

Aeroelastic Model Development for the Integrated Adaptive Wing Technology Maturation Project Wind-Tunnel Test

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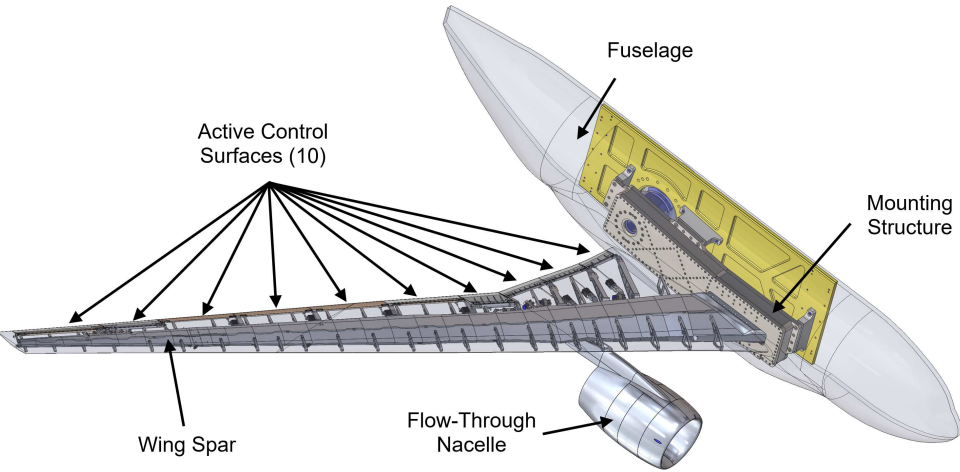
NASA Langley Research Center

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Motivation



Layout of the IAWTM (Integrated Adaptive Wing Technology Maturation) wind-tunnel model (credit: Boeing Research and Technology).

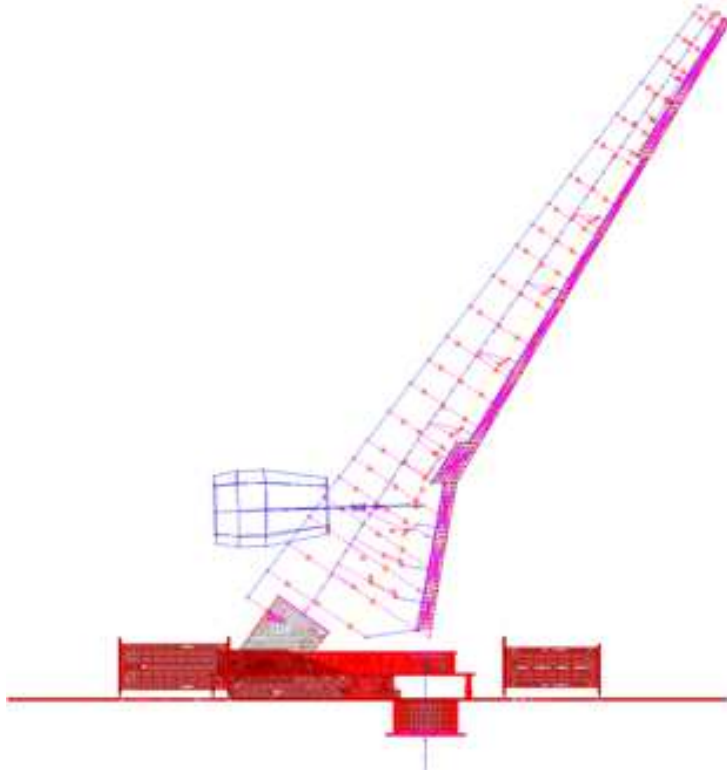
IAWTM research objectives:

- Assess flutter boundary
- Assess effectiveness of trailing edge control surfaces for:
 - flutter suppression
 - maneuver load alleviation
 - gust load alleviation
 - drag reduction

Outline

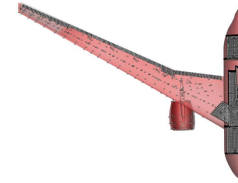
- IAWTM computational aeroelastic model development
 - Structural model
 - Aerodynamic models (of differing fidelities)
- Results
 - Generalized aerodynamic forces
 - Flutter predictions
- Conclusions & future work

Computational Models: Structural Dynamics

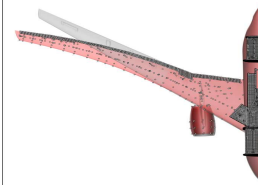


Finite element structural model (credit: Boeing Research and Technology).

