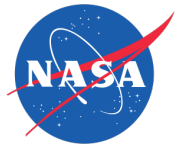

Design of a Collocation-Based Active Flutter Suppression Control Law for the IAWTM Wind Tunnel Model

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GNC-41: High Altitude / Endurance / Flutter

AIAA SciTech Forum

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Orlando, FL

Background and Overview

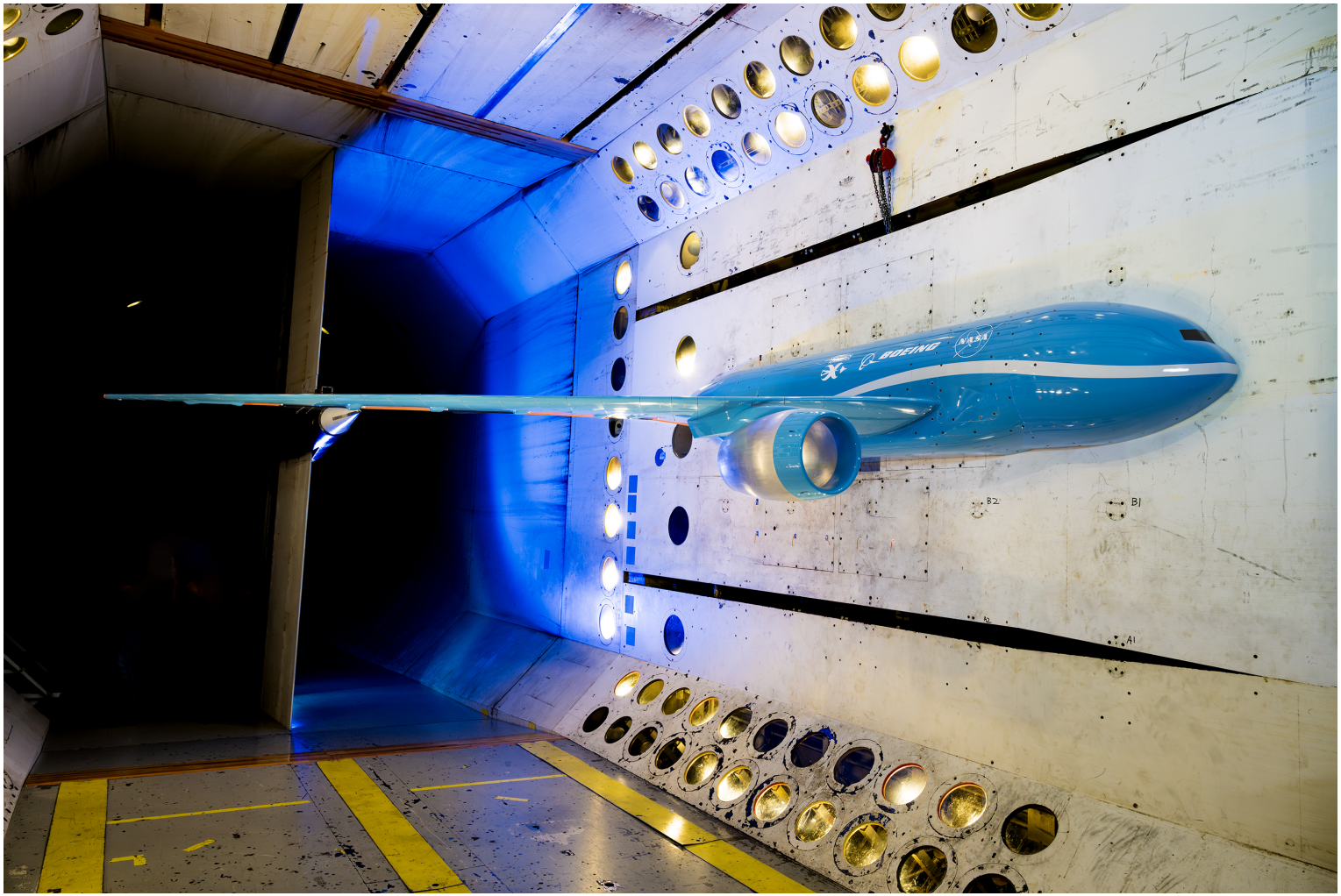
Advanced Air Transport Technology (AATT) project

- Targets fixed-wing transports
- Improve energy efficiency and environmental compatibility

