# Aeroelastic Leveraging and Control through Adaptive Structures

Robert L. Clark
Earl H. Dowell
Devendra P. Garg
Kenneth C. Hall

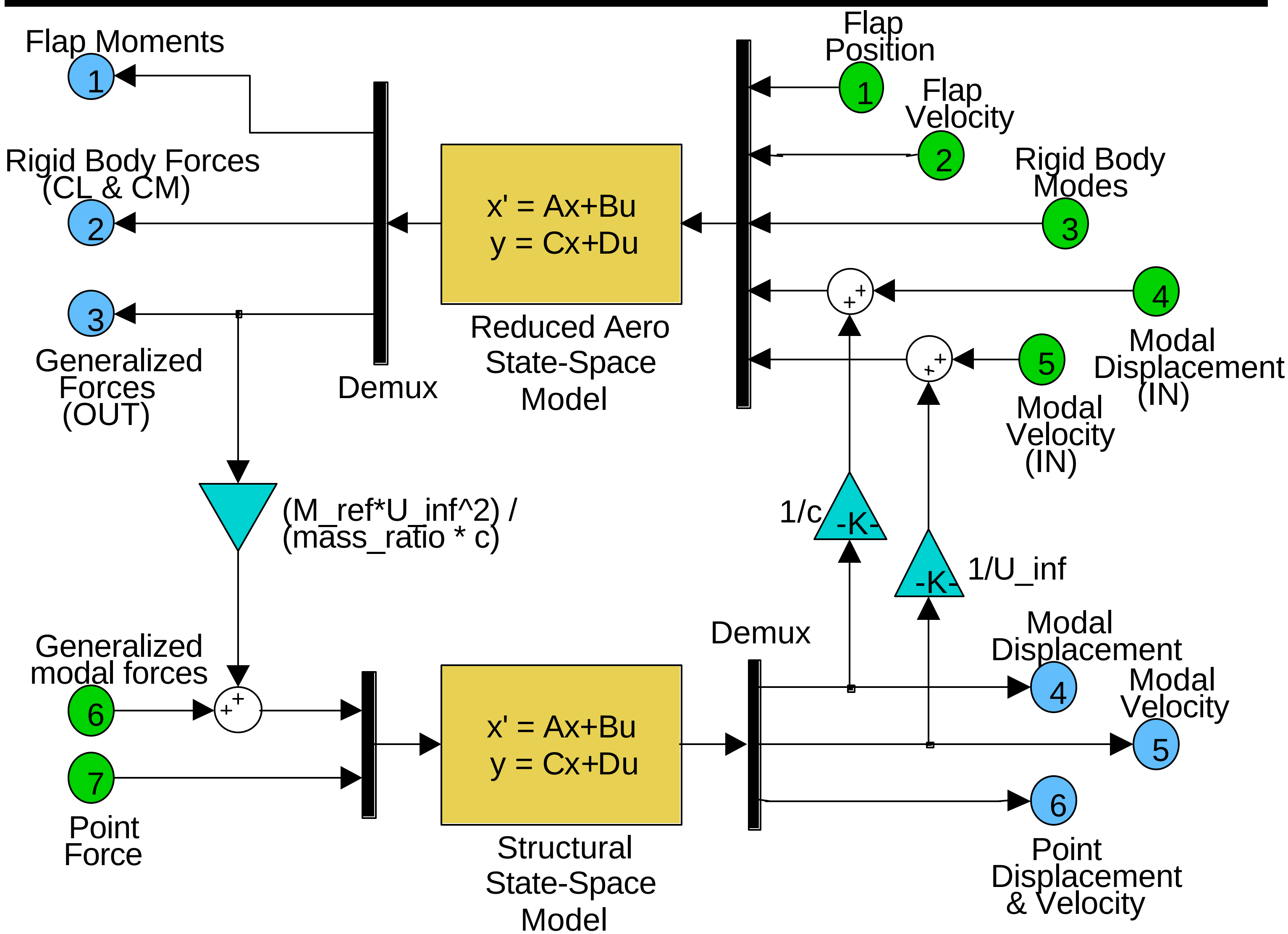
# Overall Objective

- The primary objective of the proposed program is to develop and design a distributed actuation methodology for wings of UCAVs aimed at
  - Control of higher-order flutter modes
  - Increased maneuverability
  - Reduced radar signature

