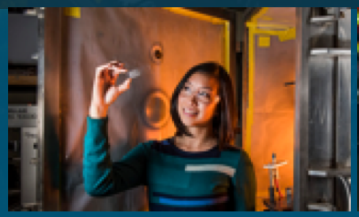
Sandia National Laboratories

Guest Lecture Stanford ME469: SPD Computational Fluids Dynamics Research Interest



PRESENTED BY

Stefan P. Domino

Computational Thermal and Fluid Mechanics

Sandia National Laboratories SAND2018-4536 PE

U.S. DEPARTMENT OF ENERGY | NNSA

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

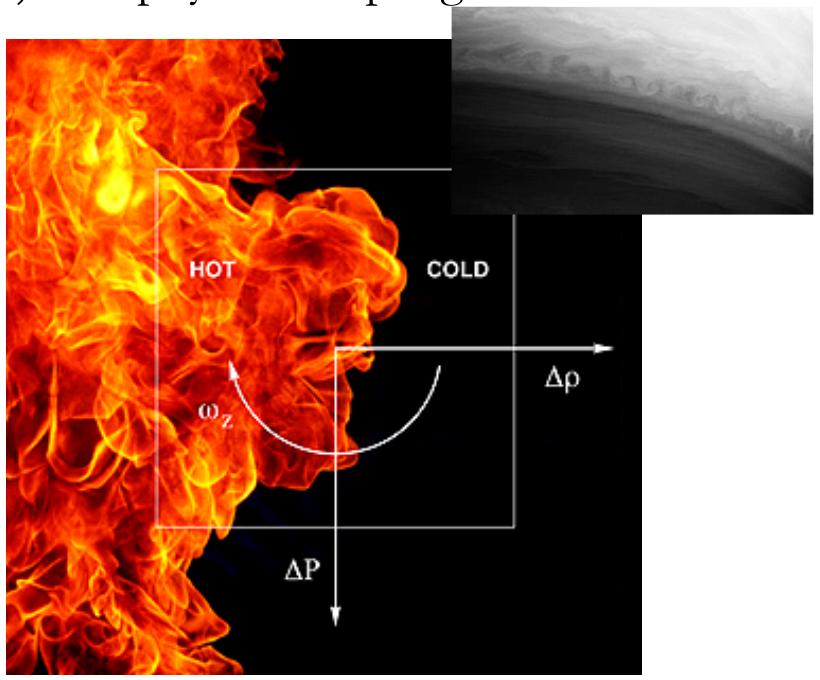
SPD Computational Fluid Dynamics Research Interest: Outline

- Overview of Fluid Applications of Interest to SPD at Sandia National Labs
- Evolution of how Modeling/Simulation Shaped Fire Physics
- Multi-physics Coupling Examples
- Wind Applications and Other non-Reacting Examples
- Computational Scales of Interest
- Conclusions
- Lecture Overview

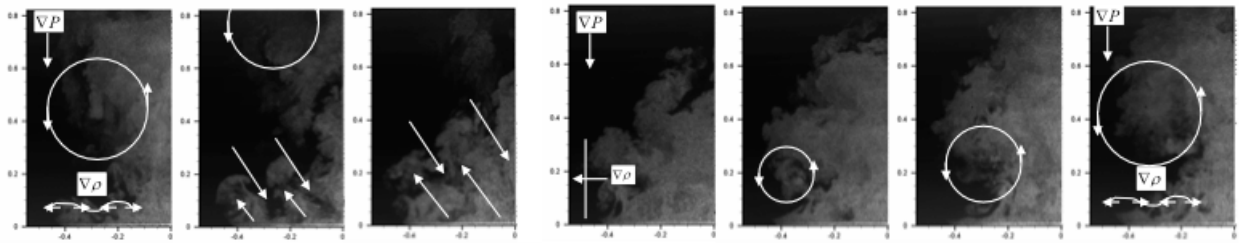
Consider the Abnormal/Thermal Environment

- Characterized by a highly sooting, turbulent, reacting flow with Participating Media Radiation (PMR) and Conjugate Heat Transfer (CHT) mutiphysics coupling

