

미국 가상원자로 통합 플랫폼(MOOSE) 개발 배경 및 현황

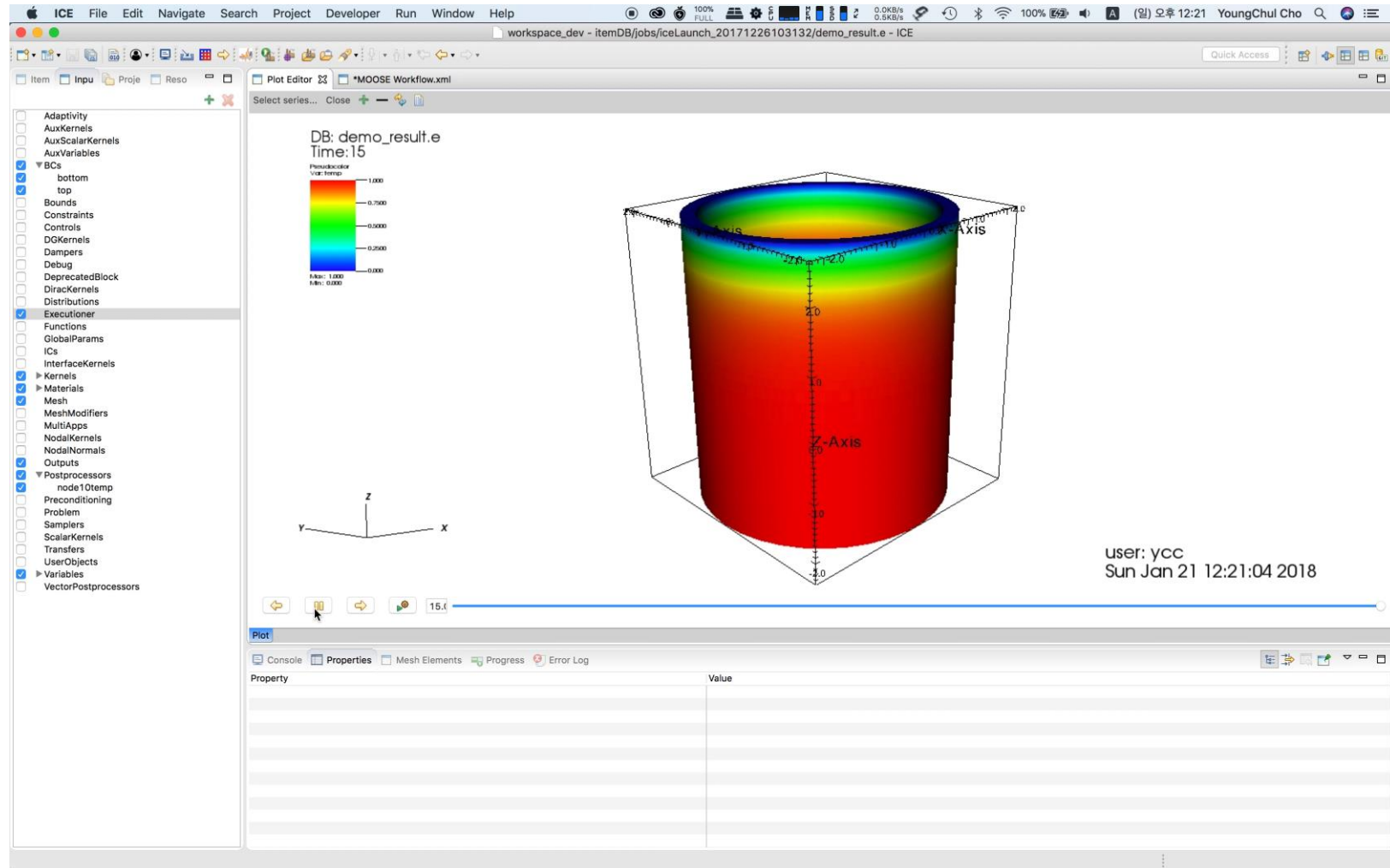
2018년 5월 16일

조영철

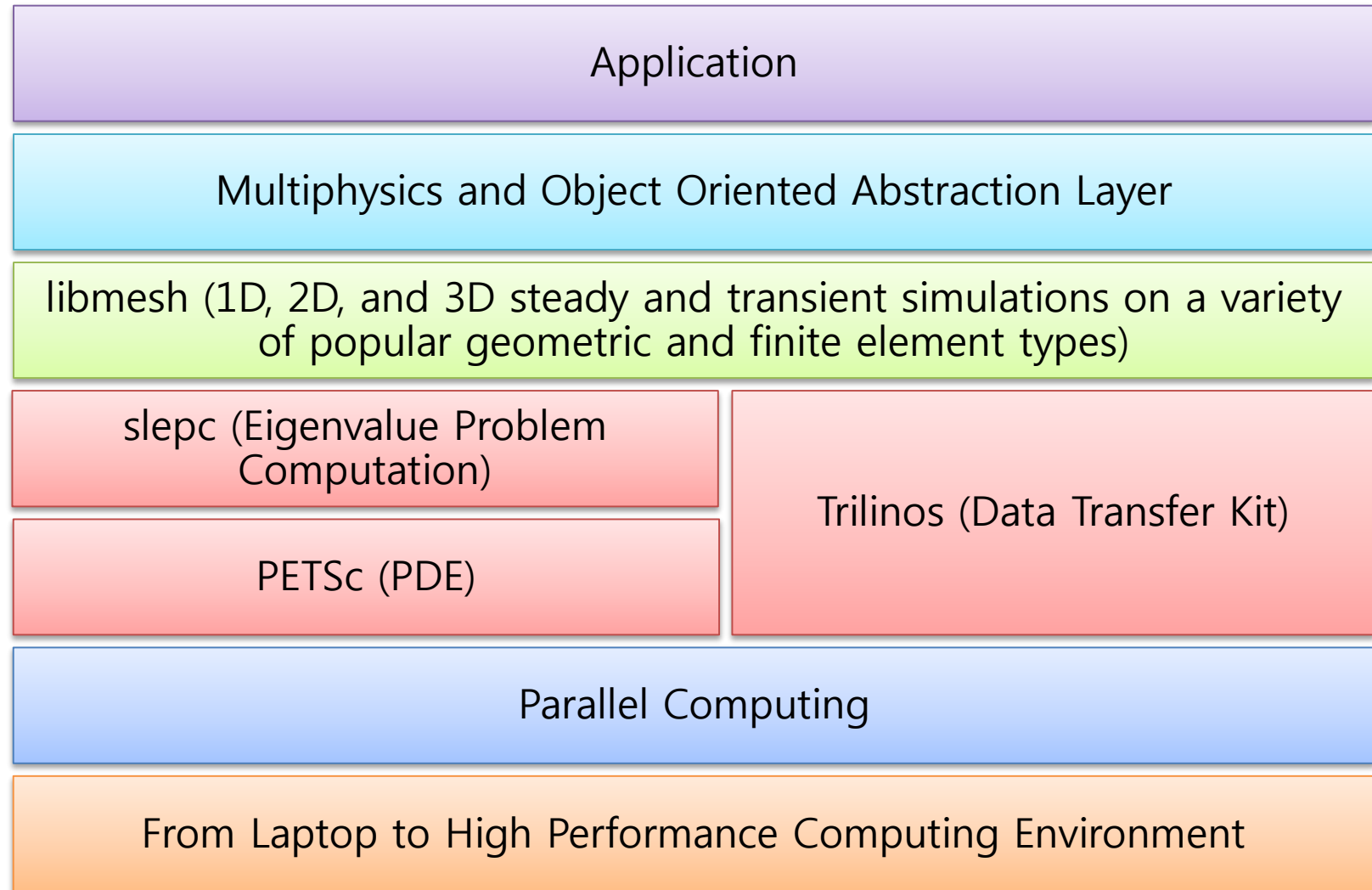
세종대학교 원자력 공학과

MOOSE Framework

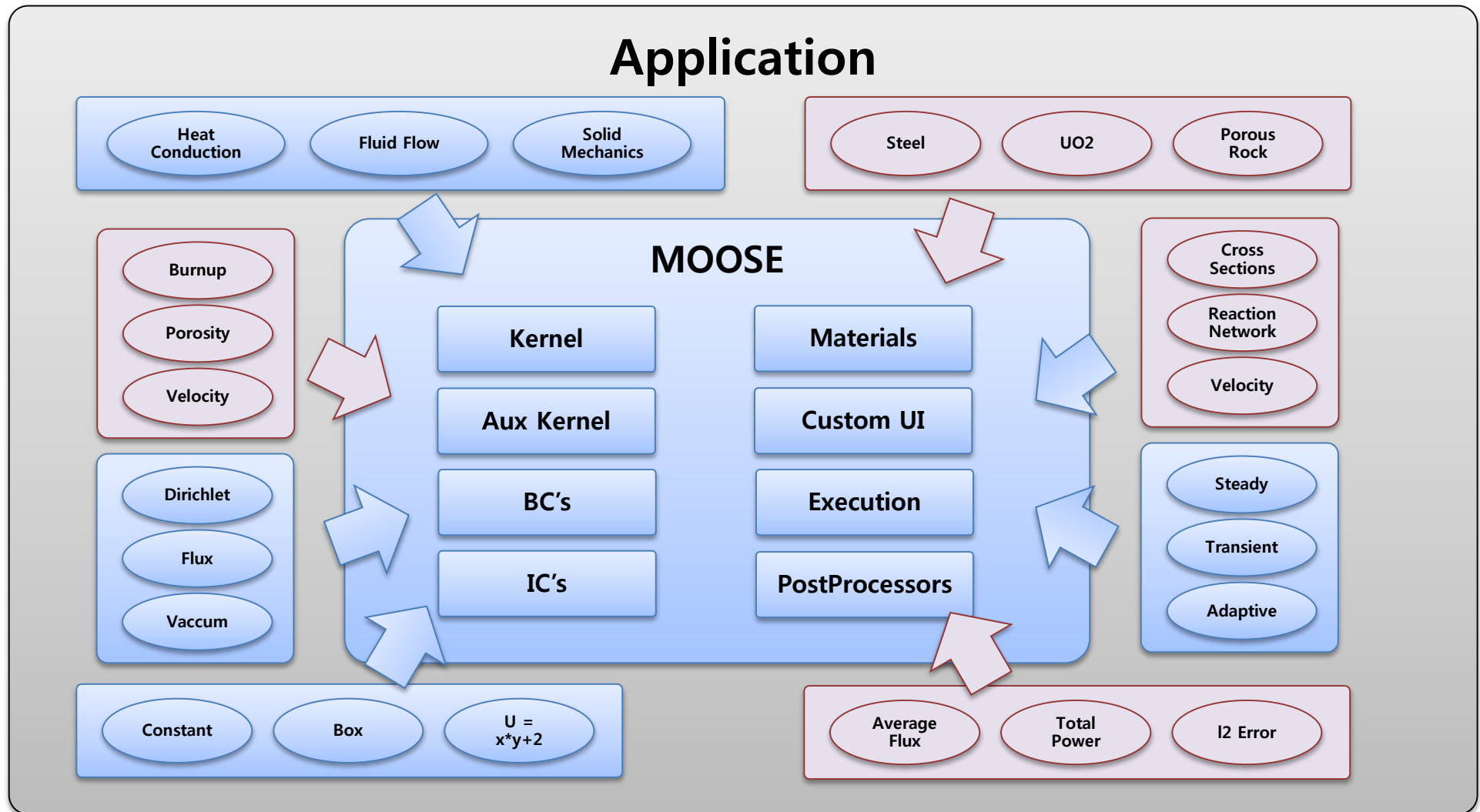
