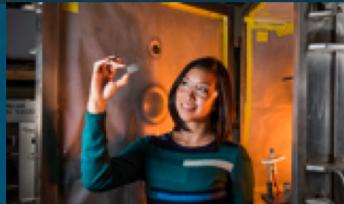
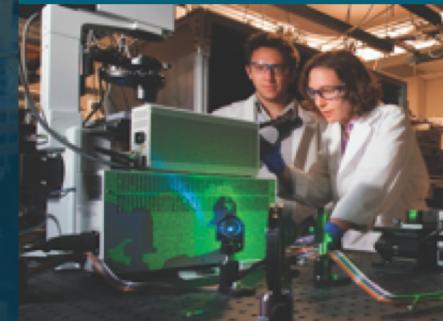


Guest Lecture Stanford ME469: Nalu Overview



Sandia
National
Laboratories



PRESENTED BY

Stefan P. Domino

Computational Thermal and Fluid Mechanics

Sandia National Laboratories SAND2018-4619 PE



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.

Nalu Overview: Outline

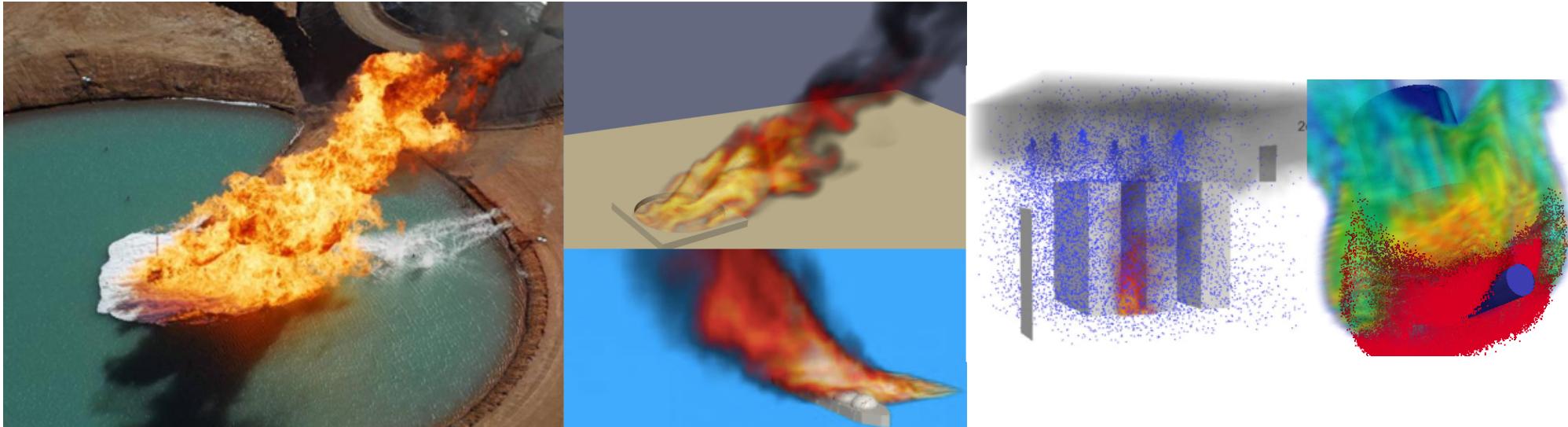


- Nalu Technology Origination: ASC
- Beyond the 32-bit Limit
- Supported Physics
- Supported Numerics
- Low- and High-order
- Moving Mesh (Sliding and Overset)
- Multiphysics:
 - Fluid Structure Interaction
 - Conjugate Heat Transfer (CHT)
 - Participating Media Radiation
- Conclusion

Core Technology Provided to Nalu Origination: Advanced Simulation and Computing Sierra/Fuego