# Time Line of Technical Approach

| Tasks | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| **Aeroelastic Modeling and Control** | Aerodynamic Model<br>Structural Model<br>Address Control Authority Requirements | Control System Design and Evaluation<br>Aeroelastic Model for Large-Scale Experiment | Control System Design for Large Scale Model |
| **Actuator Development** | Transducer Designs / Bench Tests<br>Transducer Modeling / Integration | Transducer Designs for Large Scale Model<br>Large Scale Transducer Modeling / Integration | |
| **Wind Tunnel Model Development** | Design, Development and Open-Loop Characterization | Control System Design and Closed-Loop Evaluation | Design and Development of Large-Scale Model |

# The Aeroelastic Model



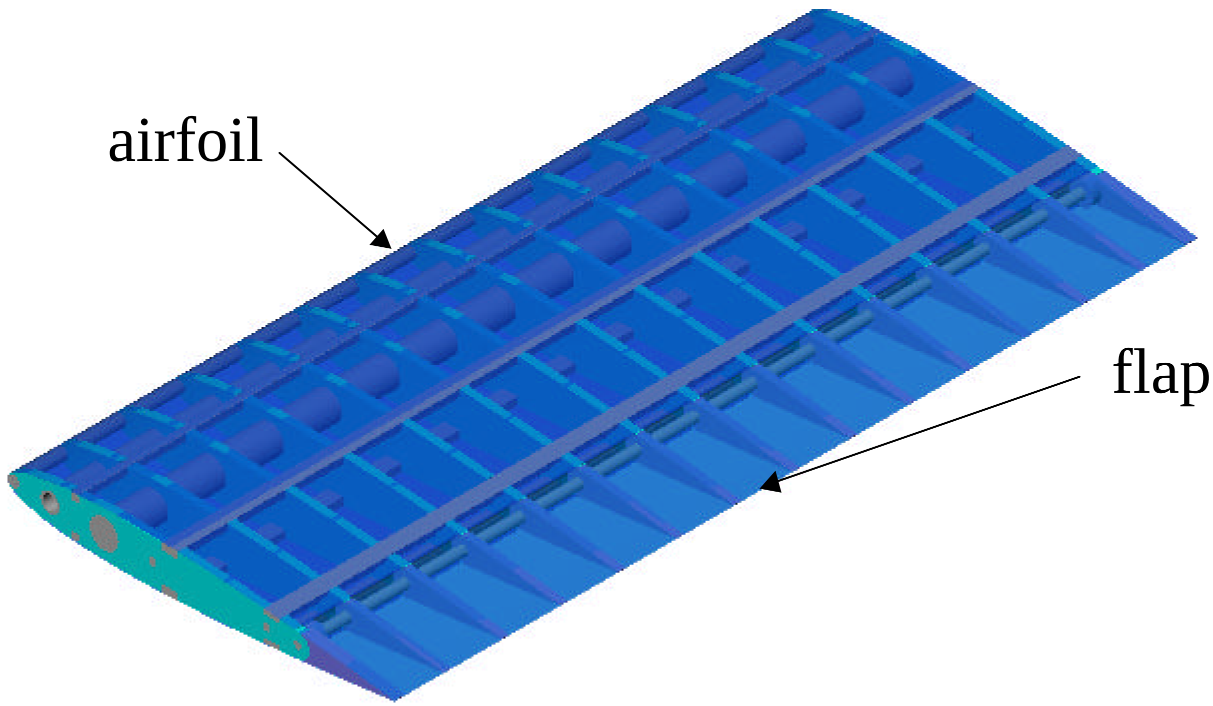
# Team Assignments/Contributions

- Duke University
  - Aeroelastic modeling, analysis, and design
  - Transducer specifications and integration
  - Control system modeling, analysis, and design
  - Bench testing
  - Wind tunnel testing
- Mide Technologies, Inc.
  - Transduction device modeling, design, and construction
  - Design and control surface integration on large-scale wing model

