INFORMATION SYSTEMS LABORATORIES

*NSAD – Nuclear Systems Analysis Operations*

# Overview of CFD Capability and Project Experience at ISL/NSAD

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**ABOUT ISL, Inc.:**

Information Systems Laboratories, Inc. (ISL) is a science and engineering innovator in the fields of advanced sensor, communications, adaptive signal processing, nuclear systems analysis and space/missile system technology supplying critical, timely, high-quality solutions and products to meet the needs of commercial and government customers.

**ABOUT NSAO :**

The Nuclear Systems Analysis Operations (NSAO), acquired by ISL early in CY 2000, has provided many years of support to the United States Nuclear Regulatory Commission (US NRC) and other domestic and international clients in detailed physical simulation of the behavior of complex nuclear systems, as well as in risk analysis and other types of support to regulatory decision-making.

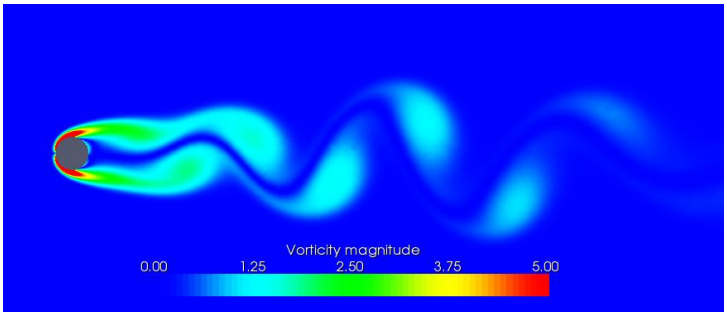
## Computational Fluid Dynamics (CFD) at ISL/NSAO

ISL/NSAO has been involved in CFD work since the mid 90's. From the outset, ISL staff have been focused on expanding our capabilities and experience base. Our growth has been fostered by significant infusions of internal funds.
The ISL/NSAO personnel have the dedication, qualifications and experience needed to understand the underlying physics for a wide range of thermal-hydraulics engineering problems, to develop analytical models and computational techniques and attain accurate and effective solutions using CFD tools.
The ISL/NSAO staff has been involved in several projects using a variety of CFD solvers, as follows:

- ***OpenFOAM***
- *Software for **Lattice-Boltzmann Methods** (in collaboration with SUNY Stony Brook)*
- ***N-PHASE** (in collaboration with Rensselaer Polytechnic Institute)*
- ***TEMPEST and COMMIX** (early work)*
- *Additional Grid Generation Software: **Gridgen, CUBIT***
- *Additional Visualization Software: **FieldView, ParaView***

The current work is focused on the areas of traditional CFD (RANS, LES) using the OpenFOAM open-source software. ISL has both a 6 processor linux cluster and a 20 processor cluster available for CFD work. Separate workstations are available for grid generation and results visualization. ISL is also developing the capability to use graphic processing units (GPUs) to execute CFD calculations.

## Selected CFD Projects at ISL/NSAD




*DNS of the laminar flow past a single cylinder. The characteristic asymmetric shedding of the wake past a cylinder is clearly recognizable.*

**HTGR Lower Plenum Heat Transfer (for US NRC)**

The goal of this project is to reduce uncertainties in predicting HTGR lower plenum heat transfer mechanisms during postulated accidents such as air ingress. Customized CFD solvers are being developed in-house, based on the OpenFOAM open-source software, and exercised on the simulation of buoyant, multi-component gas flows, including chemical reactions (oxidation) with solid graphite structures. The project encompasses separate-effect code validations and full-scale integral-effect parametric studies, in addition to simulation of flows and heat transfer in typical lower plenum geometries.

