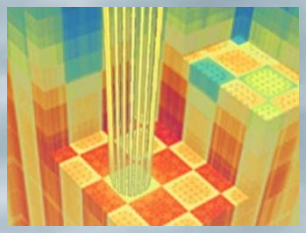
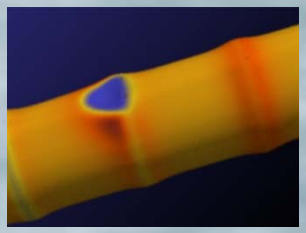
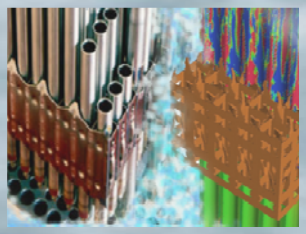
Science Council Update on FY16 Performance and FY17 Plans

Dave Kropaczek

CASL Joint IC/SC Annual Meeting
Oak Ridge National Laboratory
October 11-12, 2016







The Consortium for Advanced Simulation of LWRs
A DOE Energy Innovation Hub

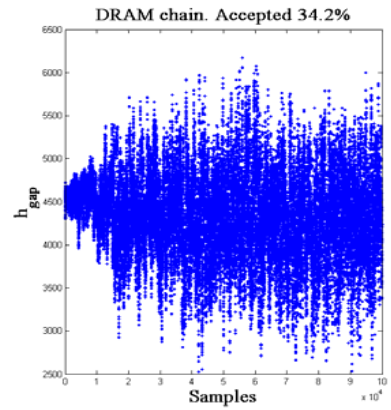
U.S. DEPARTMENT OF ENERGY

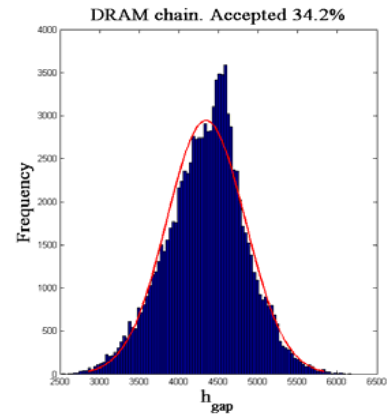
All FY16 DOE-reportable milestones completed

Milestone ID	Milestone Description	Finish Date	Status
FY16.CASL.001	Develop and test subchannel thermal hydraulics to support modeling of BWR operating conditions	January 2016	Completed On Time
FY16.CASL.002	Demonstrate Uncertainty Quantification and Data Assimilation for Watts Bar Unit 1 Cycle 1	March 2016	Completed On Time
FY16.CASL.003	Identify fuel performance capabilities needed for analysis of Reactivity Insertion Accidents (RIA) and complete initial implementation	May 2016	Completed On Time
FY16.CASL.004	Initiate VERA working group by holding first meeting	April 2016	Completed On Time
FY16.CASL.005	Complete VERA integrated Verification and Validation (V&V) requirements and planning and update V&V manuals for individual codes	June 2016	Completed On Time
FY16.CASL.006	Define post CASL sustainability strategy	July 2016	Completed On Time
FY16.CASL.007	Demonstrate VERA Core Simulator performance improvements	August 2016	Completed On Time
FY16.CASL.008	Implement VERA transient capability with internal heat conduction feedback for PWRs for analysis of Reactivity Insertion Accidents (RIA)	September 2016	Completed On Time
FY16.CASL.009	Demonstrate DNB analysis methods using CFD for Non-Mixing Vane and V5H grid spacers	September 2016	Completed On Time
FY16.CASL.010	Assess the analysis capability for core-wide PWR Pellet-Clad Interaction (PCI) screening and demonstrate detailed 3-D analysis on selected subregion	September 2016	Completed On Time
FY16.CASL.011	Qualify CFD-based PWR Crud Induced Localized Corrosion (CILC) capability to identify high-risk fuel rods	September 2016	Completed On Time

Demonstrate UQ and Data Assimilation for Watts Bar 1, Cycle 1

- Quarter-Core, 3D depletion (Progression Problem 9)
  - Large operational experience database for commercial LWRs could improve M&S fidelity
- Efficient Surrogate Based Data Assimilation (SBDA)
  - Measured attributes (synthetic data)
    - k_{eff}, fission rate (56 assemblies, 49 axial levels)
  - Delayed Rejection Adaptive Metropolis (DRAM) algorithm used in conjunction with reduced order modeling
  - Calibrate model parameters and their uncertainties
    - Multi-group cross-sections (47 groups, 18 isotope-reaction pairs)
    - Gap conductivity and Grid spacer loss
- UQ performed pre- and post-calibration
  - Significant reduction in re-quantified uncertainties for parameters of interest
- Reasonable computational cost opens the door for realistic data assimilation practice
- Future work will focus on Watts Bar 2 using actual plant operating data (boron and flux maps)

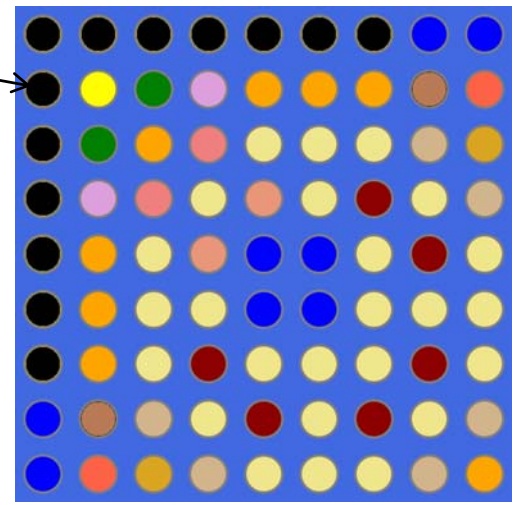




Parameter	Reference Value (Reference)	Actual Perturbed Value (± prior uncertainty)	SBDA Estimated Perturbation (± posterior uncertainty)
h_{gap}	4500 ± 2250	4359.91	4109.2 ± 504.1
g_{loss}	0.907 ± 0.03628	0.9123	0.9088 ± 0.035
Σ_f^{U-235} [0.0306-0.012396] eV	1125.219 ±2.66	1258.435	1267.01 ± 1.11
Σ_f^{U-238} [2.2313-1.3534] MeV	0.8927011±0.00528	0.93246	0.9270 ± 0.00243
Σ_f^{Pu-239} [0.0306-0.012396] eV	1361.297± 16.03	1441.313	1436.2 ± 6.11
Σ_s^{H-1} [0.0306-0.012396] eV	75.346183±0.07494	82.47610	78.72 ± 0.0382
Σ_s^{O-16} [0.0306-0.012396] eV	4.329821±0.04336	4.629821	4.611 ± 0.0211

Development to Support Modeling of BWR Operating Conditions

- BWR PCI challenge problem
- MPACT Development
  - 3D control blade movement
  - 3D axial zones, Part-length rods
  - BWR spacer grid model
  - Improve cross sections at voided conditions
  - BWR Progression Problems
- CTF Development
  - BWR preprocessor to create CTF input from VERAIn
  - Large water rods, Part-length rods
  - Multibundle iteration strategy with common bundle pressure drop
  - CTF BWR Validation In Progress (GE 3x3, BFBT 8x8, RISØ, FRIGG, Air-Water experiments)
- Convergence Assessment for Coupled Solution
  - Extreme skewed void distribution (B_4C absorber rods to simulate a BWR control blade)
  - Converged results provide confidence that current Picard iteration strategy will work for BWR cases

