Update on NRC Activities for Modeling & Simulation of Non-LWRs

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NRC Implementation Strategies

- The overall Implementation Action Plan includes 6 specific areas:
  - Strategy 1: Acquire/develop sufficient knowledge, technical skills, and capacity to perform non-LWR regulatory reviews
  - Strategy 2: Acquire/develop sufficient computer codes and tools to perform non-LWR regulatory reviews
  - Strategy 3: Establish a more flexible, risk-informed, performance-based, non-LWR regulatory review process within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes
  - Strategy 4: Facilitate industry codes and standards needed to support the non-LWR life cycle (including fuels and materials)
  - Strategy 5: Identify and resolve technology-inclusive policy issues that impact the regulatory reviews, siting, permitting, and/or licensing of non-LWR nuclear power plants (NPPs)
  - Strategy 6: Develop and implement a structured, integrated strategy to communicate with internal and external stakeholders having interests in non-LWR technologies

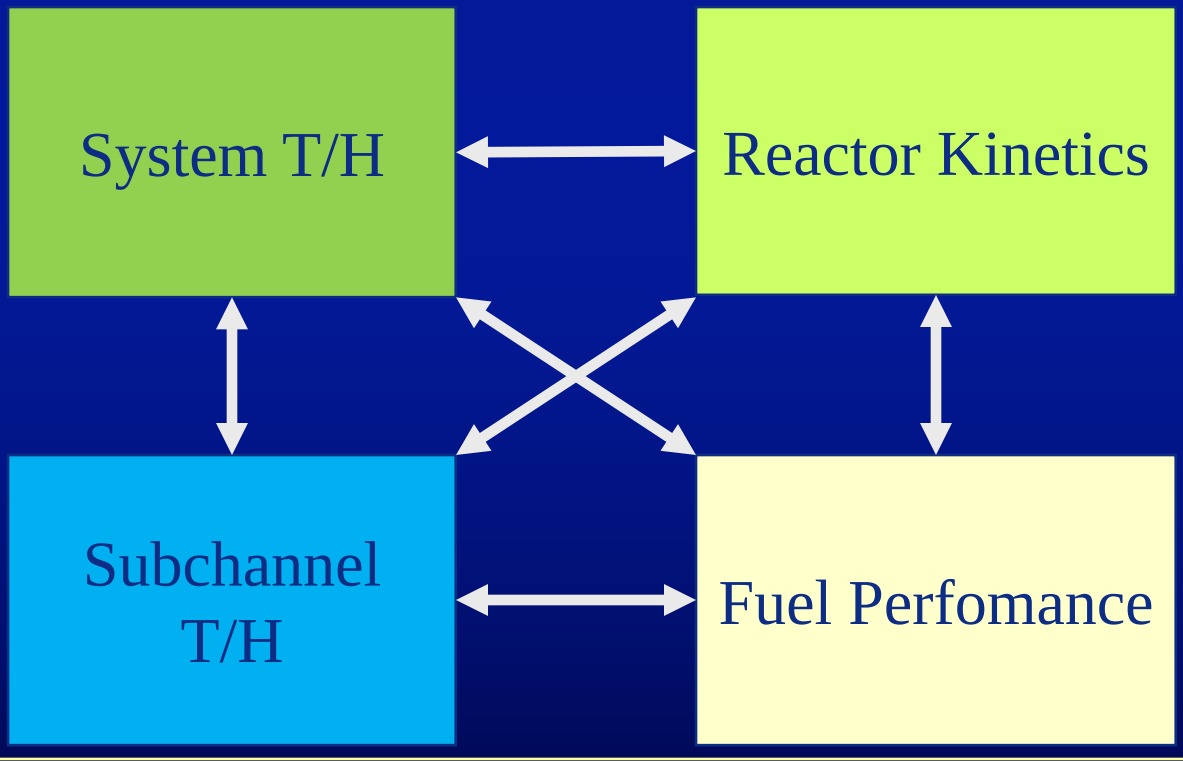
RES Activities

- Office of Nuclear Regulatory Research (RES) activities are primarily directed towards “Computer Codes and Tools” (Strategy 2) and “Codes and Standards” (Strategy 4). Significant work started in mid-2017 and is continuing into 2018.
  - “Computer Codes and Tools”
  - Division of Systems Analysis (DSA); Fuel Performance, Neutronics, Thermal-Hydraulics, Severe Accidents
  - Division of Engineering (DE); Materials, “Code & Standards”
  - Division of Risk Analysis (DRA); Probabilistic Risk Assessment