Moose Framework의 활용한 Simulation Sample



MOOSE 프레임워크 기반 App 구조

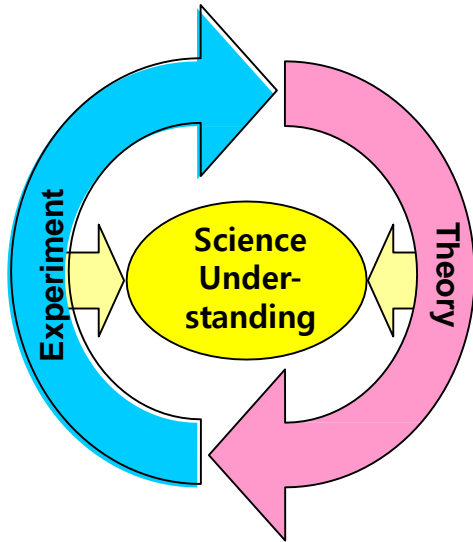


MOOSE 프레임워크 기반 App 구성

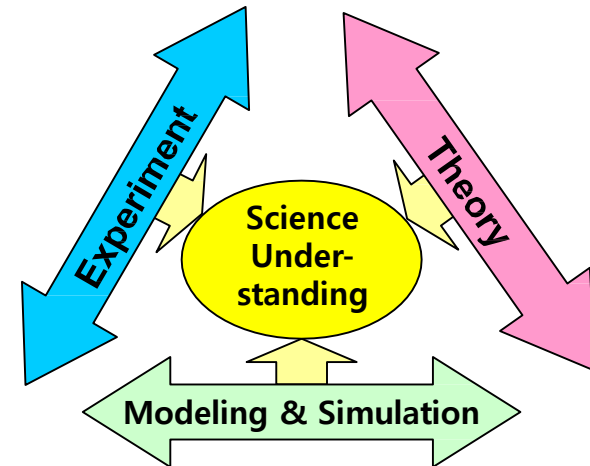


MOOSE Framework 개발 배경

현상 파악을 위한 과학 기반 접근

