

# Analysis of Two Structural Failures of F-15 Speed Brakes

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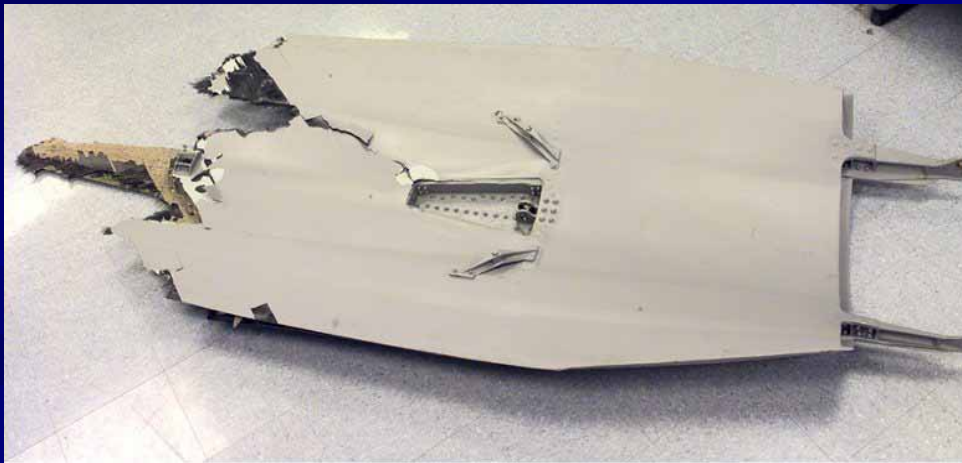
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*San Antonio, TX*

# Background

- **Summer 2005**

Two speed brakes failed during functional check flights following depot maintenance

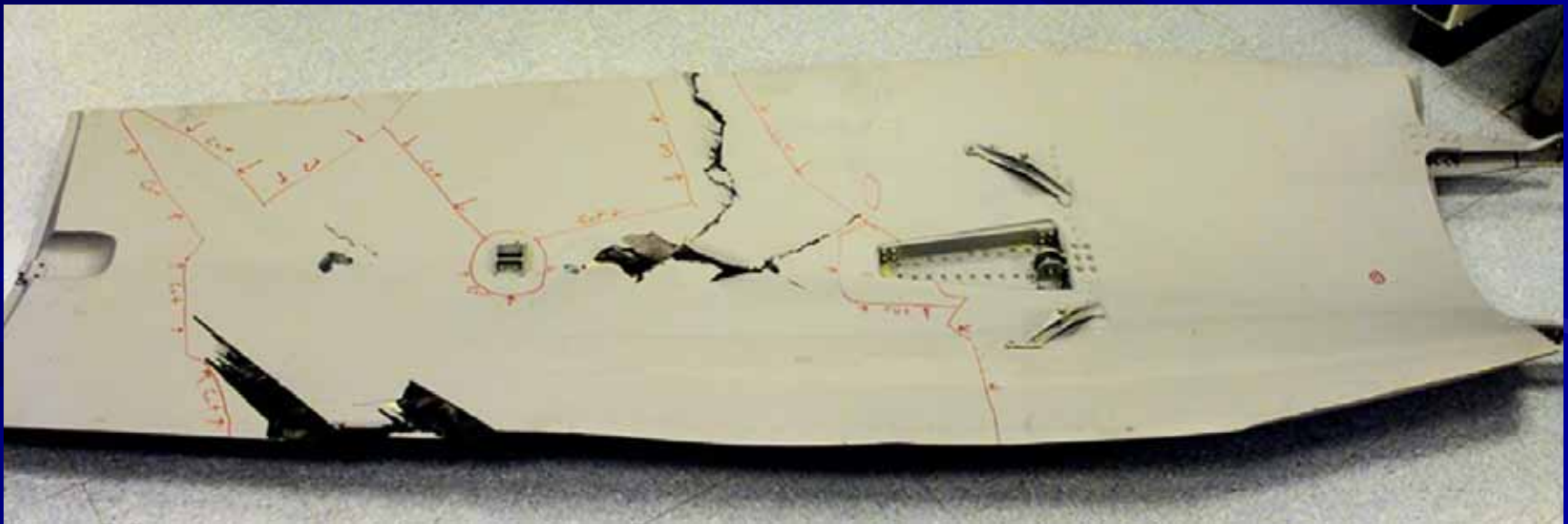


- 1<sup>st</sup> failed speed brake
- Aft portion separated in flight - it was not recovered

Reference: Failure Analysis of an F-15 Graphite-Epoxy Composite Speed Brake, P/N 68A360006 – WRALC/ENF

# 2<sup>nd</sup> Failed Speed Brake

- Second speed brake failed six weeks after 1<sup>st</sup>
- Note lateral and longitudinal crack orientations
- Red ink outlines regions of disbonding
  - Extent of disbonding prior to failure is unknown



# Speed Brake Details

- Approximately 10 ft (length) x 3 ft (width)
- Reduces air speed by increasing aerodynamic drag
  - Can be deployed at any speed, including supersonic
- Graphite epoxy skin with aluminum honeycomb core