IAWTM Sub-Project

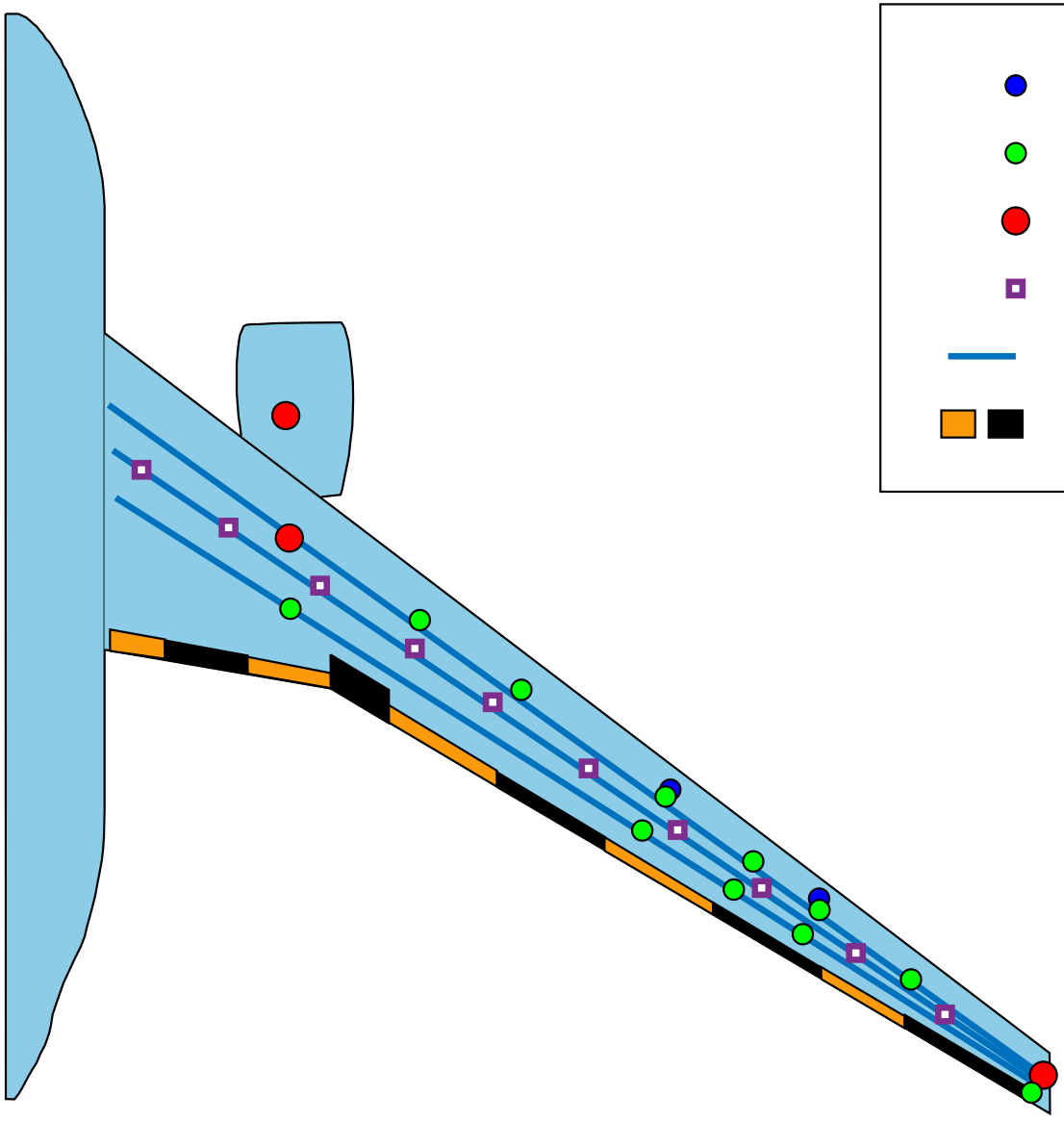
- Collaboration between NASA and Boeing
- Wind tunnel test starting in May 2024
- Multi-objective control laws
  - real-time drag optimization
  - maneuver load alleviation (MLA)
  - gust load alleviation (GLA)
  - active flutter suppression (AFS)

