ATA ENGINEERING, INC.

Taking a Glider from Design to Flight

Your Host: Matt Schumann, ATA Engineering, Inc.

Your Speaker: Tim Marinone, ATA Engineering, Inc.

Date: March 8, 2023

Who We Are

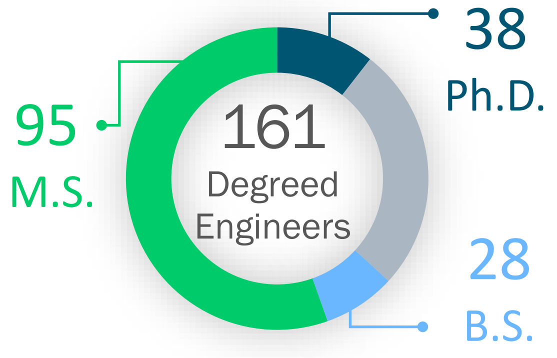
We are an ***employee-owned*** *small business with a* ***full-time staff of over 190***

Subject-matter experts recognized by:

- ✓Society of Experimental Mechanics
- ✓American Society of Mechanical Engineers
- ✓American Institute of Aeronautics and Astronautics

11 ***Registered Professional Engineers***

15 *Average years of experience*



Aerospace

Spacecraft

Hypersonics & Composites

Defense

Industrial & Mining Equipment

Themed Entertainment

What We Do

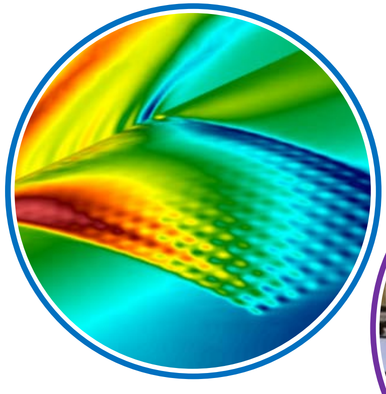
ATA Engineering's **high-value engineering services** help solve our customers' toughest product design challenges

Our Services

We provide our customers with ***complete, integrated solutions***

Design

From initial concept development to detailed structural design

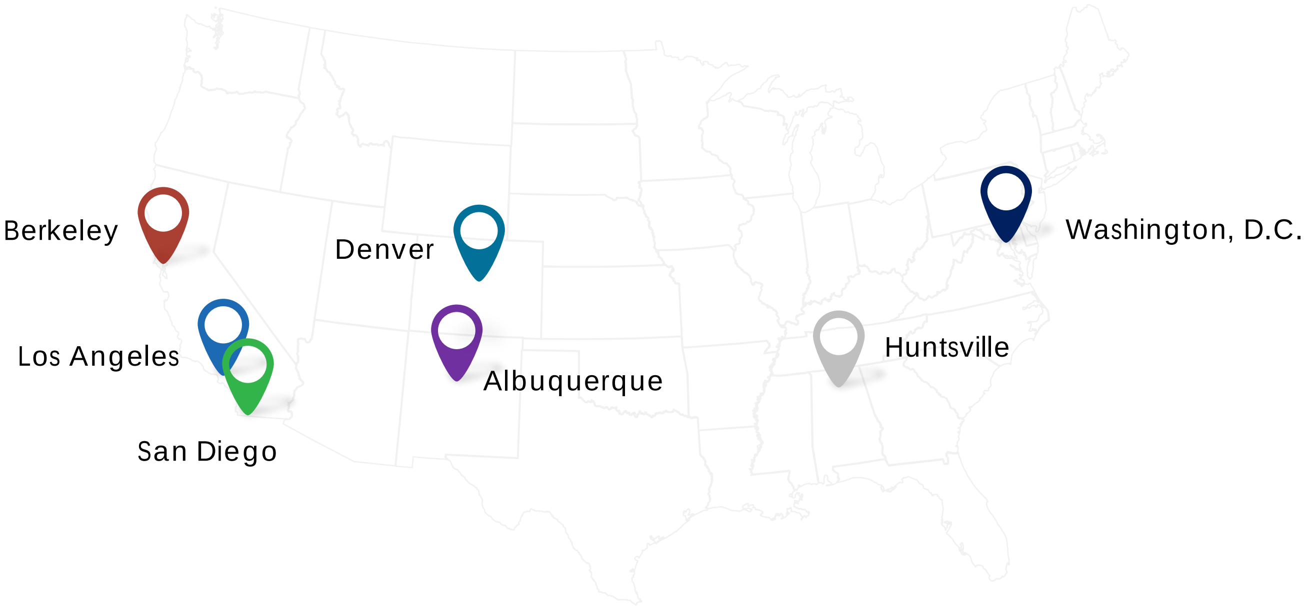


Analysis

Comprehensive structural, fluid, acoustic, and thermal analysis services

Test

Industry-leading structural test services for extreme loading environments



ATA Engineering is also a Siemens Platinum Level Solution Partner

Expert Partner
Digital Industries Software
SIEMENS

Our Software Services

ATA is a value-added reseller for ***Siemens PLM Software***

Siemens Value Added Reseller

Hotline Support

Nastran Training Material

Software Implementation

Preferred Training Provider

Software Integration

Expert Partner
Digital Industries Software
SIEMENS

Today’s Speaker

Timothy Marinone, ATA Engineering, Inc.

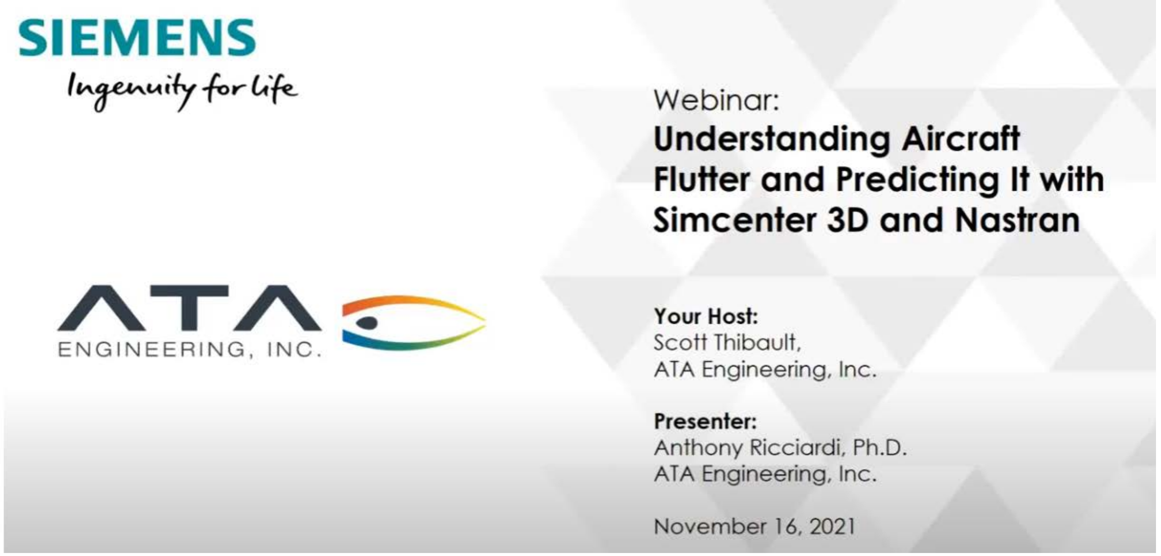
- Mr. Marinone is a Project Engineer in ATA’s Advanced Test group. For 10 years he has supported customers with a focus on vibration and modal testing of defense systems and flight vehicles and has performed real-time flutter monitoring of flight tests for military and commercial aircraft to ensure both flight safety and accurate flight measurements. He received his BS and MS in Mechanical Engineering from the University of Massachusetts Lowell in 2010 and 2012, respectively.

