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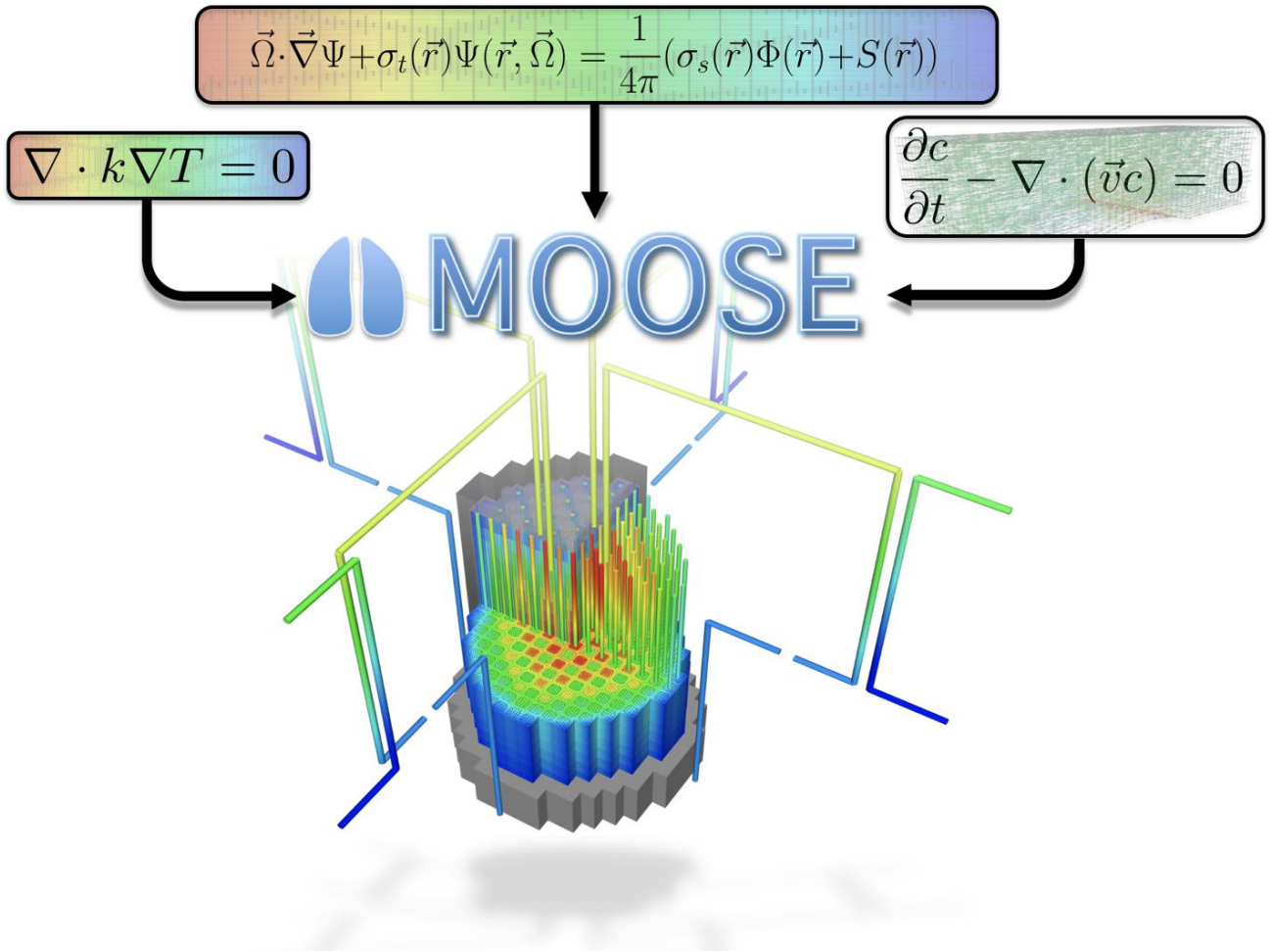
MOOSE FRAMEWORK FOR RESEARCH AND DEVELOPMENT OF FISSION AND FUSION REACTORS

