



Summary of Results from the Third Aeroelastic Prediction Workshop Flight Test Working Group

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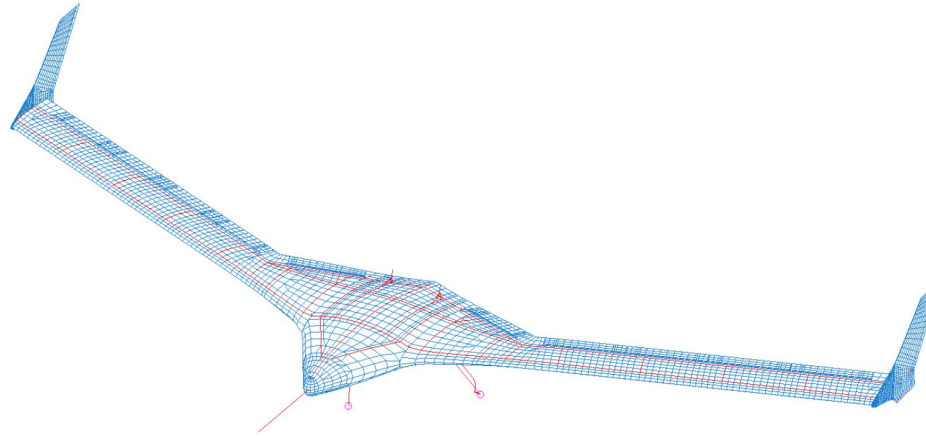
Netherlands Aerospace Centre

- Introduction
 - Background
 - X-56 Body Freedom Flutter Mechanism
 - Challenges in X-56 Flutter Modeling
 - Flight Test Working Group Challenge
- Participants
- Combined Results
- Conclusions

