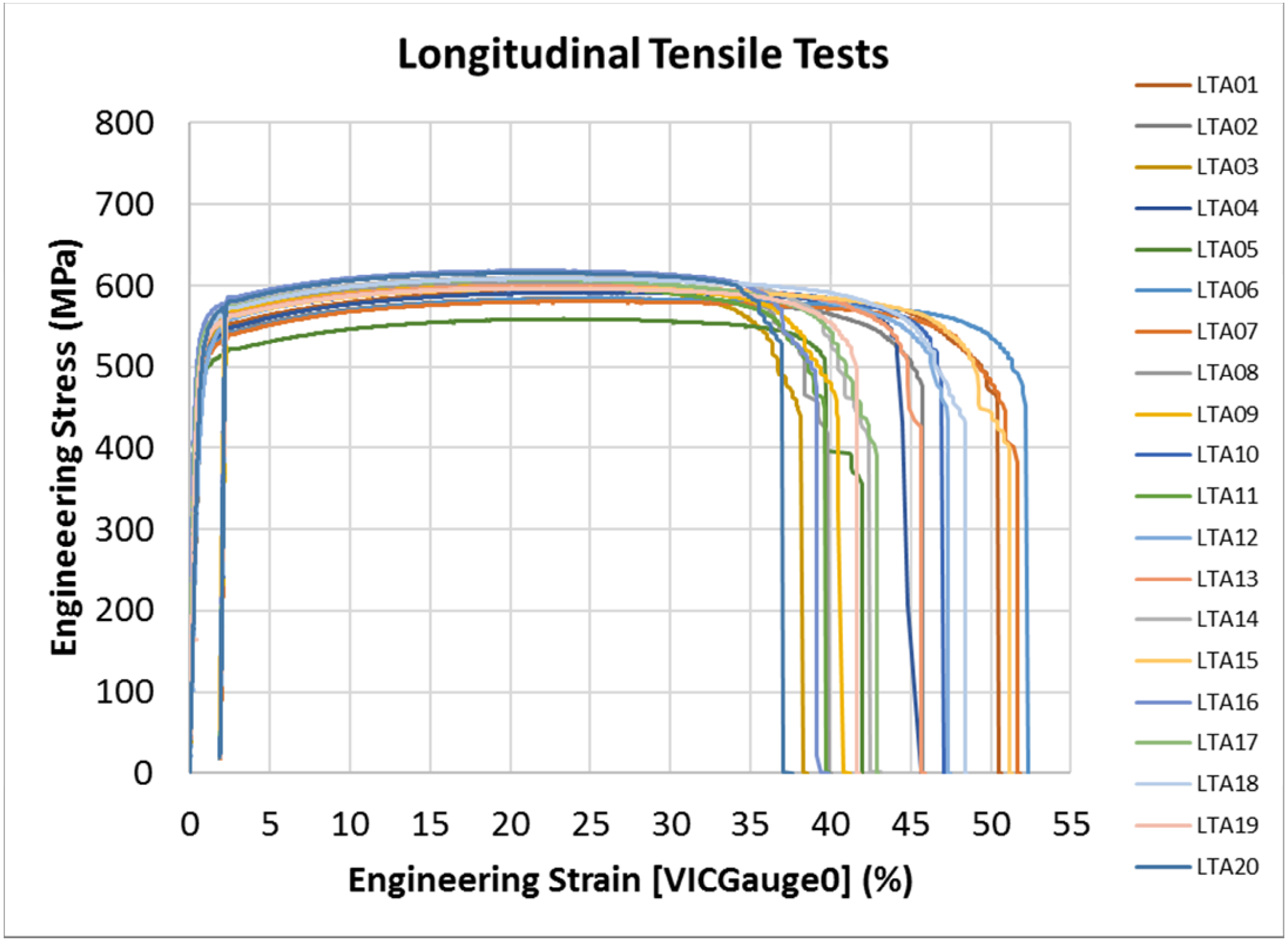


b)



a) Model of Additive Manufactured Tensile Specimen in grips (cut-away).
b) Mechanical Test Set-up. [Salzbrenner, *et.al,* JMPT 2017]