INL is managed by Battelle Energy Alliance for the US Department of Energy

Idaho National Laboratory

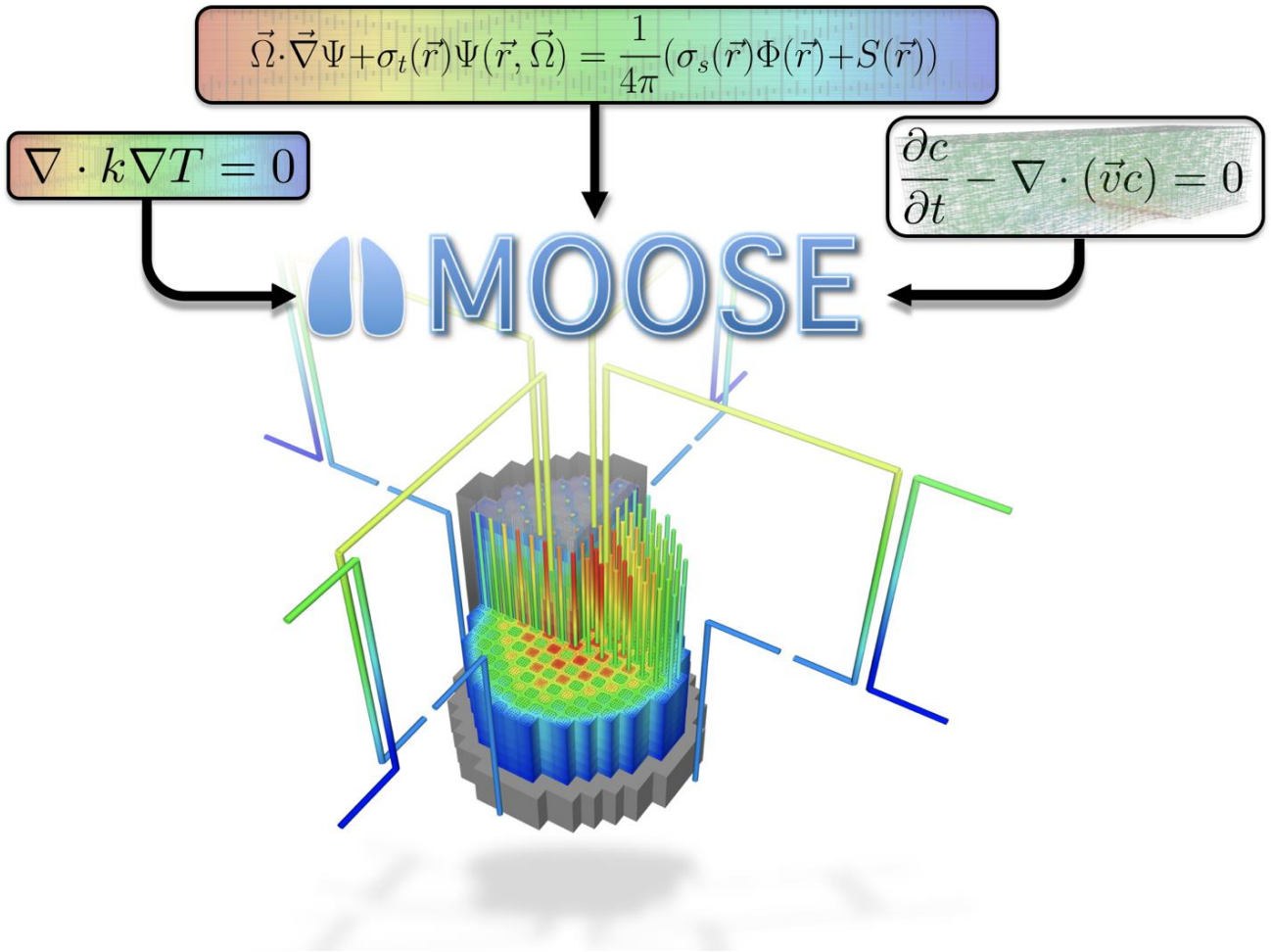
MOOSE Framework: Overview



- Developed by Idaho National Laboratory since 2008
- Used for studying and analyzing nuclear reactor problems
- Free and open source (LGPL license). Large user community
- Easy to use and customize
- Takes advantage of high performance computing
- Developed and supported by full time INL staff – long term support
- https://www.mooseframework.inl.gov

Permann, Cody J., et al. "MOOSE: Enabling massively parallel multiphysics simulation." *SoftwareX* 11 (2020): 100430.