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

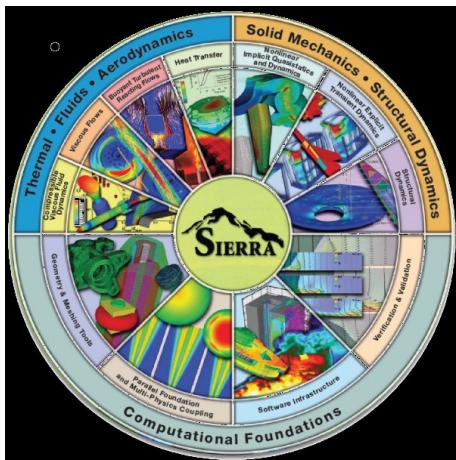


- Complex geometry has driven a generalized, hybrid unstructured discretization approach supporting Hex8, Tet4, Wedge6, and Pyramid5 elements in addition to arbitrary promotion of Hex8 to Hex27, Hex64, etc.

Goal: Beyond 32-bit Computing



- Circa 2013, many scientific production codes were limited to 32-bit
- Therefore, maximum simulation size for entities, e.g., node, edge, face, element, etc., was ~2.2 billion
- Next Generation Platforms were advocated to overcome poor MPI scaling and power needs to support Exascale computing (10^{18} floating point operations/second)
 - Platform architectures are not yet known