Agenda

This is not a Flutter Course nor a Detailed Guide for Performing Aeroelastic Predictions, Ground Vibration Tests, Model Correlation, or Flight Testing

- Flutter Overview
- The Siemens Portfolio
- The Perlan II Glider

Additional Resources



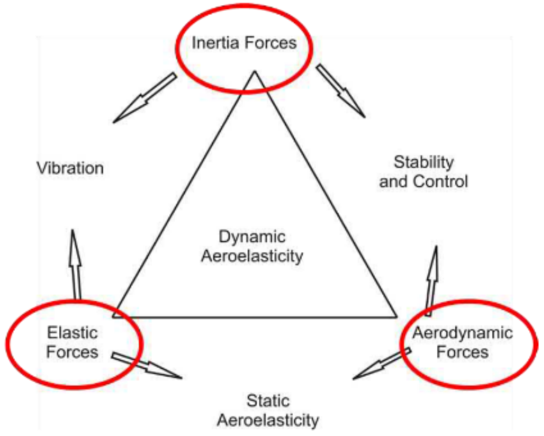
- ATA Engineering released a webinar in 2021 that specifically talked about evaluating flutter with Simcenter 3D and Nastran and walked through an example
- Siemens has a great article covering flutter
- Siemens also has a free on-demand webinar about the flutter clearance process

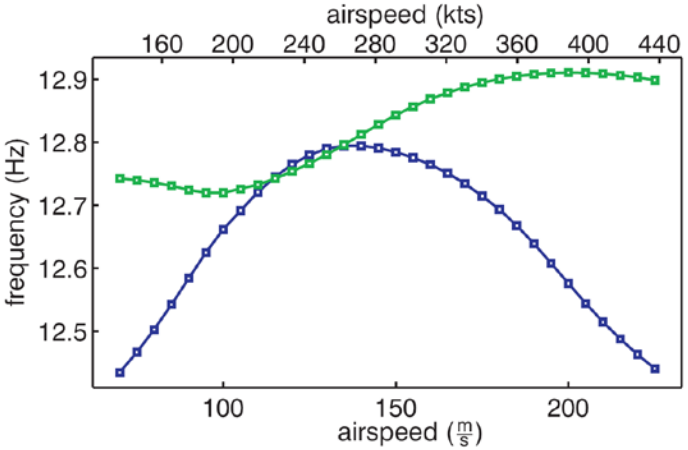
Flutter Overview

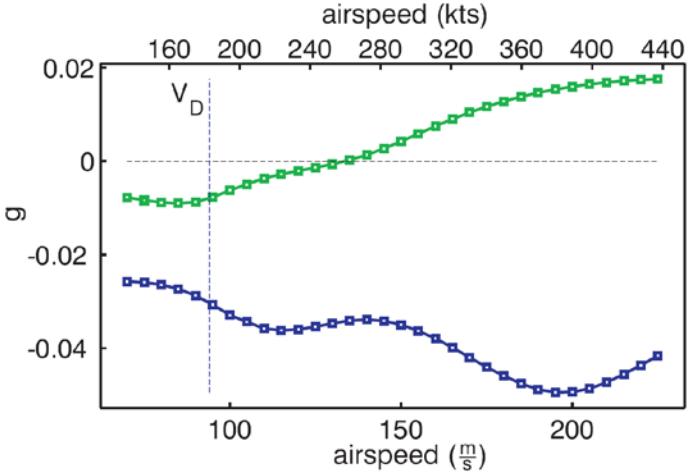
What is Flutter?

Flutter is an aero-elastic phenomenon
- Unstable self-excited vibration
- Structure extracts energy from the air stream

Flutter starts to occur at a certain speed
- Negative damping start to occur at flight points where two modes are coupled in an unstable way
- Typical coupling: wing bending/torsion, wing torsion/control surface, wing/engine