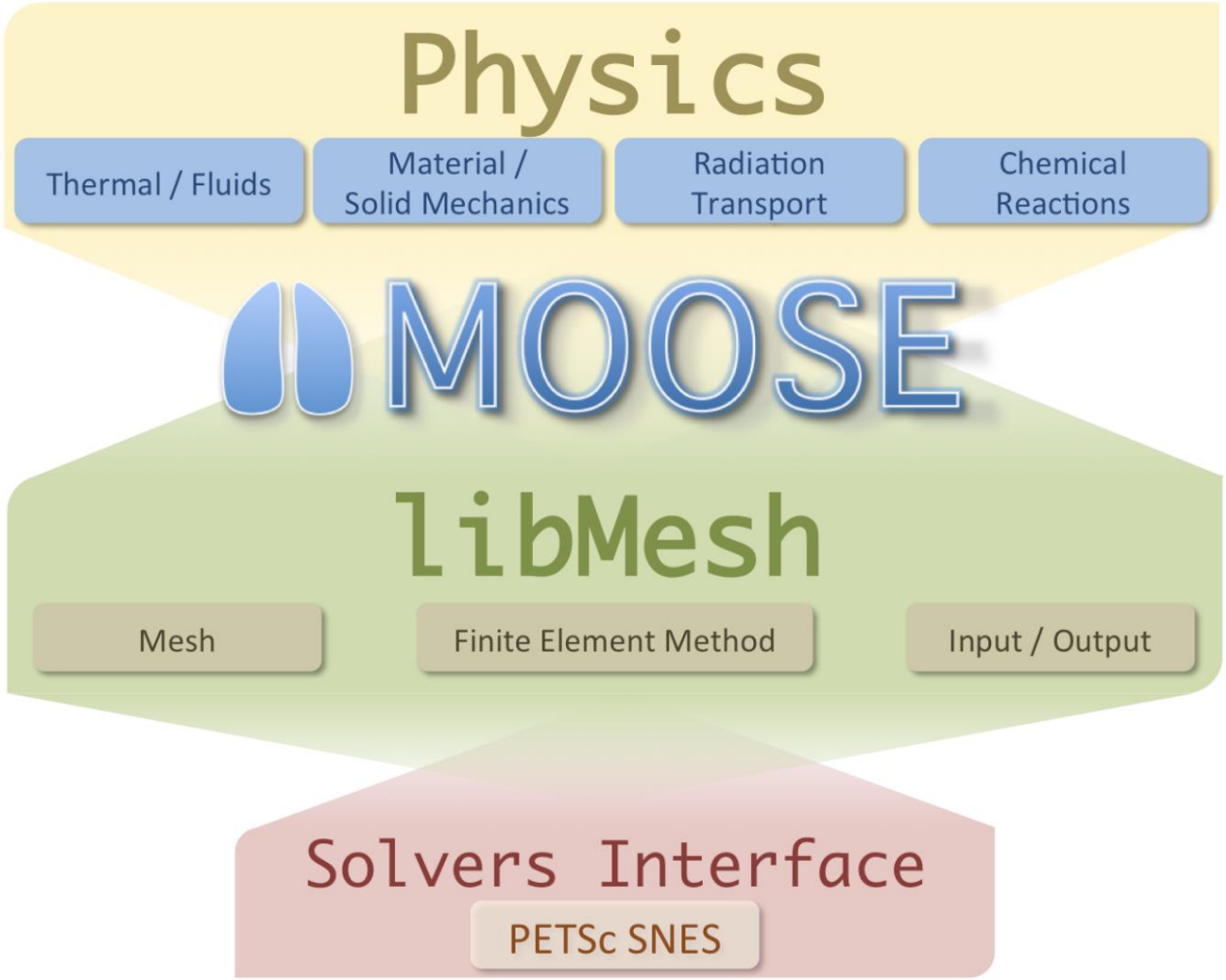
MOOSE Framework: Key Features



- Massively parallel computation – successfully run on > 100,000 processor cores
- Multiphysics solve capability – fully coupled and implicit/explicit solver
- Multiscale solve capability – multiple applications can perform computation for a problem simultaneously
- Provides high level interface to implement customized physics, geometries, boundary conditions and material models
- Initially developed to support nuclear R&D but now widely used for non-nuclear R&D also

Permann, Cody J., et al. "MOOSE: Enabling massively parallel multiphysics simulation." *SoftwareX* 11 (2020): 100430.

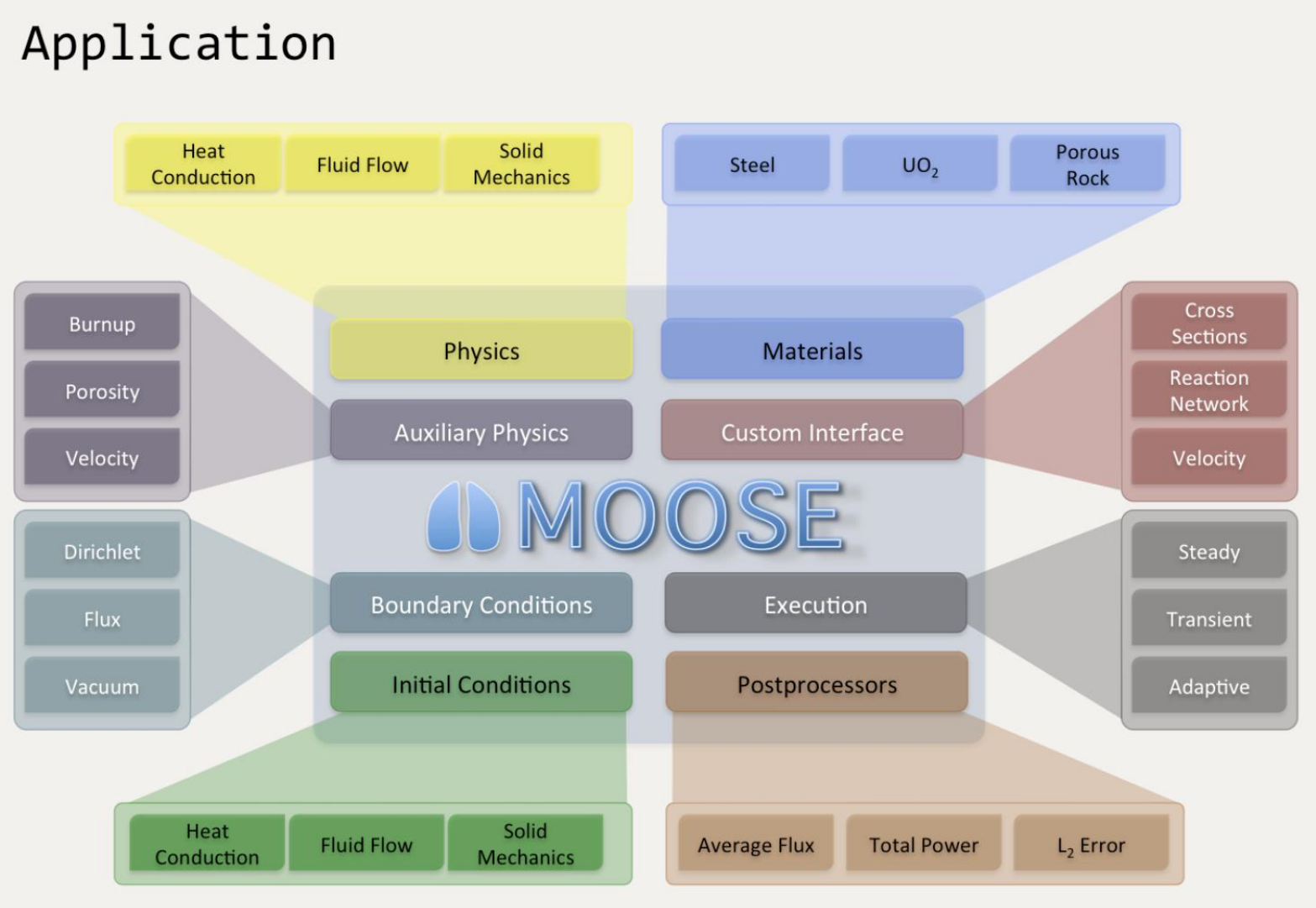
MOOSE Framework: Architecture



- **Uses the finite element library Libmesh and non-linear solver library PETSc both of which are also being continuously developed**