Mode 4
11.08 Hz



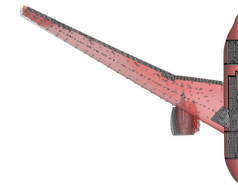
Mode 5
14.98 Hz



Mode 6
15.15 Hz



Mode 7
17.11 Hz

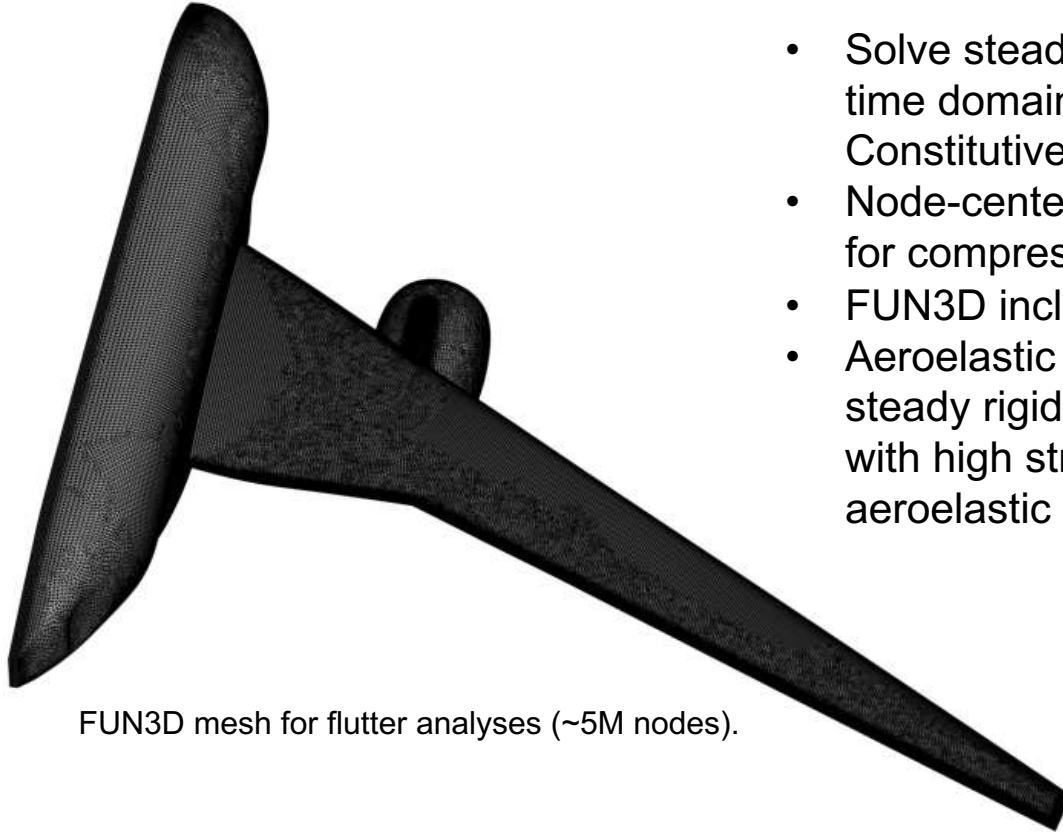


Computational Models: Aerodynamics

- Fully Unstructured 3-Dimensional Navier-Stokes (FUN3D) } Nonlinear aerodynamics
- FUN3D Stabilized Finite Element Linearized Frequency-Domain (FUN3D/SFE LFD) } Linearized aerodynamics
- Reduced-Order Modeling (ROM) with Eigensystem Realization Algorithm }
- ZAERO } Linear aerodynamics

(All results here are at Mach 0.8, 0° angle of attack.)

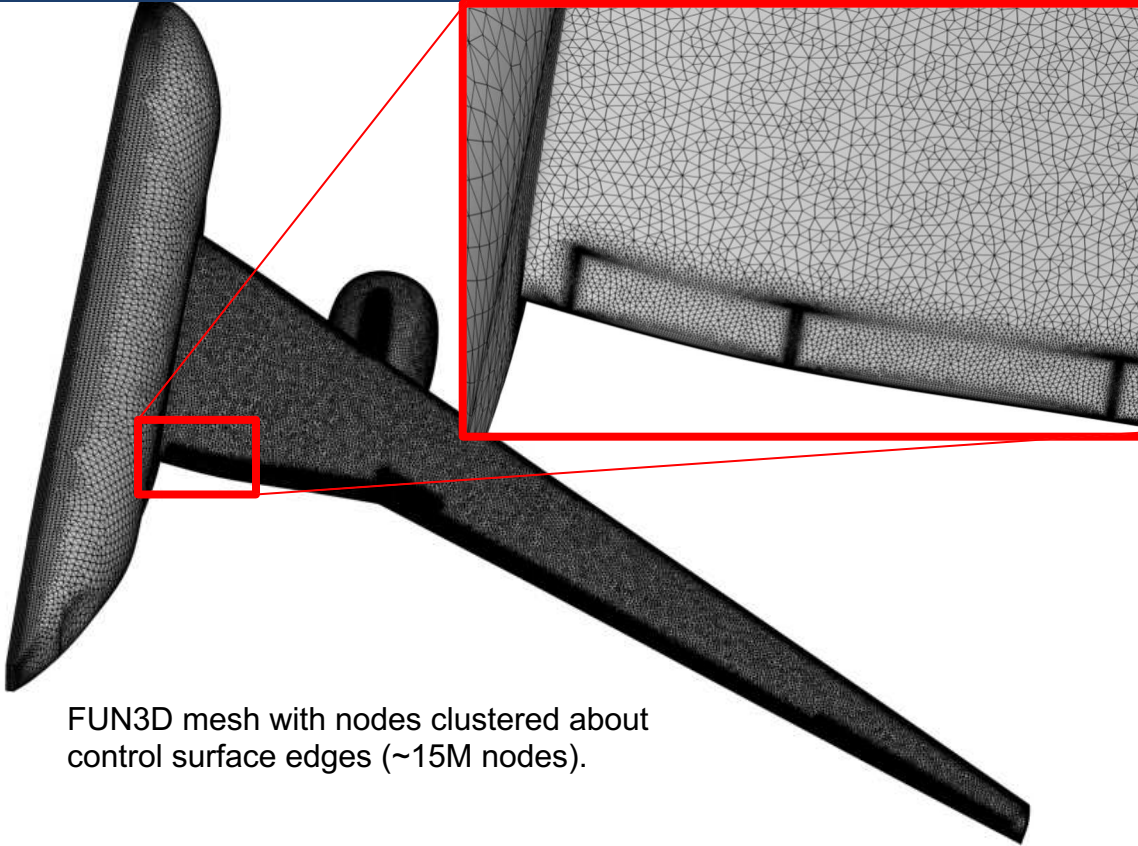
FUN3D



FUN3D mesh for flutter analyses (~5M nodes).

