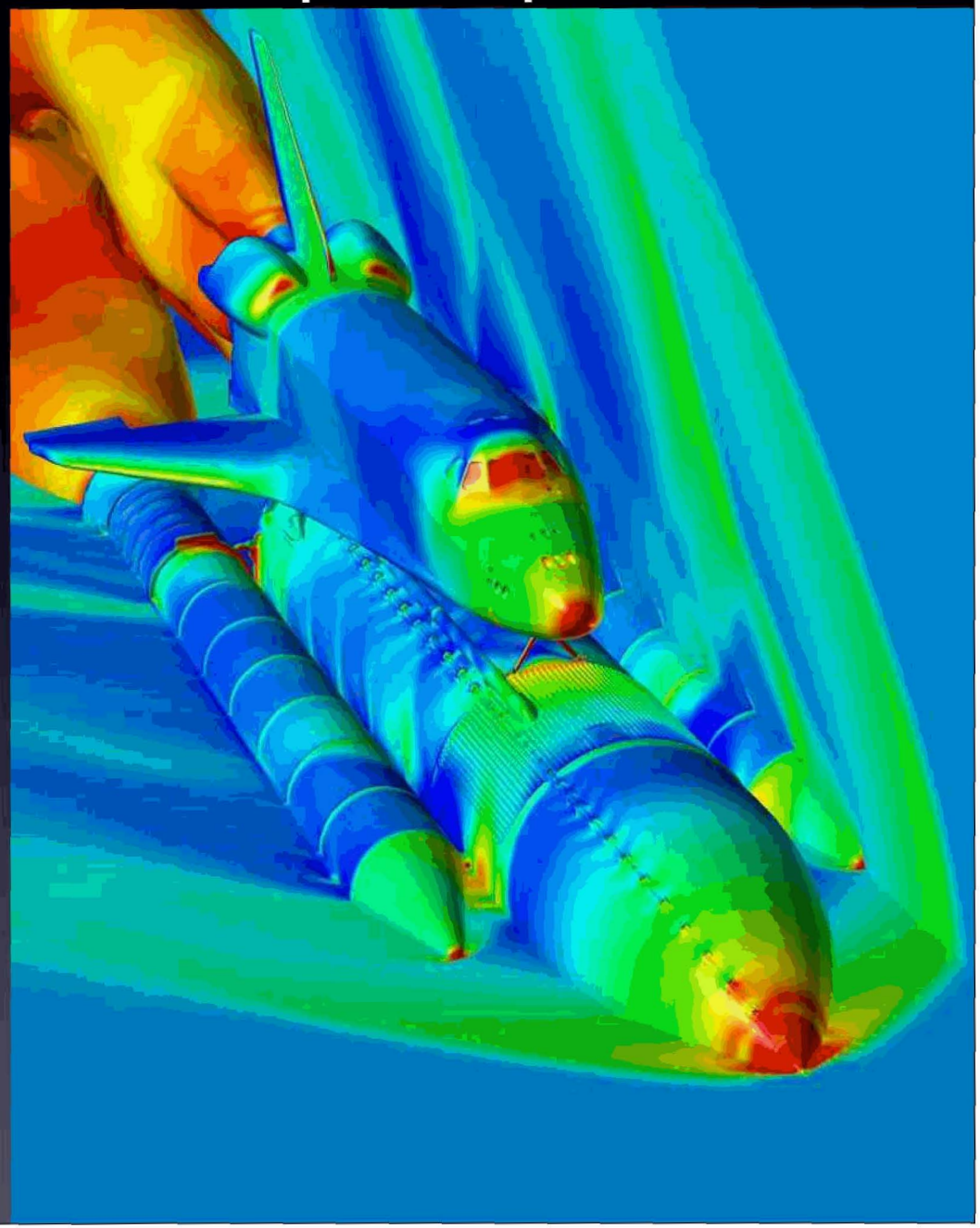
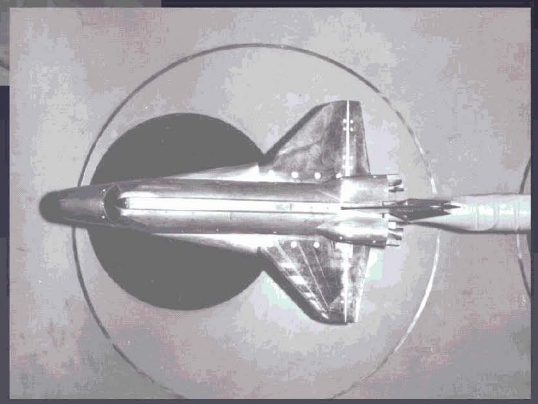
Parallel CFD Supporting NASA's Space Operations Mission Directorate



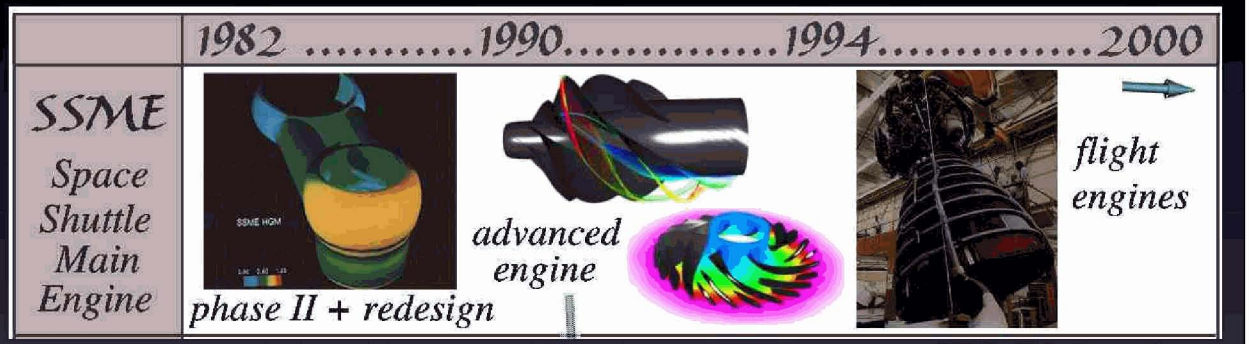
Reynaldo J. Gómez III
EG/Aeroscience & Flight Mechanics
NASA Johnson Space Center
Houston, Texas
April 21, 2008

NASA ARC & the Space Shuttle Program

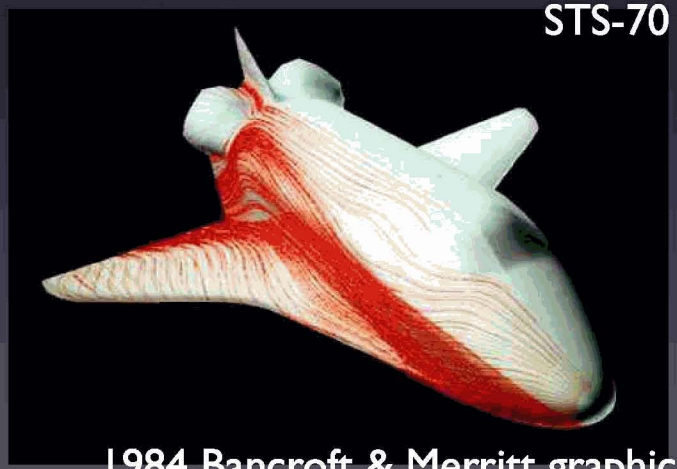
Design	Development	Operations	Retirement
ARC wind tunnel tests		NAS+CFD	FY 2010
44 A/B	176 C/D	1982-present	



