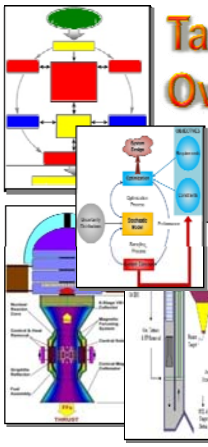
ADVANCED ENERGY TECHNOLOGIES RESEARCH

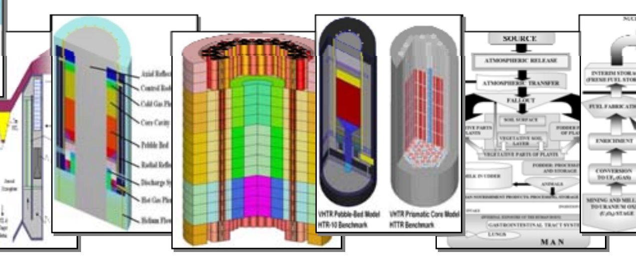
Advances in nuclear technology through pioneering research and teaching excellence

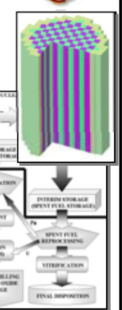
BASIC RESEARCH ON HTR THERMAL HYDRAULICS AND REACTOR PHYSICS

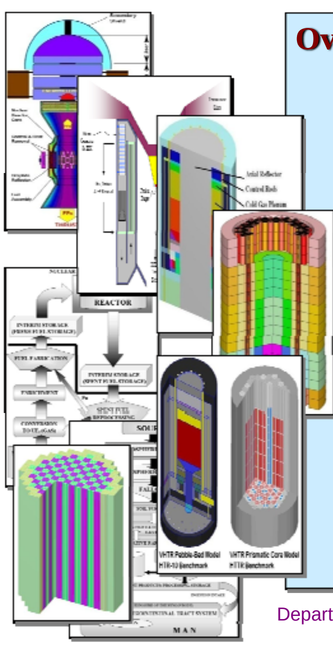


Task 2.C.2. Overview of MELCOR/PARCS Coupling

Dr. Pavel V. Tsvetkov
Nuclear Engineering, Texas A&M University

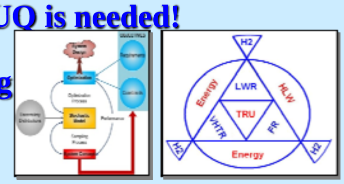


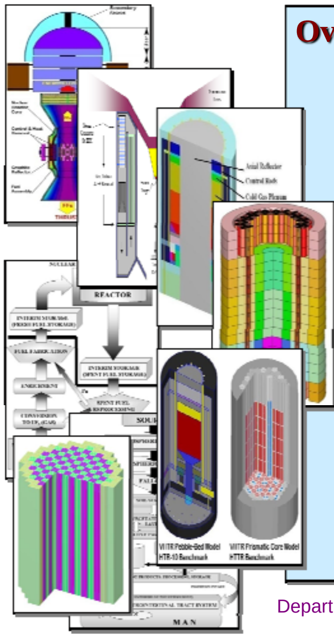




Overview of MELCOR/PARCS Coupling

- Introduction
- Task 2.C.2 overview
- HTR complexity and system codes
  Capturing details? How do we know?
- Materials, data storage and flows
- Coupling architectures and options
- High fidelity UQ is needed!
- Benchmarking
- Conclusions





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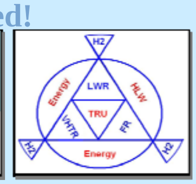
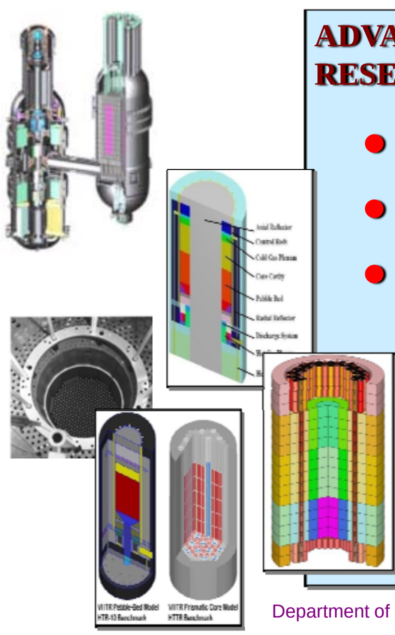




ADVANCED ENERGY TECHNOLOGIES RESEARCH

Nuclear Engineering 1992 - ...