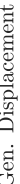
- Solve steady and unsteady RANS equations in time domain with Spalart-Allmaras (with Quadratic Constitutive Relation) turbulence model
- Node-centered, finite-volume unstructured solver for compressible flows
- FUN3D includes modal structural dynamics solver
- Aeroelastic solution generally found in 3 steps: (1) steady rigid solution, (2) static aeroelastic solution with high structural damping, (3) dynamic aeroelastic solution with low structural damping

FUN3D/SFE LFD (linearized frequency-domain)



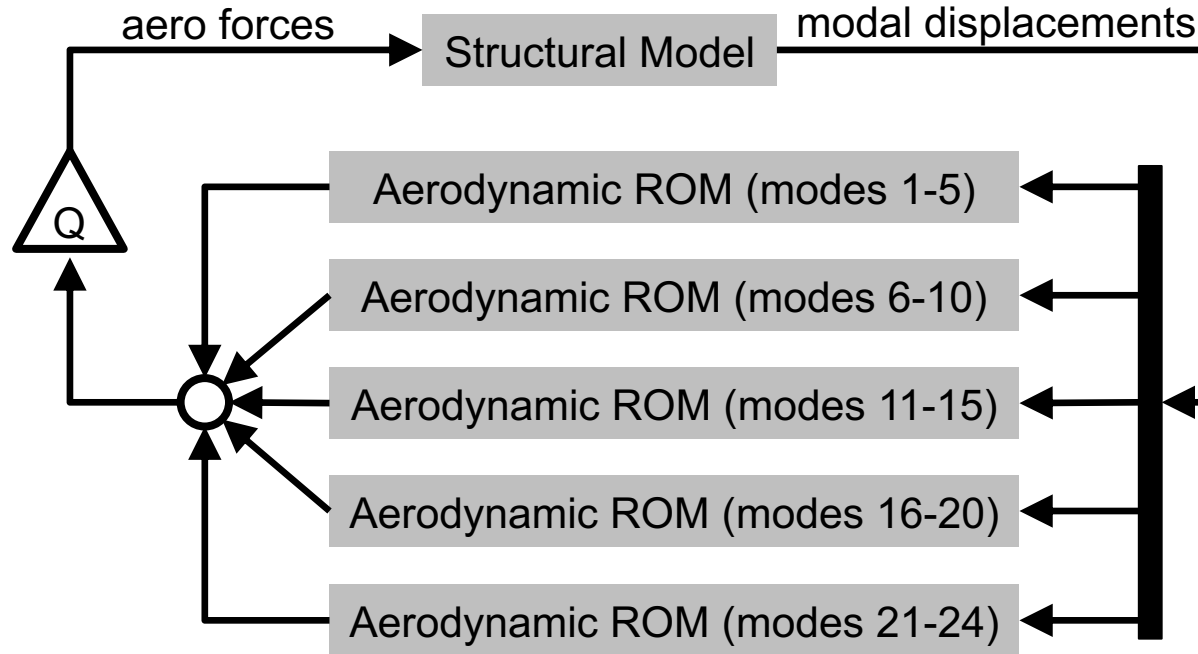
FUN3D mesh with nodes clustered about control surface edges (~15M nodes).

- Stabilized finite-element solver recently implemented in FUN3D (FUN3D/SFE)
- Linearized frequency-domain solver added to FUN3D/SFE (FUN3D/SFE LFD)
- Governing equations of flow linearized about static aeroelastic solution
- Responses to unit displacement perturbation applied to each mode are calculated
- Responses (oscillatory surface forces) projected to structural modes to calculate generalized aerodynamic forces (GAFs)