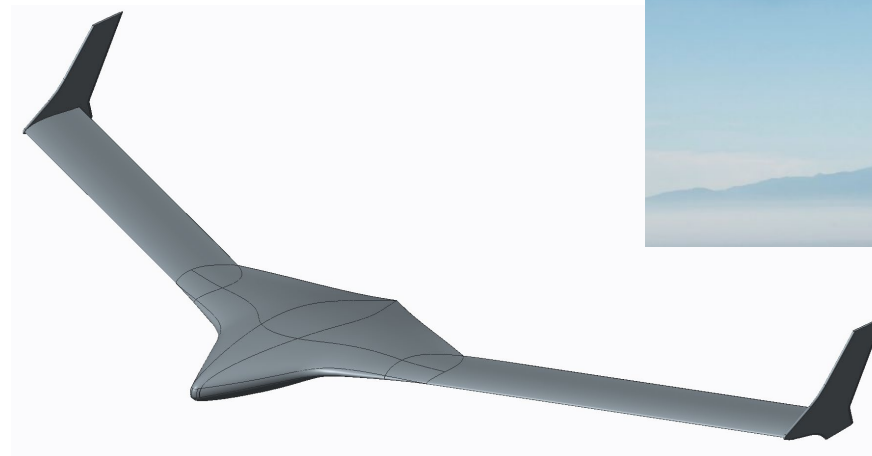


Credit: NASA/Lauren Hughes

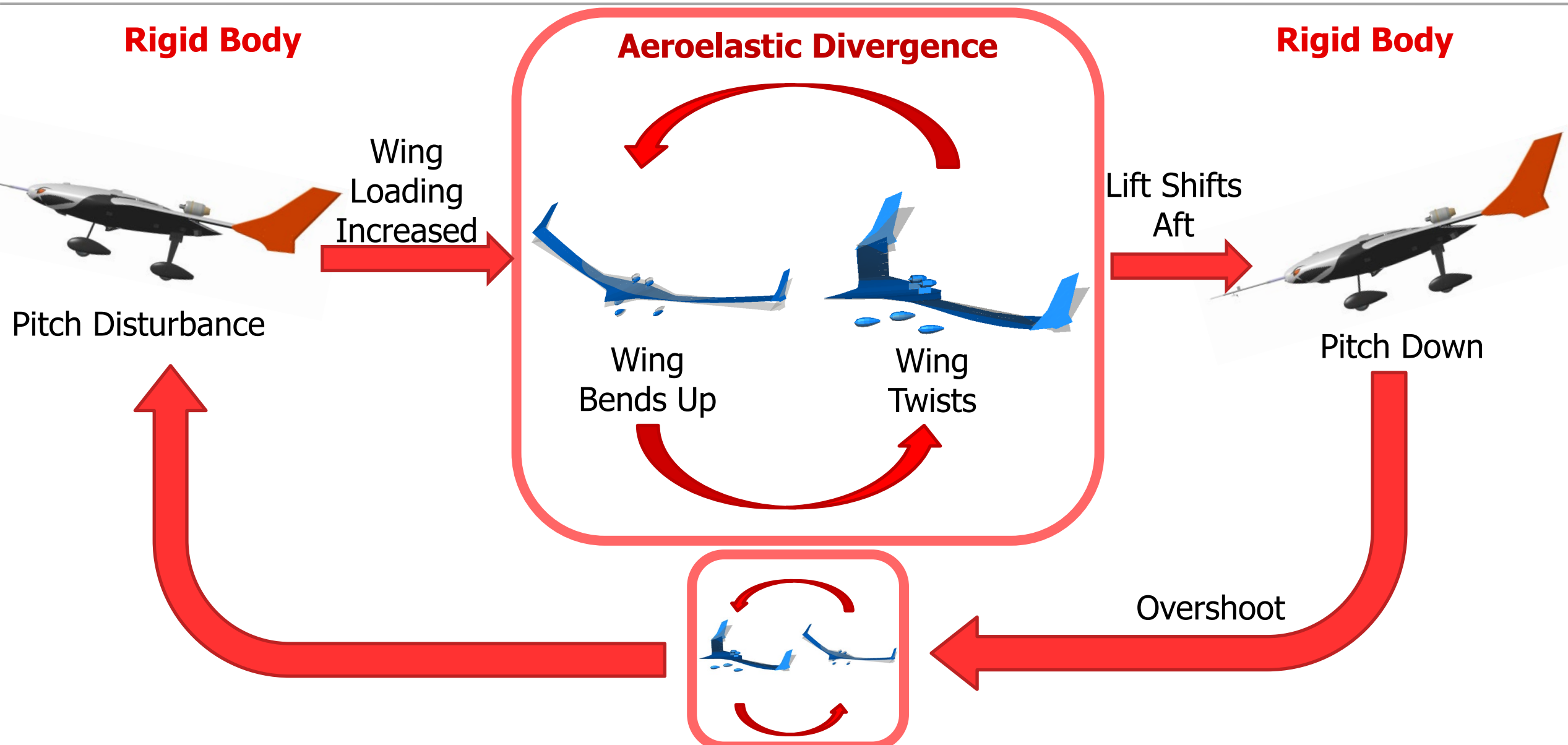
- Why flight test working group?
- Why X-56A?
- Challenges in flutter prediction
 - Rigid body modes
 - Winglet/wing interaction
 - Thick lifting center body
 - Engine/airframe interaction
- Data Released
 - Finite element model (NASTRAN®)
 - Doublet lattice model (NASTRAN®)
 - CAD geometry (IGES)
 - Airfoil cross sections
 - Frequency and damping from flight