# Causes of Failure

- **Failure Modes**

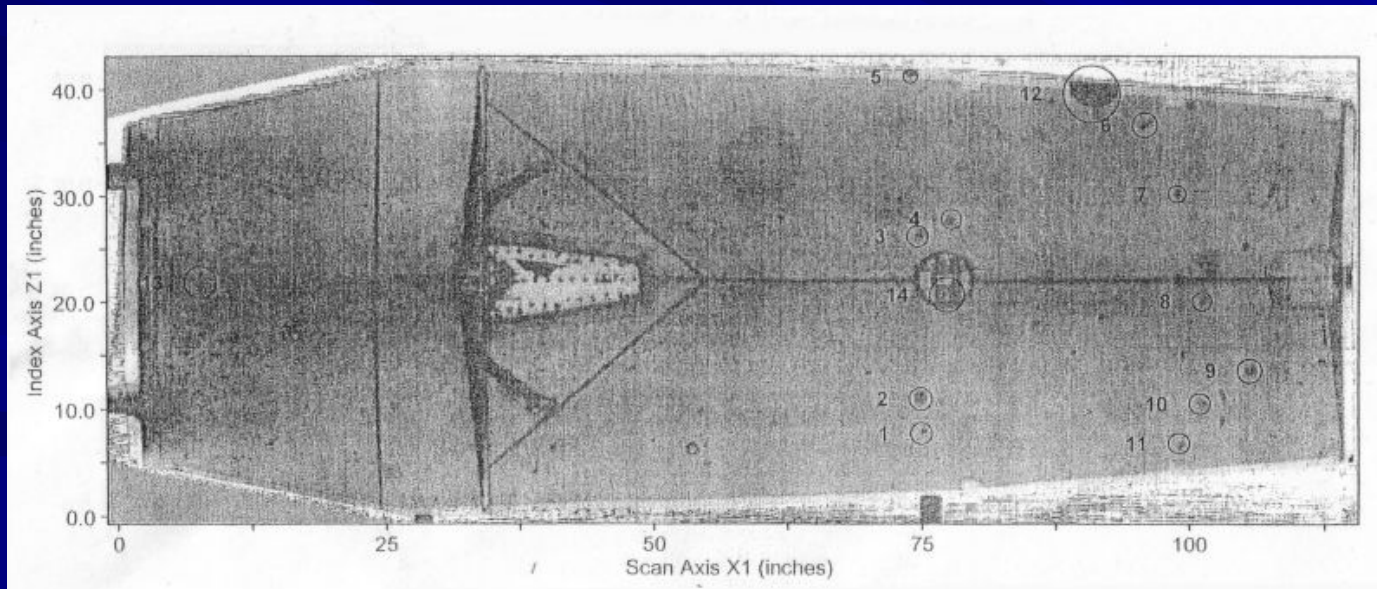
- "...compression by buckling," - WR-ALC/ENF Reports

- **Potential Failure Contributors**

- Disbonds
- Weakened areas from repairs
- Corrosion from moisture entry
- General strength degradation of aging speed brakes



- **Ultrasonic and Radiographic**
  - Can detect voids, disbonds, core damage, etc
  - Cannot detect low bond integrity
  - Cannot assess overall load capacity



# Objectives

- U.S. Air Force tasked MERC to develop a new screening test for the speed brakes
  - Determine appropriate loading conditions
  - Establish testing procedures and pass/fail criteria
  - Build and deliver the system to the Air Force
  - **Implement ASAP due to limited speed brake inventory**

- Test Development Plans

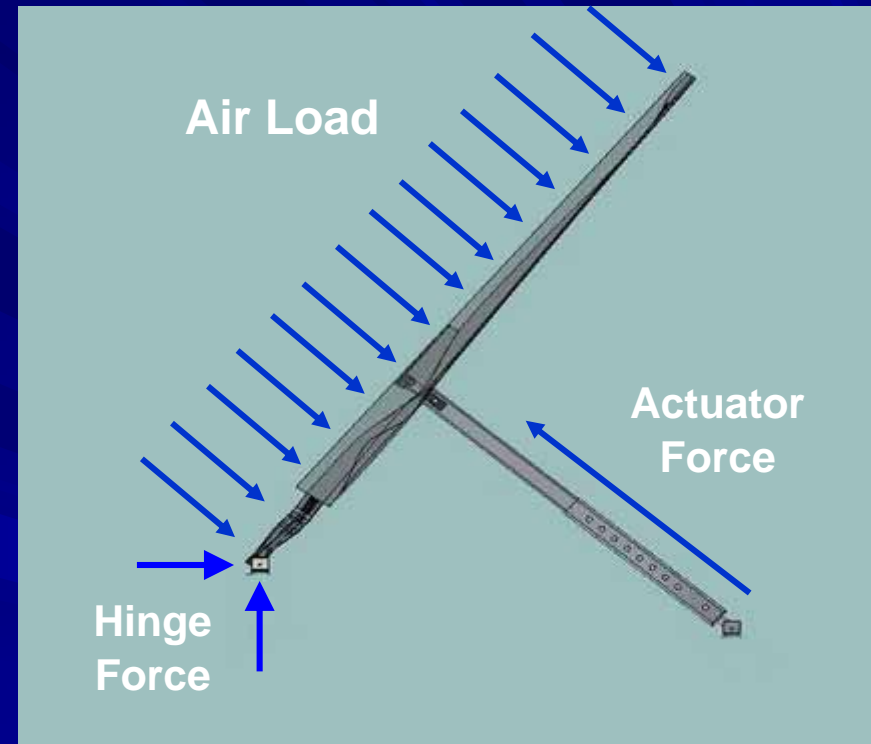
- Strength screening tests
- Study effects of disbonding
- Torsional loading possible
- Experimental tests to validate FEA

- Finite Element Analysis

- Insight into loading and failure mechanisms
- Study effects of disbonds
- Aid in developing screening tests

