Composite materials are widely used in aerospace industry for their high strength, low weight, and tailorable properties. Structural Health Monitoring (SHM) of aerospace structures is extremely critical for detection, classification and prediction of damage in composite structures. Physics-based micromechanical modeling of composite materials needs to be developed for on-time damage detection and classification in aerospace composite structures.

This thesis adds to the functionality of the composite micromechanics code, MAC/GMC, for further application within the realm of SHM. First, a baseline of MAC/GMC is performed to determine the governing failure theories that best capture the damage progression. The deficiencies associated with various layups and loading conditions within the code are addressed. Also the effects of adding variability to common fiber packing structures of the representative unit cell of composite materials was studied. Variations in fiber packing influence the macro-scale effective material properties and failure stresses. The micromechanic damage model was used to simulate a composite beam and a composite airfoil for impact load. Active wave propagation was used to investigate the damaged areas within the composite beam structure. Lastly, a coupled damage and attenuation model was developed to study different damage states such as fiber-matrix debonding.