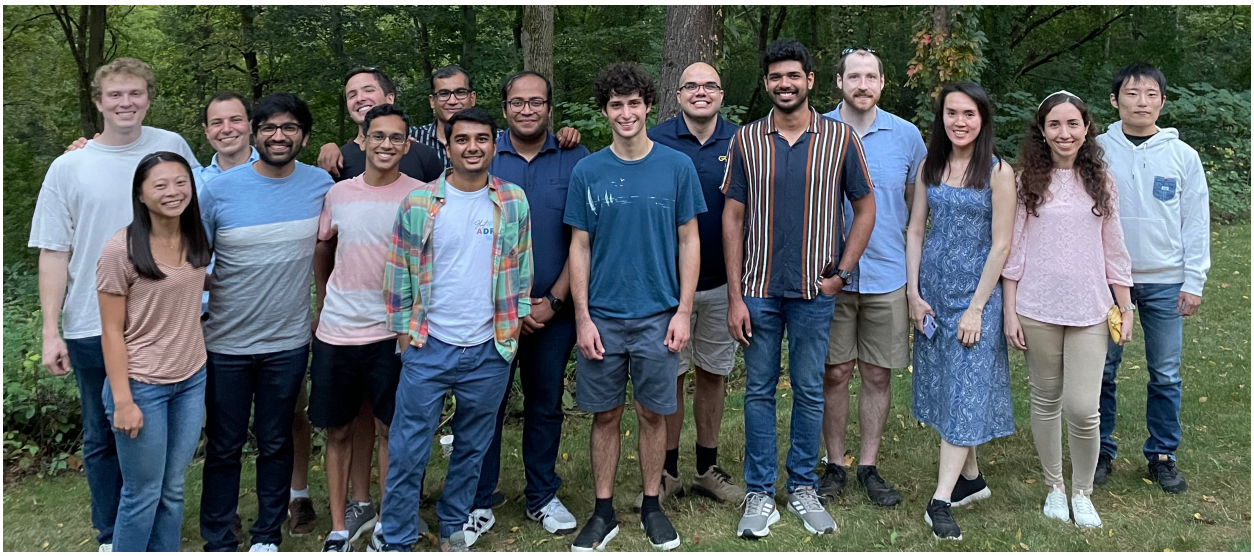
Computational Aerosciences Laboratory
2022 Highlights

2022 was supposed to be a huge year for CASLAB with up to five PhD graduations. We managed two and expect to have three more by the first quarter of 2023, so not too bad. 2022 saw a number of significant career transitions, research progress, software releases, and some exciting new directions. We expect some of these papers to hit arXiv in a month or so, but a heavily time-lagged list can be found on google scholar.

