Transonic Flutter for a Generic Fighter Configuration

The KTH-NASA Wind-Tunnel Model.

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Agenda

- Background
- Testing at NASA Langley
- DLM Predictions
- CFD Predictions
- Summary

Background

Flutter?

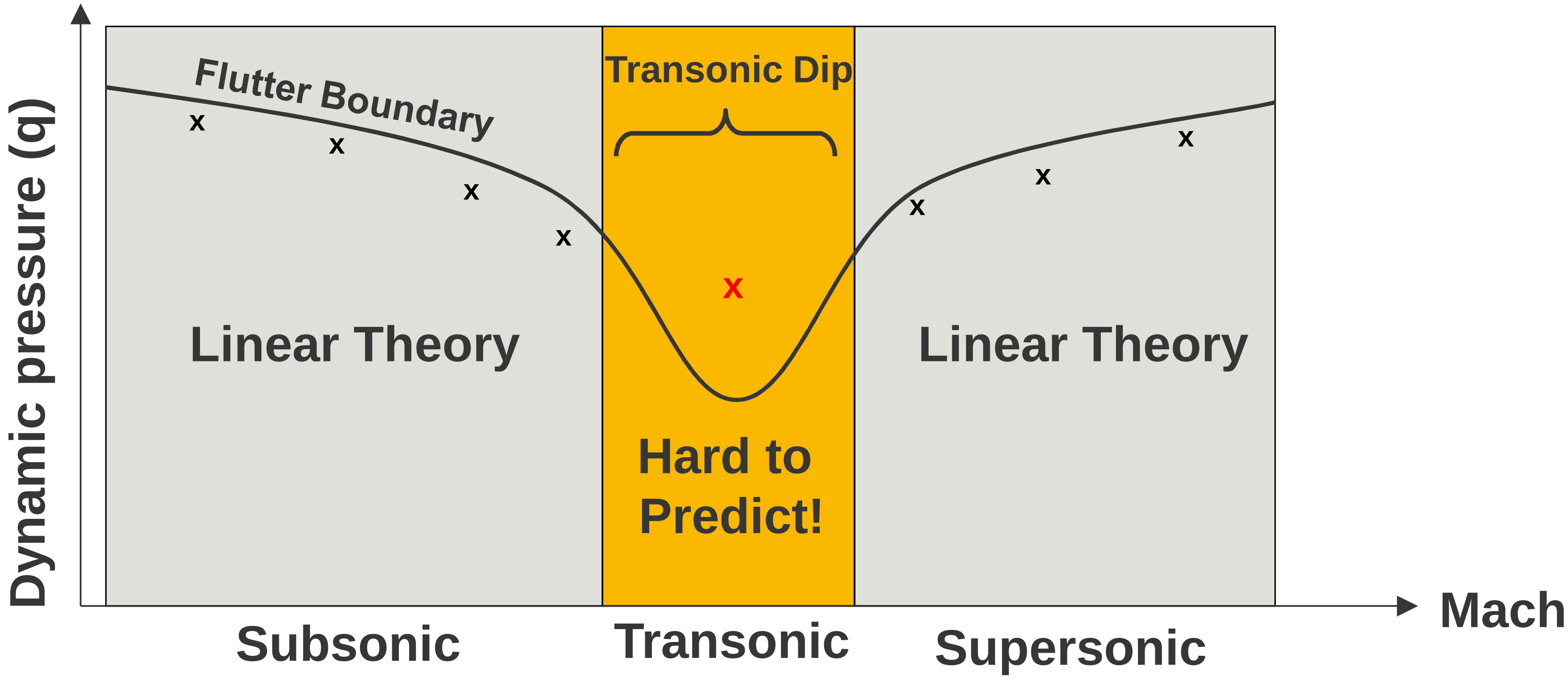
- Inertial forces, M
- Elastic forces, K
- Aerodynamic forces, Q

$$M + K + Q = 0$$

$$\downarrow$$

$$\boldsymbol{v} = \hat{\boldsymbol{v}} e^{(\sigma + i\,\omega)t}$$

Transonic flutter predictions

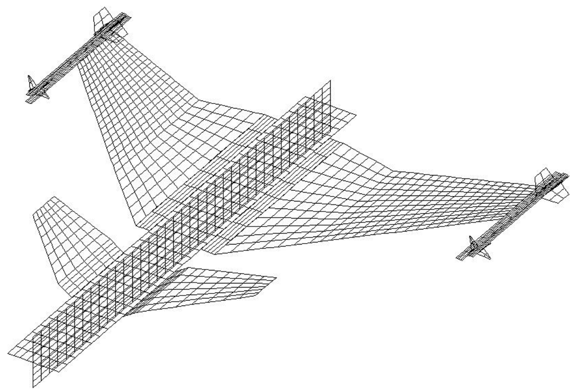


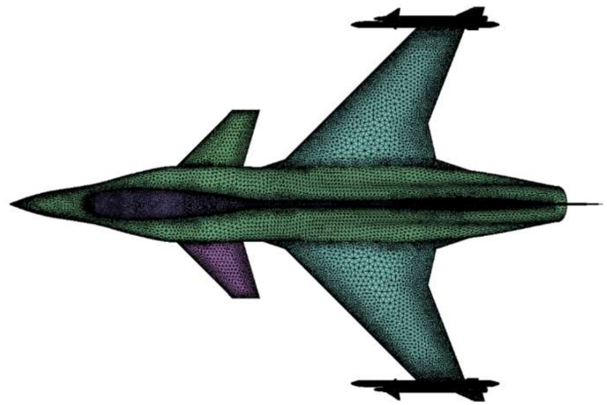
Transonic flutter experiments

- Prediction capability using different tool fidelity
  - What is "sufficiently" accurate?
  - Tradeoff between accuracy and computational cost

- Publically available data only available for civil applications, e.g. HIRENASD and DLR-F12

- Lack of publically available data for fighter aircraft with external stores. Difficult to understand nonlinear phenomena!





Testing at NASA Langley

Configuration built at KTH by Ulf Ringertz

Map the transonic dip, study possible LCO

Meas
pres

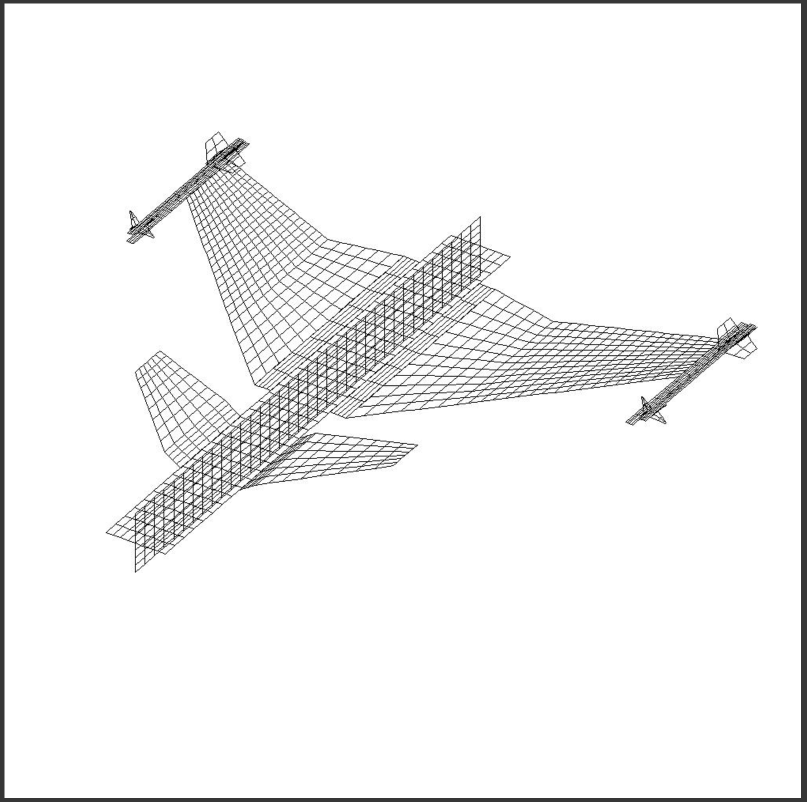
Two (transonic) flutter points found!

