PRESENT CHALLENGES IN NASA's AEROSCIENCES DISCIPLINE

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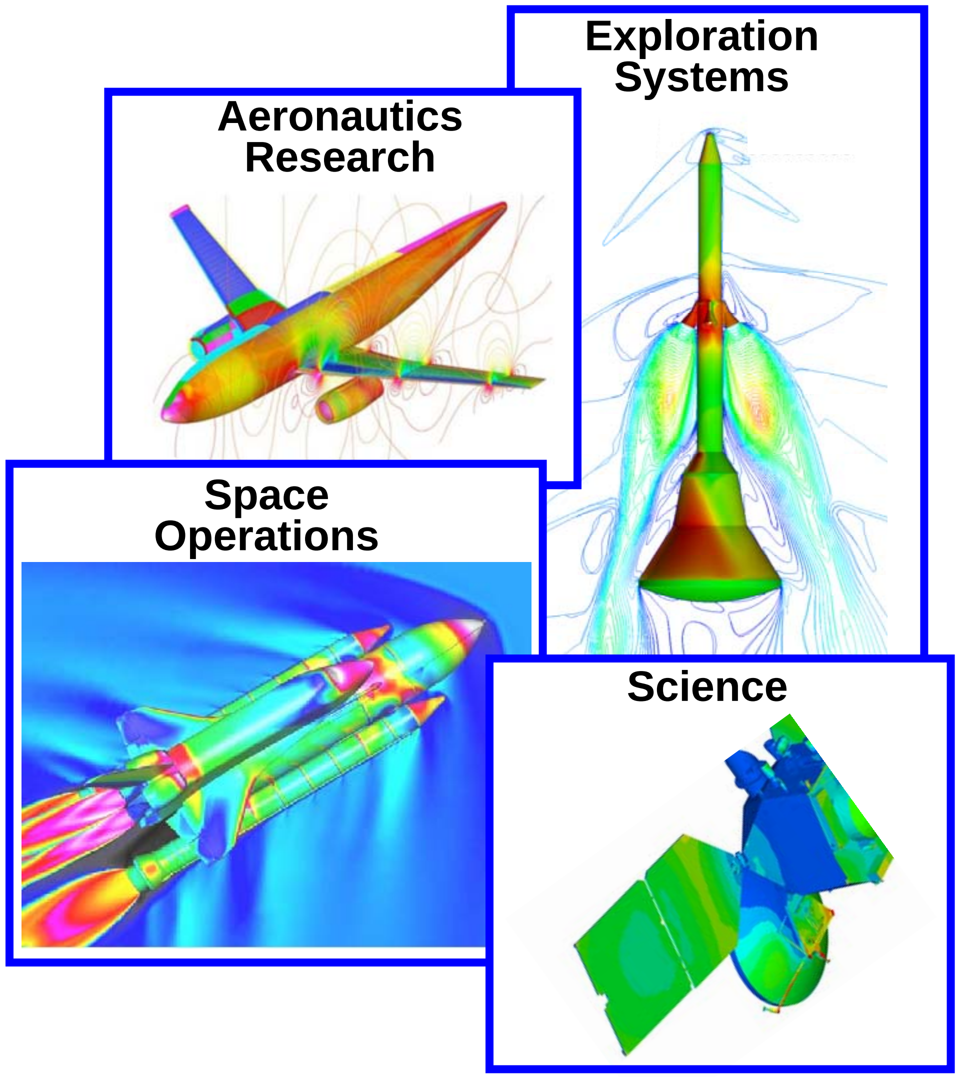
NASA's Missions and Links to the Aerosciences Discipline

- **The NASA Technical Fellows are responsible for assessing the state of and providing stewardship for their respective disciplines.**
  - A NASA-centric evaluation.
  - An assessment of the discipline to address the technical challenges within the individual NASA Missions.
- **Challenges in the four missions revealed three primary Aerosciences issues facing NASA.**

NASA's Missions



NASA Aerosciences in Brief

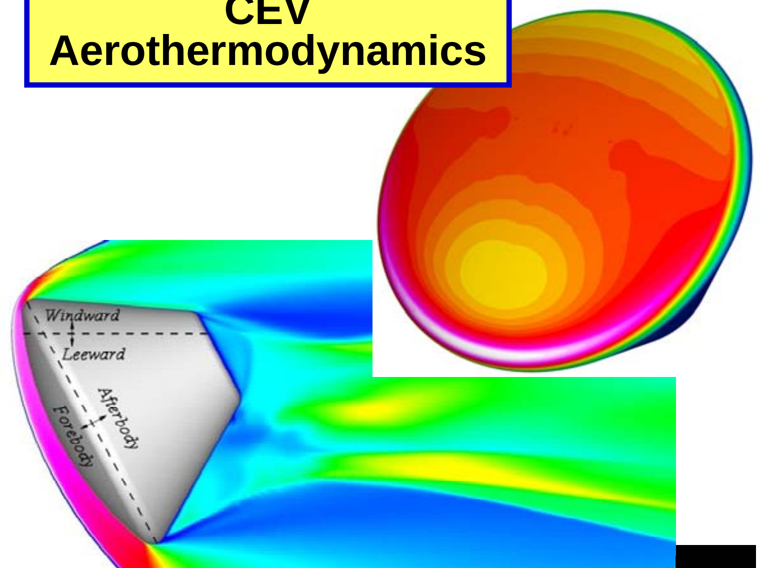
- **Aerosciences is in high demand across the Agency.**
- **Actively leveraging the surge in computational capability and tailoring ground and flight testing to merge with this capability.**
  - No longer simply validating methods using experiments.
  - Computations employed to minimize and focus test matrices and reduce vehicle development cycle times.

- **Aerosciences is far from a mature science, with many of the present challenges resulting from interactions with other disciplines.**
  - Thermal, Loads and Dynamics, GN&C, Structures, Acoustics, and Propulsion are among our primary interaction disciplines.
- **NASA's Constellation Program is presenting new challenges.**
  - Sharp angles, protuberances, and jet interactions can generate unsteady, separated flows that contribute to aeroacoustic and buffet environments.

