NASGRO®

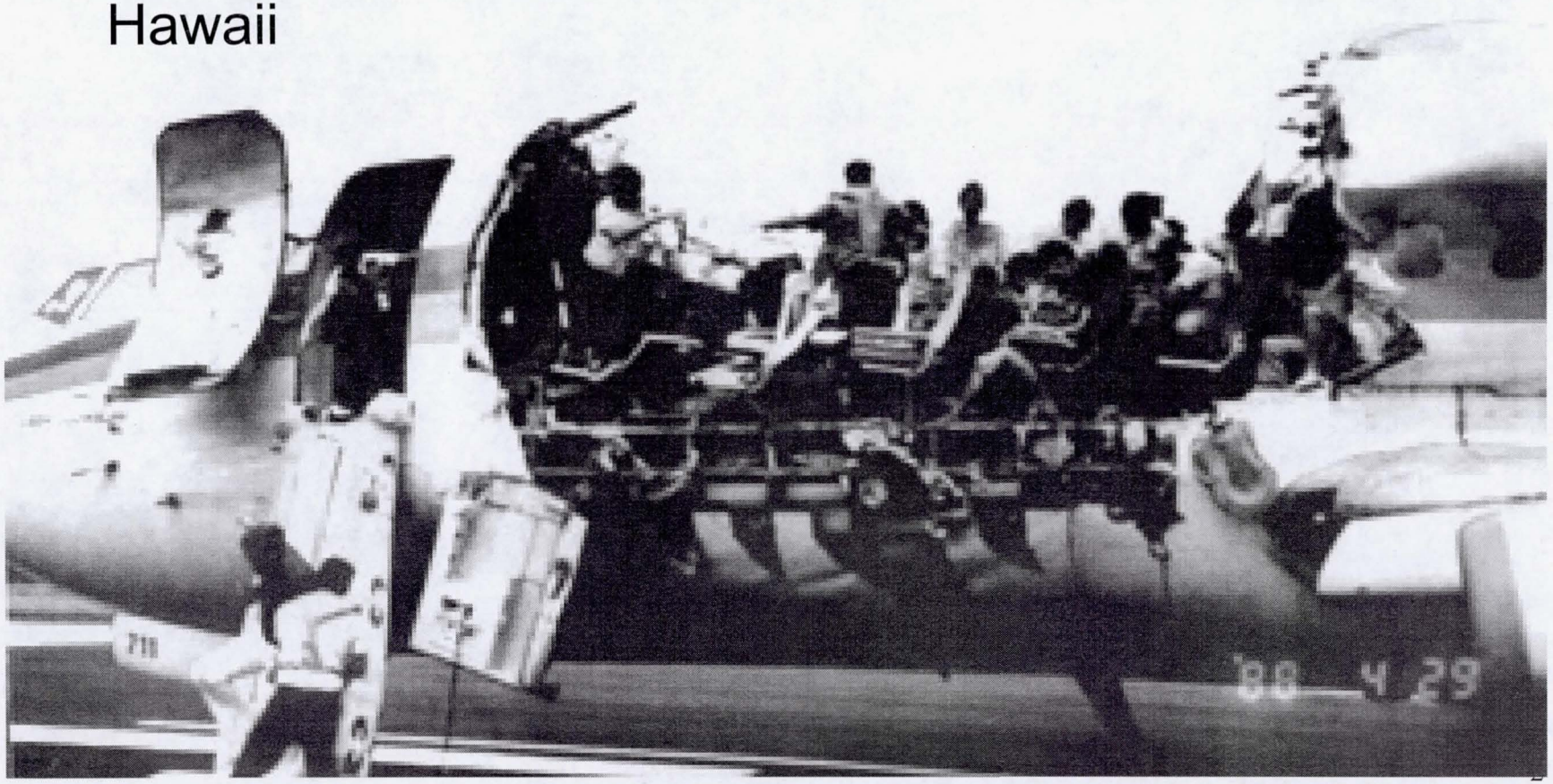
Fracture Mechanics and Fatigue Crack Growth Analysis Software

NASA JSC Team
Royce Forman
Dr. V. Shivakumar
Dr. Sambi Mettu
Joachim Beek
Leonard Williams
Feng Yeh