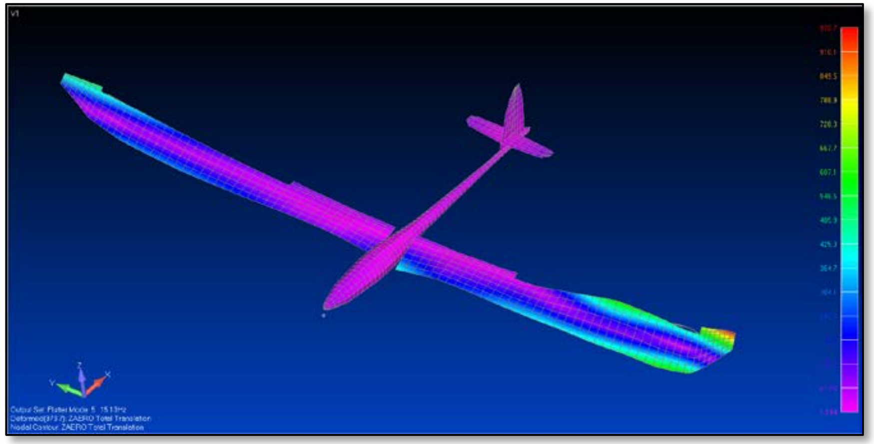




Aero-elastic Analysis Necessary for Safe Flight

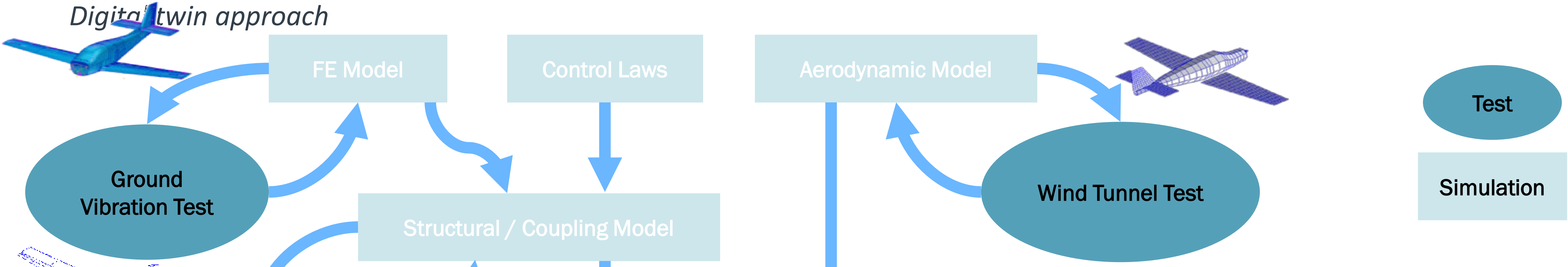
Why Perform an Aero-elastic Analysis?

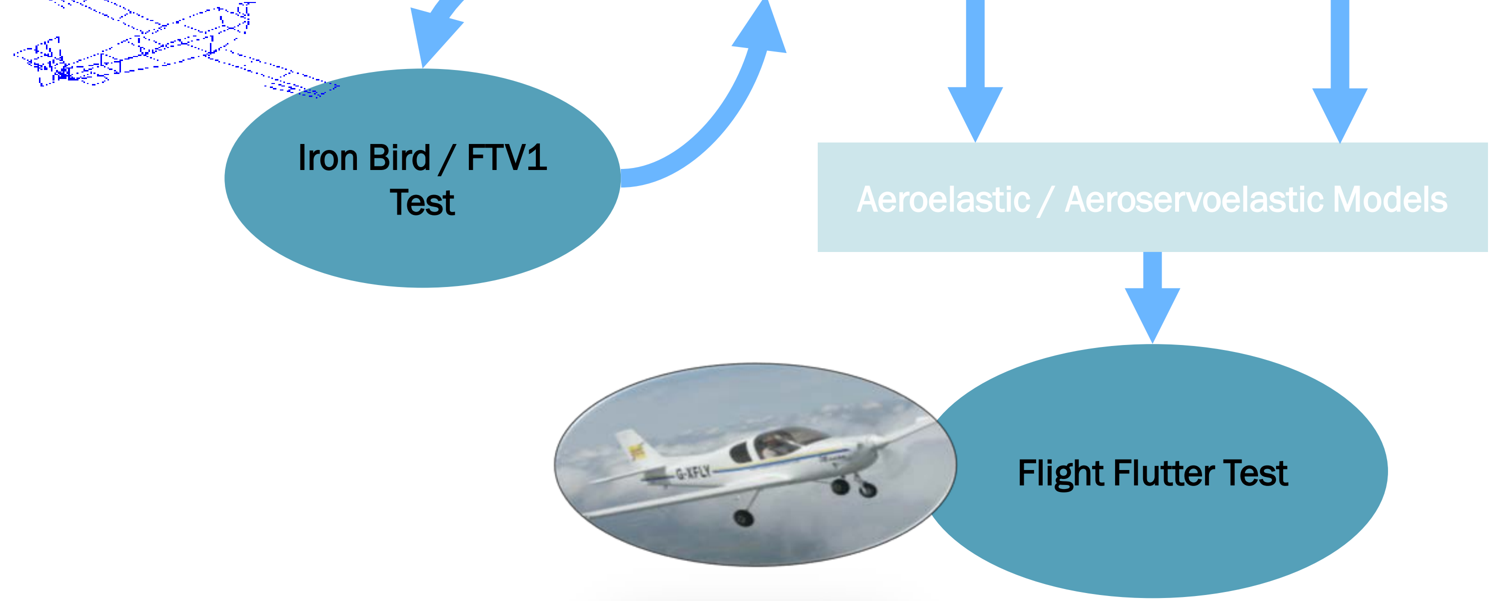
- Aero-elastic analysis allows prediction of an aircraft's aerodynamic instabilities which can result in catastrophic failure
- Analysis utilizes a finite element model (FEM) for the aircraft's natural frequencies and mode shapes
- Ground vibration testing is performed on the aircraft to correlate and update the FEM
- Aero-elastic analysis is performed to identify flight conditions where flutter is expected to occur
- Final verification of the aircraft's aero-elastic properties is performed through flight testing



