The Use of Computational Fluid Dynamics In the Aerospace Industry Past – Present - Future

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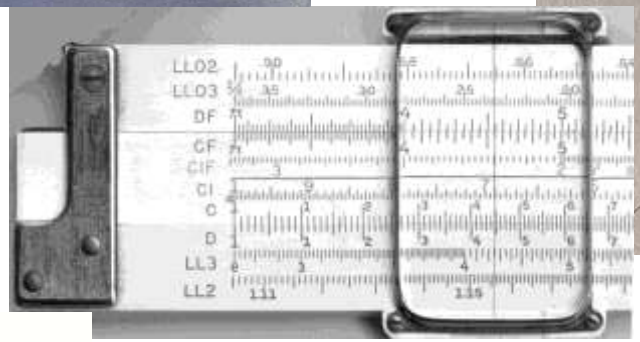
The Early Days

Not much CFD in these old birds ! Great airplanes none the less.

Equations come into play . . .



DC-8 Installed Nacelle Drag

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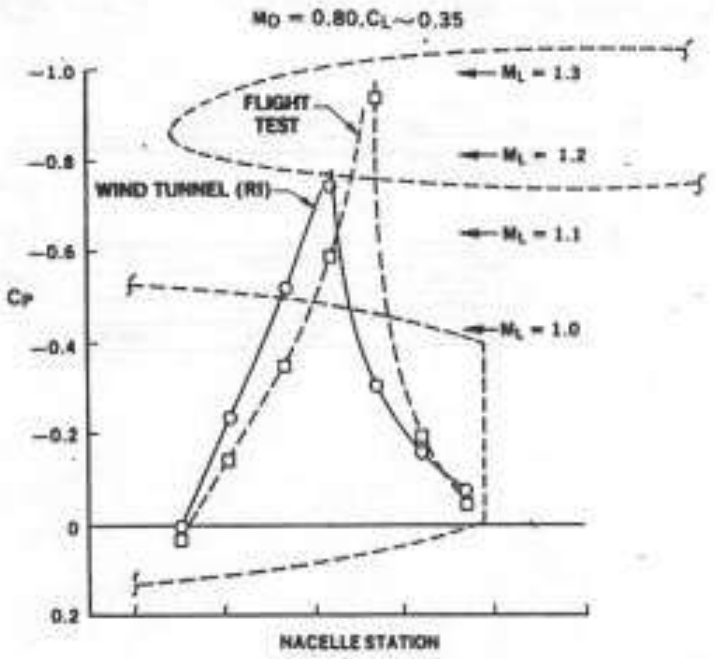
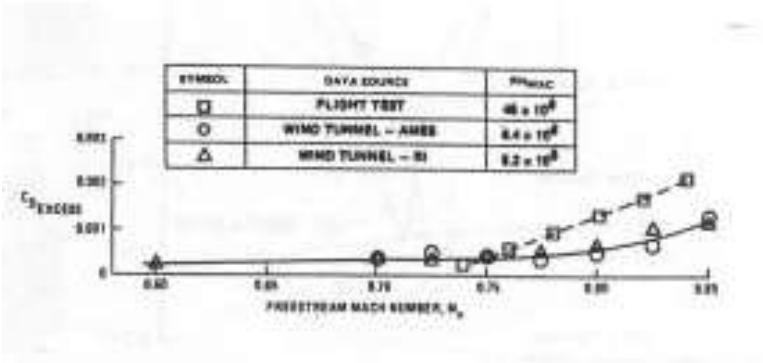
Effect of Reynolds number on

Pressures



Drag rise



Enter digital computers . . .

The CDC 6600 was preferred over IBM 360s because of the 60 bit word

Enter digital computers . . .

