NASGRO®—Fracture Mechanics and Fatigue Crack Growth Analysis Software

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Structural failure due to the consequences of naturally occurring and service-induced flaws, damage, or cracks in a part or structure, is the primary threat to the integrity, safety, and performance of nearly all highly stressed mechanical structures. Consequences of such failures include serious injury or loss of life, severe environmental damage, and substantial economic loss. One such example is the Aloha Airlines flight 243 incident in 1988 in which a 5.5-m (18-ft) section of the fuselage separated from the aircraft during flight; the cause was found to be metal fatigue exacerbated by corrosion.

The NASA-developed NASGRO® fracture mechanics analysis computer program is the standard software tool used by NASA and its contractors for fracture analysis of space hardware and safety-critical ground systems. The importance to NASA is the ready availability of an accepted, accurate, reliable, state-of-the-art code with unmatched analytic capabilities.

Under continued active development for over 25 years, NASGRO®'s initial use was for fracture control implementation on space shuttle primary structure and was later extended to other critical spacecraft hardware. However, developments in recent years have made NASGRO® so powerful and versatile that it is now used in the wider aerospace industry as well as in areas as varied as railroad and ship-building. In 2003, NASGRO® was the recipient of NASA's "Software Of The Year" Award and R&D Magazine's "R&D100" Award.

Features that make NASGRO® unique among fracture mechanics analysis tools include:

- a large library of more than 70 crack geometry solutions
- a material property database containing data for hundreds of metallic materials
- a unique crack growth equation (and seven legacy equations) able to model onset of growth, small-crack behavior, crack growth retardation effects, and instability
- capabilities to model elastic-plastic loading, failure of glass or glass-like materials under constant loading, critical crack size

Fig. 1*. Underwriter's Laboratory test equipment at NASA Johnson Space Center for the simulated internal short test.*

Major recent developments include:

- a number of advanced weight function crack geometry solutions able to accommodate complex crack plane stresses that are nonlinear due to local geometric discontinuities such as arbitrary notches and cutouts
- an advanced interpolation scheme allowing crack growth analysis over the entire range of crack growth, even in the asymptotic threshold to instability regions, at varying operating temperatures for both tabular and NASGRO® equation representation of crack growth data
- advanced failure criteria combining the effects of material yielding and crack instability, hitherto modeled as independent mechanisms; the new criteria are important in applications such as power generation
- configuration control allowing engineering managers to lock down which features and options are available to their analysts
- a built-in link allowing two-way communications between NASGRO® and Excel® spreadsheets, or between NASGRO® and other structural analysis tools

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Current development activities include:

- research into fatigue crack growth threshold behavior for several aerospace alloys to determine valid threshold parameter values that are independent of test method and environment; this research marries solid mechanics modeling with material science and has the potential to change the accepted fracture mechanics community's understanding of basic threshold mechanisms from mechanics-based plasticity approaches to include more metallurgy-based microstructural considerations
- research to implement modeling of damage tolerance for composites, such as fiber delaminations, by implementing a virtual crack closure technique in a two-dimensional, anisotropic, layered Boundary Element Analysis method; for verification of composite structures, such a tool could become a useful alternative to resource-intensive structural testing
- incorporation of new Finite Element Analysis-based crack geometry solutions to allow modeling of continuing damage such as interaction and linking of multiple cracks; such solutions are important since real-world damage rarely occurs as simplified independent single cracks