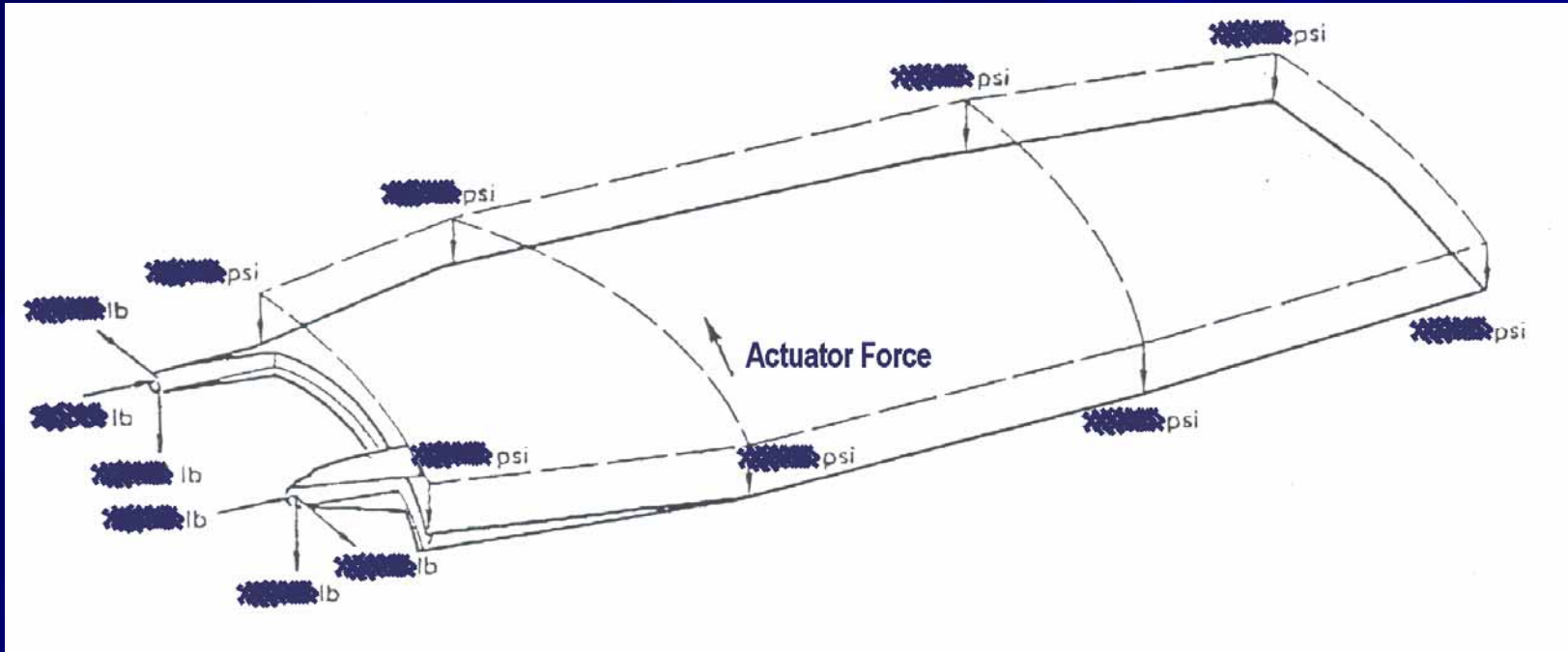
# Loading Conditions

- Loads on speed brake consist of
  - Distributed aerodynamic load (*potentially nonuniform*)
  - Concentrated actuator force
  - Inertial loads due to maneuvers
- All loads vary with speed





# Loading Conditions



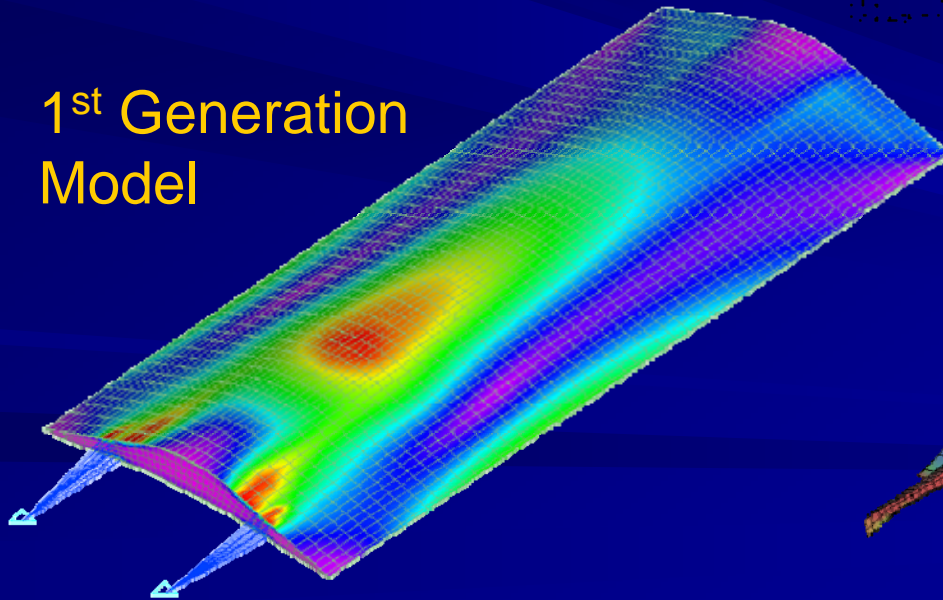
- Design (aero) load conditions obtained from McDonnell Aircraft Company