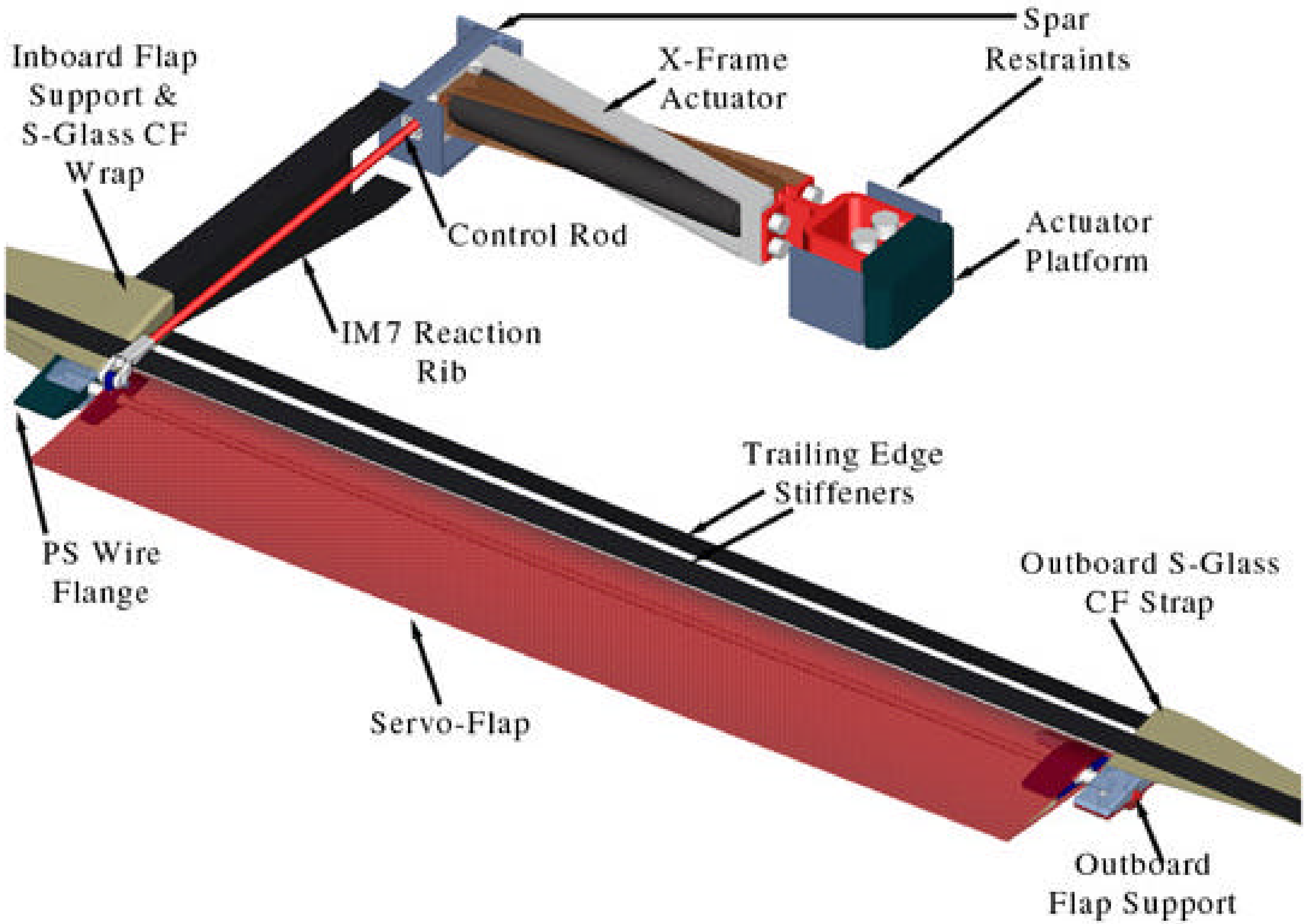
# Major Accomplishments

- Completed design and testing of high aspect ratio wing model in Duke University Wind Tunnel to correlate computer model used to design wing.
- Completed design specifications for a typical section wind tunnel model to evaluate performance of X-Frame actuator with a single control surface.
- Selected transduction device, X-Frame actuator, for distributed control surface.
- Initiated design of continuously deformable distributed control surface for control of high aspect ratio wing flutter.

