Idaho National Engineering and Environmental Laboratory

NGNP Neutronics & Thermal-Hydraulics Research & Development Plans

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NGNP R&D Plan: Thermal - Hydraulics & Neutronics - Outline

- *Introduction*
  - *The Process*
  - *Scenario Identification*
  - *PIRT*
  - *Validation Needs*
- *Work Planned for RELAP5*

The R&D Process is based on…

- *Identifying the most demanding scenarios for candidate plant design*
- *Isolating key phenomena in scenarios*
- *Determining whether analysis tools can be used to confidently analyze plant behavior in scenarios: Validation*
- *Performing R&D to upgrade analysis tools where needed*

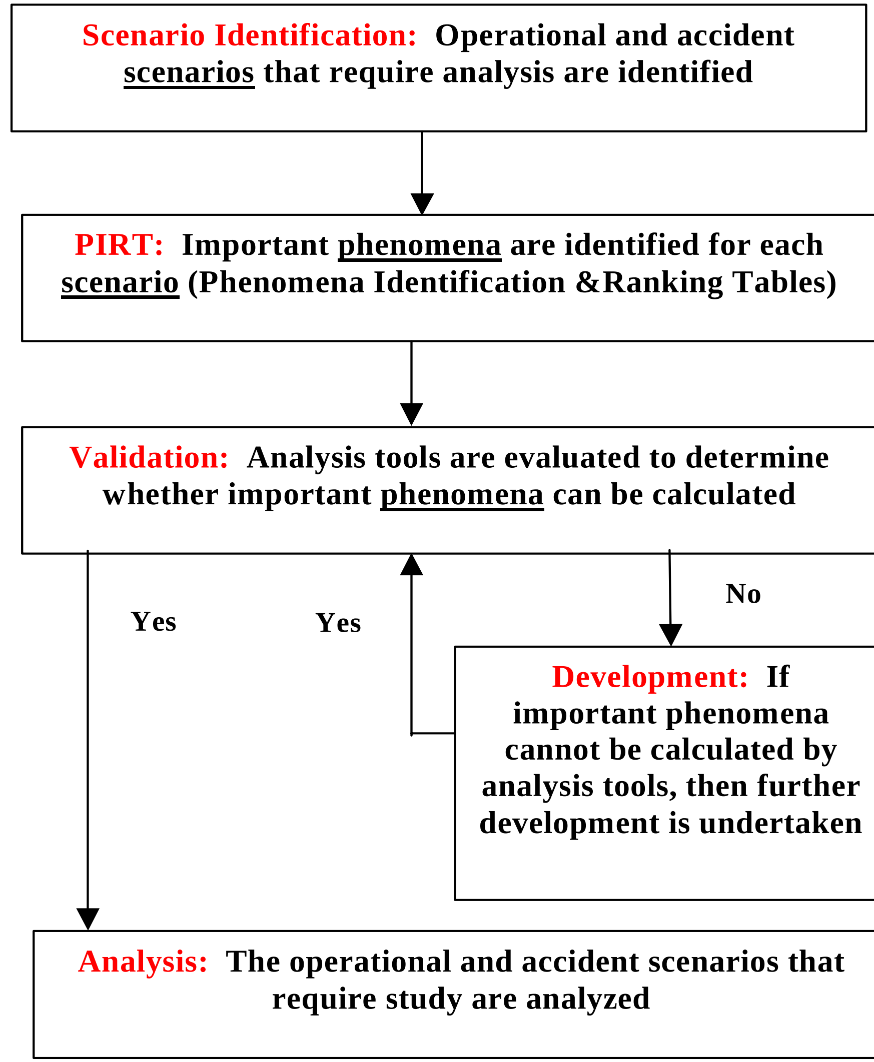
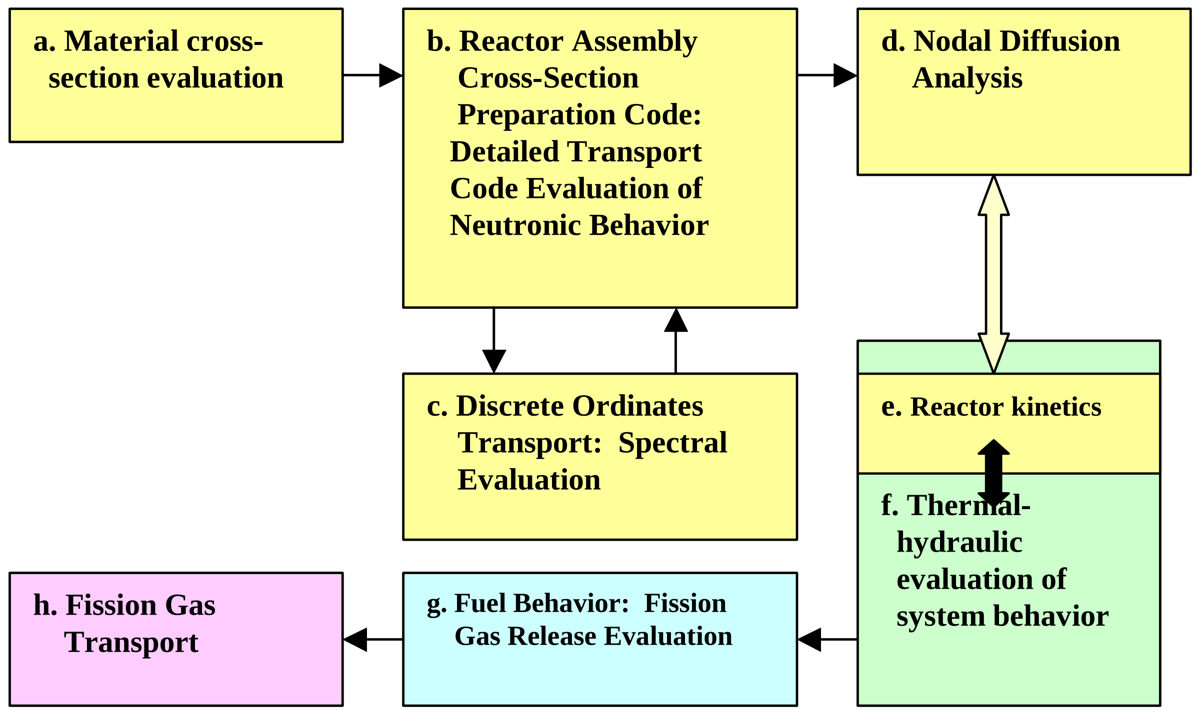