Credit: NASA

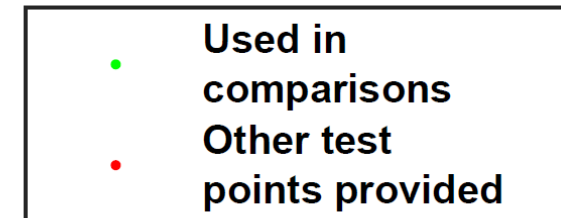
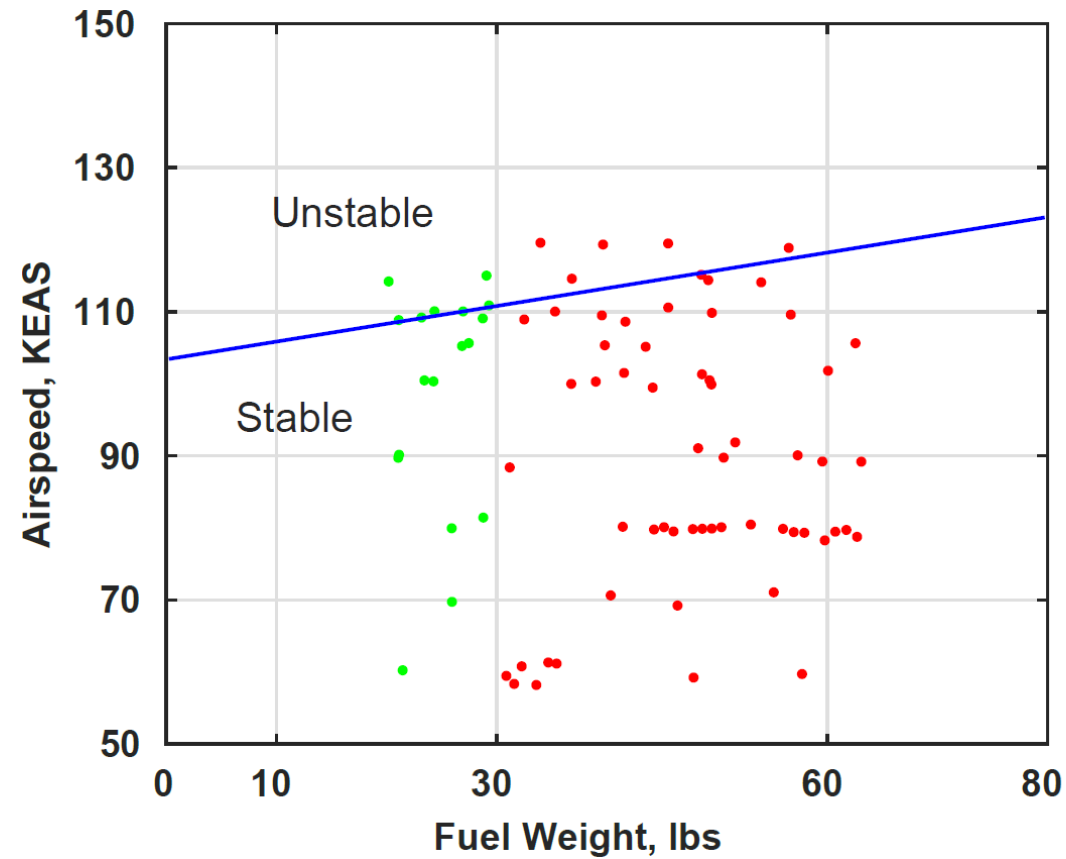


X-56 Body Freedom Flutter Mechanism





- Flight Envelope
 - Fuel weight, lbs
 - 10 lb used for analysis
 - Equivalent airspeed, knots