ar

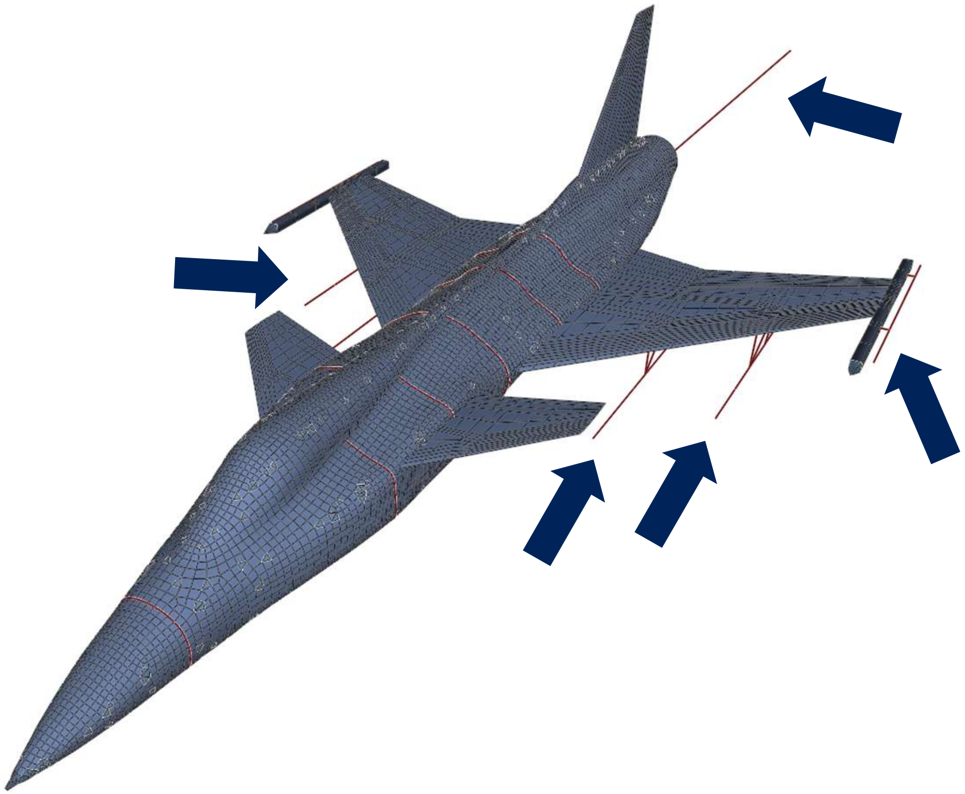
nonlinear
Euler/NS methods

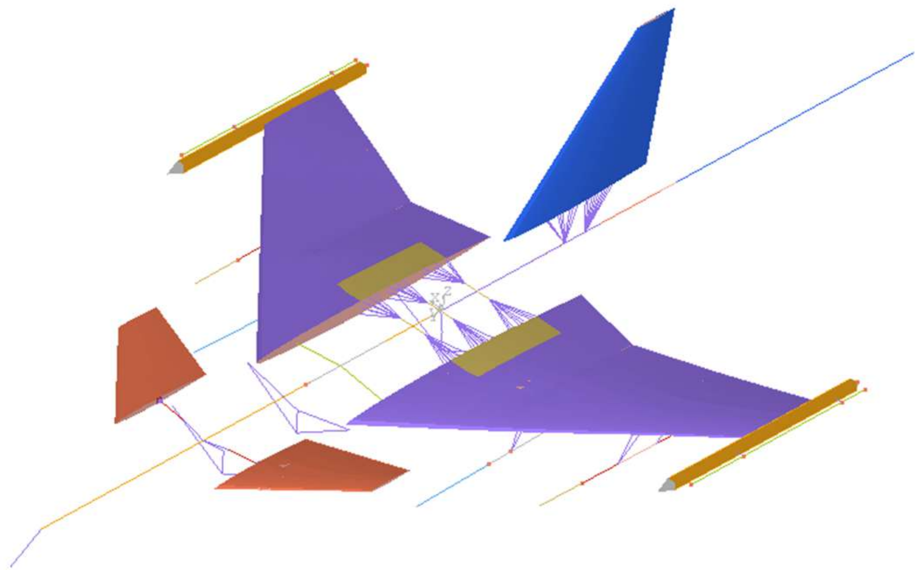
Tune corrections for linear methods

DLM Calculations



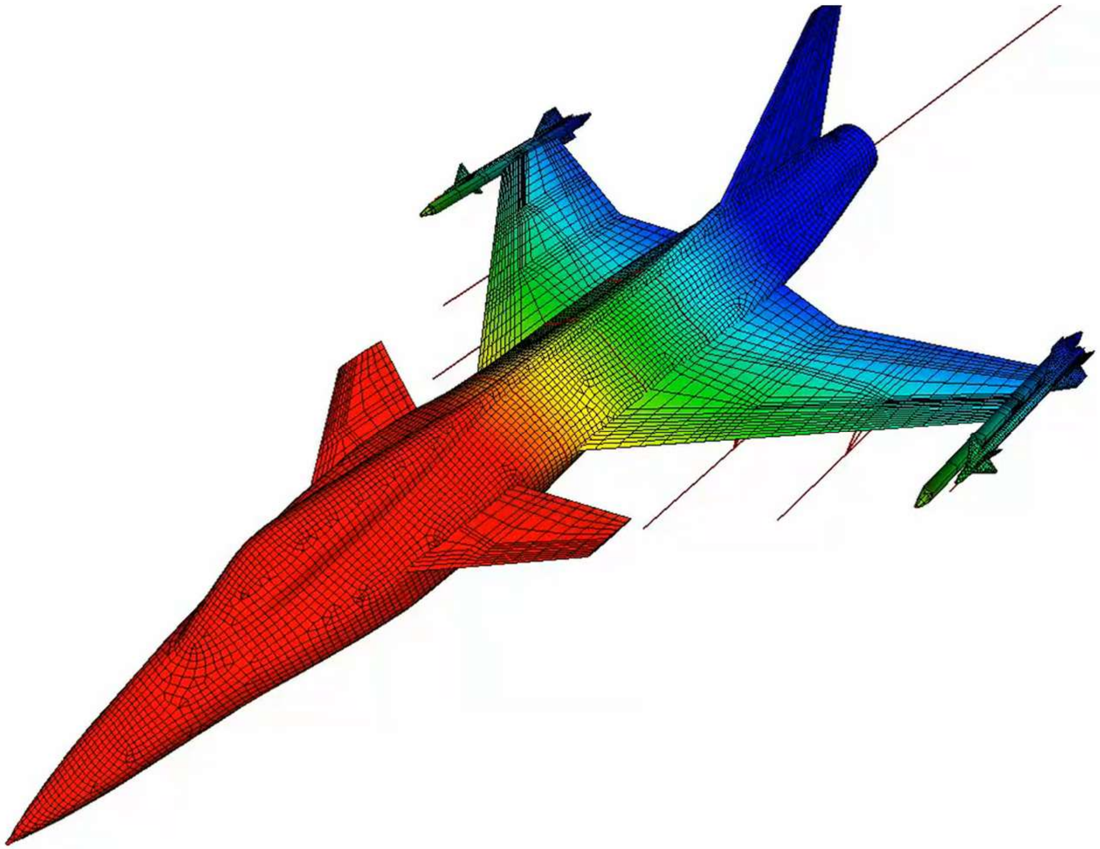
Structural model





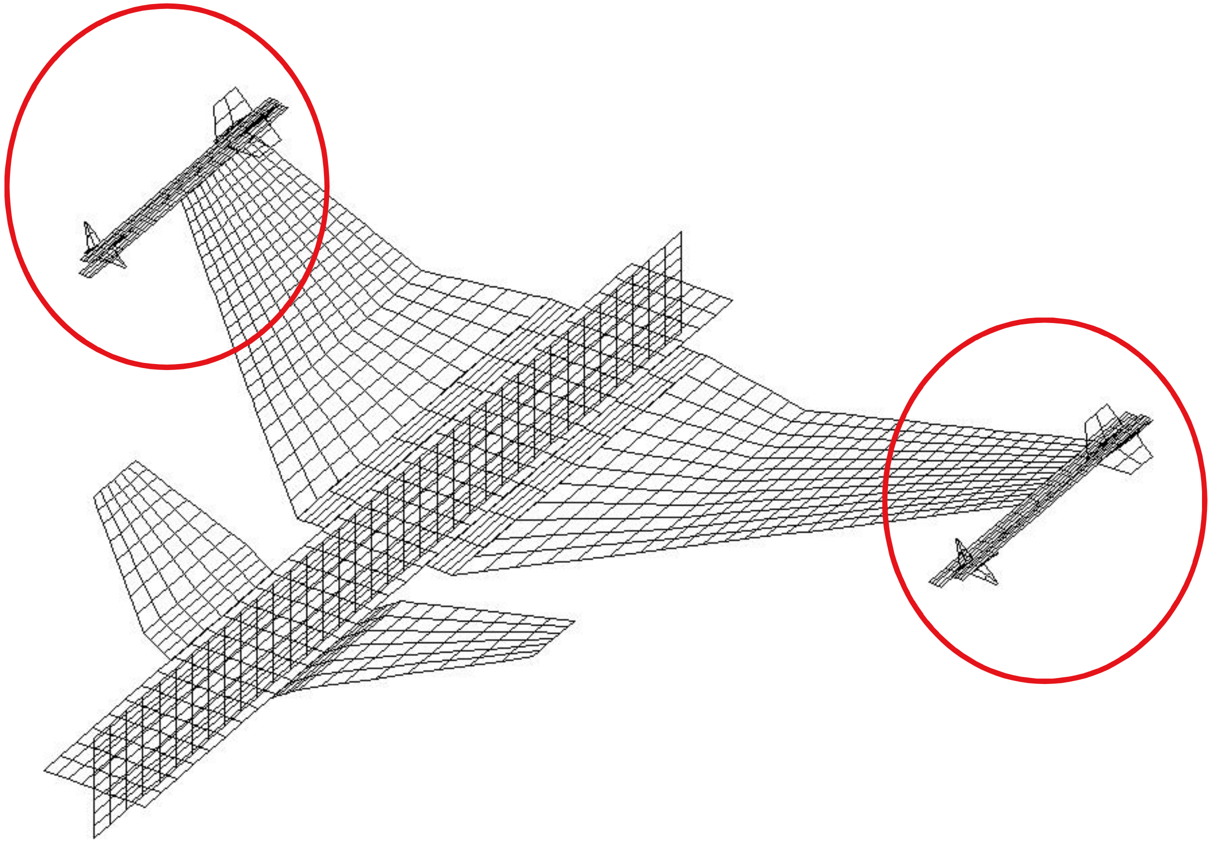