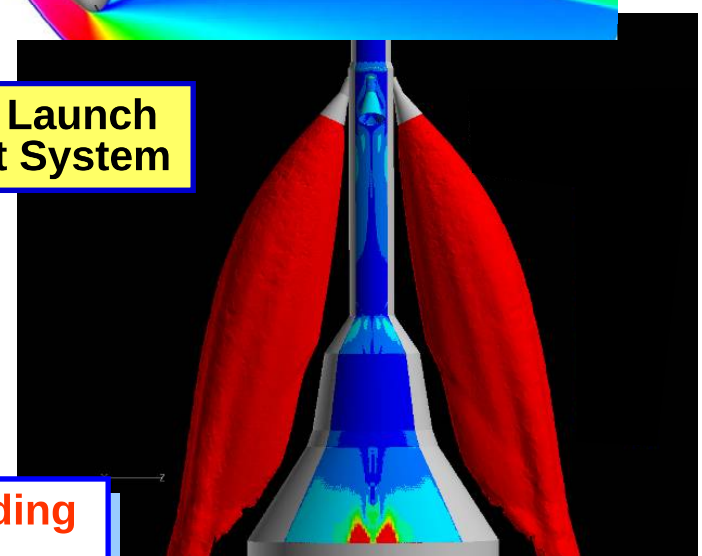
Aerosciences High Demand Areas

- **Aerodynamic Database Construction.**
  - Aerodynamic Performance.
  - Loads and Dynamics.
  - Guidance, Navigation, and Control.
- **Aero-Interactions.**
  - Aerothermodynamics.
    - Aeroheating.
  - Aeroacoustics.
    - Environments.
  - Aeroelasticity.
    - Unsteady aerodynamics.
  - Aeropropulsion.
    - Integration.
    - Plume interaction.

CEV Aerothermodynamics



CEV Launch Abort System



Red indicates areas where holes in capability exist leading to research and technology integration opportunities.

Aeroscience Capability Shortfalls

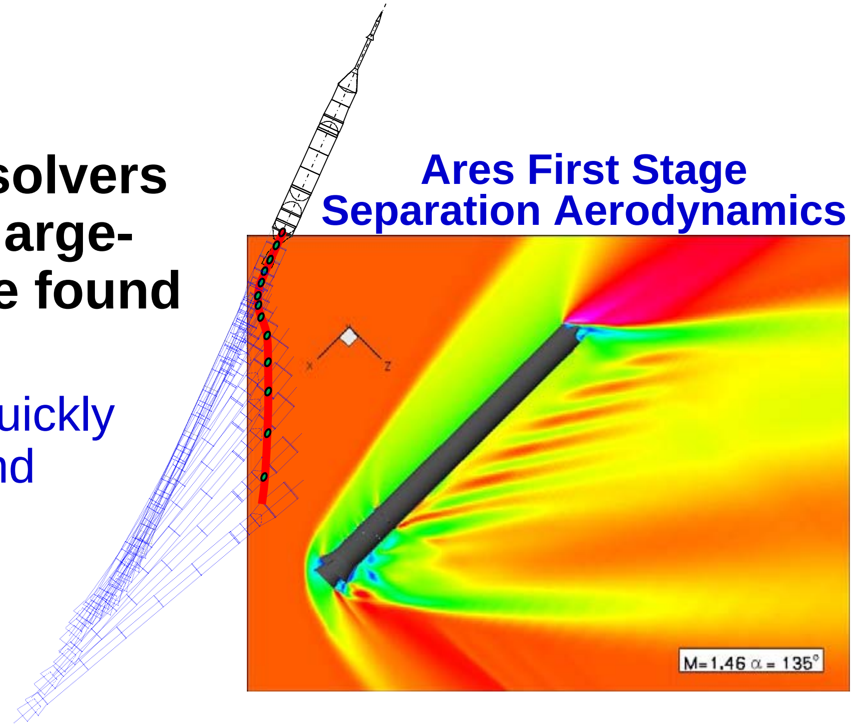
Three aeroscience areas are currently hindering the prediction of environments and performance for NASA flight vehicles. (In order of criticality)

1. **Prediction, characterization and quantification of unsteady, separated flows**
   - Testing is very expensive and time-consuming
   - Acoustics and buffet loads estimation require accurate characterization of these flows.
2. **Assessment of Aero-thermodynamic Environments.**
   - Spacecraft ascent/reentry, hypersonic air vehicles.
   - High-Mach boundary layer transition, ablative TPS performance.
3. **Aero-propulsion interaction.**
   - Aero-plume interactions, reaction control systems, hypersonic air vehicle propulsion systems.