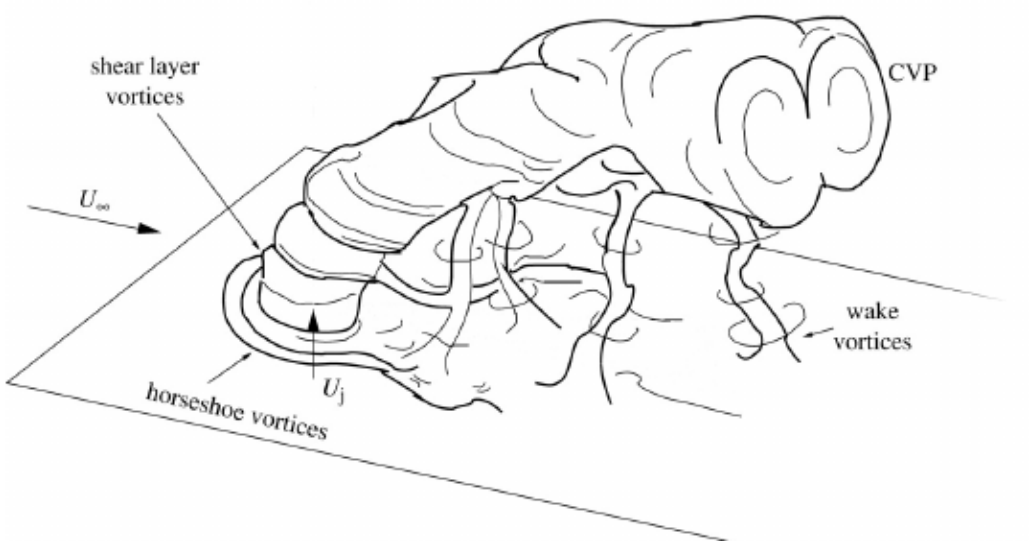
Time-averaged (inset transient)



Vorticity generation



Evolution of a Mindset….. Cross Flow



LES of pulsed jet in cross flow; Coussement et al, JFM, 2012

- Conclusion: The inclusion of a cross-flow wind profile couples vorticity of the pool and streamwise momentum which drives the formation of column vortices, increases the importance of mixing and, therefore, convective loads on the object become more important

- Change in mindset: Invest in validation use cases to highlight the importance of fire accident scenarios in the presence of an external momentum field

Ten meter (top) experiment and three meter (bottom) simulation

Evolution of a Mindset…..Whirling-like Flow

Brush fire (Curtin Springs, Australia)

Fire whirls from a 3-meter diameter pool in the Fire Laboratory for Accreditation of Modeling by Experiment, or FLAME, facility at Sandia National Laboratories. (Photo by Richard Simpson; A. Hanlin, lead experimentalist)

Evolution of a Mindset: From Simple to Complex

SAND2019-7052 C

- Peak radiative heat fluxes to engulfed objects is a function of fuel type, pool size, obstructions/accident geometry, and presence of cross-flow
- As cross-flow and geometric complexity of accident scenarios increase, SNL has found that transitioning from a Reynolds-Averaged Navier-Stokes (RANS) to a more predictive Large-eddy simulation (LES) approach is required → HPC on Next-Gen platforms