Base Material Tension Data



BCJ Material Model

- Temperature and history-dependent viscoplastic internal state variable model
- Stress is dependent on damage ϕ and evolves according to

$$\dot{\sigma} = \left(\frac{\dot{E}}{E} - \frac{\dot{\phi}}{1-\phi}\right)\sigma + E(1-\phi)(\dot{\epsilon} - \dot{\epsilon_p})$$

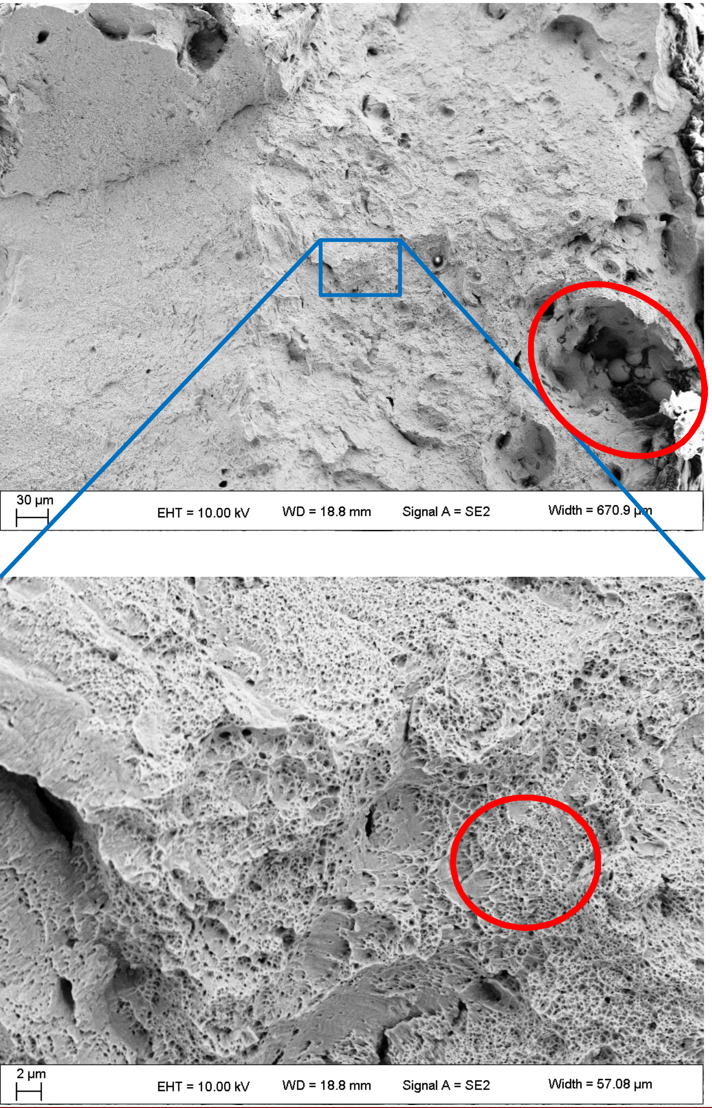
- Flow rule includes yield stress and internal state variables for hardening and damage

$$\dot{\epsilon}_p = f\, sinh^n\left(\frac{\frac{\sigma_e}{1-\phi} - \kappa}{Y} - 1\right)$$

- The isotropic hardening variable κ evolves in a hardening minus recovery form.

$$\dot{\kappa} = \kappa\frac{\dot{\mu}}{\mu} + (H(\theta) - R_d(\theta)\kappa)\dot{\epsilon}_p$$