Wind Tunnel Test



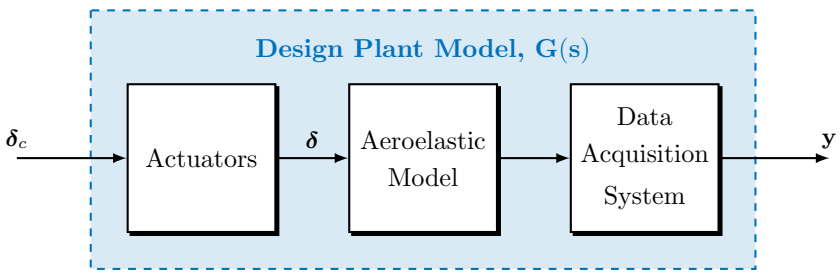
Credit: NASA / Mark Knopp

Instrumentation

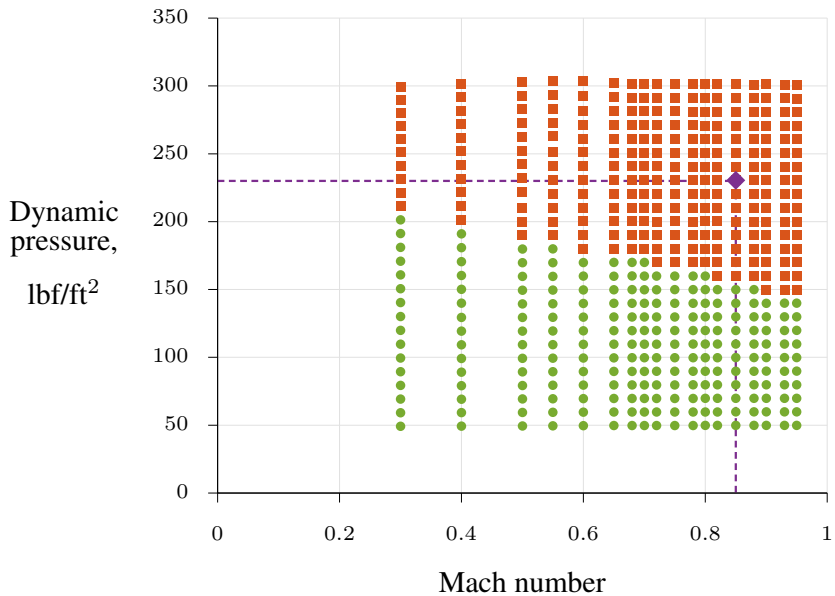


- Single a_x accelerometer
- Single a_z accelerometer
- Triaxial accelerometers
- Strain gauges
- FOSS cables
- Control surfaces

Plant Model Characteristics



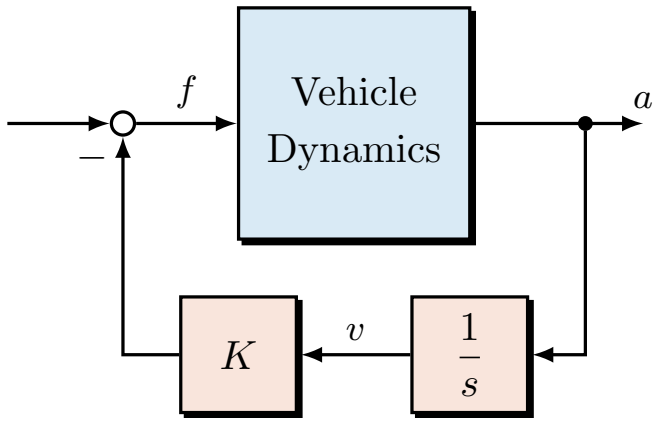
Analysis Points



Collocation Approach

Identically-Located Accelerometer and Force (ILAF): feed back local velocity to force input to increase damping of all aeroelastic modes

