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

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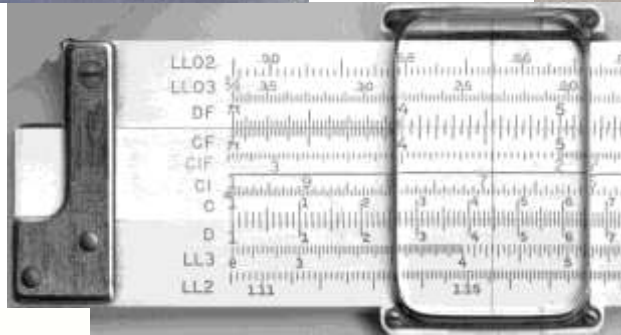
The Early Days



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



Equations come into play . . .



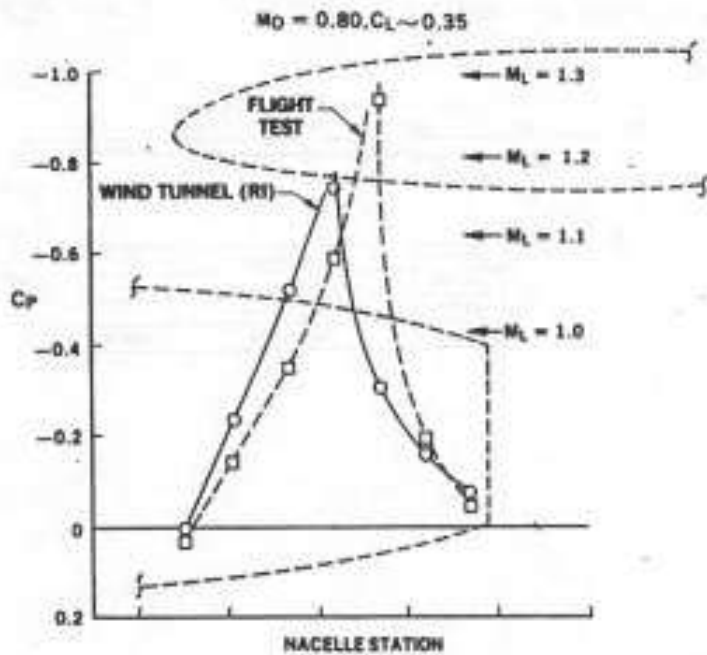
DC-8 Installed Nacelle Drag



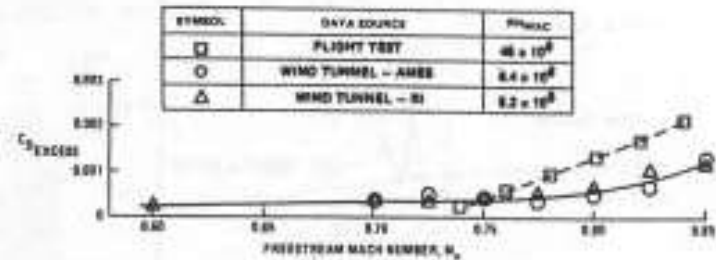
DC-8 Installed Nacelle Drag

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 . . .



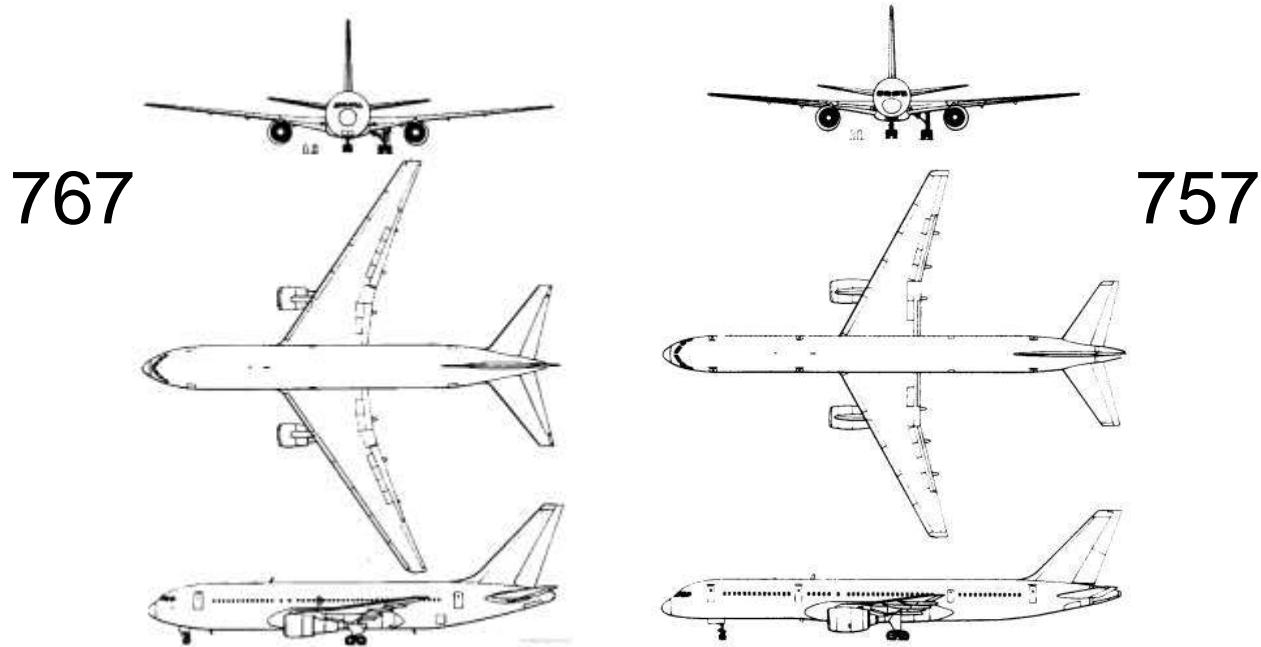
Linear potential equation could be solved – no viscosity and no Transonic flow (no shocks) – resulted in missed slat loads and a drag issue between wing/strut/nacelle on inboard side