Airframe design validation process in support of certification

Digital twin approach





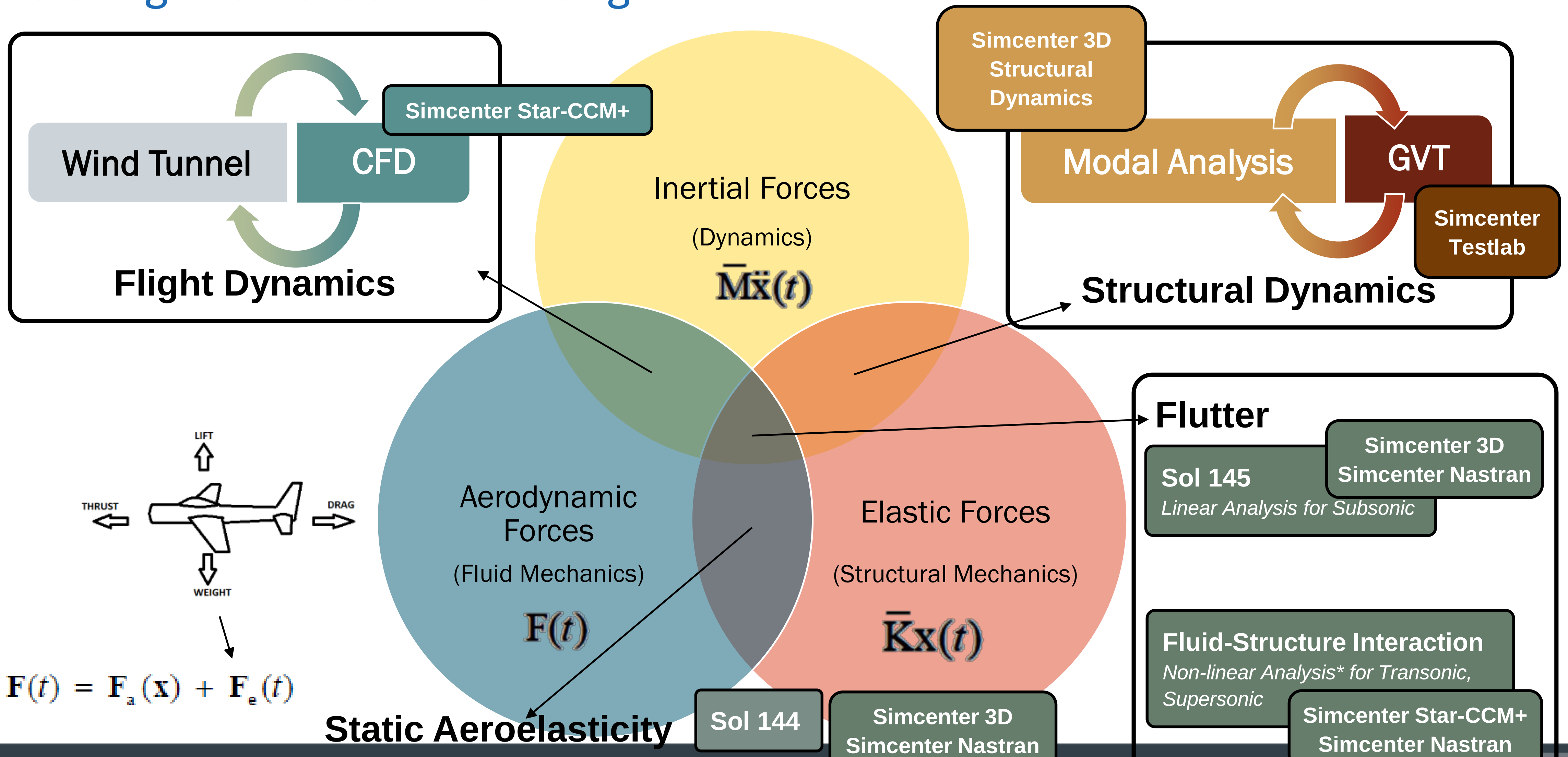
This process is used to proof compliance to FAA or ESA Aeroelastic Stability Requirements. It validates that the aircraft is flutter free throughout the entire flight envelope, plus an additional safety margin.

Certification-critical validation activities
➔ need to process with well-controlled data flow