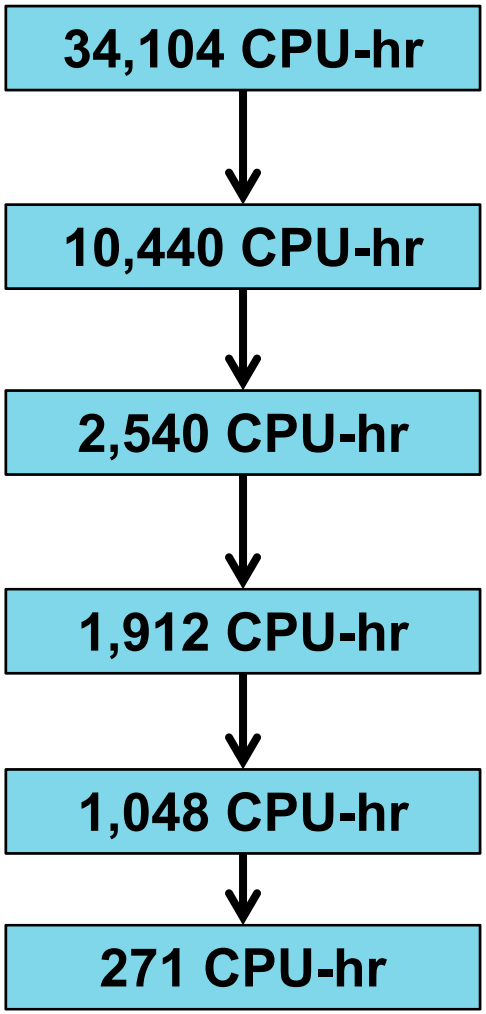


Exit Void Fraction

0.116	0.228	0.413	0.493	0.534	0.565	0.590	0.611	0.628	0.649
0.228	0.367	0.484	0.540	0.575	0.602	0.626	0.651	0.676	0.700
0.413	0.484	0.558	0.601	0.632	0.659	0.688	0.717	0.739	0.772
0.493	0.540	0.601	0.643	0.670	0.696	0.724	0.747	0.835	0.859
0.534	0.575	0.632	0.670	0.684	0.699	0.732	0.760	0.830	0.870
0.565	0.602	0.659	0.696	0.699	0.702	0.739	0.770	0.829	0.868
0.590	0.626	0.688	0.724	0.732	0.739	0.759	0.802	0.834	0.867
0.611	0.651	0.717	0.747	0.760	0.770	0.802	0.809	0.842	0.865
0.628	0.676	0.739	0.835	0.830	0.829	0.834	0.842	0.864	0.855
0.649	0.700	0.772	0.859	0.870	0.868	0.867	0.865	0.855	0.834

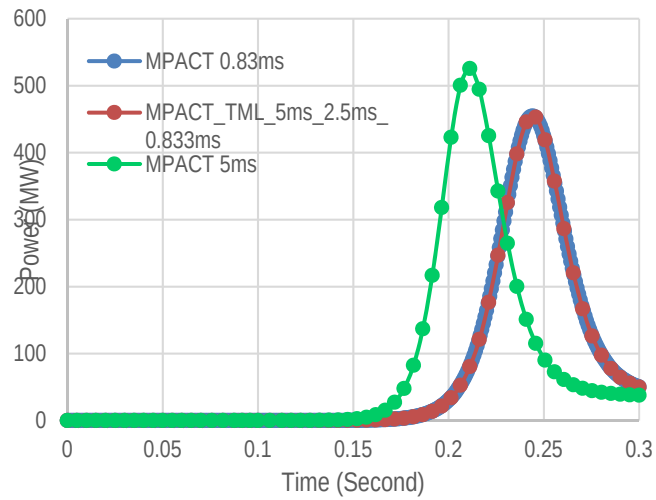
Demonstrate VERA Core Simulator Performance Improvements (Progression Problem #7)

- Milestone L3:RTM.PRT.P7.05 (Apr 2014)
  - MPACT/CTF – 56 energy groups, P2 Scattering
  - 2,784 cores, 12.25 hours wall time
- Milestone L3:RTM.PRT.P9.02 (Aug 2014)
  - MPACT/CTF – 56 energy groups, Transport Correction
  - 2,784 cores, 3.75 hours wall time
- Direct Coupling (March 2015)
  - MPACT/CTF – 47 energy groups, Transport Correction
  - 4,234 cores, 36 minutes wall time
- Initial Performance improvement (June 2015)
  - Speedup cross-section interpolation
  - 4,234 cores, 27 minutes wall time
- MOC Performance Improvements (April 2016)
  - MOC, Subgroup, Cross-section, CTF speedups
  - 4,234 cores, 15 minutes
- Current (May 2016)
  - CMFD and Partitioning speedups
  - 928 cores, 20 min or 464 cores, 35 minutes
  - Target deployment platform of ~1000 cores shows reasonable run times for industry applications



Implement and Demonstrate MPACT transient PWR capability for RIA

- MPACT Internal Heat Conduction model
- An efficient transient numerical algorithm was developed and implemented in MPACT
  - Transient Multi-Level Method (TML)
  - 68% reduction in run time
- Hot Zero Power (HZP) and Cold Zero Power (CZP) rod ejection experiments performed at the SPERT facility
  - SPERT Test 86, 60 and 84 results were performed
  - Acceptable accuracy demonstrated for the MPACT transient solver
- The computational feasibility of a Watts Bar core transient capability with MPACT was demonstrated
  - Super-prompt critical event (HFP)
  - Quarter-core model
  - EOS w/ 4234 Processors, 3.3 hrs. (TML enabled)
- FY17 MPACT/CTF coupling to be investigated in anticipation of FY18 RIA milestone (w/ BISON)

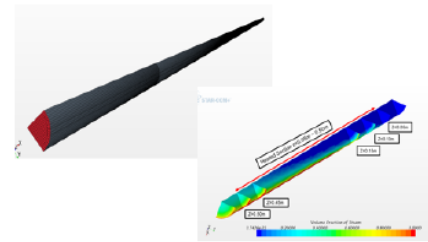


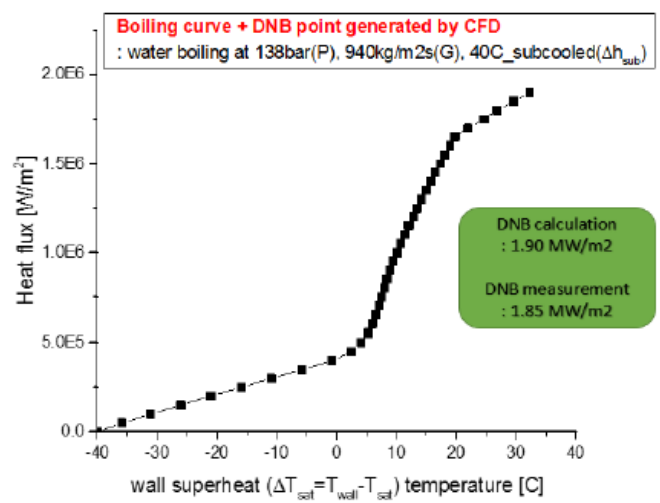
3D SPERT TEST 60 (HZP Super-prompt critical)	Running time (2880 cores on Titan)
MPACT 0.83ms (Ref.)	6 hrs. 59 mins
MPACT 5ms	1hrs 54mins
MPACT TML (5ms for MOC time step, 2.5ms for CMFD time step, and 0.83ms for PK time step)	2 hrs. 30mins