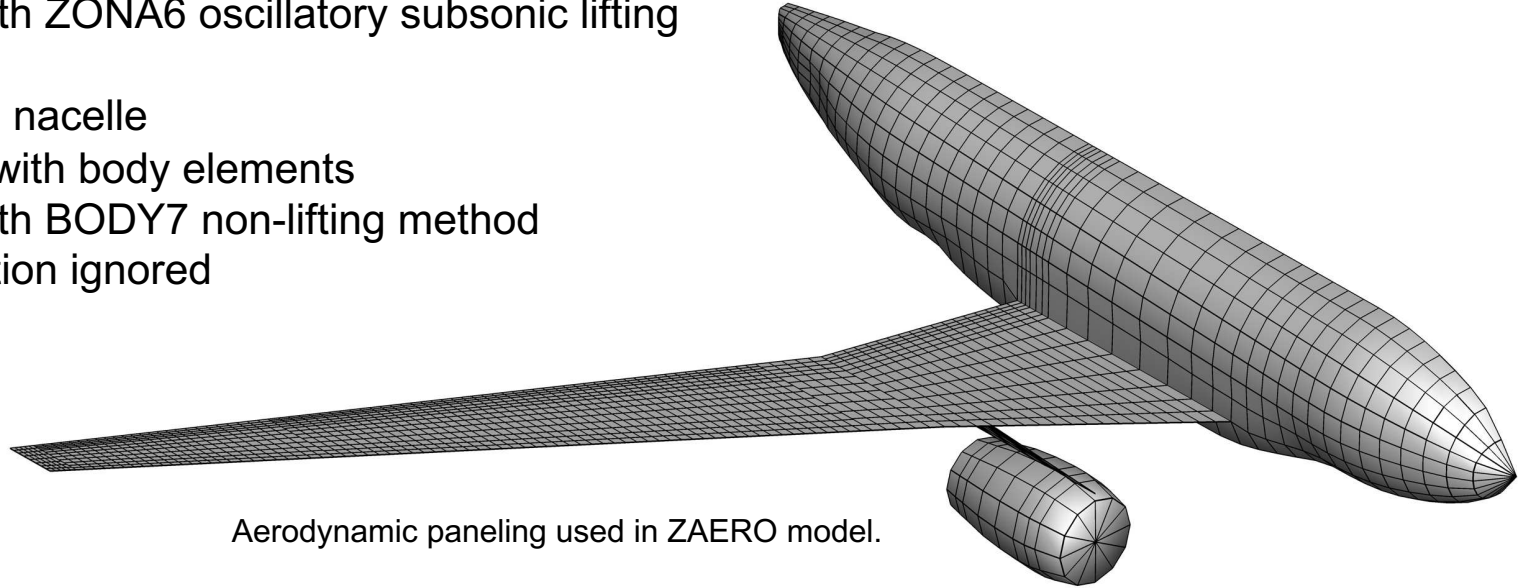
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ROM using Eigensystem Realization Algorithm (2/2)



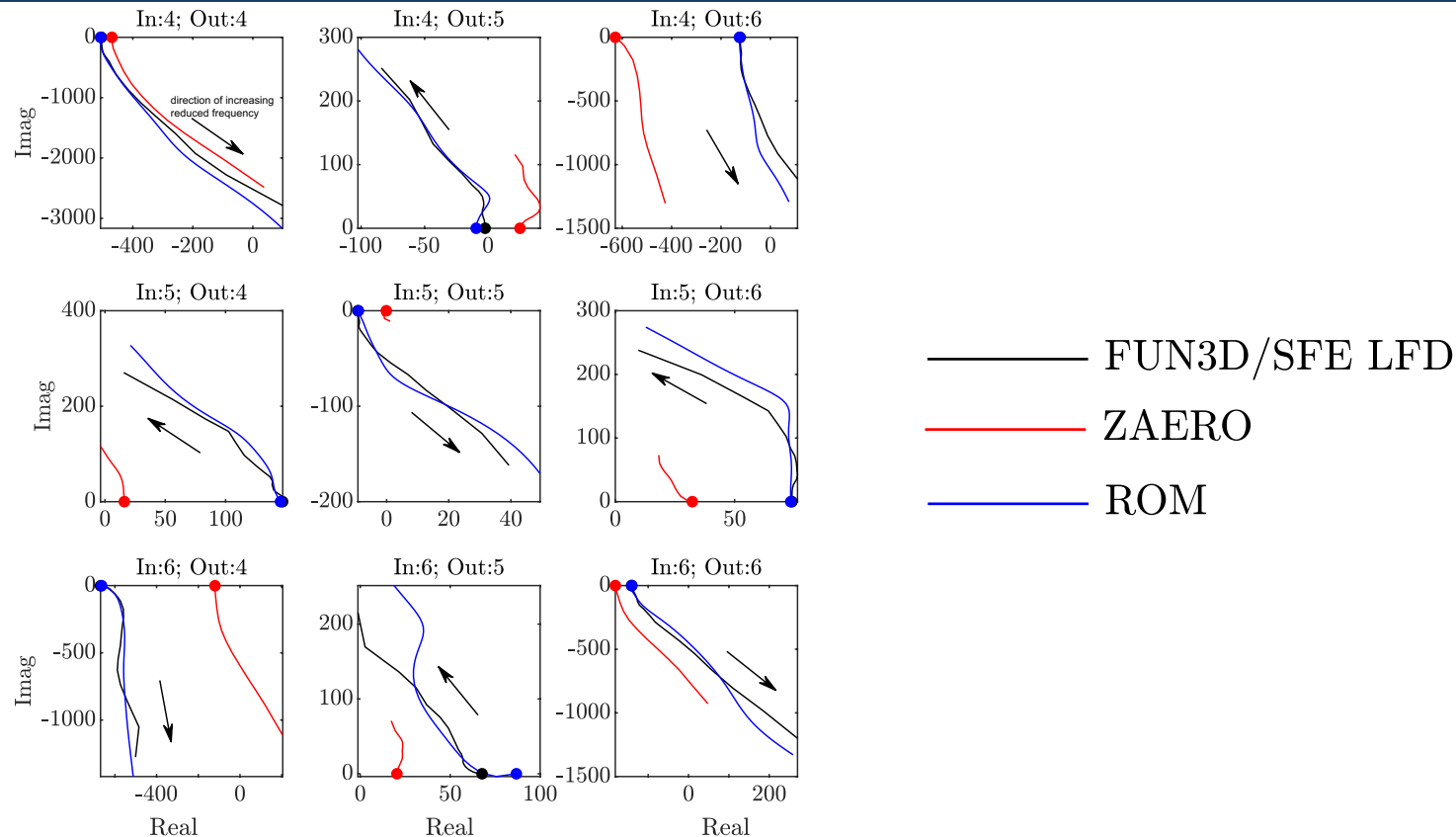
ZAERO

- Wing and pylon
 - Modeled with flat plate elements
 - Solved with ZONA6 oscillatory subsonic lifting method
- Fuselage and nacelle
 - Modeled with body elements
 - Solved with BODY7 non-lifting method
- Fuselage motion ignored