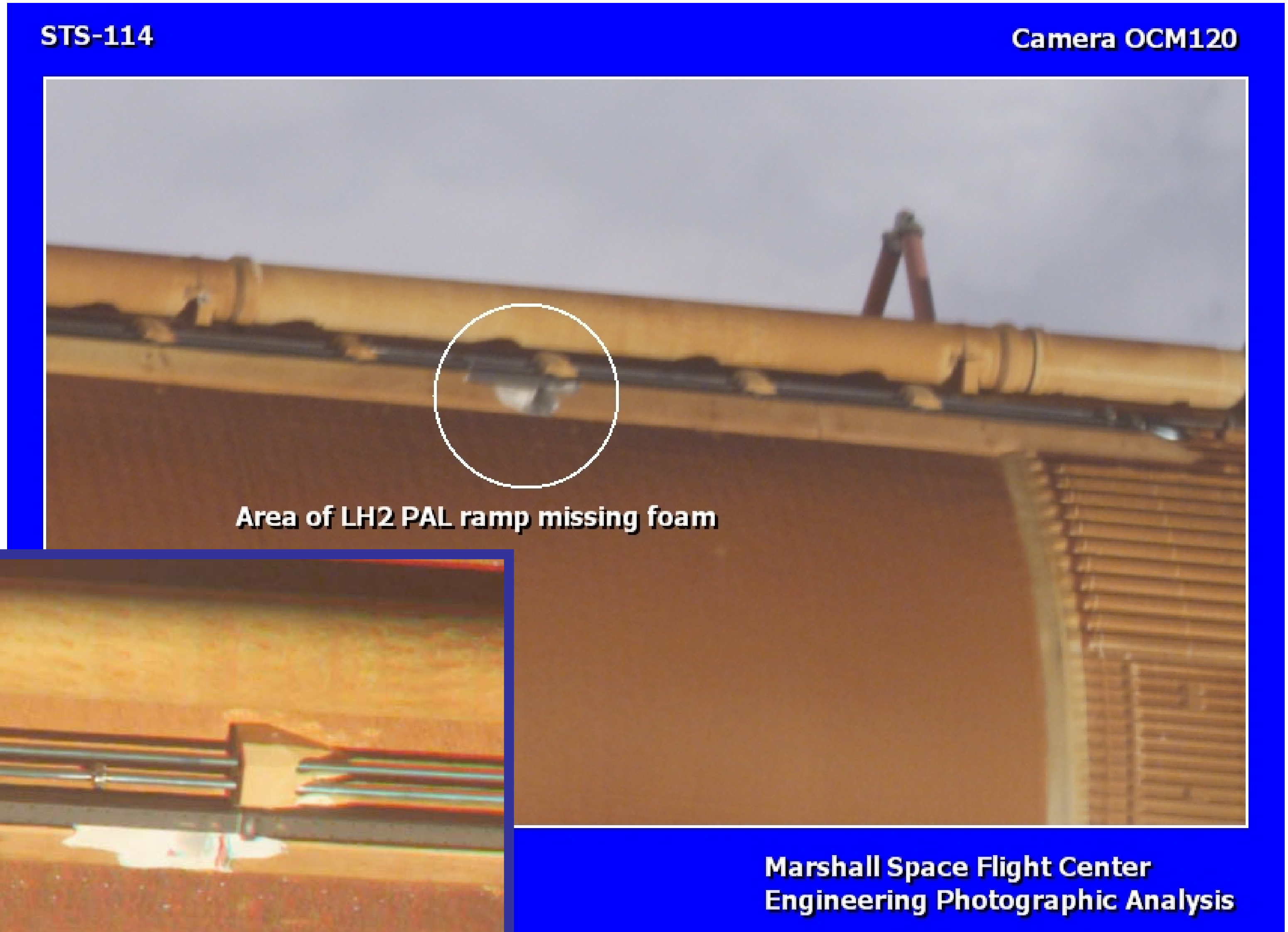
Unsteady Separated Flow Computations

- **Reynolds Averaged Navier-Stokes solvers are relatively capable of predicting large-scale separated flows such as those found in Strouhal Vortex shedding.**
  - Flows involving smaller scale eddies quickly become intractable due to modeling and computation times.
- **Advanced modeling techniques such as Detached Eddy Simulation (DES) can significantly reduce the size of eddies that can be captured and extend the capabilities of computations.**
  - Limited experience with these techniques and computational resources are still significant.
- **Interesting flow cases are mildly separated and incipient separated flows.**
  - Require modeling of eddies smaller than those simulated by DES.

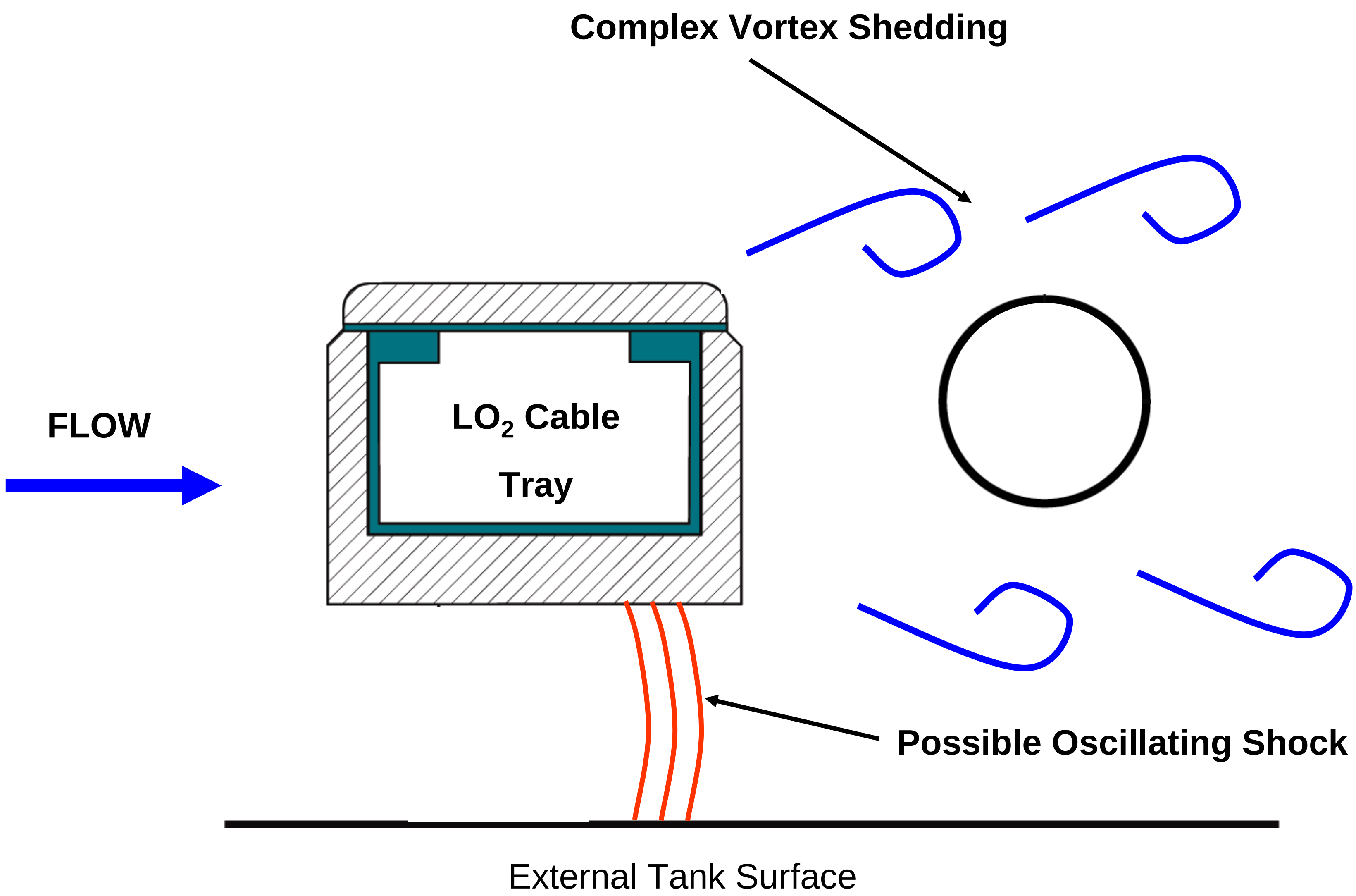
Ares First Stage Separation Aerodynamics