Demonstration of DNB Analysis Methods Using CFD

- GEN-I boiling model (Macrolayer approach)
  - Relies on near wall void fraction distribution
  - Parametric studies of microscopic boiling closures with varying operating conditions
    - DNB detection threshold (α_{dry}= 0.9)
    - Evaluation of lift force
  - DNB model validation
    - Vertical pipe flow DNB test (ANL)
    - Excellent agreement with independent datasets (< 20% deviation) over range of test conditions
- GEN-II boiling model development (Microlayer approach)
  - More physical based model reduces need for calibration and will allow for capturing surface characteristics
  - Heat partitioning by wet and dry area fraction heat transfer
    - Bubble departure cycle (growth and wait time)
    - Departure diameter relative to underlying dry spot
    - Activation and interaction between nucleation sites
  - Ongoing focus on microscopic data in experimental boiling studies for closure development

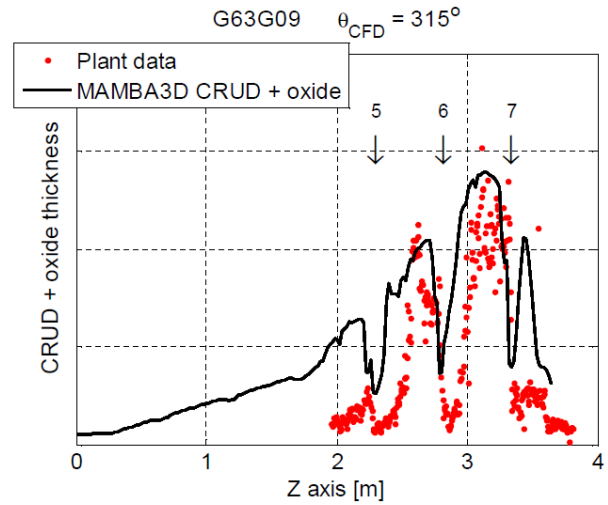
- **A pipe flow DNB data (ANL)**
  - 7.7mm tube water boiling test
  - Pressure: 138bar
  - Mass flux: 940-2650 kg/m2-s
  - Inlet subcooled level: 0-1.25MJ/Kg (100K sub)

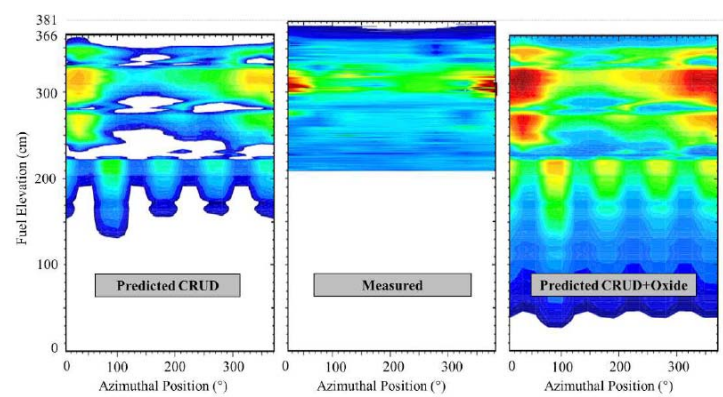




Qualify CFD-based PWR CILC capabilities for the identification of high-risk fuel rods

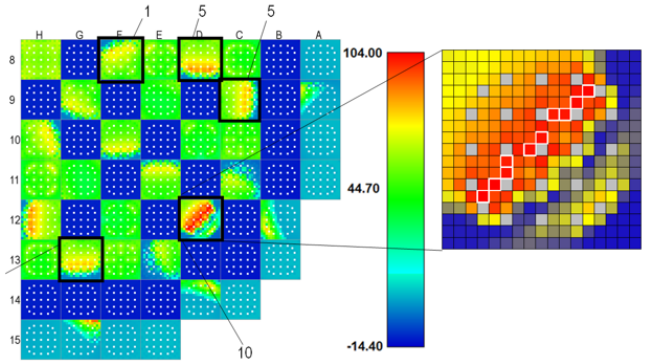
- VERA-CS full core simulation of Seabrook
  - Detailed power distribution provided as input to STAR-CCM+
- Coupled STAR-CCM+/MAMBA-3D analysis
  - Seabrook Cycle 5 (5x5 sub-region)
  - Comparison of CRUD and oxide distributions to measured plant data
  - Includes new uniform oxidation growth model
- Qualitative and quantitative results
  - Axial and azimuthal location of the maximum CRUD + oxide thickness in the failed rod well-predicted
  - Prediction of thick CRUD + oxide at fracture location upon removal from the assembly
  - Predicted local striping patterns consistent with observation
- Development needs
  - Computational resource prohibitive for full-core modeling
    - CFD-informed sub-channel necessary
    - MAMBA-3D efficiency improvements

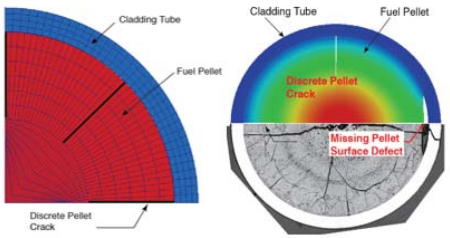


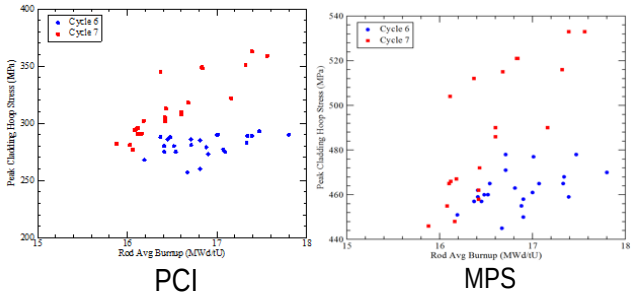


Assess Analysis Capability for Core-Wide PWR PCI Screening (Watts Bar 1, Cycles 6-7)