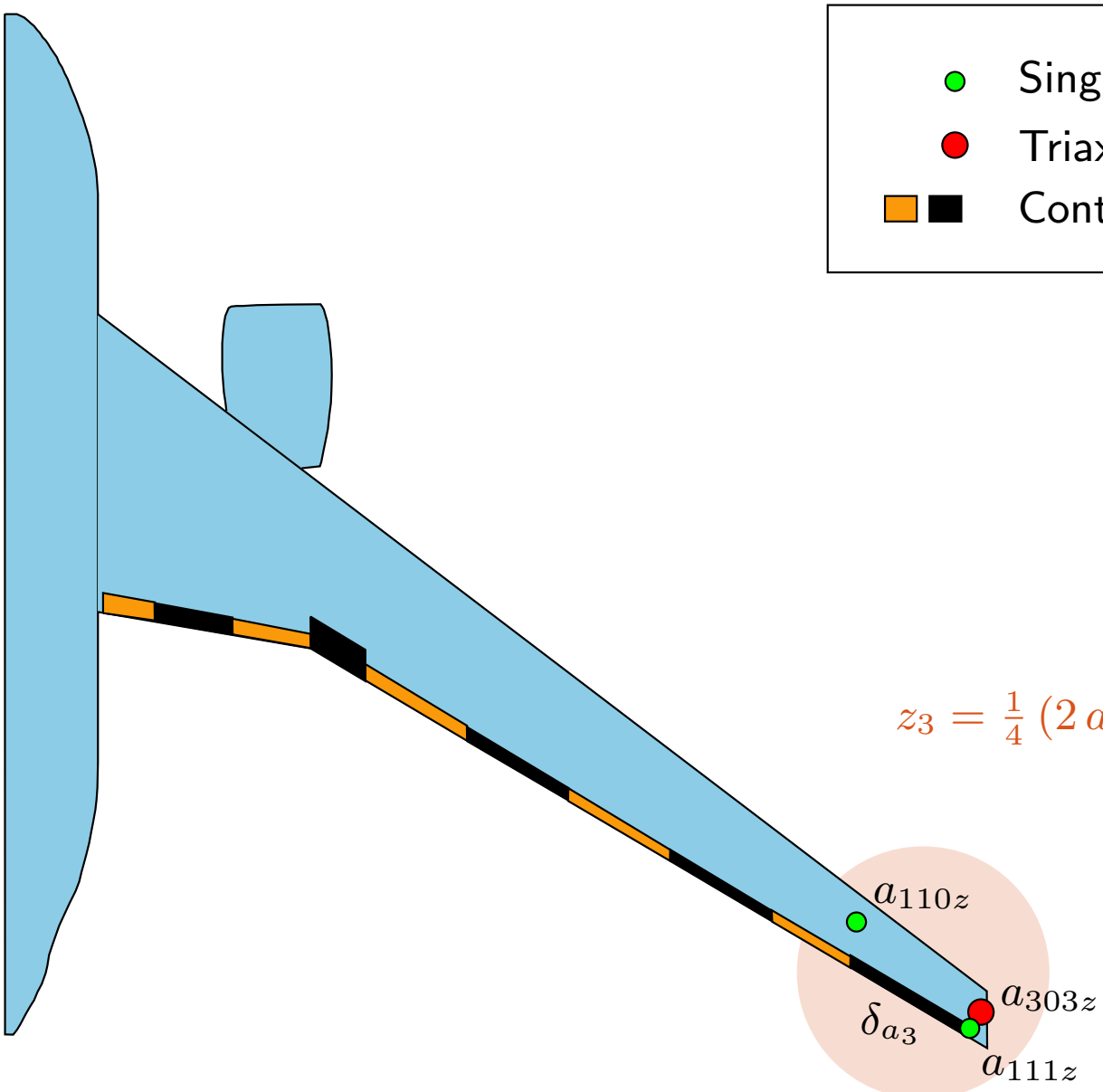
Simple and robust concept based on physical insight



Theory is violated:

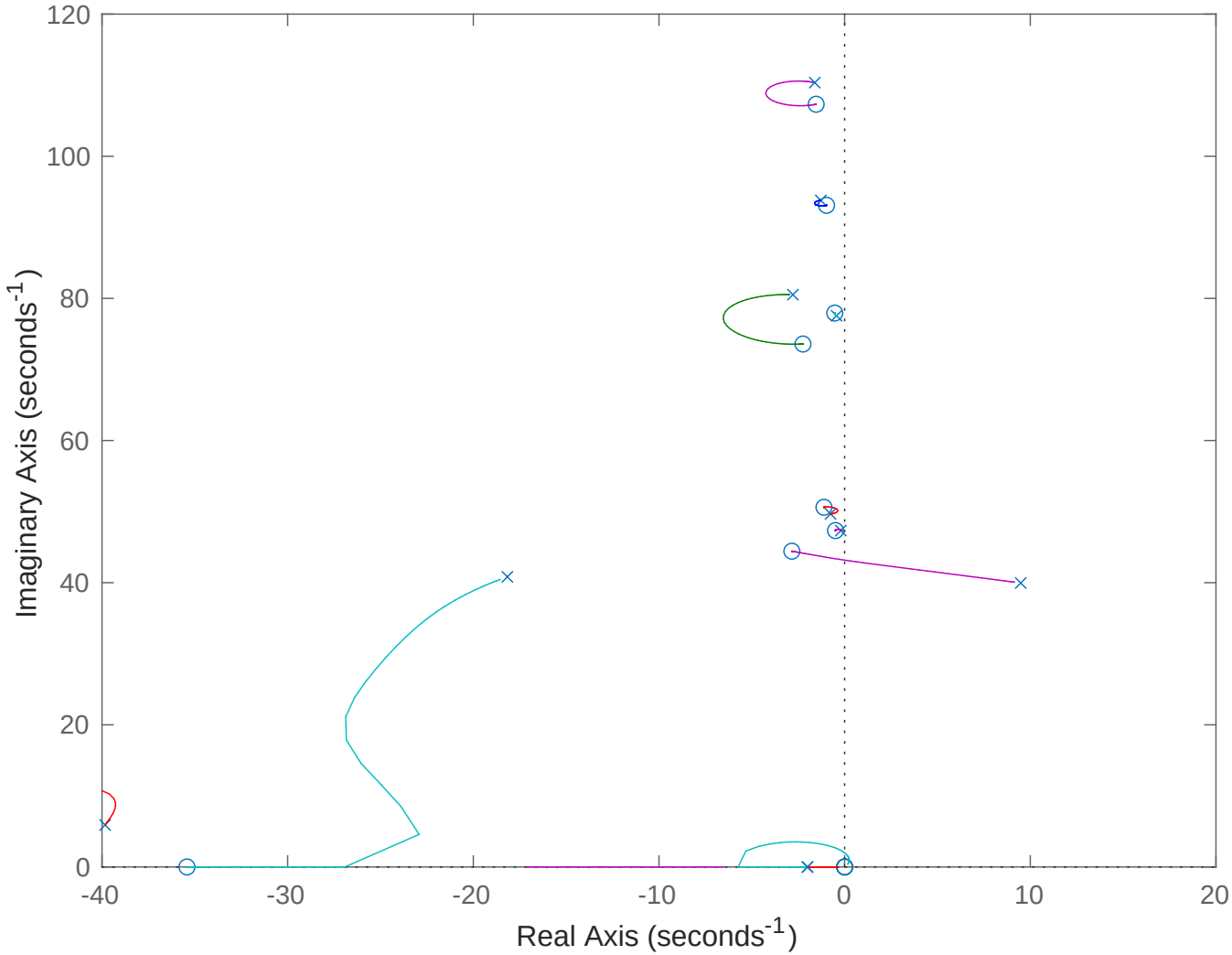
- Accelerometers and ailerons are not collocated
- Control surfaces are not force inputs