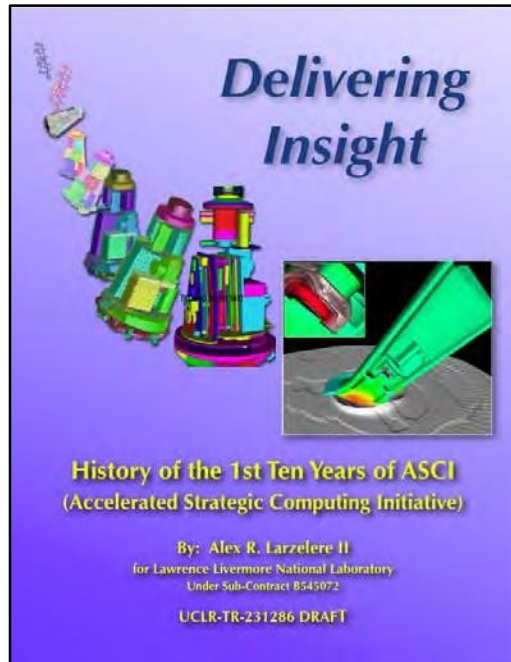


Traditional Science Approach



Addition of Science Based Modeling and Simulation

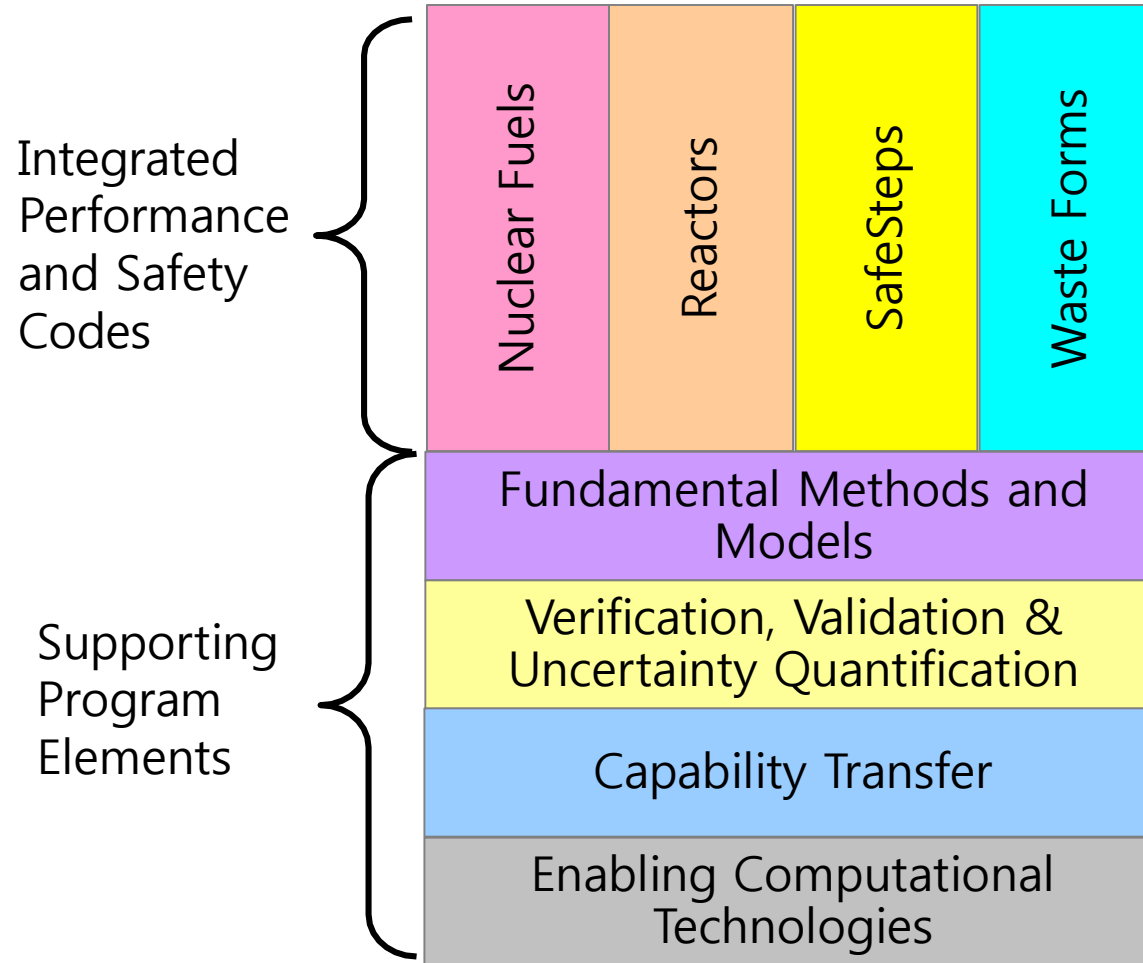
ASCI(*) 프로젝트 성공 및 이에 기반한 HPC 환경과 관련 기법 도입