Southwest Research Institute Team
Dr. Craig McClung
Joe Cardinal

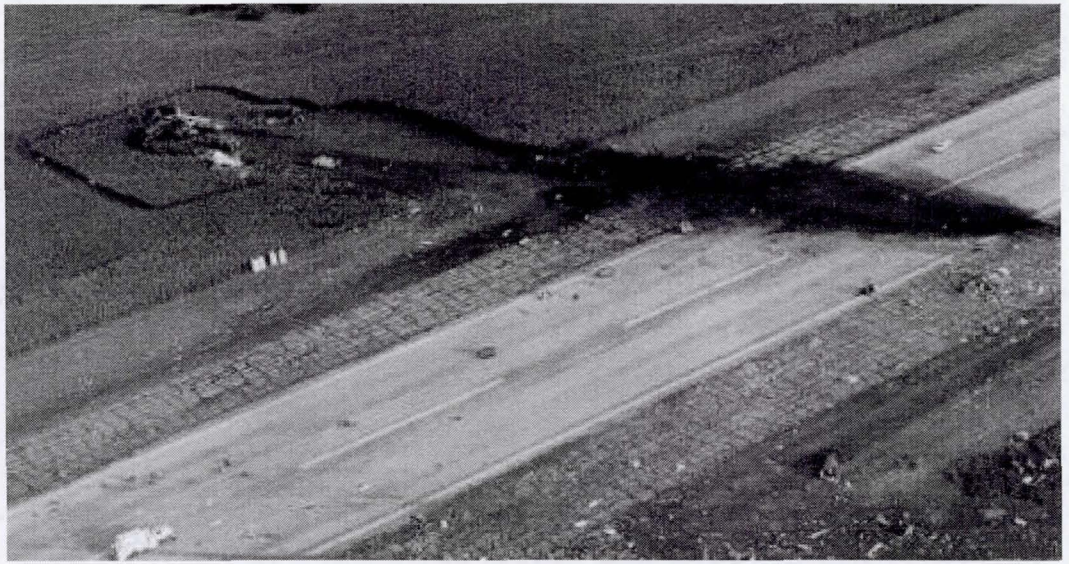
Consequences of Fracture

Aloha Airlines 737
April 1988
Hawaii



Consequences of Fracture

United Airlines DC-10
July 1989
Sioux City, Iowa



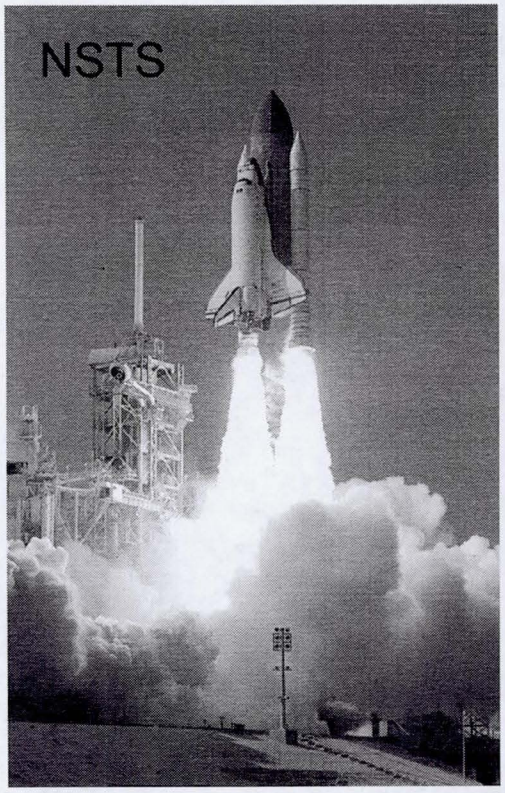
NASA Fracture Control Requirements

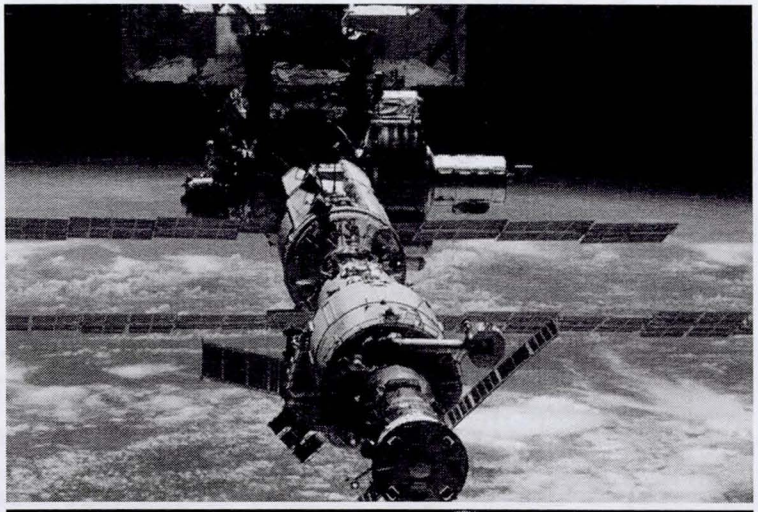
- NASA Technical Standard NASA-STD-5007
  - Establishes requirements for fracture control of all NASA manned spaceflight systems and payloads on manned spaceflight systems
  - Mandatory for manned systems; optional for unmanned systems
  - Fracture control process includes non-destructive evaluation as well as analyses of fracture-critical parts
  - Fracture mechanics & fatigue crack analysis software package *NASGRO* meets the analysis requirements