Computer Codes and Tools

Computer Codes and Tools

- Unlike conventional LWRs, computer codes & tools for non-LWRs must be more closely coupled. "Multi-physics" is the term often applied. Feedback between codes responsible for various phenomena is important.



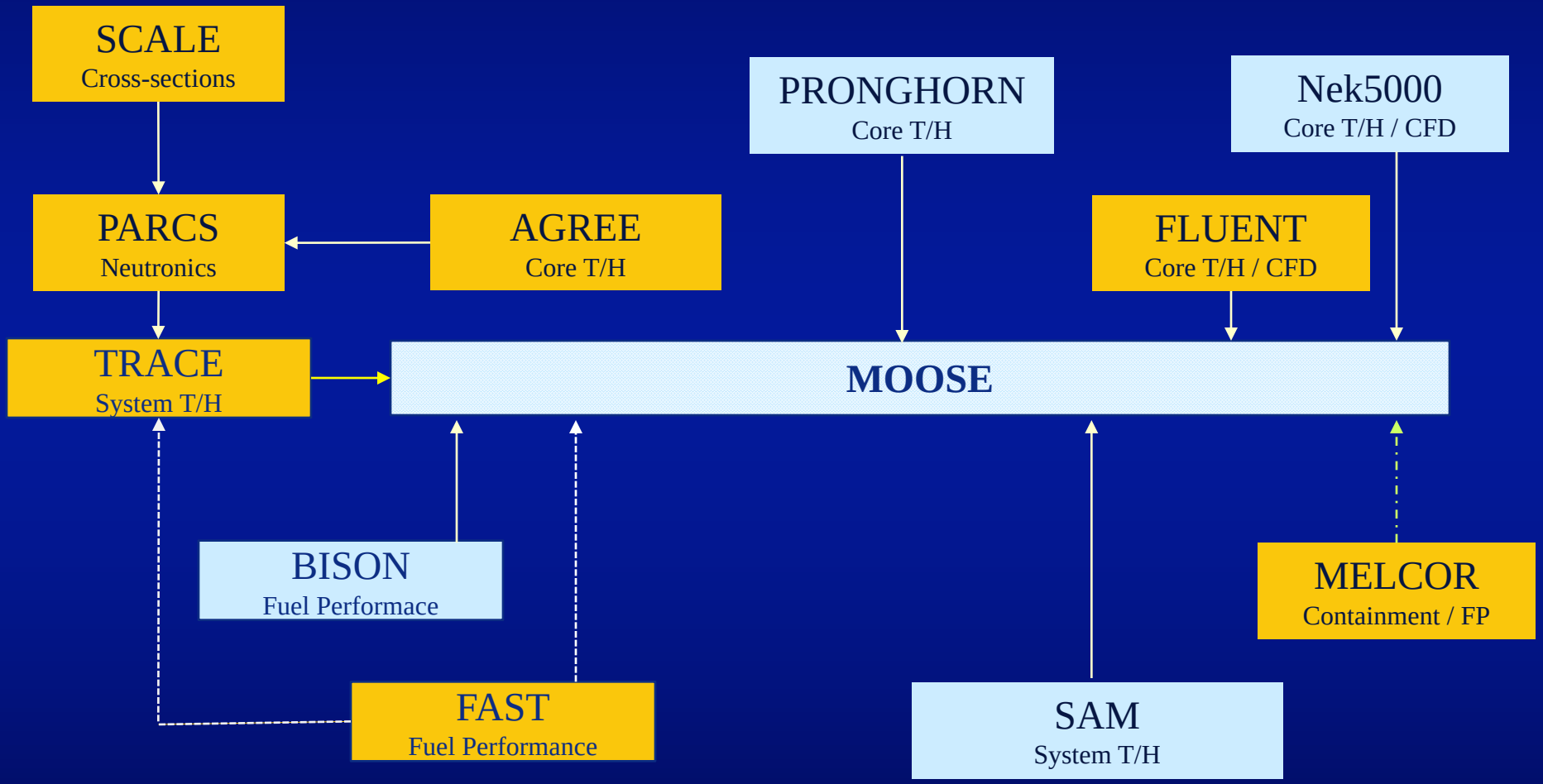
Code Selection Criteria

- **Physical Phenomena and Modeling Requirements**
  - PIRTs for HTGR, SFR identify phenomena
  - “pre-PIRT” produced for fuel salt MSRs
- **“Multi-Physics” Environment Needs**
  - Transient feedback between thermal-hydraulics/neutronics/fuel performance to require a tight-coupling between analysis codes
- **Cost Avoidance**
  - Make use of DOE products to reduce/eliminate development costs
  - Learning curve for new tools is a concern
- **Staffing Considerations**
- **Computational and Operating System Considerations**
  - Linux vs Windows
  - HPC Requirements :