Accelerometers and Control Surfaces

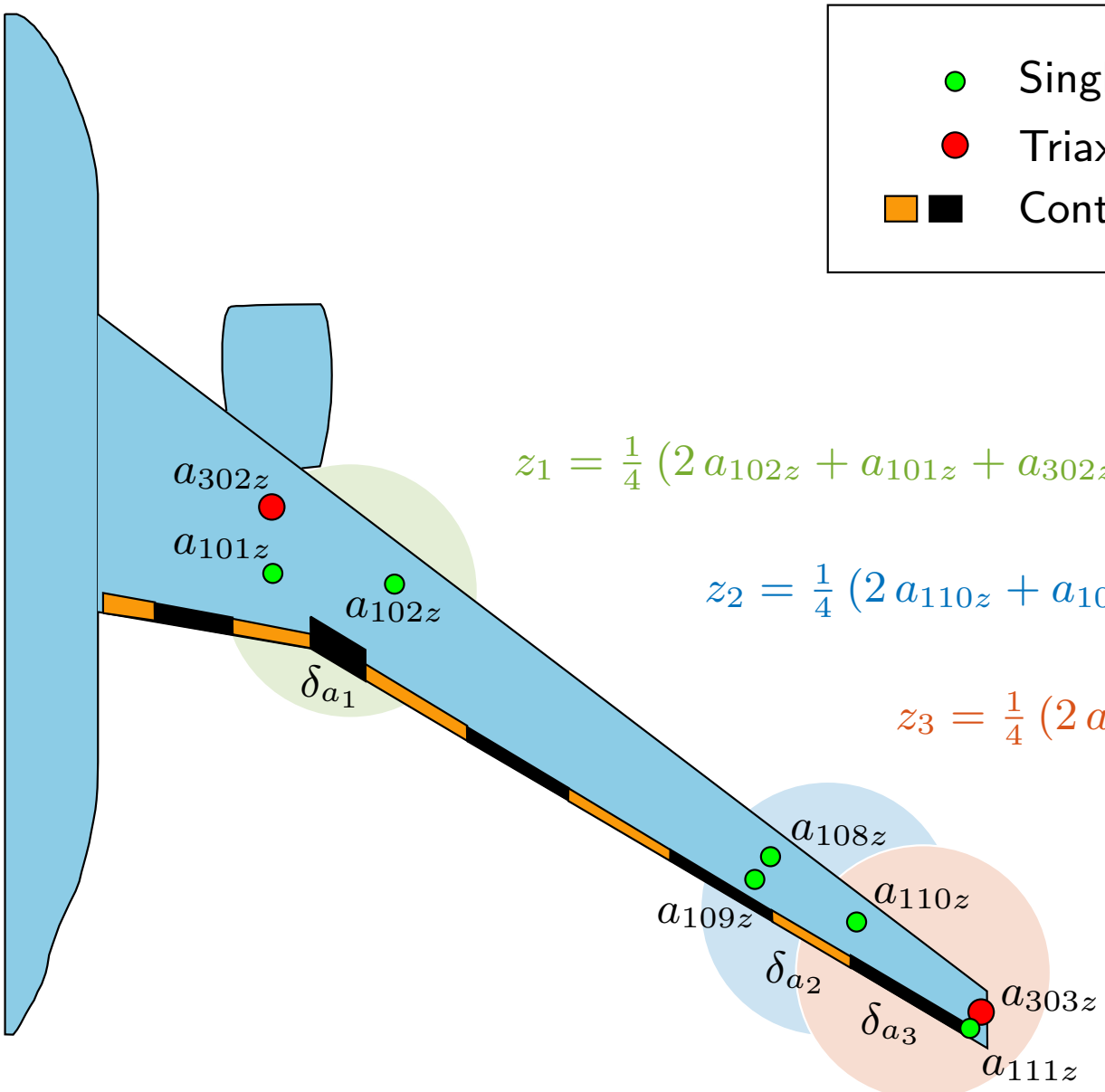


$$z_3 = \frac{1}{4}\left(2\,a_{110z} + a_{111z} + a_{303z}\right) \rightarrow \delta_{a_3}$$

Root Locus for $z_3 \rightarrow \delta_{a_3}$ (Design Point)