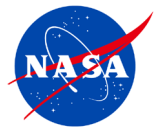




Participants

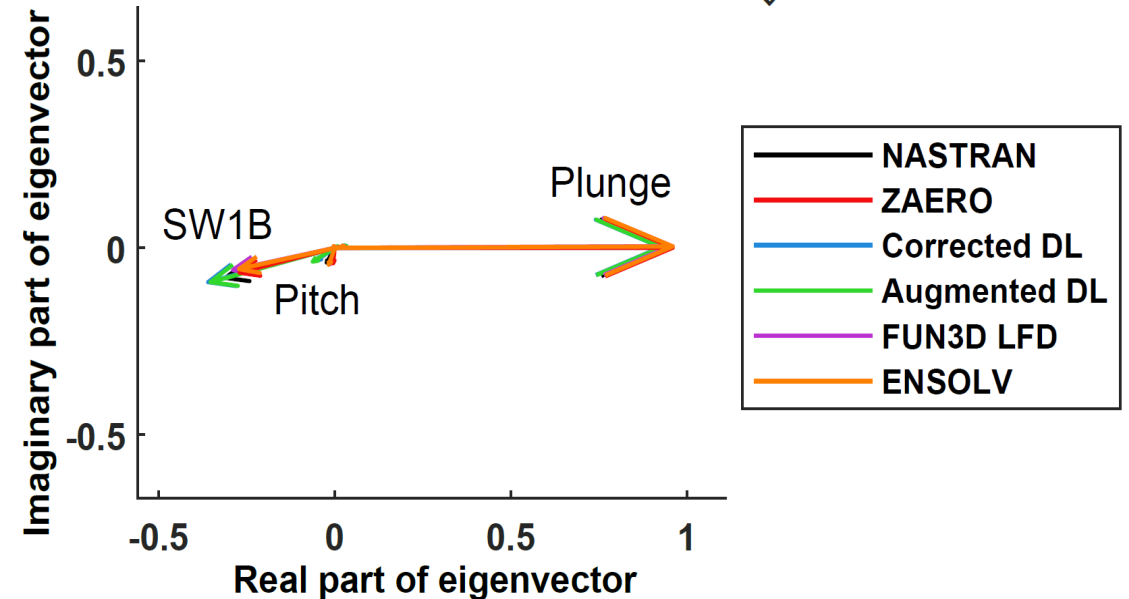
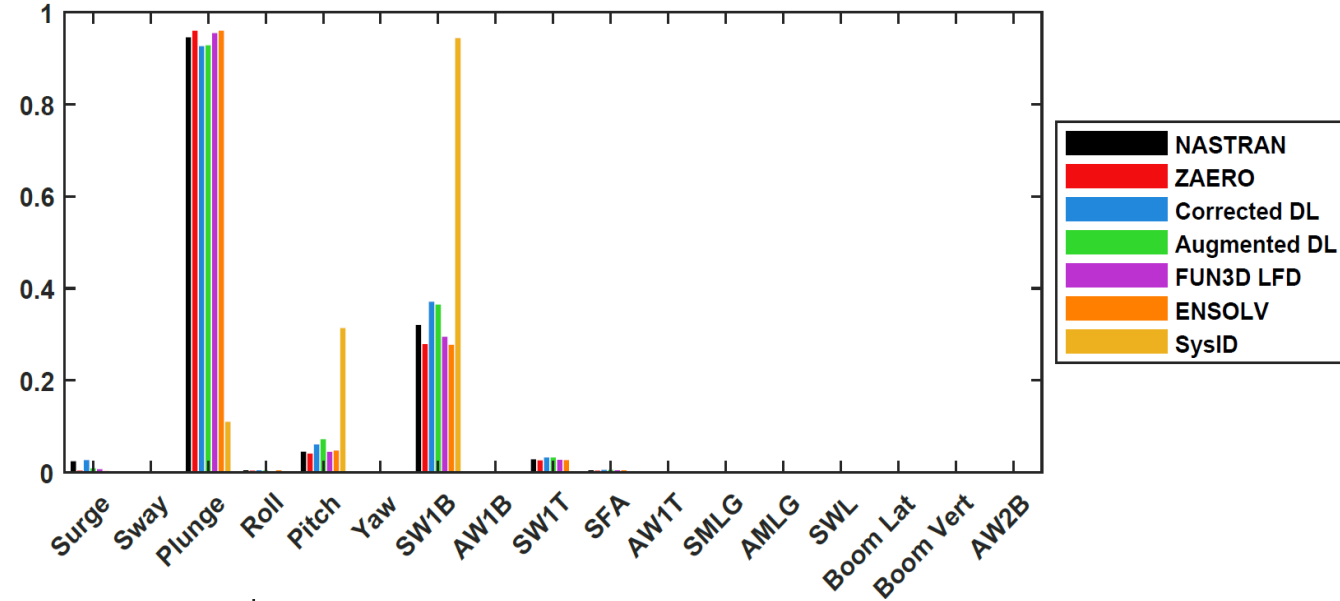


Analysis Code/Approach	Methods	Analysis Team
FUN3D LFD	RANS	Steve Massey, Bret Stanford, Kevin Jacobson
ZAERO™	Linearized Potential Flow	Jos Aalbers, Huub Timmermans, Iren Mkhoyan and Peter Blom
ENSOLV	RANS	
NASTRAN®	Linearized Potential Flow	Jeffrey Ouellette, Felipe Valdez, Chris Miller, Matthew Boucher
Corrected DL	Hybrid lifting surface	
Augmented DL	Hybrid lifting surface	
Transfer Function Fit	Flight Data	
System Identification	Flight Data	Jared Grauer