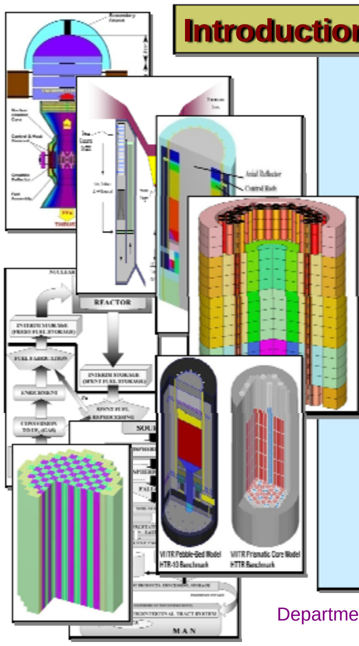
- 18 students since 2005
- 7 M.S., at least 6 Ph.D.s by 2012
- **R&D** – advanced energy systems,
  – methods, tools development

M.S. – 1995 (Russia)

Ph.D. – 2002 (TAMU)

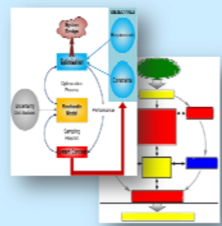
NUEN Faculty since 2005

Introduction



Introduction

- System Analysis and Optimization Methods
  - Monte Carlo Methods
- Complex Engineered Systems
  1. HTGRs=VHTRs/NGNP, Co-Generation, High Fidelity Modeling, UQ, Benchmarking
  2. Symbiotic Nuclear Energy Systems, Waste Minimization, Sustainability
- Nuclear System Design
- Direct Nuclear Energy Conversion Systems



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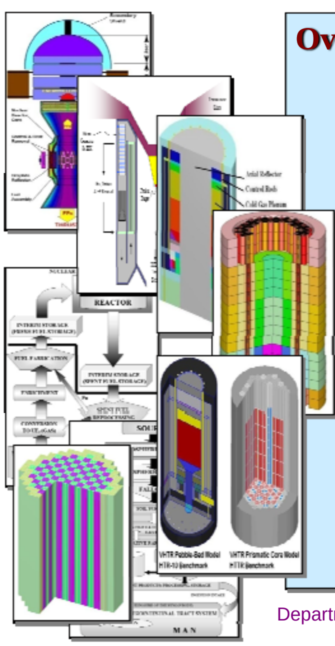

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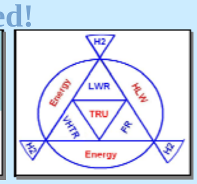

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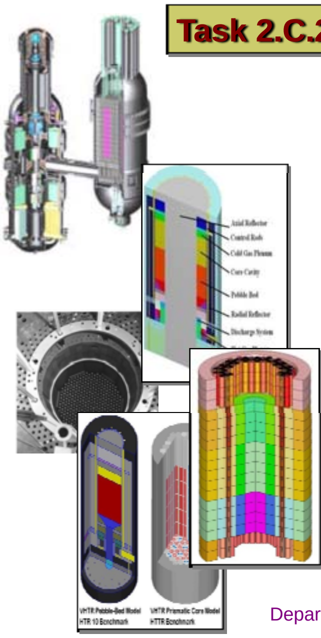
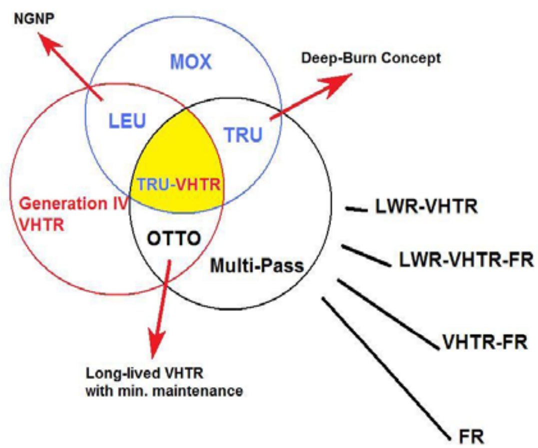
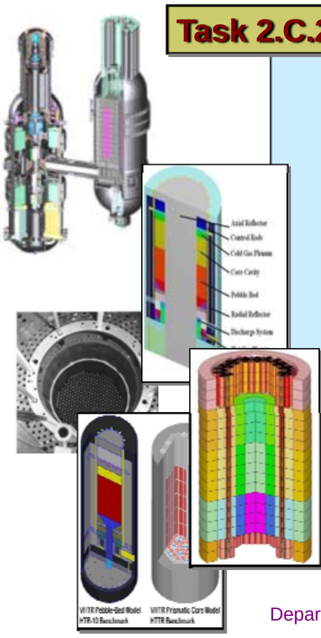