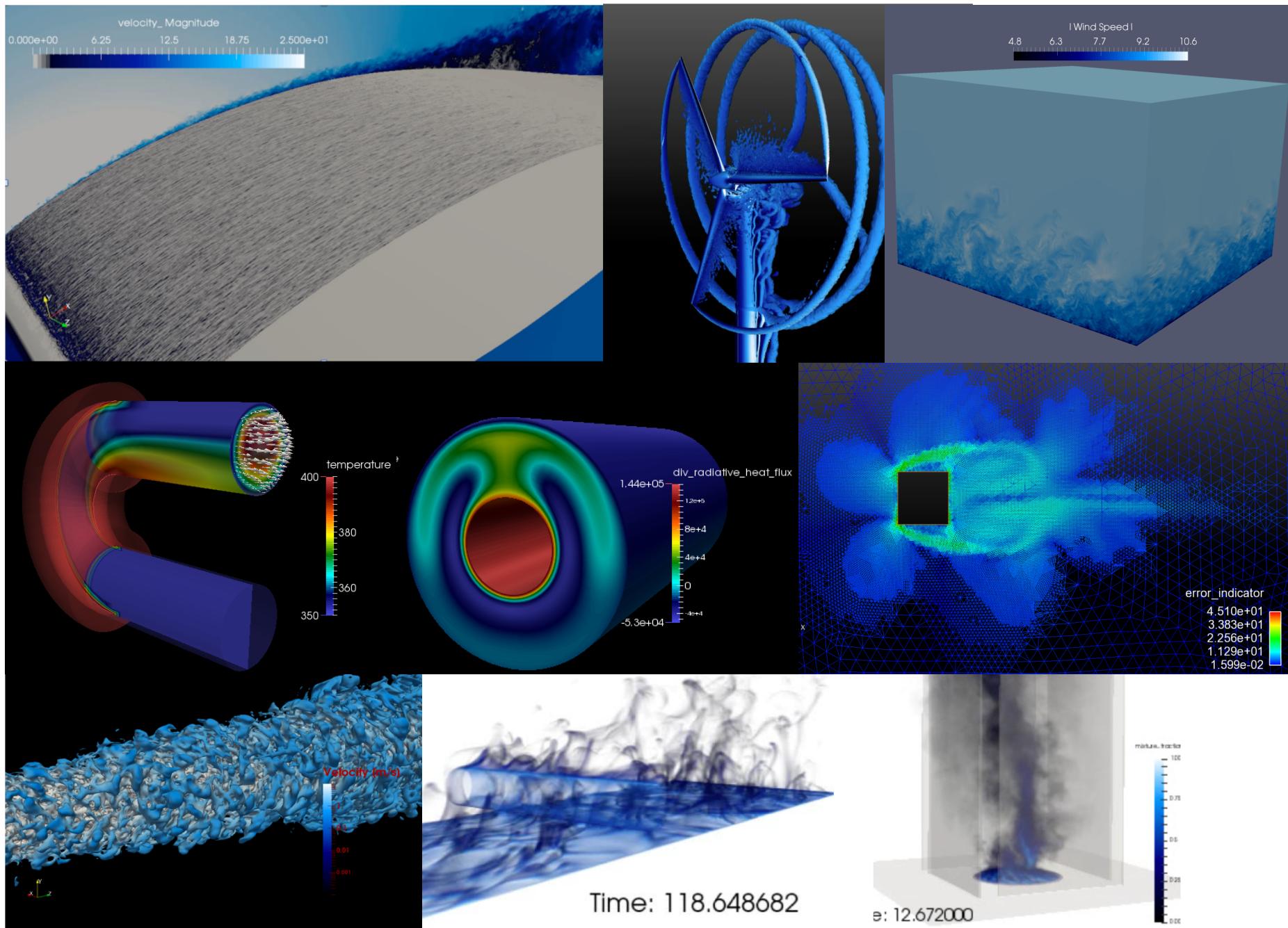


+ ASC IC
Investments



Sierra Toolkit/Trilinos (open-source)
MPI+X parallelism
Support for new architectures

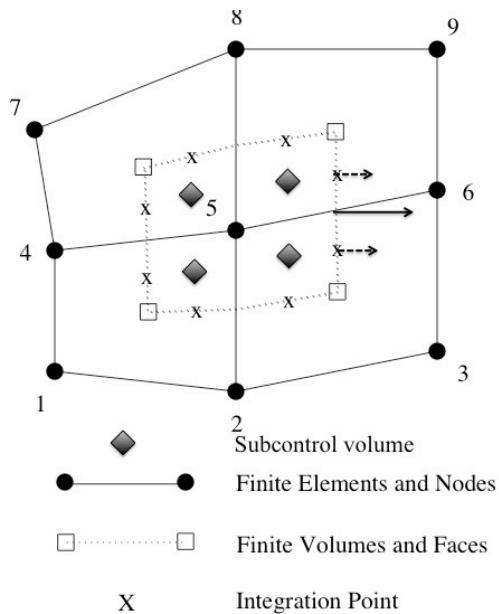
Supported Physics



Supported Discretizations: CVFEM/FEM/EBVC



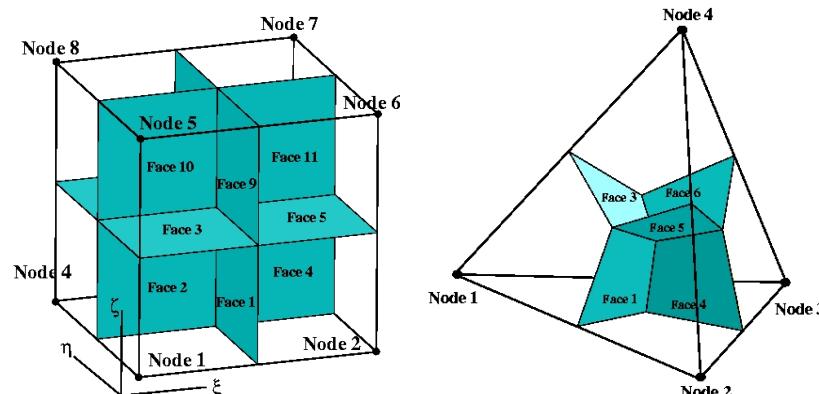
- The core discretization used in the low Mach code base has been the Control Volume Finite Element Method, CVFEM
- Finite Element Method and Edge-based Vertex-Centered, EBVC, are also supported



$$\int w \frac{\partial \bar{\rho} \tilde{u}_j \tilde{\phi}}{\partial x_j} d\Omega = - \int \bar{\rho} \tilde{u}_j \tilde{\phi} \frac{\partial w}{\partial x_j} d\Omega + \int w \bar{\rho} \tilde{u}_j \phi n_j d\Gamma$$