# Typical Section Model



# X-Frame Actuator Technology (Courtesy of Mide Technology Corporation)



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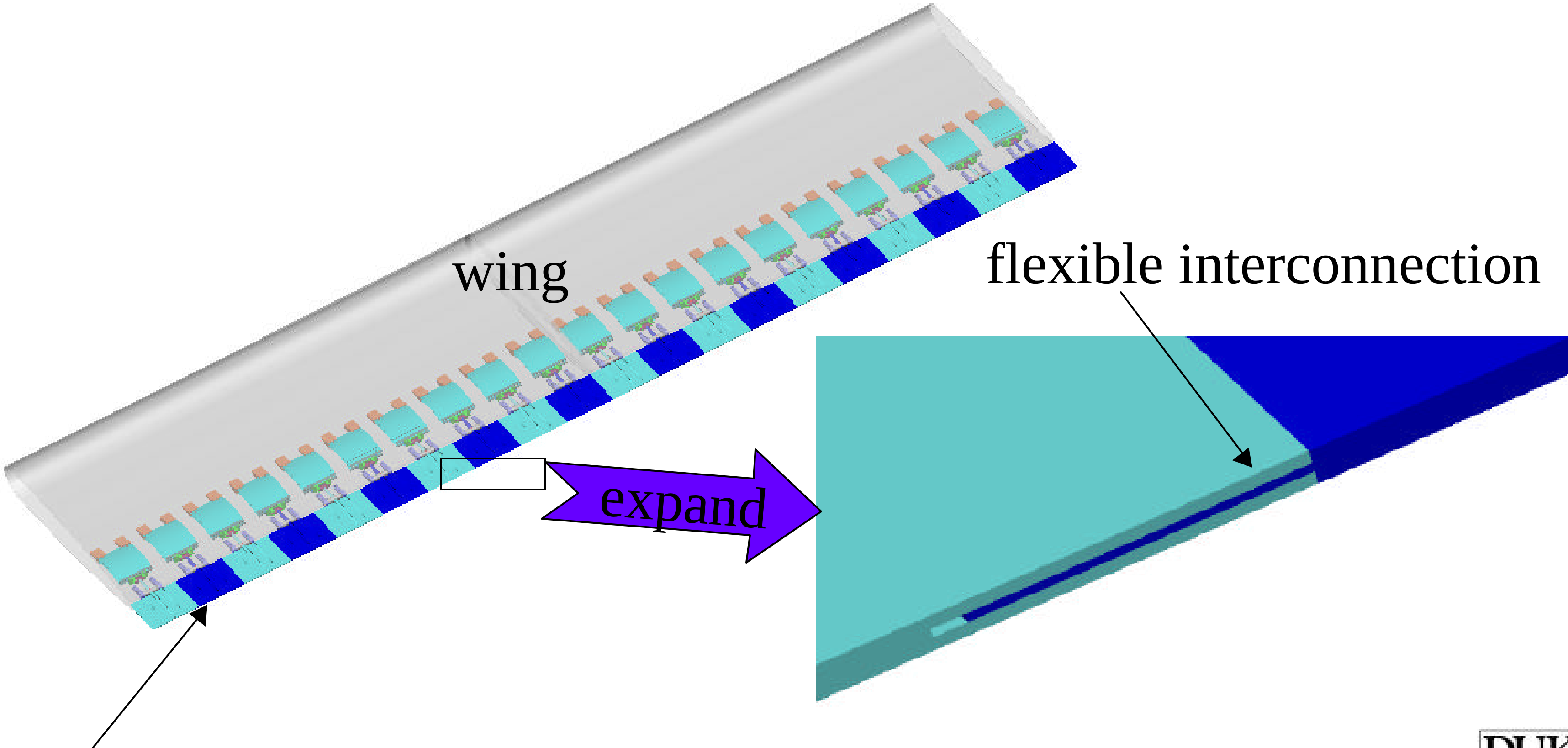
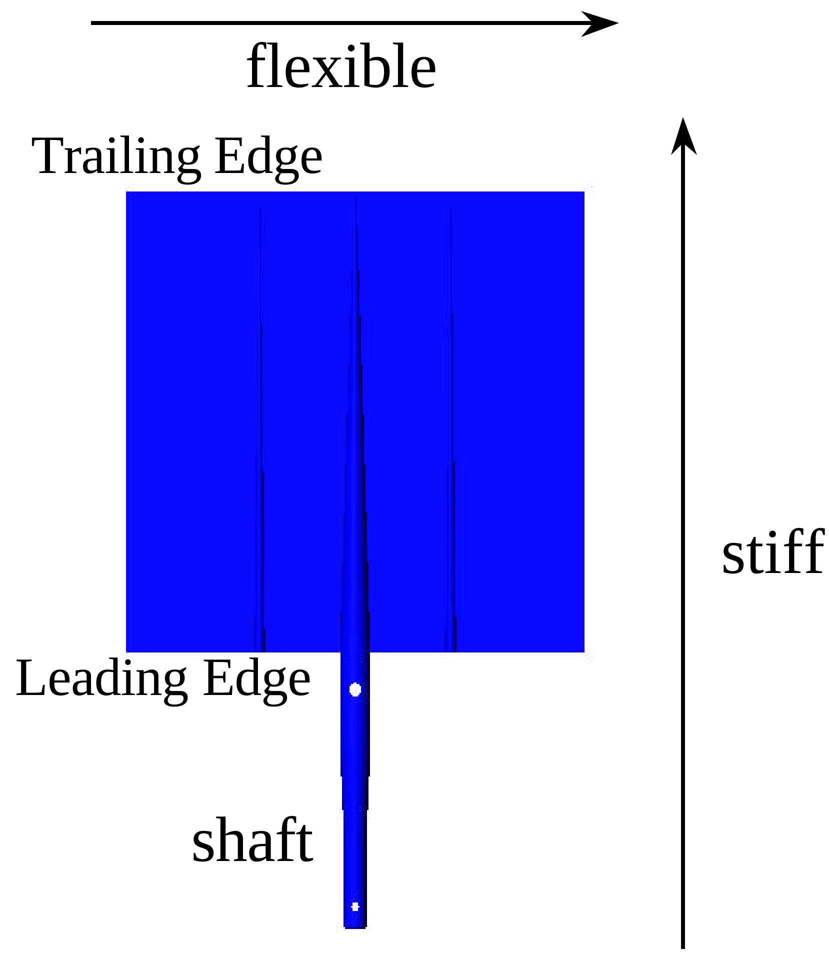
# Distributed Control Surface




FLEXible Distributed Control Surface (FLEXDCS)