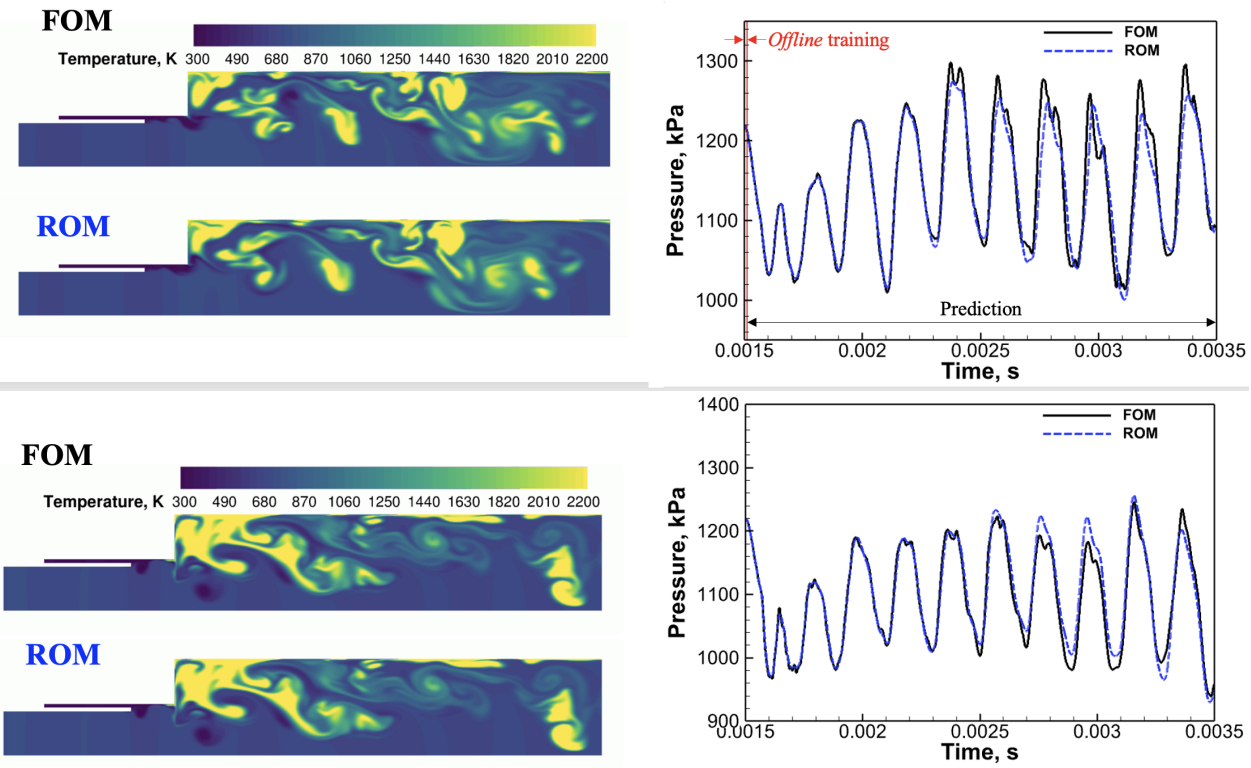


Center of Excellence on Multi-fidelity Modeling of Rocket Combustor Dynamics

The center made significant research progress over the past year. A snapshot (Cheng Huang's contribution) is shown in the figure below. Adaptive Reduced Order Models (ROMs) are demonstrated to have the capability to be *truly* predictive even in extremely stiff, chaotic, chemically reacting problems. The top row shows the adaptive ROM trained for 10 micro-seconds making predictions for a long time horizon. The bottom row shows the same ROM above (i.e. one trained for 10 micro-seconds for the flow in the top row), used to predict the flow when the oxidizer mass flow is increased by 50%. This is the culmination of five years of experience, building on the work of / collaborating with Benjamin Perherstorfer (NYU) and Karen Willcox (UT). This does not mean ROMs are now ready to be applied in any situation - there is still work to be done in making adaptive basis and adaptive sampling more robust. Also, while static ROMs can give many orders of magnitude cost reduction, our adaptive ROMs currently yield between one and two orders of magnitude cost reduction. Thus, there are open research questions remaining. Karen Willcox's group also made significant progress in non-intrusive ROMs this year. A full list of publications can be found here.

Chris released PERFORM (Prototyping Environment for Reacting Flow Order Reduction Methods) a simple, easy-to-use testbed for members of the ROM community to quickly prototype and test new methods on challenging (yet computationally-manageable) reacting flow problems.

Nick released PLATFORM (Parallel Linear Algebra Tool FOr Reduced Modeling) that eases memory and I/O bottlenecks for ROM preprocessing operations at scale.