Linear potential equation could be solved – no viscosity and no Transonic flow (no shocks) – resulted in missed slat loads and a drag issue between wing/strut/nacelle on inboard side

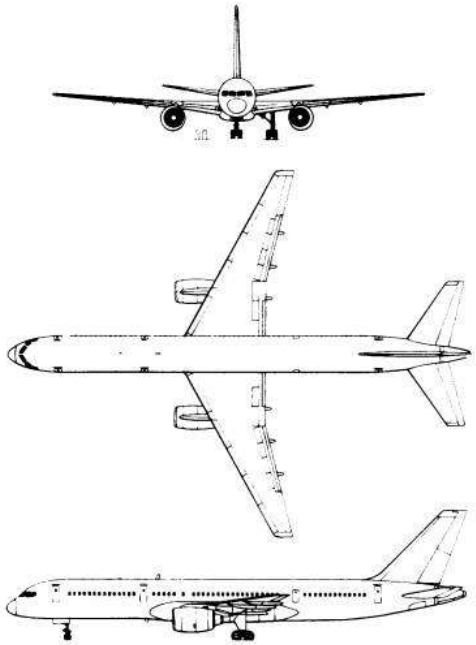
Enter bigger digital computers . . .

The advent of the vector processor enabled using the Euler equations to model the flowfield. This provided for rotational flows and weak shocks

Just one year later in development

767

757



The Cray and Antony Jameson's Flo22 Euler code had a significant impact on the 757. Notice that for the same wing thickness the wing has much less sweep. That makes the wing lighter (less structural span) and provides for better low speed performance

1990s - Cray continues to dominate

Cray Y-MPEL

Full Navier Stokes

CFD is better than the wind tunnel in some aspects

Parallel Processing Begins

Cray T916

VECTOR & BANDWIDTH SPEED-UP

Cray T932

SGI Origin 3800

Cray X1

SCALAR SPEED-UP

(Distri. Mem. Architecture)

