# CFD SIMULATION OF MANEUVERING PROJECTILE AERODYNAMICS


## *Project Description*

For maneuvering munitions, the effect of many weapon control mechanisms such as canards, reaction jets, deployable pins, pulsed flaps, and micro-jets on aerodynamics and flight dynamics is critical to overall guided flight performance. The control devices are used to provide control forces needed for desired maneuvers (Figure 1). The idea is to determine if these control devices can provide the desired control authority for course correction for munitions. Many of these mechanisms fall outside the range of conventional aerodynamic control and accurate well-validated tools for prediction of aerodynamic loads are needed. These control mechanisms result in highly complex, unsteady flow interactions and their accurate modeling during guided flight with active control is a major challenge. To meet this challenge, a set of well-validated advanced CFD, and CFD coupled with flight dynamics and flight control system tools is needed for prediction of aerodynamic loads and unsteady aerodynamics associated with conventional and new aerodynamic control technologies for maneuvering precision munitions.

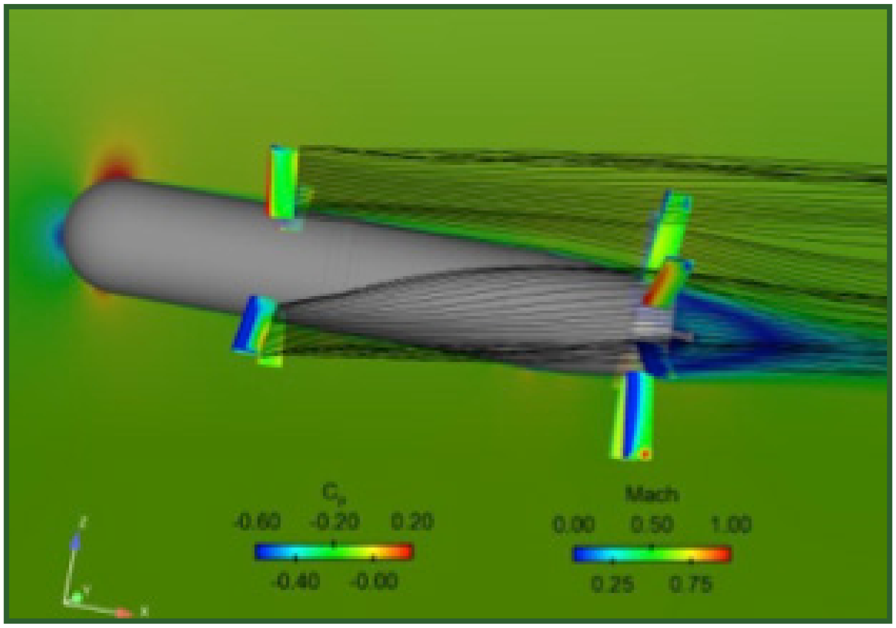
## *Relevance of Work to DOD*

Our goal is to understand how control mechanisms, such as canards, fins and reaction jets, affect the aerodynamic behavior of projectiles. We will then be able to accurately predict the non-linear behavior of such projectiles by capturing detailed flow physics in flight. Increased understanding of fundamental flows through advanced CFD and multidisciplinary coupled methods will allow exploitation of flow physics in a novel manner and will lead to increased maneuverability for next generation munitions.

## *Computational Approach*

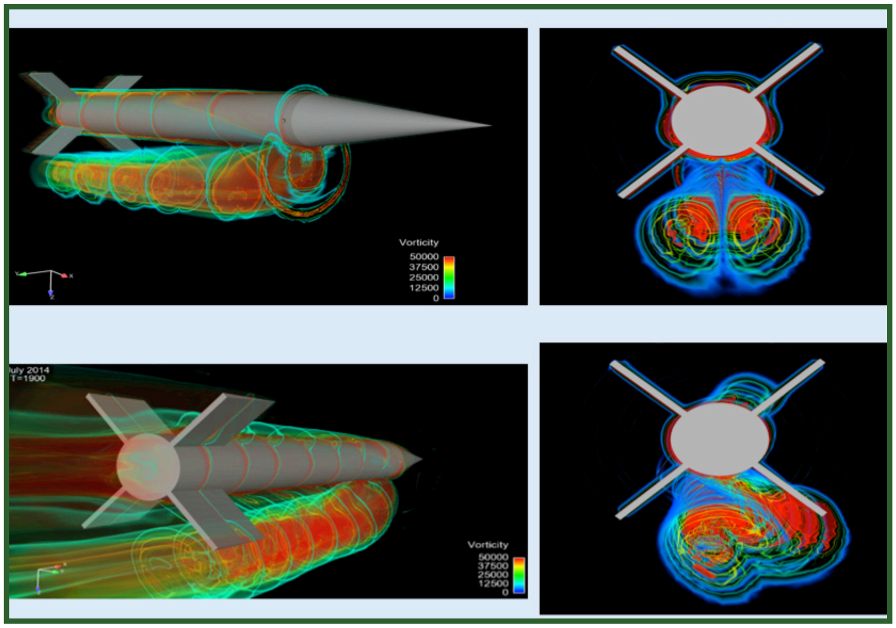
The computational approach is to couple CFD with rigid body dynamics and the flight control. The control system strategy is conveyed through the control law. The control law stipulates a set of operations that are performed on sensor data to determine how the controls should be changed in flight. The aerodynamic forces and moments are computed at every time-step in the CFD part and transferred to the control code which performs both rigid body dynamics and the flight control simulations. The flight control design models both controlled and prescribed motions. The output of rigid body dynamics state and the control variables are transferred to the CFD flow-solver, which then computes the aerodynamic forces and moments.

All simulations were performed on a 10,752-core SGI Altix ICE 820 System and a 43,172-core Cray XE-6 system. Domain decomposition was performed using the METIS tool developed at the University of Minnesota. Jobs were run with from 128 to 1024 processors on grids of 10M, 20M, 30M, and 60M grid. Very good parallel performance was been observed up to 256 processors for three grids (10, 20, and 30M). With the 60M grid, more work is available to each processor, and in this case we see a perfect linear speed-up for all processors up to 1,024.




## *Results*

Results were obtained for steady and pulsed-jet interactions with supersonic free-stream flow for a finned-projectile (Figure 2). Computed steady-state results show reasonable predictions of the magnitude of the jet interaction forces and moments for a rolling, fin-stabilized projectile. More research is planned to investigate the transient jet interaction effects for the case of a rolling projectile to determine if any unsteady effects are present due to roll, and also to perform simulations using a coupled CFD and rigid body dynamics technique to determine if and how the jet interaction force and/or moment change due to the dynamics of the rigid-body projectile motion. This coupled capability is being exercised and demonstrated on a canard-controlled projectile. Physics-based, virtual fly-out simulations were performed for a guided pure roll-control maneuver and a guided cross-range control maneuver using the coupled procedure. Computed results clearly show the projectile maneuvered to its commanded values.




## *Future*

Future research efforts will extend the capability of the coupled procedure for simulation of guided control maneuvers due to jets, micro-flaps, and other flow control mechanisms. These research efforts will provide accurate unsteady aerodynamics and flight dynamics predictions associated with guided maneuvers. This will ultimately lead to increased maneuverability for the next-generation low-cost munitions to hit moving targets.

*Figure 1: (top)*
*Canard and fin vortices and their mutual interactions.*
*Figure 2: (bottom)*
*Vorticity contours showing flow interaction effects of a pulse jet on the afterbody fins during jet-controled maneuvers.*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