New projects:

Foundational Approaches for End-to-end Formal Verification of Computational Physics. Sponsor: NSF (With Prof. Jean-Baptiste Jeannin)

The current state of the art in numerical analysis relies on paper proofs. In practical implementations, the impact of rounding error is seldom quantified, and even when quantified, not formalized. The interplay with the implementation (C code level and below) is also not clearly assessed. Practicioners use intuitive techniques such as convergence tests, and the method of manufactured solutions to manually check the viability of a numerical algorithm. Since these techniques yield necessary yet not sufficient checks, scientists rely on their expertise to guide applications. Our work offers the possibility of the user setting a tolerable error threshold, and being assured of achieving it via their implementation in several computational physics tasks. Our proofs are mechanically checked in an interactive theorem prover, and provide end-to-end guarantees from the problem expressed on a sheet of paper to the implementation at the C code level, and down to the executable code that computes numerical results. The mechanically-checked proofs use a variety of mathematical results ranging from convergence of functions to floating-point arithmetic and C semantics, thereby using various theories in one proof of correctness.

Data-driven Multi-fidelity optimization for front end air inlet / cooling pack design. Sponsor: Ford

In a prior project, the we developed a suite of reduced order models for the flow in the front end air inlet of electrified vehicles In the proposed work, this framework will be extended with the goal of enabling formal design optimization with geometric variations. : The ROMs will be integrated into a robust multi-fidelity framework which will integrate *both* high-fidelity data and

ROM surrogates into a design optimization framework to reliably identify optimal designs among parameters such as fan size, heat exchanger size, etc.

Conference/Invited Talks/Workshops

1. Conference presentations SIAM UQ (Atlanta), ECCOMAS (Oslo), (Rome), WCCM (Online), APS DFD (Indianapolis)

2. Workshops : Physics-Informed Machine learning (Santa Fe), Challenges & Benchmarks for Quantitative AI (Rome), Turbulence Modeling: Roadblocks, and the Potential for Machine Learning (NASA Langley).

3. Colloquium talks at University of Waterloo (Canada) and Notre Dame.

Career Transitions

1. Shaowu Pan began his career as an Assistant Professor at RPI

2. Vishal Srivastava began his career as Research Engineer at NIA/NASA Langley

3. Aniruddhe Pradhan began his career as HPC Engineer at KLA Tencor

4. Nicholas Arnold Medabalimi will begin his career as Computational Physicist at LLNL

5. Chris Wentland will begin his career as Post doctoral fellow at Sandia National Laboratories

6. Karthik was promoted to (Full) Professor of Aerospace Engineering

7. Karthik begins his term as Director of Michigan Institute of Computational Discovery & Engineering on 01/01/2023. Read about it here

8. Karthik began his term as Associate Editor of Physical Review Fluids

9. Karthik began his term on FAA's Advanced Aviation Advisory Committee (AAAC).

10. Mehdi Khalloufi began his career as senior research specialist at Dow Chemical.

New members

1. Noah Zambrano (PhD student): Noah got his bachelor's degree in Mechanical & Aerospace Engineering from the University of Florida and is an NSF GRFP Fellow.

2. Achu Shankar (PhD student): Achu got his Bachelors & Masters in Aerospace Engineering from IIT, Madras.

3. Malhar Prajapati (Masters student) and Satya Sai Charan Malladi (Masters student) contributed to research projects.

CASLAB team of 2022

Post Doctoral Fellows: Elnaz Rezaian, Mehdi Khalloufi.
PhD Students: Nicholas Arnold-Medabalimi, Vishal Srivastava, Christopher Wentland, Aniruddhe Pradhan, James Duvall, Christian Jacobsen, Bernardo Pacini, Jasmin Lim, Niloy Gupta, Daisuke Uchida, Sahil Bhola, Noah Zambrano, Achu Shankar.
Affiliated PhD Students: Mohit Tekriwal (Aero), Brandon Lefleur (Nuclear).
Lead: Karthik Duraisamy.

Prior Newsletters

Newsletter from 2021
Newsletter from 2020
Newsletter from 2019
Newsletter from 2018
Newsletter from 2017

Thank you for reading our newsletter. As a token of appreciation, here is a video from a recent trip in Pure Michigan

Visit us at `https://caslab.engin.umich.edu/`.