From KTH (cfg3)

Structural modes

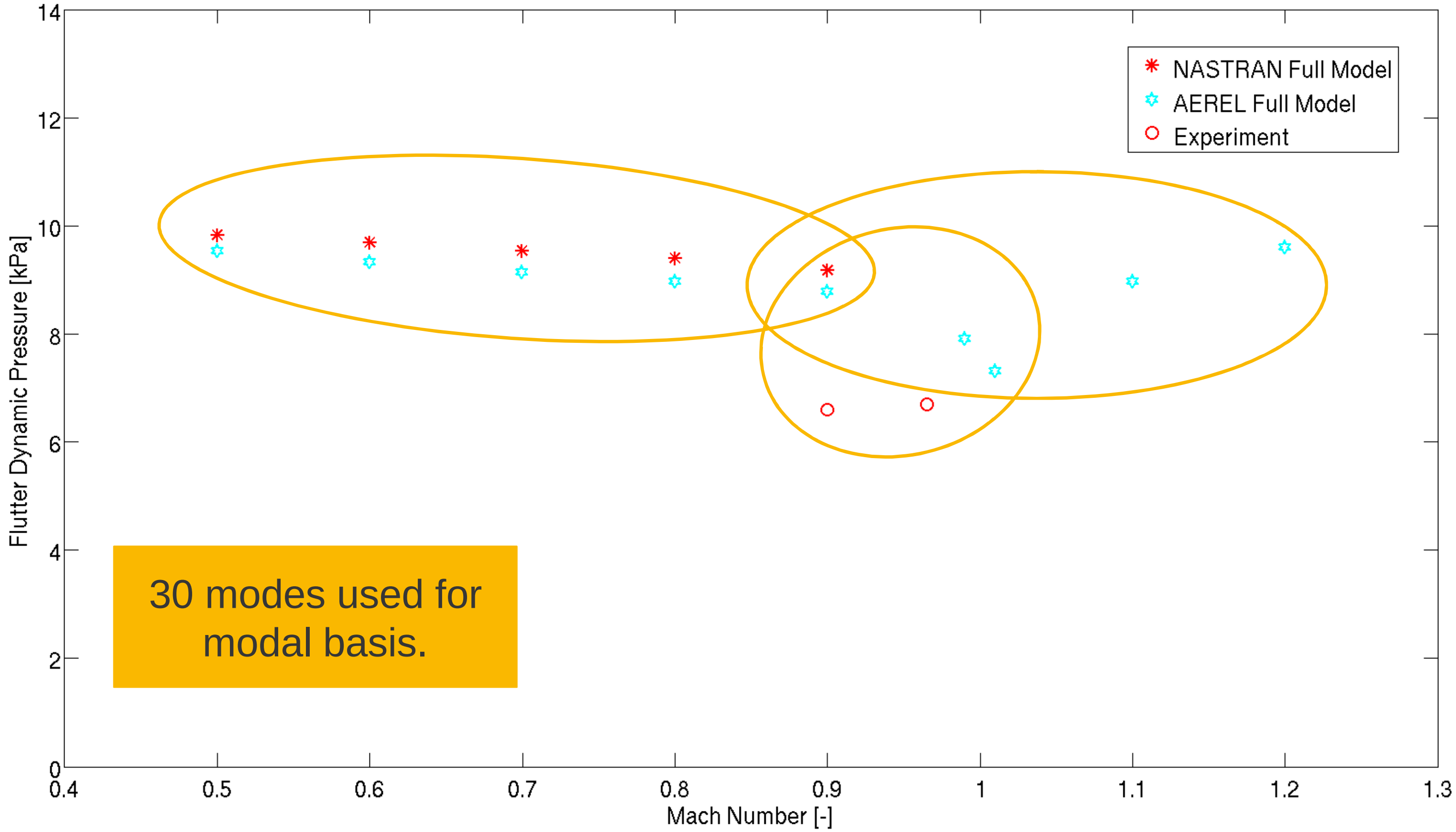


Mode	Frequency [Hz]
Sting yaw	3.81
Sting pitch	6.71
AS wing bending	8.53
SY wing bending	8.93
AS wing tip torsion	12.16
SY wing tip torsion	12.38
Fuselage yaw	14.87