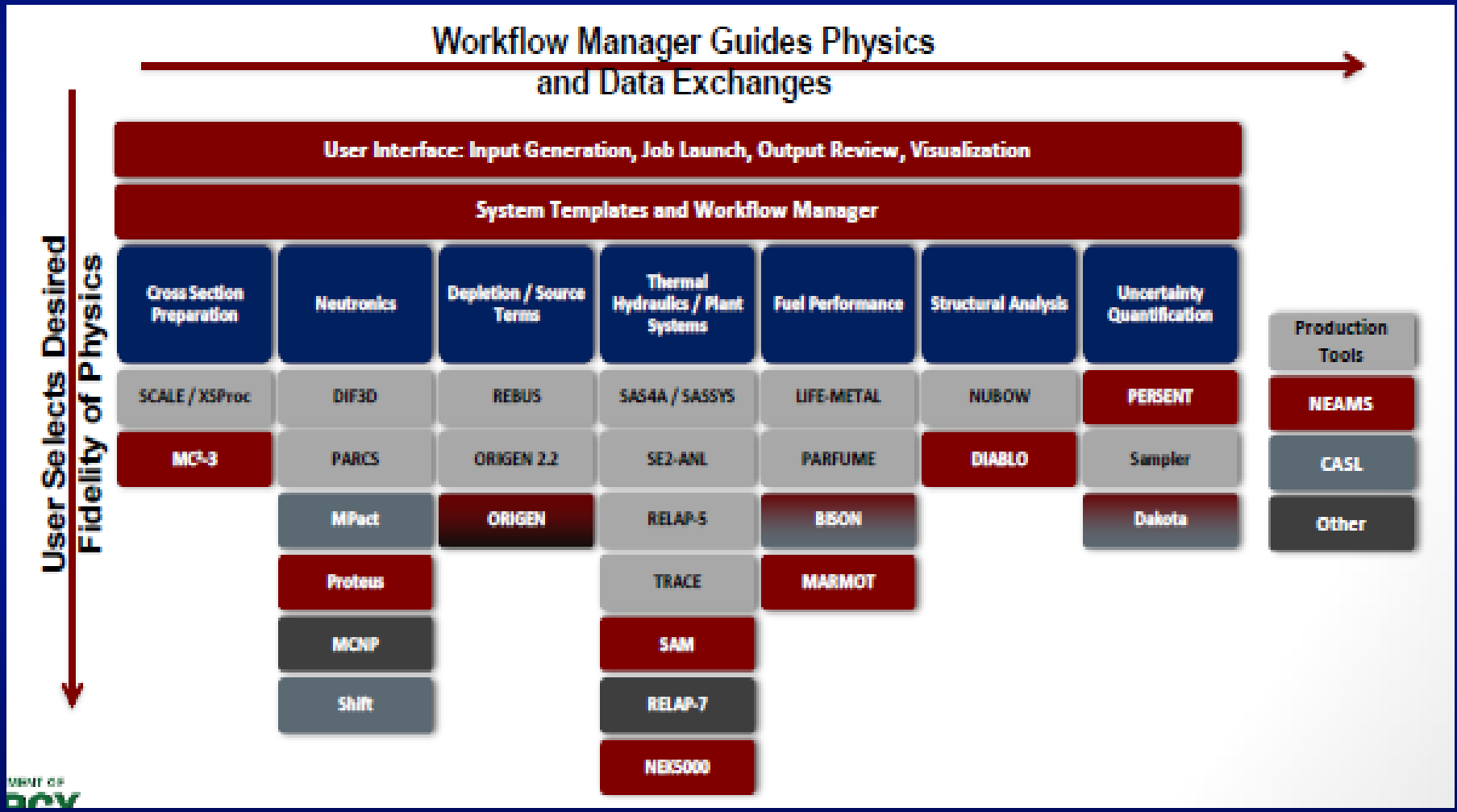
or

?

Comprehensive Reactor Analysis Bundle (CRAB)



NEAMS Workbench



DSA Functional Areas

- Fuel Performance
  - Establishing a contract to support FAST code development.
  - Adding He, Na coolant properties, advanced reactor material properties into FAST.
  - Most work also applicable to ATF.
- Neutronics
  - Develop multigroup library and group structure that is applicable to fast reactors.
  - Upgrade PARCS so that it accounts for the reactivity effect of axial and radial core expansions.
  - Implement the Paul Scherrer Institute (CAMP Member) modifications to TRACE/PARCS for fast reactor cross-sections & reactivity.