RANS-based → LES-based

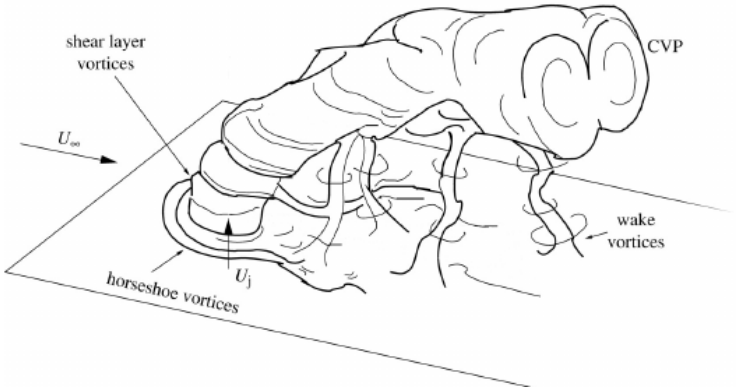
Quiescent; q''_r
~ 100 kw/m^2

Cross-flow; q''_r
~ 200 kw/m^2

Whirls
>> 200 kw/m^2

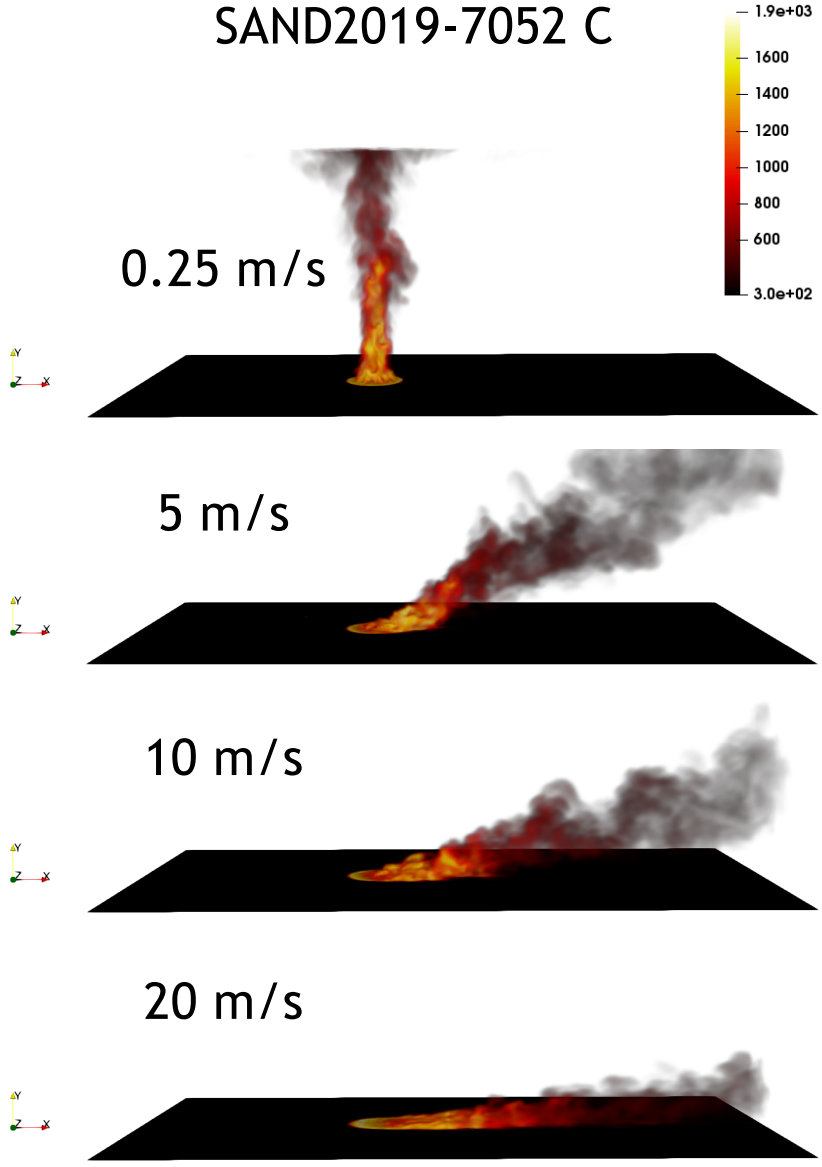
Core Research Objective: Understand Large-Scale Fire Dynamics

- The coupling of cross-wind with a hydrocarbon fire event drives large-scale column vortex formation – very similar to classic jet-in-cross flow behavior (see below)
- Increased mixing yields increased radiative heat fluxes
- Although lab-scale efforts exist for quantities such as flame drag distance and tilt angles, none exist for scale of interest to SNL, e.g., 10 meters and beyond
- SNL is quantifying large-scale fire physics (Γ, θ, ect.) through theory and simulation



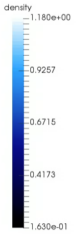
LES of pulsed jet in cross flow; Coussement et al, JFM, 2012