Accelerometers and Control Surfaces

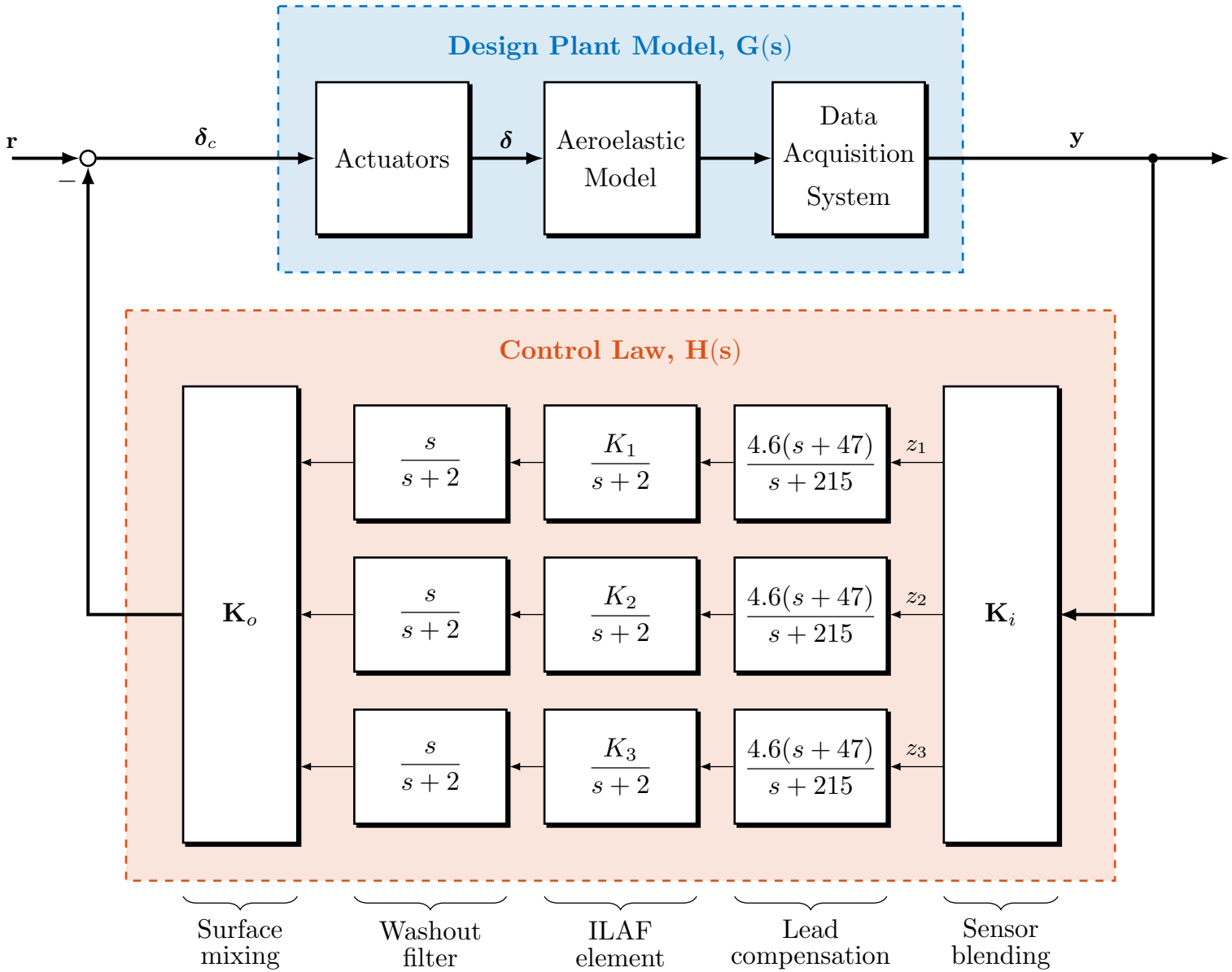


$$z_1 = \frac{1}{4}\left(2\,a_{102z} + a_{101z} + a_{302z}\right) \rightarrow \delta_{a_1}$$

$$z_2 = \frac{1}{4}\left(2\,a_{110z} + a_{108z} + a_{109z}\right) \rightarrow \delta_{a_2}$$

$$z_3 = \frac{1}{4}\left(2\,a_{110z} + a_{111z} + a_{303z}\right) \rightarrow \delta_{a_3}$$