Ref: https://www.mooseframework.inl.gov

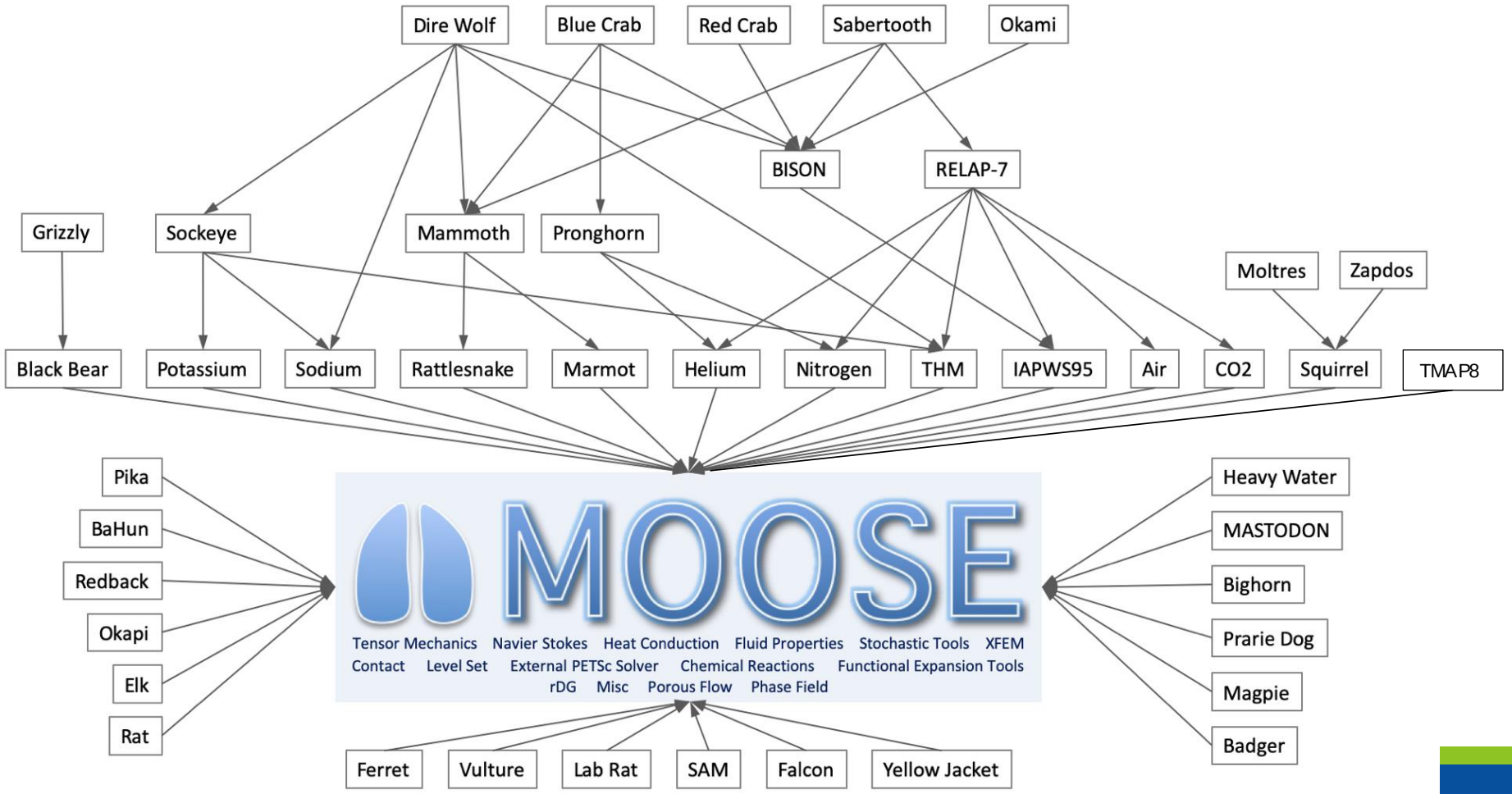
MOOSE Framework: Modular Pluggable System



- Standard and customized physics (mechanics, chemistry, heat conduction, electricity, magnetism etc)
- Materials – Support provided to implement and use wide variety of materials
- Standard and customized boundary conditions
- Different execution types
- Used for development of specific applications for light water reactors, high temperature gas reactors, molten salt reactors, liquid metal fast reactors and microreactors