- Failure potential assessment
  - Pre-screening of all fuel rods within the core as a function of fuel rod history
    - Max. CL temperature and clad hoop stress, fuel-clad gap thickness
  - VERA-CS+BISON (R-Z) model with azimuthal symmetry
    - Quarter-core model, approximately 15,000 fuel rods
    - Approximately 38,000 core hours / cycle of simulation time
- Local effects analysis
  - Selection of rods for further analysis based on core-wide maximum clad hoop stress during points near reactor startup (2D)
    - Limiting rods identified by smallest gap, higher local burnup and higher LHR (alternative to cumulative damage index used to capture SCC degradation)
  - BISON detailed time-dependent 2D (R-Z and R-θ) and 3D analysis simulating startup
  - Discrete crack and/or missing pellet surface geometry modeling (sensitivity study)
- Three modes of operation for full core reactor analysis:
  - **Offline (VERA-CS + Bison)**: use VERA-CS data to inform stand alone runs of Bison for each fuel rod (fast, one-way coupling)
  - **Inline (Tiamat-Inline)**: Run VERA-CS and Bison simultaneously with one-way coupling (fast, R-Z and stacked 1.5D)
  - **Fully-coupled (Tiamat)**: Resolved VERA-BISON iterative solution (slow, but provides baseline for accuracy assessment)

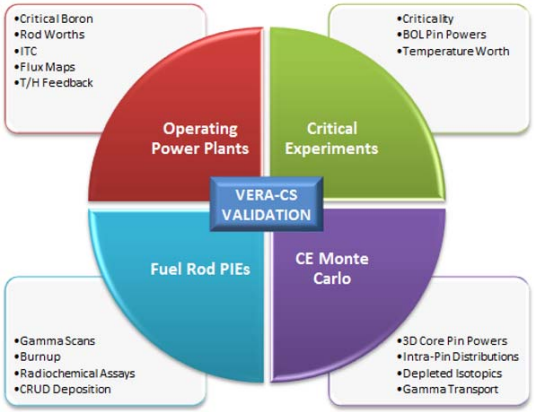


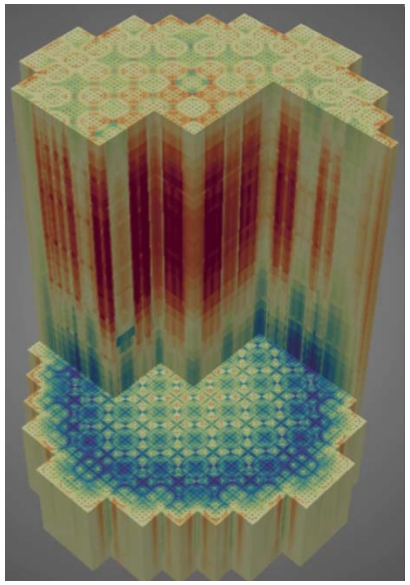




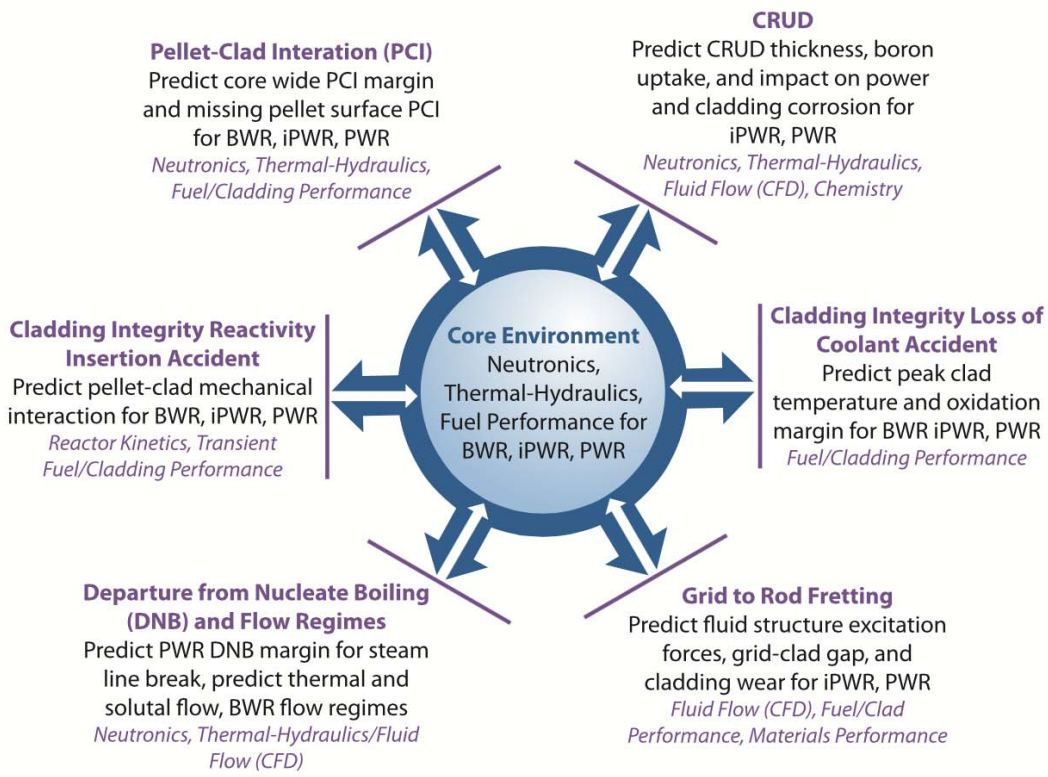
Reactor Applications

- Current models and analysis
  - Watts Bar Unit 1 (Cycles 1-14) (W 4-loop, 17x17 fuel)
  - Watts Bar Unit 2 (Cycle 1 Startup) (W 4-loop, 17x17 fuel)
  - Krško (NEK) Cycle 1 (W 2-loop, 16x16 fuel)
  - AP1000® First Cycle (17x17 fuel, MSHIM operation)
  - Seabrook Unit 1 (Cycles 1-5) (W 4-loop, 17x17 fuel)
- Planned models
  - Catawba Unit 1 and Unit 2 (W 4-loop, 17x17 fuel)
  - McGuire Unit 1 and Unit 2 (W 4-loop, 17x17 fuel)
  - Davis-Besse Cycles 1-15 (B&W, 15x15 fuel)
  - Palo Verde Nuclear Generating Station (CE System 80, 16x16 fuel)
  - TMI Cycles 1-10 (B&W, 15x15 fuel)
  - NuScale SMR First Cycle
- Represents a broad spectrum of design and operating conditions for current and future operating fleet
  - Fuel product, lattice, absorber types, and nuclear design
  - Core measurement systems (fixed/movable detectors, detector type)
  - Operating conditions (cycle length, power, flow, control strategy)
- Key component of the VERA-CS V&V plan
  - Improved confidence in robustness of the software (physics, geometry, and numerical solvers)





CASL Challenge Problems are Focused on Key Industry Reactor Performance Areas



CASL FY17 Planning Schedule

Event	Date	Planning Action
May Collocation	5/9/16	FY 17 planning kick off / L1 milestone definition
May FA One On Ones	5/26/16	Discuss draft L2 milestones
June Collocation	6/23/16	Discuss status of L2/L3 milestone planning
July Collocation / Roundtable	7/22/16	Finalize L2, L3 milestones
August Collocation	8/11/16	Discuss draft budgets (including partner funding)
August FA One on Ones	8/25/16	Finalize budgets
September Collocation	9/15/16	Discuss draft PoR Document
End of FY	9/30/16	Finalize FY 17 baseline

Separate Focus Area workshops held for FMC (May), RTM & PHI (June), VMA (July) and THM (Sep) to support technical planning process