$$w = w_I; \frac{\partial w_I}{\partial x_j} = -\delta(x - x_{scs})$$

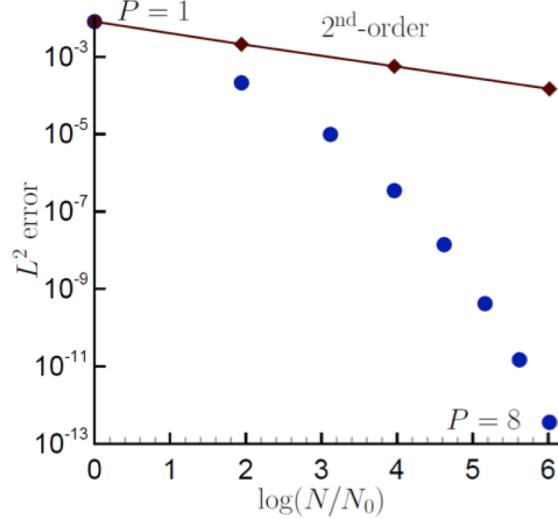
$$\int w \frac{\partial \bar{\rho} \tilde{u}_j \tilde{\phi}}{\partial x_j} d\Omega = \sum_{ip} (\bar{\rho} \tilde{u}_j)_{ip} \tilde{\phi}_{ip} n_j dS = \sum_{ip} \dot{m}_{ip} \tilde{\phi}_{ip}$$



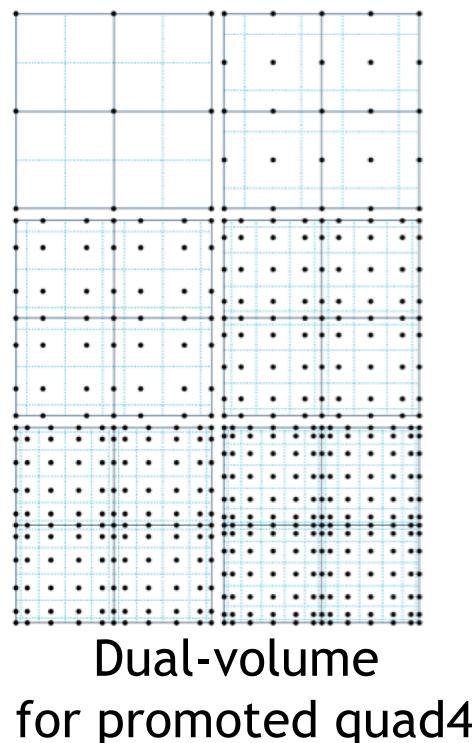
Scientific Research Platform to Evaluate Higher-Order Methods on Next Generation Platforms

7

- As the cost of parallel assembly increases, should we strive to perform more local work? Higher-order achieves this design-point (at the cost of a larger memory footprint)



Spectral convergence



Time: 0.055000



Time: 0.055000

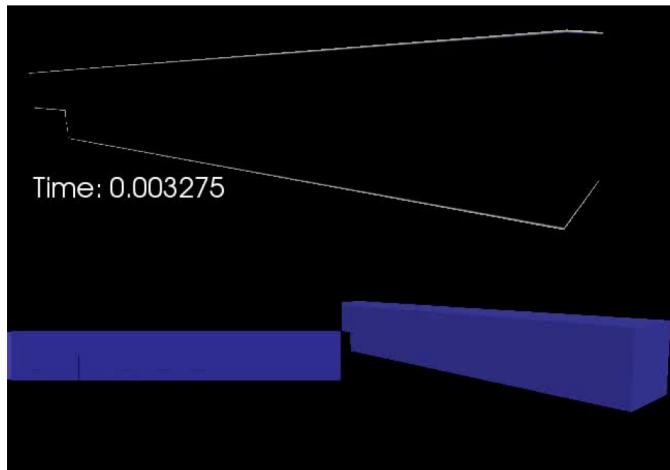


Flow-past rotating cube
Re~4000, RPM~3200
Same node count,
 $P=1$ (top) $P=2$ (bot)