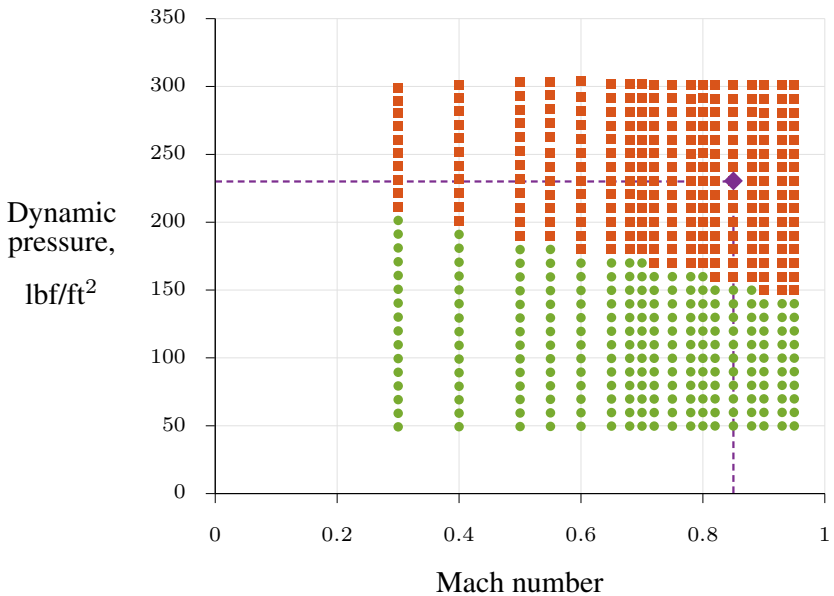
Block Diagram of the Closed-Loop System



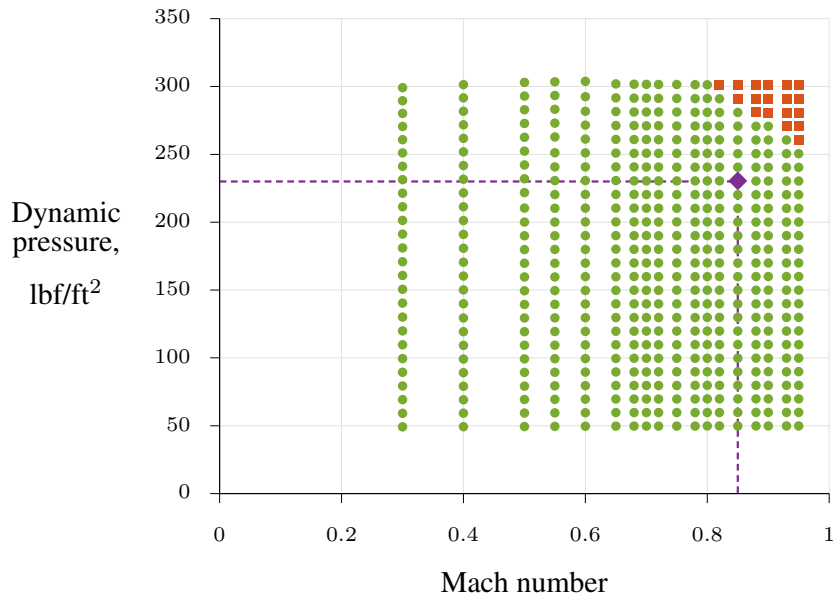
Analysis Points

Using fixed gains, $\mathbf{K} = \begin{bmatrix} 44.2 & 0 & 0 \\ 0 & 77.4 & 0 \\ 0 & 0 & 99.5 \end{bmatrix} \frac{\text{deg}}{\text{g}}$

Open Loop



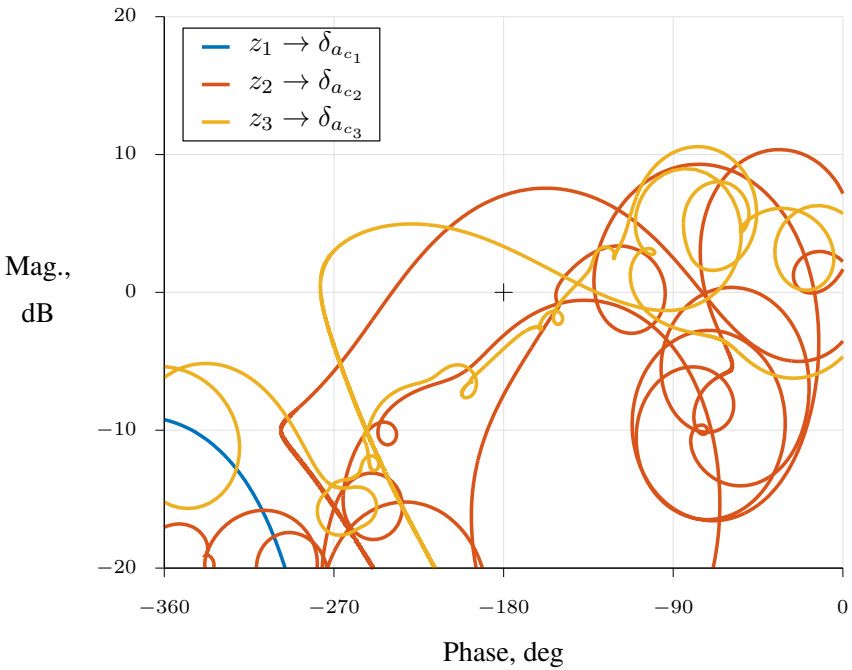
Closed Loop



Design point for the model stabilized

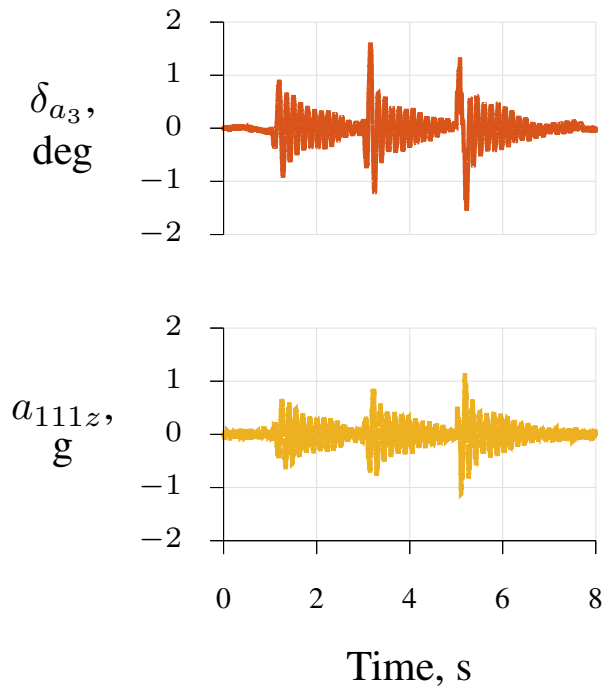
Analysis (Design Point)

SISO Nichols Chart



More than ±3 dB and 28 deg

Time-domain simulation



Stable, adequate control usage

Summary

Conclusions

- An ILAF control law could stabilize the test envelope
- Sensor blending scheme adequately approximated collocation
- MIMO loops can provide better robustness than a SISO loop
- Relatively simple architecture that can be updated quickly

Future and Ongoing work

- Iterate on design with model updates
- Schedule gains with tunnel conditions using robust methods
- Include uncertainties and tunnel turbulence