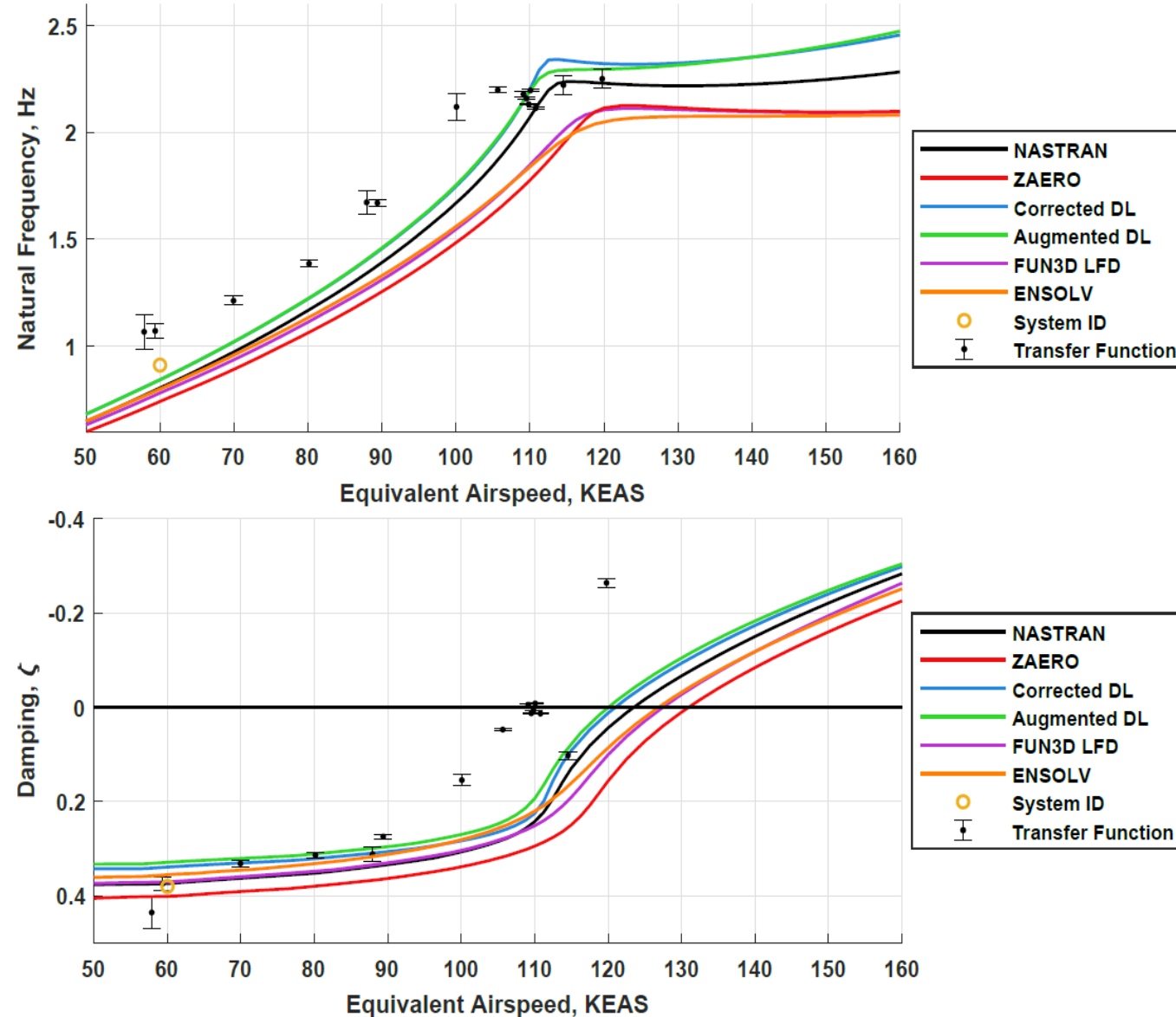


- Flutter Mode shapes
- Frequency and damping
 - Body freedom flutter vs equivalent airspeed
 - Paper also shows bending torsion flutter
- Aerodynamic Work
 - Which modes are dissipating energy or extracting energy from the flow?
- Generalized Aerodynamic Forces
 - Omitted from presentation for time

- Normalized to unit magnitude
- All the computational models gave similar flutter mode shapes
 - Phase matches for plunge and symmetric bending
 - The corrected doublet lattice shows phase shift in pitch mode
- System ID did not give correct flutter mode
 - Missing a torsion mode