All FY17 DOE-reportable milestones

Milestone ID	Milestone Description	Finish Date
FY17.CASL.001	Develop and deliver nuclear cross section data library supporting Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) designs	Feb-17
FY17.CASL.002	Prepare and release update to VERA to the Radiation Shielding Information Computational Center (RSICC) for distribution outside of CASL	Feb-17
FY17.CASL.003	Perform core design and Crud Induced Induced Power Shift (CIPS) analysis of a future core design and compare to industry risk analysis	Mar-17
FY17.CASL.004	Complete and document Watts Bar Nuclear Unit 2 Startup Analysis	Mar-17
FY17.CASL.005	Complete and demonstrate VERA with cores simulator coupled with Monte Carlo ex-core transport capability	Apr-17
FY17.CASL.006	Complete and document assessment of VERA against the Verification and Validation Plan	Jun-17
FY17.CASL.007	Establish solution-verified Computational Fluid Dynamics (CFD) model of Westinghouse 5 x 5 bundle for Departure from Nucleate Boiling (DNB) validation studies	Jul-17
FY7.CASL.008	Complete and demonstrate improved VERA CRUD Induced Power Shift (CIPS) capabilities	Aug-17
FY17.CASL.009	Develop, Demonstrate, and Assess advanced Computational Fluid Dynamics (CFD) Based Capability for Prediction of Departure from Nucleate Boiling (DNB)	Sep-17
FY17.CASL.010	Complete benchmarking of BISON against Loss of Coolant Accident experiments.	Sep-17
FY17.CASL.011	Complete and document CASL research and development on grid-to-rod fretting (GTRF) challenge problem	Sep-17

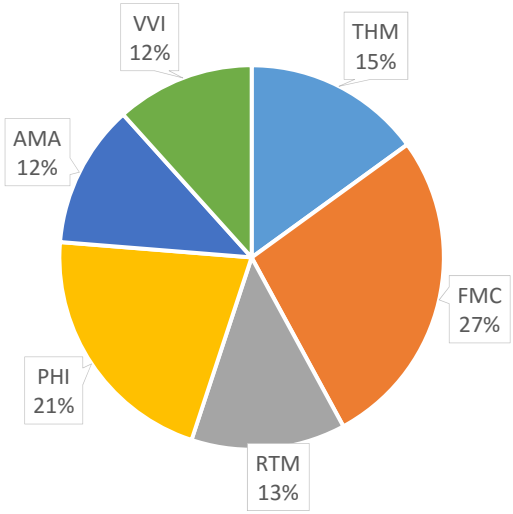
FY17 Planning Highlights

- Further CIPS/CILC capability development within VERA, with a focus on source term and validation
- Initial DNB capability developed, focus on Gen-II model and validation
- Further PCI capability development within VERA, with a focus on fuel fracture and contact dynamics and validation
- Transient VERA development to support RIA
- Continued focus on fundamental research for multi-phase CFD (BWR flow regime closure relations)
- Continue RIA and LOCA fuel performance work - fundamental model development and benchmarking
- GTRF work to wind-down in FY17
- V&V work being performed across all Focus Areas

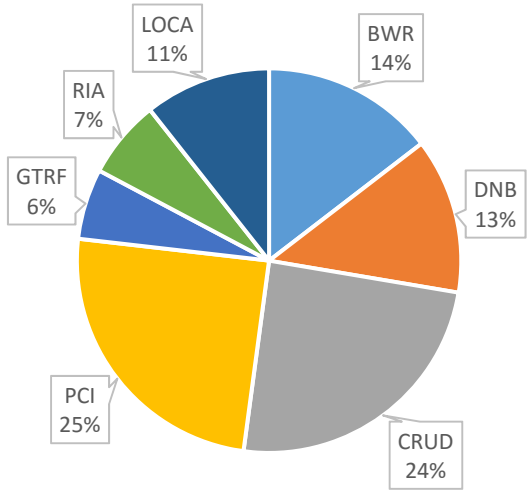
Will continue to reassess plan and adjust such that impactful capabilities are developed

Budget Distribution by FA Milestones

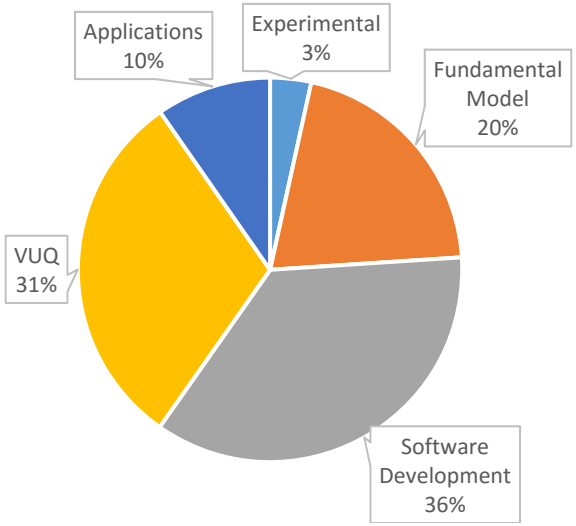
Budget Distribution by Focus Area



Budget Distribution by Challenge Problem



Budget Distribution by R&D Category



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FMC FY17

Milestone Focus

- GTRF wear modeling and validation
- CRUD source term development
- Oxide and hydride formation
- Fuel fracture, relocation and clad contact dynamics
- BISON fuel performance capability development
- V&V activities supporting CRUD, PCI, LOCA and RIA