Incorporating porosity as initial damage



Void Growth

Pre-existing voids captured by void growth

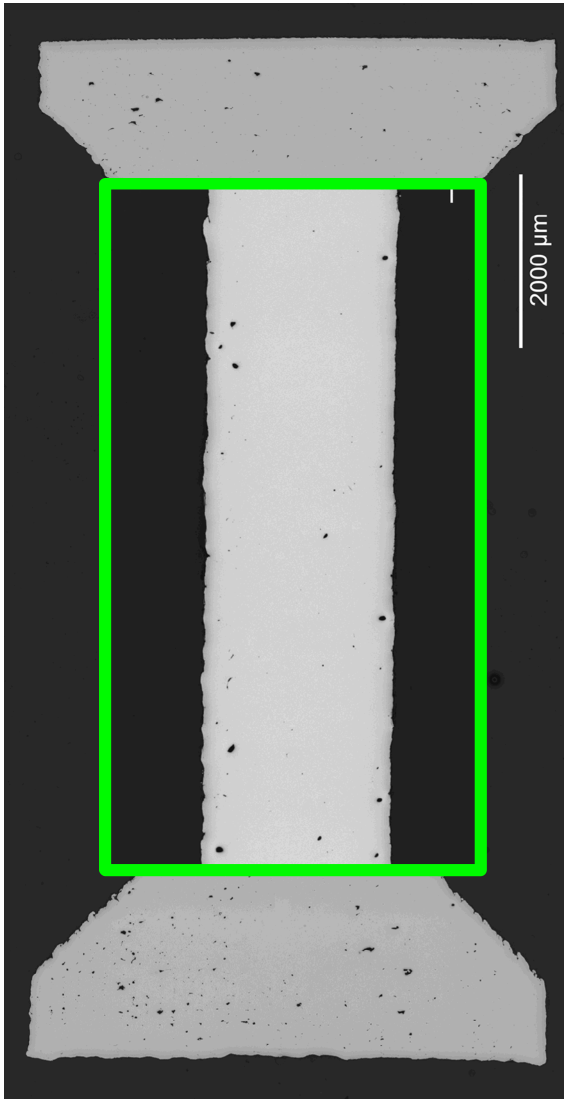
$$\dot{\phi} = \sqrt{\frac{2}{3}}\dot{\epsilon}_p \frac{1-(1-\phi)^{m+1}}{(1-\phi)^m} \sinh\left[\frac{2\,(2m-1)}{2m+1}\frac{\langle p\rangle}{\sigma_e}\right]$$

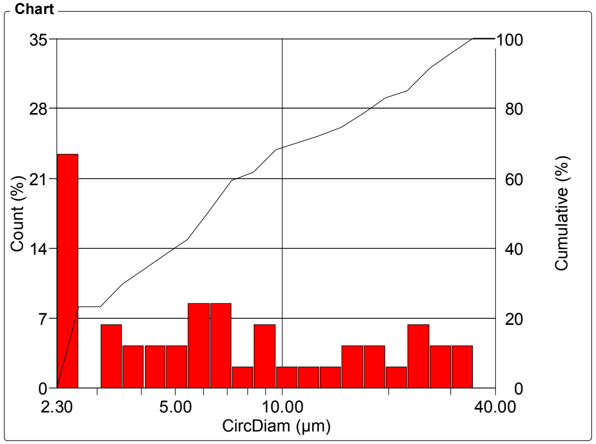
Void Nucleation

Fine scale voids (< 1μm) indicate nucleation

$$\dot{\eta} = \eta\dot{\epsilon}_p \left(N_1\left[\frac{4}{27}-\frac{J_3^2}{J_2^3}\right] + N_2\frac{J_3}{J_2^3} + N_3\frac{\langle p\rangle}{\sigma_e}\right)$$