The Siemens Portfolio

$$\bar{M}\ddot{x}(t) + \bar{K}x(t) = F(t)$$

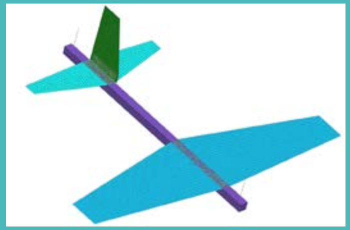
Simulating the Aeroelastic Triangle

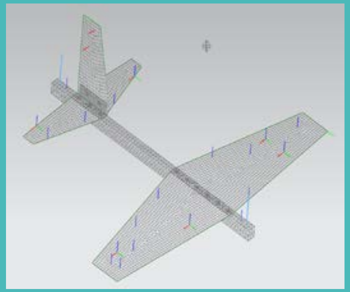


Structural Dynamics supported by Test AND Simulation

Complete, streamlined solution for structural dynamics

Pre-Test Analysis





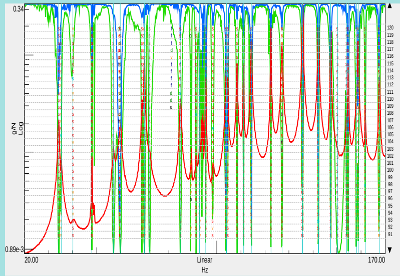
Simcenter 3D Structural Dynamics

Test

Instrument

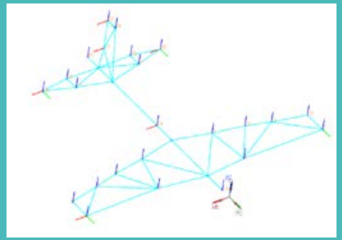
Measure

Modal Analysis

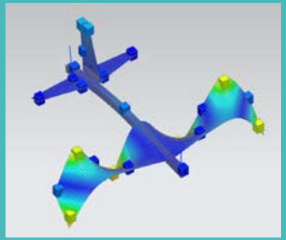


Simcenter Testlab Structures Acquisition & Analysis

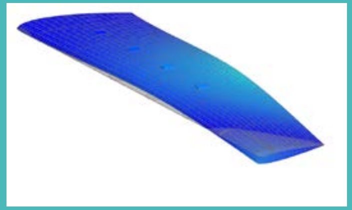
Correlation & Updating

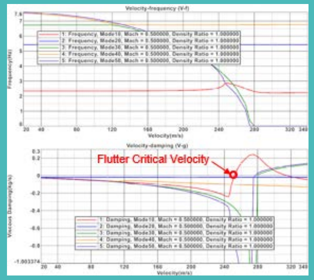


Simcenter 3D Structural Dynamics



Flutter simulation



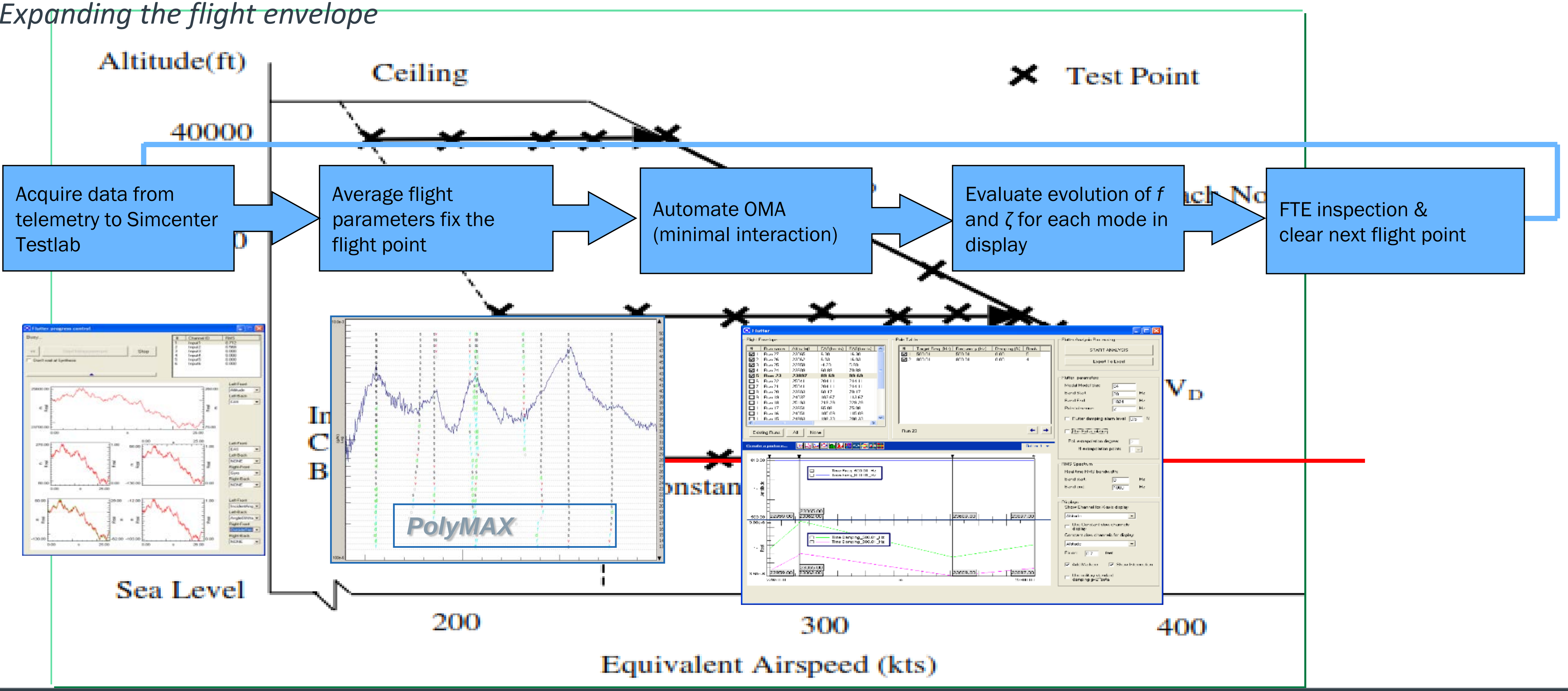


Simcenter 3D Aero elastics

Flutter testing procedure

Expanding the flight envelope

Acquire data from telemetry to Simcenter Testlab → Average flight parameters fix the flight point → Automate OMA (minimal interaction) → Evaluate evolution of *f* and *ζ* for each mode in display → FTE inspection & clear next flight point

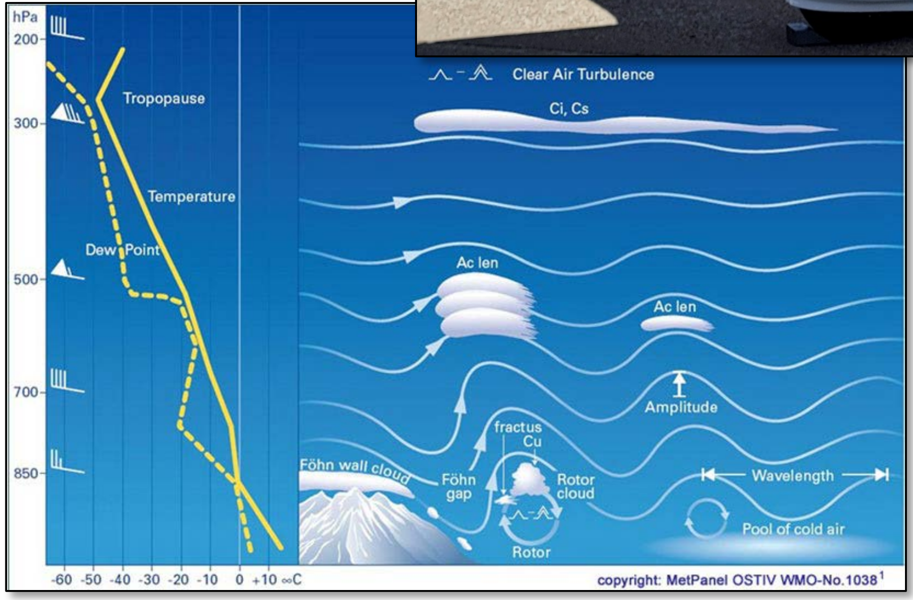


The Perlan 2 Glider

Airbus Perlan Mission 2 Overview

Reaching the Edge of Space

- Perlan 2 is a composite sailplane designed to fly to 90,000’
  - Previous record (altitude for powerless flight) set by Perlan I in 2006 at 50,671’
  - Perlan 2 holds record at 76,000’ as of September 2018
- Perlan 2 utilizes stratospheric mountain waves
  - Altitude at 90,000’ has air density less than 3% of sea level
  - Temperatures reach -70 °C

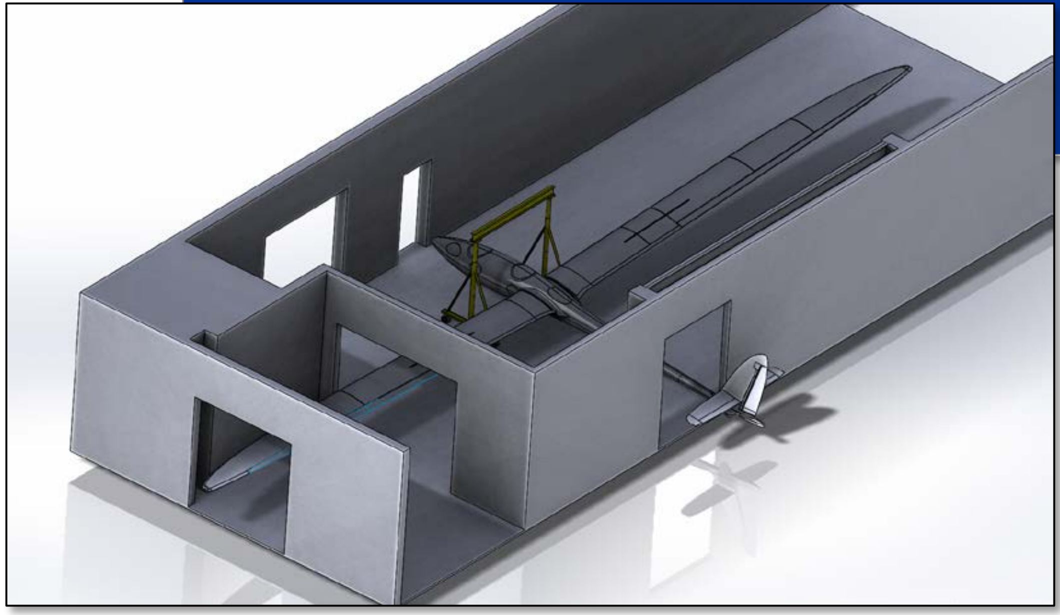


Perlan Flight Video – 3 minutes

Finite Element Model to Represen Aircraft

Model Creation

- Model was created from solid geometry
  - Missing large amount of information needed for stiffness and mass
  - Required test data to get an accurate representation (especially in joints)
  - We also used the solid geometry to make sure that the glider would fit inside ATA's test lab.