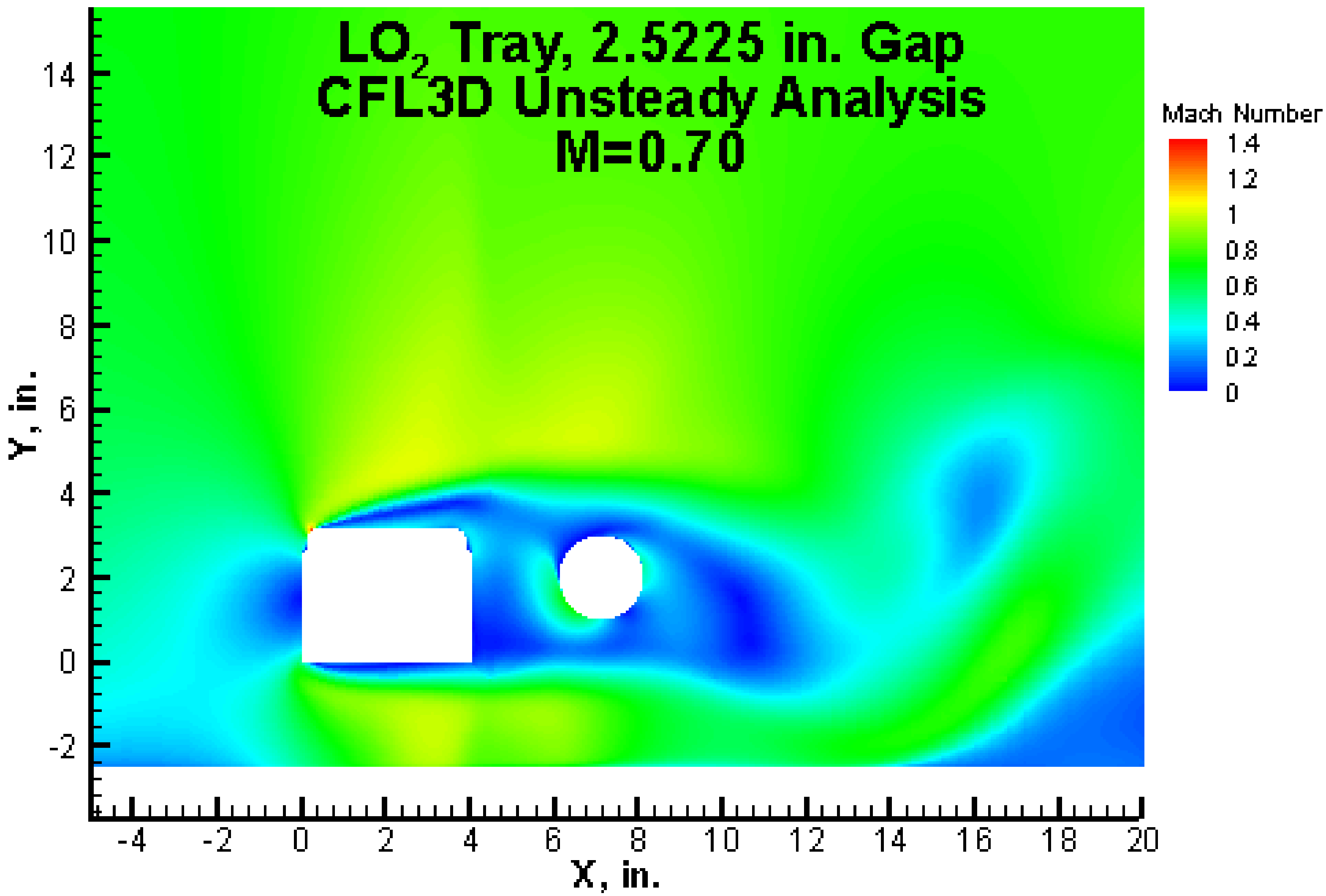
STS-114 PAL Ramp Foam Loss



Unsteady, Separated Flow Prediction Example: Shuttle Cable Tray Buffet Loads



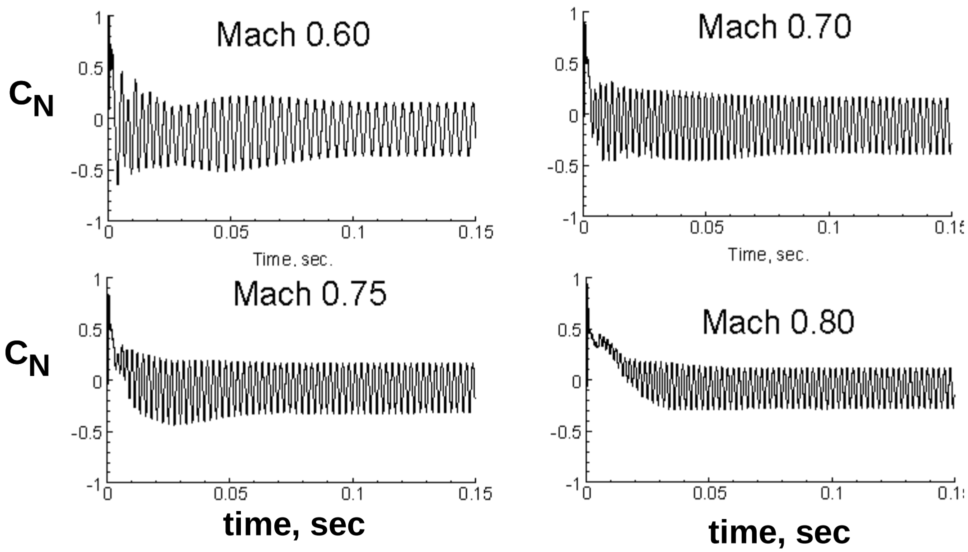
Simulation of Cable Tray Vortex Shedding (Present RANS Technology)

