Ongoing Validation of Computational Fluid Dynamics for Supersonic Retro-Propulsion

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Introduction

During the **Entry, Decent, and Landing** phase of planetary exploration, previous methods of deceleration do not scale with **high mass** spacecraft.

Supersonic Retro-Propulsion (SRP) is a viable method to decelerate large spacecraft including those that will carry **humans to Mars**.

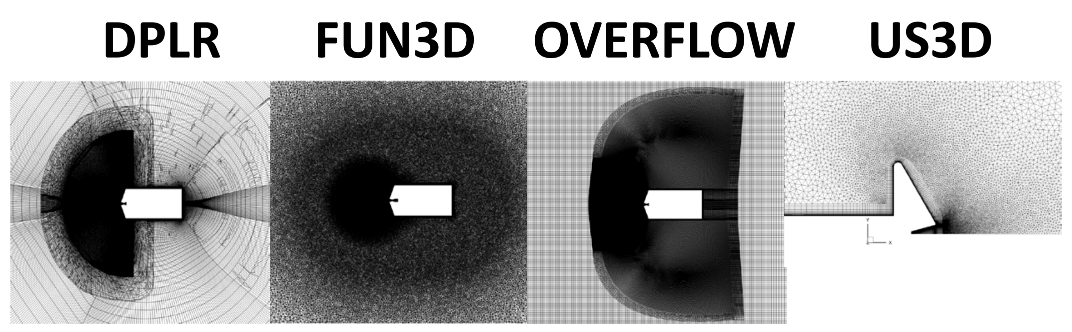
Flow data at these conditions are difficult to obtain through flight or wind tunnel experiments

CFD Validation

Computational Fluid Dynamics is of increasing importance to properly understand the flow physics of Supersonic Retro-Propulsion.

First, **CFD must be validated**. The validation process includes comparing results from different CFD solvers to each other and to wind tunnel results.

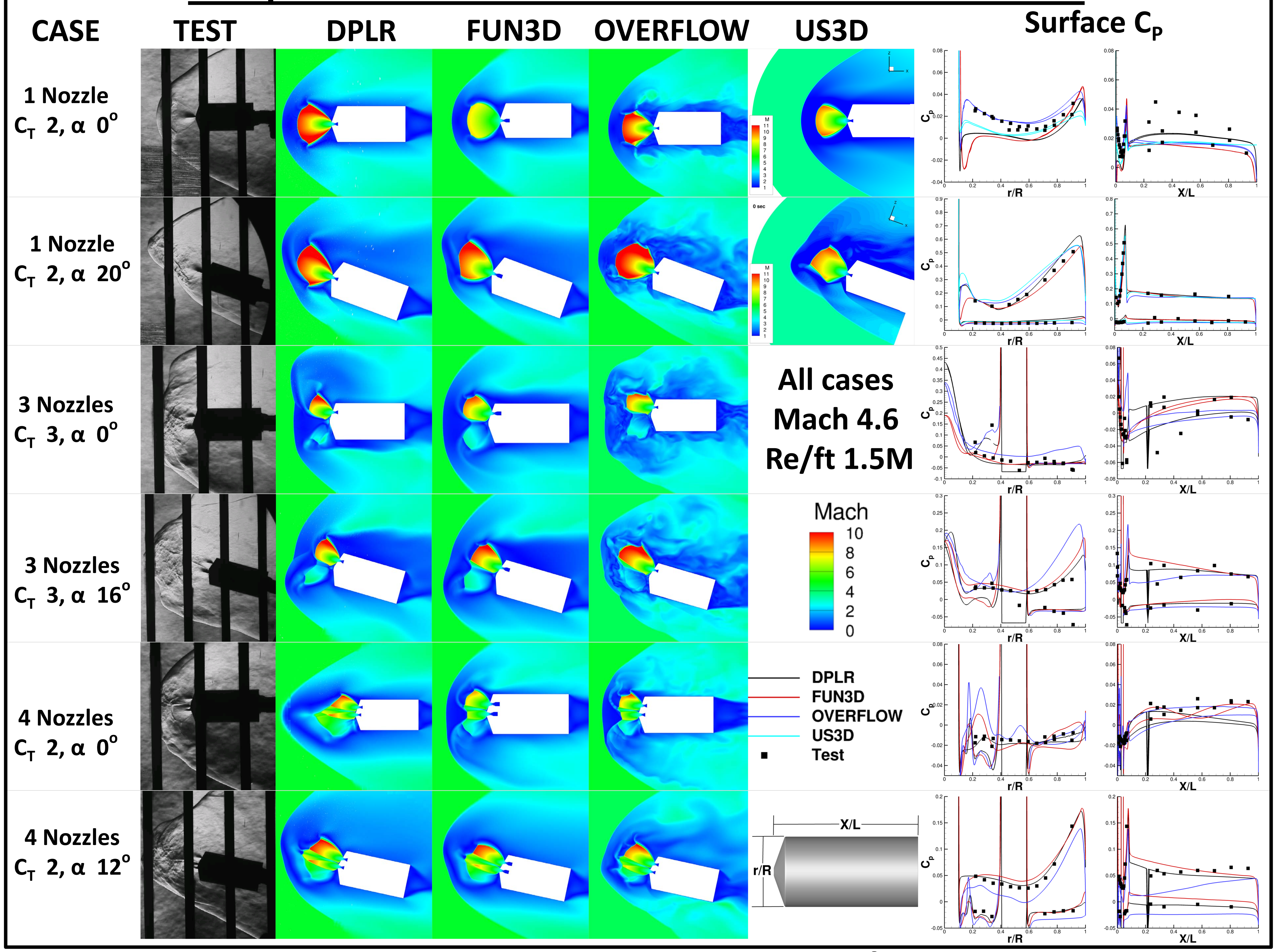
LaRC UPWT Test 1853 was designed specifically for SRP CFD validation and four NASA Navier-Stokes solvers were employed: **DPLR** (Data Parallel Line Relaxation), **FUN3D** (Fully Unstructured Navier-Stokes Three Dimensional), **OVERFLOW** (OVERset grid FLOW solver), and **US3D** (UnStructured Three Dimensional).