L1:CASL.P15.03	GTRF Challenge Problem Final Report
L2.FMC.P15.xx	Development of CRUD deposition code for CIPS/CILC analysis and integration within VERA
L2:FMC.P13.05	Bison modeling of impact of load following operation on PCI
L2:FMC.P13.09	PCI modeling of Braidwood
L2:FMC.P14.01	System-Level corrosion source term model development
L2:FMC.P15.01	Watts Bar CIPS experience comparing & benchmarking BOA to MAMBA (3D/1D) ◆ LANL owned
L2:FMC.P15.02	Oxidation model application to LWR conditions
L2:FMC.P15.03	Model of thermal creep and instantaneous plasticity for Zr alloy and VPSC implementation
L2:FMC.P15.04	Accident capability development
L2:FMC.P15.05	GTRF Cladding Wear Modeling and Experimental Validation
L2:FMC.P15.06	Assess BISON for BWR fuel failure PCI analysis
L2:FMC.P15.08	LOCA experimental benchmark
L2:FMC.P15.09	MAMBA development and support work scope for FY17
L2:FMC.P15.10	Continued contact improvements for PCI
L2:FMC.P15.11	Contributions and leadership for L1 BISON FPO milestone
L2:FMC.P15.12	Multi-model loop of contact dynamics w parametric variation
L3:FMC.CLAD.P15.01	Microstructural Modeling Of Intergranular And Transgranular Fracture Modes In Zr-Alloys Subjected to Thermo-Mechanical Loading Conditions
L3:FMC.CLAD.P15.02	3D cluster dynamics model with cylindrical coordinates for hydride precipitation kinetics in zirconium cladding with complex spatial temperature
L3:FMC.CLAD.P15.03	Coupled hydrogen - oxide model
L3:FMC.CLAD.P15.04	H & O incorporation and transport in oxide
L3:FMC.CLAD.P15.05	Experiments to evaluate dose rate effects on Zr oxidation
L3:FMC.CLAD.P15.06	First-principles thermodynamics and kinetics of hydride and oxide formation in cladding
L3:FMC.CLAD.P15.07	Cluster dynamics modeling of hydride precipitation in fuel clad containing MPS defect
L3:FMC.CRUD.P14.xx	Development of MAMBA test suite & PHI Integration of MAMBA-3D code
L3:FMC.CRUD.P15.01	Loop exptl data supporting CRUD source term
L3:FMC.CRUD.P15.02	Oxide particulate formation- CRUD source term
L3:FMC.CRUD.P15.03	Kinetic behavior of spinels as it relates to steel corrosion and as a source of CRUD
L3:FMC.CRUD.P15.04	Coordination of EPRI-NNL-CASL source term
L3:FMC.CRUD.P15.05	FMC leadership -- CRUD source term
L3:FMC.FUEL.P14.01	Develop BISON 1.5D Capability for LWR Fuel
L3:FMC.FUEL.P14.02	Extend XFEM/PCMI capabilities
L3:FMC.FUEL.P15.01	Continued evaluation of MPS fuel failures in commercial power plants
L3:FMC.FUEL.P15.02	Evaluation of ramp tests for LOCA
L3:FMC.FUEL.P15.03	Predictive simulations of Pellet-Clad-Interaction (PCI), Missing-Pellet-Surface (MPS) and Loss of Coolant Accident (LOCA) using a VPSC-MOOSE and a VPSC-ABAQUS interface
L3:FMC.FUEL.P15.04	Verify and Validate 1.5D Capability
L3:FMC.FUEL.P15.05	WEC support of BISON development
L3:FMC.FUEL.P15.06	Evaluation of Fuel Failure in Ramp Tests for PCI
L3:FMC.FUEL.P15.07	Continued improvements in numerical/mechanical BISON models
L3:FMC.FUEL.P15.08	RIA experimental benchmark
L3:FMC.FUEL.P15.09	Modeling Corrosion and Mechanical Integrity of Zirconium Alloys Fuel Cladding During LOCA High Temperature Transients Using BISON (UW)
L3:FMC.FUEL.P15.10	Fuel radial relocation (support transients)
L3:FMC.FUEL.P15.11	Bison modeling of impact of load following operation on PCI
L3:FMC.GTRF.P14.01	Oxide growth on wear penetration
L3:FMC.GTRF.P15.01	Continued gap development work
L3:FMC.GTRF.P15.02	Industry input and applications of CASL GTRF capabilities
L3:FMC.GTRF.P15.03	hydride & fuel-gap contact impact on GTRF
L3:FMC.GTRF.P15.04	Grid-fluid-rod mechanics with turbulent excitation
L4:FMC.CLAD.P15.01	Hydrogen pickup & hydride precipitation -- experimental validation targets
L4:FMC.CRUD.P14.xx	Establish Framework for integration of CRUD deposition model and develop implementation plan.

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RTM FY17

Milestone Focus

- Nuclear Data library
- MPACT performance
- SHIFT development and performance
- BWR modeling
- Transient MPACT
- MPACT V&V

L1:CASL.P15.01	MPACT/Shift coupling for excore analysis
L2:RTM.P14.01	Deliver validated MPACT PWR/BWR library
L2:RTM.P14.02	SQA and Verification for MPACT Library Generation
L2:RTM.P15.01	MPACT V&V
L2:RTM.P15.02	Development of transient MPACT-CTF capability for RIA (with DNB)
L3:RTM.MCH.P14.01	Advanced VERA-Shift integration
L3:RTM.MCH.P14.04	MC methods development
L3:RTM.MCH.P14.05	Implementation of OTF Doppler broadening in Shift
L3:RTM.MCH.P15.01	Integrate CASL-BWR assembly geometry modelling into Shift through VERA-CS
L3:RTM.MCH.P15.02	Shift Optimization
L3:RTM.MCH.P15.03	Shift decomposition and memory optimization
L3:RTM.PRT.P14.01	2D/3D method
L3:RTM.PRT.P15.01	Determine benchmark gamma heat deposition results for selected CASL Benchmark problems
L3:RTM.PRT.P15.02	MPACT Development
L3:RTM.PRT.P15.03	Demonstrate mesh refinement convergence in MPACT
L3:RTM.PRT.P15.04	Robust and stable axial solver
L3:RTM.PRT.P15.05	Control rod cusping
L3:RTM.PRT.P15.06	MPACT Development - ORNL
L3:RTM.XSN.P14.07	Accounting for capture gamma power in MPACT and development of an approximate gamma smearing model.
L3:RTM.XSN.P14.08	Procure Independent Cross Section Libraries from Studsvik
L4:RTM.PRT.P14.01	2D/1D Shape Functions
L4:RTM.PRT.P14.02	MMS for MPACT
L4:RTM.PRT.P14.03	Gray acceleration and/or positive TCP0
L4:RTM.PRT.P14.04	The implementation of azimuthal dependent xsecs in MPACT for BWR applications.
L4:RTM.PRT.P14.05	Adaptive depletion timestepping

THM FY17

Milestone Focus

- Gen-II model development
- Gen-II DNB validation
- BWR closure development (slug flow, annular flow, and high void fraction)
- CRUD Challenge Problem support
- STAR-CCM+ software development, testing, and V&V activities

L1:CASL.P15.02	Develop, Demonstrate and Assess Advanced CFD-based Capability for Prediction of DNB
L2:THM.P15.01	1-Industrial DNB Method Assessment
L2:THM.P15.02	GEN-II DNB Method Completion and Assessment
L2:THM.P15.03	BWR Modeling Assessment
L3:THM.CFD.P12.01	Hydra-TH Shelving
L3:THM.CFD.P14.01	Preliminary STAR-CCM+ VVUQ Assessment Report
L3:THM.CFD.P14.02	Status of preliminary annular flow model development (KTH)
L3:THM.CFD.P14.03	Westinghouse FRIGG facility data analysis, documentation, and test planning
L3:THM.CFD.P15.01	STAR-CCM+ V&V Repository
L3:THM.CFD.P15.02	CD-adapco Contract and Licenses (funding is license fee)
L3:THM.CFD.P15.03	Status STAR-CCM+/MAMBA Coupling
L3:THM.CFD.P15.04	Generate CFD Data for CIPS/CILC Hi2lo
L3:THM.CFD.P15.05	GTRF Collaboration NEAMS
L3:THM.CFD.P15.06	CRUD/CILC deliver
L3:THM.CFD.P15.07	STAR-CCM+ V&V Assessment Report for DNB
L3:THM.CFD.P15.08	BWR High Void Fraction Validation
L3:THM.CLS.P13.09	Experimental study of subcooled flow boiling heat transfer up to the DNB limit for both uncoated and synthetically CRUD-ed surfaces
L3:THM.CLS.P15.01	Continuous improvement of Closures for PWR and BWR simulations / objectives definition
L3:THM.CLS.P15.02	Delivery of selected DNB Data for GEN-II
L3:THM.CLS.P15.03	ITM/DNS for Closures
L3:THM.CLS.P15.04	GEN-II DNB Mechanism Completion
L3:THM.CLS.P15.05	GEN-II DNB Testing and Validation
L3:THM.CLS.P15.06	Data Driven DNB advancements
L3:THM.CLS.P15.07	Boiling Algorithms and Test bed in openFOAM
L3:THM.CLS.P15.08	Hydrodynamic Closures for DNB
L3:THM.CLS.P15.09	Boiling Validation TAMU Data
L3:THM.CLS.P15.10	Device-Scale Multiphase Flow Experiments and Data Analysis
L3:THM.CLS.P15.11	Continuous improvement of Closures for PWR and BWR simulations
L3:THM.CLS.P15.12	Formal UQ of Hydrodynamic Closures with Dakota
L3:THM.CLS.P15.13	BWR Full Assembly Testing and Validation
L3:THM.CLS.P15.15	BWR Annular Flow Closures
L3:THM.CLS.P15.17	ITM/DNS High Void + Machine Learning
L3:THM.CLS.P15.18	Full Scope DNB Tests with dedicated post processing
L3:THM.CLS.P15.19	BWR Slug Flow

