Models that can reliably predict mechanical properties such as stiffness, yield strength, fracture toughness and fatigue life are essential for critical-to-function parts in a wide range of applications. While standardized test methods and models are well established for homogeneous bulk materials, these approaches are often not valid for several real-world applications due to interwoven complexities of geometry, scale, process dependence and time evolution. Over the past 15 years, my research has focused on developing physics-based models that rely on a combination of analytical, experimental and numerical approaches to make sufficiently accurate predictions in the presence of such complexity, while minimizing computational and experimental expense. This latter fact is vital to increasing the likelihood of adoption of these models by practitioners in industry. In this talk, I shall demonstrate how I developed and validated these models for two different applications: the prediction of fatigue life of solder interconnects in microelectronics devices, and in ongoing work, for predicting the mechanical response of cellular structures made with AM. I shall close my talk by reviewing some of the current efforts in our state in the growing field of Additive Manufacturing, and discuss the opportunities that I believe lie ahead in the related areas of research collaboration, workforce development and community engagement.