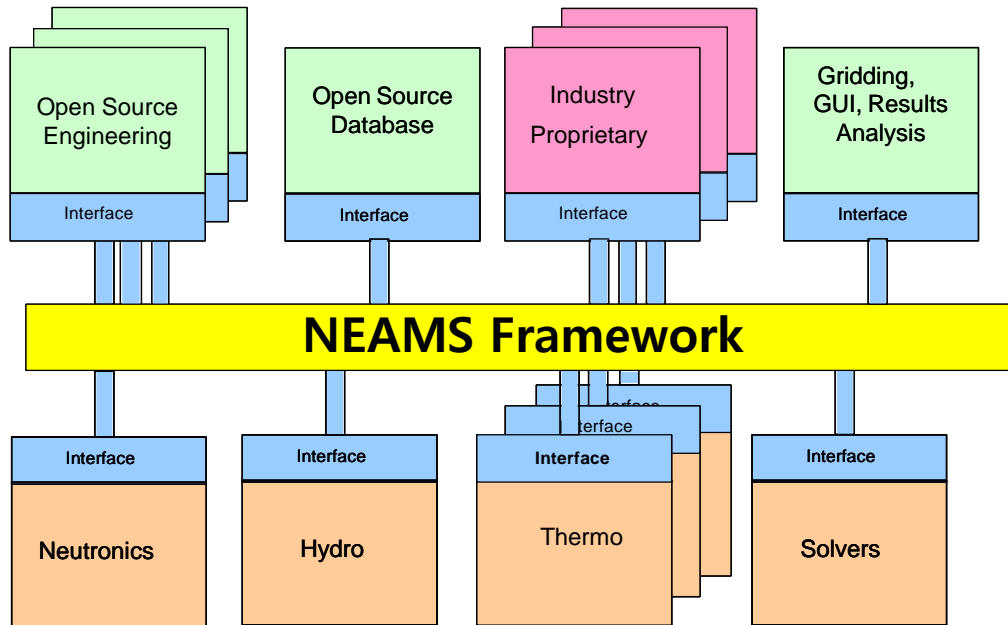
- **Vision** – Have a clear and compelling vision of the mission, and develop a comprehensive program to create new capabilities
- **Leadership** – Headquarters need a “team of rivals” at the national laboratories for leadership of the program
- **Partnership** – Success requires the best from universities, industry and national laboratories
- **Endurance** – Accomplishing the ambitious goals will take time and funding. But it must deliver increasing capabilities “early and often”

(*) 1990년 ~ 2010년 사이 HPC 기술을 주도했던 슈퍼컴퓨터의 대명사

필요한 주요 요소 제공

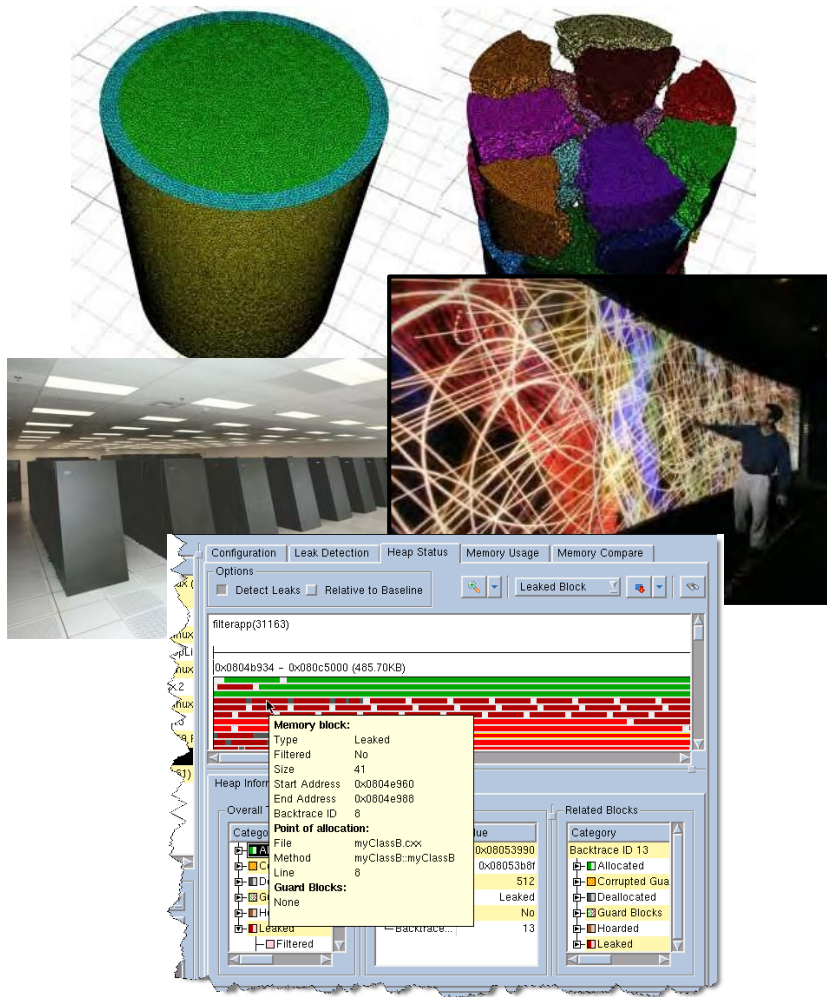


Capability Transfer



- Enable the efficient transfer of advanced modeling and simulation capabilities from the science domain to the industry engineering domain
- Understand the roadblocks and where possible provide technologies to overcome them
- One identified roadblock is the interoperability of existing codes, proprietary codes, open source and newly developed advanced codes
- To overcome this, develop the NEAMS interoperability framework

Enabling Computational Technologies



- Software quality
- Application development tools
- Problem setup tools (e.g. mesh generation)
- Numerical libraries (e.g. solvers)
- Results analysis (e.g. visualization)

MOOSE Framework 현황

Framework 추가 추이

년도	개수	추가된 Framework 명
2009	32	actions, auxkernels, base, bcs, constraints, dampers, dgkernels, dirackernels, executioners, functions, geomsearch, ics, indicators, kernels, markers, materials, mesh, meshmodifiers, multiapps, outputs, parser, postprocessors, preconditioners, predictors, restart, splits, timeintegrators, timesteppers, transfers, userobject
2010	1	vectorprocessors
2013	3	interfacekernels, nodalkernels, partitioner
2014	1	distributions
2016	2	relationshipmanagers, samplers
2017	1	problems, systems, variables
2018	1	linesearches

모듈 추가 추이

년도	추가된 모듈 개 수	추가된 모듈 명
2009	5	combined, heat_conduction, linear_elasticity, navier_stokes, solid_mechanics
2010	6	chemical_reactions, contact, phase_field, richards, tensor_mechanics, water_steam_eos
2015	6	fluid_properties, level_set, porous_flow, rdg, stochastic_tools, xfem
2017	1	functional_expansion_tools
2018	1	material