PHI FY17

Milestone Focus

- MAMBA-3D Integration with VERA
- TIAMAT development and testing (BISON/VERA coupling)
- CTF capability development and benchmarking (CFD-informed)
- BWR capability development
- VERA-CIPS capability development

L1:CASL.P15.04	Create VERA-CIPS: VERA-CS+MAMBA3D
L2:PHI.P15.01	Demonstrate initial VERA-CIPS capability
L2:PHI.P15.02	Accuracy and fidelity improvements in CTF using StarCCM+ and experiments
L2:PHI.P15.03	Eliminate known contributors to error in VERA-CS for PWRs
L2:PHI.P15.04	Demonstration of Tiamat for cycle depletion
L2:PHI.P15.05	Establish BWR core simulator capability for control cell
L3:PHI.BWR.P15.01	Update of VERAin, VERAout,and VERAview for BWR modeling
L3:PHI.BWR.P15.02	Perform BWR Coupled Code Benchmarks
L3:PHI.CMD.P14.01	Integrate MAMBA-3D within VERA
L3:PHI.CMD.P14.02	Demonstration of load-follow with VERA-CS+Bison
L3:PHI.CTF.P14.01	Specification of a CFD-informed subchannel benchmark suite
L3:PHI.CTF.P14.04	Taylor Blythe to complete PhD
L3:PHI.CTF.P15.01	CFD-informed CTF for CRUD
L3:PHI.CTF.P15.02	CTF two-phase flow model improvements
L3:PHI.CTF.P15.03	CTF Improvements (speed, robustness, and parameter exposure)
L3:PHI.INF.P14.01	Migration of common utilities from MPACT and CTF into a common repository
L3:PHI.INF.P14.02	VERA Release during PoR14
L3:PHI.INF.P14.03	PHI Infrastructure Support in PoR14
L3:PHI.INF.P15.01	Non-Source Release of VERA
L3:PHI.INF.P15.02	VERA Release during PoR15
L3:PHI.INF.P15.02	Develop archival storage solution for AMA analyses
L3:PHI.INF.P15.03	PHI Infrastructure Support in PoR15
L3:PHI.PCI.P14.02	Tiamat-like tests in MOOSE
L3:PHI.PCI.P14.03	Review of Bison usage in VERA
L3:PHI.PCI.P14.04	Checkpoint execution of Bison MultiApps
L3:PHI.PCI.P15.01	Creation of a 1D Bison-informed fuel model available to both MPACT and CTF
L3:PHI.PCI.P15.02	Advancement of Bison-informed fuel model in VERA-CS
L3:PHI.PCI.P15.03	Investigation of time-integration strategies for fully-coupled Tiamat
L3:PHI.PCI.P15.05	Baseline MOOSE-Bison support
L3:PHI.PWR.P14.01	PoR14 documentation of VERA-CS user support activities
L3:PHI.PWR.P15.01	PoR15 documentation of VERA-CS user support activities
L3:PHI.RIA.P15.01	Initial implementation of transient VERA-CS
L3:PHI.VCS.P13.01	Validation of VERA-CS with BEAVRS Cycle 2
L3:PHI.VCS.P14.01	Code Improvements to VERA-CS for BWRs
L3:PHI.VCS.P14.02	Create an initial global CRUD source-term capability in CTF
L3:PHI.VCS.P15.02	Assess the status and prepare a plan to prepare the VERA-CS (MPACT, CTF, ORIGEN, VERAIn, VERAview, VERAout, couplings) and VERA-CIPS V&V Documents
L3:PHI.VCS.P15.04	Develop and improve VERA-CS for CE System 80+
L3:PHI.VCS.P15.05	CTF enhancements for RETRAN interfacing
L4:PHI.CTF.P15.01	Subchannel closure model improvement
L4:PHI.VCS.P14.01	coupled MPACT+CTF for transient analysis (advisor: Lee)

VVI FY17

Milestone Focus

- V&V Implementation Plan
- Dakota capability development and workflow automation
- UQ and V&V process/strategy implementation across focus areas
- Hi2Lo development activities for CASL codes

L2:VVI.P15.05	VERA Assessment against V&V Implementation Plan
L2:VVI.P15.1	Hi2Lo Development for CASL Codes
L2:VVI.P15.2	Dakota capability development and improvement
L2:VVI.P15.3	UQ and VV process/strategy implementation
L2:VVI.P15.4	Dakota capability development and workflow automation
L3:VMA.VUQ.P13.03	QUESO statistical computing enhancements
L3:VVI.DAK.P15.01	Hi2Lo and active subspace capability development and Dakota integration
L3:VVI.DAK.P15.02	QUESO capability development and Dakota interface
L3:VVI.DAK.P15.03	Active subspace capability development, verification, and applications in Dakota
L3:VVI.H2LP15.01	CTF (CFD) calculations, development, and validation
L3:VVI.H2LP15.02	Star CCM+ (CFD) calculations, development, and validation
L3:VVI.H2LP15.03	Mamba (Chemistry) Hi2Lo Calculations, demonstration, and validation
L3:VVI.H2LP15.04	Bison (Fuels/SM) calculations, development, and validation
L3:VVI.VUQ.P15.01	UQ for SHIFT
L3:VVI.VUQ.P15.03	MAMBA V&V
L3:VVI.VUQ.P15.04	Star CCM+ Mesh Sensitivity and Uncertainty Model Quantification and Development
L3:VVI.VUQ.P15.05	V&V implementation, Validation data management
L3:VVI.VUQ.P15.16	VV Training/Workshop
L3:VVI.VUQ.P15.17	Development of Uncertainty-Guided Deep Learning with Application to Fluid Closures
L3:VVI.VUQ.P15.xx	Software quality assurance, plan, assessments, etc.