First Aircraft GVT Performed at ATA

Assembly and Test Setup

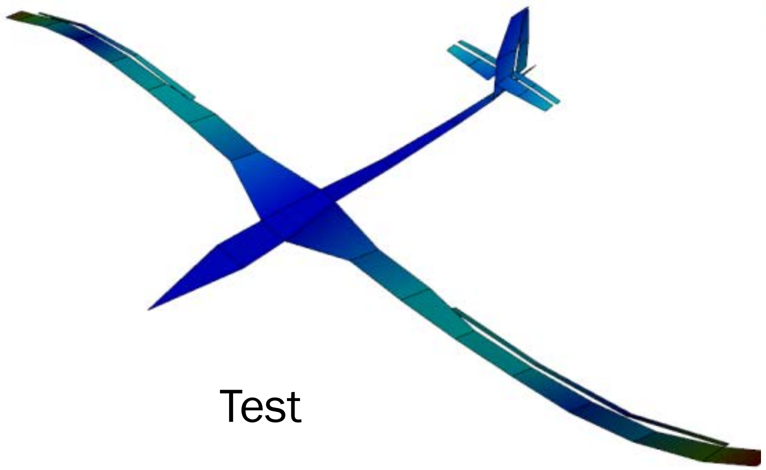
- Sailplane trailered down from Oregon
- Fuselage, wings, and tails offloaded
- Individual components were weighed to obtain mass and C.G.
- Wings and tails were assembled onto fuselage
- Accelerometers were installed
- Sailplane suspended with bungees and shakers were installed

A GVT in 90 seconds

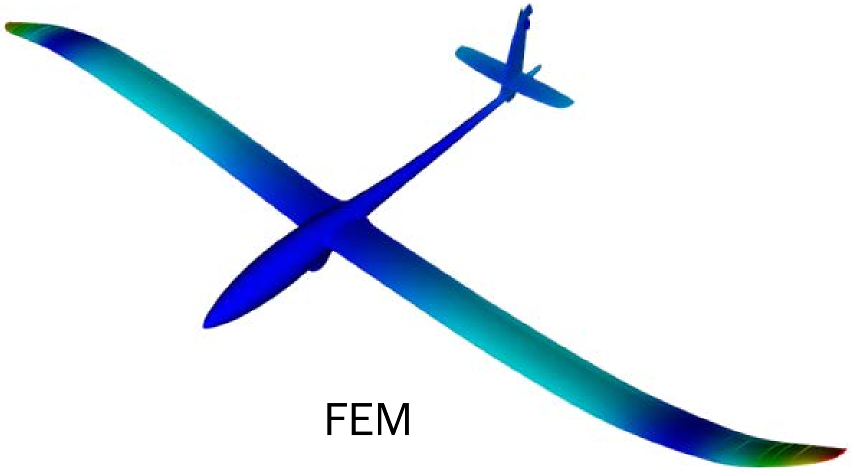
Updating the FEM

Mass and Stiffness Correlation

- Mass and C.G.
  - Major components tuned by adjusting density and non-structural mass of the elements
- Stiffness properties
  - Adjust material and spring properties to best match the test mode shapes and frequencies