DSA Functional Areas

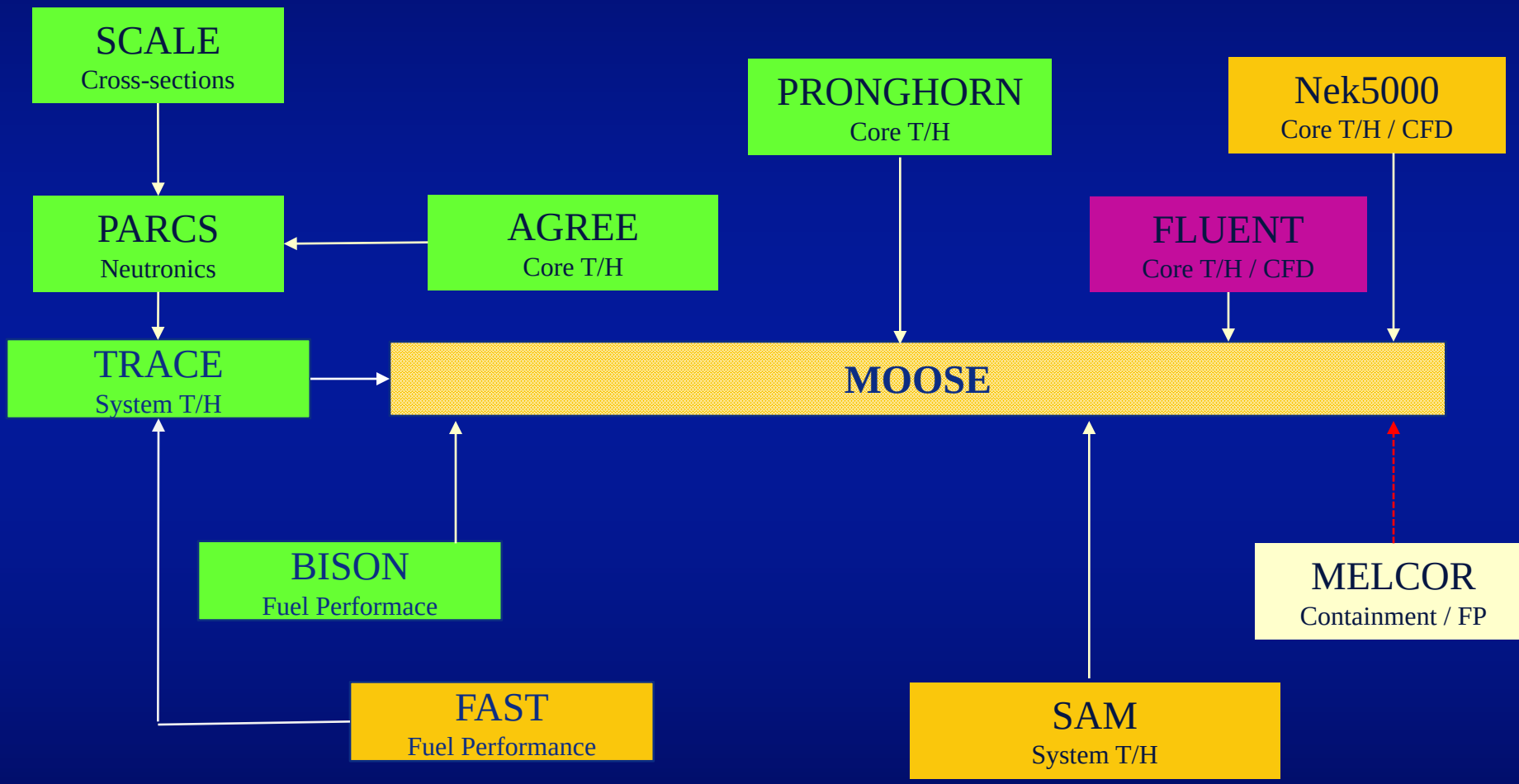
- Thermal-Hydraulics
  - A “pre-PIRT” exercise was completed to identify modeling and simulation needs for fuel salt MSRs. Report to document findings is in progress. Panel covered both T/H and neutronics.
  - Report on SFR phenomena and required modeling features is being prepared.
  - An MOU with DOE has been prepared for access and use of the CASL & NEAMS codes by NRC. Pilot study defined.
  - Several staff have received training on MOOSE.
  - SAM and PRONGHORN codes obtained and are being tested at NRC. Contract for PRONGHORN assessment . (INL)

DSA Functional Areas

- Severe Accident Phenomena
  - Review existing capabilities of MELCOR and other codes for SFR and identify modeling needs. (SNL)
  - Review severe accident work performed for NGNP and MELCOR development. (SNL)
  - DSA/FSCB program review at SNL (Aug. 9-11, 2017) will focus on accident progression and source term for these designs.
- Off-Site Consequences
  - Evaluate MACCS for modeling non-LWR accident releases and implement modeling improvements as needed . (SNL)
  - Evaluate MACCS for probabilistic calculations of offsite dose as a function of distance to inform EPZ size determinations . (SNL)