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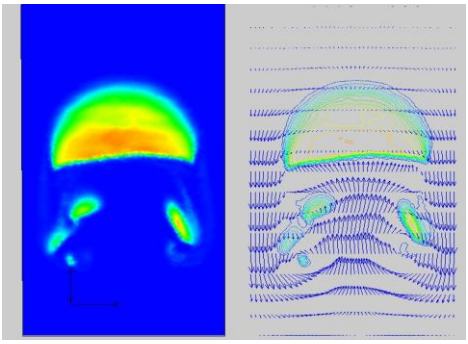
**Participation in the OECD/NEA-NRC International Benchmark problem "BFBT" (internally funded)**

Significant CFD work was conducted at ISL/NSAO in the area of two-phase (liquid/gas) flow modeling. This work centered on collecting and developing physical models that are coded in external subroutines and linked at runtime with the CFX solver. These two-phase flow modeling enhancements include:

- Local (small-scale) resolution of fundamental two-phase flow parameters (interfacial area, drag coefficients, heat transfer coefficients, etc.), as opposed to the adoption of area- or volume-averaged quantities.
- Implementation of algorithms for "interface tracking" (solution of an interfacial area transport equation), to achieve increased accuracy without compromising computing time.
- Capability for mechanistically simulating a range of two-phase flow regimes.

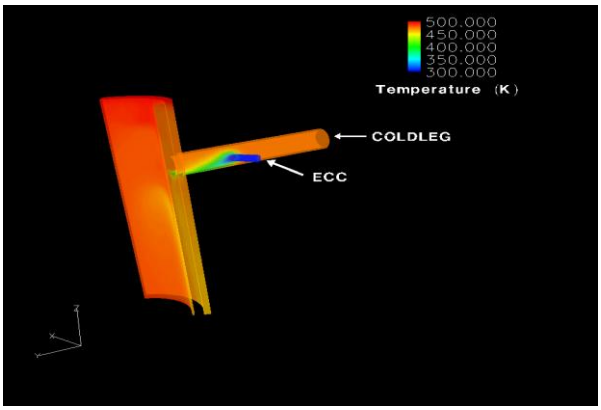
The developed two-phase CFD framework was applied to the international benchmark problem "BFBT – BWR Full-size fine-mesh Bundle Test", comprising the comparison of predicted vs. measured void distribution data in a full-scale mock-up of a boiling water reactor fuel bundle.



*A test case reveals that the two-phase CFD framework developed at ISL/NSAO allows for resolution of a gas bubble rising in a water pool, with CPU time comparable to that of less accurate methods.*

**PWR Sump (for US NRC)**

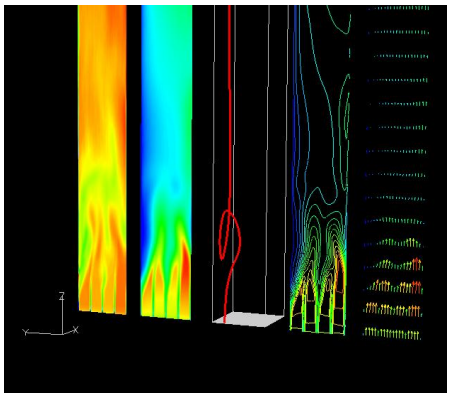
This problem models of flow filtration through a porous medium upstream of the sump pump (on the sump screens) with release of air bubbles due to the pressure drop experienced by the water flowing through the porous layer. The challenge is to capture the behavior of the bubbles as they coalesce and tend to escape the bulk fluid due to the buoyancy forces that act against the drag forces exerted by the fluid on the bubbles, with potential risk for bubble entrainment in the pump suction nozzle.




*Temperature distribution in the cold leg and downcomer of a typical PWR following injection of cold water from the Emergency Core Cooling System.*

**PTS Downcomer (for US NRC)**

The purpose of this project was to study the potential for thermal plume formation when cold water is injected into the cold leg of a pressurized water reactor and flows into the reactor vessel downcomer. A one-quarter downcomer model with a single cold leg and high-pressure injection line was developed to study the plume behavior. A solid structure model was included to explore the impact of the heated walls on plume development.



**ESBWR Chimney (for US NRC)**

A multi-field approach was adopted to model a two-phase (liquid-steam) flow driven by density difference in a vertical duct. The simulation is representative of the two-phase flow that is expected to occur in a chimney partition of the Economic Simplified Boiling Water Reactor (ESBWR) designed by General Electrics Co. The figure on the left shows some of the calculated flow parameters.

**For additional information on ISL/NSAO CFD capabilities, please contact:**

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