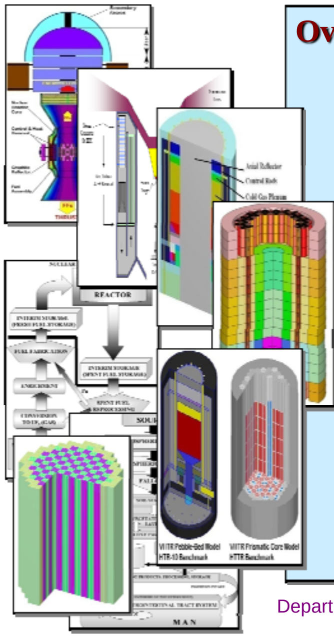
Leveraging capabilities & resources

Task 2.C.2 overview



- Sample cases (Dr. Vierow+)
  - MELCOR input/output
- PARCS/MELCOR Interface (Dr. Tsvetkov+)
- Initial interface testing (All)
- PARCS/MELCOR system benchmarks (All)
  - (HTR test suites based on historical data)
- SCALE/PARCS/MELCOR

Leveraging capabilities & resources



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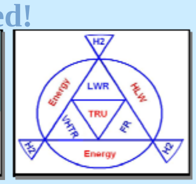
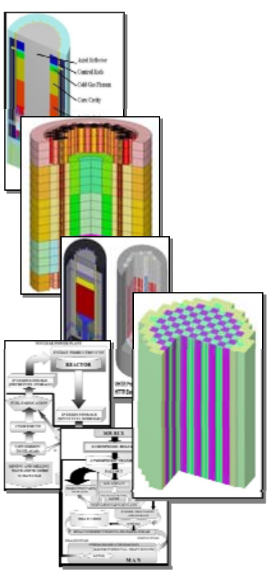
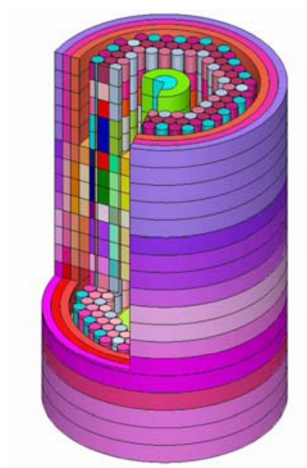


HTR complexity and system codes

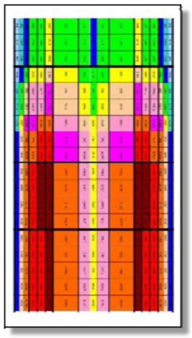


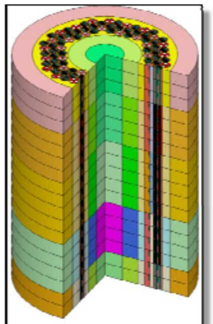


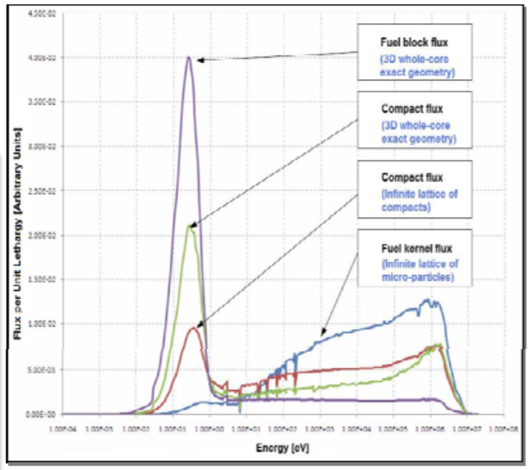
Capturing details? How do we know?