Fig. 1. Research & Development Process

The calculation process…

- *Consists of 8 steps and*
- *Requires adequate data e.g. cross-sections to enable validation of analysis tools.*
- *Requires the analysis tools to have reasonable† agreement with data for key phenomena.*



† *Reasonable agreement: calculated value sometimes lies within data uncertainty band and shows same trends as data.*

NGNP must be shown to be safe…

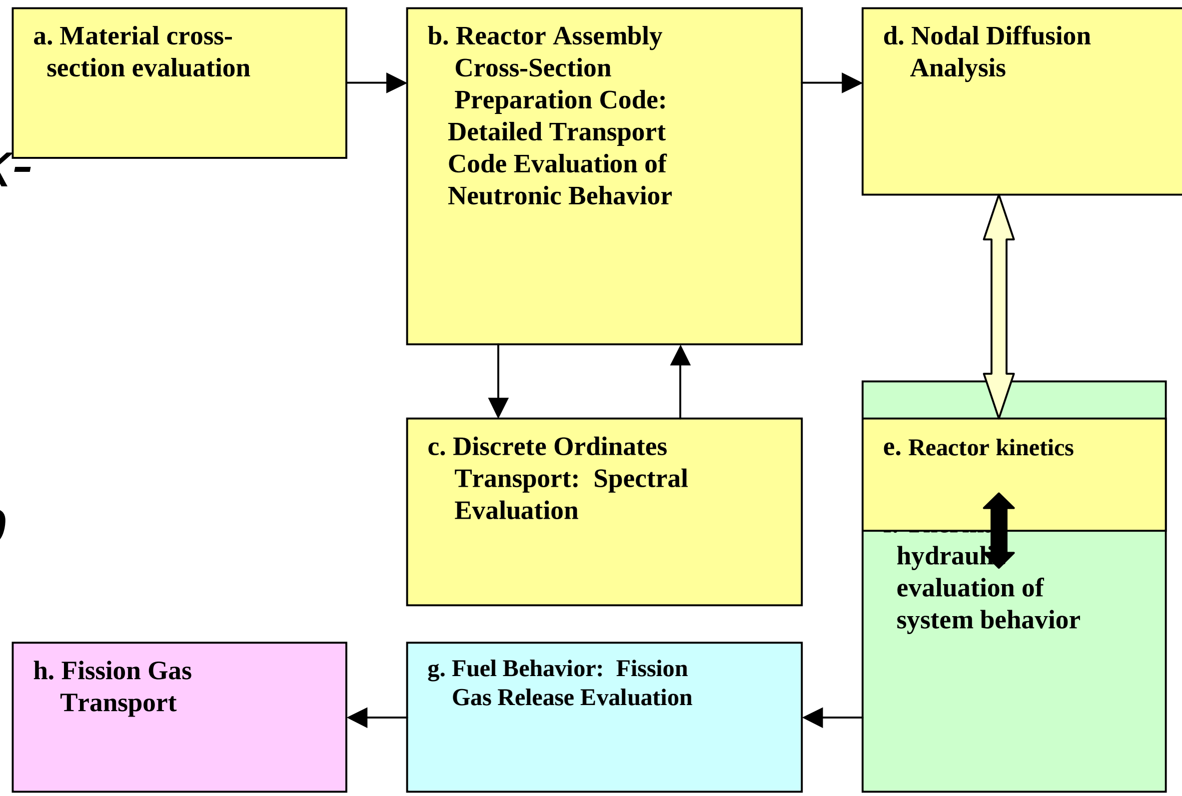
- *In complete operational and accident envelopes:*
  - *Anticipated operation occurrences, e.g., accidental withdrawal of control rods or loss of main and shutdown loops*
  - *Design basis accidents*
- *By using analysis tools capable of calculating:*
  - *Fuel behavior, including migration of fuel kernel in fuel sphere,*
  - *Fuel power distribution*
  - *Thermal-hydraulic behavior—operational & accidents*
  - *Potential for air ingress, water ingress, and graphite oxidation.*
  - *Fission product migration as function of fuel failure*

R&D Plans: Using a "First-Cut" PIRT

- *Based on prioritization of scenarios and phenomena :*
  - *Identified by experienced gas-cooled system designers*
  - *Engineering judgment*
- *Aimed at requirements for performing reasonable calculations of plant behavior for:*
  - *Operational conditions (rated power)*
  - *Pressurized conduction cooldown transient scenario (PCCS)*
  - *Depressurized conduction cooldown transient scenario (DCCS) including possible air/water ingress*

