Computational Fluid Dynamics Analysis of a Multi-Phase Simple Jet Final Report April 30, 2010

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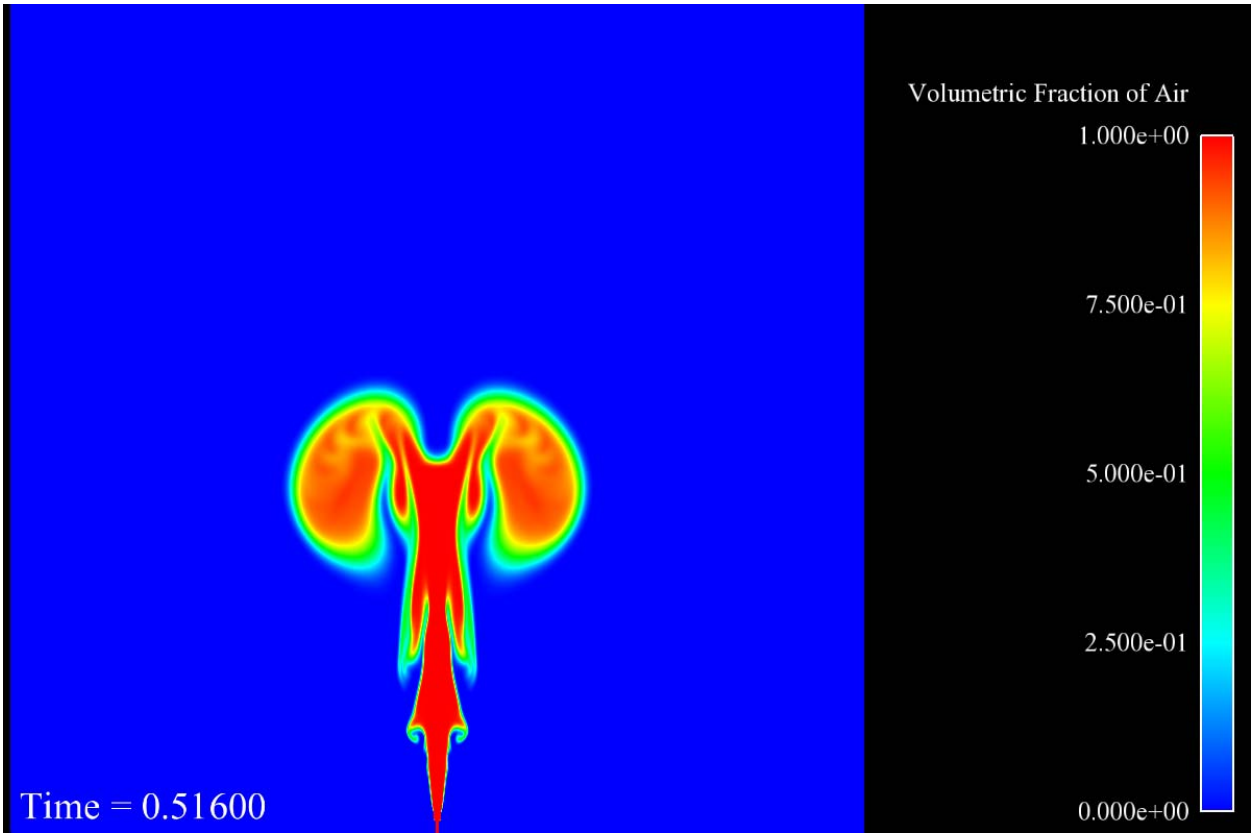
ABSTRACT

Currently, the United States Naval submarine fleet is susceptible to many threats while in port. These threats include attack from air based platforms such as helicopters and fixed wing aircraft to sea based threats such as attack boats and mine laying vessels. To counteract these increasing threats and provide more protection for the venerable submarines in port, the Navy has tasked our clients, engineers at Naval Station Dahlgren, to create a proof of concept for a sub-sea borne weapon system.

The engineers at Naval Station Dahlgren have been experimenting with a Concentric Canister Launcher (CCL), capable of deploying common air-to-air missiles (i.e. Sidewinder, Zuni, Jato) from a standard submarine torpedo tube underwater. This would provide submarines a much needed defense system while operating in shallow port waters where they cannot dive for protection. To allow the missile to be fired from underwater, the Navy has been experimenting with a cold gas compressed air method that has been proven to pierce the water long enough for a missile to escape without being distorted by the water. The water must be pierced long enough because the missiles used are all designed for air-to-air and cannot withstand a water environment.

Very little research has been done on compressed air piercing water. This is due to the fact that it is very difficult to obtain data of the physical properties of a jet stream without the measuring instrument disturbing the flow of the jet itself. Without an accurate depiction of what happens within the compressed air jet, it is hard to optimize the design and make it reach the surface in the shortest possible time. Optimizing the design entails piercing the water quicker and launching from a deeper depth.

The purpose of this project is to model a simple multiphase compressed air jet using computational fluid dynamics. By modeling the multiphase compressed air jet virtually, the physical properties inside the air jet can be estimated accurately. Using this data, the compressed air jet can be optimized to reach the surface quicker. Two models were created to gather this data. A single nozzle model was tested with different naturally occurring effects such as: surface tension, gravity, hydrostatic pressure, and compressibility, and a four nozzle version with the same natural effects present.

The computational data was then compared to experimental results gathered at Dahlgren. All of the computational models showed physical characteristics found with experimental testing with entrainment being present and the formation of ‘pinch offs’. However, the most accurate model had the effects of gravity and compressibility turn on. This model most closely followed the speed of the jet tip and the desired 10.7 degree angle of spread was present.

The design team looks to further their work on this project and eventually develop a 3D four nozzle model that has a moving current.