Aerodynamic DLM model

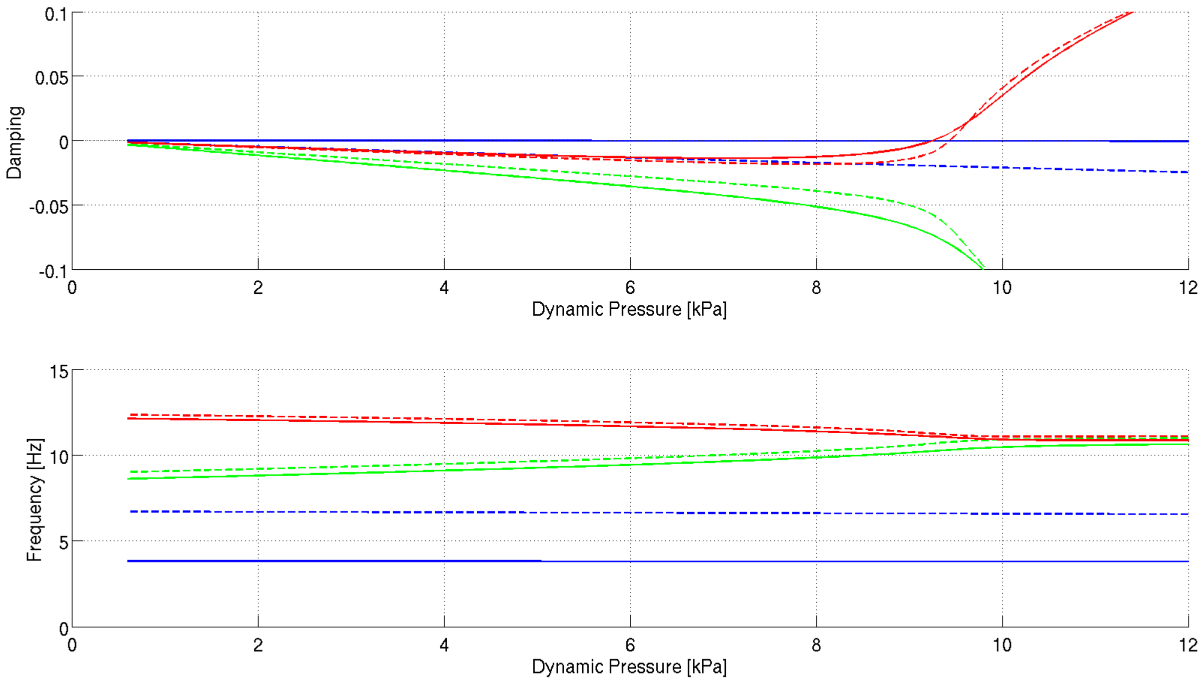


DLM + experimental flutter results



30 modes used for modal basis.

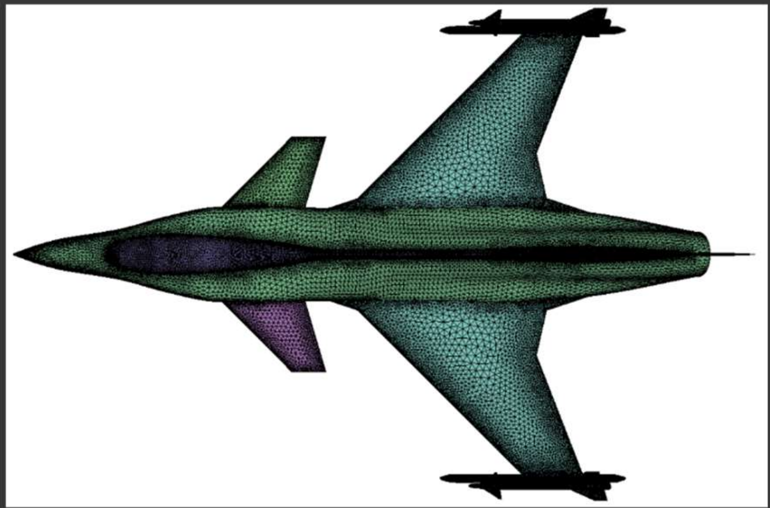
DLM Flutter characteristics (Mach 0.9)



Sting Wing Bending Wing Torsion

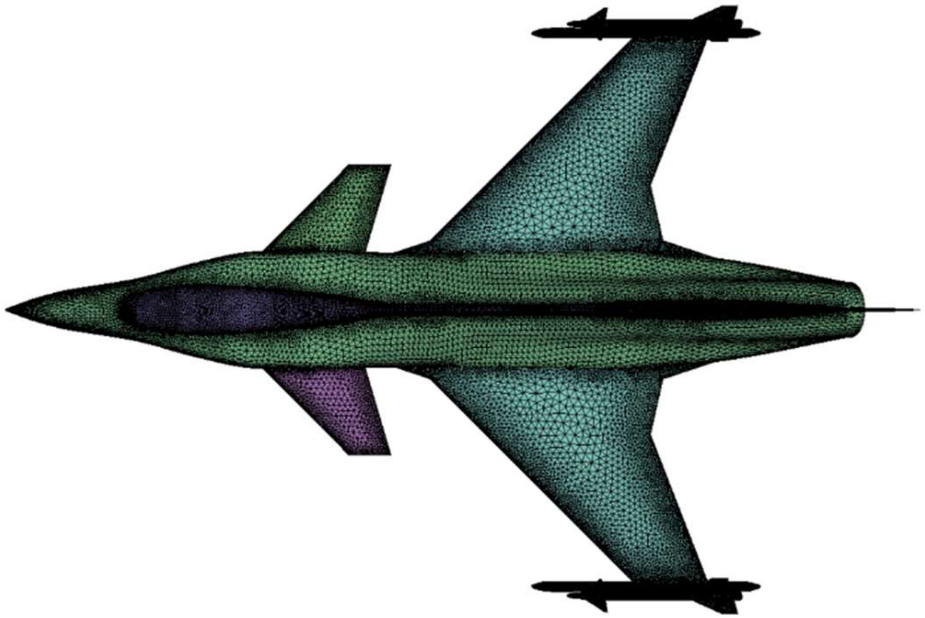
- "Textbook" flutter coupling
- Low-damped sting modes