HTR complexity and system codes

- Micro-particle fuel
- Compact or Pebble
- Block Stack or Pebble Bed
- Core Internals







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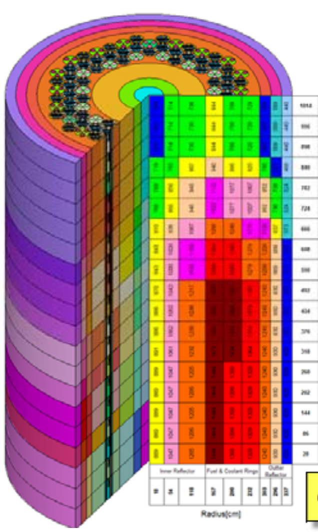

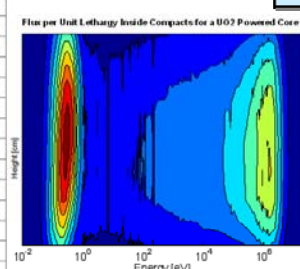

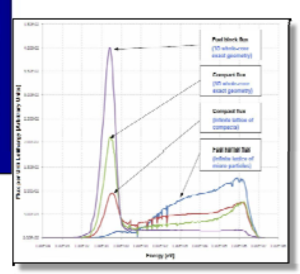

Capturing details? How do we know?

HTR complexity and system codes

Dr. Vierow Group

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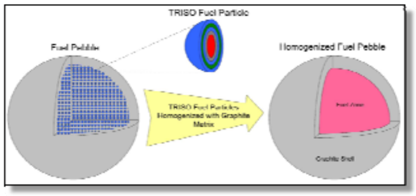

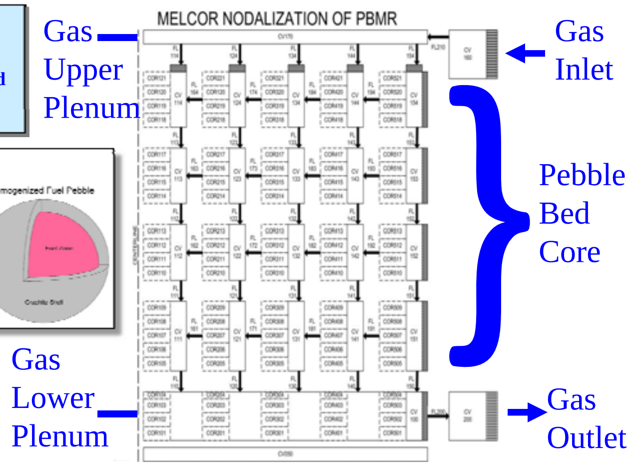

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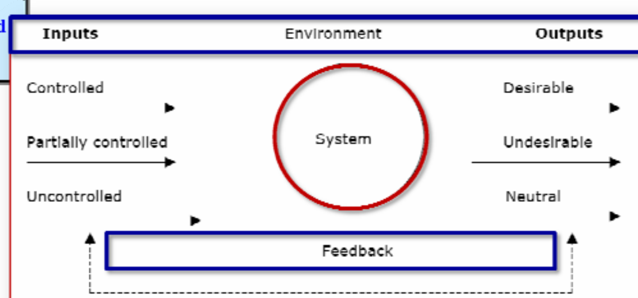

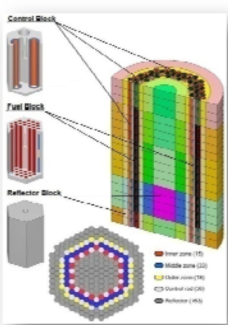

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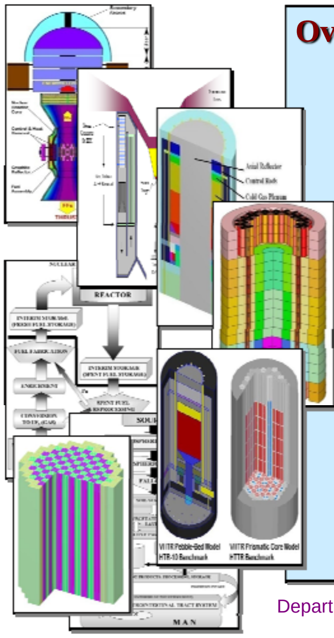