OA-12 / IA9 1973 Unitary Tests

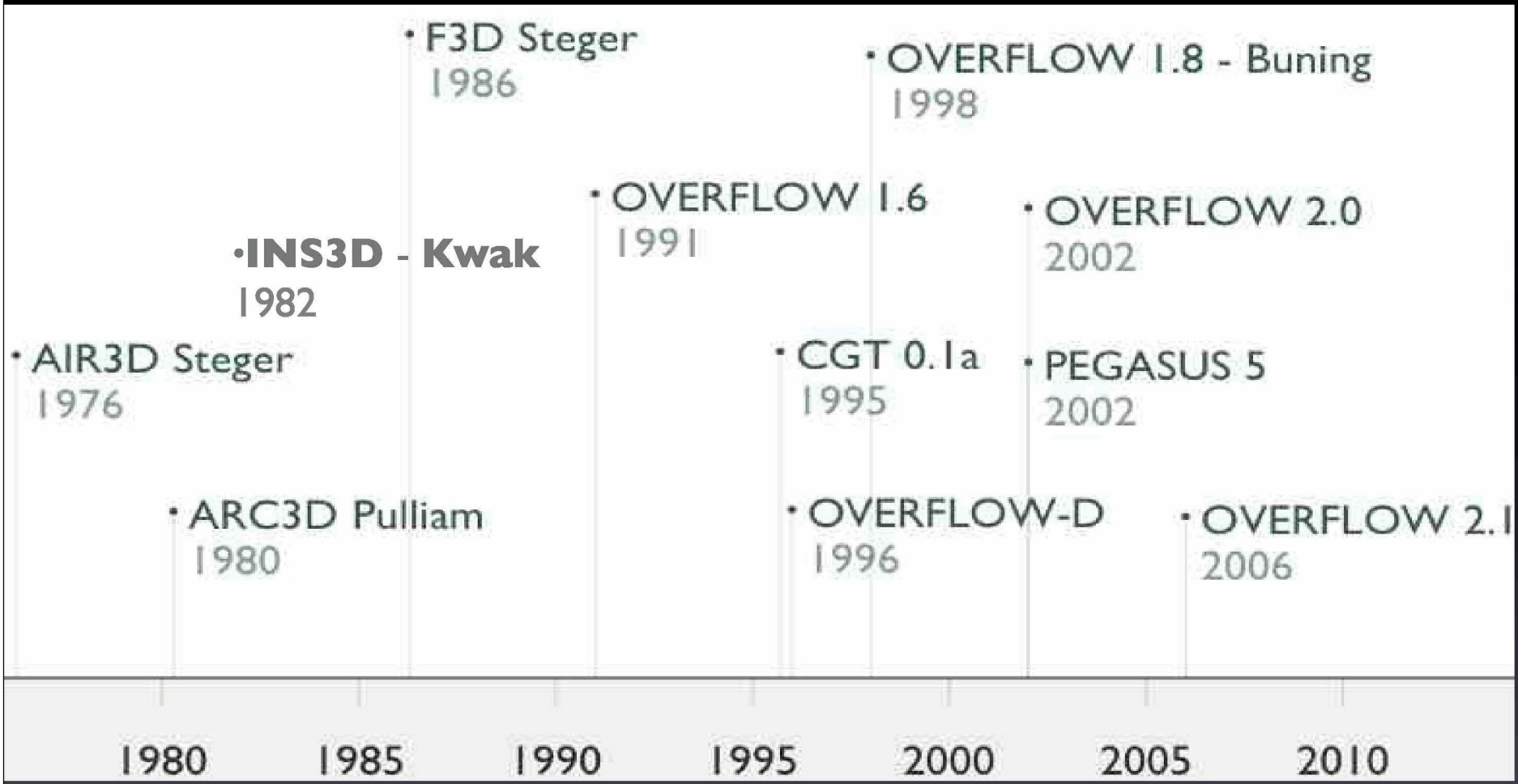


STS-70 & subs



1984 Bancroft & Merritt graphic
Cray X-MP solution

Space Shuttle CFD parallels NAS history

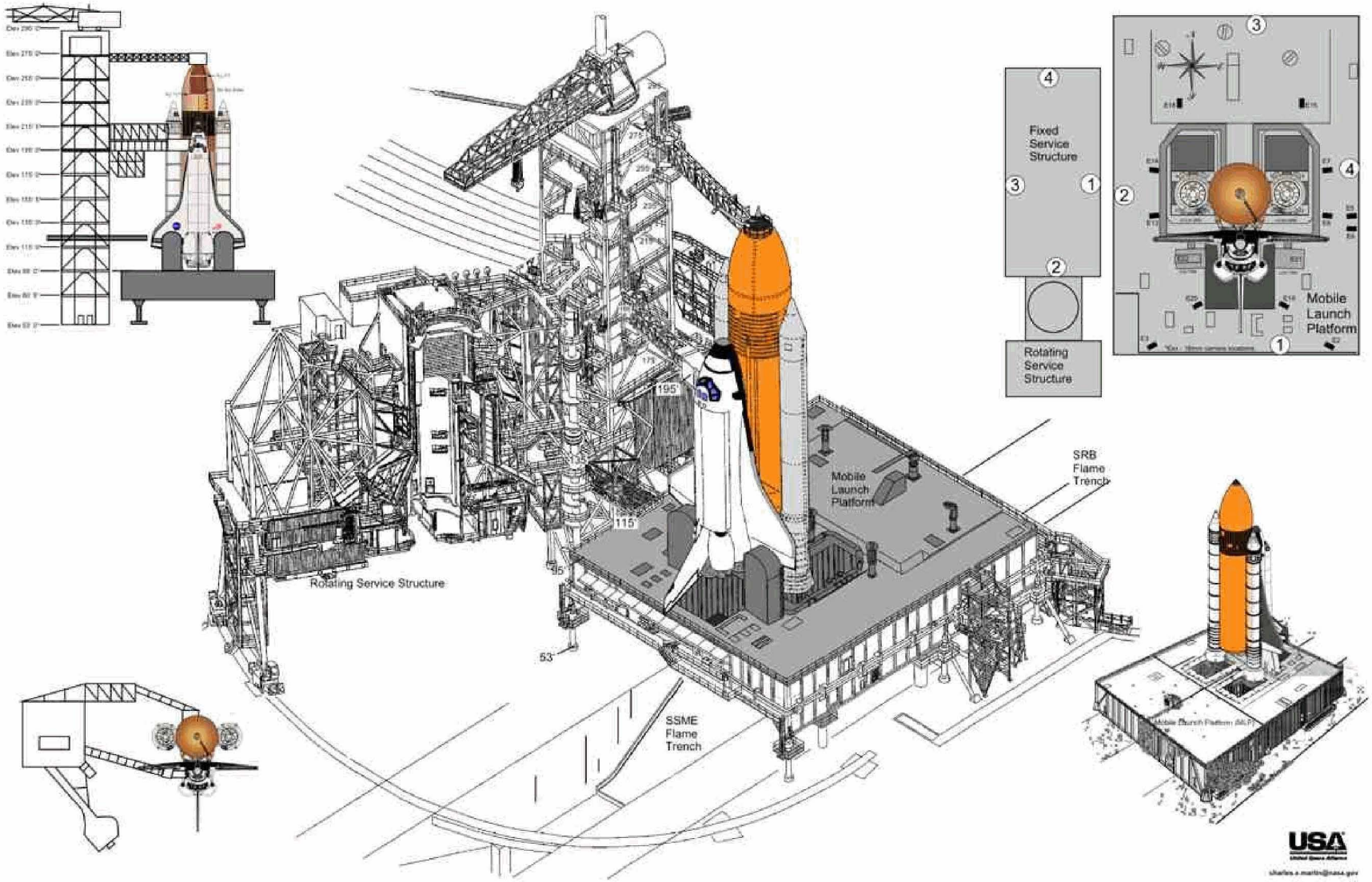


300,000 grid points
Proof of concept

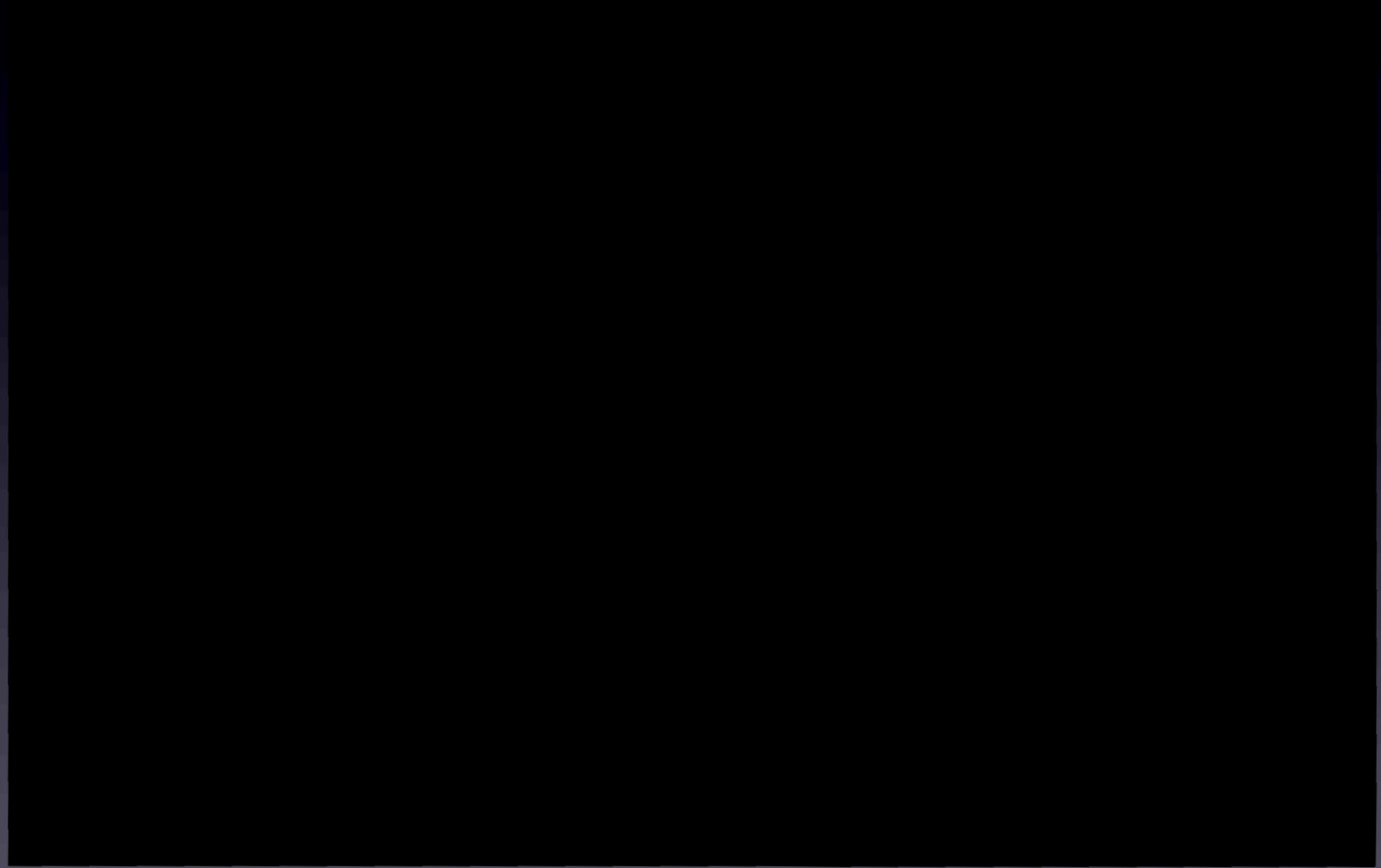
16.2 million grid points
Matched flight derived wing loads within 5%