SAND2019-7052 C

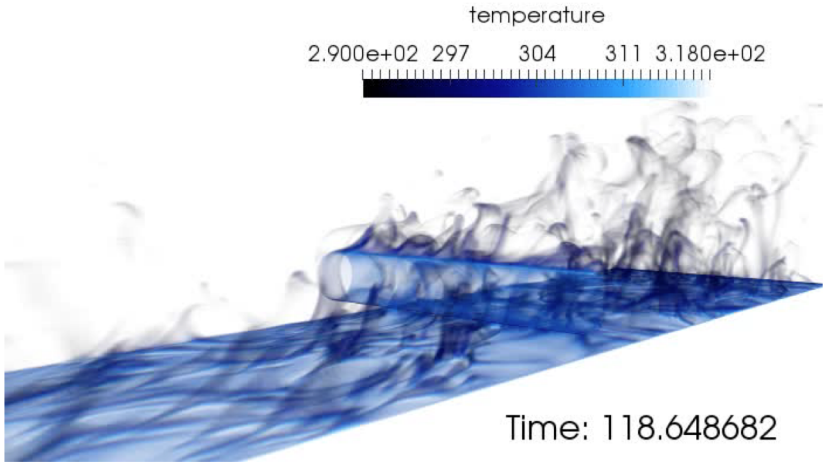


10 m pool fire
LES-based numerical study

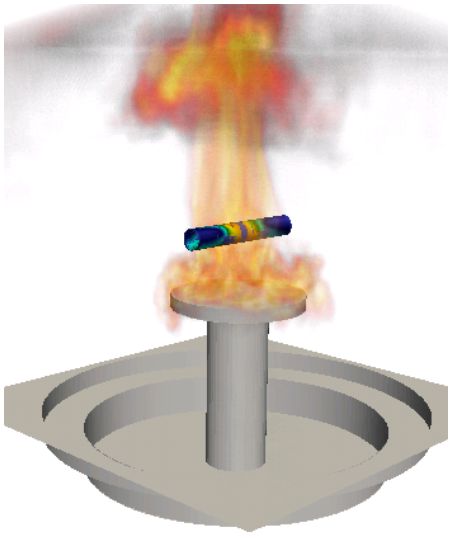
Several Multi-physics Flow Examples



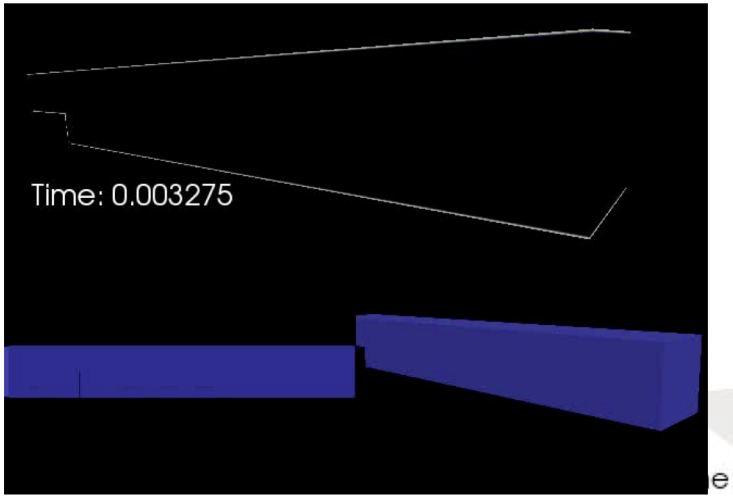
Helium plume (low-/high-order)