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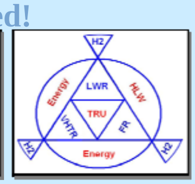
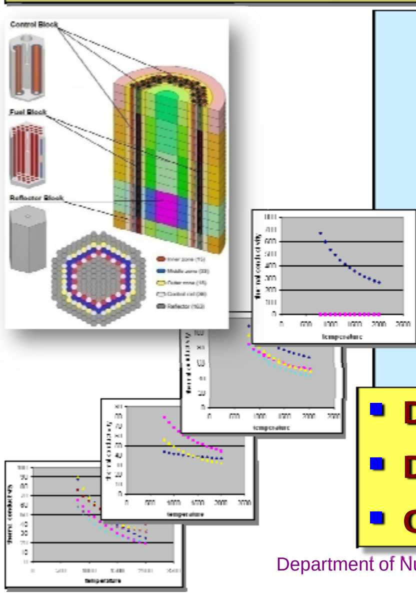
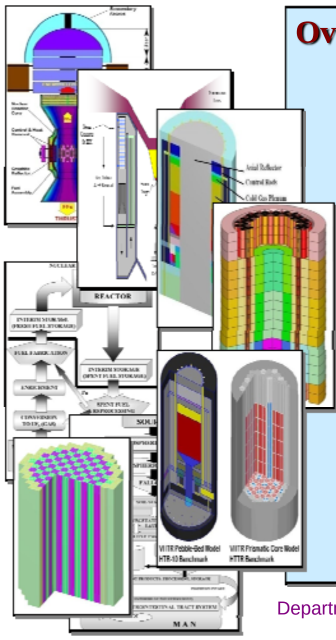


Materials, data storage, and data flows



- MatWeb (42,000 existing materials)
- NIST (ceramic materials)
- Ceramic industry database
- AMPTIAC (advanced materials data)
- MATPRO library
- INSC database
- Fuels data (IAEA, BNL, …)
- Graphite data
- Helium data
- European material property databases

- **Database vs. Input File or Both?**
- **Data format?**
- **Covariance data?**



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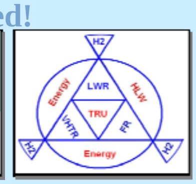

Coupling architectures and options

Non-intrusive/black box: calls, sockets, etc.
Semi-intrusive: direct linkage, subroutines
Fully intrusive: integration

Motivation for coupling?

- to take advantage of computational resources and maturity levels of individual codes
- to enhance prediction capabilities
- to provide a modern tool for VHTR safety and design evaluations

Low level coupling: $A \xrightarrow{\iiint} B$

Medium level coupling: $A \overset{\vec{r}}{\rightleftarrows} B$

High level coupling: $A \overset{t,\,\vec{r}}{\rightleftarrows} B$

Local transient phenomena reconstruction? Limiting system consequences?..

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Coupling architectures and options

Non-intrusive/black box: calls, sockets, etc.
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MELCOR/PARCS direct coupling

$$MELCOR \xrightarrow[\boxed{\text{MELCOR TH-core solver}}]{T(\vec{r}),\dot{m}(\vec{r}),\vec{v}(\vec{r}),\ldots} PARCS$$

MELCOR/AGREE/PARCS coupling

$$PARCS\ /\ AGREE \xrightarrow[\boxed{\text{AGREE TH-core solver}}]{\text{3D } T(\vec{r}),\dot{m}(\vec{r}),\vec{v}(\vec{r}),\ldots\Rightarrow\text{MELCOR-TH}} MELCOR$$

MELCOR/PARCS-PK coupling

$$PARCS\ /\ PK \xrightarrow[\boxed{\text{MELCOR TH\&PK solvers}}]{\text{PARCS PK}\Rightarrow\text{MELCOR}} MELCOR$$

MELCOR/PARCS-power coupling

$$PARCS\ /\ AGREE \xrightarrow[\boxed{\text{PARCS/AGREE core solver}}]{\text{3D } p(\vec{r},t)\Leftrightarrow\text{MELCOR}\rightarrow T_{in}} MELCOR$$

Local transient phenomena reconstruction? Limiting system consequences?..

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- State-of-the-art level
  = legacy software + modernization vs. new codes
- Degree of coupling, modularity vs. embedding
  = independent codes + external interface vs. integrated framework
- Degree of resolution in transient phenomena reconstruction
  = high fidelity transient consequences propagation prediction
- Applied controls and interface features
  = information exchange, collaboration, and effort coordination
- Framework should anticipate refinements and increasing fidelity.
- Resources, parallelism , message passing vs. data passing
- Benchmarking and uncertainty quantification

Local transient phenomena reconstruction? Limiting system consequences?..