96.4 million grid points
Detailed airloads used for redesigns & flight support

Launch Complex Geometry

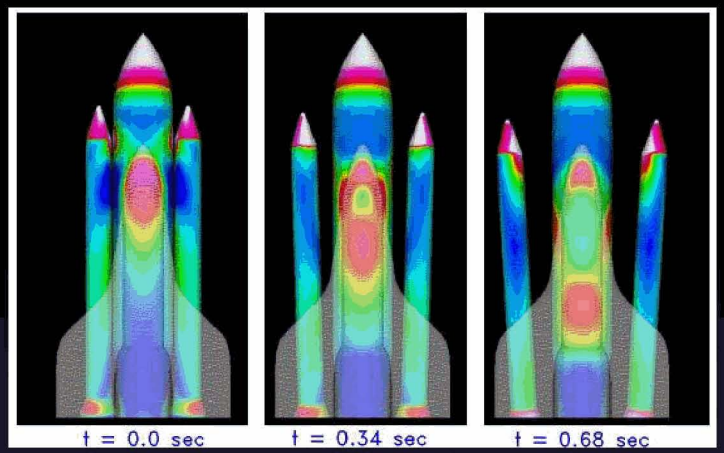


Space Shuttle Mission Overview (Video)

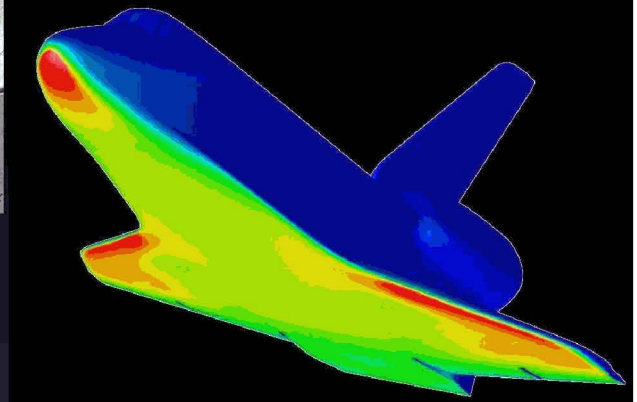


Parallel computing from prelaunch to landing

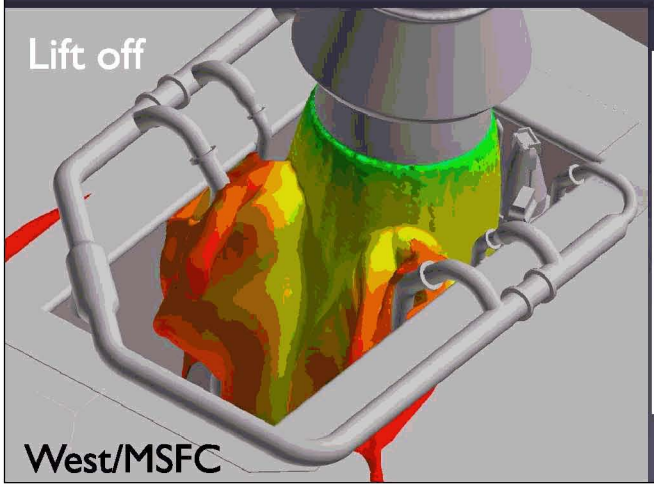
On-orbit Assessments
Hypervelocity Orbital Debris