\* McDonnell Aircraft Company document MDC A0920, Vol. 2

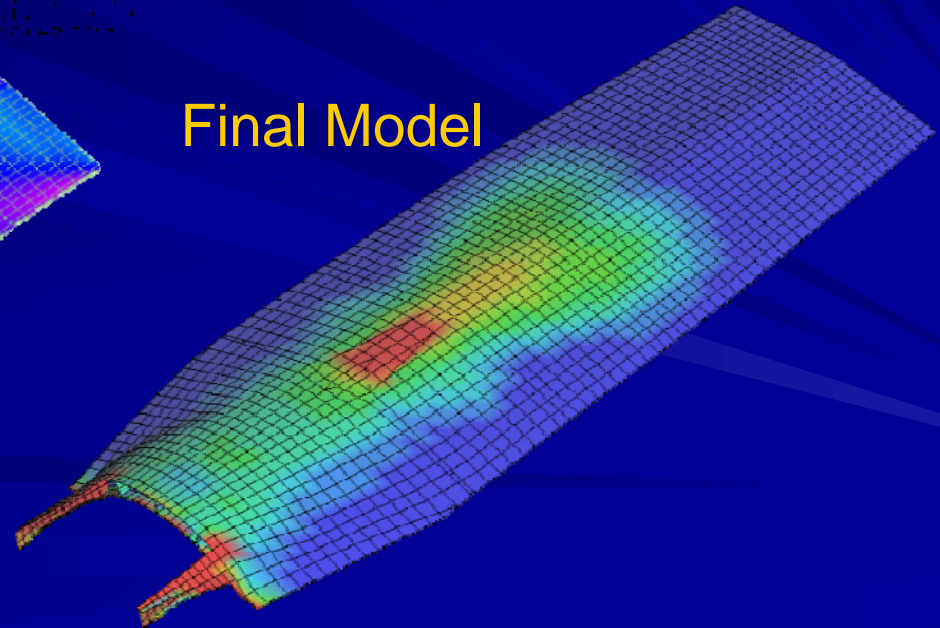
# Finite Element Analysis

- Because of time constraints, two FE models were developed
  - **1<sup>st</sup> Gen Model** (simplified geometry and isotropic materials) was developed within hours to provide general mechanical insight while awaiting final model
  - **Final Model** required 2-3 weeks to develop because of complex tapered composite thicknesses, orthotropic material properties, and nonlinear analysis