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



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

IDC HPC User Forum
Austin, Texas Sept 6-8, 2016

Full Navier Stokes



CFD is better than the wind tunnel in some aspects

Parallel Processing Begins



Cray T916



Cray T932

← **VECTOR & BANDWIDTH
SPEED-UP** →



SGI Origin 3800



Cray X1

SCALAR SPEED-UP
(Distri. Mem. Architecture)



IBM SP



**Cluster Computing
(DQS/LSF)**

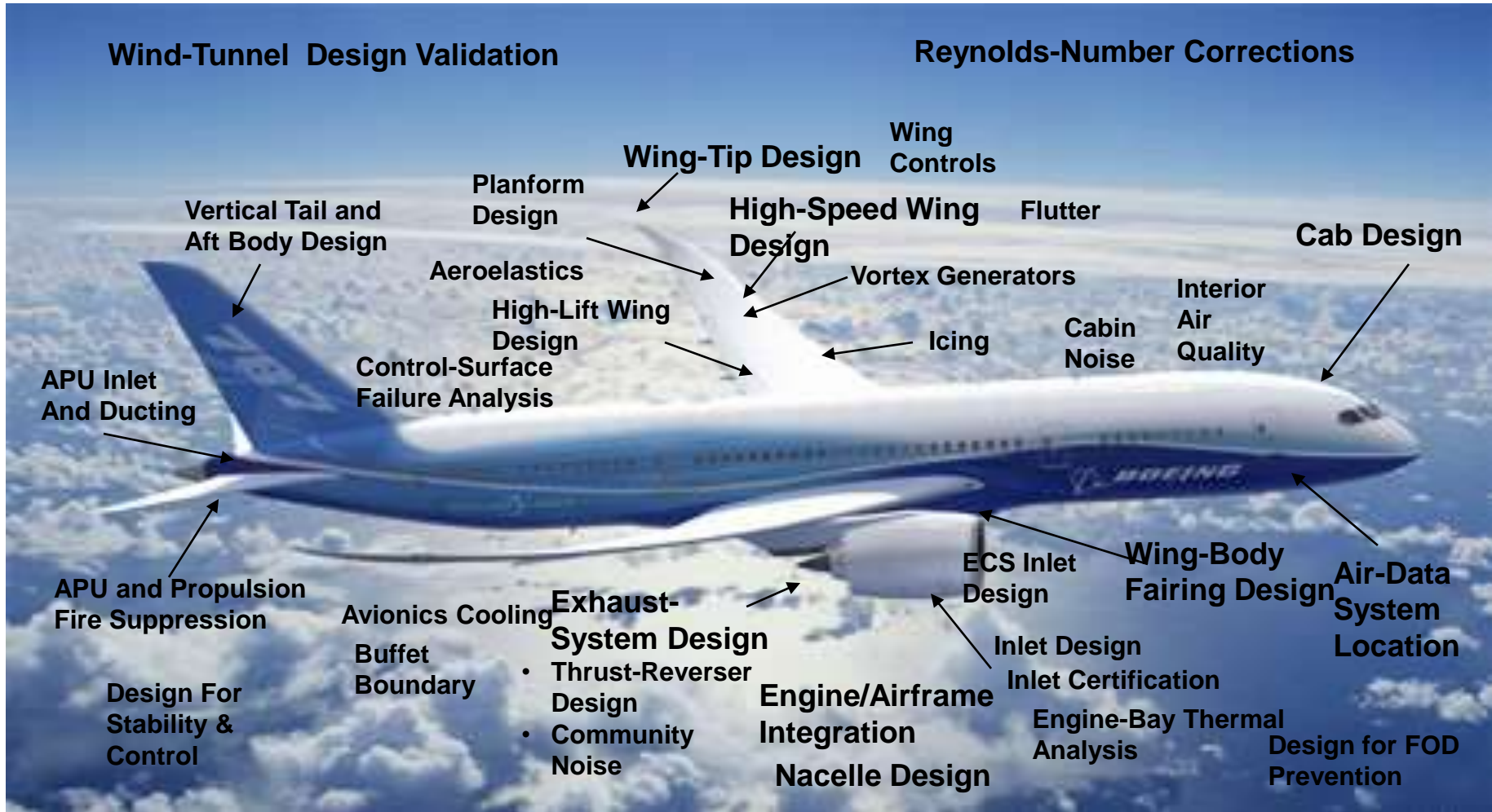
← **Cluster
SPEED-UP** →



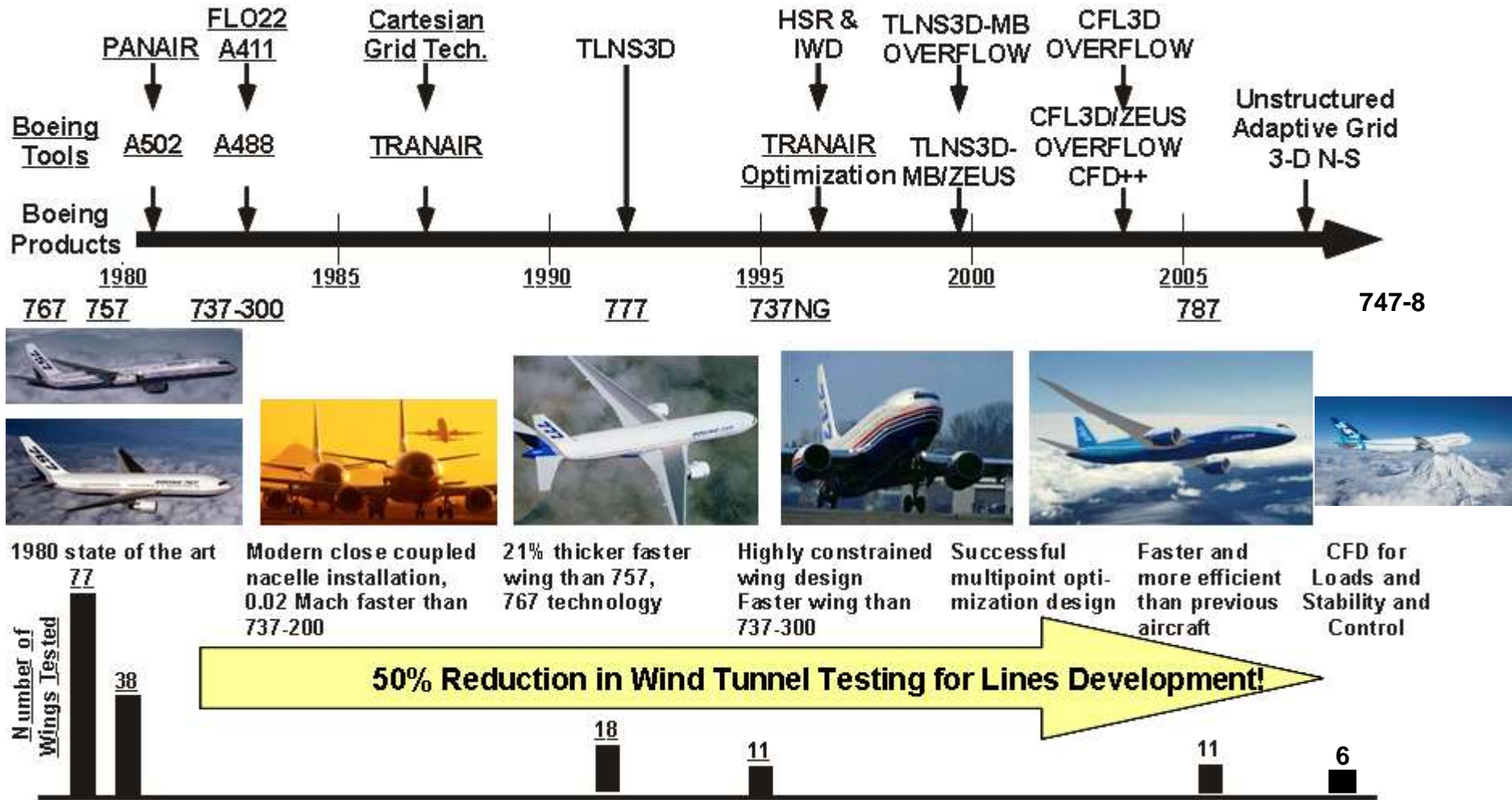