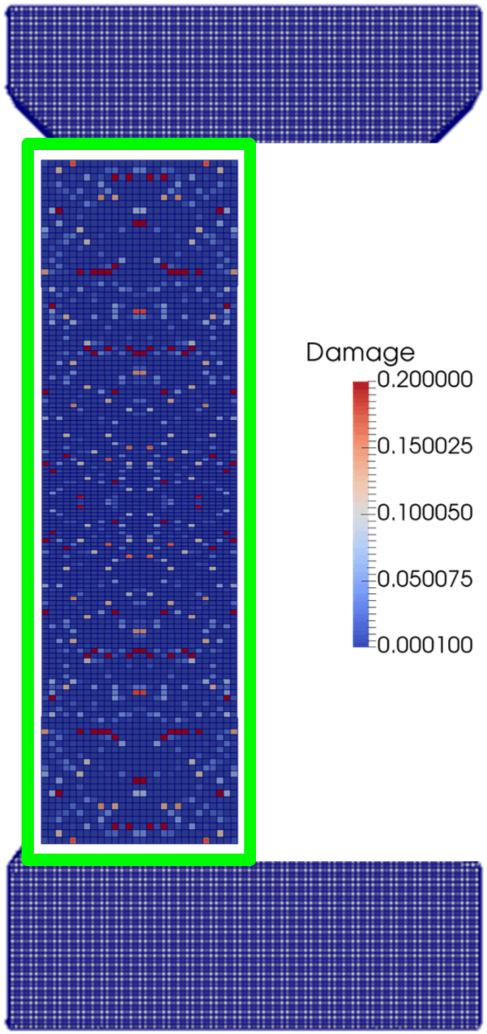
Porosity Distribution is Directly Mapped to Mesh