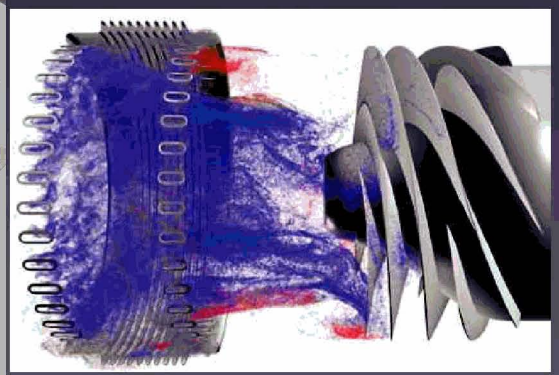


AIAA-2003-1248
Contingency Abort

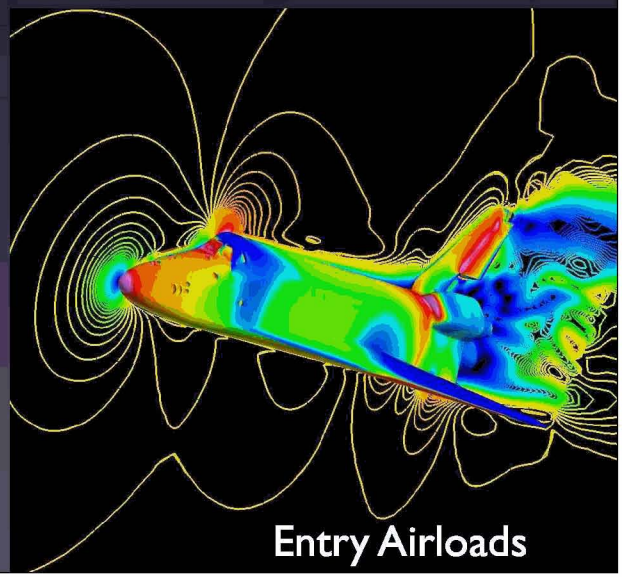


Transonic airloads
Roll maneuver





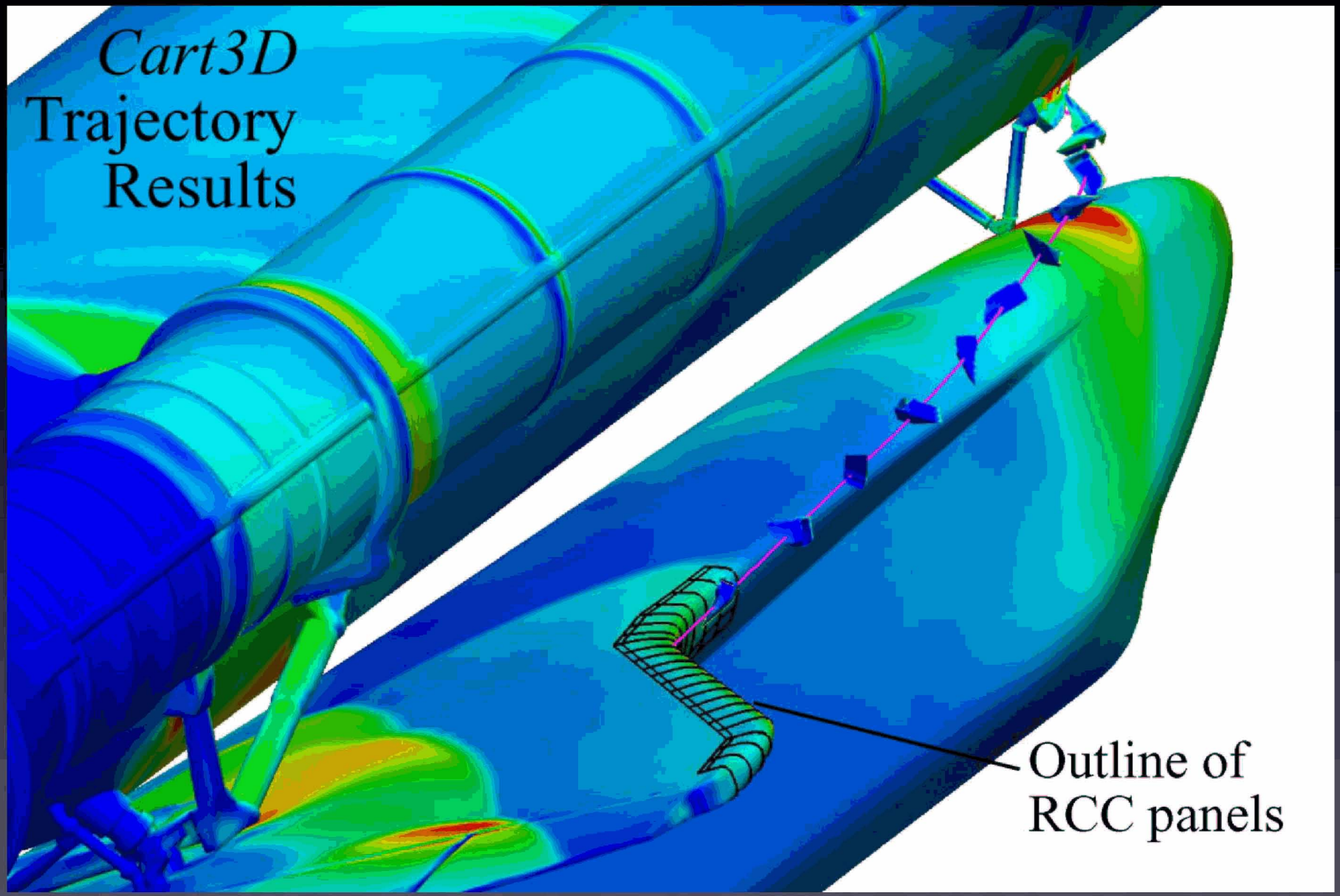
Cetin Kiris/ARC



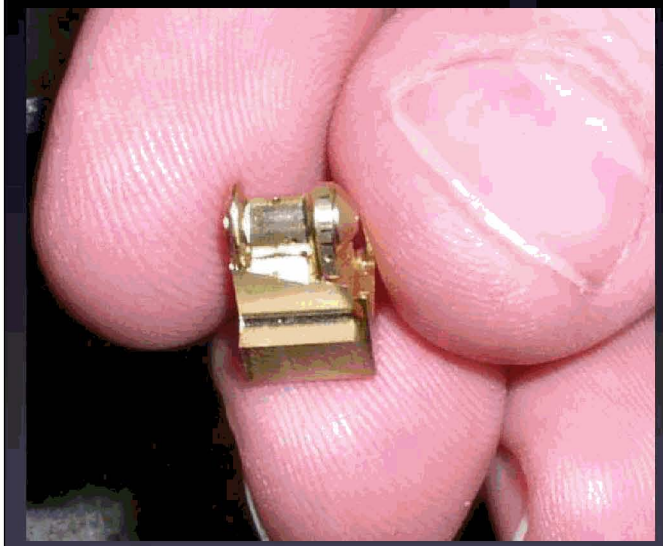
Entry Airloads

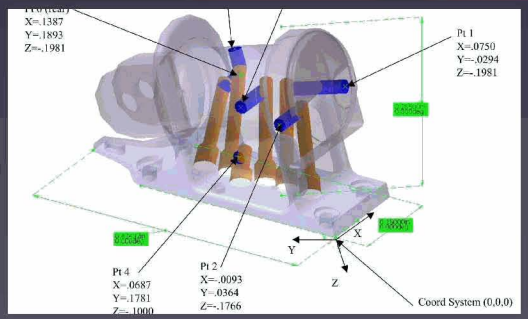
STS-107 Debris

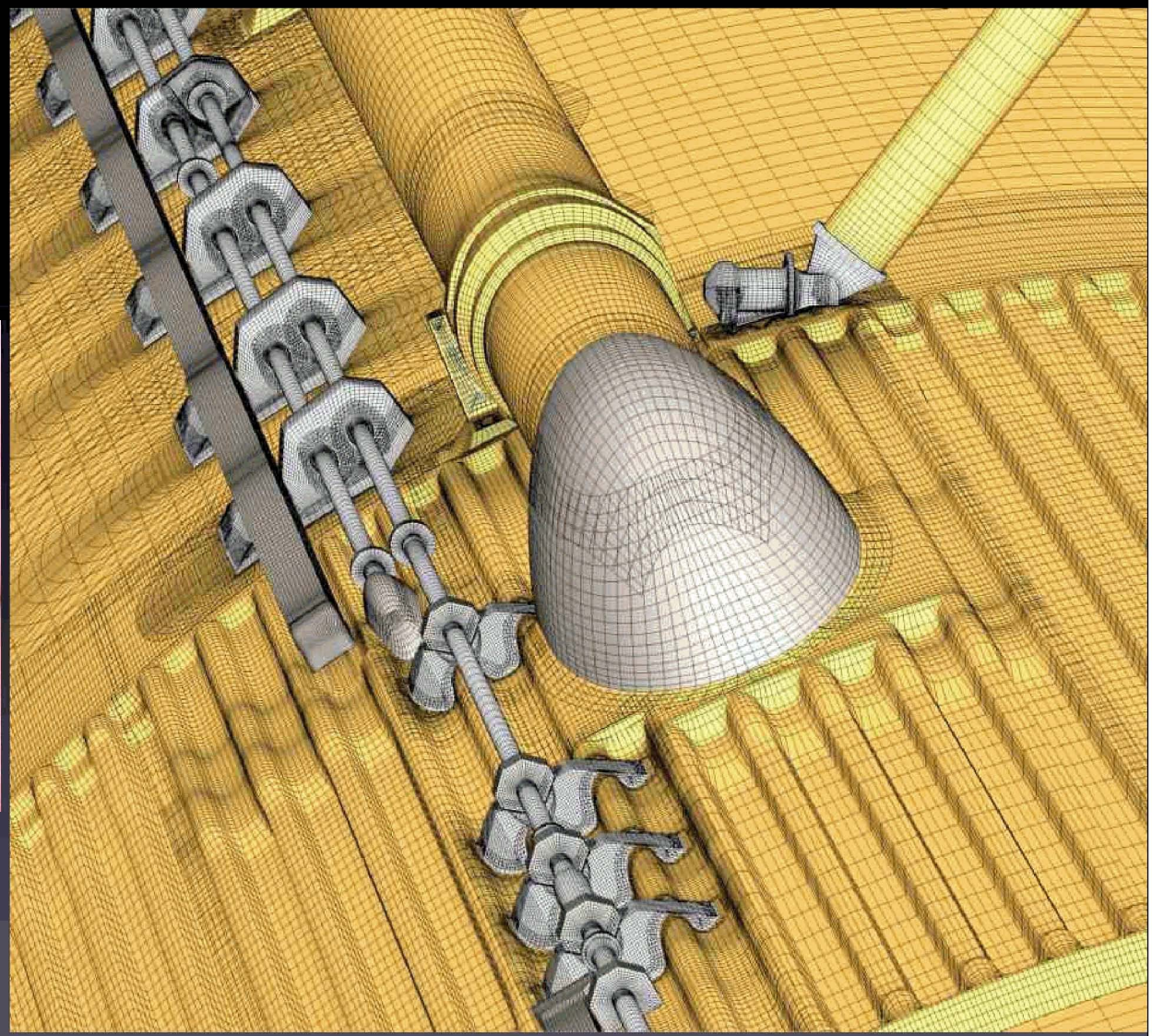