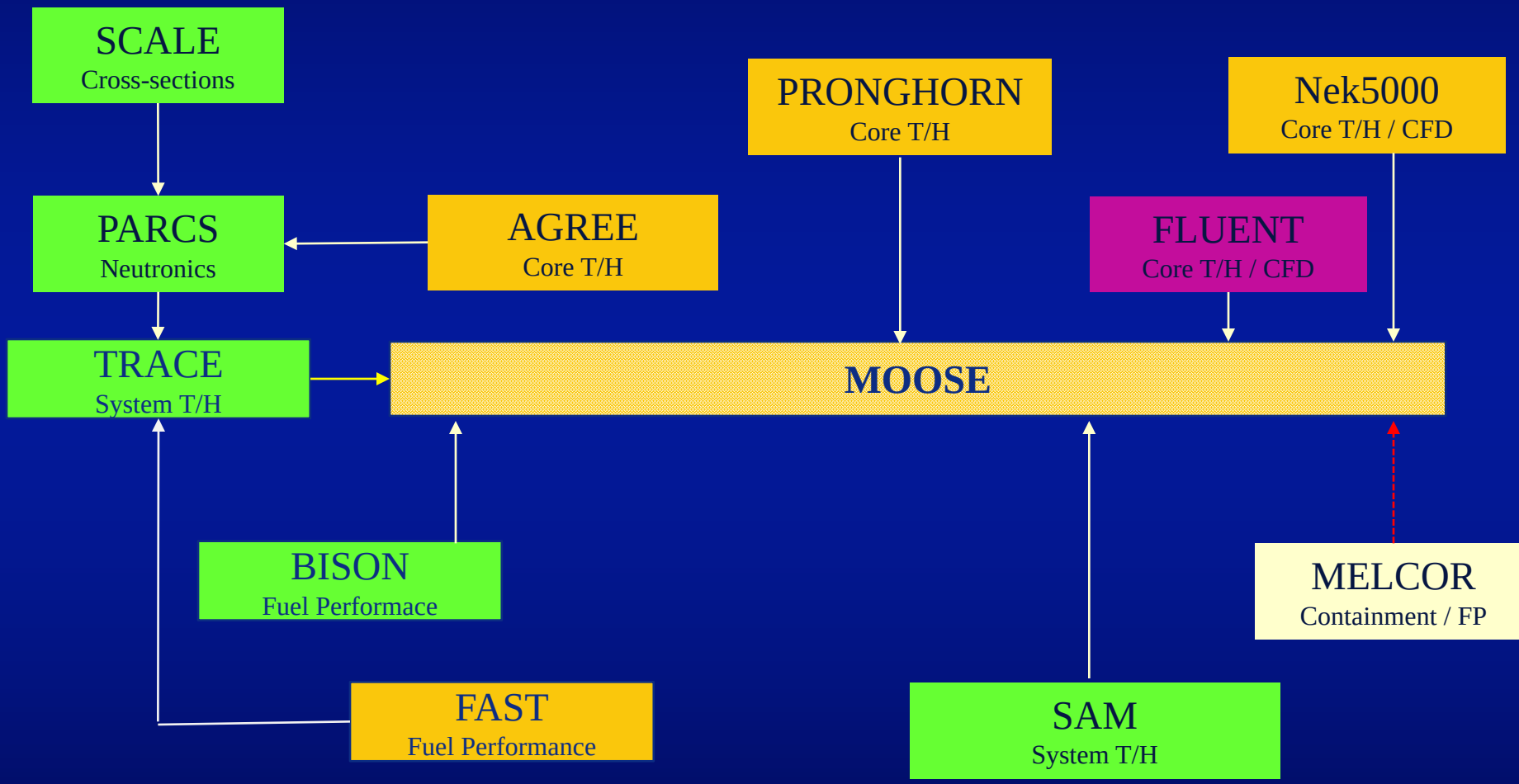
Comprehensive Reactor Analysis Bundle (CRAB)