1<sup>st</sup> Generation  
Model

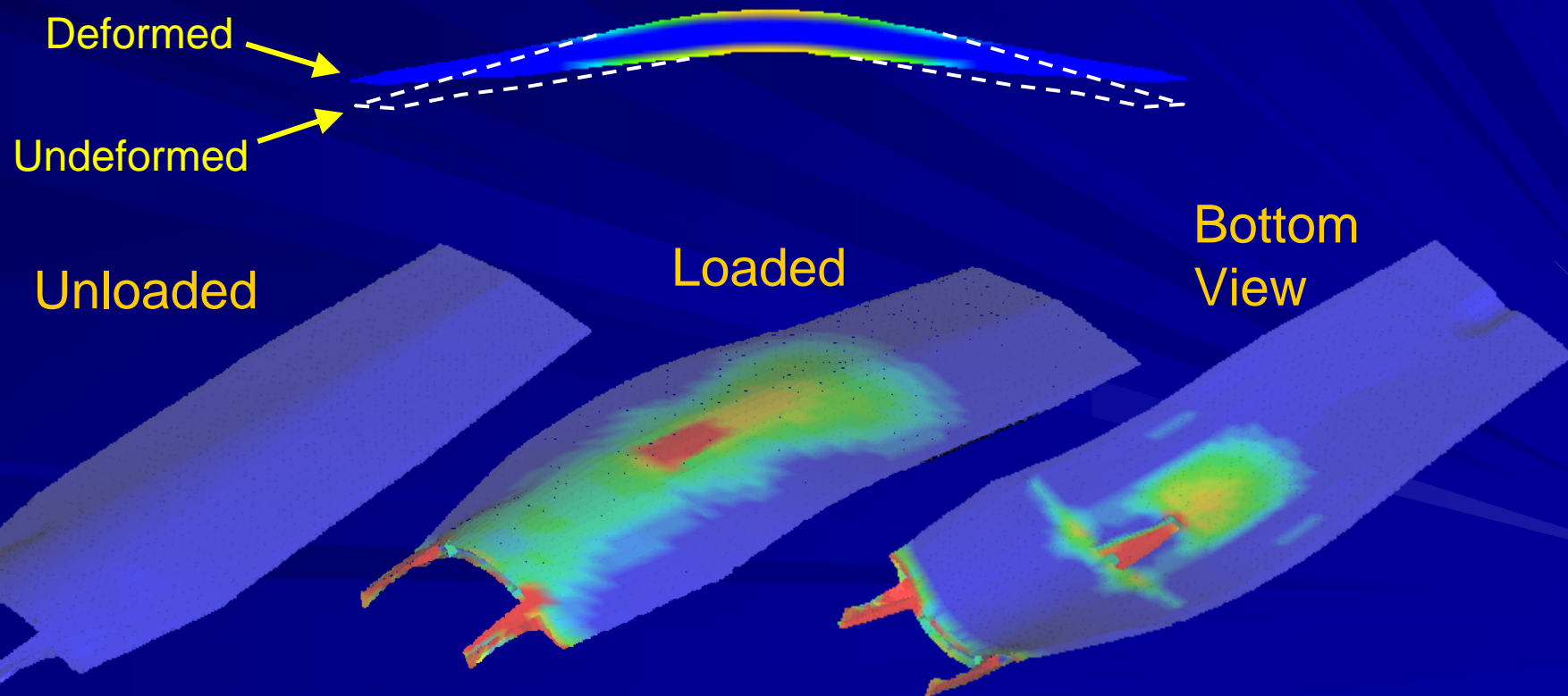


Final Model



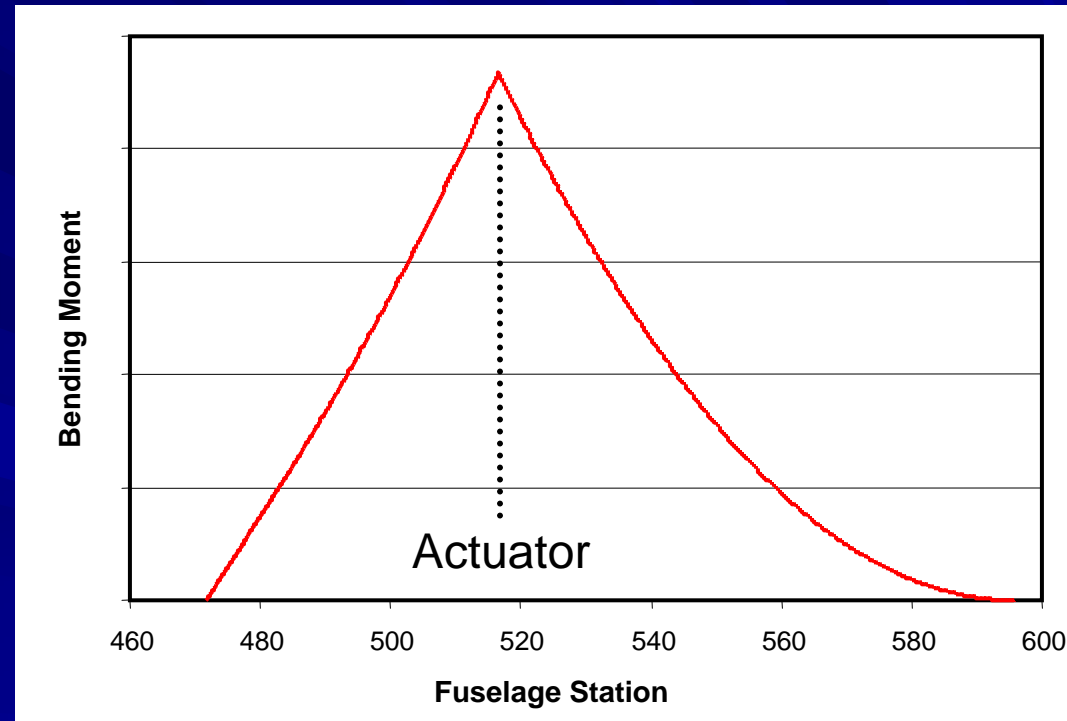
# Finite Element Analysis

- High tensile stresses aft of actuator on upper and lower surfaces
- Nonlinear "flare-out" mechanism of cross section at high loads places lower surface in tension and reduces moment of inertia



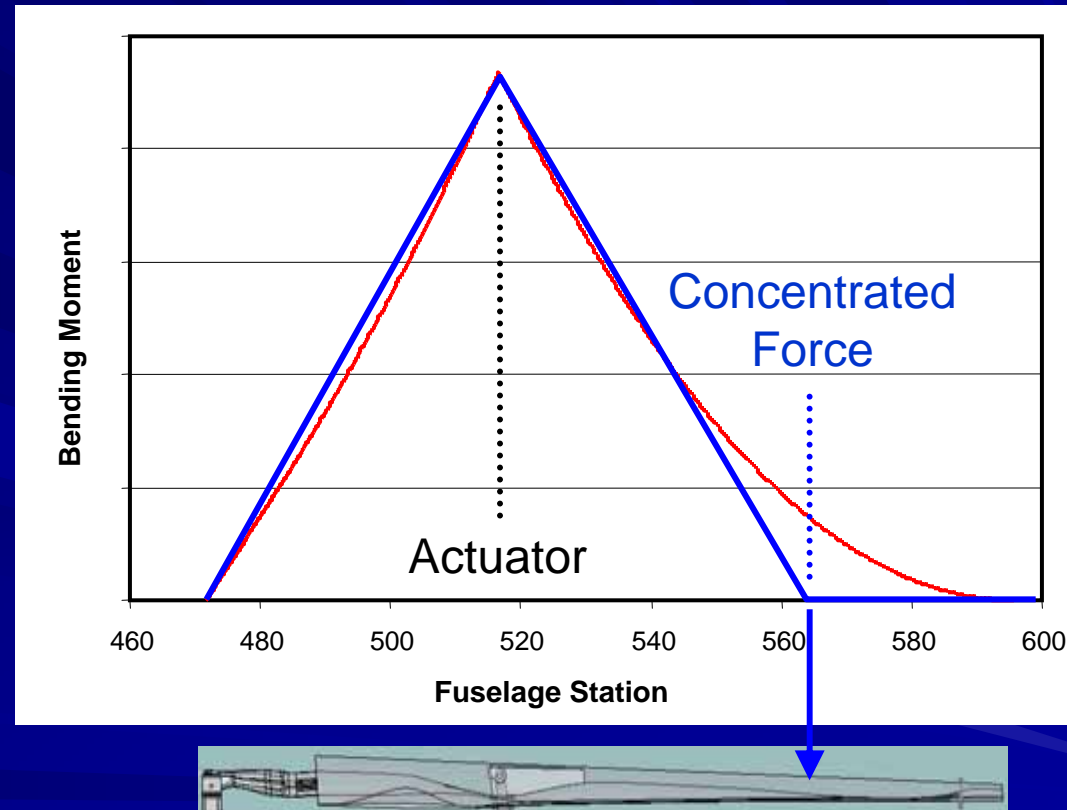
# Bending Moment

- Bending moment due to distributed aerodynamic loading reaches a maximum at actuator mount