추가된 모듈 추이

년도	추가된 모듈 개 수	추가된 모듈 명
2009	5	combined, heat_conduction, linear_elasticity, navier_stokes, solid_mechanics
2010	6	chemical_reactions, contact, phase_field, richards, tensor_mechanics, water_steam_eos
2015	6	fluid_properties, level_set, porous_flow, rdg, stochastic_tools, xfem
2017	1	functional_expansion_tools
2018	1	material

MOOSE Framework 기반 App 현황 (1/2)

App 명	주요 기능
Bison	A finite element-based nuclear fuel performance code
RELAP-7	A next generation nuclear systems safety analysis code
Mastodon	A highly-parallelizable, finite-element analysis code capable of three-dimensional nonlinear soil-structure analysis including the simulation of source-to-site wave propagation
Grizzly	A code for modeling degradation of nuclear power plant systems, structures, and components due to exposure to normal operating conditions
Mammoth	A code to couple the MOOSE applications for radiation transport (Rattlesnake), thermal-fluids (RELAP-7), and fuel performance (BISON) into a single simulation framework
Marmot	A mesoscale fuel performance code
Rattlesnake	A radiation transport solver for the linearized Boltzmann radiation transport equation

MOOSE Framework 기반 App 현황 (2/2)

App 명	주요 기능
SAM (*)	Provide fast-running, whole-plant transient analyses capability with improved-fidelity for SFR, LFR, and MSR/FHR.
Bighorn (**)	A Computational Fluid Dynamics (CFD) simulation code for modeling and predicting the multi-component, multi-phase fluid dynamics in multi-dimensions
Falcon	A code to simulate the tightly coupled fluid-rock behavior in hydrothermal and engineered geothermal system (EGS) reservoirs, targeting the dynamics of fracture stimulation, fluid flow, rock deformation, and heat transport in a single integrated code, with the ultimate goal of providing a tool that can be used to test the viability of EGS in the United States and worldwide.

(*) Argonne National Lab에서 개발

(**) 개발 중

MOOSE 활용 사례 (1/9)

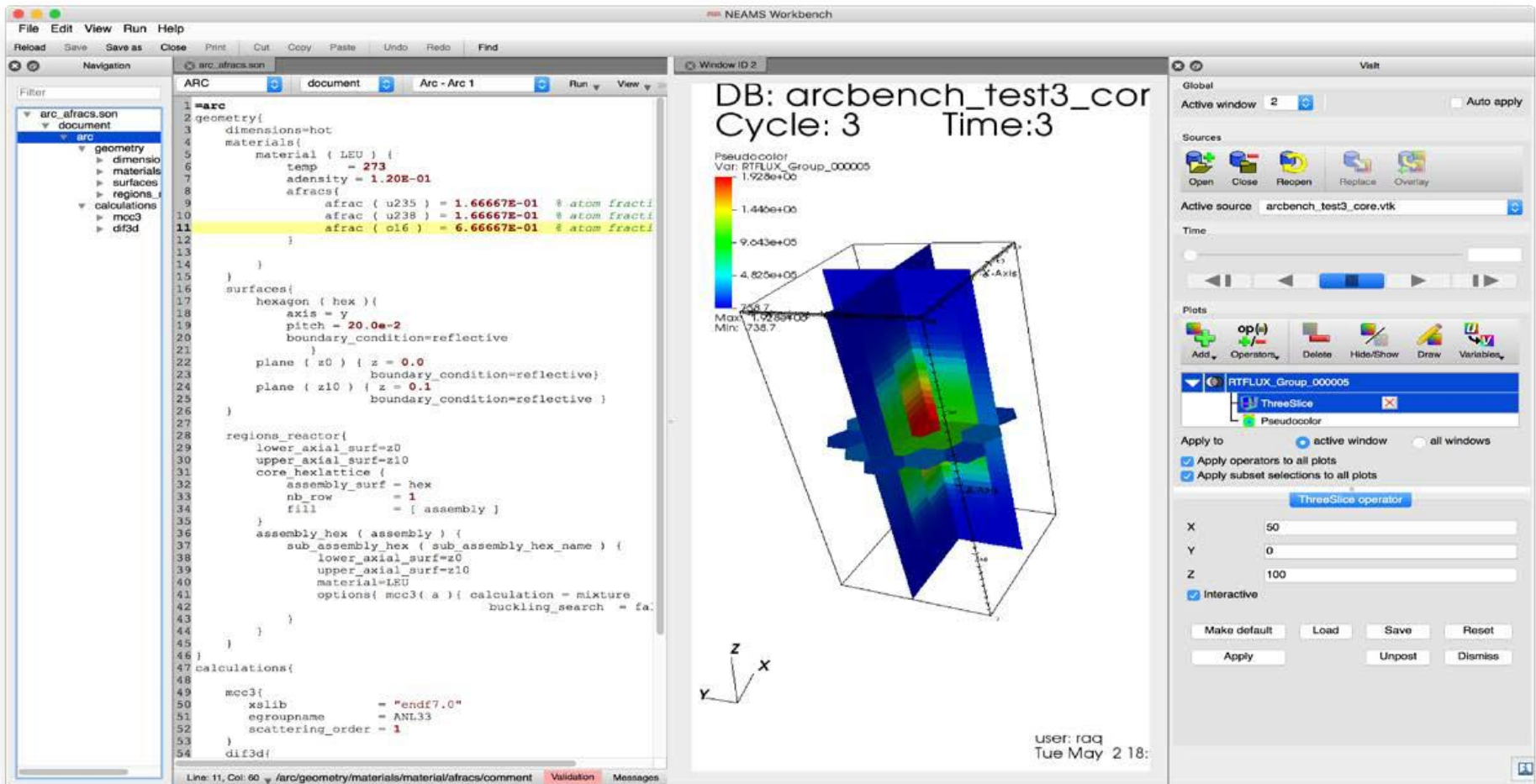
- Couple NRC's TRACE code with BISON for Accident Tolerant Fuels (ATF) analysis
- Coupling approach:
 - Develop Blue CRAB(*), a MOOSE-Wrapped App (executable MOOSE-based code using MOOSE Multi Apps and Transfers) to couple NRC's TRACE nuclear reactor system code with CASL/NEAMS BISON fuel performance code.



