# Nonlinear Fatigue Monitoring

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## INTRODUCTION

The prediction of the future failure of structures subject to fatigue is very difficult. This is primarily due to the fact that the vast majority of structures' fatigue lifetimes (90-95%) are spent in nucleation of very tiny flaws into measurable crack sizes. Due to the large variation in nucleating flaw sizes and the mathematics of flaw growth, the fatigue lifetimes, even of high quality structures, can vary by a factor of as much as 10 to 20 in a small fleet. This large variation in fatigue lifetimes leads to conservative statistics, which often prompts the premature retirement or overhaul of vehicles or other structures, since they focus on the weakest members of the fleet, while the remainder of the fleet is sound.

In the case of military and civilian aircraft, structural components are primarily considered primarily in two groups, viz. those where undergoing NDE/NDI with service life management by current fracture mechanics techniques is feasible, within the limitations of current technical complexities and future service condition predictions, and those where it is not feasible or economical to undergo NDE/NDI, and must be managed by conservative statistical techniques. This results in the grounding of many aircraft at lifetimes that are far short of their inherent lifetime, thus limiting the possibility of fatigue failure in the weakest airframe in the fleet.

Currently, several models of civilian and military aircraft are reaching the limits of their intended calendar service life. Civilian aircraft, with their greater duty cycle of use, tend to approach their design fatigue use limits, while military transport aircraft, with their lower duty cycle of use, tend to face retirement due to aging phenomena such as corrosion, multiple site damage, and widespread fatigue damage, leading to uncertainty in their remaining safe service life. Consequently, owners of these aircraft are facing the economic penalties of shutting down many healthy aircraft, or of assuming the increasing risk of continued operation under current practices. The legal liabilities of continued uncertain operation tend to force the owners to accept the economic penalties of premature retirement or to look for additional alternatives. Until now, no reliable method for real time condition assessment has been devised on which to base continued use of structures subject to fatigue.

Oak Ridge National Laboratory (ORNL) has developed techniques for directly sensing conditions that indicate impending fatigue failure. These techniques have been proven to be reliable on other physical and biological systems, and have been demonstrated in laboratory scale experiments to be able to sense precursors of fatigue failure in fiberglass, aluminum, and steel under pristine conditions and of simulated corrosion and multiple site damage of from 1 to 20% of fatigue life in advance of actual failure under load.