AIAA 2005-1223



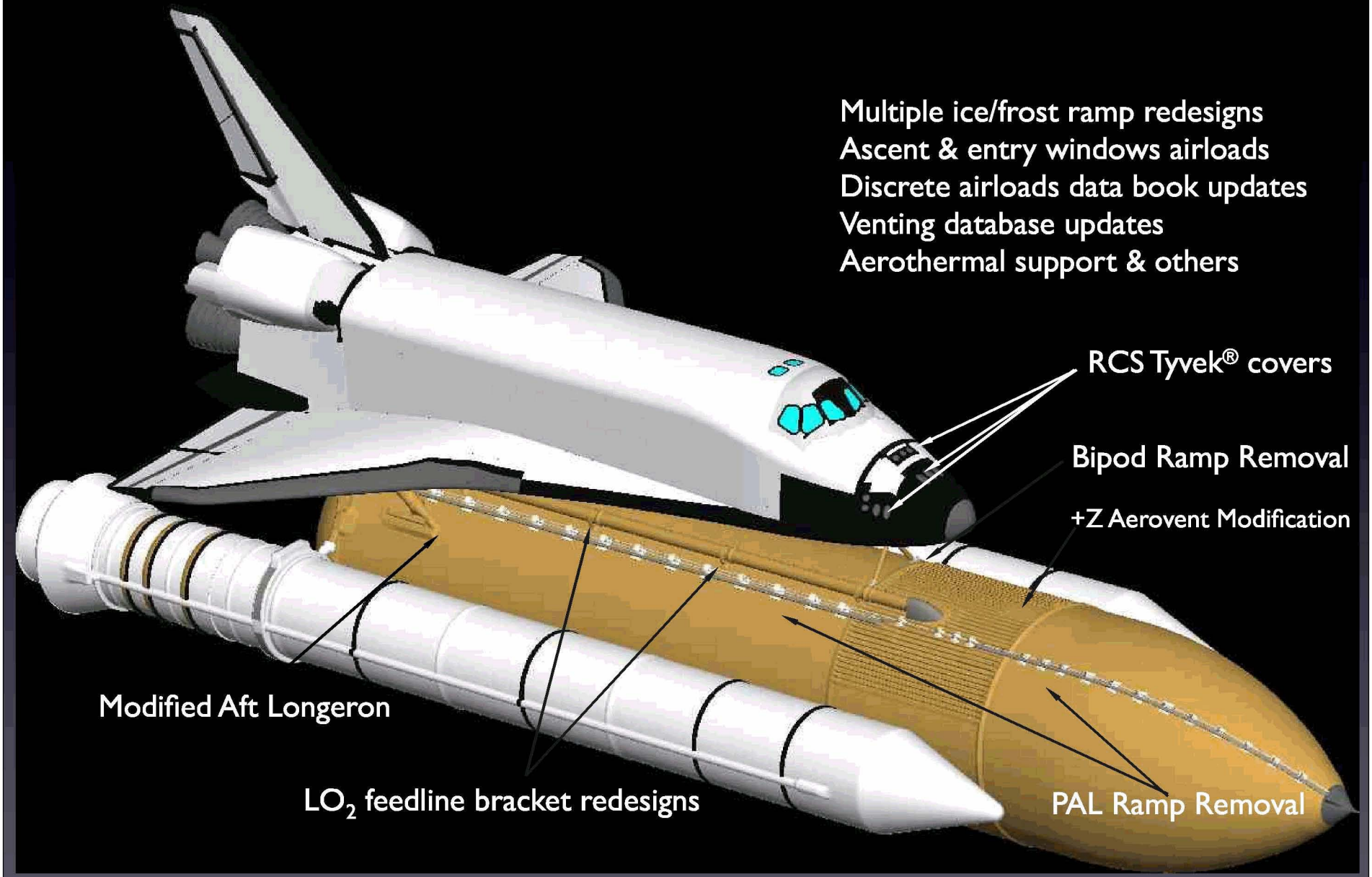
Wind tunnel validation & CFD extrapolation





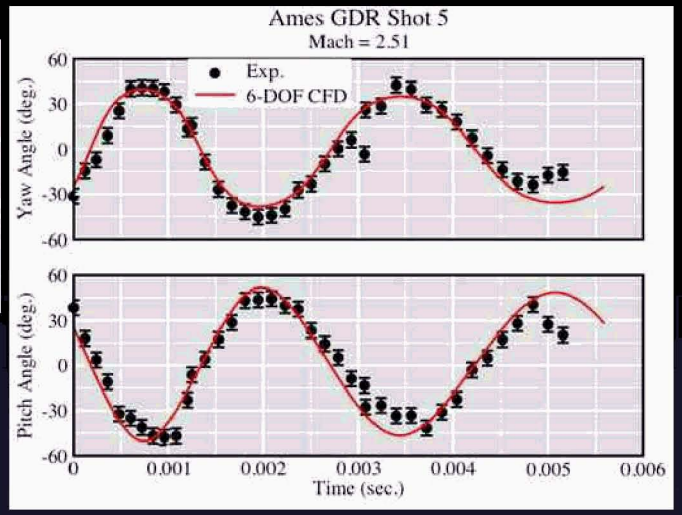


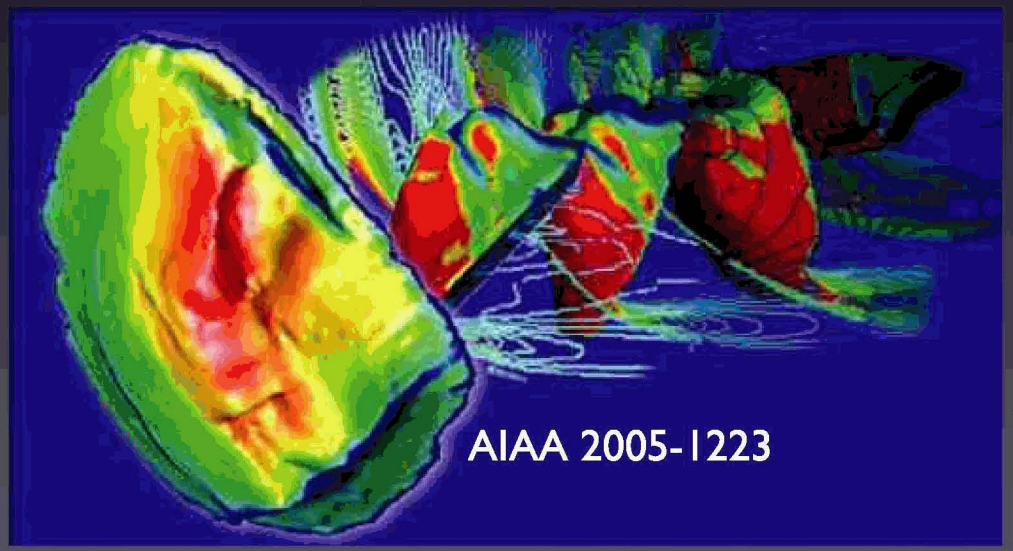
Many External Tank redesign assessments used solutions run on Columbia



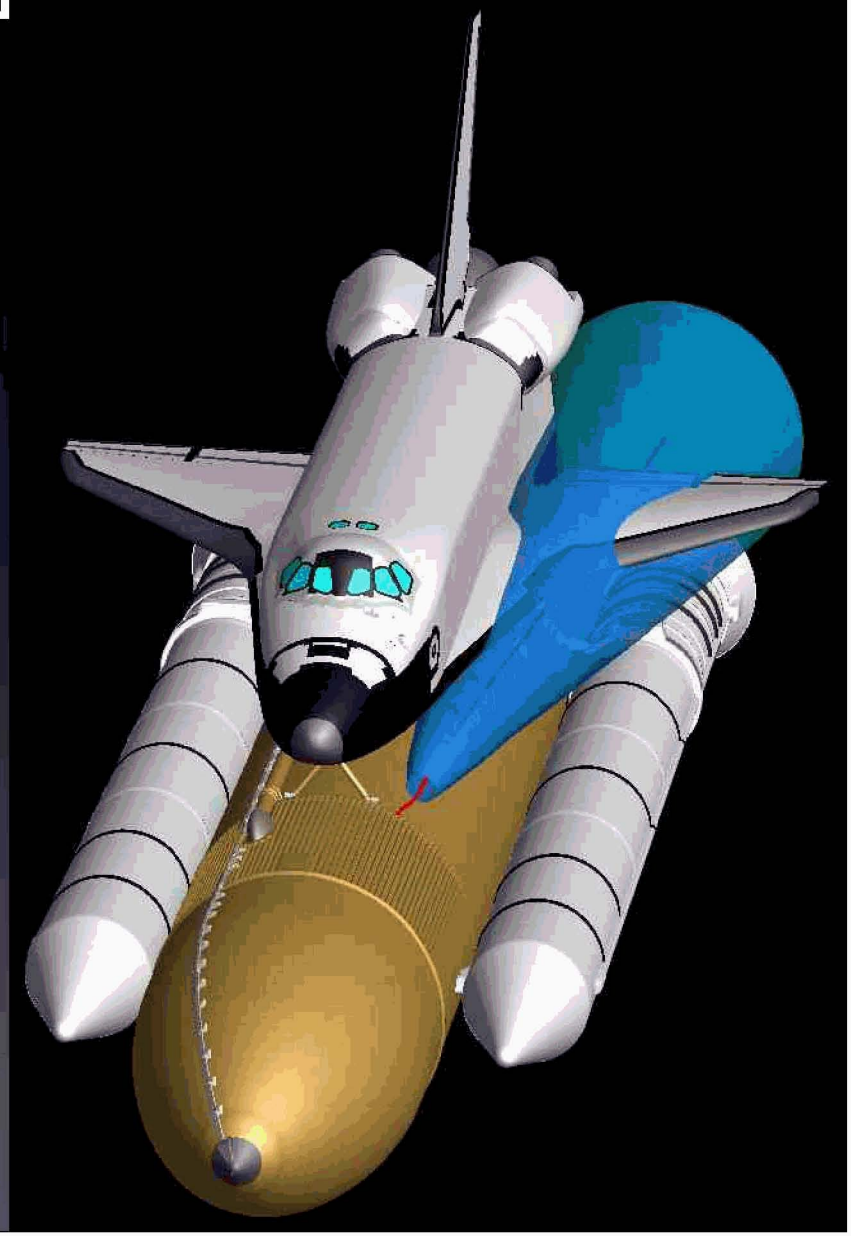
Debris transport aerodynamic models & prediction tools developed at NAS