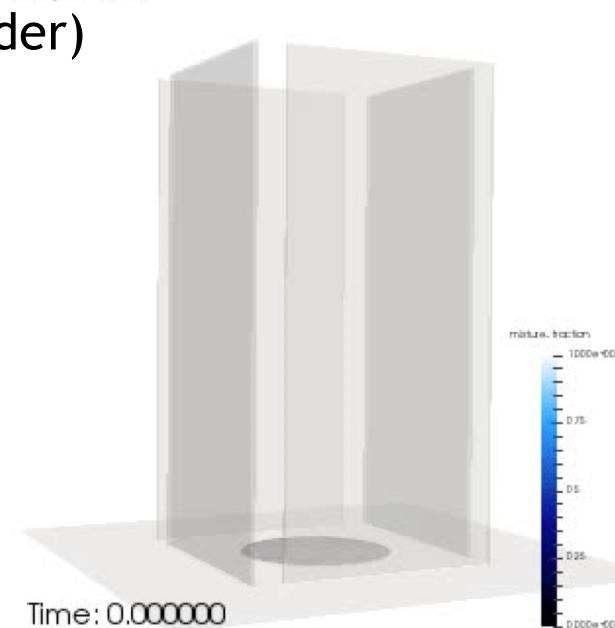
Several Multi-physics Flow Examples



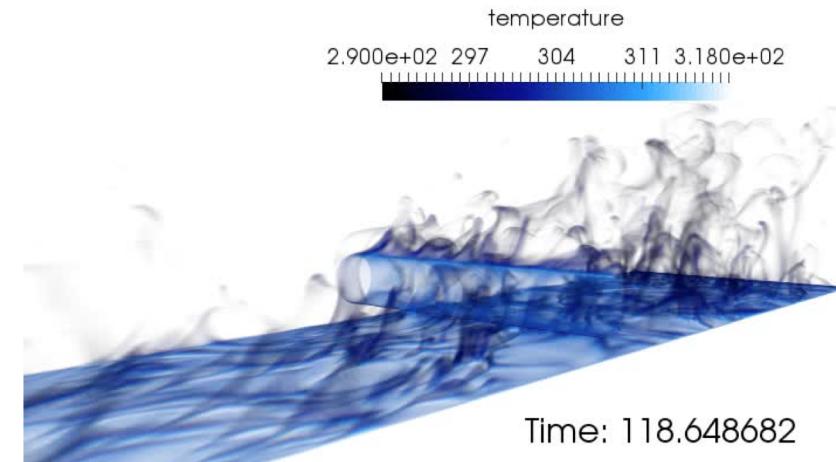
Helium plume (low-/high-order)
R1, 20cm



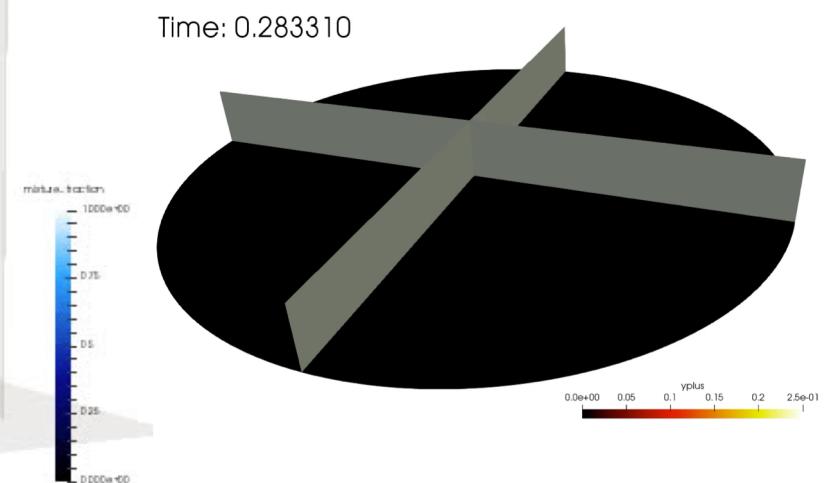
Heated backstep



Whirling behavior



Cylinder in cross flow



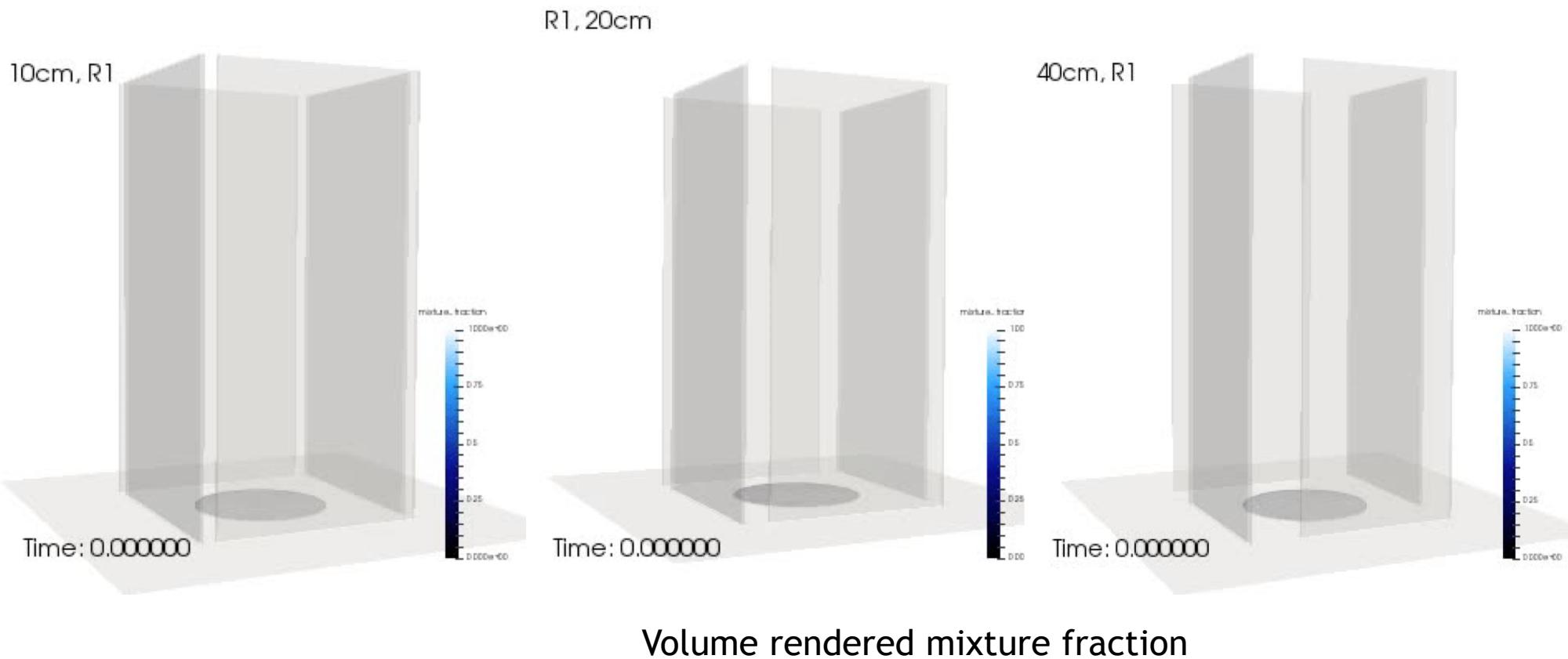
Impinging Jet DNS

Evolution of a Mindset.... Modeling Whirling-like Flow

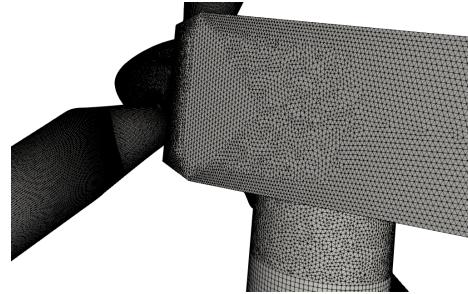


SAND2019-7052 C

- Idealized chamber in which swirl is provided by selective wall placement in the experimental design
- Gap varied between 10, 20, and 40 cm
- Objective: Can the onset of swirl be predicted? What is the strength?