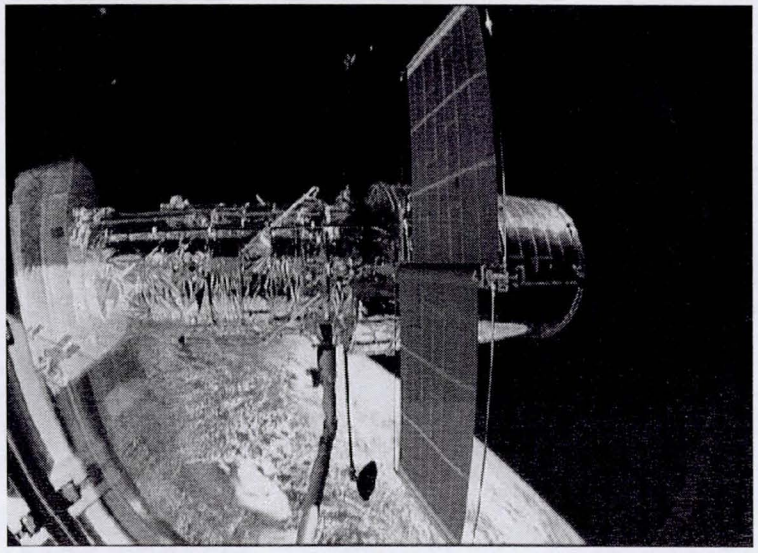
NASGRO® Reduces Risk

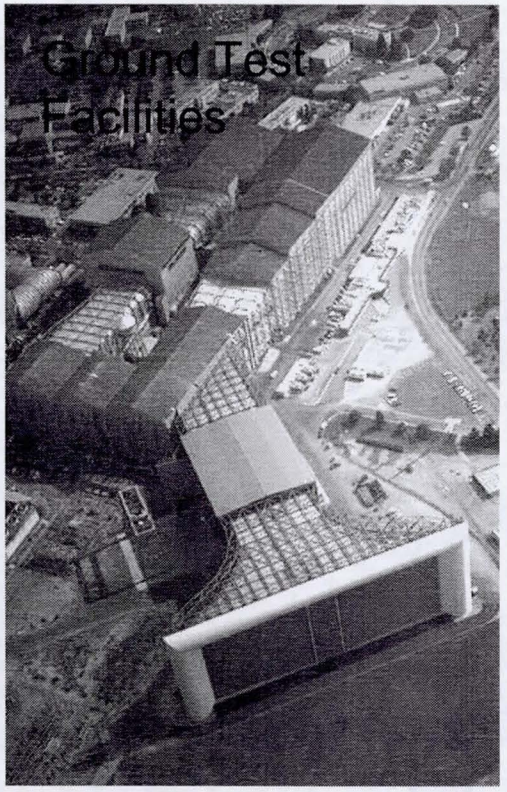
- Fracture mechanics & fatigue crack analysis software
  - Provides optimal design of fracture-resistant structures
    - ⇨ Determines safe stresses for a specified lifetime
  - Provides specification of fracture control plans at the design stage
    - ⇨ Determines safe lifetime for a specified design
    - ⇨ Determines required inspection intervals (if any) to maintain safety
  - If damage is discovered…
    - ⇨ Determines safe remaining life (if any)
    - ⇨ Determines required inspection intervals (if any) to maintain safety
  - Accurately simulates crack growth and failure in real structures
    - ⇨ Calculate fatigue crack growth rate and remaining life
    - ⇨ Calculate conditions (loads, crack sizes) that cause failure