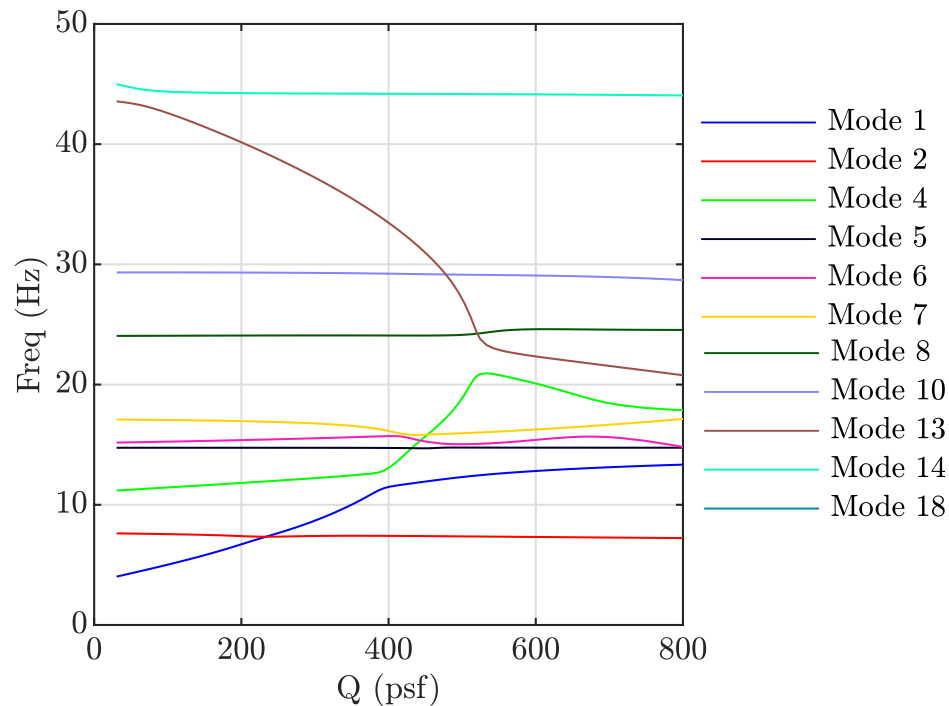
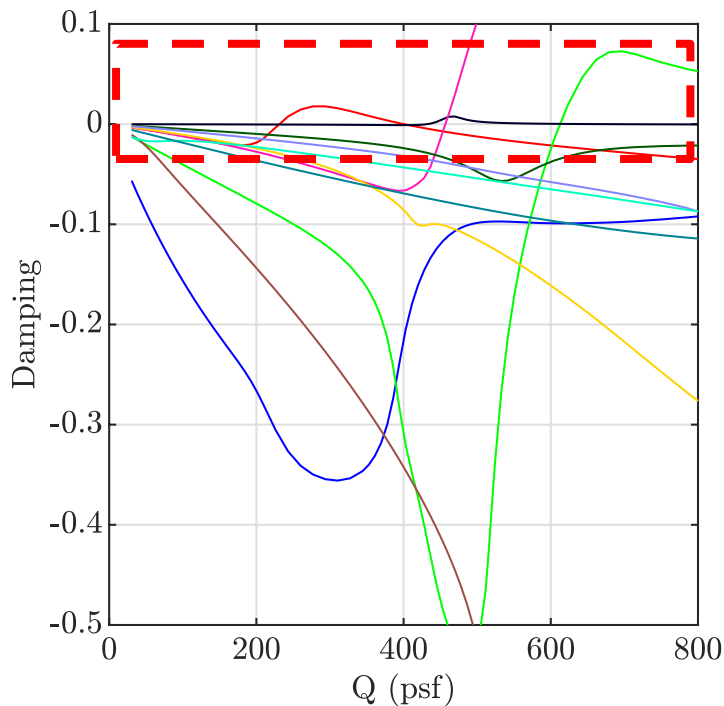


Aerodynamic paneling used in ZAERO model.