Ref: https://www.mooseframework.inl.gov

MOOSE Framework: Applications



Open Apps

Black Bear
TMAP8
Squirrel
Moltres
Mastodon
Pika
Falcon

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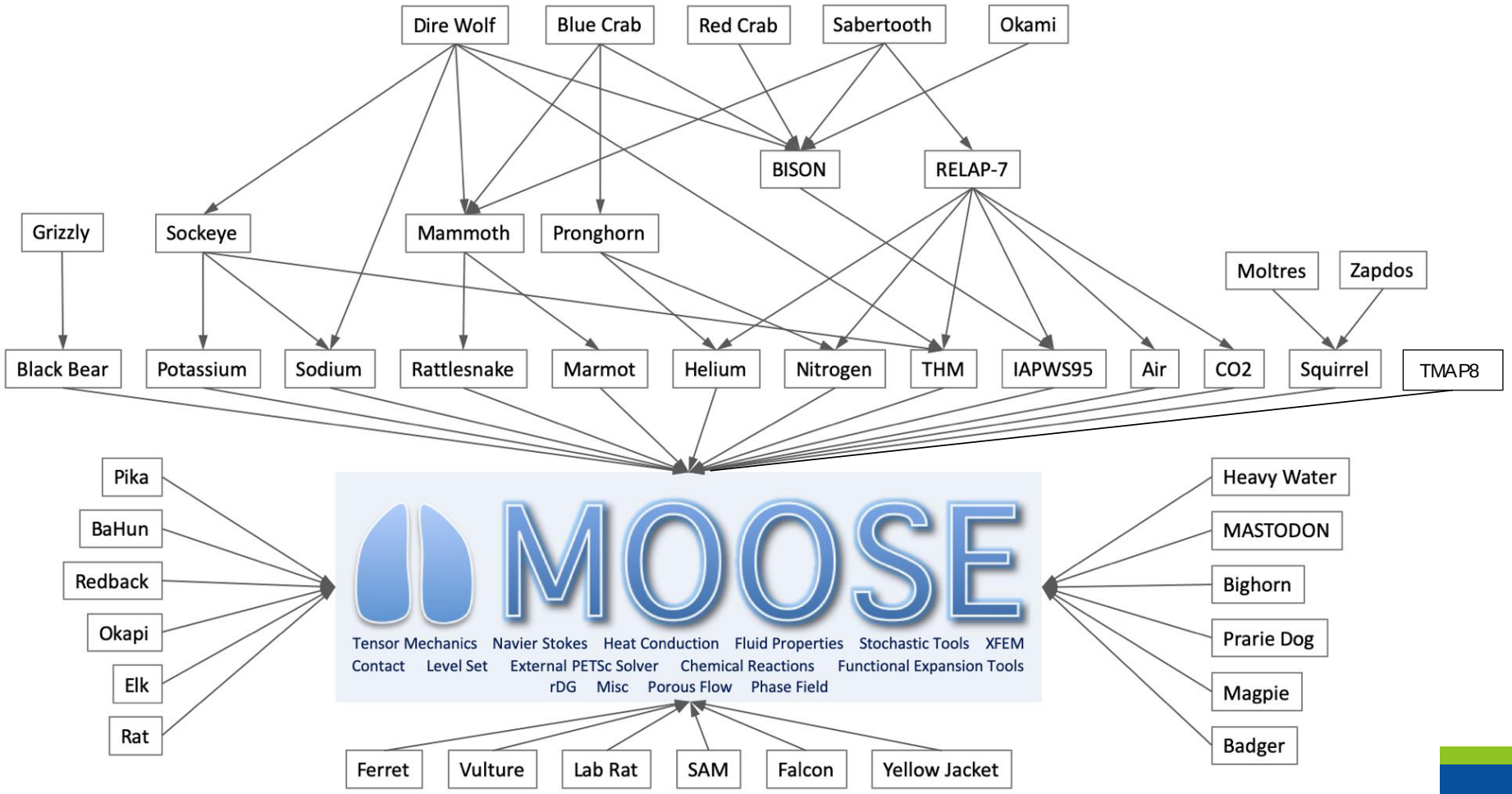
Ref: https://www.mooseframework.inl.gov

MOOSE Framework: Applications



Restricted Apps

Bison
Grizzly
Sockeye
Marmot
Rattlesnake
Pronghorn
RELAP-7
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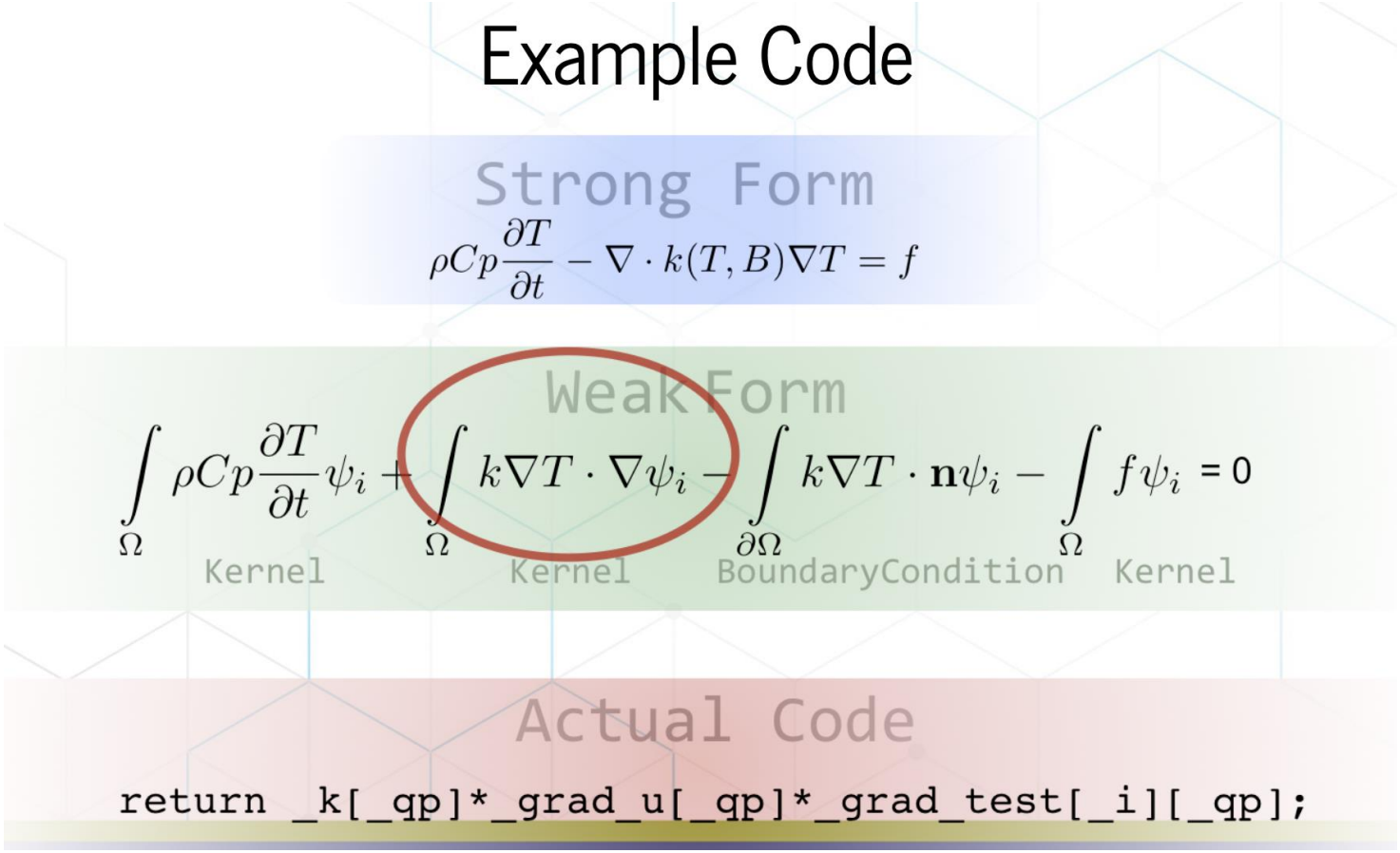
Ref: https://www.mooseframework.inl.gov