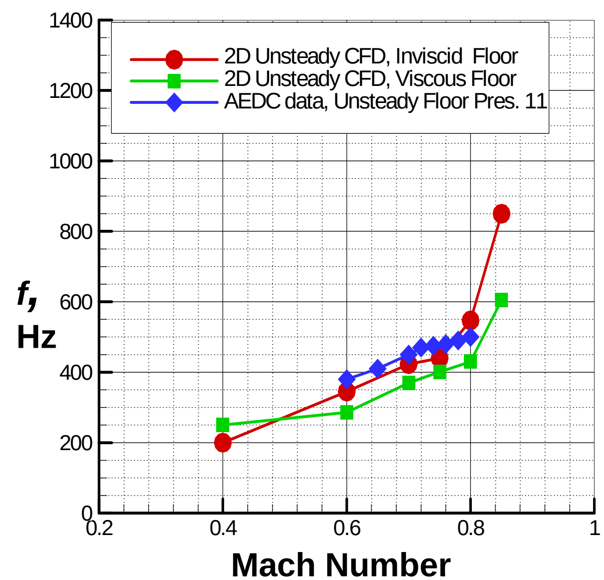


AEDC Test Results Compared with Computed Strouhal Vortex Shedding Oscillations about the LO_2 Cable Tray

CFL3D code (2-D): unsteady, viscous

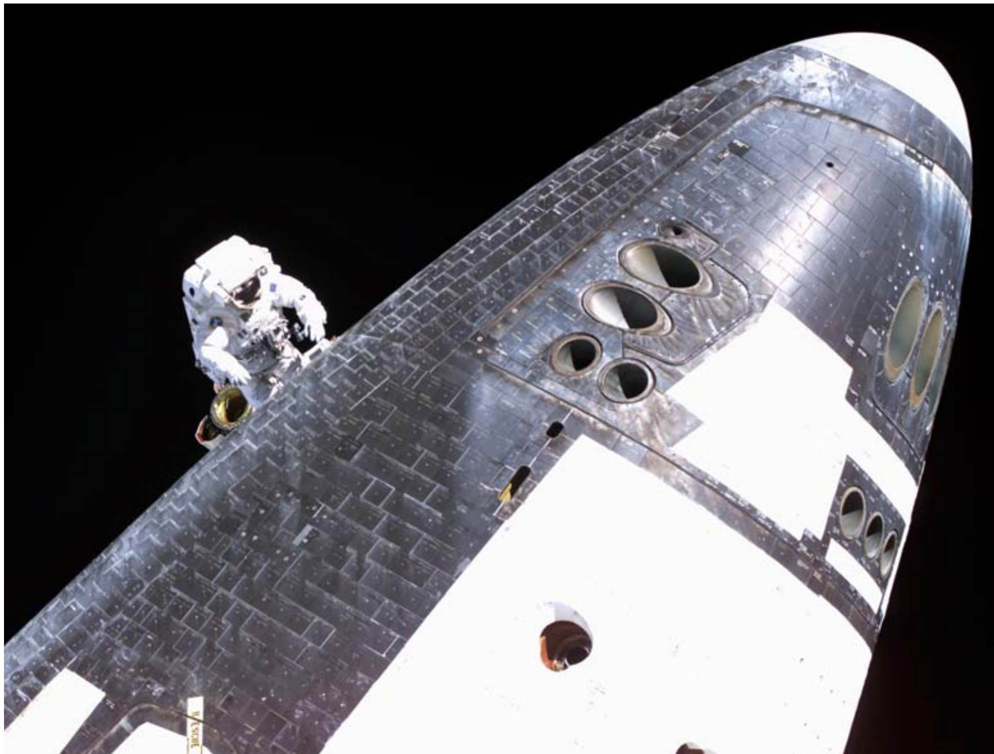
90 deg crossflow simulation





- **CFD can accurately predict boundaries and frequencies of large-scale vortex shedding events.**
- **Small-scale fluctuations due to separated flow and turbulence limit the ability of computational methods to accurately predict amplitudes.**
- **Moving computations to this next level of physics detail is a significant challenge for HPC.**
  - Computation time, memory, storage, post-processing results.