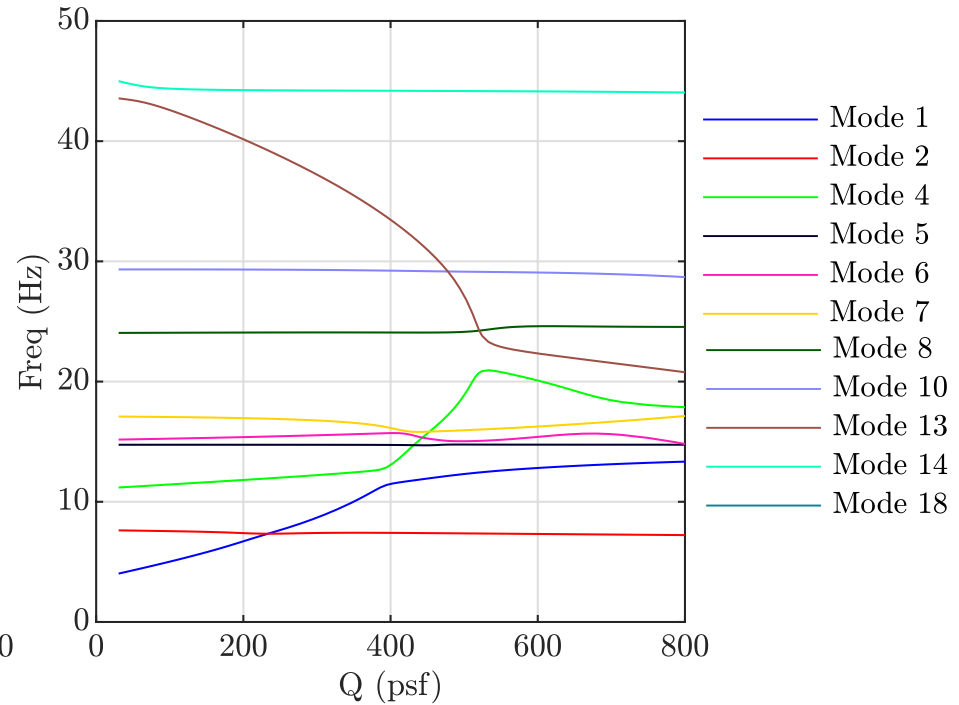
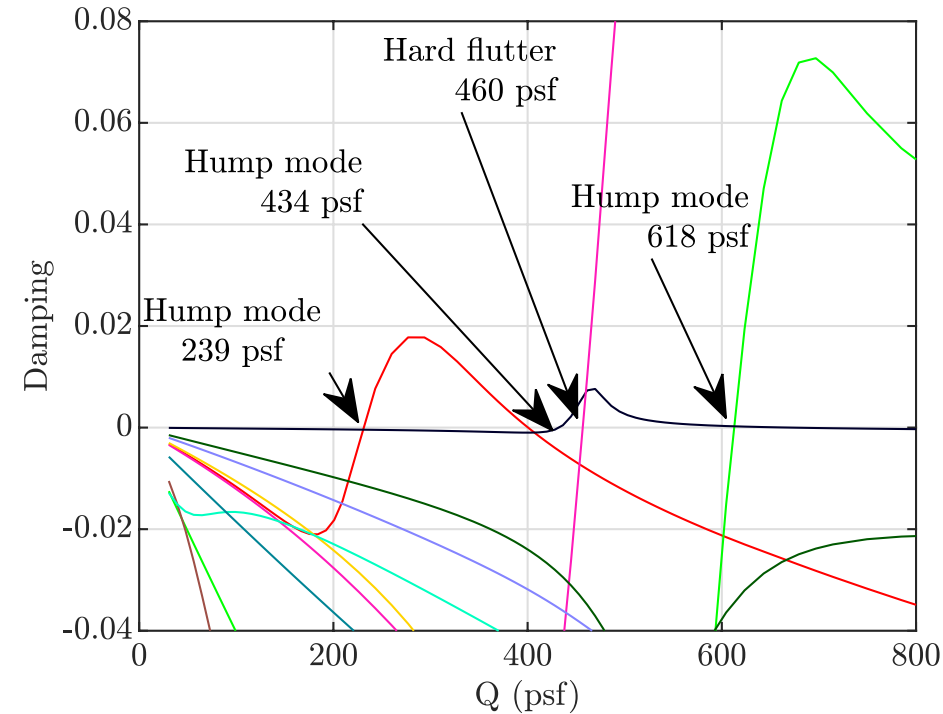
Results: Comparisons of GAFs