Test

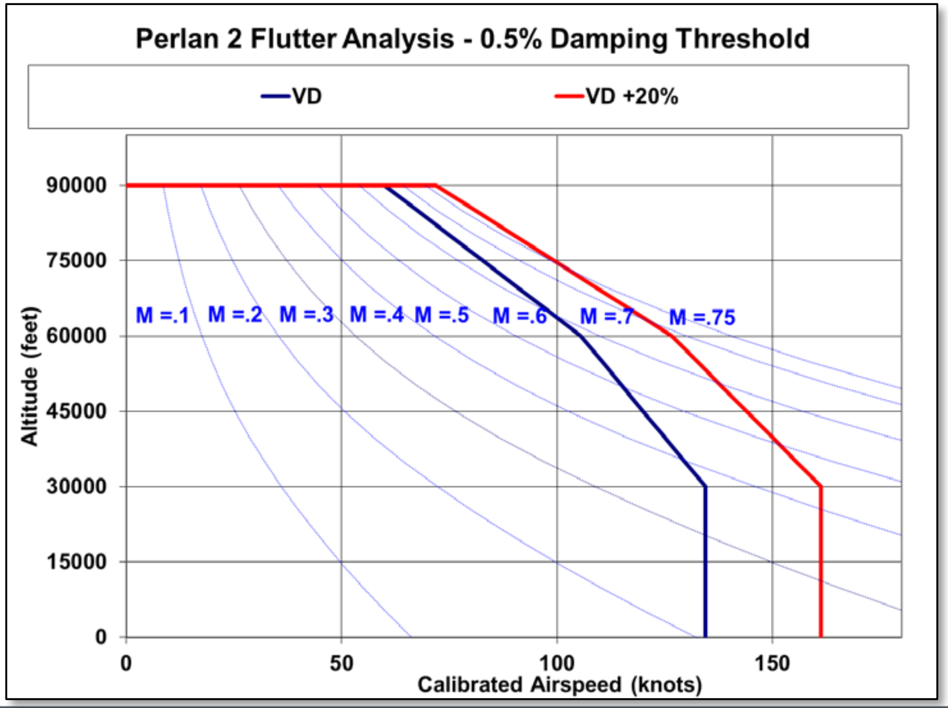


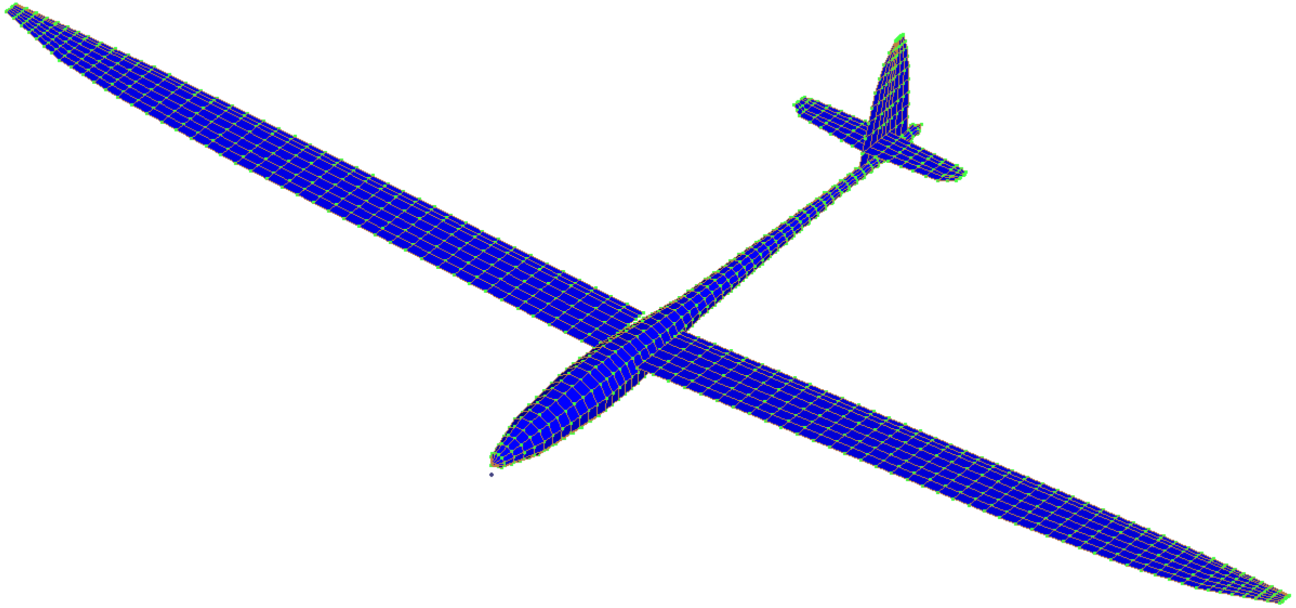
FEM

Aeroelastic Model Created using FEM

Model Development

- Geometry from the FEM was used to develop the model for analysis of the provided flight envelope
  - Lifting surfaces are modeled as plates (wings, h-stab, v-stab)
  - Non-lifting surfaces are modeled as bodies (fuselage)