768-CPU Linux NetworX



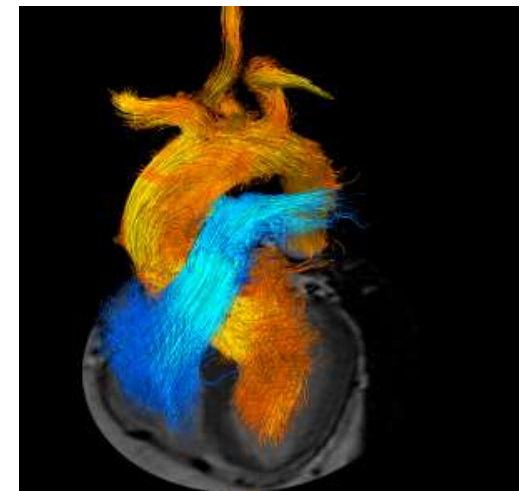
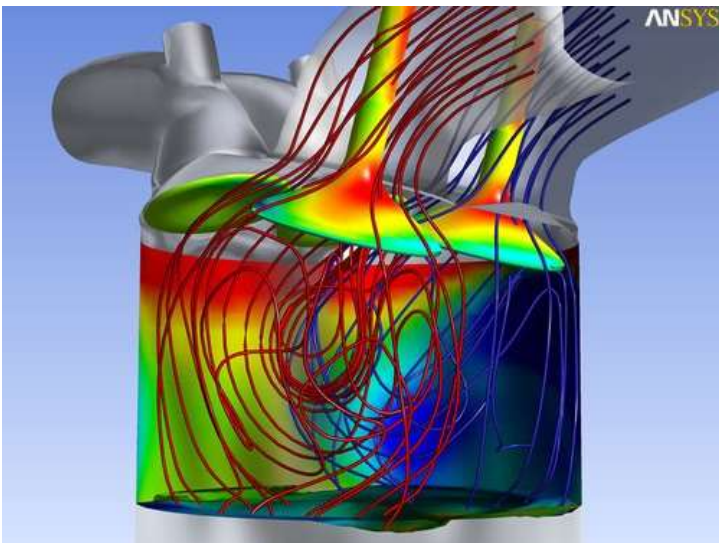
CFD Impacts the Majority of the 787



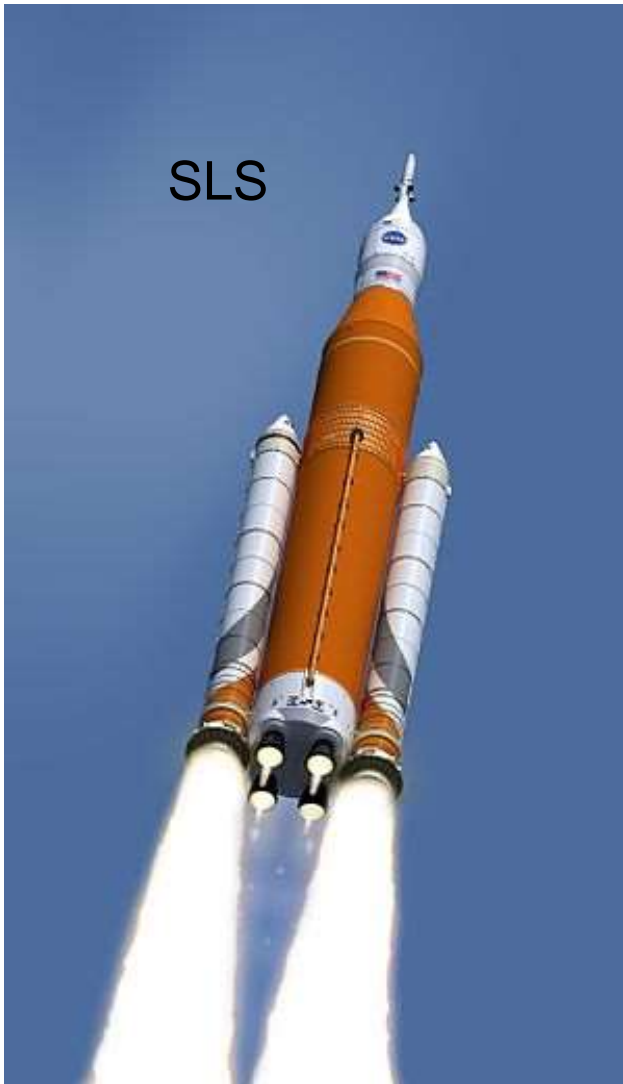
The Business Case



Non-Airplane Applications



What's next ? ? ?