(*) CRAB: Comprehensive Reactor Analysis Bundle

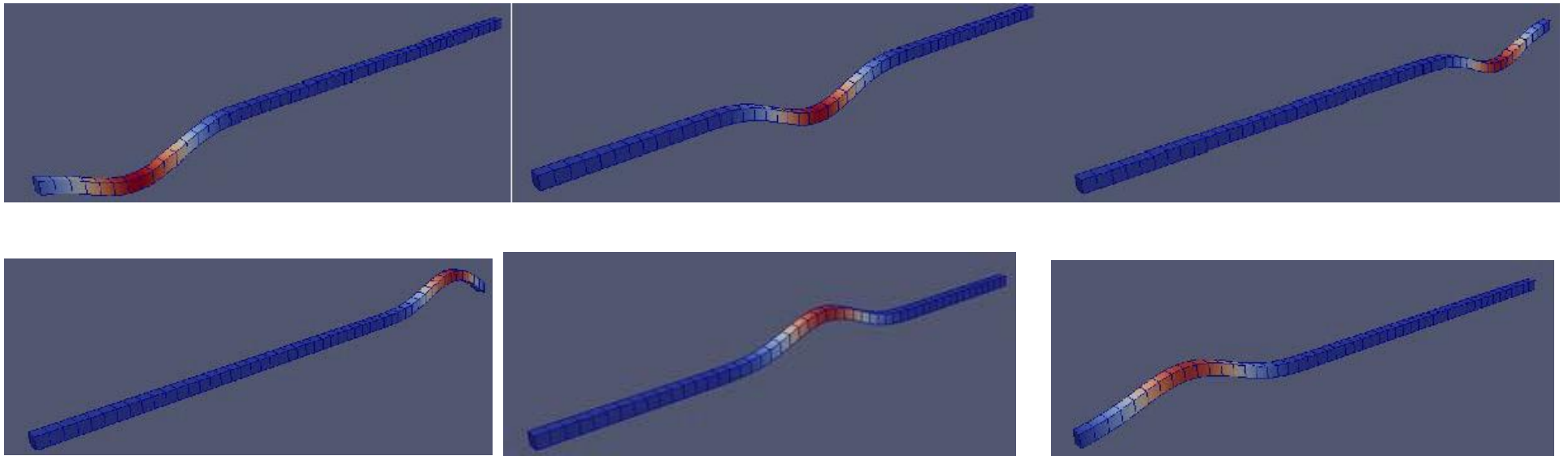
MOOSE 활용 사례 (2/9)

- NEAMS Workbench Integrated Environment



MOOSE 활용 사례 (3/9)

- Seismic analysis of a nuclear power plant

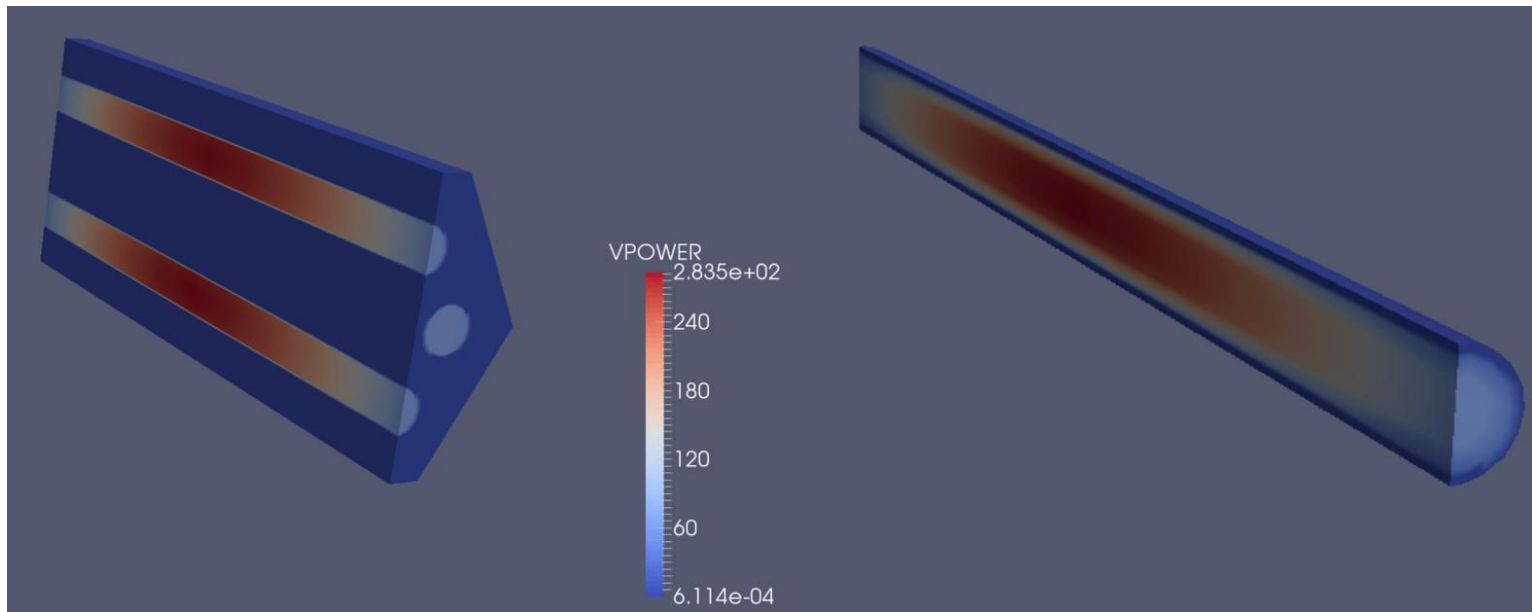


Wave propagation through one-dimensional column in MOOSE at different times and locations

Salome Uwizerimana의 2015년 석사학위 논문 (Structural Modeling and Dynamic Analysis of Nuclear Power Plant Structures) 에서 발췌

MOOSE 활용 사례 (4/9)