MOOSE Framework: Solving Specific Physics



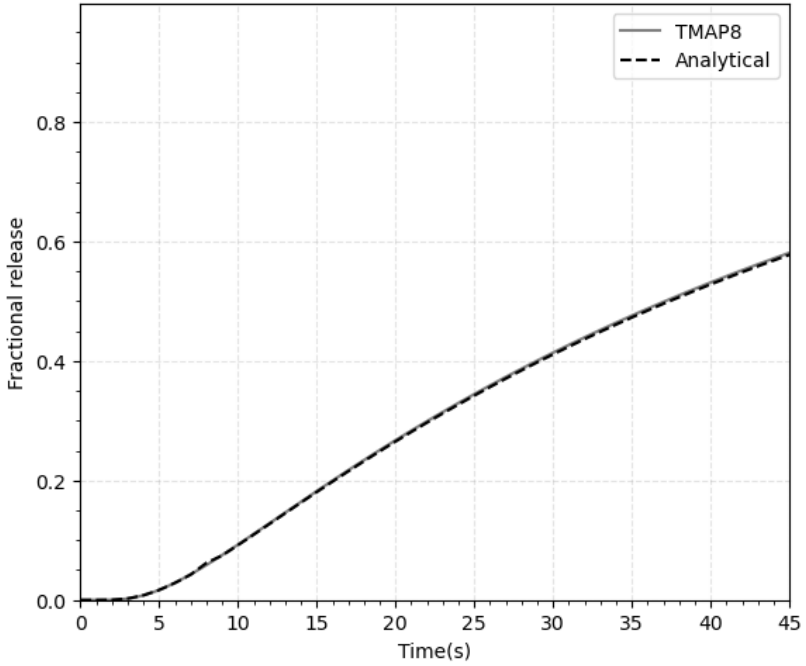
Custom "kernels", representing specific physics, can be developed easily and incorporated into the simulation

Ref: https://www.mooseframework.inl.gov

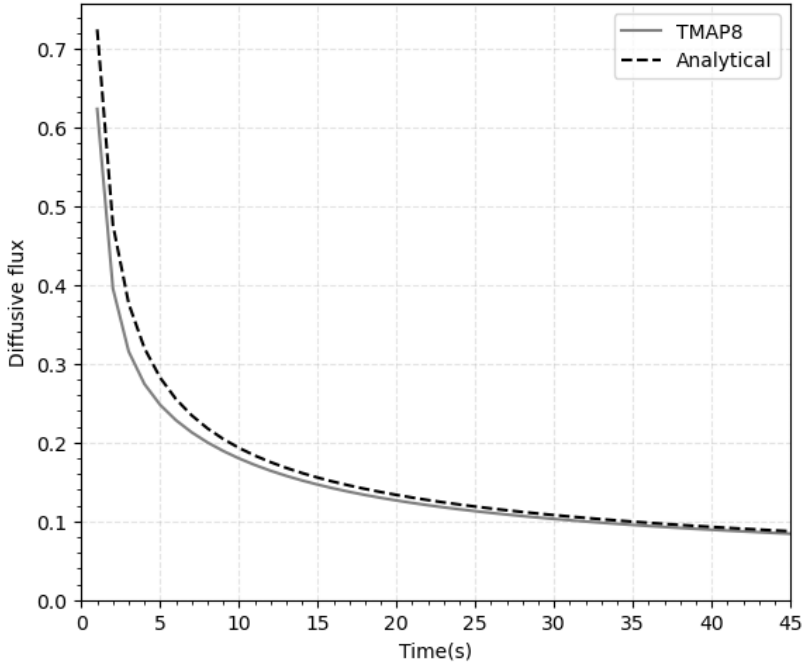
Tritium Migration Analysis Program - TMAP8