STS-114 Gap Filler Removal

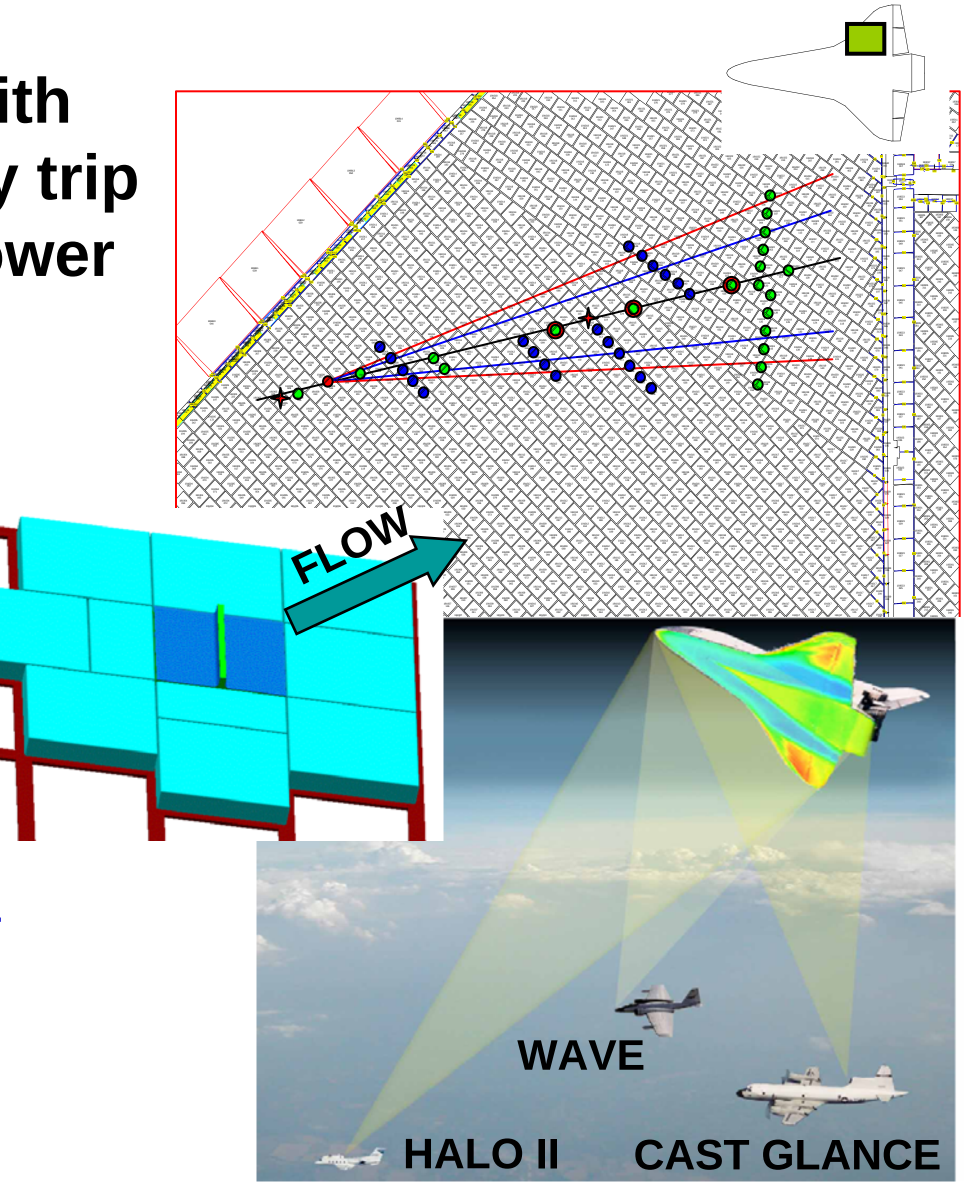


- **August 3, 2005: Steve Robinson performs an unplanned EVA to remove a protruding gap filler.**

- **EVA necessitated by Aeroscience discipline’s inability to confidently predict reentry heating due to protruding gap filler.**

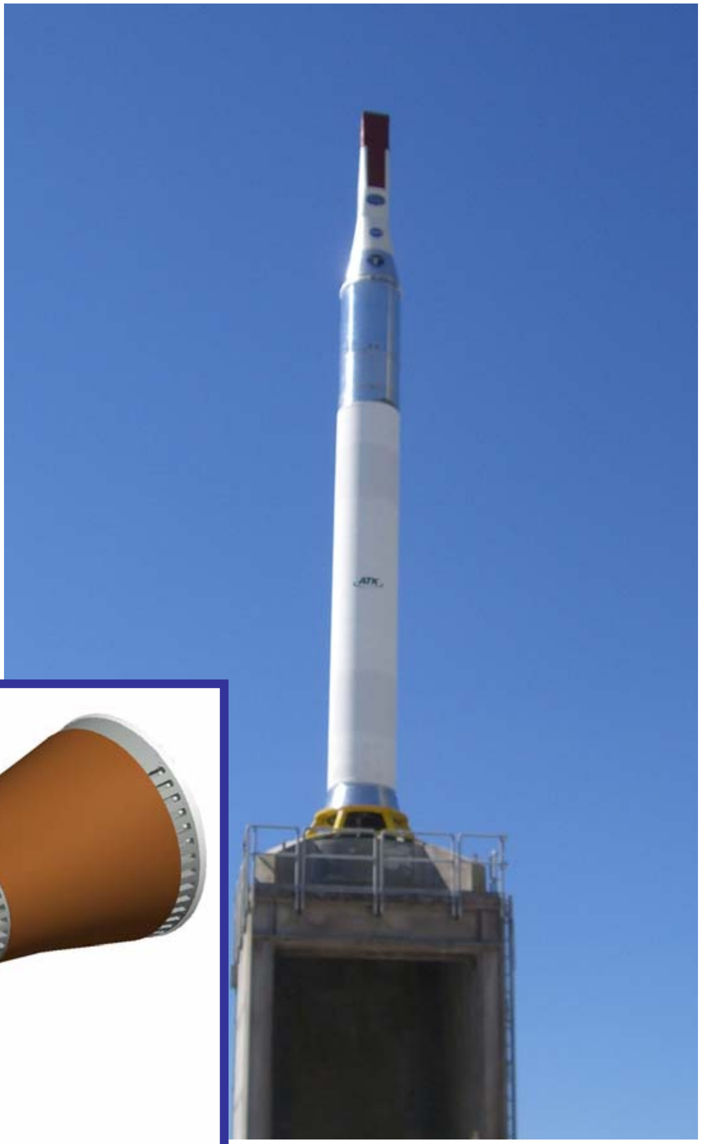
Forced Transition Shuttle Experiment

- **Series of Shuttle flights with modified tiles to artificially trip boundary layer on wing lower surface.**
- **Controlled high-enthalpy transition data.**
  - Three levels of experiment complexity.
  - Modifications include boundary layer trip and additional instrumentation.
  - Remote imaging is also under investigation.