# Bending Moment

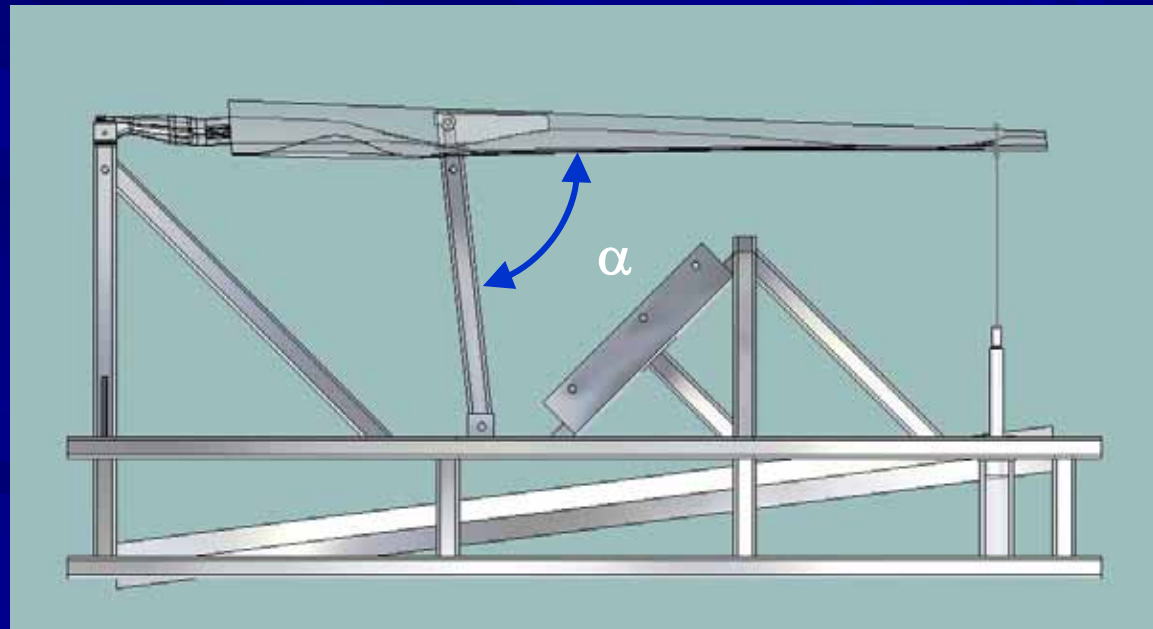
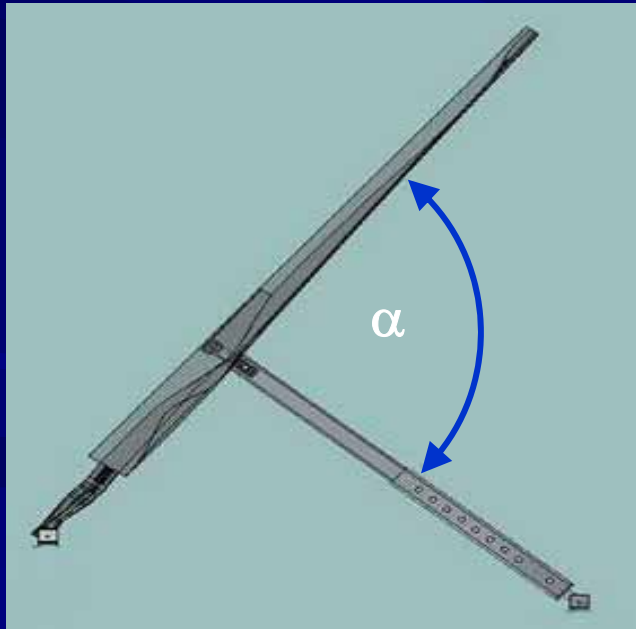
- A single force of proper magnitude and location gives a similar bending moment distribution in speed brake