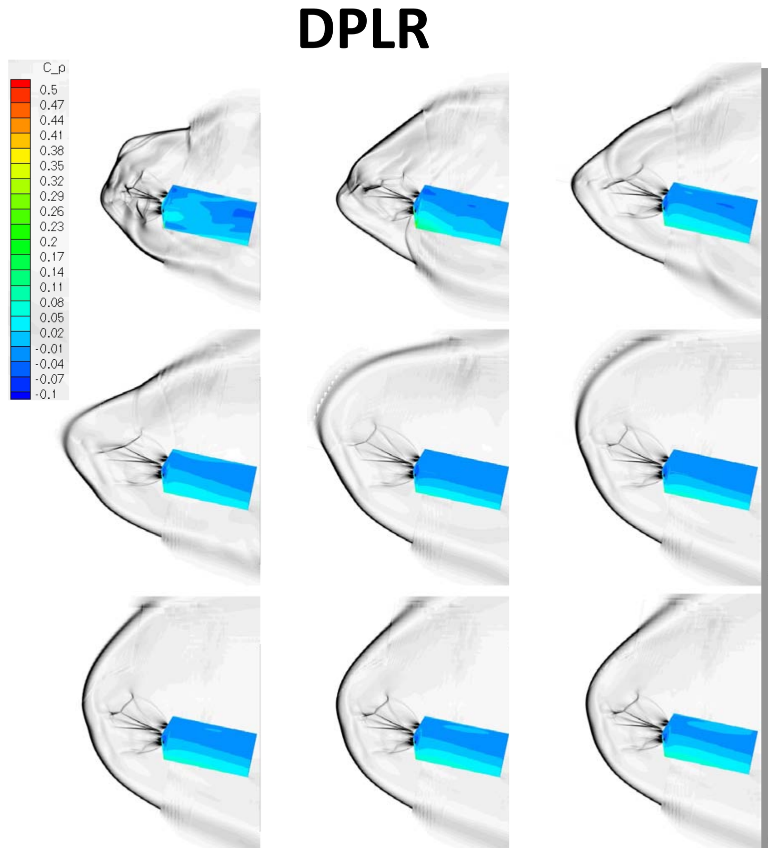
Process

Computational **grids** of the wind tunnel model were created, and **time-accurate** solutions were generated by each solver (see time sequence images below). Qualitative and quantitative properties of the **CFD results** were then ***compared*** to **test data** (see comparison images to right).