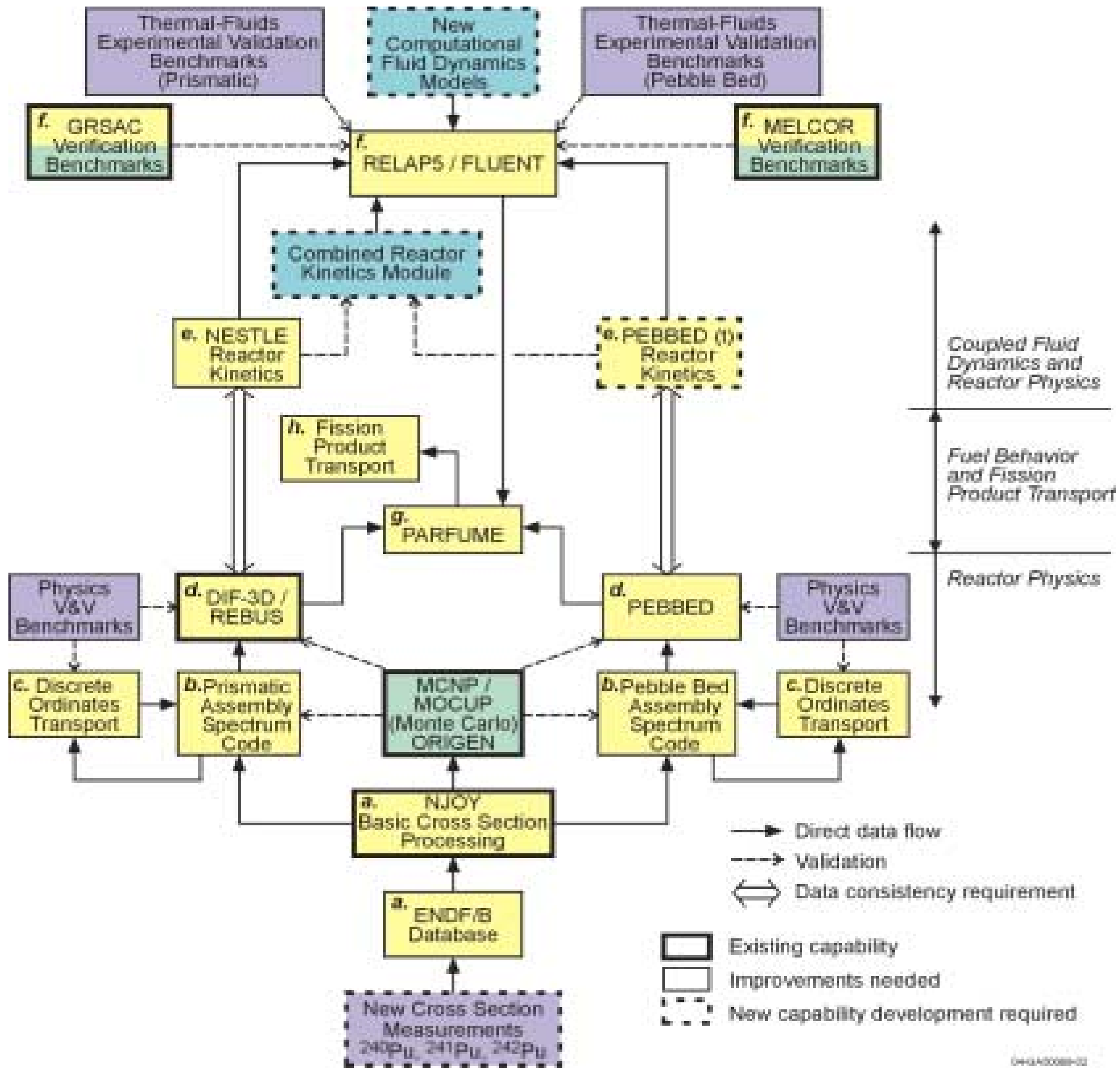
R&D Plan based on…

- *Assumption: It is equally likely that the NGNP will be pebble-bed or block-type reactor*
- *Validation (& development if required) of tools identified in Steps b through h.*



Including for example:

- *Step b: COMBINE or DRAGON*
- *Step c: ATTILA*
- *Step d: DIF-3D*
- *Step f: RELAP & Fluent*
- *Step g: PARFUME*