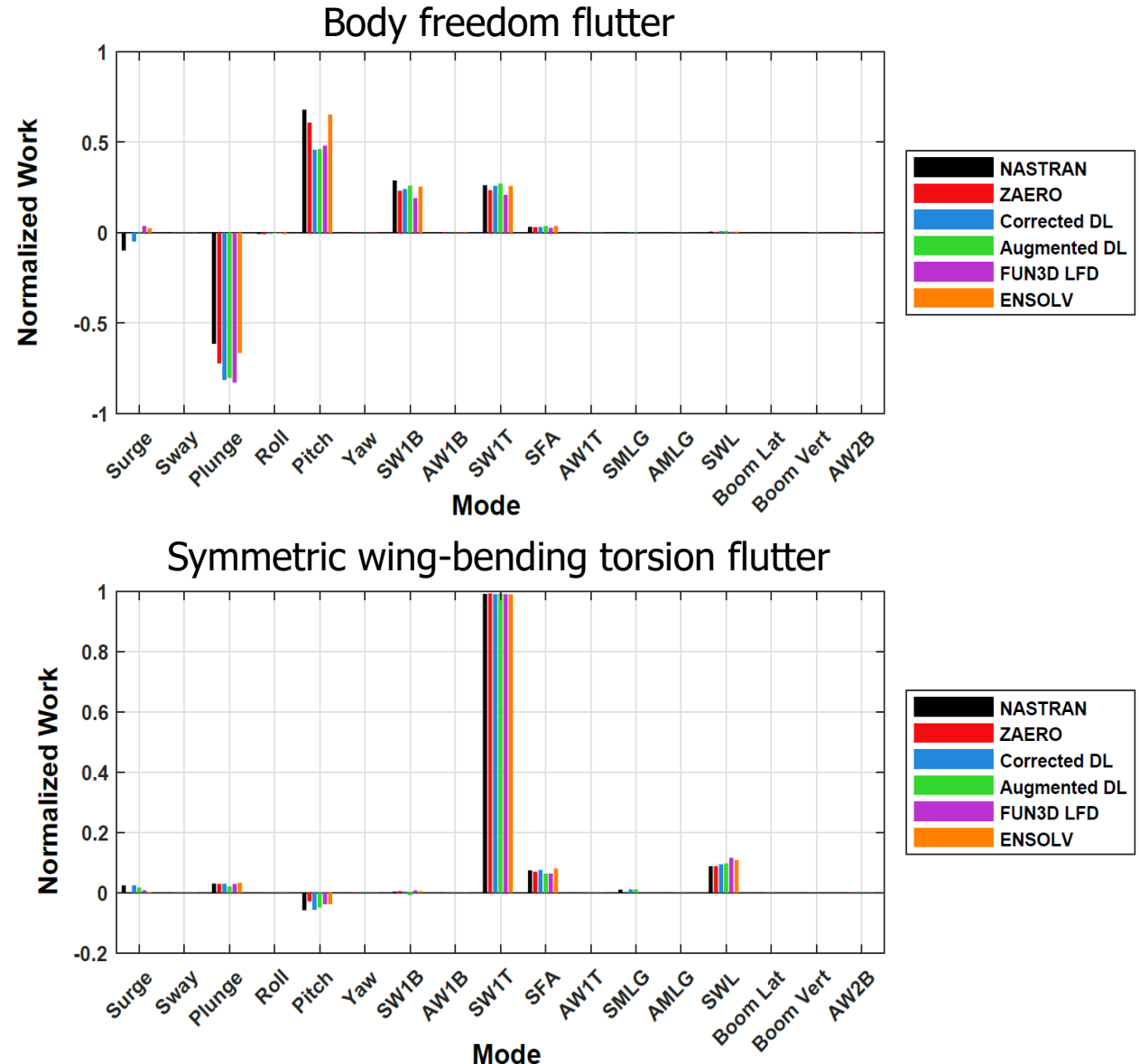


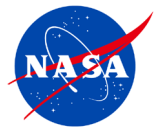
- Body freedom flutter
- 10 lb fuel in analysis
- P-k flutter analysis
 - All using the same analysis
- ω_n , natural frequency
- $\zeta = 1$, critically damped
- Models give consistent predictions
 - Predict flutter 10-20 knots high
 - Predict lower frequency
- Flight test analysis show differences in frequency



- Aerodynamic work
 - Nonconservative work over the cycle

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 - Which modes are destabilizing
 - Normalized to unit magnitude
- Aerodynamic work showing more difference between the methods
 - FUN3D and Corrected DL show more dissipation by plunge
- Aerodynamic work nearly identical for bending torsion flutter





- Flutter predictions of X-56A flex wings from the Flight Test Working Group of the Third Aeroelastic Prediction Workshop
 - Five computational models from three groups presented
 - Two flight-test data analyses from two groups
- All methods gave reasonable predictions of flutter speed
 - All methods predicted a higher flutter speed
 - Different test data analyses can show different results
- Lessons for future workshops
 - Better to provide a more detailed geometry to teams
 - Engines could have shown more differences in results
 - Multiple approaches to analyzing test data are useful