AIAA-2006-0662

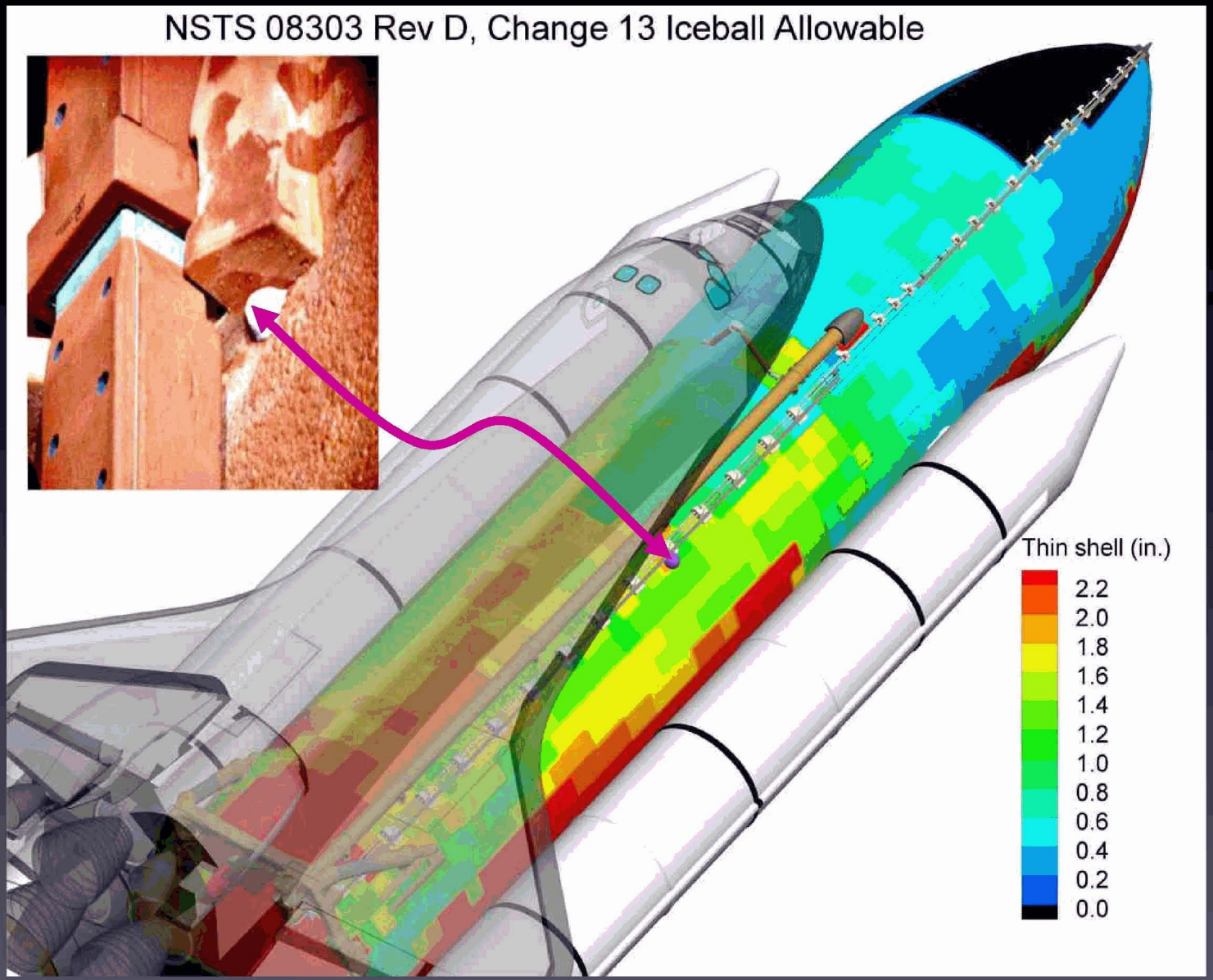




AIAA 2005-1223

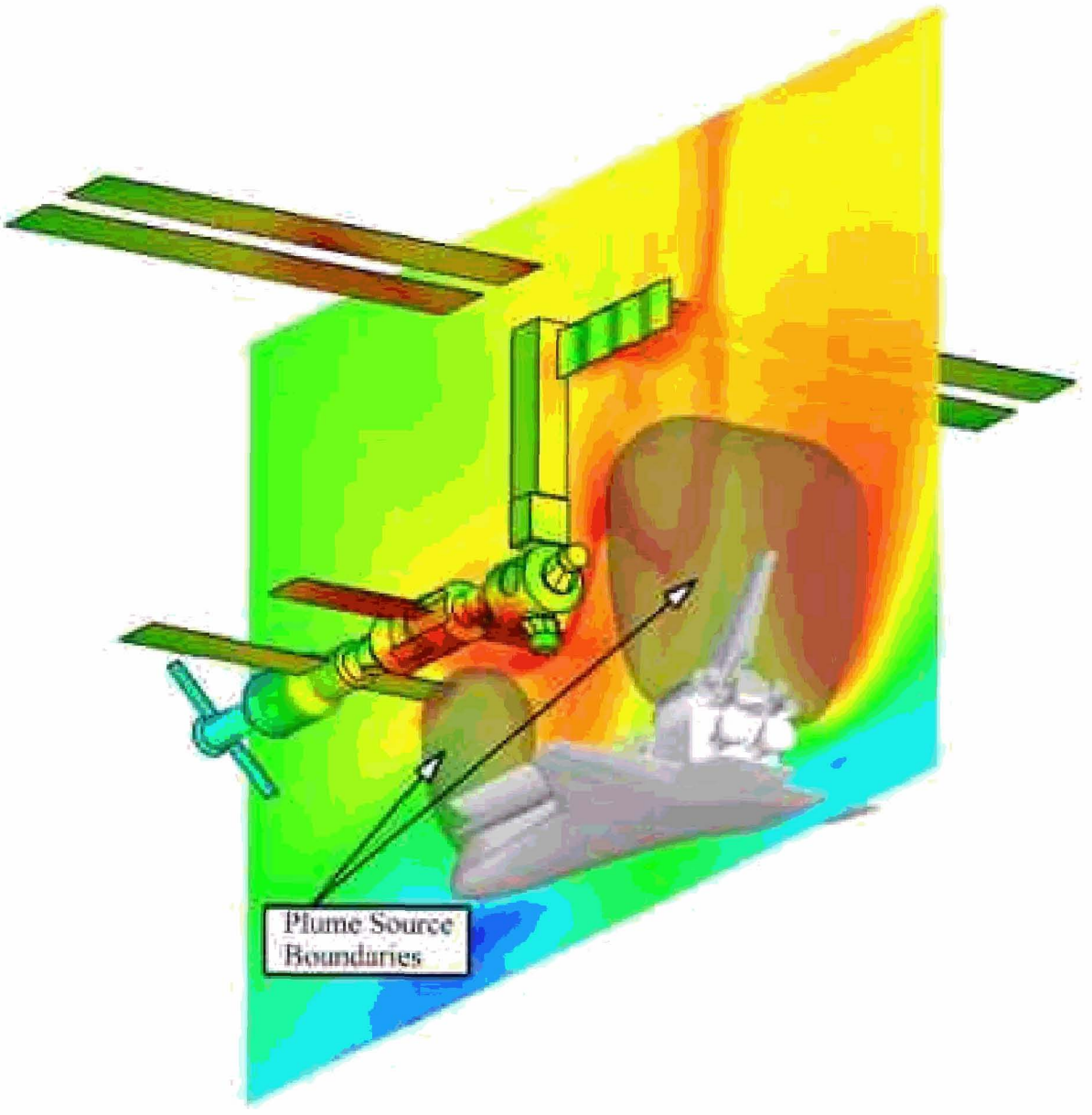


NSTS 08303 day of launch ice ball launch commit tool developed by Stuart Rogers/ARC NAS-07-004