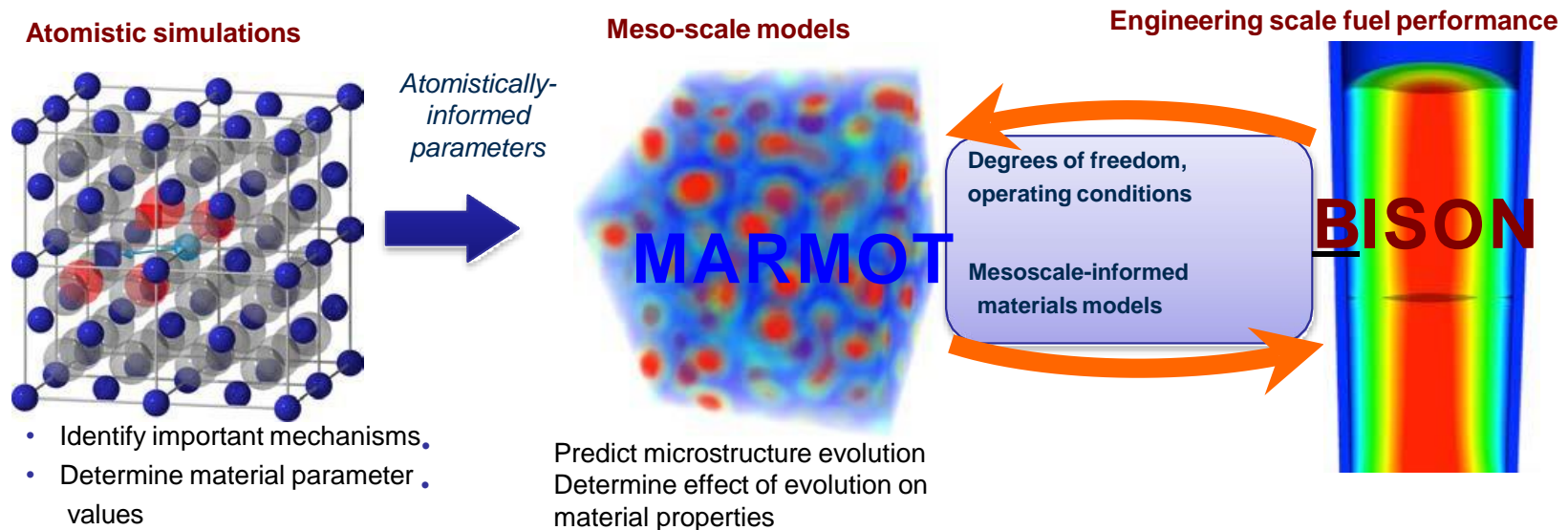
- MOOSE 기반 App인 Warthog를 활용한 BISON과 PROTEUS의 직접적인 코드 연계



View of the power density result for PROTEUS (left) and its mapped solution to the BISON fuel pin mesh (right)

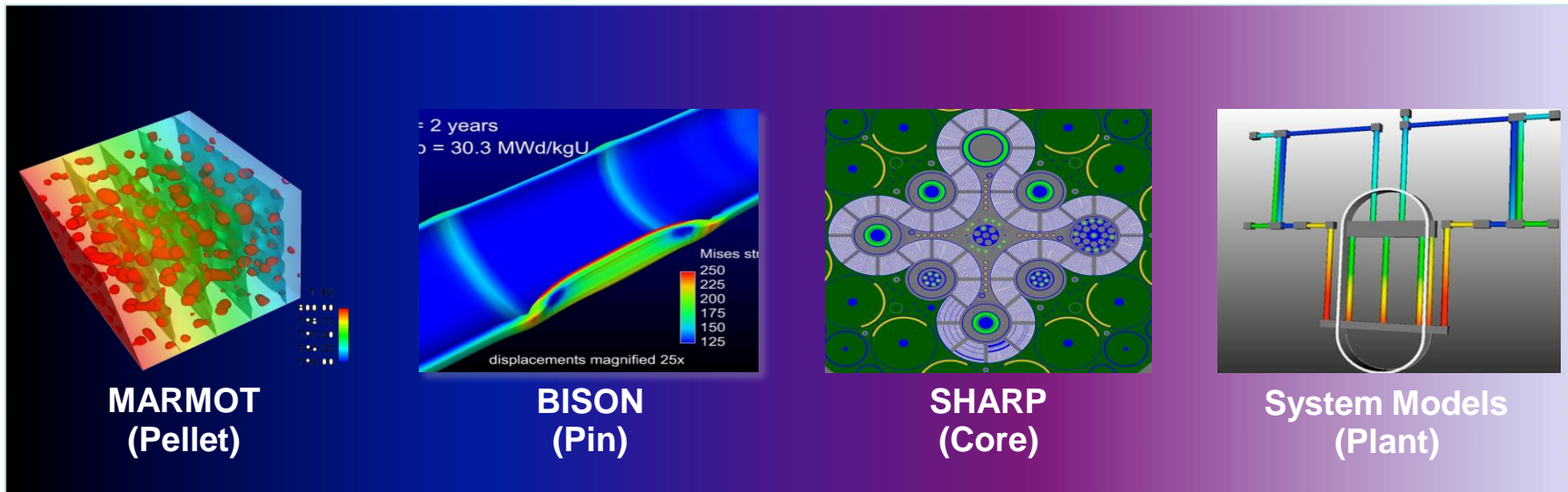
MOOSE 활용 사례 (5/9)

- Develop improved, mechanistic, and predictive models for fuel performance using hierarchical, multiscale modeling

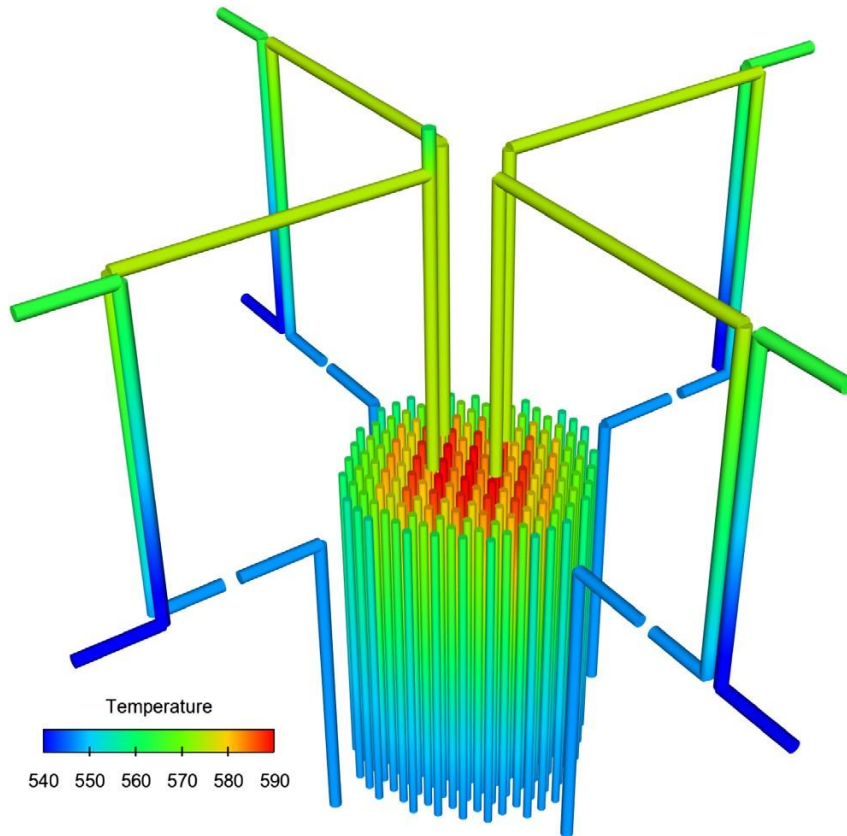


MOOSE 활용 사례 (6/9)