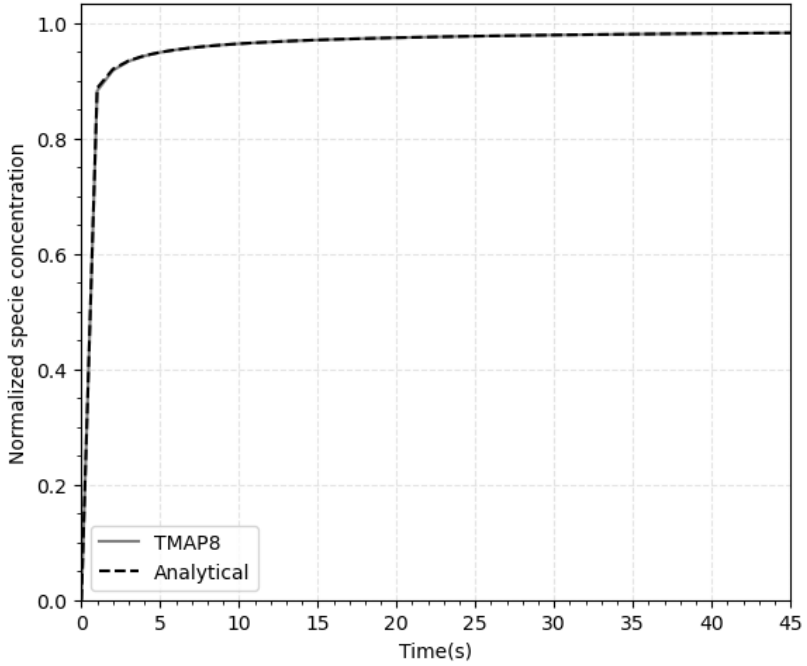
- MOOSE based implementation of the TMAP program
- Supporting research and development of fusion reactors
- System-level mass and thermal transport related to migration of hydrogen isotopes
- Earlier versions of TMAP used for several real-world applications: ITER, fusion related experiments, tritium production technologies
- Accounts for multiple traps and diffusing species. Accounts for several species, that contribute significantly to the reactions with diffusing isotopes.

TMAP8: Verification and Validation



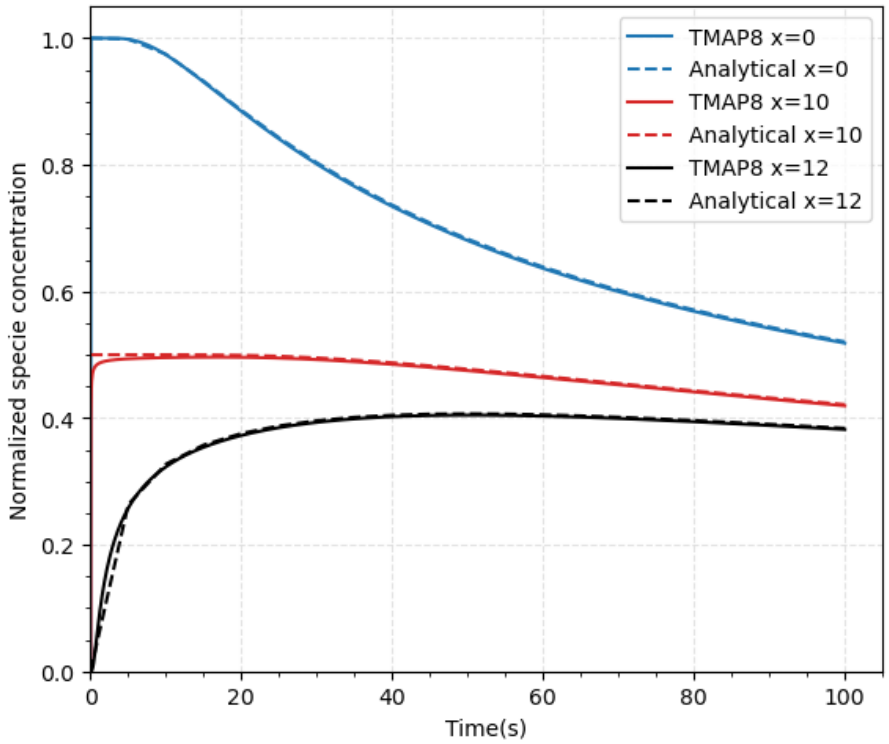
Depletion source problem



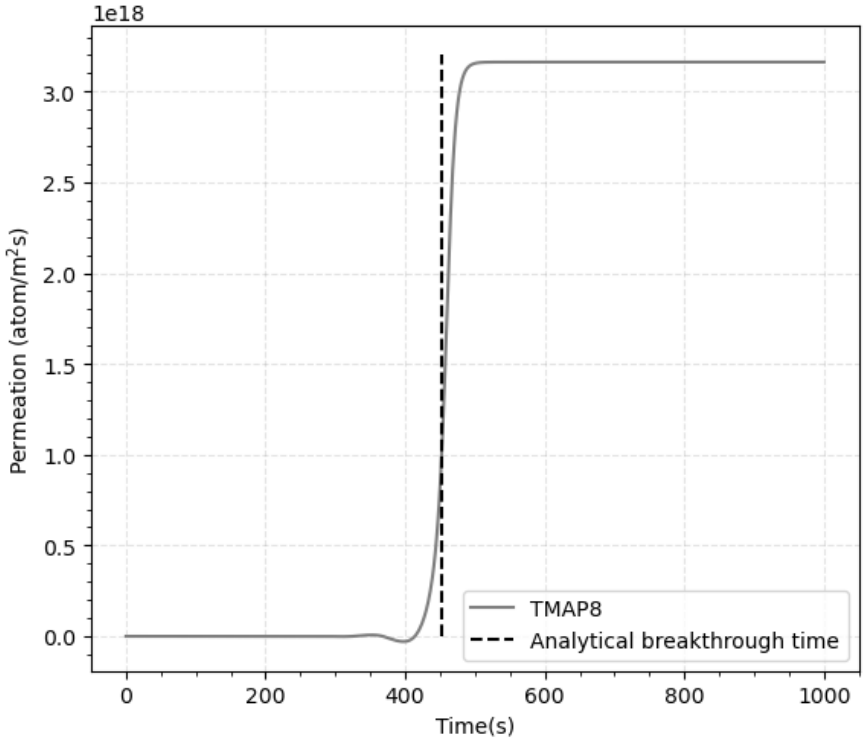


Diffusion problem with constant source

TMAP8: Verification and Validation (contd.)



