Abstract:
The prediction of the spontaneous formation of a crack and its propagation in load-carrying structures such as the wing of an airplane presents a long-standing problem in computational solid mechanics. In a complex loading situation such as a bird strike, multiple interacting cracks are typically initiated simultaneously. The path along which each crack grows is not known in advance and must be determined as part of the solution. What makes problems even more complex is the fact that the crack path also depends on the material used.

Recently anisotropic composite materials are replacing the more traditional isotropic materials in part because of their higher specific strength which promises significant weight savings. Because of their inhomogeneous microstructure consisting of stiff fibers embedded in a relatively soft matrix these materials can exhibit many different failure mechanisms, such as microbuckling of individual fibers or delamination of adjacent plies. It is critical to capture the dominating failure modes in a computer simulation in order to predict the correct crack path.

The effectiveness of computational techniques in traditional FE codes in predicting inelastic material failure has lagged behind their capabilities in elastic stress analysis. The available special techniques for predicting crack growth generally do not have a satisfactory level of fidelity because they usually require the path of the crack growth to be known in advance and tend to be highly mesh-dependent. This difficulty arises because the mathematical framework on which all such methods are based assumes that the body remains continuous as it deforms. Hence, these methods must treat discontinuities such as cracks as a pathological situation requiring special techniques.

As an attempt at improving this situation, a reformulation of continuum mechanics known as Peridynamics has been proposed by Dr. S.A. Silling, Distinguished Member of the Technical Staff at Sandia National Laboratories. The resulting new approach, known as Peridynamics, does not suffer from the inapplicability of the classical equations when a crack is present and offers a unique computational capability for modeling fracture.

An explicit, meshless code based on Peridynamics has been co-developed at Sandia and The Boeing Company over the last several years. The prediction of failure in composite materials enables Boeing to more efficiently perform design iterations and reduce the number of costly tests.

In the first part of my talk I will discuss the various aspects of Peridynamics I have been working on over the last 6 years, first as a Postdoctoral Fellow at MIT and later as a Research Engineer in the Boeing Math Group, as well as outline my future research interests.

In the second part of my talk I will discuss my more recent involvement in optimization of composite structures. I have had the great opportunity to collaborate with Dr. Evin Cramer, Technical Fellow at The Boeing Company, on this extremely interesting, important and challenging area of research requiring a truly multidisciplinary approach.

Bio:
Dr. Olaf Weckner received his MS and PhD from the Technical University of Berlin, both with the highest distinction *summa cum laude*. For his graduate work in Engineering Science he received the prestigious Erwin-Stephan award given only to the top 1 % of all students in 2001. For his doctoral thesis he was awarded a $40,000 postdoctoral scholarship from the German Academic Exchange Service *DAAD* to continue his research at the Massachusetts Institute of Technology. He then joined the The Boeing Company as a Research Engineer in 2004 where he has since been working on simulating damage propagation in composite structures in order to predict damage tolerance. Applications include ground and in-flight impact as well as large notch tension / compression tests. More recently Dr. Weckner started working on multidisciplinary optimization of composite structures.