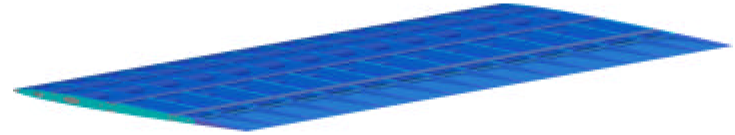
# FLEXDCS Structure



# Motivation for FLEXDCS

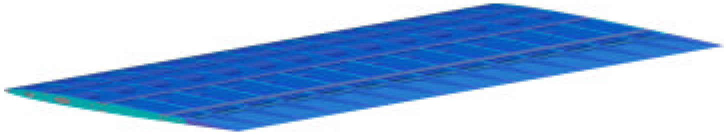
- Maneuverability
- Control of higher-order flutter modes
- Reduced signature for radar
- Spatial smoothing filter using discrete active materials

# Theoretical Model



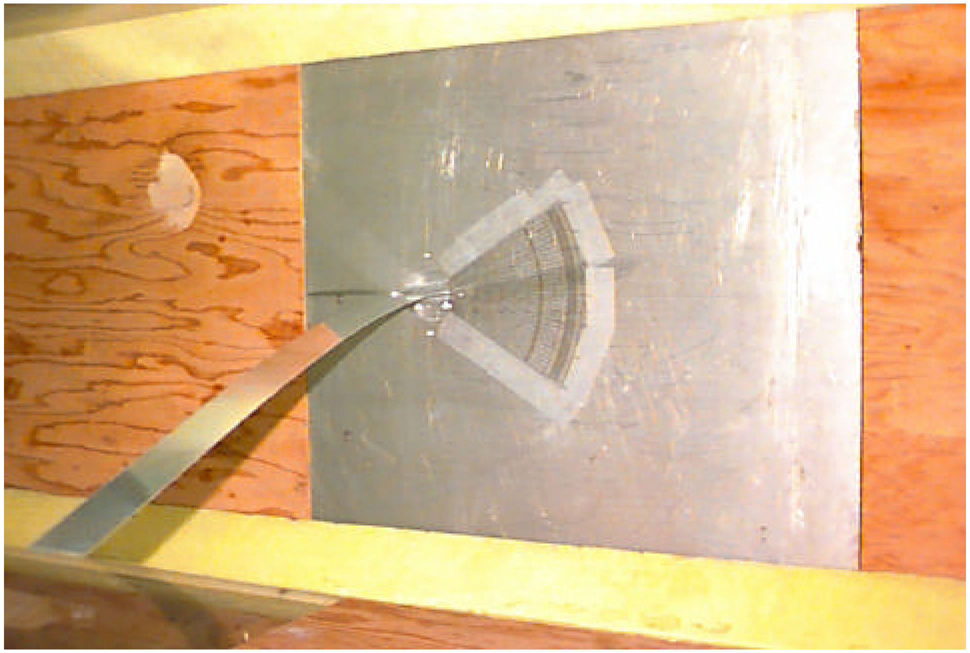
- A nonlinear aeroelastic model has been developed that predicts flutter and LCO as a function of important parameters, e.g.
  - Coupling among flap-wise and edge-wise bending and torsional motions
  - Static angle of attach and gravity loading
  - Magnitude of disturbance required to initiate LCO below the nominal flutter boundary
- Flutter typically occurs due to coupling of a higher order flap-wise bending mode and the fundamental torsional mode.

# Experimental Model



- An experimental model has been designed, constructed, and initial tests have been conducted.
- Flutter occurs as predicted in a higher order span-wise mode.
- Large static deformations occur in the model prior to the onset of flutter as the static angle of attack of the model is increased.
- As predicted, the flutter speed decreases with increasing angle of attack.
- These initial tests were conducted with a vertically mounted model to eliminate the effects of gravity.
- Future tests will include the combined effects of gravity and static aerodynamic loading due to angle of attack. Also, the effects of large disturbances will be explored.

# Experimental Models





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# Program Impact

- Correlation between theoretical and experimental models are good and indicate that basic physics of the nonlinear aeroelastic system have been captured.
- Concepts investigated and under development are directly related to UAV and UCAV needs of the Air Force, Army, and Navy.
- The large-scale wind tunnel model development is planned as a logical progression to future application on a flight vehicle.