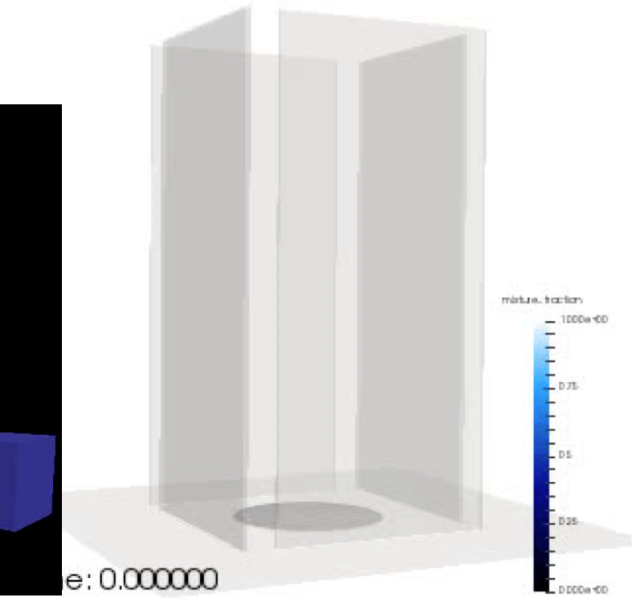
Cylinder in cross flow



Object-in-fire



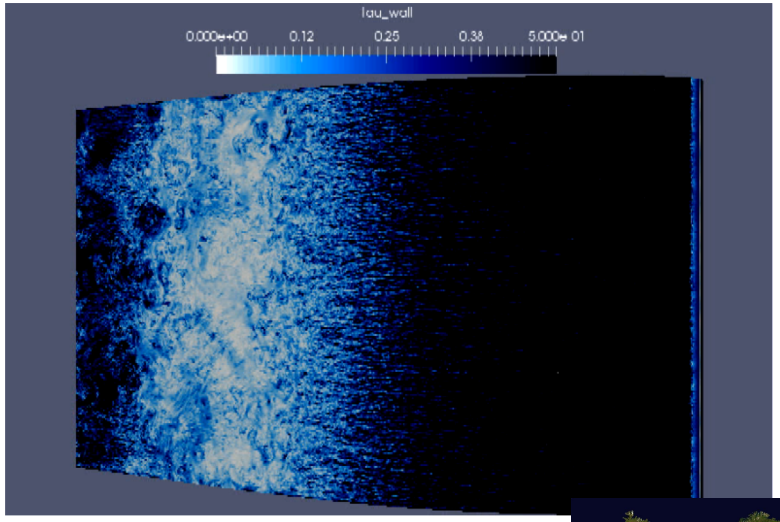
Heated backstep



Whirling behavior

Wind Energy Applications… Towards Exascale (10^{18} FLOPS)

- High Performance Computing (HPC) enables science



High Reynolds number flow past a wind energy turbine blade section (Barone and Domino, 2016), ~1800 year simulation on one CPU