SLS



Dark Star



Helios

What's next ? ? ?



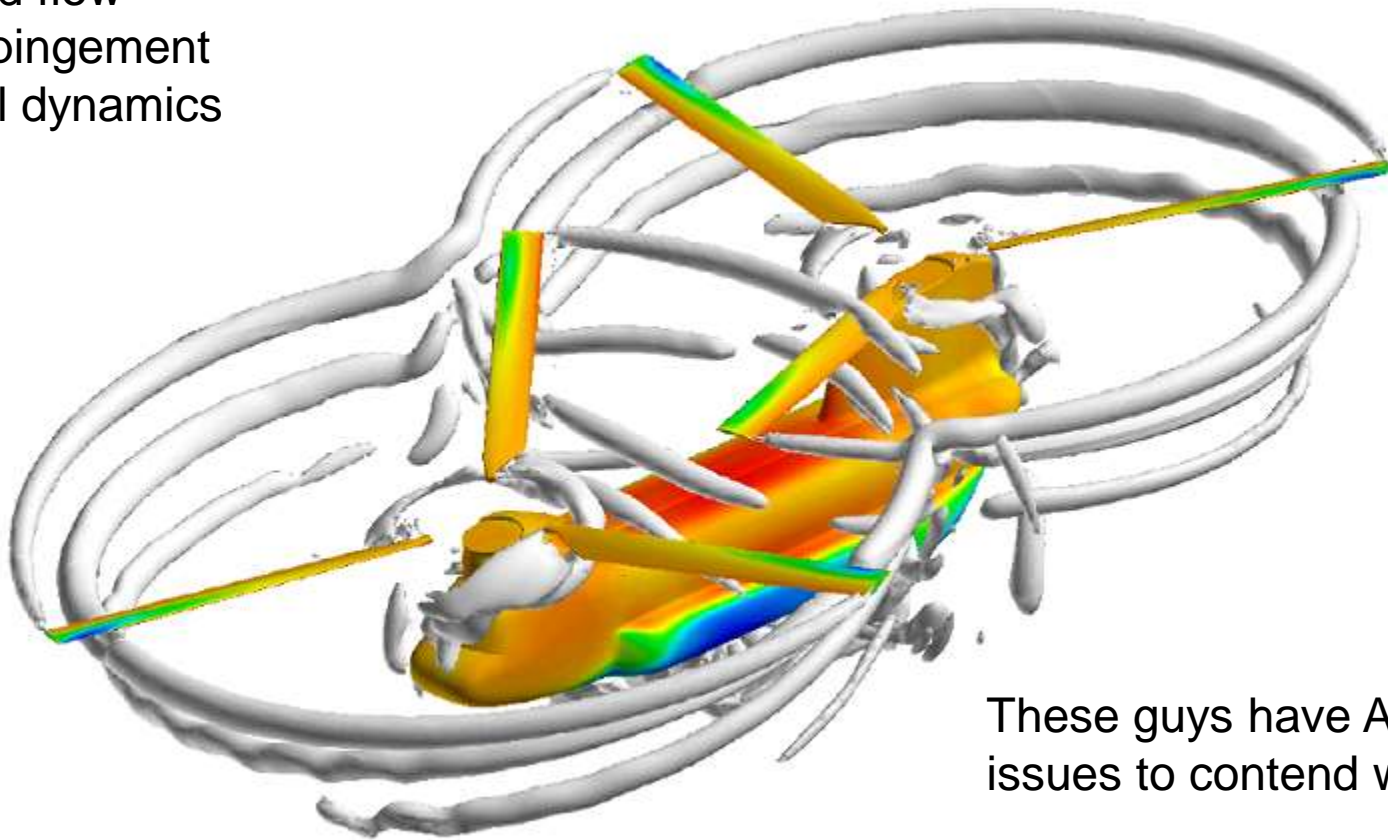
NASA Lockheed X-56



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) – you figure out how to make this possible!!