

Marc T. Henry de Frahan

US citizen, Applied Mathematics/Mechanical engineer

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Work Experience

Computational Scientist, National Renewable Energy Laboratory 2019-present

Reacting flows, wind turbine physics, performance portability on GPUs, numerical methods, continuum methods, kinetic Monte-Carlo

Principal investigator for several projects (*Adaptive Mesh and Algorithm Refinement*, 500k; *Scalable Parallel Discrete Events Simulations*, 550k)

Principal developer of several Exascale Computing Project software (Pele, ExaWind)

Post-doctoral Researcher, National Renewable Energy Laboratory 2016-2019

Next-generation simulations of wind farms and reacting flow processes

Education

Ph.D. in Mechanical Engineering 2011-2016

University of Michigan, Ann Arbor, MI

Thesis: *Numerical simulations of shock and rarefaction waves interacting with interfaces in compressible multiphase flows*

Advisor: E. Johnsen, Assistant Professor of Mechanical Engineering

M.S. in Applied Mathematics Engineering 2009-2011

Université Catholique de Louvain, Belgium

Thesis: *Implementation of a Discontinuous Galerkin Method for hyperbolic PDEs on GPUs*

Advisors: Prof. J-F Remacle, Prof. P. Chatelain, Prof. V. Legat.

B.S. in Applied Mathematics Engineering 2007-2009

Université Catholique de Louvain, Belgium

Research Interests

Fluid mechanics - turbulence, multiphase flows, hydrodynamic instabilities

Energy - reacting flows, wind turbines and farms

High order numerical methods for computational fluid dynamics

High performance computing with graphics processing units

Machine learning for improved physics models

Journal Articles

M. B. Kuhn, M. T. Henry de Frahan, P. Mohan, G. Deskos, M. Churchfield, L. Cheung, A. Sharma, A. Almgren, S. Ananthan, M. J. Brazell, L. A. Martinez-Tossas, R. Thedin, J. Rood, P. Sakievich, G. Vijayakumar, W. Zhang, M. A. Sprague, **AMR-Wind: A performance-portable, high-fidelity flow solver for wind farm simulations**, *Wind Energy*, 2025

M. Hassanaly, N. T. Wimer, A. Felden, L. Esclapez, J. Ream, M. T. Henry de Frahan, J. Rood, M. Day, **Symbolic construction of the chemical Jacobian of quasi-steady state (QSS) chemistries for Exascale computing platforms**, *Comb. and Flame*, vol. 270, 113740, 2024