Late Roman Timeline

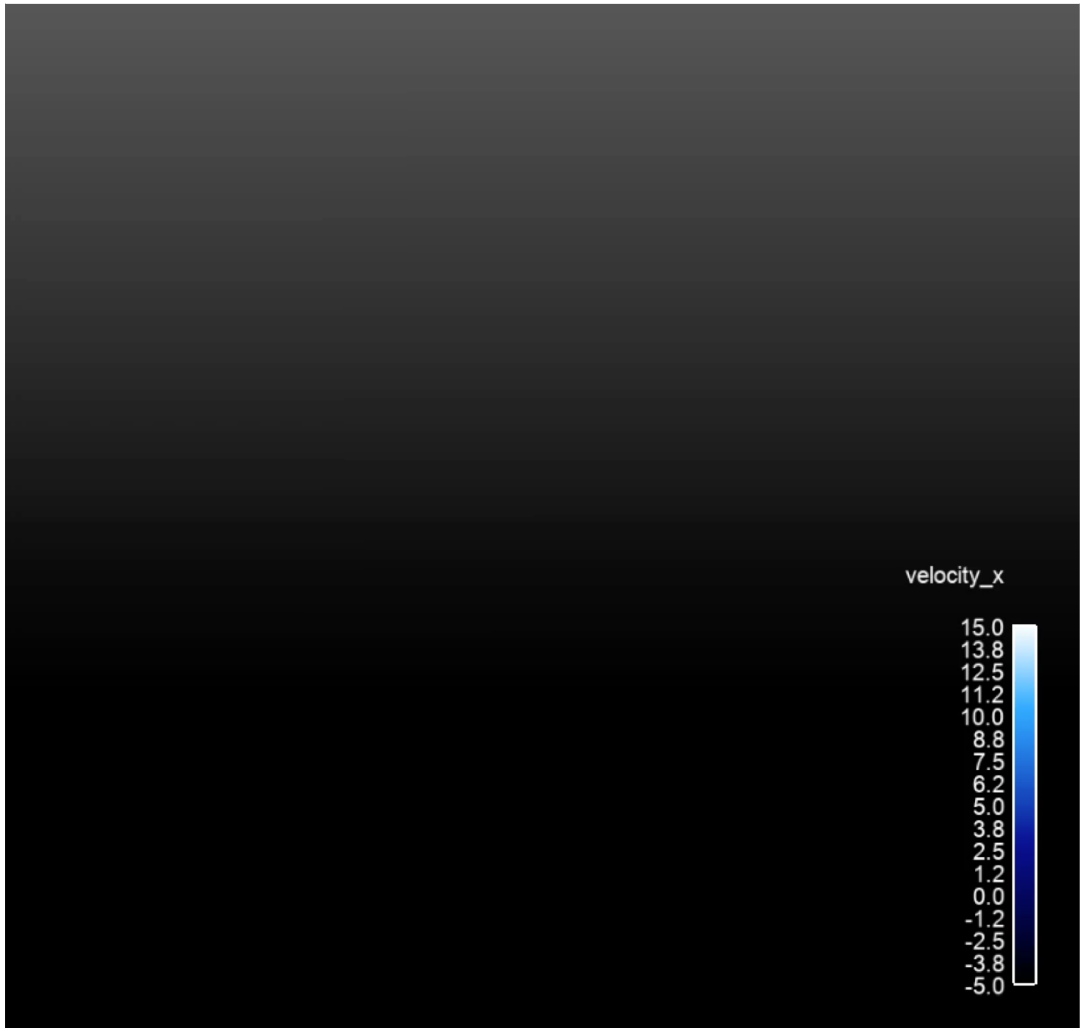
250 AD - 300 AD

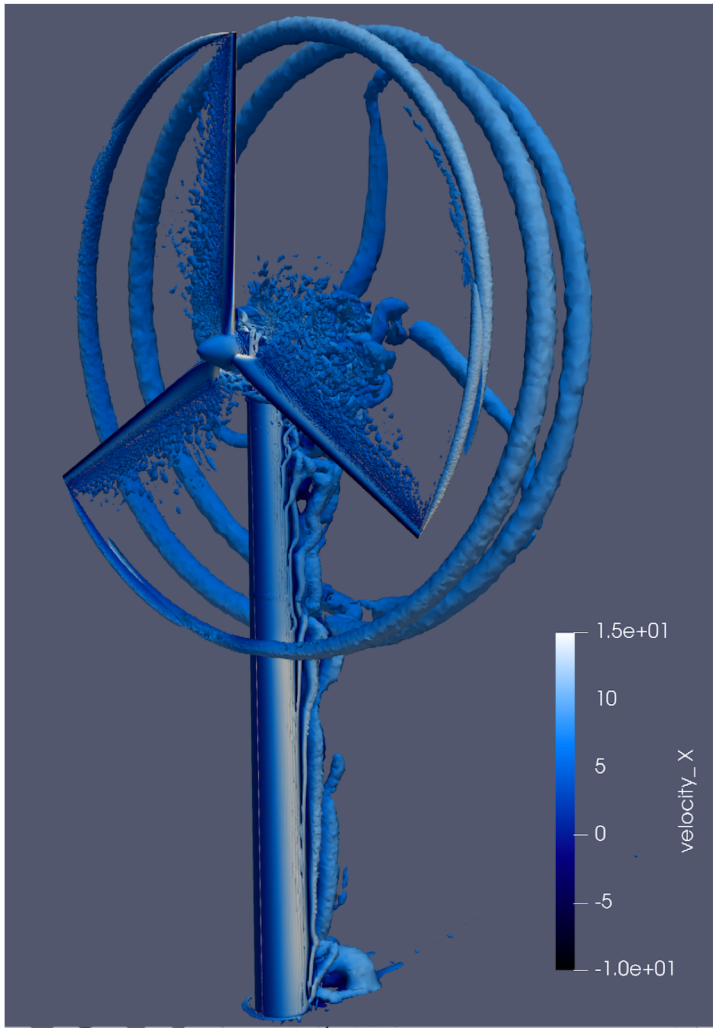
250 AD: The Goths invade Anatolia (AKA, Asia Minor), in sea-borne raids they plunder *Nikopolis*

EXASCALE COMPUTING PROJECT

LOW-MACH

Wind Energy Applications Including Blade-Resolved Simulations





Vestas V27 225 kw wind turbine simulation

SPD Computational Fluid Dynamics Research Interest: Conclusion

- Interest ranges from turbulent, reacting flow (fires) to wind energy applications
- Multi-physics coupling allows for very complex fluid flow simulation and predictions
- Most engineering and "real-world" flows include a wide range of time and length scales
- HPC enables science and the pursuit of physics modeling and insight

Guest Lecture Overview

- SPD Computational Fluid Dynamics Research Interest
- Introduction to the low-Mach Number Approximation
- Common low-Mach Discretization Approaches
- Splitting and Stabilization Errors
- Advection Operators
- A Validation Methodology: Code and Solution Verification
- High Performance Computing for CFD
- Multiphysics Coupling
- Nalu Overview