NASGRO® Use Inside NASA



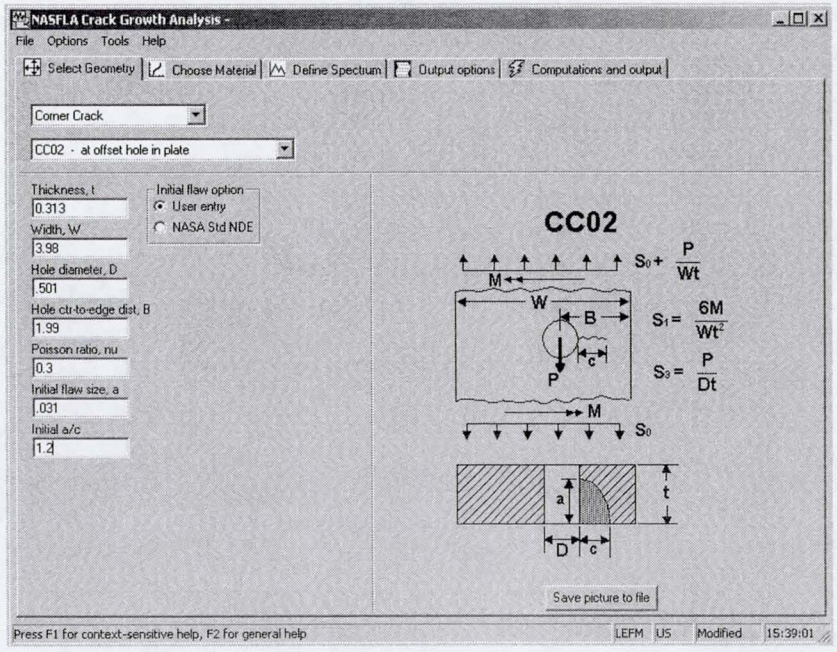


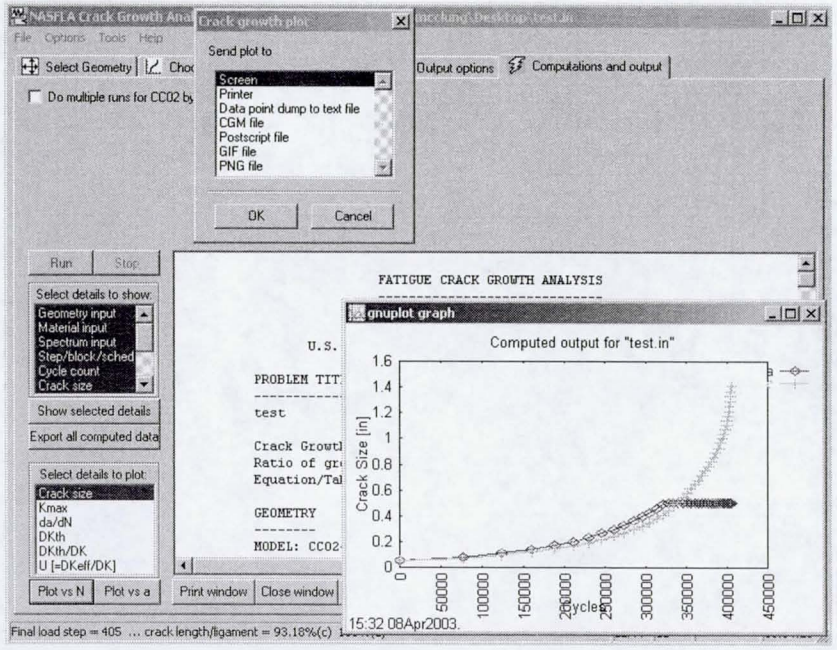




NASGRO® Components:
Crack growth module

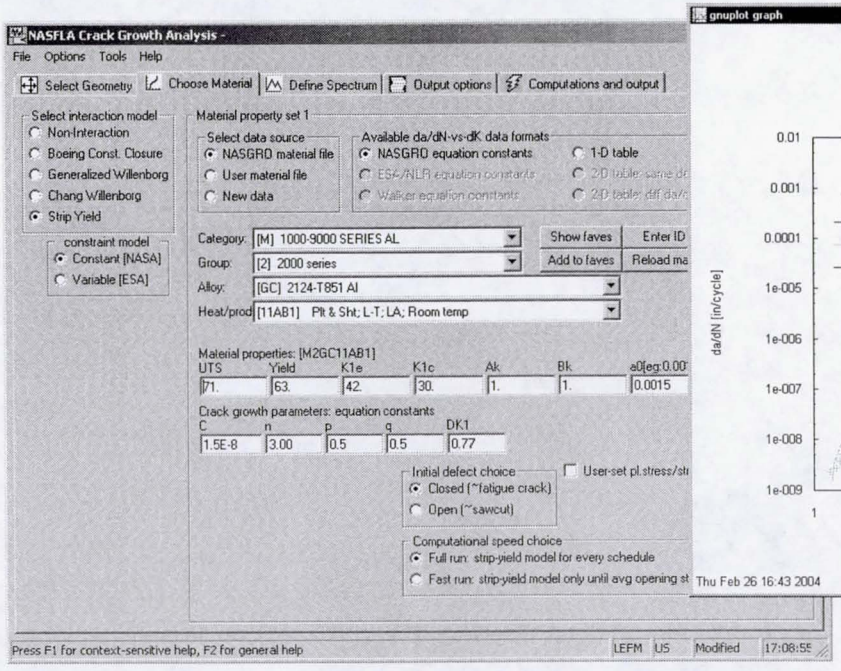
- Calculate fatigue crack growth or component life, critical crack sizes, or stress intensity factors for a library of 50+ different crack configurations
- Multiple crack growth equations
- Elastic-plastic crack growth analysis