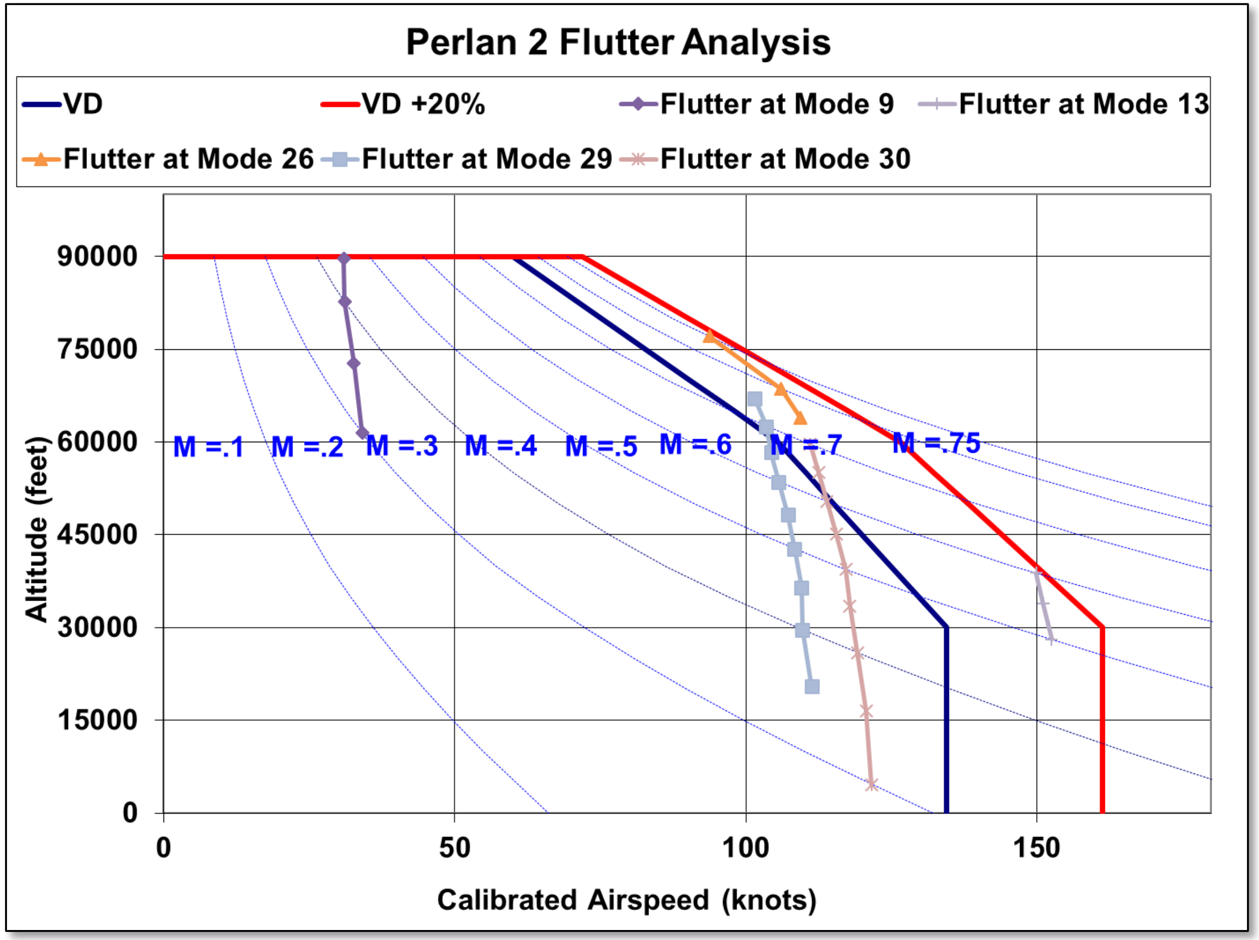




Instabilities Observed in Flight Envelope

Final Flutter Results

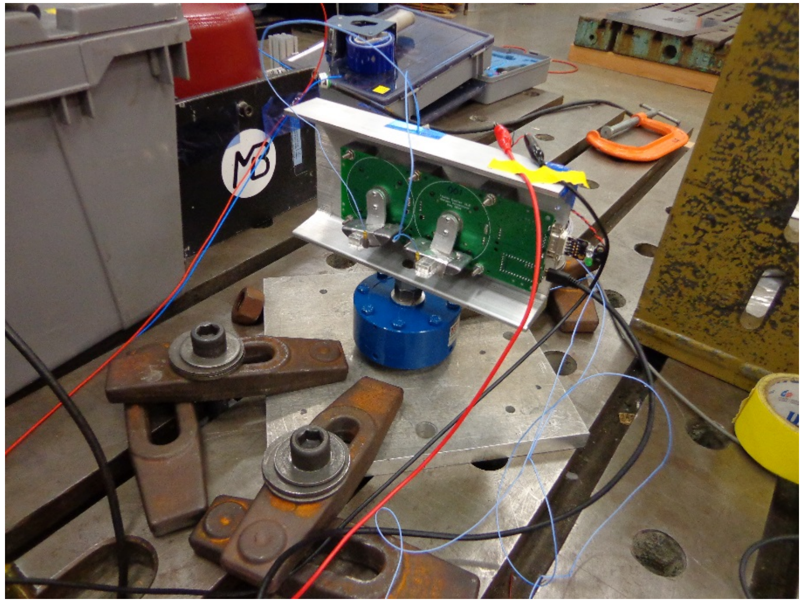
- Instabilities observed at airspeeds/altitude combinations expected to see during flight
- Recommendations were made to increase aileron torsional stiffness
- Flight testing required to validate analysis

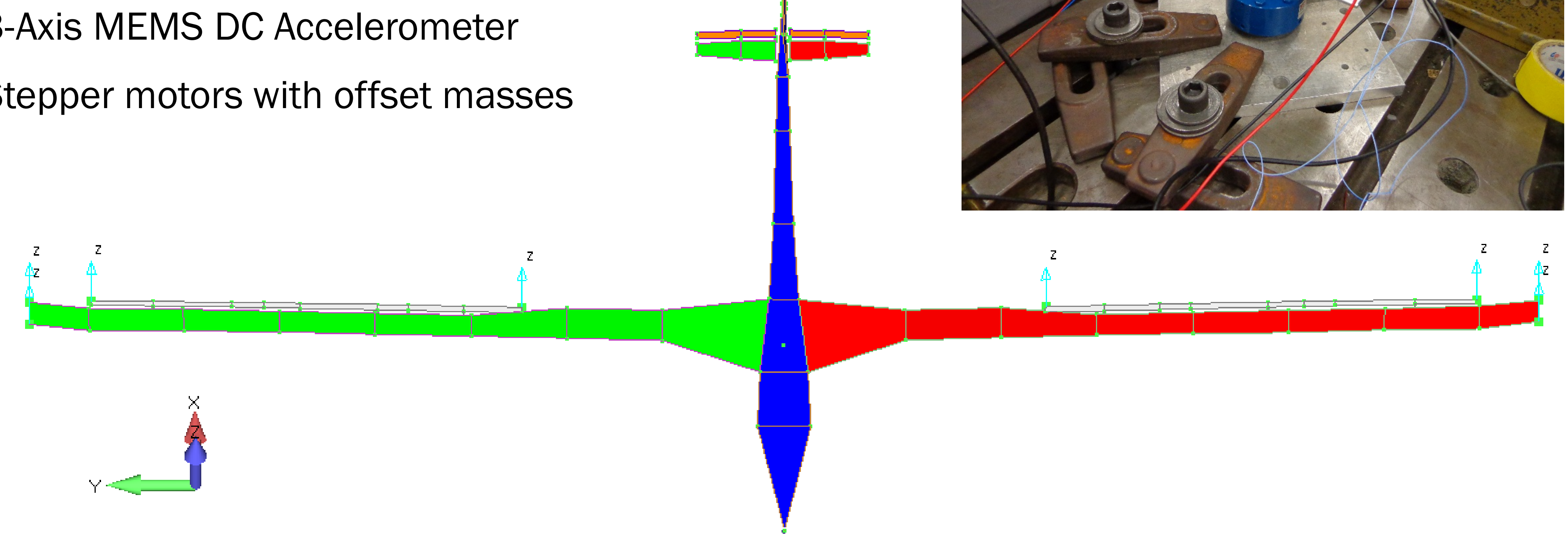


Preparing for Flight Testing

Instrumentation Checkout

- Custom data acquisition system:
  - Arduino board for data acquisition
  - 3-Axis MEMS DC Accelerometer
  - Stepper motors with offset masses

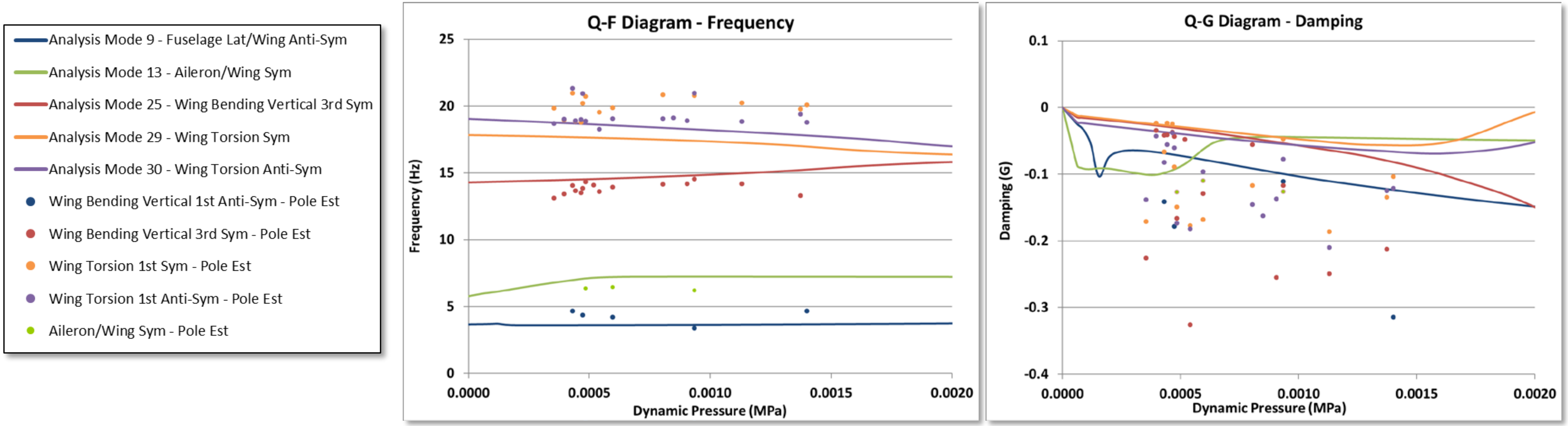




Flight Testing Results

Data Processing

- Frequencies correlate well with analysis
- Scatter in damping results



Acknowledgments/Thank You/Q&A

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