- I. Barrio Sanchez, A. S. Almgren, J. B. Bell, M. T. Henry de Frahan, W. Zhang, **A New Redistribution Scheme for Weighted State Redistribution with Adaptive Mesh Refinement**, *J. Comp. Phys.*, vol. 504, 1, 112879, 2024
- M. T. Henry de Frahan, L. Esclapez, J. Rood, N. T. Wimer, P. Muldowney, B. A. Perry, L. Owen, H. Sitaraman, S. Yellapantula, M. Hassanaly, M. J. Rahimi, M. J. Martin, O. A. Doronina, Sreejith N. A., M. Rieth, W. Ge, R. Sankaran, A. S. Almgren, W. Zhang, J. B. Bell, R. Grout, M. S. Day, and J. H. Chen, **The Pele Simulation Suite for Reacting Flows at Exascale**, *Proc. 2024 SIAM Conf. Parallel Proc. Sc. Comput.*, 15-25, 2024
- A. Sharma, M. J. Brazell, G. Vijayakumar, S. Ananthan, L. Cheung, N. deVelder, M. T. Henry de Frahan, N. Matula, P. Muldowney, J. Rood, P. Sakievich, A. Almgren, P. S Crozier, M. Sprague, **ExaWind: Open-source CFD for hybrid-RANS/LES geometry-resolved wind turbine simulations in atmospheric flows**, *Wind Energy*, vol 27, 3, 225-257, 2024
- N. Wimer, L. Esclapez, N. Brunhart-Lupo, M. T. Henry de Frahan, M. Rahimi, M. Hassanaly, J. Rood, S. Yellapantula, H. Sitaraman, B. Perry, M. Martin, O. Doronina, S. Appukuttan, M. Reith, M. Day, **Visualizations of a Methane/Diesel RCCI Engine using PeleC and PeleLMEx**, *Phys. Rev. Fluids*, 8, 110511, 2023
- L. Esclapez, M. Day, J. Bell, A. Felden, C. Gilet, R. Grout, M. T. Henry de Frahan, E. Motheau, A. Nonaka, L. Owen, B. Perry, J. Rood, N. Wimer, and W. Zhang, **PeleLMEx: an AMR Low Mach Number Reactive Flow Simulation Code without level sub-cycling**, *J. Open Source Software*, 8, 90, 5450, 2023
- N. T. Wimer, M. T. Henry de Frahan, S. Yellapantula, **Deep reinforcement learning to discover multi-fuel injection strategies for compression ignition engines**, *Int. J. Eng. Res.*, vol 24, 9, 2023
- A. Giuliani, A.S. Almgren, J.B. Bell, M.J. Berger, M.T. Henry de Frahan, D. Rangarajan, **A weighted state redistribution algorithm for embedded boundary grids**, *J. Comp. Phys.*, 111305, 2022
- M. T. Henry de Frahan, J. S. Rood, M. S. Day, H. Sitaraman, S. Yellapantula, B. A. Perry, R. W. Grout, A. Almgren, W. Zhang, J. B. Bell, J. H. Chen, **PeleC: An adaptive mesh refinement solver for compressible reacting flows**, *Int. J. High. Perf. Comp. App.*, vol. 37, 2, 2022
- B. Perry, M. T. Henry de Frahan, S. Yellapantula, **Co-optimized machine-learned manifold models for large eddy simulation of turbulent combustion**, *Comb. and Flame*, 244, 112286, 2022
- H. Sitaraman, N. Brunhart-Lupo, M. T. Henry de Frahan, S. Yellapantula, B. Perry, J. Rood, R. Grout, M. S. Day, R. Binyahib, K. Gruchalla, **Visualizations of direct fuel injection effects in a supersonic cavity flameholder**, *Phys. Rev. Fluids*, 6, 110504, 2021
- J Quick, R. King, M. T. Henry de Frahan, S. Ananthan, M. Sprague, P. Hamlington, **Field Sensitivity Analysis of Turbulence Model Parameters for Flow Over a Wing**, *Int. J. Uncert. Quant.*, vol. 12, 1, 85–106, 2022
- H. Sitaraman, S. Yellapantula, M. T. Henry de Frahan, B. Perry, J. Rood, R. W. Grout, M. S. Day, **Adaptive mesh based combustion simulations of direct fuel injection effects in a supersonic cavity flame-holder**, *Comb. and Flame*, 232, 111531, 2021

M. T. Henry de Frahan, N. T. Wimer, S. Yellapantula, R. W. Grout, **Deep reinforcement learning for dynamic control of fuel injection timing in multi-pulse compression ignition engines**, *Int. J. Eng. Res.*, vol 23, 9, 2021

S. Yellapantula, M. T. Henry de Frahan, R. King, M. S. Day, R. W. Grout, **Machine learning of combustion LES models from reacting direct numerical simulation**, *Data Analysis for Direct Num. Sim. of Turb. Comb.*, Pages 273-292, 2020

M. T. Henry de Frahan, S. Yellapantula, R. King, M. S. Day, and R. W. Grout, **Deep learning for presumed probability density function models**, *Comb. and Flame*, 208:436–450, Pages 436-450, 2019

P. Mohan, M. T. Henry de Frahan, R. King, and R. Grout, **A block-random algorithm for learning on distributed, heterogeneous data**, *arXiv:1903.00091*, 2019

M. T. Henry de Frahan, and R. Grout, **Data recovery in computational fluid dynamics through deep image priors**, *arXiv:1901.11113*, 2019

M. T. Henry de Frahan, J. L. Belof, R. M. Cavallo, V. A. Raevsky, O. N. Ignatova, A. Lebedev, D. S. Ancheta, B. S. El-dasher, J. N. Florando, G. F. Gallegos, E. Johnsen, and M. M. LeBlanc, **Experimental and Numerical Investigations of Beryllium Strength Models Using the Rayleigh-Taylor Instability**, *featured article in J. Appl. Phys.*, 117(22):225901, 2015

M. T. Henry de Frahan, S. Varadan, and E. Johnsen, **A new limiting procedure for discontinuous Galerkin methods applied to compressible multiphase flows with shocks and interfaces**, *J. Comput. Phys.*, 280(0):489 – 509, 2015

M. T. Henry de Frahan, P. Movahed, and E. Johnsen, **Numerical simulations of a shock interacting with successive interfaces using the Discontinuous Galerkin method: the multilayered Richtmyer-Meshkov and Rayleigh-Taylor instabilities**, *Shock Waves*, 25(4):329–345, 2015