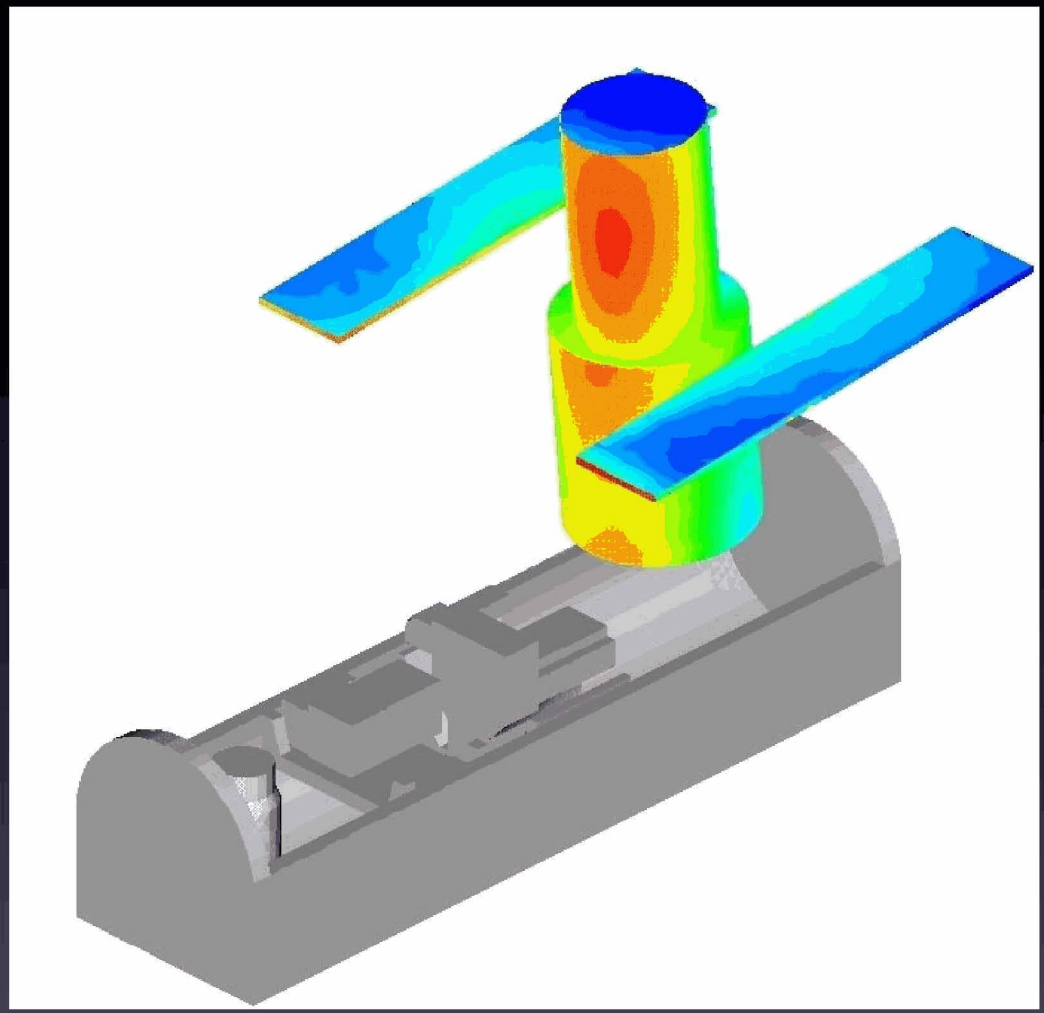
Rarefied Direct Simulation Monte Carlo Simulations

F. E. Lumpkin et al
27th JANNAF
Conference 2003



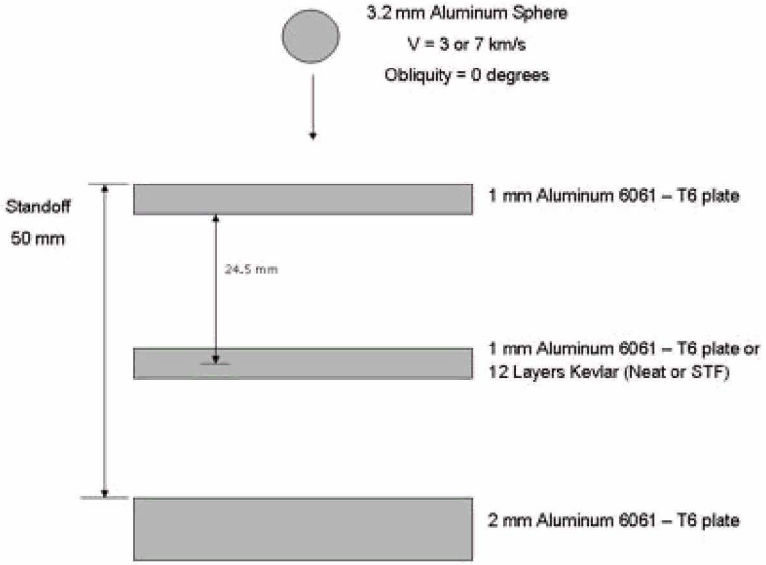
Hubble Servicing Mission Support

Venting of the airlock into the payload bay can overload the HST solar arrays. DSMC simulations are used to redesign vents and specify vent rates to minimize risks to the hardware.



LeBeau, G. J., and Lumpkin, F. E., III, "Application highlights of the DSMC Analysis Code (DAC) software for simulating rarefied flows", Computer Methods in Applied Mechanics and Engineering, 191, 595-609, 2001.

Orbital debris hypervelocity impacts > 3 km/sec



AIAA 2009-2400

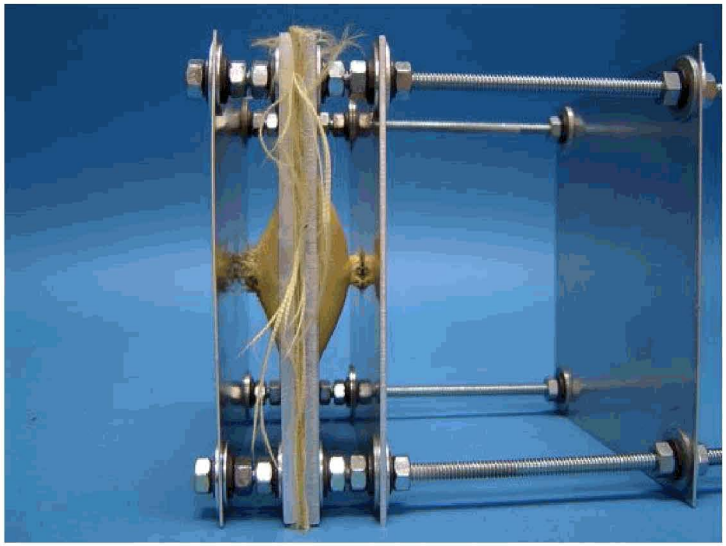
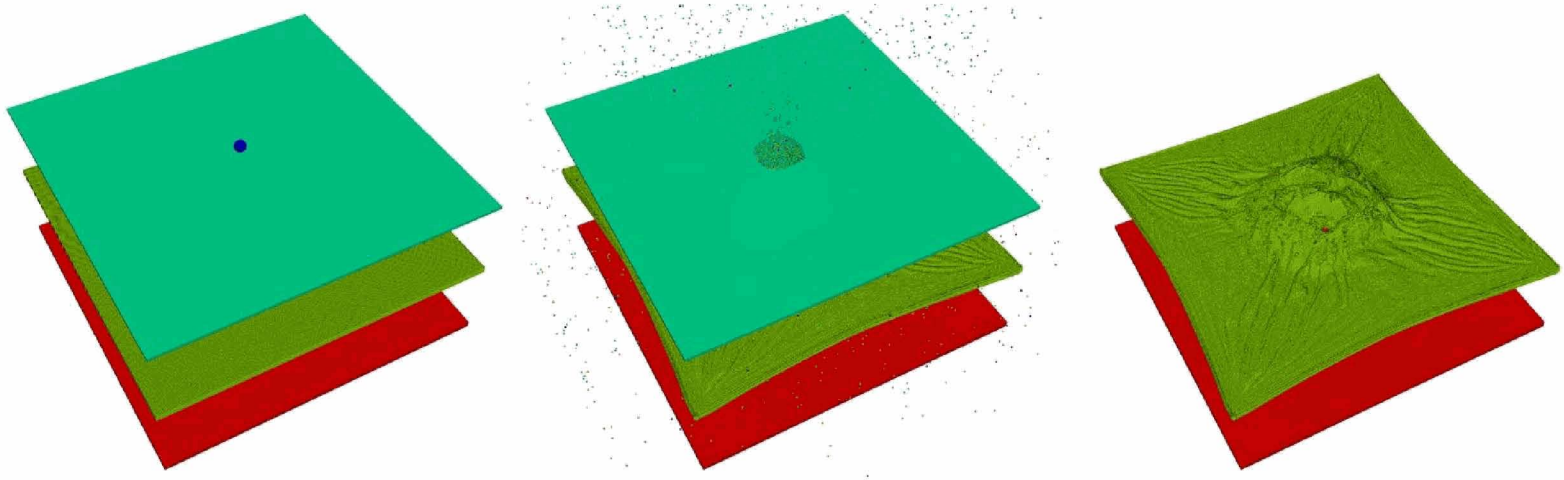
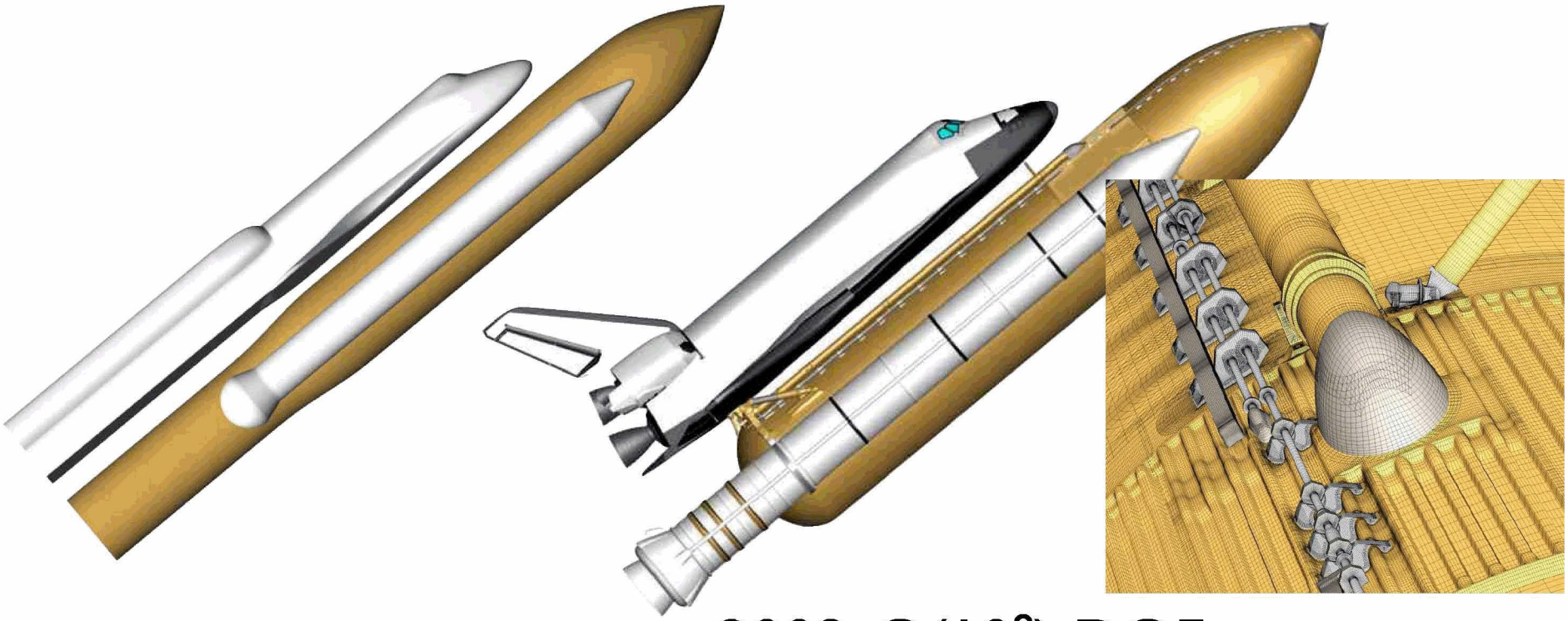