Gas-Cooled Reactors



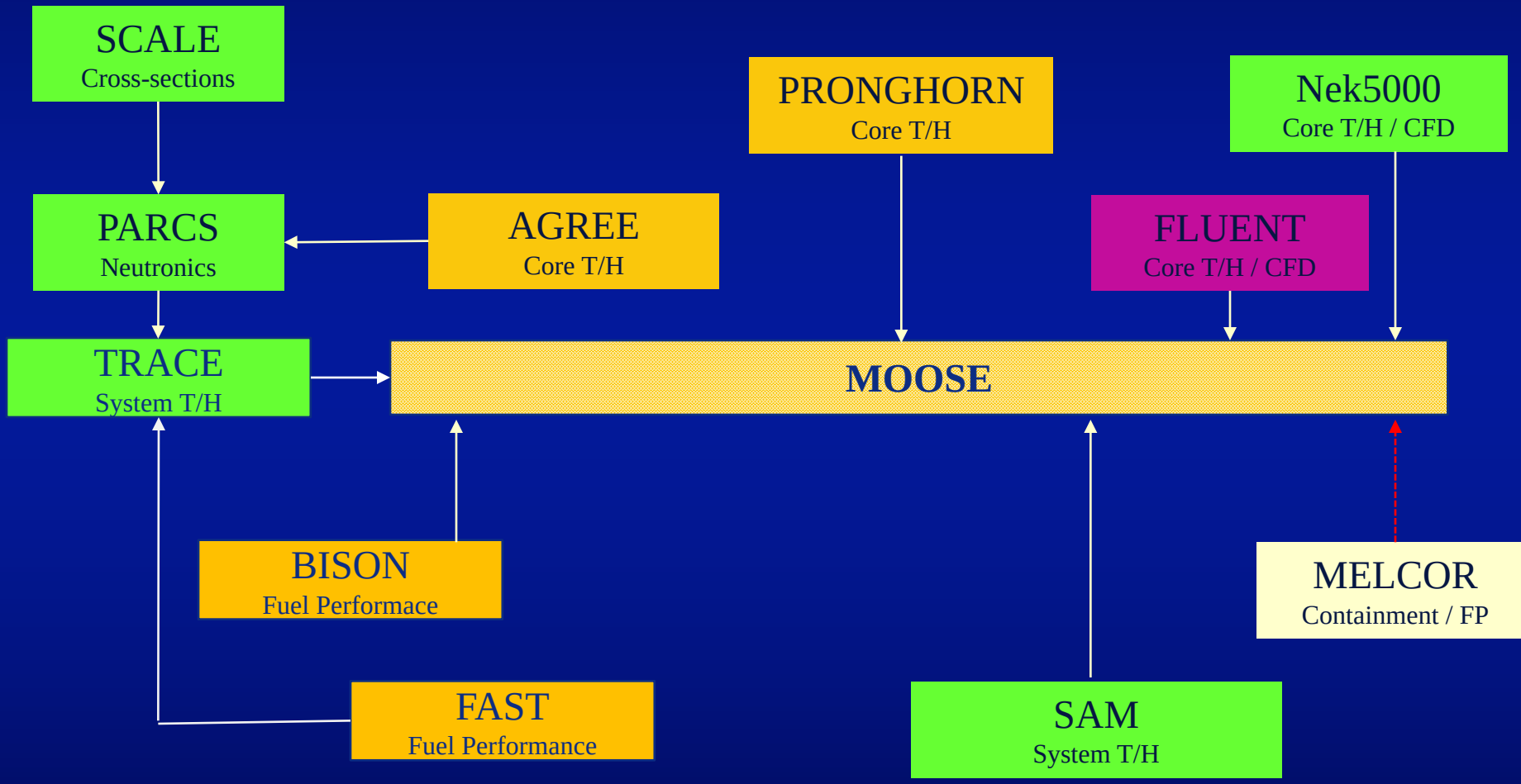
Comprehensive Reactor Analysis Bundle (CRAB)

Sodium Fast Reactors



Comprehensive Reactor Analysis Bundle (CRAB)

Molten Salt Reactor (Fuel Salt)