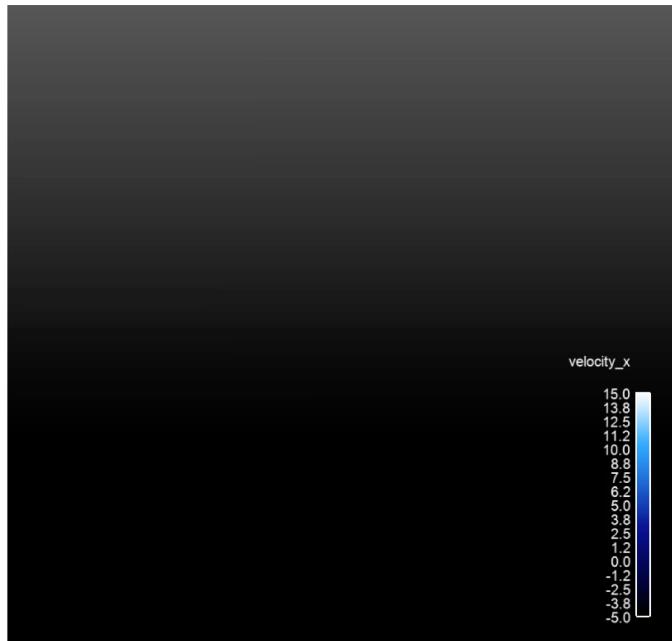


Unique Wind Energy Needs

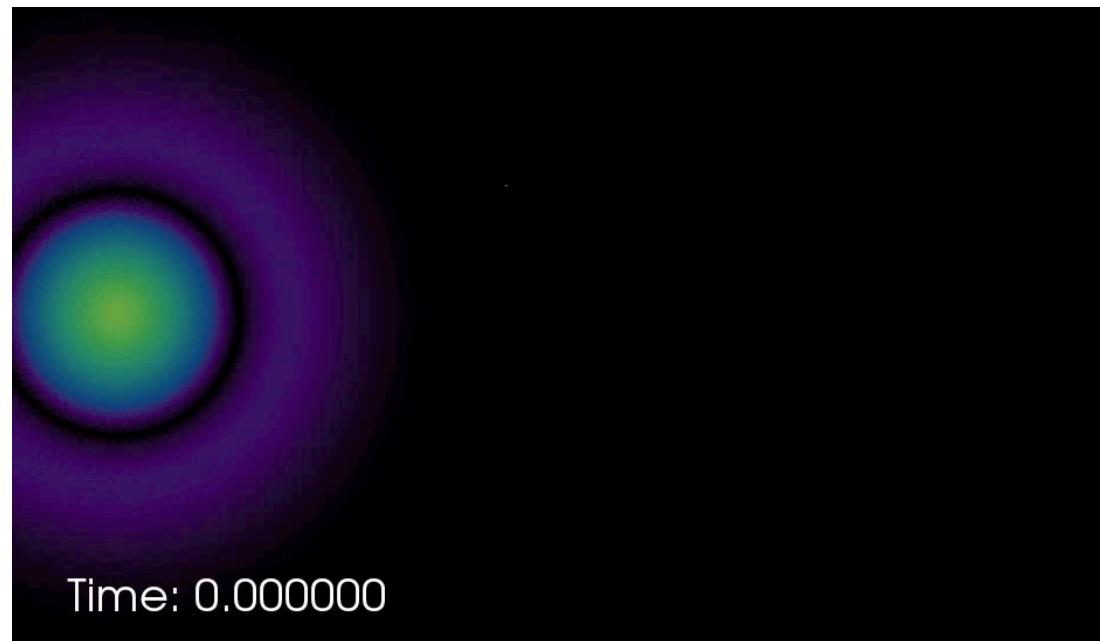


- Low-dissipation methods with suitable nonlinear stabilization operators to perform blade-resolved physics
- Complex rotating blades, pitching blades, with possible yaw
- Transition from low-order (near the blade) to higher-order (in the wake)

Generalized, unstructured, hybrid low-order simulations shown



Horizontal Axis Wind Turbine
(HAWT)



Vertical Axis Wind Turbine
(VAWT)