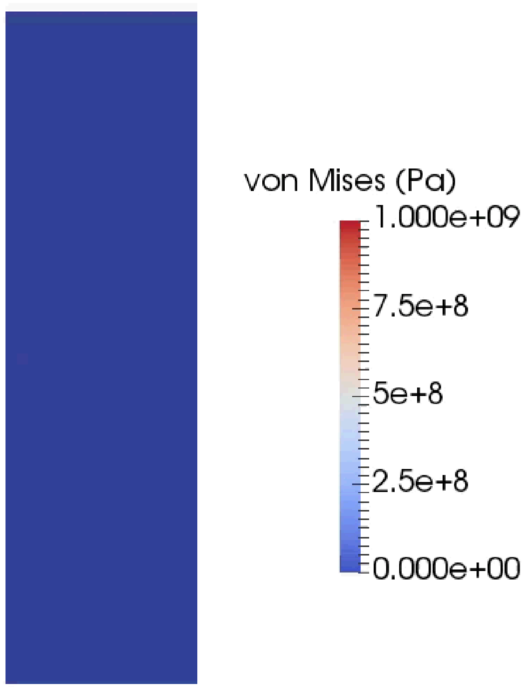


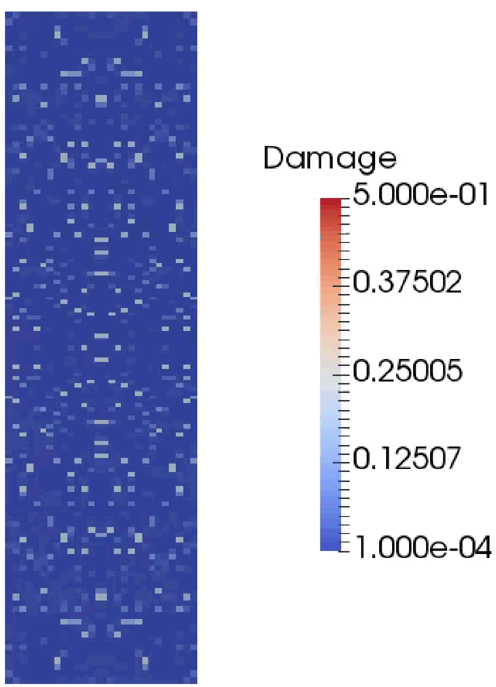
Porosity Mapping

x,y,z,r_{pore}

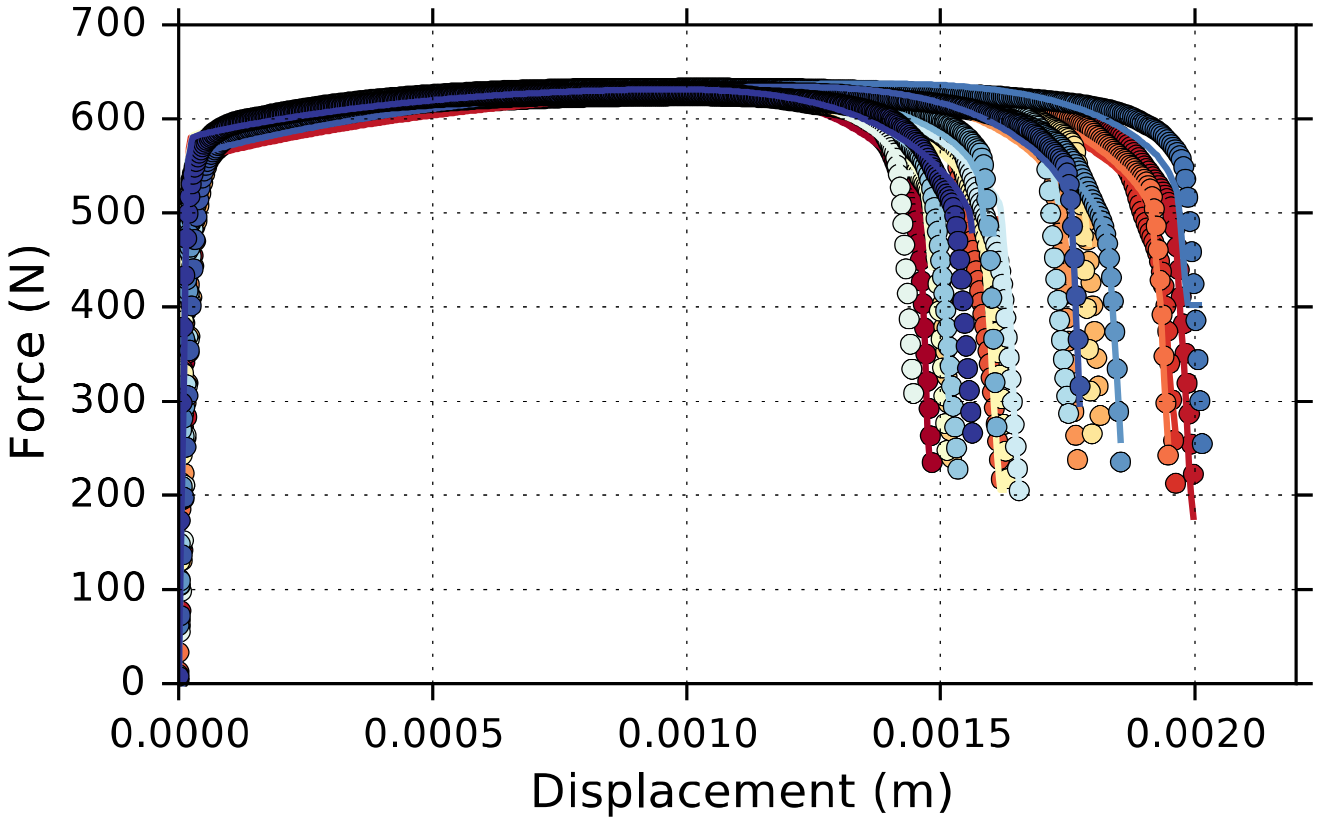


Tensile Calibration Results



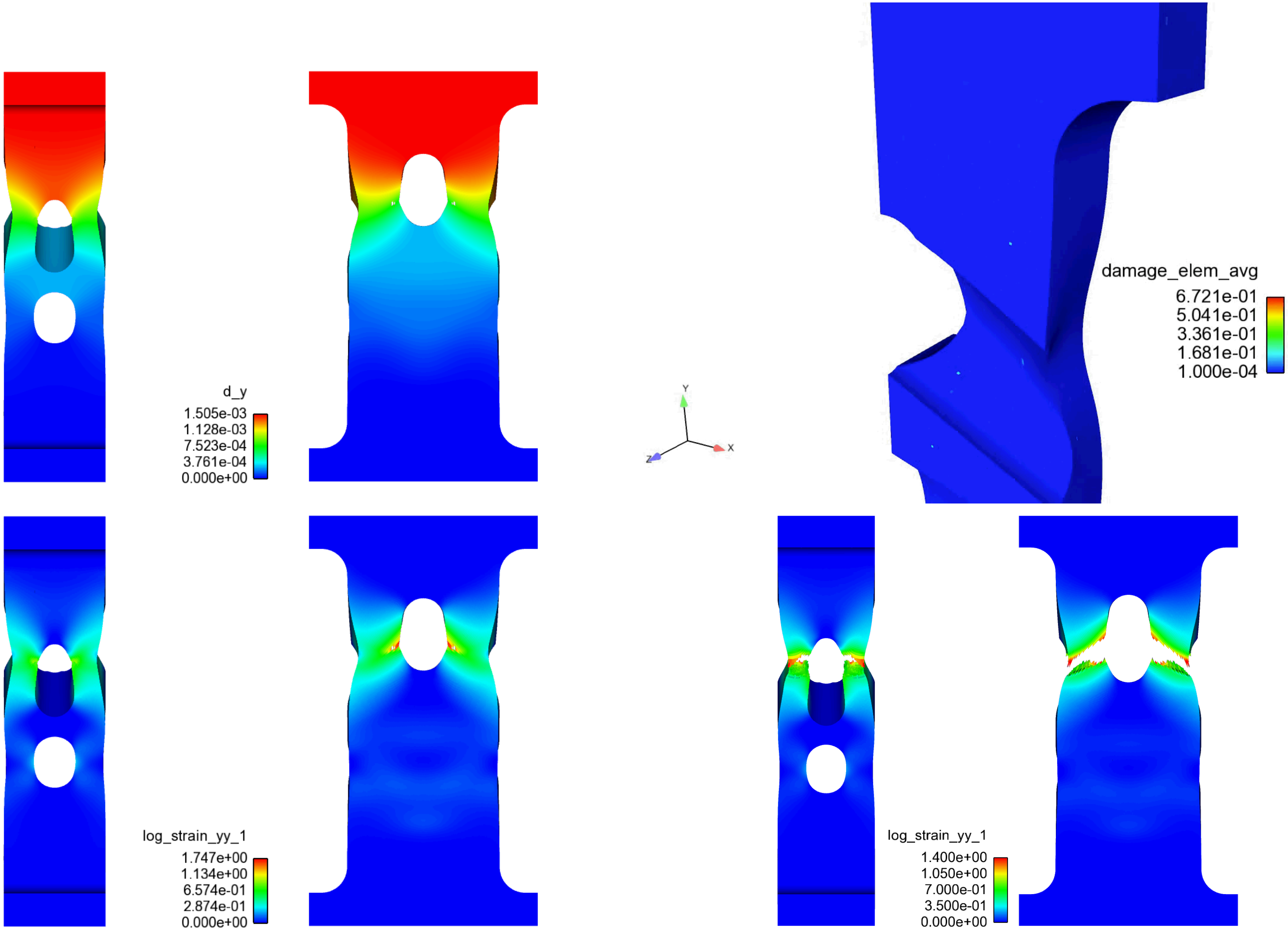


Calibration Results With Void Growth and Nucleation



- Each test has unique parameter set

Challenge Geometry Was Simulated With Each Parameter Set for Many Porosity Realizations



Challenge Geometry Force-Displacement Distributions