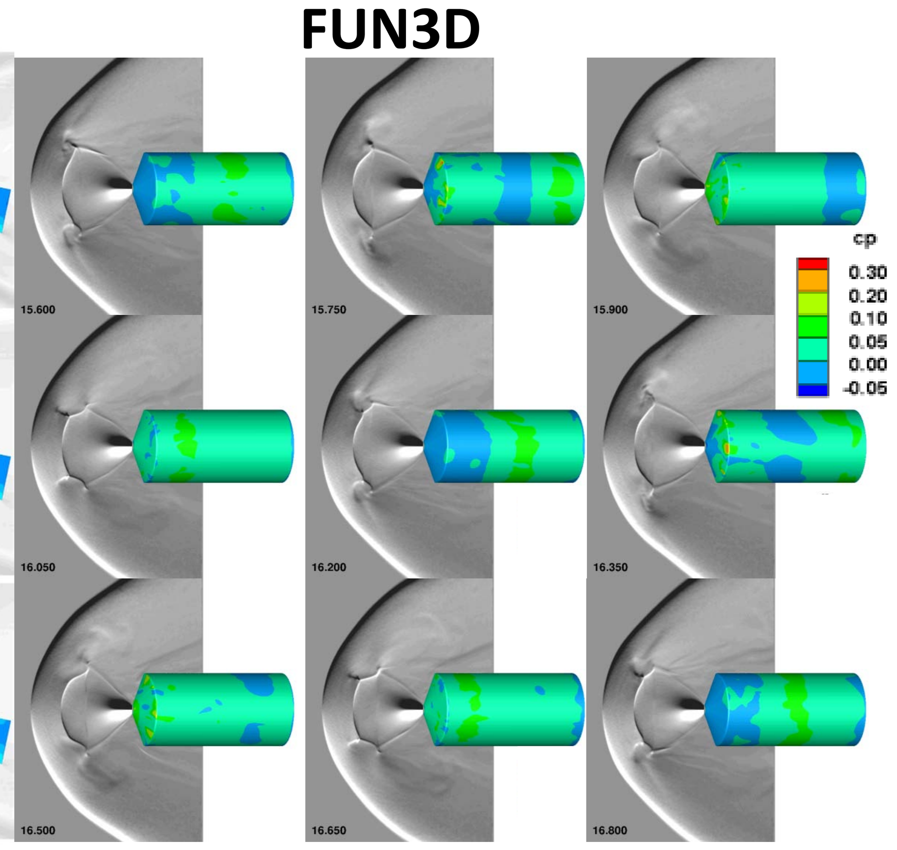
Comparison of CFD Results to Wind Tunnel Test Data