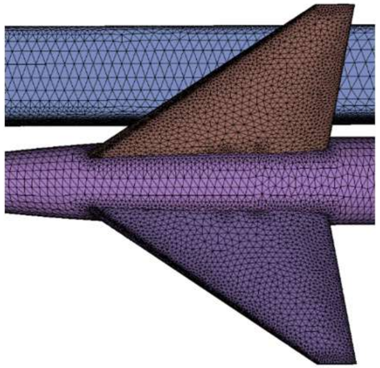
CFD Calculations



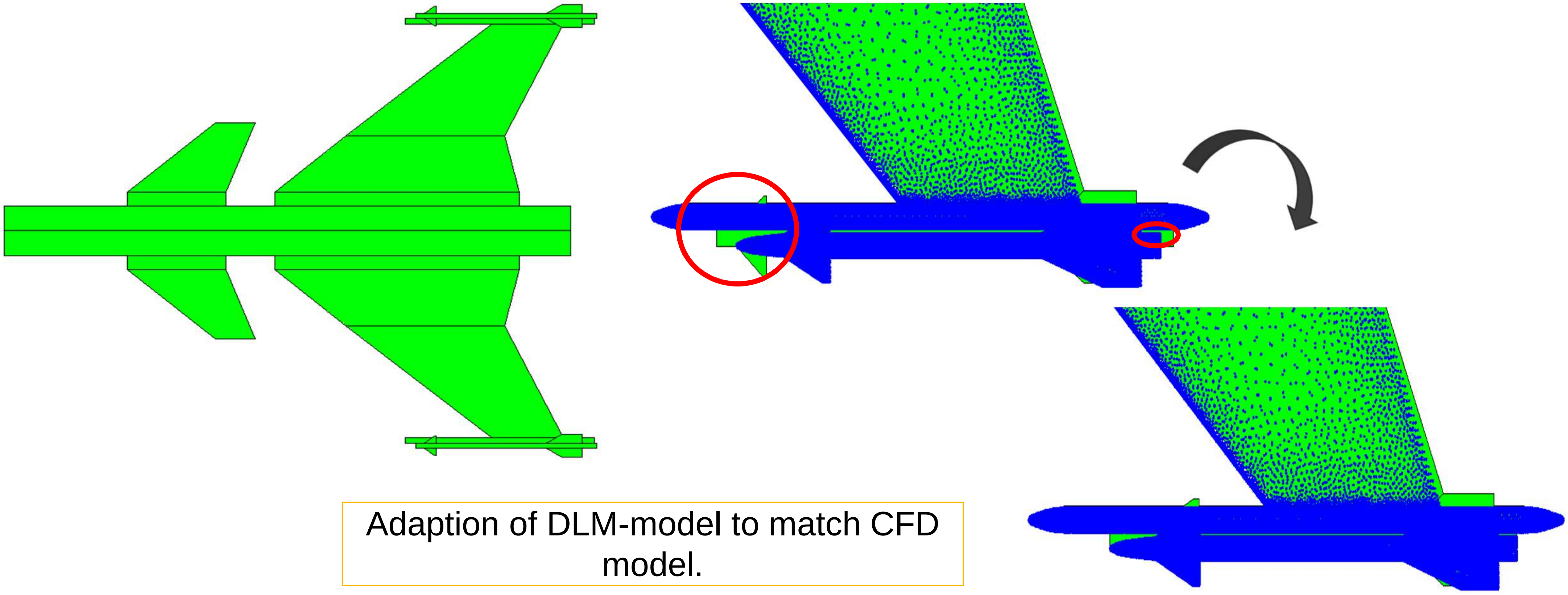
CFD modelling (1/2)

- Same FE-model as DLM calculations
- CFD model from KTH: 8d1162k
  - Coarse Euler, 1.2 million points
  - Underwing stores not modelled aerodynamically
- Uncertainty if this was the correct geometry but OK for exemplifying phenomena and characteristics





CFD modelling (2/2)



Adaption of DLM-model to match CFD model.

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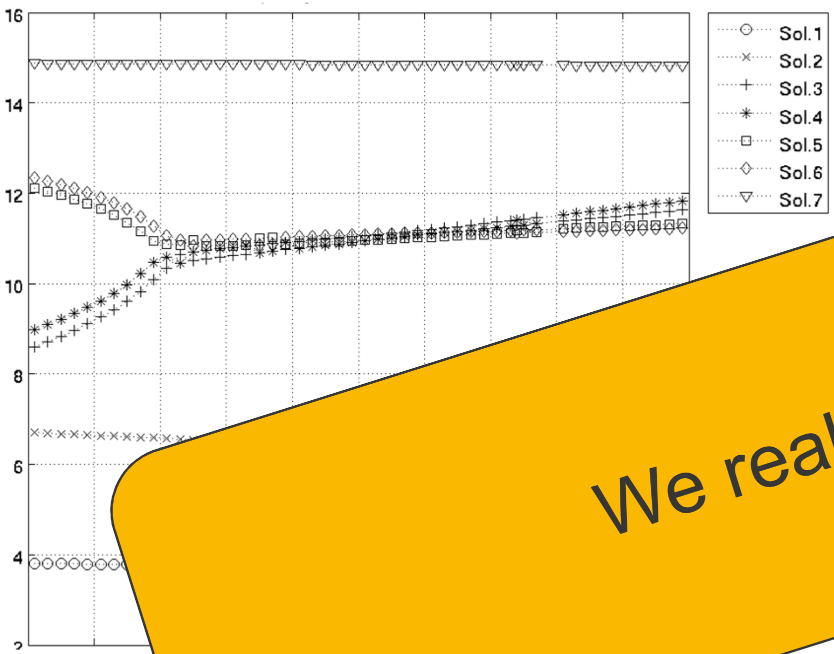
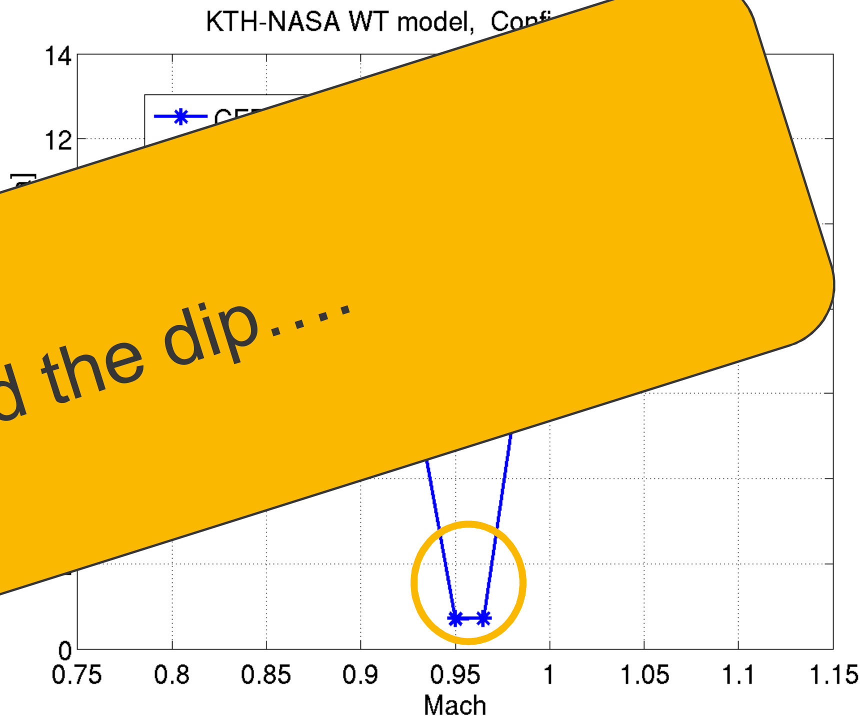
CFD initial flutter results





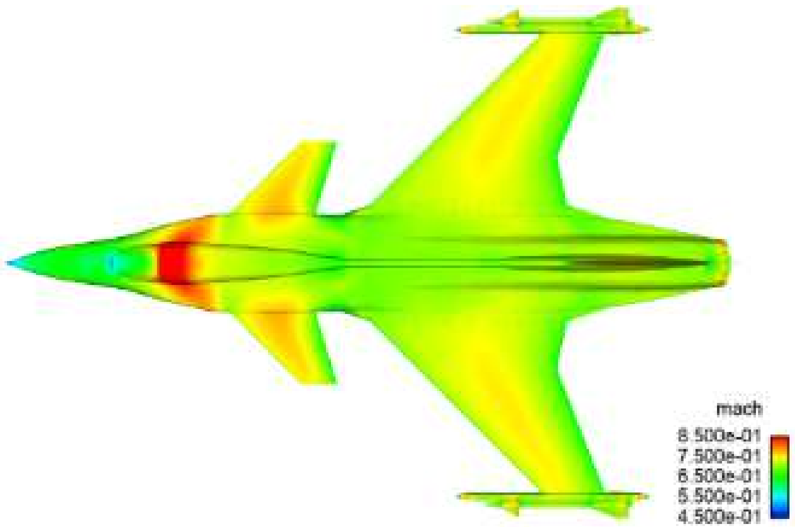
We really found the dip….

esults!