Portion of R&D Need Matrix…

Region of System	Operational Conditions	Depressurized Conduction Cooldown	Pressurized Conduction Cooldown
Inlet Plenum			IP1: Validation of CFD mixing calculation during transient.
Core	CO1: Nuclear data measurements to reduce calculational uncertainty. CO2: Modification of cross-section generation code to treat low-energy resonances with upscattering. CO3: Development of improved method for computing Dancoff factors. **CO4: Characterization of hot channel temperatures and fluid behavior at operational conditions.** CO5: Validation using integral experimental data.	**CD1: Validation of systems analysis codes to demonstrate capability to predict thermal behavior.** CD2: Validation of models that calculate fission product release from fuel. CD3: Validation and calculation of air ingress and potential water ingress behavior into reactor vessel and core region.	**CP1: Validation of systems analysis codes to demonstrate capability to predict thermal and hydraulic behavior.**
Outlet Plenum	**PO1: Validation of CFD mixing using mixed index refraction (MIR) facility data & data available in literature. Perform calculation of fluid behavior with validated code.**	PD1: Validation of CFD mixing during operational transients and effect on turbine operational characteristics. Perform calculation of fluid behavior.	PP1: Validation of CFD mixing during operational transients and effect on turbine operational characteristics. Perform calculation of fluid behavior.
RCCS	RO1: Validation of natural convection characteristics in cavity at operational conditions. RO2: Characterization of natural convection characteristics in cavity at operational conditions.	RD1: Validation of heat transfer & convection cooling phenomena present in reactor cavity and via RCCS.	RP1: Validation of heat transfer & convection cooling phenomena present in reactor cavity and via RCCS.

Because a system-wide modeling capability is required for NGNP analysis…

- *Modeling thermal, neutronic, and dynamic coupling of Core, Reactor Vessel, Balance-of-Plant, Shutdown Cooling System, and Reactor Cavity Cooling System is required for design and safety studies*
- *Several codes will provide the basis for these studies*
  - *RELAP5-3D/ATHENA*
  - *Fluent*
  - *GRSAC*
- *FY-05 system analysis R&D is focused on RELAP5-3D/ATHENA development and validation*

FY-05 Subtasks

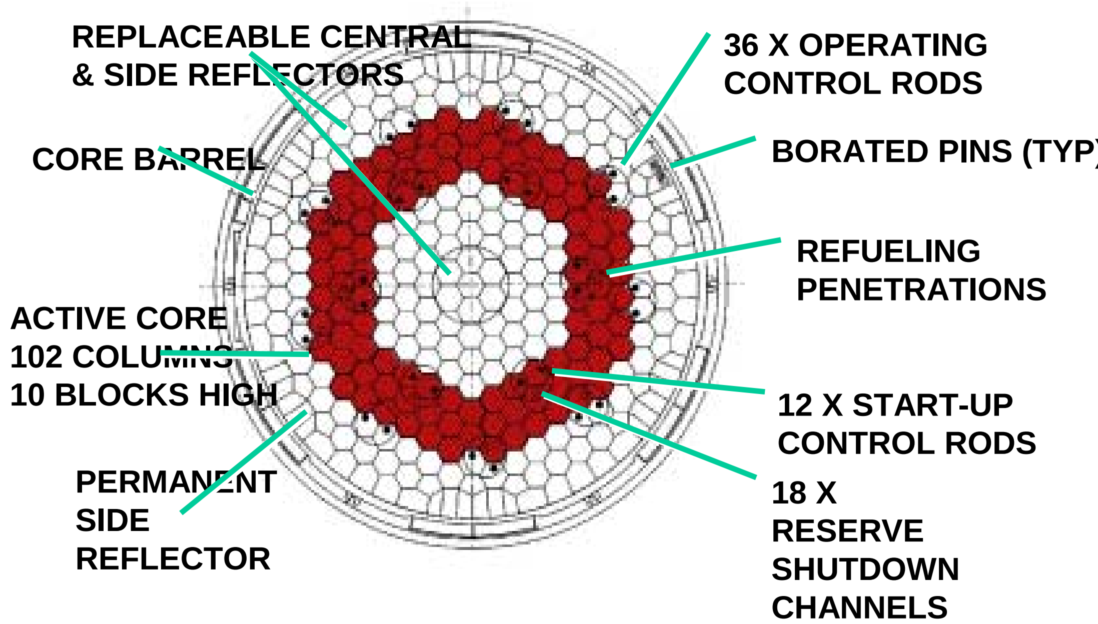
- *Assess heat transfer models using existing gas flow data*
- *Enable heat structures to conduct/radiate heat axially and radially*
- *Continue diffusion modeling for air ingress*