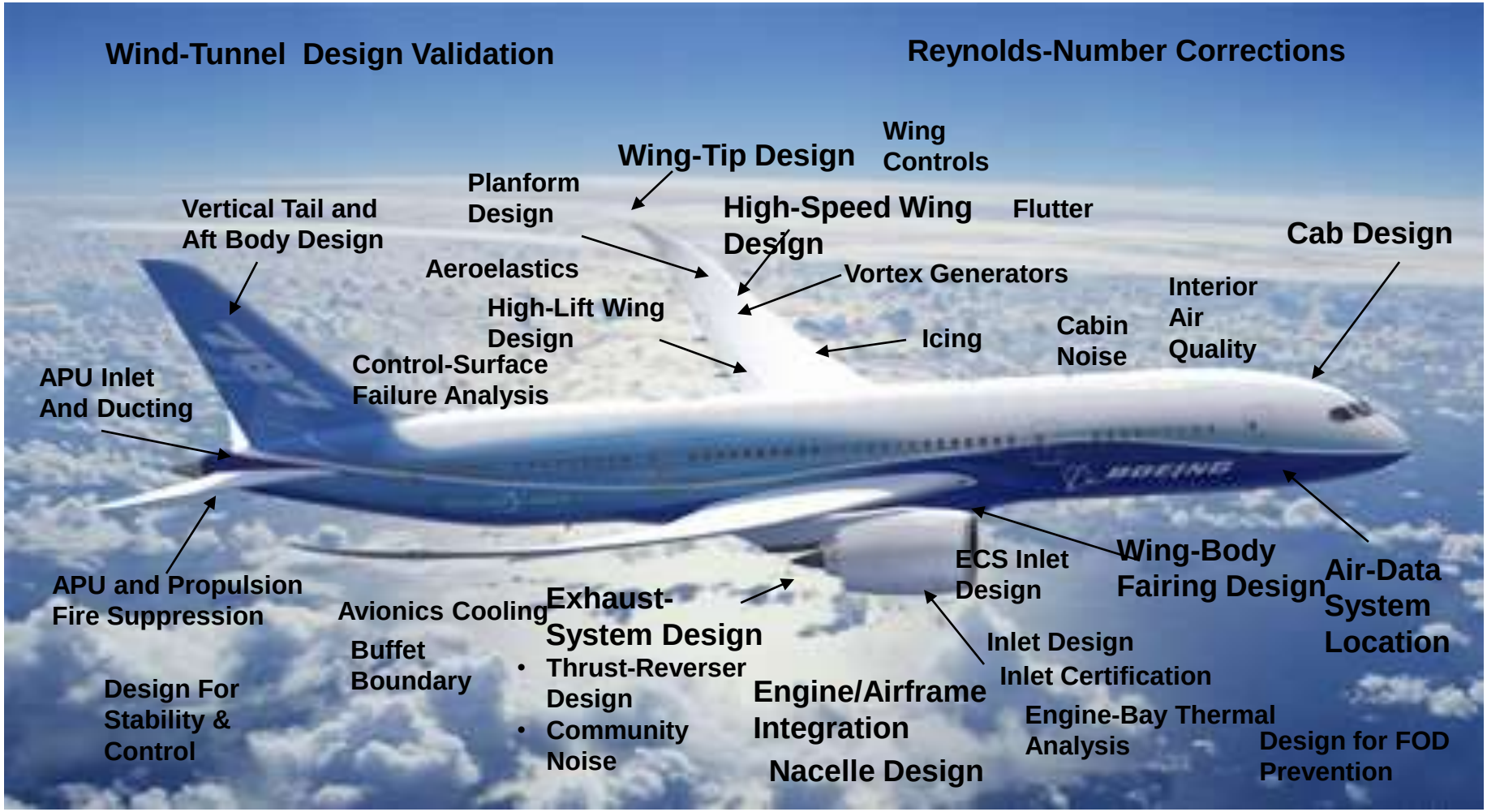
IBM SP

Cluster Computing (DQS/LSF)