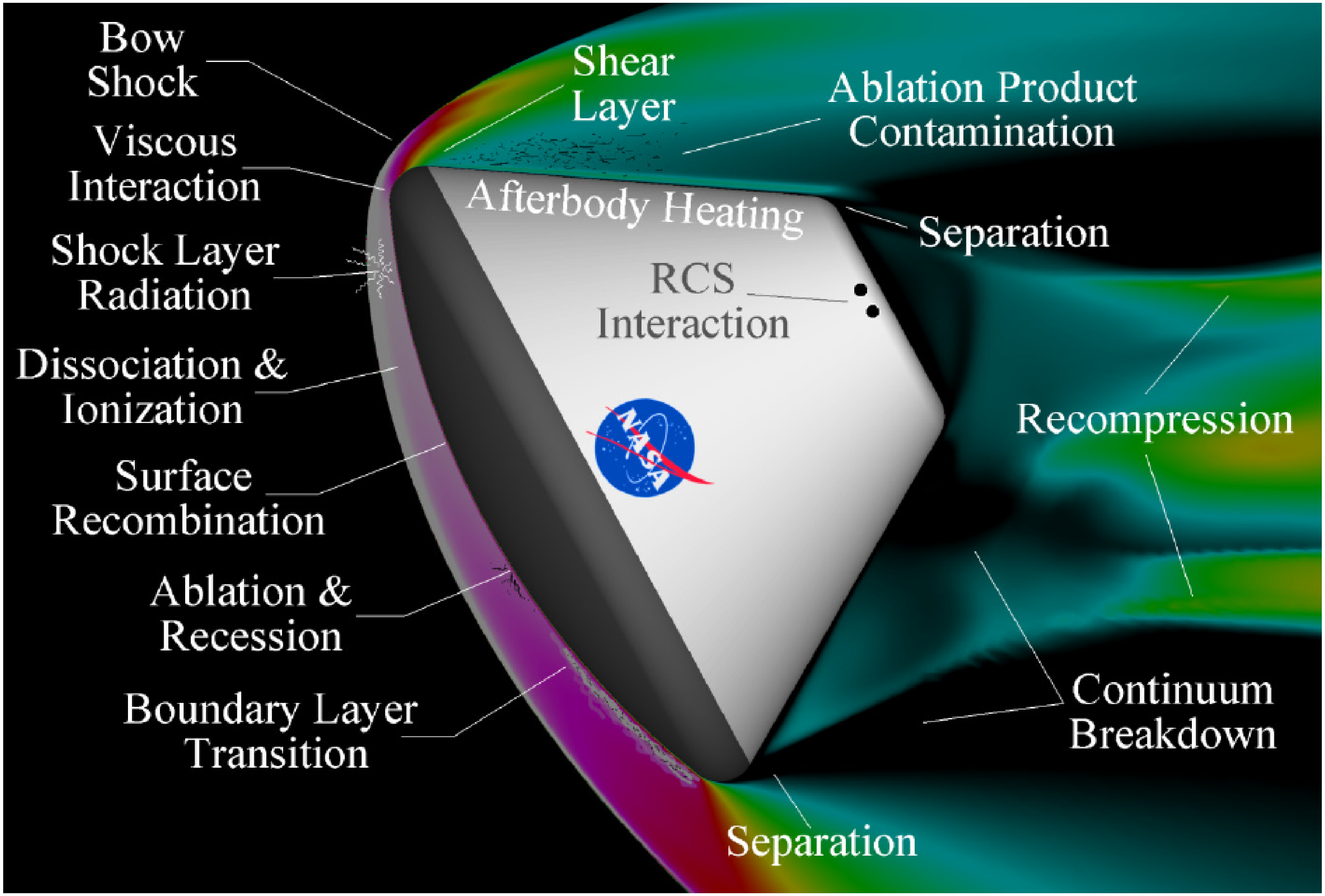


HyBoLT Experiment

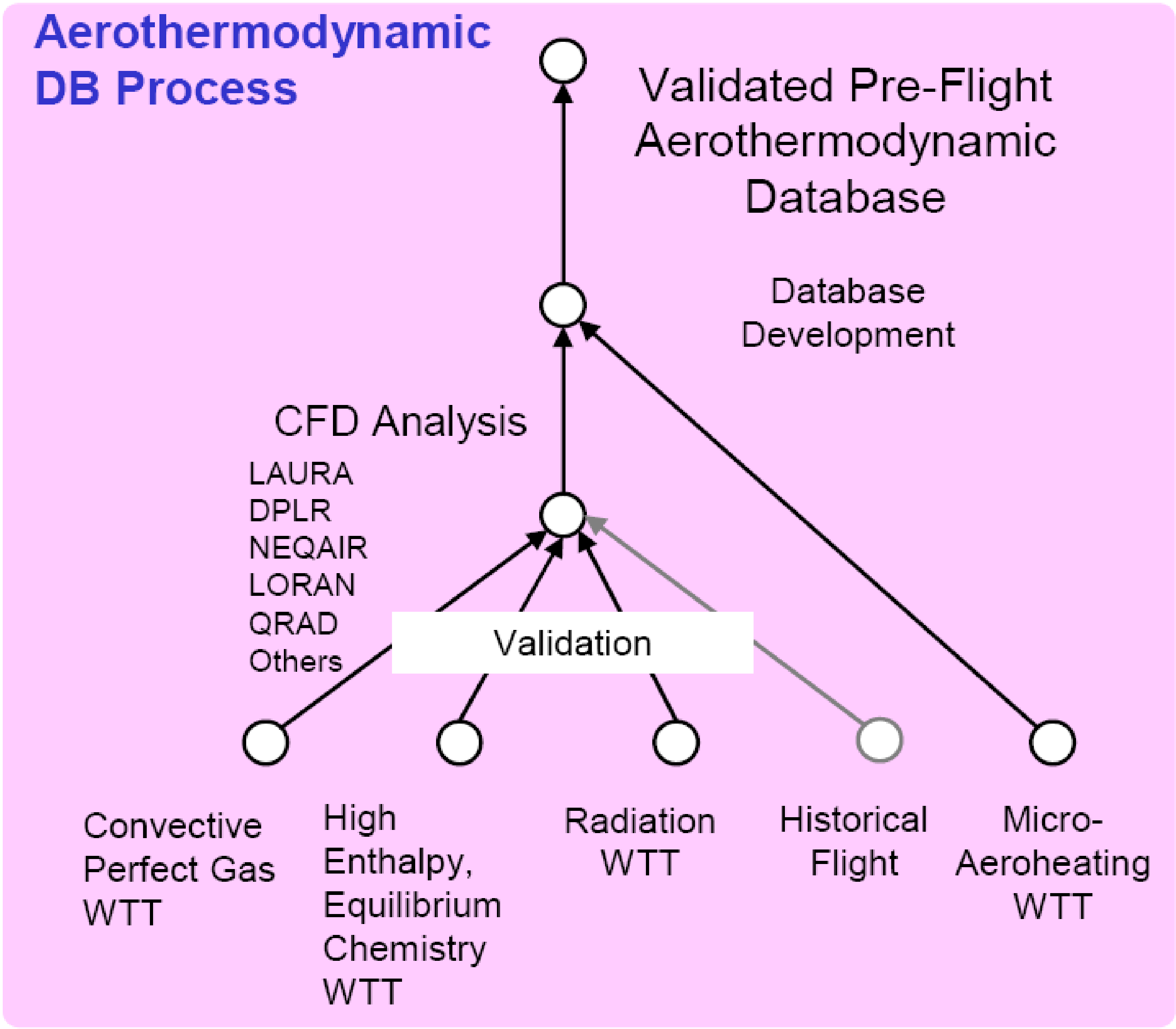
- Payload launched on ATK ALV/X-1 developmental launch vehicle.
- Side A - Natural transition.
- Side B – Tripped transition.
- Data acquired between Mach 2.5 and Mach 7.5.
- Launch from Wallops Flight Facility.