NASGRO® Components:
Material property module

- Store, retrieve, and curve-fit fatigue crack growth and fracture data
- NASA database:
  - 476 different metallic materials
  - 3000 sets of fatigue crack growth data
  - 6000 fracture toughness data points
  - Statistically-derived crack growth equations for all materials
- Users can create their own database



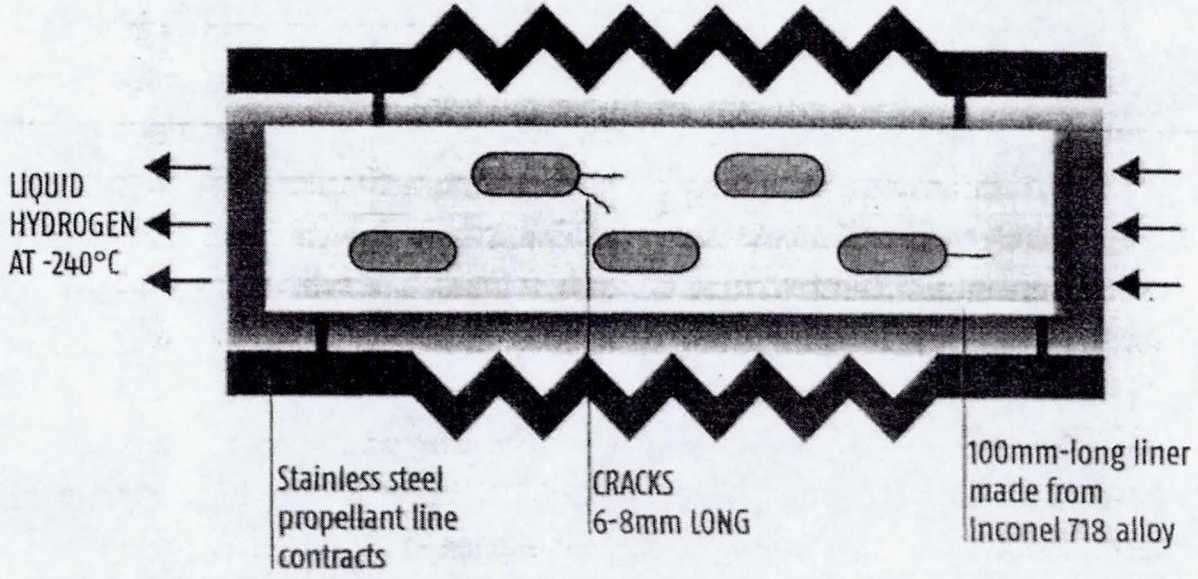
Typical NASGRO® analysis:

Crack growth or component life calculation

- Problem:
  - Actual crack or flaw is reported in component
  - Hypothetical flaw: assume worst-case scenario based on applied loading, component geometry, and crack location
- Analysis input:
  - Crack and component geometry
  - Component material
  - Load type and spectrum
- Analysis results:
  - Fatigue crack growth rate and remaining life
  - Conditions (loads, crack sizes) that cause failure
  - Safe stresses to attain a specified lifetime
  - Component inspection intervals for safe operation

NASGRO Sample Application:
Orbiter feedline flowliner crack analysis

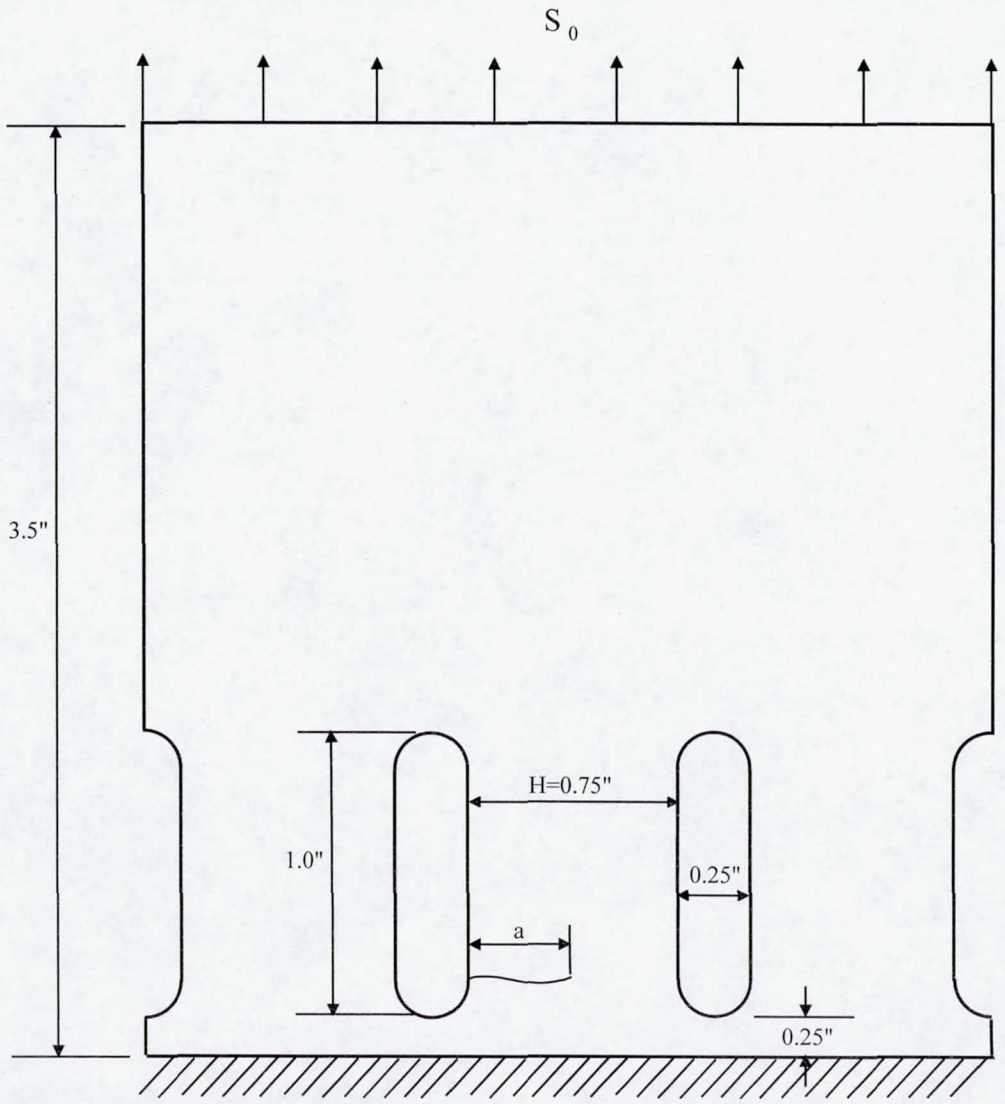
- Objective: To determine the service life of the Shuttle Orbiter flowliners containing cracks by using a fracture-based assessment to account for crack propagation