AMA FY17

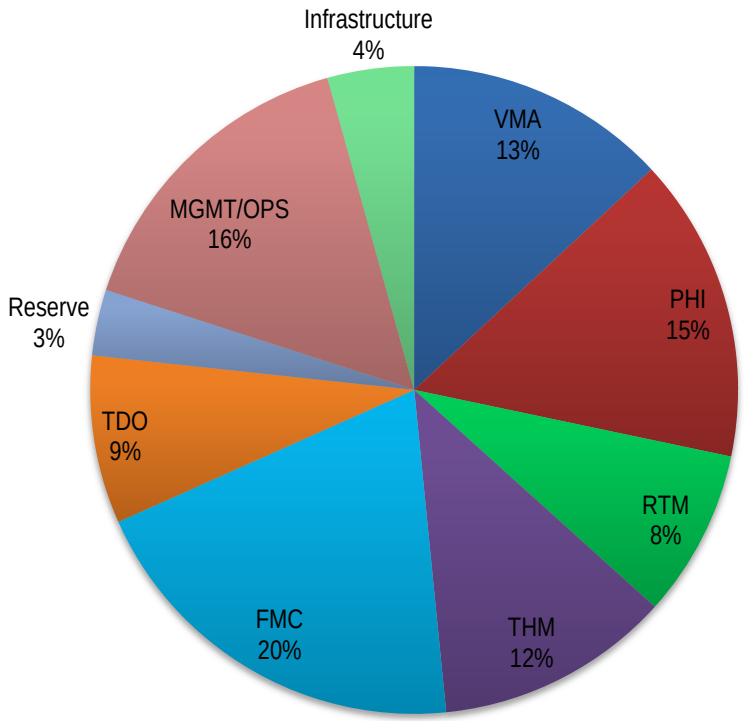
Milestone Focus

- Test Stand Support
- Challenge Problem capability assessment
- Operating reactor cycle benchmarking
- New applications development
- Software testing, V&V activities

ACT:AMA.TS.P15.01	Westinghouse Test Stand
ACT:AMA.TS.P15.02	Areva Test Stand
ACT:AMA.TS.P15.03	NuScale Test Stand
ACT:AMA.TS.P15.04	University of Illinois Test Stand
L2:AMA.P14.01	WBN2 Startup Analyses
L2:AMA.P15.01	AP1000 Startup Benchmarking
L2:AMA.P15.02	TMI Unit 1 Benchmark
L3:AMA.CP.P14.01	Independently Review and Assess CASL CRUD capabilities
L3:AMA.CP.P14.03	Development of VERA Application to PWR DNB Margin Improvement
L3:AMA.CP.P14.04	Catawba 2 Cycle 22 CIPS Calculations with VERA
L3:AMA.CP.P14.06	Design Application of Hi2Lo Mixing Model
L3:AMA.CP.P15.01	Development of New VERA model for CIPS Application
L3:AMA.CP.P15.02	Develop LOCA Boundary Condition for Assessment of BISON PCT/Oxidation Capability
L3:AMA.CP.P15.03	Initial VERA margin assessment of core design conditions associated with PWR OTDT/OPDT trip protection
L3:AMA.CP.P15.04	Extended VERA Application for Safety Analysis with System Code Interoperability
L3:AMA.CP.P15.05	Demonstrate VERA for Whole-Core PCI Risk
L3:AMA.CP.P15.06	Initial CILC Application with STAR-CCM+ and MAMBA-3D
L3:AMA.CP.P15.07	Perform Comparisons of BOA and MAMBA Results for a Commercial Reactor with CIPS
L3:AMA.CP.P15.08	Validation of CTF for Transients Including RIA
L3:AMA.CP.P15.11	Assess and Demonstrate VERA Transient RIA Capability for a Commercial Reactor
L3:AMA.RX.P14.01	WBN1 Model Update
L3:AMA.RX.P14.04	Investigate Feasibility of Performing TMI Cycles 1-10 Benchmark with PIE Data
L3:AMA.RX.P14.05	Complete VERA Progression Problem Analyses
L3:AMA.RX.P14.06	Test Inline Shift Capability in MPACT
L3:AMA.RX.P14.07	Assess and Apply Initial Vessel Fluence Capability
L3:AMA.RX.P14.08	Review B&W Critical Results and Rerun with latest Code Version
L3:AMA.RX.P14.09	Apply Shift Depletion for CE MC Lattice Calculations
L3:AMA.RX.P14.10	Evaluation and Testing of VERA for CE System-80 Design
L3:AMA.RX.P15.03	Catawba 1 Benchmarking
L3:AMA.RX.P15.04	Catawba 2 Benchmarking
L3:AMA.RX.P15.05	McGuire 1 & 2 Benchmarking
L3:AMA.RX.P15.06	Analyses of AP1000 RCCA Exchanges with BISON
L3:AMA.RX.P15.07	Assess and Perform Critical Experiment Benchmarking
L3:AMA.RX.P15.08	Perform Initial Evaluation of Excore Detector Capability
L3:AMA.RX.P15.11	Palo Verde Benchmarking
L3:AMA.TS.P15.01	Complete Test Stand Annual Report

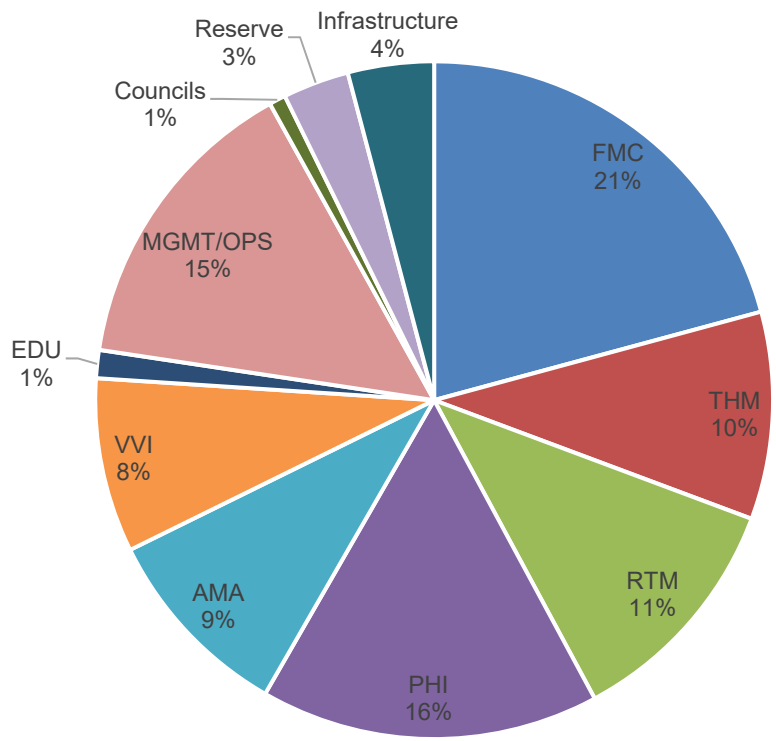
Budget – Total Funding Distribution

FY16 Total Funding



$30.4M

FY17 Total Funding



$30.3M ($23M New, $7.3M Carryover)

Summary of Budget

- VMA split into AMA and VVI focus areas
  - AMA take on CP integration and Test Stand support
  - VVI take on overall coordination of VUQ activities across Focus Areas
  - VUQ activities are being performed in each Focus Area
- TDO eliminated
  - Education broken out (direct report to SLT)
- Management and Ops remained flat
- Beginning of year reserve $1.3M
  - Will be allocated to address emerging issues and for use in spring plan of record

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