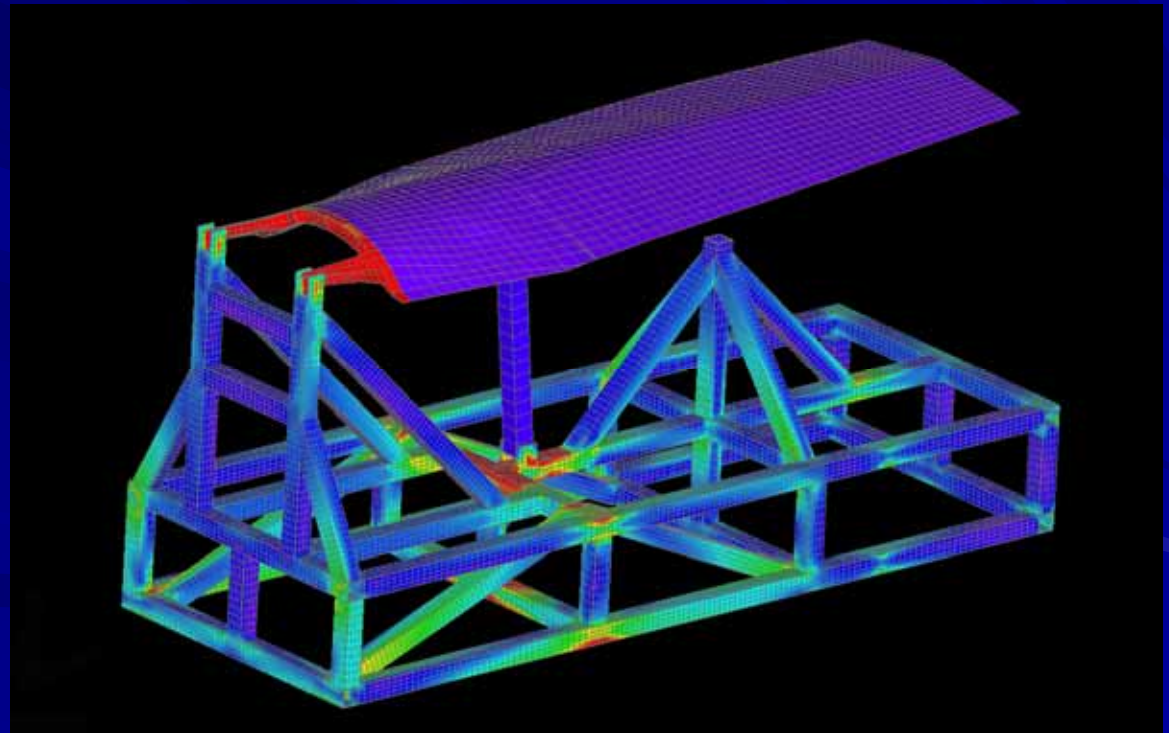
# Test Fixture Development

- Preliminary design features
  - Multiple actuator angles,  $\alpha$
  - Concentrated force(s) applied near aft tip of speed brake
  - Push, pull, and torsional loading possible



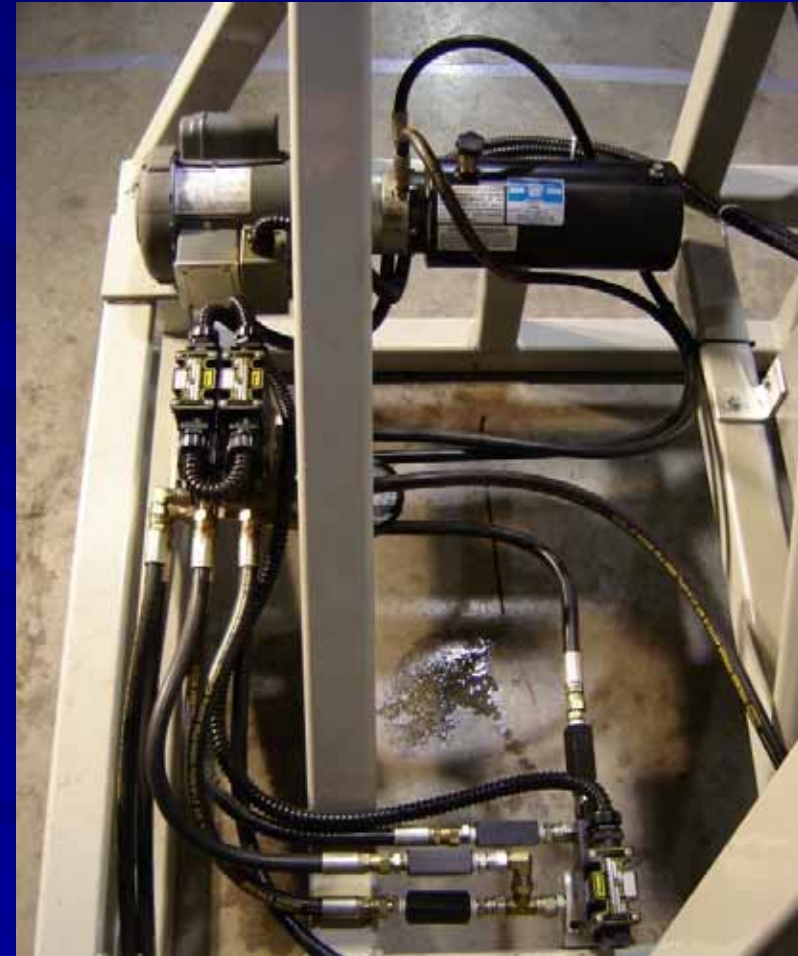
# Structural Analysis

- Initial strength analyses performed by hand
- Follow-up FE analysis performed to...
  - Check for stress concentrations
  - Ensure minimal deflections of free-standing structure