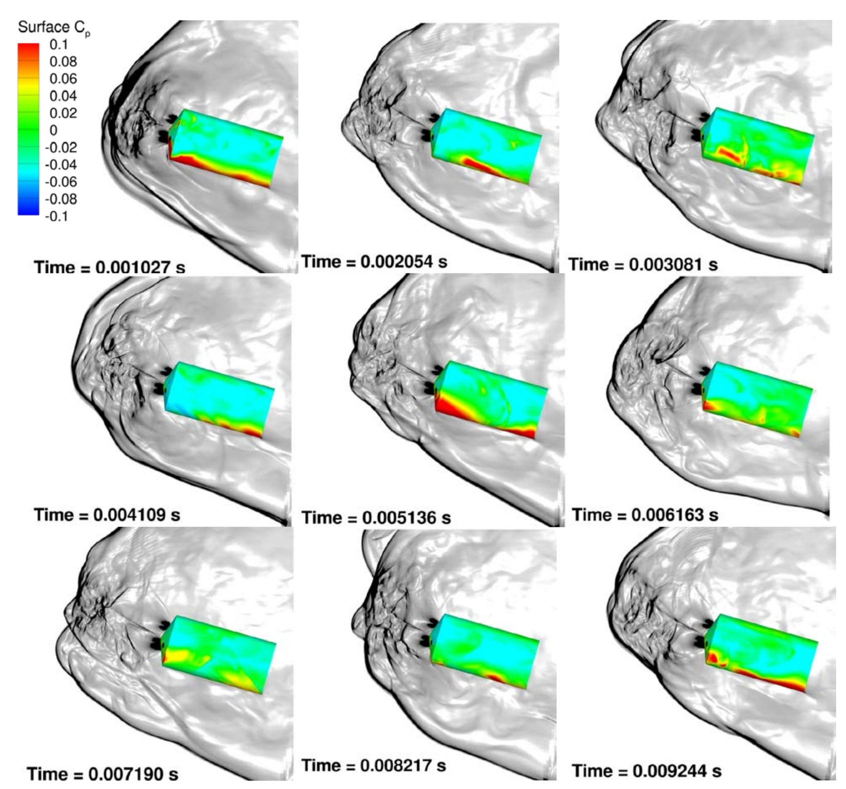
4 Nozzles, C_T 2, α 12° DPLR



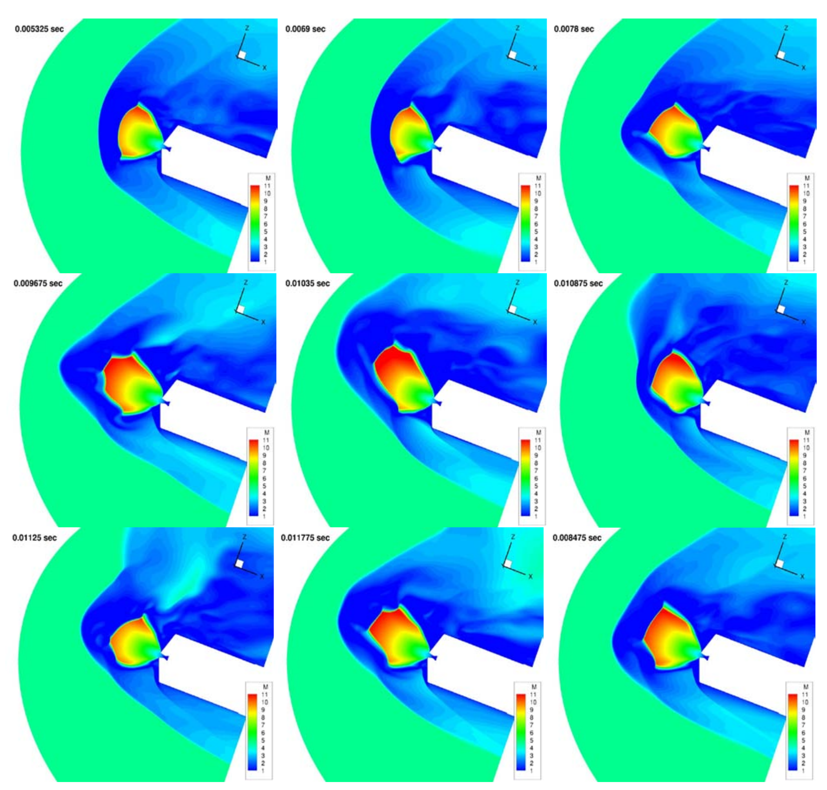
1 Nozzle, C_T 2, α 0° FUN3D



3 Nozzles, C_T 3, α 16° OVERFLOW



1 Nozzle, C_T 2, α 20° US3D



Results

The flow field was **inherently unsteady** at these low thrust coefficients (C_T=T/qA). Flight conditions will require larger C_T's, where the flow is more steady (see C_T 6 image to right).

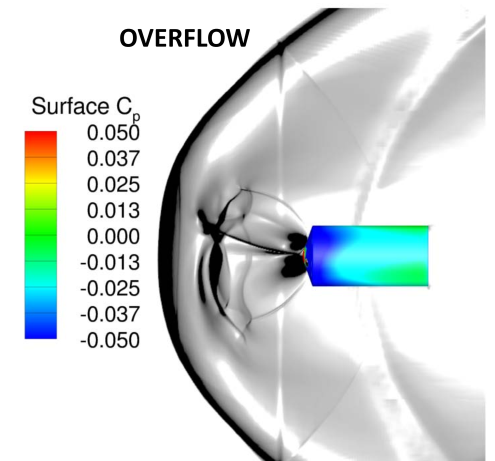
Thrust is the major contributor to total axial force (see bar chart to right).

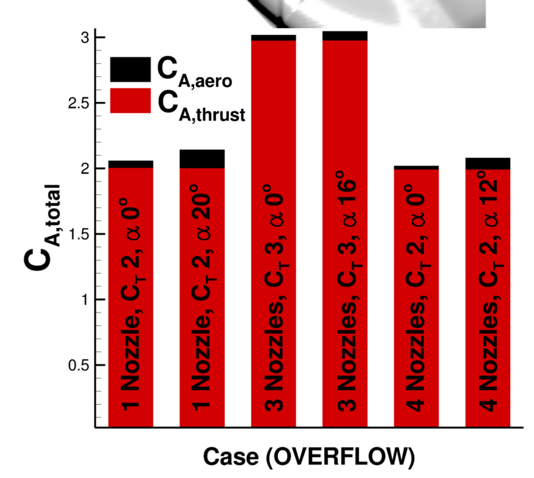
Differences between solvers are largely attributed to **grid resolution** and **turbulence model**.

Data **sampling rates** differ greatly between the CFD and the test data, making **unsteadiness** a large contributor to code-to-test differences.

The CFD results compare well to test data which is a large step towards validating CFD for SRP.

3 Nozzles, C_T 6, α 0°
Mach 3.5, Re/ft 1M





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