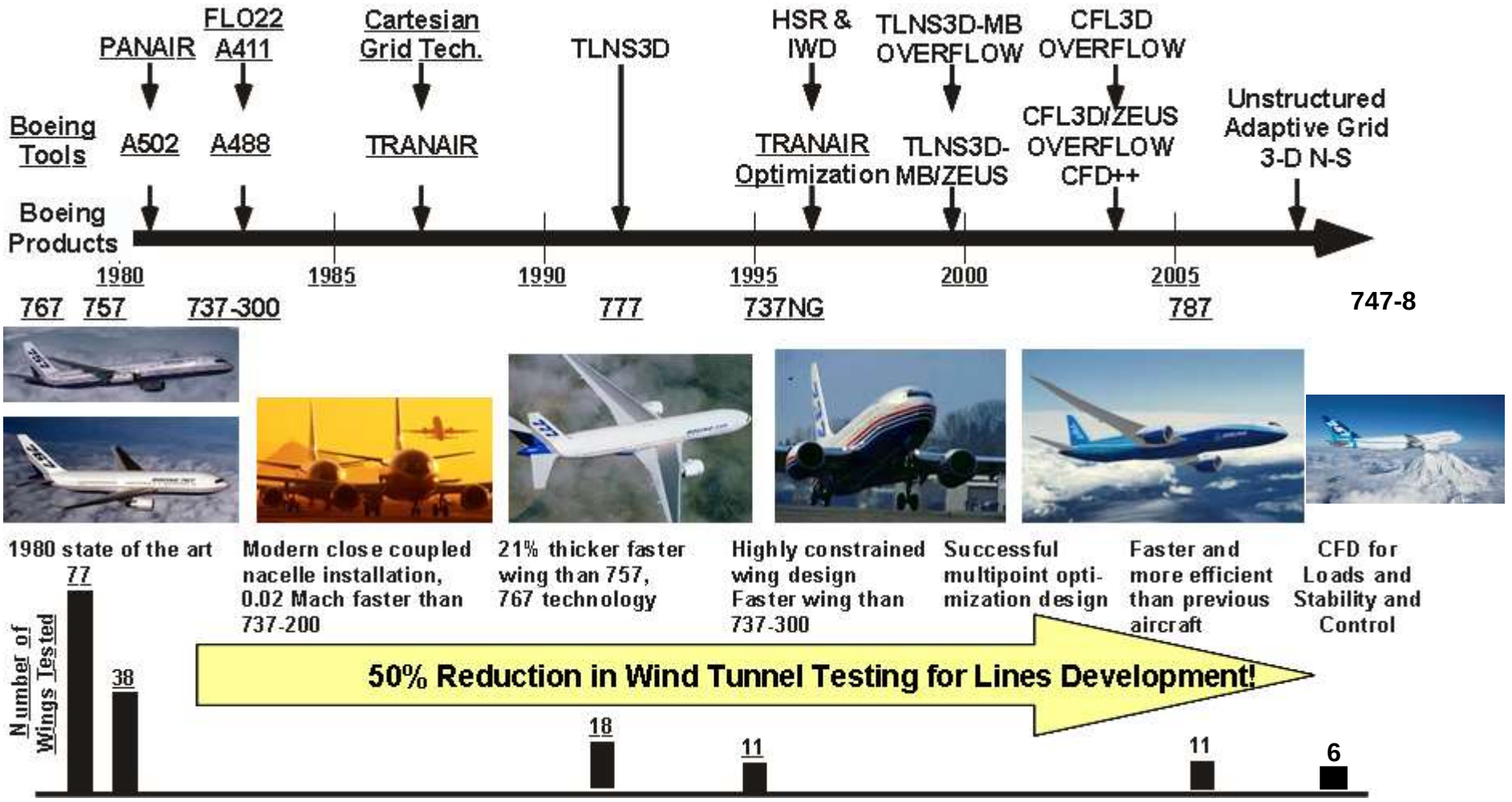
Cluster SPEED-UP

768-CPU Linux NetworX

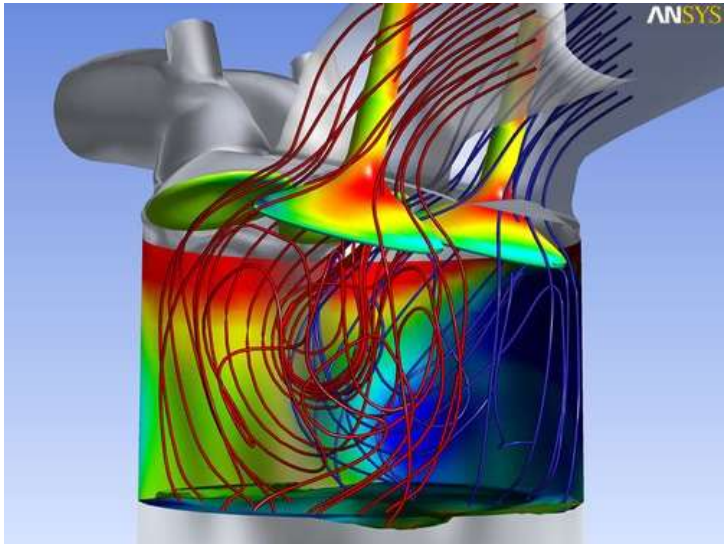
CFD Impacts the Majority of the 787

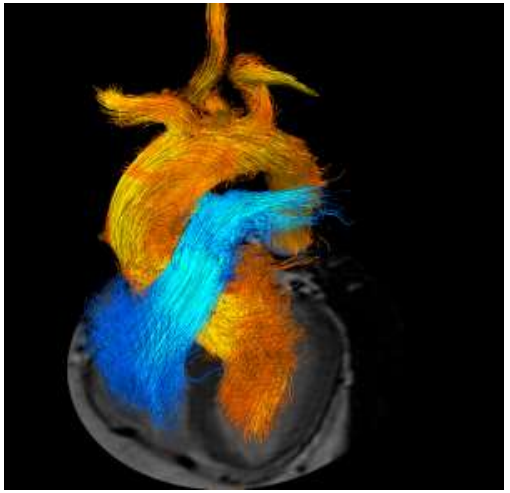


The Business Case



Non-Airplane Applications





What's next ? ? ?

