**Objectives:**
- Develop stochastic multiscale model for CFRPs and CNT/CFRP structures which utilize nanoscale information
- Investigate nonlinear, multifunctional, and causal effects of damage initiation and propagation in advanced composites
- Utilize low fidelity damage models for macroscale integration and analysis of composite structures

**Motivation**
- Advanced composite structures present many mechanical/multifunctional benefits
- Nanocomposites with CNTs: stiff and strong, ideal filler material
- Lack of accurate predictive models for material engineering or structural analysis
- Experimental trial and error is too expensive and time consuming
- Large divide between theory and experiments

**Information Transfer**
- Microstructure level modeling
  - Atomistic infromed damage model & vary by crosslinking degree
- Macroscale level modeling
  - Integrating microstructure data into macroscale model

**Polymer Damage Model Validation**
- Various validation strategies used:
  - Benchmarcking with established models
  - Experimental approaches
  - Comparing local stress fields

**Microstructure Investigations**
- Microstructures with 0.1% wt CNT generated
  - Tested in transverse direction
  - Elastic and damage response was studied
- Unoptimized designs
- Can be used more effectively with comprehensive models to predict damage and failure

**Stress Field in Vicinity of Nanofillers**
- Two softening phases observed in MD
- Two softening phases observed in local FE

**Response Distribution**
- Two sources of variability:
  - Volume fraction
  - Matrix properties
- 1000 simulations, randomly sampled
- Processing time: 30-45 minutes
- Transverse loading – tight response, failure strain change
- Shear loading – large spread; higher non-linearity for stiffer response
- Average response discouraged for design

**Integration to the Macroscale**
- Macroscale model integration for structural analysis
- Structural composite bonded joints as case study
- Limited use due to lack of appropriate analysis methods and damage initiation, progression and failure criteria
- Introduction of bolts leading to overdesign
- Can be used more effectively with comprehensive models to predict damage and failure

**Methodology**
- Structural Analysis -> FE
- FE integration point -> Microstructure representation
- Microstructure Analysis -> MoC Micromechanics
- Matrix -> Low fidelity damage models
- Matrix analysis -> atomistically informed damage model

**Bridging Elastic Information**
- Two-parameter response surface created from MD data
- Polymer CNT/Matrix: Damage evolution law based on the microstructure

**Distribution of Properties**
- Obtained a PDF of elastic constants
  - Comparisons with experiment:
    - 8.2% error in mean of E1
    - 3.1% error in standard deviation of E1
    - 3.3% error in mean of E2
    - 10.6% error in standard deviation of E2

**Low-fidelity Damage Model for Matrix**
- Represent matrix response using Schapery potential theory
- Straight forward for isotropic damage since single ISV required
- Orthotropic response requires modified definition of the ISVs
- One ISV for strain in each direction
- ISV as a function of binary parameters activated on existence of strain
- Elastic constants are a function of ISVs

**ADAPTIVE INTELLIGENT MATERIALS & SYSTEMS CENTER**