Orion Aerothermal Environment

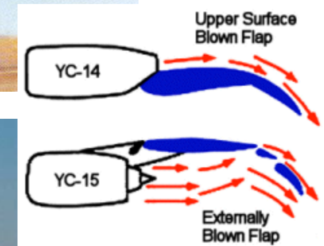


Orion Crew Module Aerothermodynamic Database Construction

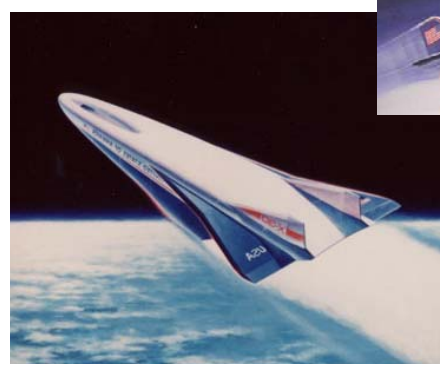
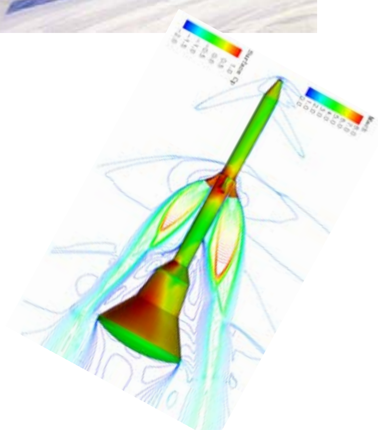


Aero-Propulsion Interaction

- **Interest in aero-propulsion interaction began growing in the 1970's with the development of powered-lift systems.**
- **Continued into the 1980's and 1990's with the National Aerospace Plane Program.**
  - More focused hypersonic program continuing today.
- **Problems continue to be manifested in spacecraft design in the form of rocket and reaction control system plume interactions with spacecraft and their associated aerodynamics.**

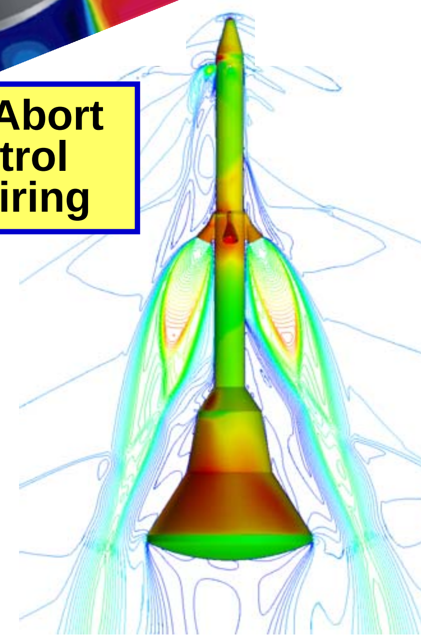


Aero-Propulsion Interaction Challenges

- **Analysis requires addition of physics not traditionally found in aeroscience predictions.**
  - Wide temperature and speed variations within the simulation.
  - Propulsion by-products.
  - Reacting flows.
- **Computations are expensive and immature.**
  - High operation counts due to added physics.
  - Stiffness in governing equations.
- **Testing is complex and costly.**
  - Plumbing.
  - Hot gases.

CEV LAV Abort Control Motor Firing



CEV LAV Abort and Control Motors Firing

Observations

- **Aerosciences holds key, if not driving, roles in NASA's missions.**
  - Operation in and transition out of and into atmospheres are critical aspects of all NASA Mission directorates.
- **High Performance Computing is an enabling tool allowing NASA to develop and apply the Aerosciences methods that are designing the vehicles that will take man beyond low earth orbit for the first time in over 30 years.**
  - NASA has established a strong synergy between computation, ground, and flight testing that leverages the strengths of each to reduce engineering costs and design cycle times.
- **Significant challenges continue to press High Performance Computing environments.**
  - Unsteady flow computations, chemically reacting, and other multiphysics flows require a new level of computing capability.
    - Computing speed, memory, and mass storage are the typical areas for enhancement.
  - Post-processing is already an issue.
    - Long download times for simulations.
    - Volume of data is outstripping desktop capabilities for model and result displays and processing.