Figure 1. Stuffed Whipple shield schematic, and a Stuffed Whipple shield impact test (NASA JSC photo).



Parallel Development

- Shuttle support CFD tools developed on vector machines and transitioned to parallel architectures
- Engineering capability (DOF) doubling every 2 years

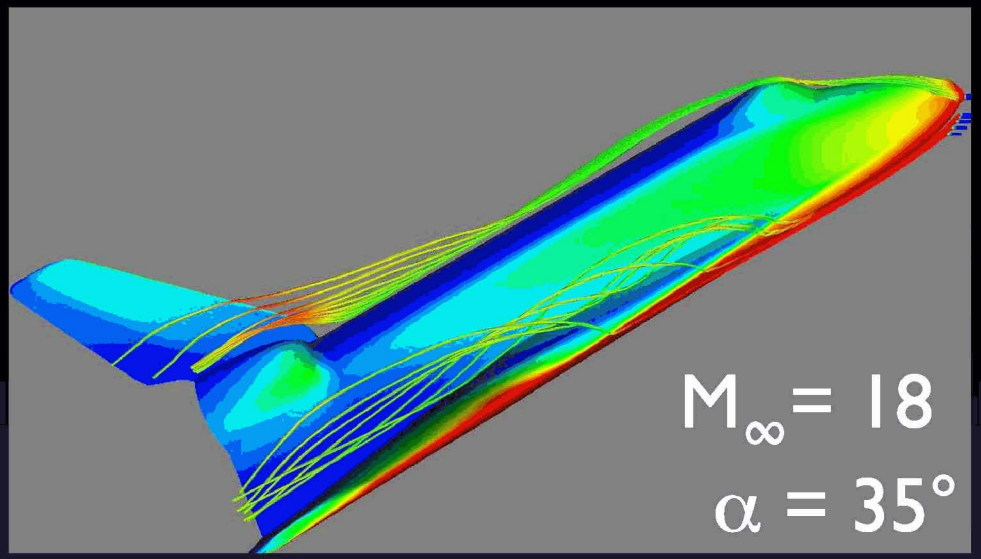


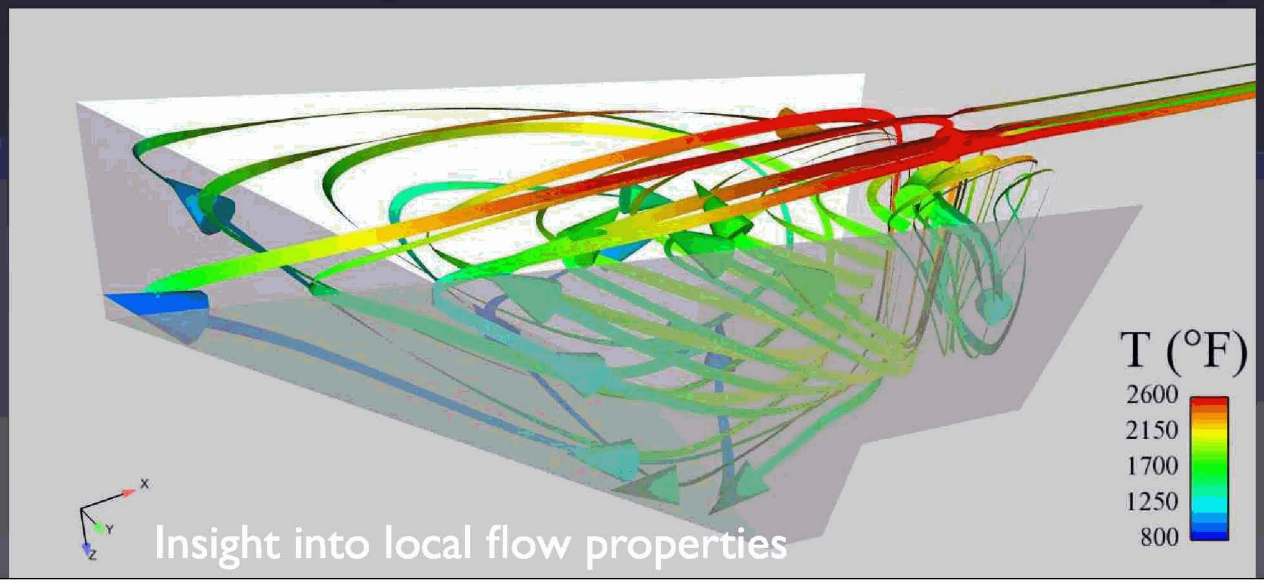
1989: O(10^5) DOF

2009: O(10^8) DOF

Inflight entry analyses

AIAA 2008-4246





We went to the moon without CFD or parallel computers. Why do we need them now?

- Reduce number of physical tests and improve relevance when you do test
  - Nearly 100,000 hours (11 years) of Shuttle wind tunnel testing
  - Many facilities have shut down or been mothballed
- Provides flight increments/ environments that cannot be obtained otherwise

Verification & Validation requirements are increasing.

Guide for Verification and Validation of Computational Fluid Dynamics Simulations, AIAA G-077, 1998.

Columbia Accident Investigation Board Report, Volume I, August 2003.

A Renewed Commitment to Excellence: An Assessment of the NASA Agency-wide Applicability of the Columbia Accident Investigation Report, PB2005-100968, January 30, 2004.

Standard for Models and Simulations, NASA-STD-7009, July, 11, 2008.

… and there is still more work to do.

- Some STS-1 flight anomalies are still beyond current CFD tool capabilities, e.g.
  - Acoustics and heating on complex configurations with strong shock wave-boundary layer interactions
  - RCS/aero/thermal interactions
- Physical models (turbulence, chemistry, ...) are key limitations that need to be improved.
- Uncertainty quantification (where are the CFD error bars?)