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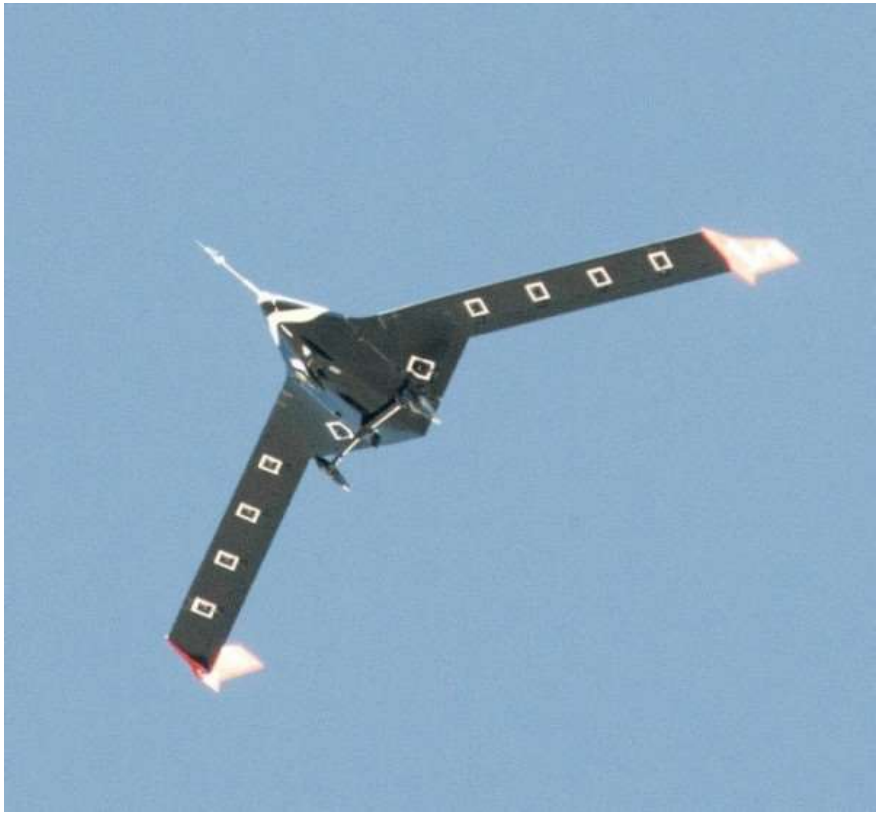
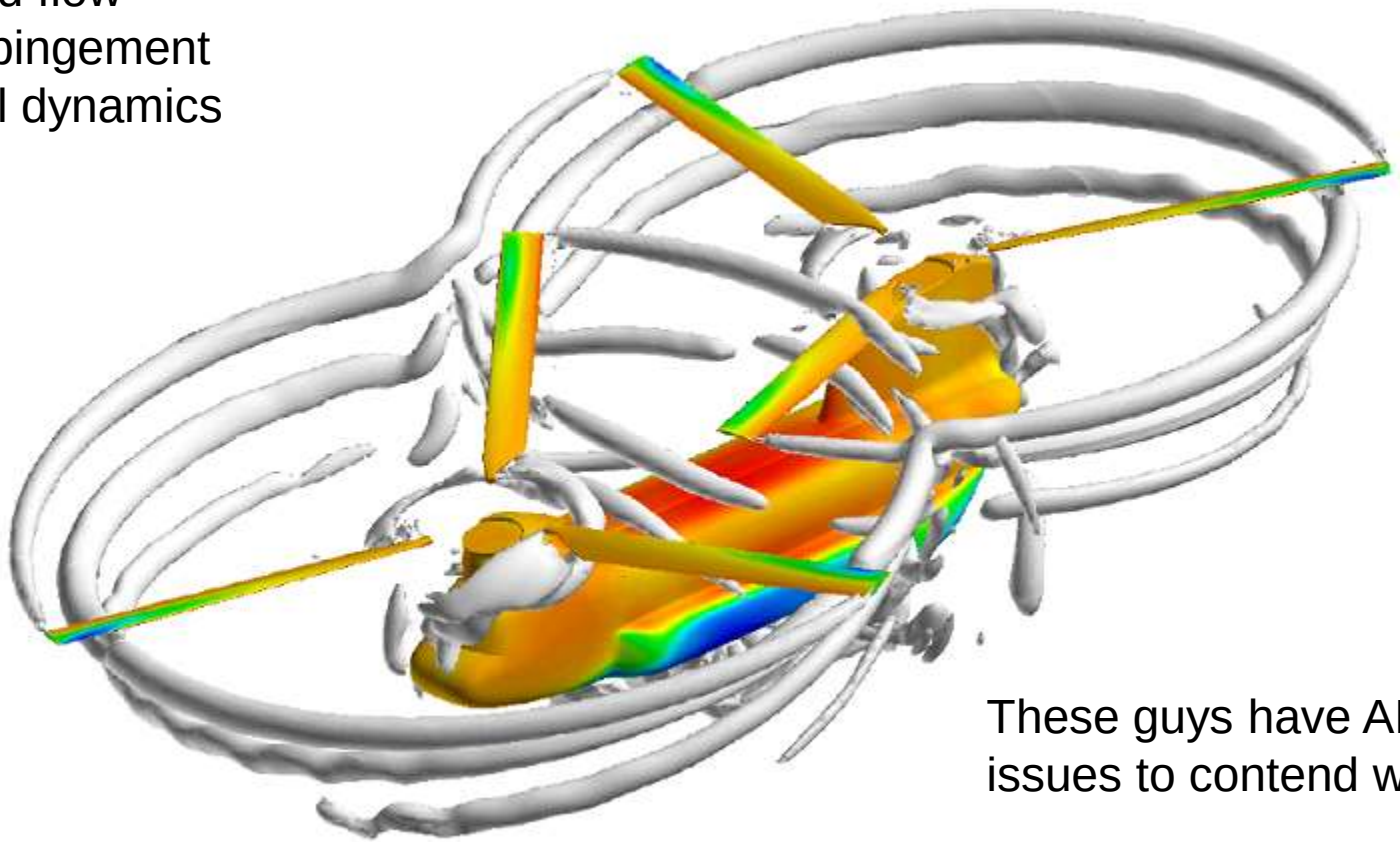


NASA Lockheed X-56

To increase airplane performance, vehicles must get lighter. To do this, design tools must couple aero, structures and controls (and propulsion)

What's next ? ? ?

Unsteady flow
Separated flow
Wake impingement
Structural dynamics



These guys have ALL the issues to contend with !

Conclusions

Over the past 40 years CFD has played a key role in improving the performance of flight vehicles.

Current tools, however, are severely limited in their range of application. We still can't model separated and/or time-dependent flows. The Navier Stokes equations rely upon approximations (the turbulence model).

We can see a way forward – direct numeric simulation, aka DNS. The problem with DNS is that it will require a model that is 10**6 times larger than current models that can be solved in a practical amount of time.

IF we can achieve a Moore's Law level of performance improvement over the next 30 years then in 2050 we'll be able to do the full airplane DNS calculation in a few hours (that's the practical part).

I'm not a computer guy (and I'm retired) – <u>you</u> figure out how to make this possible!!