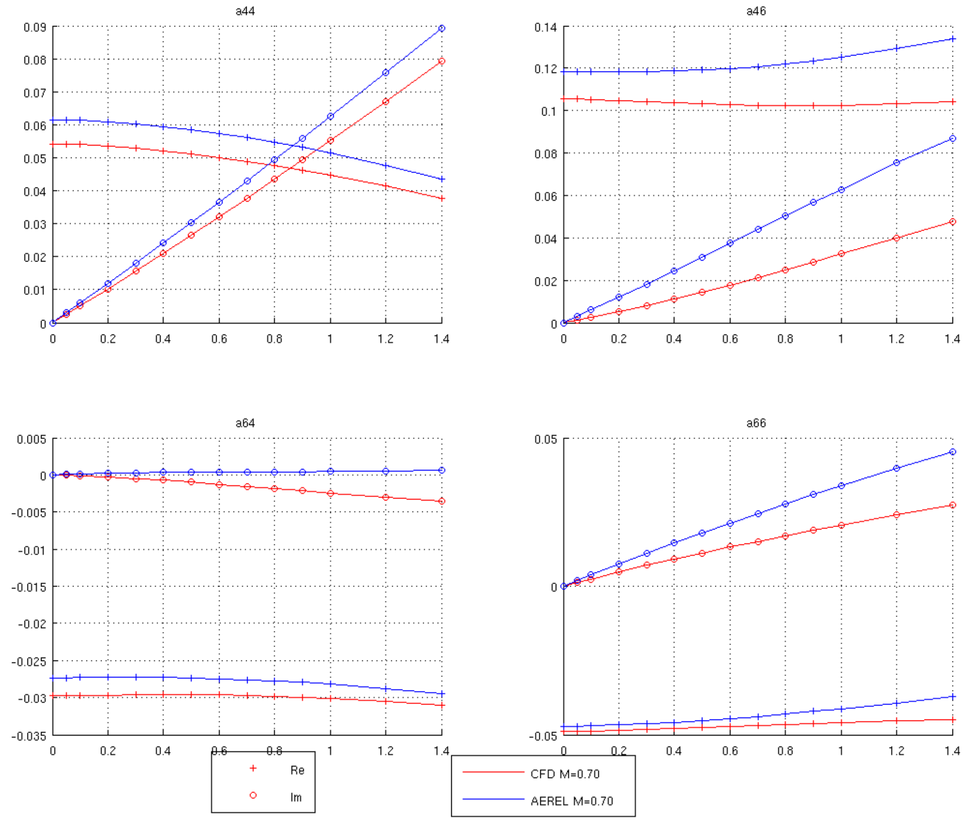
Excessive transonic dip!