NASGRO Sample Application:

Orbiter feedline flowliner crack analysis

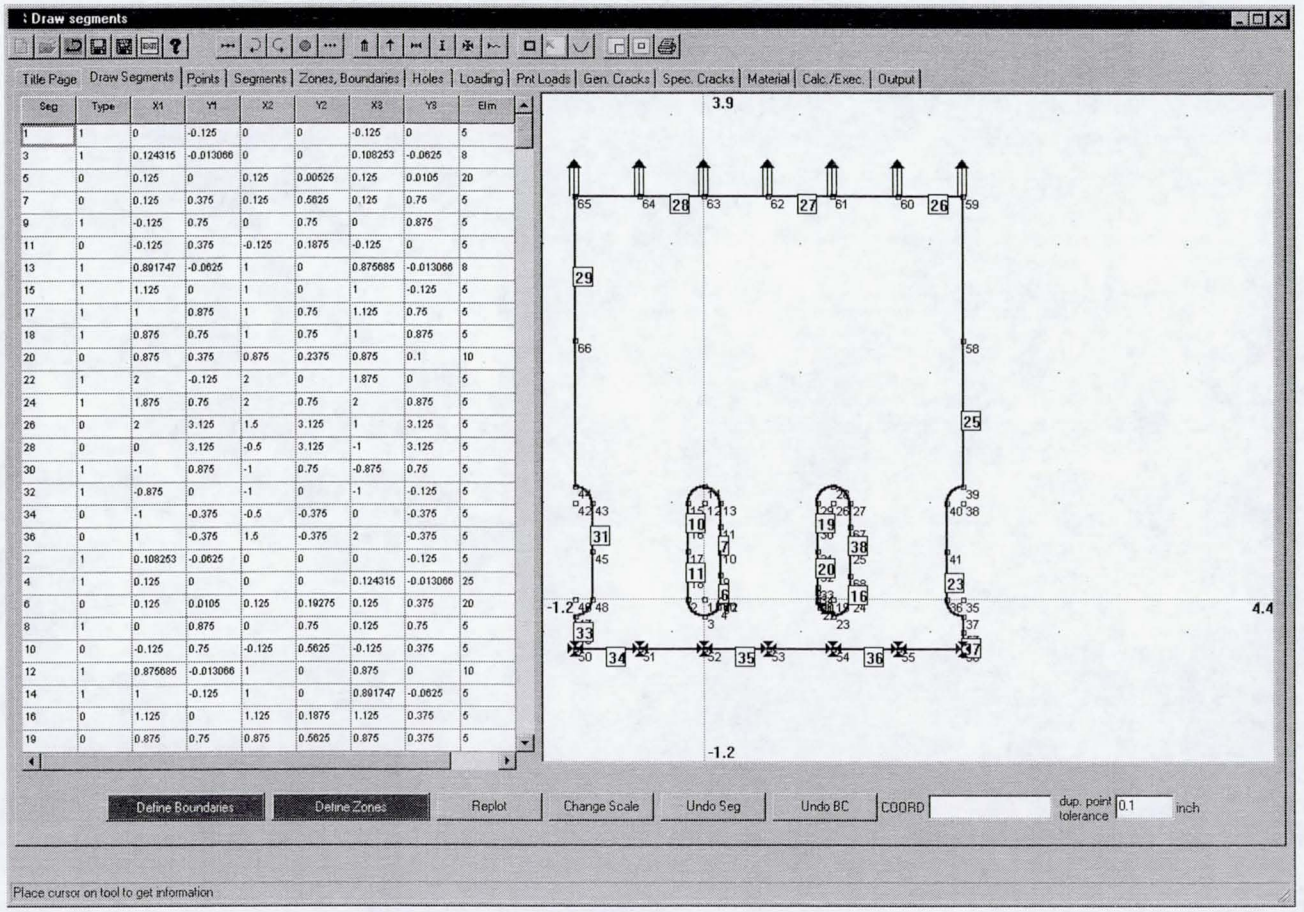
- Problem: Flowliner crack geometry not easily represented by any of 50+ standard cracks in NASGRO crack library



NASGRO Sample Application:

Orbiter feedline flowliner crack analysis

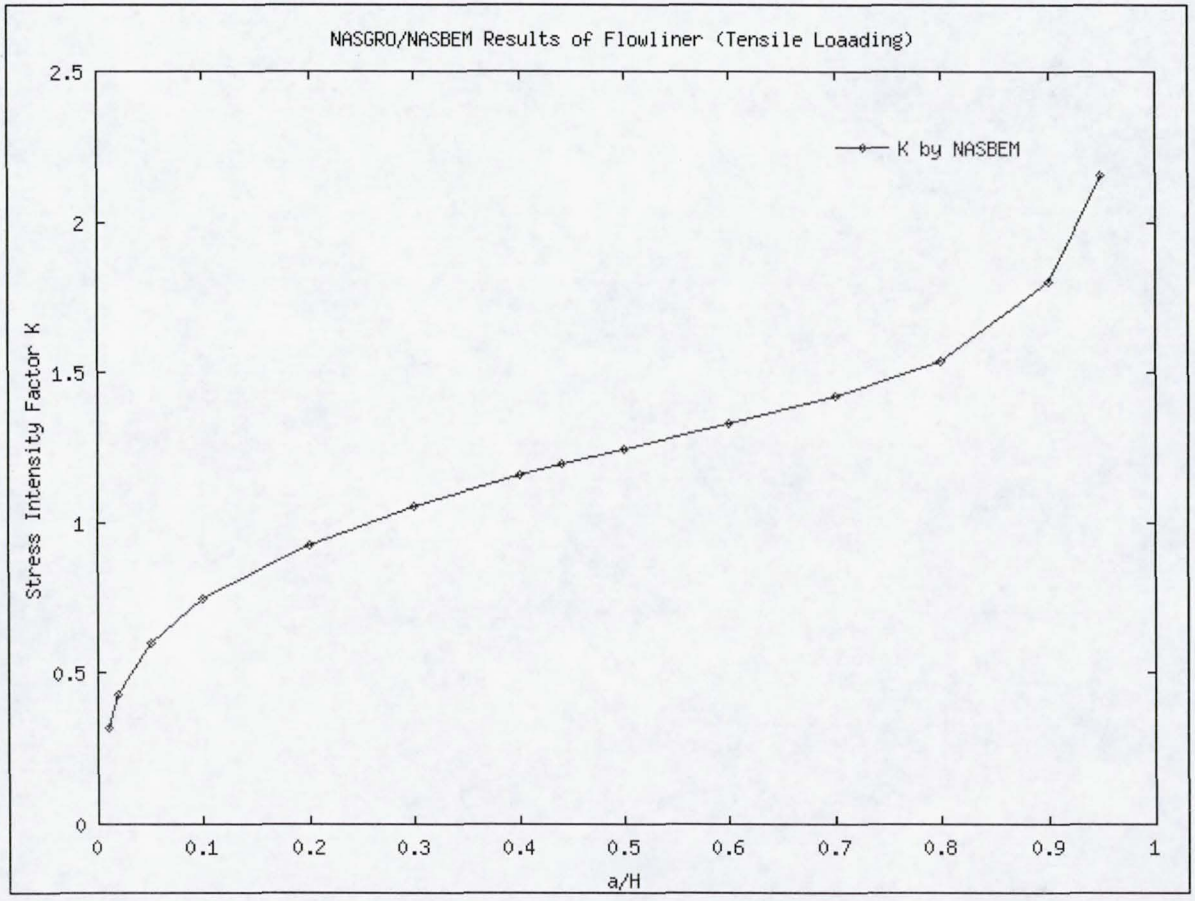
- Solution: Use NASGRO's Boundary Element Analysis module for its
  - CAD-like drawing tools to custom-build crack model
  - Computational core to calculate crack driving force K



NASGRO Sample Application:

Orbiter feedline flowliner crack analysis

- NASBEM results used in concert with other tools (e.g. NASTRAN structural analysis code) to determine:
  - crack growth between flowliner holes as function of flight service history
  - flowliner service life



Summary and Challenges for the Future

- NASGRO® reduces the risk of fracture
- NASGRO is used extensively around the world
  - Standard code for analysis of space hardware for NASA and its international partners
  - Supported and used by DoD, FAA, and private industry in aircraft, rotorcraft, turbine engines, and many others
- Spaceflight systems for future space missions will use innovative materials and methods of construction
  - New materials will require testing and characterisation for their properties for use in fracture analyses
  - New systems, components, configurations, and manufacturing techniques will need to be certified for flight