Gas Flow Heat Transfer

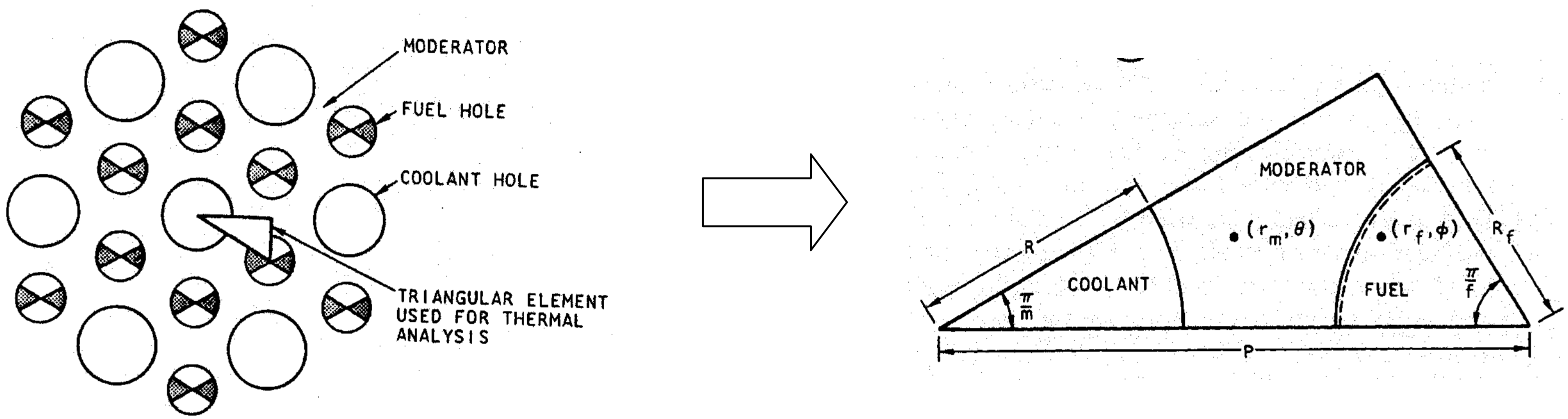
- *A range of heat transfer modes will occur during normal and accident conditions*
  - *Forced convection*
  - *Mixed convection*
  - *Downflow and upfLow*
  - *Strong gas property variations*
- *RELAP5-3D/ATHENA will be assessed using relevant, existing data*
  - *McEligot, Magee and Leppert [1965], Perkins and McEligot [1975], Reynolds [1968], Shumway [1969] and Vilemas and Poskas [1999]*

Core thermal conduction/radiation model for conduction cooldown modeling

- *A heat structure models each graphite block*
- *Each heat structure conducts and radiates heat to its neighbors axially and radially*
- *A uniform block temperature is assumed*



Operational and early time accident temperature distribution requires a detailed analysis



Symmetry within a graphite block defines a "primitive" that can be modeled to evaluate temperature distribution using a 3D heat conduction code (e.g. FIDAP, ABAQUS, Fluent)

Air ingress following LOCA requires a gas diffusion model

- *Air ingress may lead to oxidation of the graphite blocks*
- *Development of a diffusion model was begun under I-NERI sponsorship in FY-04*
- *This subtask will complete the initial model and debug*