C. A. Di Stefano, G. Malamud, M. T. Henry de Frahan, C. C. Kuranz, A. Shimony, S. R. Klein, R. P. Drake, E. Johnsen, D. Shvarts, V. A. Smalyuk, and D. Martinez, **Observation and modeling of mixing-layer development in high-energy-density, blast-wave-driven shear flow**, *Phys. Plasmas*, 21(5):056306, 2014

Conference Proceedings

N. T. Wimer, L. Esclapez, M. T. Henry de Frahan, M. Rahimi, M. Hassanaly, B. Perry, J. Rood, S. Yellapantula, H. Sitaraman, M. Martin, O. Doronina, S. Nadakkal Appukuttan, M. Rieth, M. Day, **Examination of a Methane/Diesel RCCI Engine Using Pele**, 13th U.S. National Combustion Meeting, 2023

P. T. Bauman et al, **Experiences Readyng Applications for Exascale**, *Supercomputing*, 2023

M. T. Henry de Frahan, M. Rahimi, O. Doronina, B. Perry, S. Yellapantula, I. Cormier, M. Day, M. Martin, **Simulation of Methane Oxyc Combustion in Supercritical Carbon Dioxide**, *Turbomachinery Technical Conference and Exposition, ASME*, doi: 10.1115/GT2023-101568, 2023

S. A Beig, G. R. Whitehouse, A. H. Boschitsch, A. Sharma, M. J. Brazell, M. T Henry de Frahan, M. A. Sprague, **Developing a Vorticity-Velocity-Based Off-Body Solver to Perform Multifidelity**

Simulations of Wind Farms, *2022 AIAA SCITECH Forum. American Institute of Aeronautics and Astronautics*, doi: 10.2514/6.2023-1542, 2022

C. Adcock, M. T. Henry de Frahan, J. Melvin, G. Vijayakumar, S. Ananthan, G. Iaccarino, R. D. Moser, and M. Sprague, **Hybrid RANS-LES of the Atmospheric Boundary Layer for Wind Farm Simulations**, *2022 AIAA SCITECH Forum. American Institute of Aeronautics and Astronautics*, doi: 10.2514/6.2022-1922, 2021

J. Melvin, M. T. Henry de Frahan, S. Ananthan, G. Vijayakumar, M. Sprague, R. Moser, **Using the Active Model Split Hybrid Turbulence Model for the Simulation of Blade-Resolved Wind Turbines**, *Wind Energy Science Conference*, 2021

S. Yellapantula, B. A. Perry, M. T. Henry de Frahan, M. E. Mueller, and R. W. Grout, **Machine Learning based models for joint PDF shapes for multi-scalar mixing in turbulent flows**, *11th U.S. National Combustion Meeting*, 2019

M. T. Henry de Frahan, L. Khieu, and E. Johnsen, **High-order Discontinuous Galerkin Methods Applied to Multiphase Flows**, *22^d AIAA Computational Fluid Dynamics Conference. American Institute of Aeronautics and Astronautics*, doi: 10.2514/6.2015-3045, 2015, AIAA CFD Best Student Paper Award (3^d place)

M. T. Henry de Frahan and E. Johnsen, **Discontinuous Galerkin method for multifluid Euler equations**, *In 21st AIAA Computational Fluid Dynamics Conference. American Institute of Aeronautics and Astronautics*, doi: 10.2514/6.2013-2595, 2013

M. T. Henry de Frahan, P. Movahed, and E. Johnsen, **Investigating the multilayered Richtmyer-Meshkov instability with high-order accurate numerical methods**, *In 29th International Symposium on Shock Waves 2, Springer International Publishing*, 2015

Awards and Fellowships

President's Team Award National Renewable Energy Laboratory	2024
Best Visualization Award Supercomputing 2023	2023
Chairperson's Team Award National Renewable Energy Laboratory	2023
Milton van Dyke Award American Physical Society - Division of Fluid Dynamics	2022
President's Award for Exceptional Performance National Renewable Energy Laboratory	2022
Gallery of Fluid Motion Award Winners American Physical Society - Division of Fluid Dynamics	2020
President's Team Award National Renewable Energy Laboratory	2019

Better Scientific Software Fellowship (honorable mention) Better Scientific Software (Department of Energy organization)	2018
AIAA CFD Best Student Paper Award (3^d place) American Institute of Aeronautics and Astronautics	2015
Rackham Predoctoral Fellowship University of Michigan	2015
Rackham Centennial Fellowship University of Michigan	2013
High Distinction M.S. in Applied Mathematics Engineering at the Université Catholique de Louvain	2011