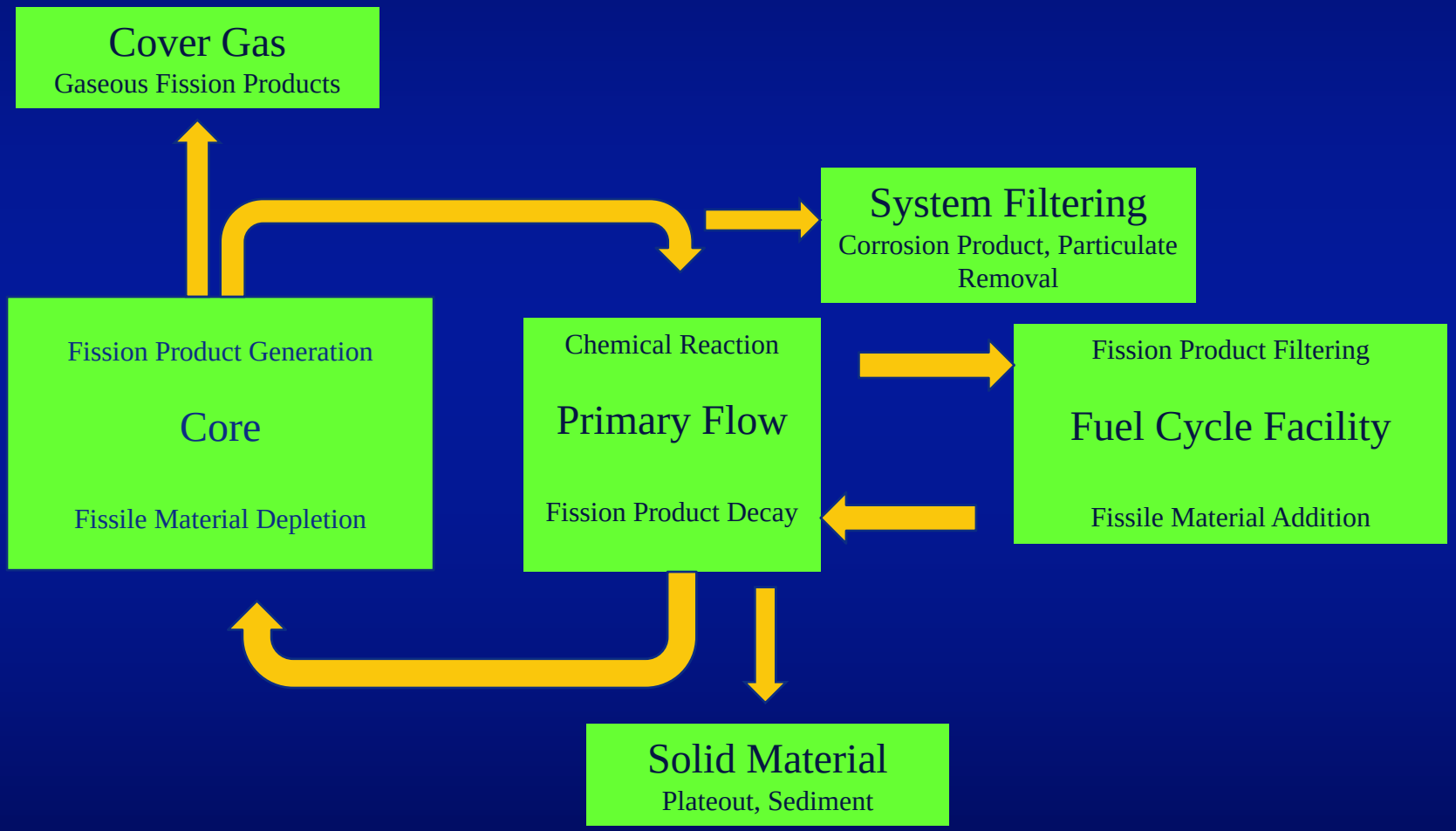


Molten Salt Reactors

- **Some special considerations for MSRs include:**
  - Thermophysical properties of salts (k , μ, ρC_p, etc.)
  - Delayed neutrons & transport of precursors
  - Fouling & plate-out of precipitants and contaminants
  - Tritium generation and transport, diffusion through HX surfaces
  - Cross-sections (absorption, scattering in Li, Be, F, C, etc.)
  - Solidification temperature of salts + fission products
  - Fuel salt volatility
  - Molten salt break flow
  - Chemical interactions
- **System inventory needs to be known at initiation of an event. Accident analysis wants "worst time in life".**

Comprehensive Reactor Analysis Bundle (CRAB)

Molten Salt Reactor (Inventory Control)



Summary

- The NRC now has a preliminary plan for a code suite applicable to non-LWRs; GCR, SFR, MSR.
- Next steps involve identification of “gaps” in code capability and that necessary to evaluate accident scenarios in non-LWRs.
- Modeling and simulation of MSRs is new, different and complex - - but not impossible! Available codes should be capable of MSR simulation with development to address “gaps”. Experiments are needed !!!