2.5 Deterministic Versus Probabilistic Approaches

The ASIP design guidance of MIL-HDBK-1530 and JSSG-2006 is based on deterministic analyses. The growth of the largest, single flaw that might be in the most critical location of a structural element is predicted using a sequence of stresses from expected operational use of the aircraft. Maintenance actions for the element are conservatively scheduled from damage tolerance analyses of the predicted time for the flaw to grow to a critical size. This design philosophy has worked well. However, cracking scenarios can arise in an aging fleet that are not amenable to analyses based on the growth of a monolithic crack. For example, widespread fatigue damage can produce complex cracking scenarios in which the structural conditions of the elements in a load path are unknown and conservative assumptions would lead to unacceptable inspection intervals. In these scenarios, structural risk analyses are being used to assess the structural integrity of the load path.

In a probabilistic risk analysis, structural integrity is characterized in terms of the single flight probability of failure of the load path. This probabilistic evaluation of strength versus stress is dynamic since strength degrades as fatigue cracks in the load path grow and the condition of the structure might change during maintenance actions. In a risk analysis, the condition of the structure is modeled in terms of distributions of damage at the critical locations and fracture mechanics tools are used to predict the growth of the damage distributions as a function of flight hours. Probability of failure as a function of flight hours is calculated from the distribution of strength at time T and the expected distribution of stress that will be experienced at time T. Maintenance actions would be scheduled at intervals that provide an acceptably small failure probability. Lincoln [2000] has suggested that $10^{-7}$ is an acceptable upper bound on single flight failure probability for Air Force applications.

There are a number of approaches to defining and modeling the stochastic contributors to a probabilistic evaluation of a structure and for calculating the probability of failure. The simplest of models involves only the distributions of strength and stress. For two or three stochastic contributors in the model, the failure probability can be made using direct double or triple integration. If there are more than three random components, fracture probability must be calculated using a Monte Carlo simulation or a failure function (FORM/SORM) approach, [Madsen, 1987]. Examples of the use of risk analysis in airframe structures can be found in Lincoln [1997], Cochran, et al., [1991], and Berens, et al. [1998]. Examples of the use of probabilistic analyses in engine structures can be found in Yang and Chen [1985], Harris [1987], and Roth, [1992].