- The NEAMS Pellet-to-Plant Simulation Toolkit



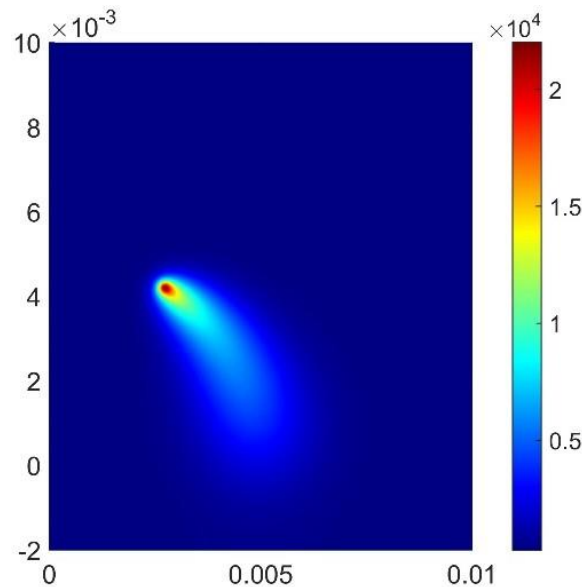
MOOSE 활용 사례 (7/9)



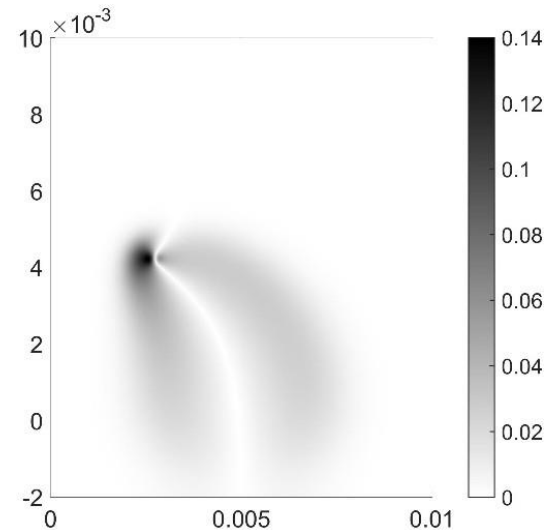
- Temperature (Kelvin) in the RELAP-7 piping network of cooling channels for the AP1000 full reactor simulation

MOOSE 활용 사례 (8/9)

- Comparison of FEM software for 2D heat transfer analysis in sheet metal laser cutting



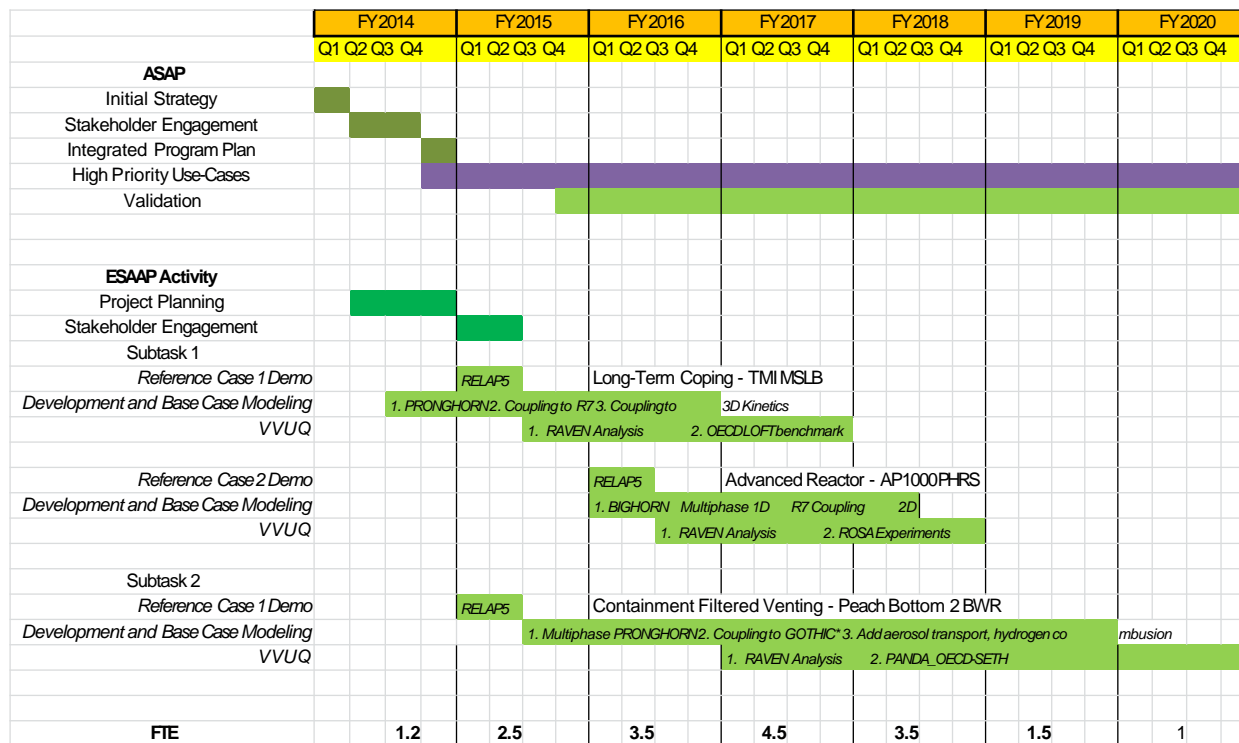
MOOSE temperature distribution at $t = 0.05$ s (moving laser case).



Abaqus vs. MOOSE relative error distribution at $t = 0.05$ s for the moving laser.

MOOSE 활용 사례 (9/9)

- Enhanced Severe Transient Analysis for Prevention Technical Program Plan



Overall schedule and proposed staffing levels for the ESTAP