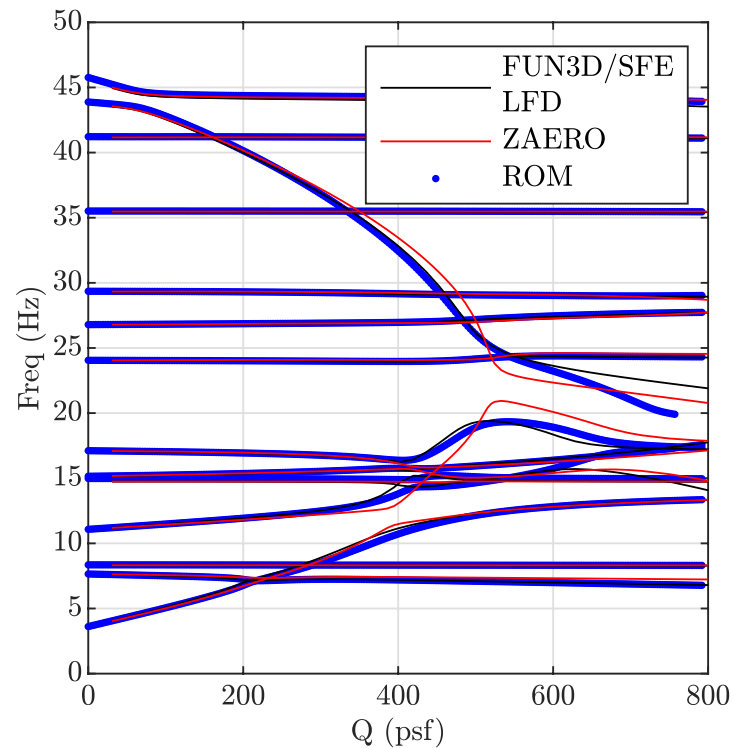
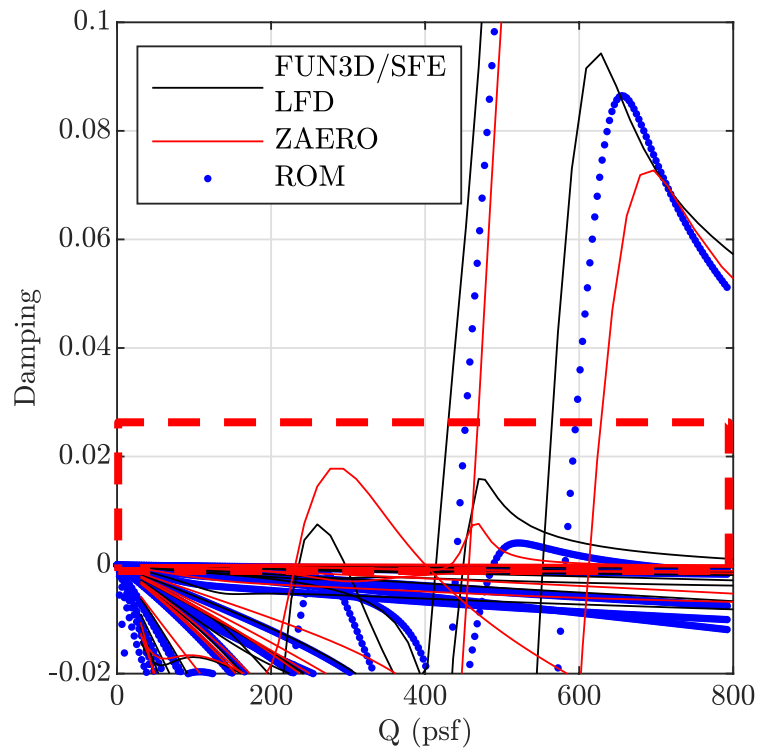
Results: ZAERO Flutter Prediction (1/2)



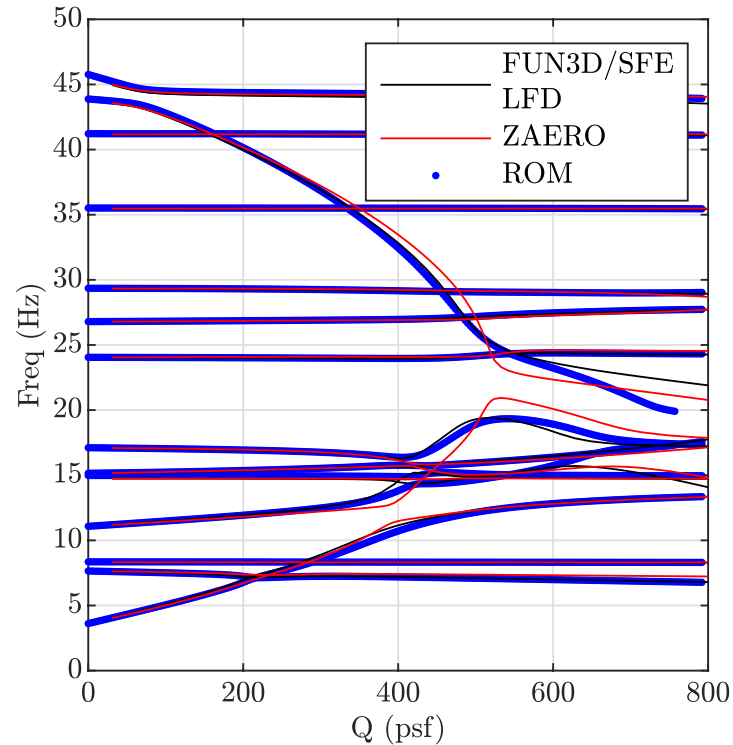
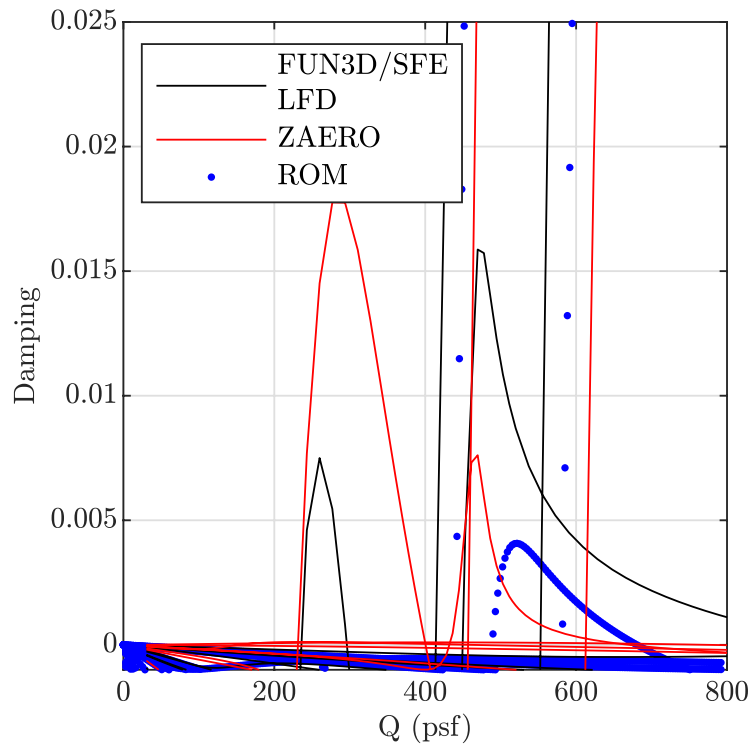
Results: ZAERO Flutter Prediction (2/2)