Leadership Experience

Acting Group Manager for the High Performance Algorithms and Complex Fluids group, NREL Group lead for a team of 15+ scientists	2020-2021
Mechanical Engineering Graduate Council, University of Michigan - STEM Communication Chair Communicate graduate student research to lay audiences - President Promote social, academic and professional development for ME graduate students - Graduate Seminar Chair Organize monthly seminars to showcase graduate student research	2013-2016
Graduate Student Advisory Committee, University of Michigan Representative for Department of Mechanical Engineering Identify and plan activities to promote community among engineering graduate students	2014-2015

Mentorship and Teaching Experience

Prakash Mohan, National Renewable Energy Laboratory Postdoctoral research mentor	2022-Present
Arth Sojitra Mentor for summer internship on the lattice boltzmann method	2023
Grace Wei CSGF practicum mentor on the kinetic Monte-Carlo methods	2023
Nick Wimer, National Renewable Energy Laboratory Postdoctoral research mentor	2019-2021
Bruce Perry, National Renewable Energy Laboratory Postdoctoral research mentor	2019-2021
Likhith Ganedi, Carnegie-Mellon University Mentor for summer internship on hybrid particle-continuum solvers	2021

Jani Adcock, Stanford University CSGF practicum mentor, Ph.D. committee member	2020-2023
Julia Ream, Florida State University Co-advisor of Ph.D. committee for work on turbulent supercritical CO2 simulations	2019-2023
Prakash Mohan, University of Texas-Austin Mentored Ph.D. graduate student for a project on deep learning for LES models	2018
Jalil Alidoost, University of Michigan Mentored senior undergraduate for a project on diffusive and kinetic properties of chair motion in the Shapiro Library	2015-2016
Colby Hanley, University of Michigan Mentored freshman undergraduate for a project on multi-GPU profiling for high-performance computing	2015-2016
Graduate Student Instructor for ME 523: Computational Fluid Dynamics University of Michigan, Ann Arbor, MI	Fall 2013

Research Experience

DOE I-Corps Cohort 15 Department of Energy Immersive two-month training for researchers to define technology value propositions, conduct stakeholder discovery interviews, and develop viable market pathways for their technologies.	Fall 2022
Deep Learning Specialization Coursera Topics: neural networks (CNN, RNN), deep learning frameworks (Keras, Tensorflow)	2017-2018
Argonne Training Program on Extreme-Scale Computing, Argonne National Laboratory Invited to an intensive 2-week workshop on high performance computing	Summer 2017
NextProf Engineering Future Faculty Workshop, University of Michigan Invited to participate in a workshop to prepare for faculty positions	Fall 2015
International High Performance Computing Summer School, Hungary Invited to attend NSF workshop to learn new paradigms in scientific computing	Summer 2014
Lawrence Livermore National Laboratory, Livermore, CA Student intern Comparing Beryllium strength models with experimental data Supervisors: Dr. B. Remington and Dr. R. Cavallo	Summer 2012
Computational Methods in High Energy Density Plasmas, UCLA, CA Invited to attend a 6 week long workshop by the Institute for Pure and Applied Mathematics at the University of California - Los Angeles	Spring 2012

Lawrence Livermore National Laboratory, Livermore, CA Student intern Studied hydrodynamic instabilities in inertial confinement fusion targets Characterized growth factors during capsule compression Supervisors: Dr. L. J. Suter and Dr. D. S. Clark	Summer 2010
Lawrence Livermore National Laboratory, Livermore, CA Student intern Studied hot electron signatures and capsule preheat in the context of inertial confinement fusion as developed at the National Ignition Facility Supervisors: Dr. L. J. Suter and Dr. C. A. Thomas	Summer 2009
Lawrence Livermore National Laboratory, Livermore, CA Student intern Studied and optimized National Ignition Facility inertial confinement fusion target geometries using view factor calculations Supervisors: Dr. L. J. Suter and Dr. C. A. Thomas	Summer 2008

Volunteer Service and Outreach

NREL Postdoctoral Committee Organizing networking and professional development activities	2016-2018
DAPCEP Instructor Organized and taught a 6-week long engineering discovery course for Detroit-area middle school students	Spring 2015
Volunteer Instructor, Adams Academy Engineering Club Instructed fun basic science and engineering projects at a local primary school	2014-2016
Graduate Student Recruiter, University of Michigan Organized and participated in recruitment events graduate students visiting the Mechanical Engineering department	2012-2016

Skills

Scientific programming

C/C++, Python, GPU (CUDA, SYCL, ROCM, Kokkos, AMReX), MPI, OpenMP, OpenACC, Git

Operating systems

GNU/Linux, OSX

Languages

English, French