Developed Open-Source BSD-clause 3 Distribution Policy



- Philosophy: Open-source collaborations



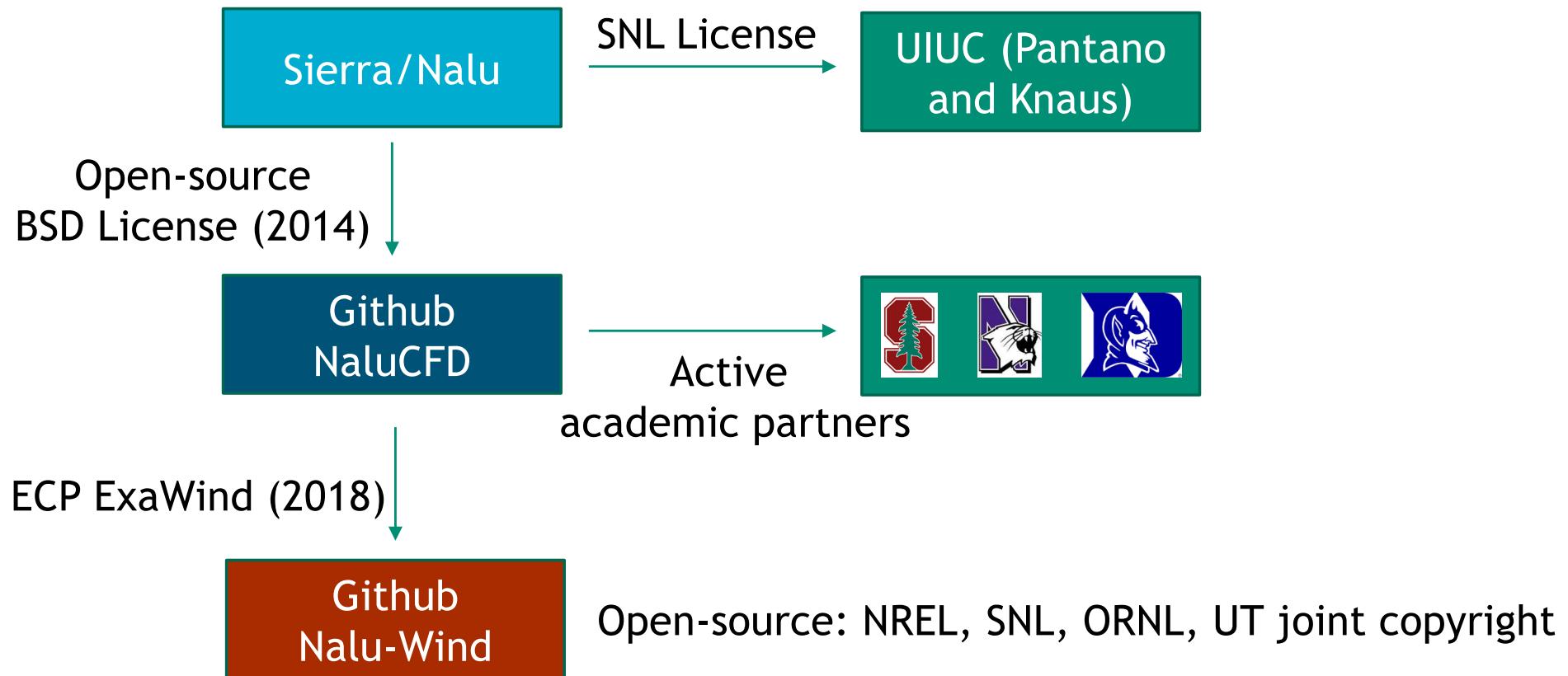
<https://github.com/NaluCFD>



Nalu History



- A time-history of the Nalu code base:
- By CFD standards, this is a relatively new code base



Nalu Overview: Conclusion



- Nalu's technology has its roots in the ASC Sierra/Fuego effort
- Multi-physics capabilities are in development
- Research platform for high-order low-Mach methods
- Open-source collaboration model
- Funded through ASC, ECP, A2e, ASCR, and LDRD