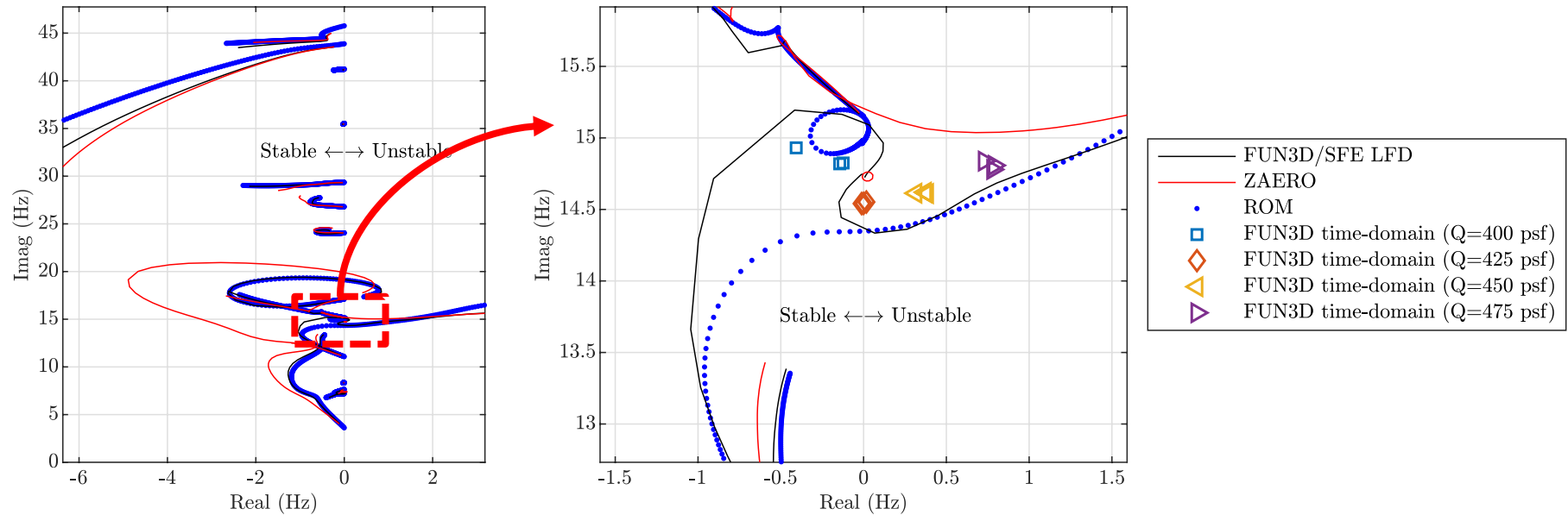
Results: Comparison of Flutter Predictions (1/3)



Results: Comparison of Flutter Predictions (2/3)



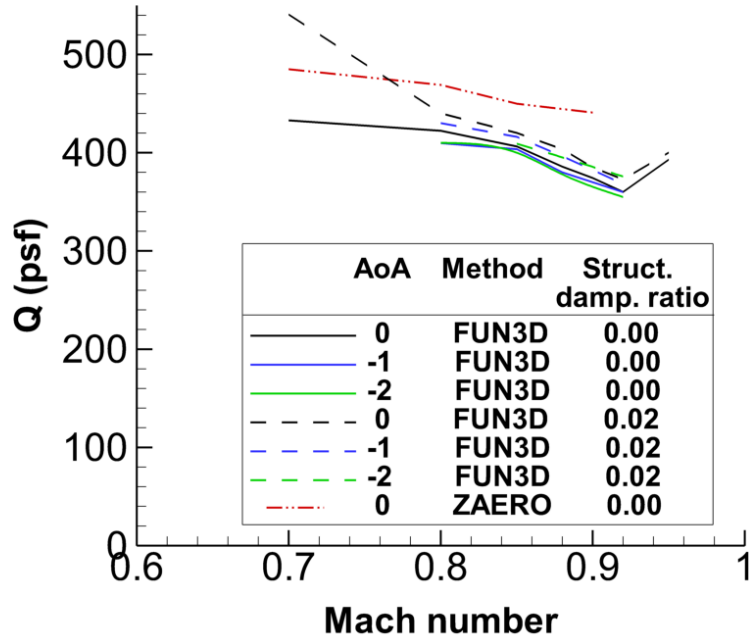
Results: Comparison of Flutter Predictions (3/3)



Results: Summary of Flutter Predictions

Method	Hard Flutter Prediction		
	Q (psf)	Freq (Hz)	Unstable Mode Number
FUN3D time-domain	422	14.5	-
FUN3D/SFE LFD	414	14.4	5
ROM	440	14.3	4
ZAERO	460	14.7	6

Conclusions & Future Work



- Several computational aeroelastic models developed with differing levels of fidelity
- Flutter predictions for between 414 and 460 psf, at frequencies between 14 and 15 Hz (Mach 0.8, AoA=0)
- Linear method seems to do well at this particular condition
- Future work:
 - Conduct similar comparison at different angles of attack and Mach numbers (fill in plot at left with LFD and ROM predictions)
 - Generate control laws

Acknowledgments

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