

# Marc T. Henry de Frahan

US citizen, Applied Mathematics/Mechanical engineer

marchdf@gmail.com  
github.com/marchdf

## Work Experience

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**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

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**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

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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

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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. Mullowney, 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.*

A. Sharma, M. J. Brazell, G. Vijayakumar, S. Ananthan, L. Cheung, N. deVelder, M. T. Henry de Frahan, N. Matula, P. Mullowney, 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

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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**, 13<sup>th</sup> 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 OxycCombustion 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**, 11<sup>th</sup> *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<sup>d</sup> *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<sup>d</sup> 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

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<b>Chairperson's Team Award</b> National Renewable Energy Laboratory	2023
<b>Milton van Dyke Award</b> American Physical Society - Division of Fluid Dynamics	2022
<b>President's Award for Exceptional Performance</b> National Renewable Energy Laboratory	2022
<b>Gallery of Fluid Motion Award Winners</b> American Physical Society - Division of Fluid Dynamics	2020
<b>President's Team Award</b> National Renewable Energy Laboratory	2019
<b>Better Scientific Software Fellowship (honorable mention)</b> Better Scientific Software (Department of Energy organization)	2018
<b>AIAA CFD Best Student Paper Award (3<sup>d</sup> place)</b> American Institute of Aeronautics and Astronautics	2015
<b>Rackham Predoctoral Fellowship</b> University of Michigan	2015
<b>Rackham Centennial Fellowship</b> University of Michigan	2013
<b>High Distinction</b> M.S. in Applied Mathematics Engineering at the Université Catholique de Louvain	2011

## Leadership Experience

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<b>Acting Group Manager for the High Performance Algorithms and Complex Fluids group, NREL</b> Group lead for a team of 15+ scientists	2020-2021
<b>Mechanical Engineering Graduate Council, University of Michigan</b> - 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
<b>Graduate Student Advisory Committee, University of Michigan</b> Representative for Department of Mechanical Engineering Identify and plan activities to promote community among engineering graduate students	2014-2015

## Mentorship and Teaching Experience

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<b>Prakash Mohan, National Renewable Energy Laboratory</b> Postdoctoral research mentor	2022-Present
<b>Arth Sojitra</b> Mentor for summer internship on the lattice boltzmann method	2023
<b>Grace Wei</b> CSGF practicum mentor on the kinetic Monte-Carlo methods	2023
<b>Nick Wimer, National Renewable Energy Laboratory</b> Postdoctoral research mentor	2019-2021
<b>Bruce Perry, National Renewable Energy Laboratory</b> Postdoctoral research mentor	2019-2021
<b>Likhit Ganedi, Carnegie-Mellon Univeristy</b> Mentor for summer internship on hybrid particle-continuum solvers	2021
<b>Jani Adcock, Stanford University</b> CSGF practicum mentor, Ph.D. committee member	2020-2023
<b>Julia Ream, Florida State University</b> Co-advisor of Ph.D. committee for work on turbulent supercritical CO2 simulations	2019-2023
<b>Prakash Mohan, University of Texas-Austin</b> Mentored Ph.D. graduate student for a project on deep learning for LES models	2018
<b>Jalil Alidoost, University of Michigan</b> Mentored senior undergraduate for a project on diffusive and kinetic properties of chair motion in the Shapiro Library	2015-2016

<b>Colby Hanley, University of Michigan</b> Mentored freshman undergraduate for a project on multi-GPU profiling for high-performance computing	2015-2016
<b>Graduate Student Instructor for ME 523: Computational Fluid Dynamics</b> University of Michigan, Ann Arbor, MI	Fall 2013

## Research Experience

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<b>DOE I-Corps Cohort 15</b> 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
<b>Deep Learning Specialization</b> Coursera Topics: neural networks (CNN, RNN), deep learning frameworks (Keras, Tensorflow)	2017-2018
<b>Argonne Training Program on Extreme-Scale Computing, Argonne National Laboratory</b> Invited to an intensive 2-week workshop on high performance computing	Summer 2017
<b>NextProf Engineering Future Faculty Workshop, University of Michigan</b> Invited to participate in a workshop to prepare for faculty positions	Fall 2015
<b>International High Performance Computing Summer School, Hungary</b> Invited to attend NSF workshop to learn new paradigms in scientific computing	Summer 2014
<b>Lawrence Livermore National Laboratory, Livermore, CA</b> Student intern Comparing Beryllium strength models with experimental data Supervisors: Dr. B. Remington and Dr. R. Cavallo	Summer 2012
<b>Computational Methods in High Energy Density Plasmas, UCLA, CA</b> 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
<b>Lawrence Livermore National Laboratory, Livermore, CA</b> 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
<b>Lawrence Livermore National Laboratory, Livermore, CA</b> 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**

Summer 2008

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

## **Volunteer Service and Outreach**

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### **NREL Postdoctoral Committee**

2016-2018

Organizing networking and professional development activities

### **DAPCEP Instructor**

Spring 2015

Organized and taught a 6-week long engineering discovery course for Detroit-area middle school students

### **Volunteer Instructor, Adams Academy Engineering Club**

2014-2016

Instructed fun basic science and engineering projects at a local primary school

### **Graduate Student Recruiter, University of Michigan**

2012-2016

Organized and participated in recruitment events graduate students visiting the Mechanical Engineering department

## **Skills**

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### **Scientific programming**

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

### **Operating systems**

GNU/Linux, OSX

### **Languages**

English, French