Partially preloaded slab problem



Permeation problem with trapping

Verification and validation work is ongoing

Summary

- **MOOSE**
  - is a finite-element, multiphysics framework that is being used to develop codes for performing research for fusion and fission reactors.
  - is open source and provides high level interface to sophisticated non-linear solvers and massively parallel computational capability.
  - has a modular structure and is used to develop codes specialized to perform nuclear physics, geothermal science, magneto-hydrodynamics, seismic events, reactive transport, compressible and incompressible fluid flow, microstructure evolution and advanced manufacturing processes.

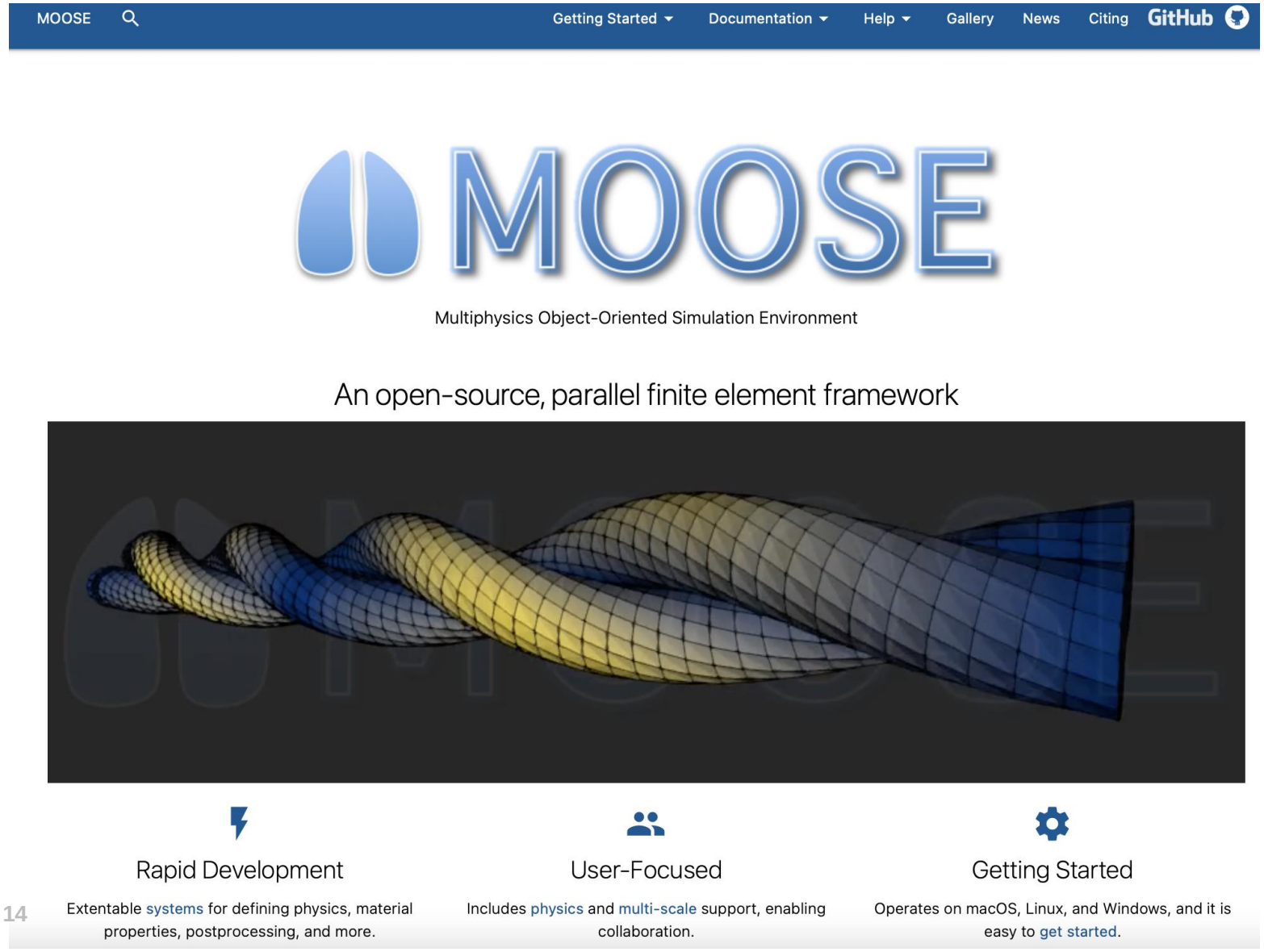
- **TMAP8**
  - is an open-source MOOSE-based application for analyzing mass and thermal transport in regard to hydrogen isotopes for fusion applications.
  - accounts for multiple traps, diffusing species and other factors.
  - is being developed, verified and validated against several cases.

Acknowledgements

- MOOSE is supported through the INL Laboratory Directed Research & Development (LDRD) Program, the Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program, and the DOE Office of Science under DOE Idaho Operations Office Contract DE-AC07-05ID14517

- TMAP8 development is supported by the U.S. Department of Energy Office of Science, Office of Fusion Energy Sciences, under the DOE Idaho Operations Office contract number DE-AC07-05ID14517.

Further Information



MOOSE Website:

https://mooseframework.inl.gov

TMAP8 Website:

https://mooseframework.inl.gov/TMAP8/

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Idaho National Laboratory

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