A closer look at the CFD results…

M=0.70



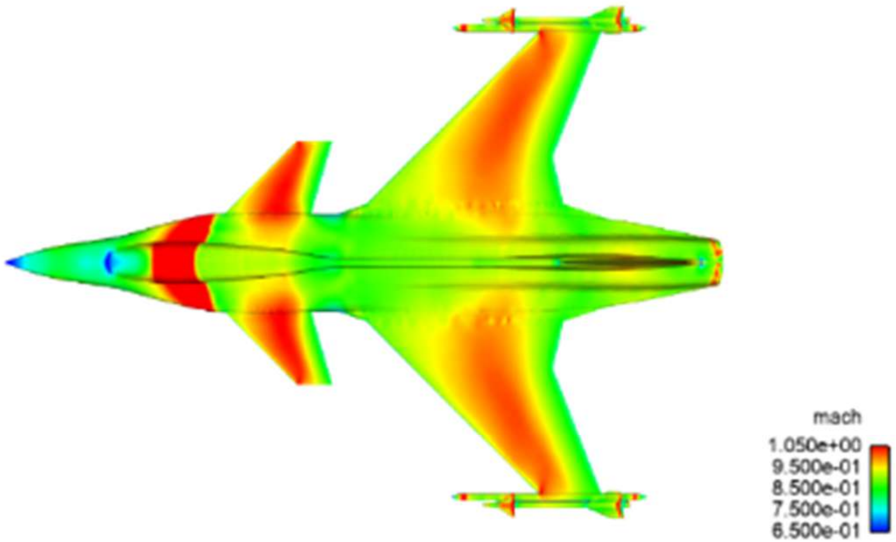
Wing bending **Wing torsion**



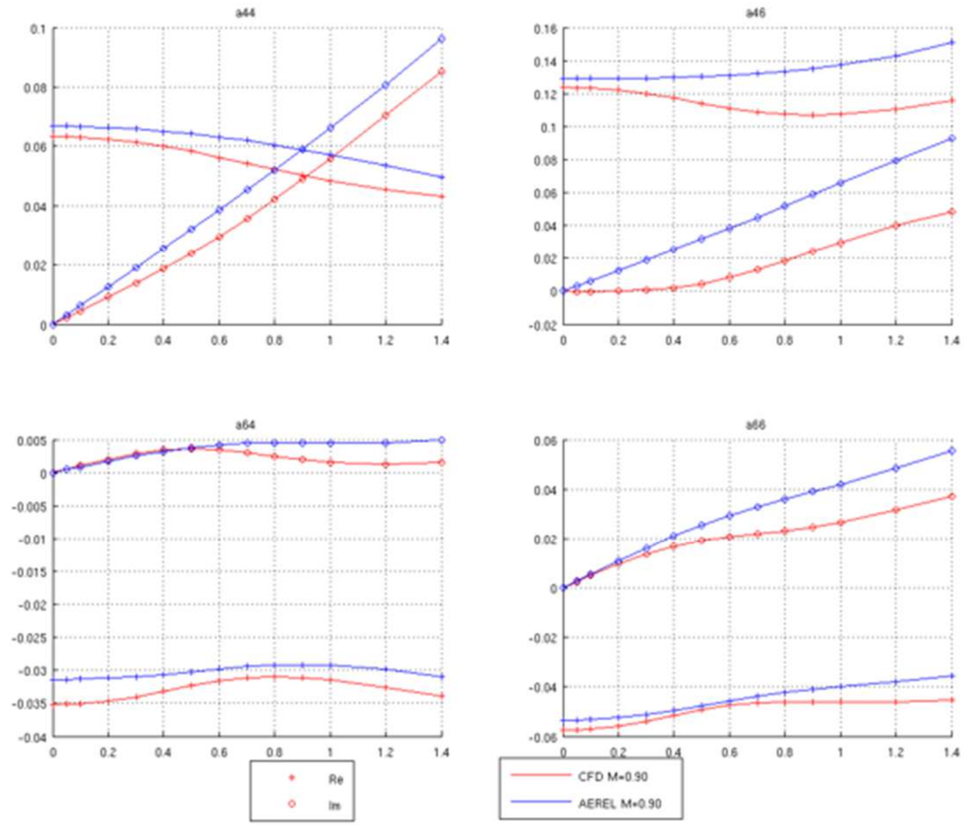
CFD DLM

A closer look at the CFD results…

M=0.90



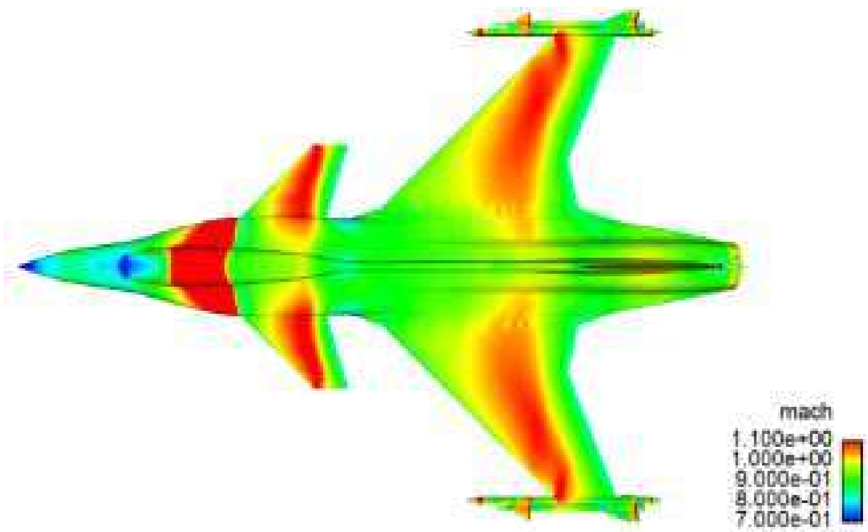
Wing bending **Wing torsion**



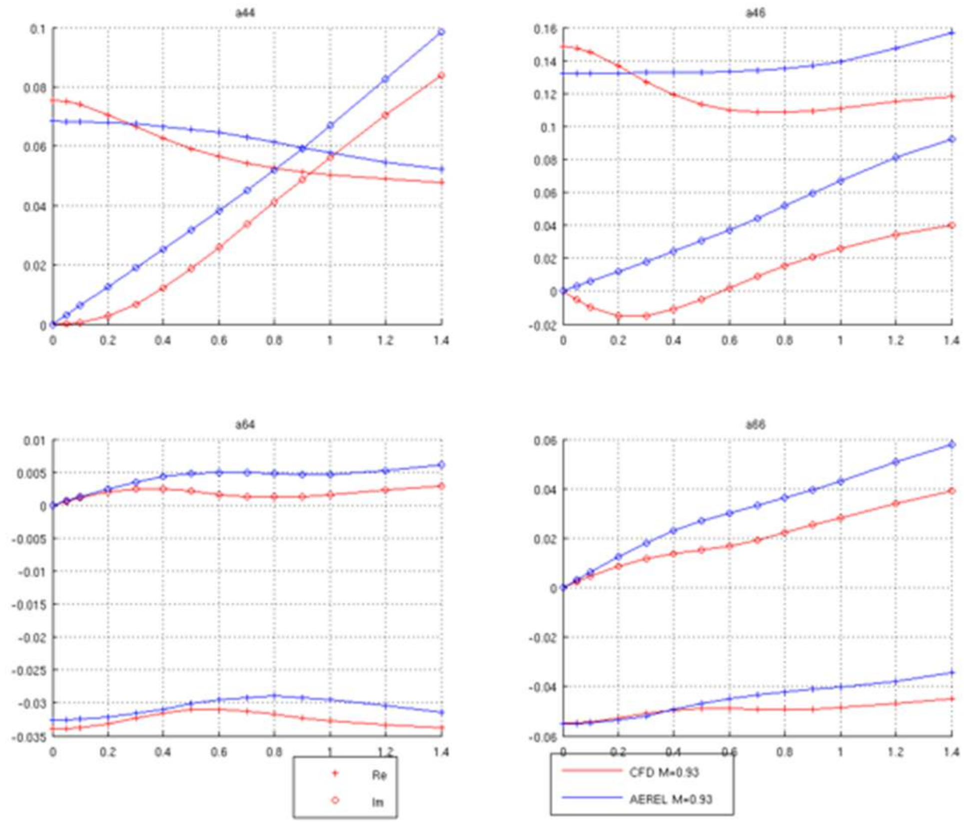
CFD DLM

A closer look at the CFD results…

M=0.93



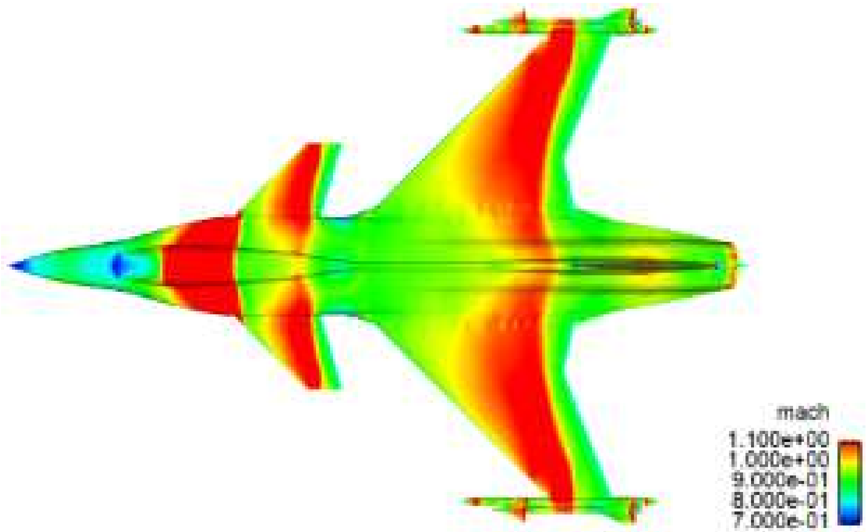
Wing bending | **Wing torsion**



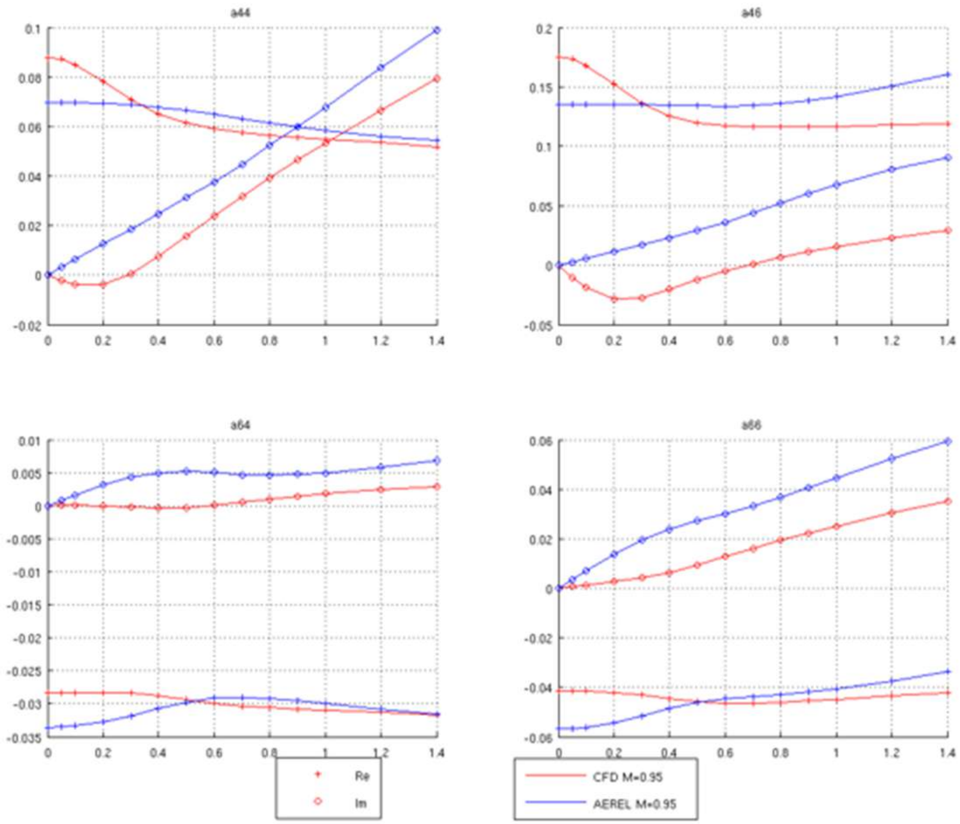
CFD — DLM —

A closer look at the CFD results…

M=0.95



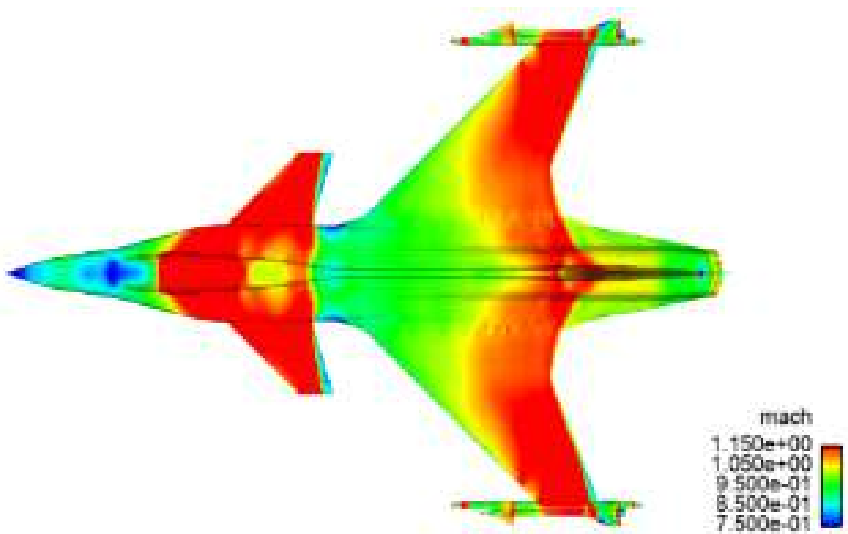
Wing bending **Wing torsion**



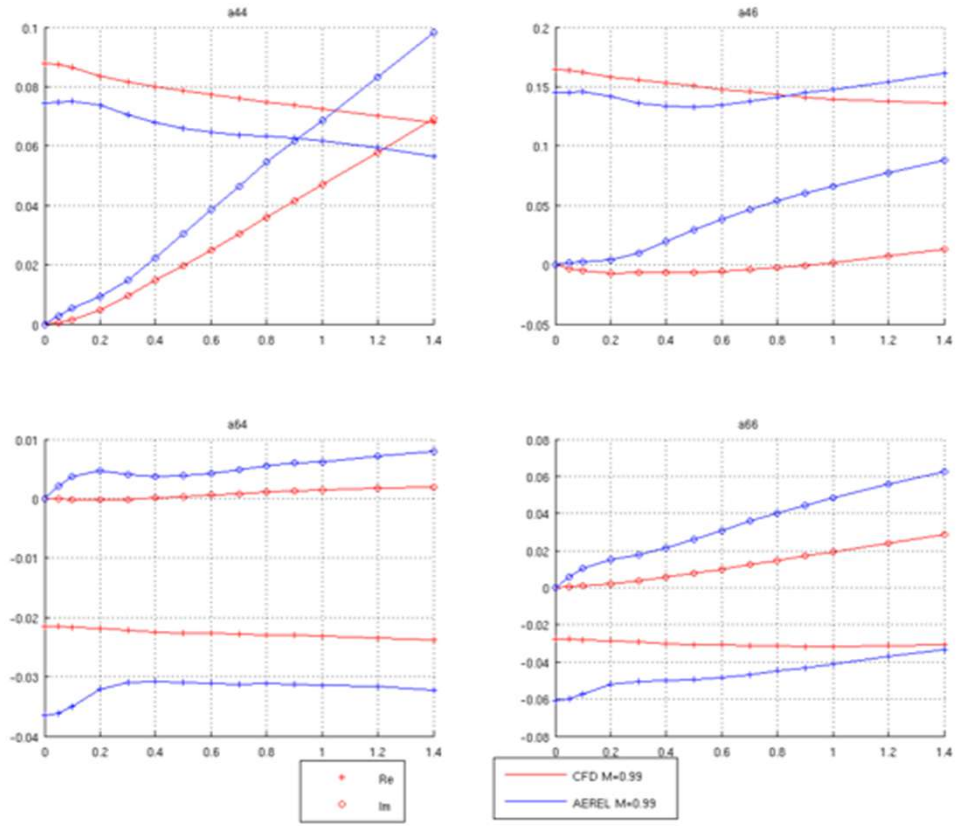
CFD DLM

A closer look at the CFD results…

M=0.99



Wing bending **Wing torsion**



CFD DLM

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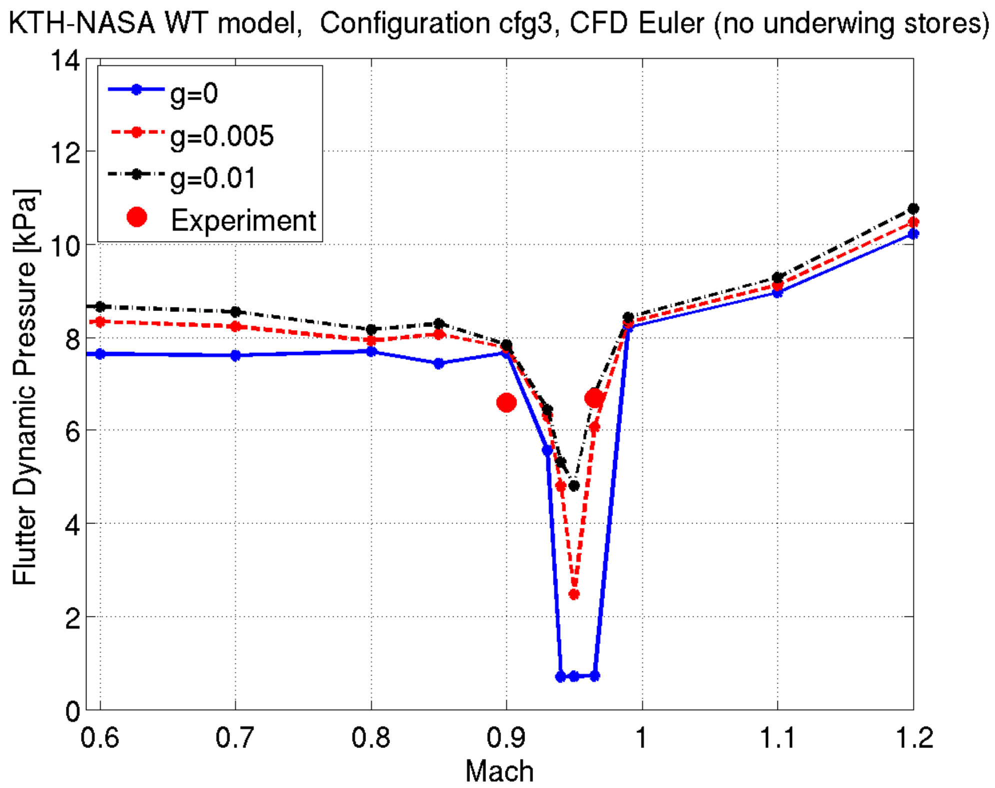
CFD + Structural damping

- Sensitive in transonic!
- Realistic structural damping:
  - 0.5-1.0 %
- No measurement of structural damping during the tests at NASA Langley



Summary

Summary 1/2

- DLM is robust but over-predicts transonic flutter results.
- CFD calculations can predict the transonic dip, but are not robust. What is numerics and what is physics?
- Structural damping can help in avoiding excessive transonic dips

Summary 2/2

- What is ”sufficiently” accurate for transonic flutter predictions of complex store configurations?

- More experiments are needed, for gathering both static and dynamic data

- Need: methods for flutter predictions that are accurate in transonic but also fast enough to enable a large number of store configurations to be analyzed.
  - Modularity is key!

Future Work?

- More tests at NASA Langley, without underwing stores, to isolate transonic flutter characteristics.

- Find methods that have a balance between accuracy and speed in transonic
  - 2.5D methods, airfoils instead of panels?
  - Improved meshing tools.

- Static deformation and its effect on transonic flutter results

Thank you!

Questions?