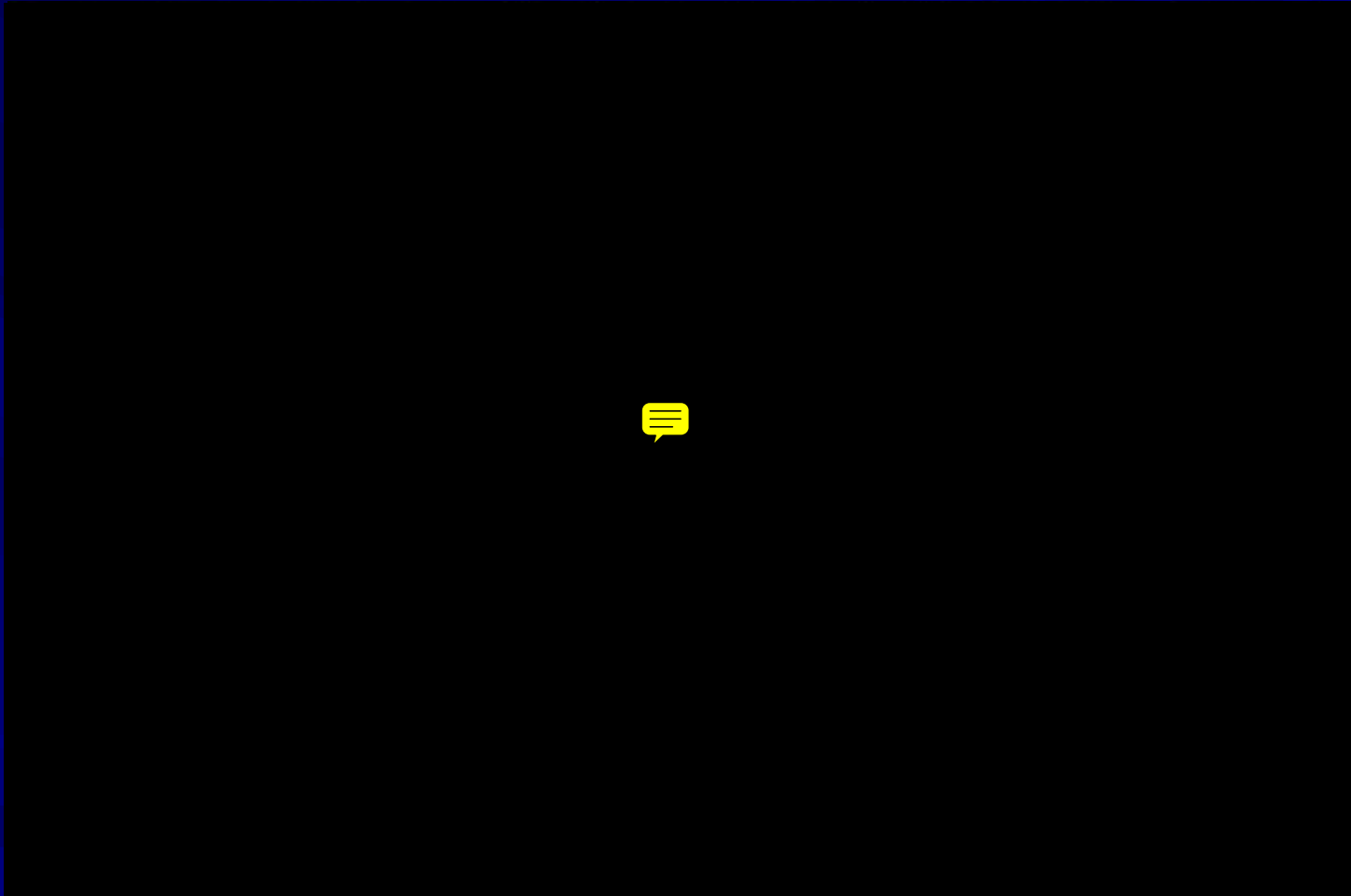


# Test Fixture Fabrication

- System built at MERC



# Test Video



# Test Results

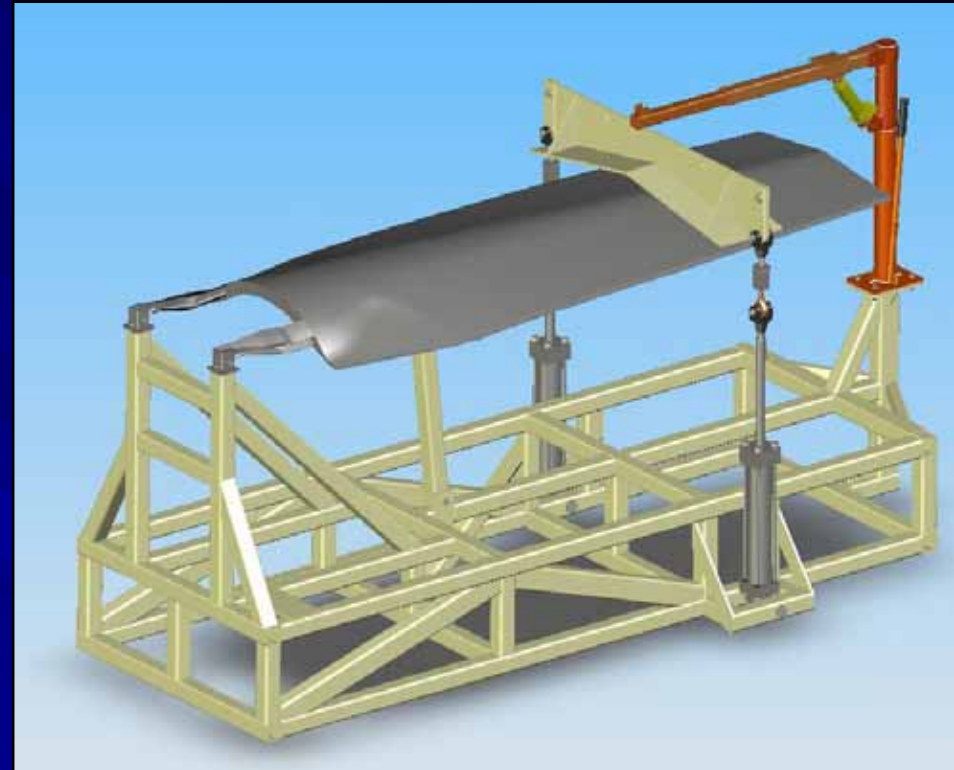
- Speed brake tested to failure in fixture
- Failure mode same as in-flight failures
  - Lateral and longitudinal cracks aft of actuator well
- Pass/fail criteria defined, test process established





# Final Test Fixture Design

- Integrated hydraulic loading system
- Load cradle contoured to fit speed brake upper surface



# Complete Test System



- Final test fixture design with fully automatic hydraulic controls
- One button operation for complete test

# Test System Implementation

- System currently in use at WR-ALC
- Preliminary testing identified several sub-standard speed brakes
- Tests allowed AF to relax strict NDI standards





# Thanks to the Team



**Brian Fulwood**

**Bob McGinty**

**Mike Meyer**

**Dave Harper**

**Gerry Ringe**

**John Land**

**Horace Smith**

# Questions / Comments