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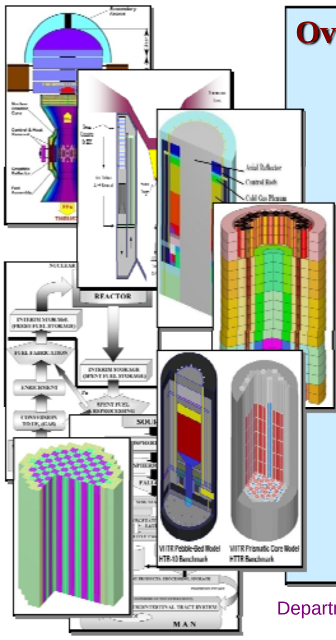

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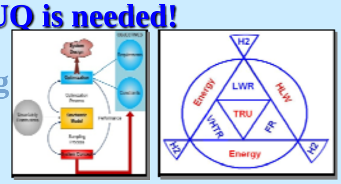

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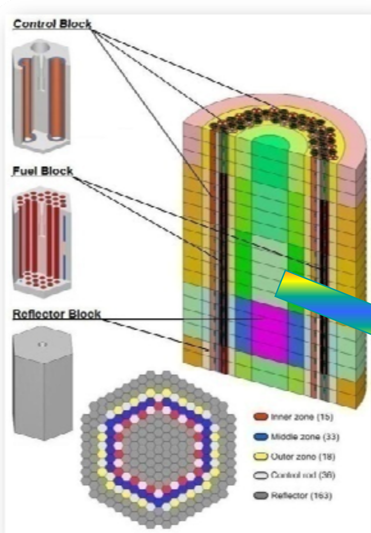
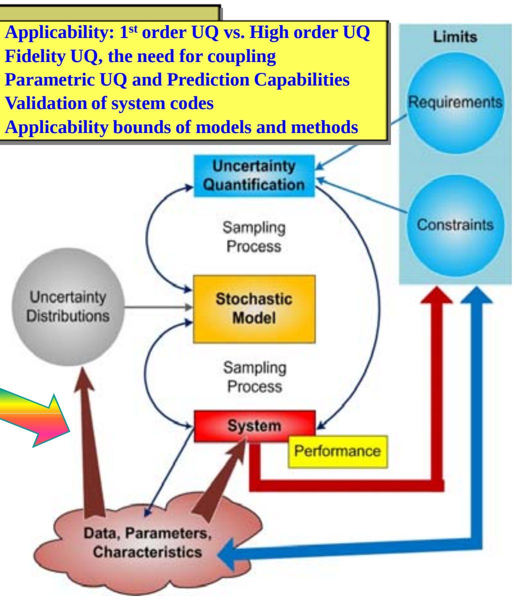
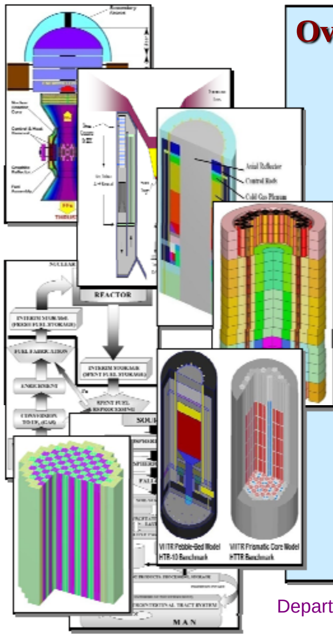
High fidelity UQ is needed!

Applicability: 1st order UQ vs. High order UQ
Fidelity UQ, the need for coupling
Parametric UQ and Prediction Capabilities
Validation of system codes
Applicability bounds of models and methods







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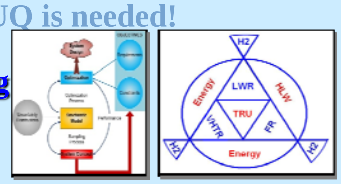
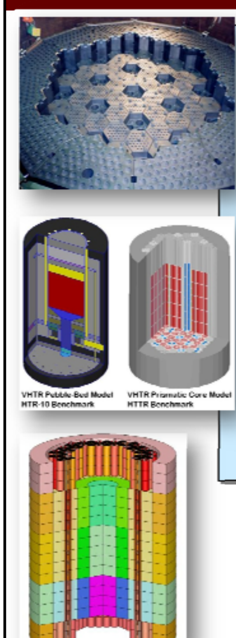
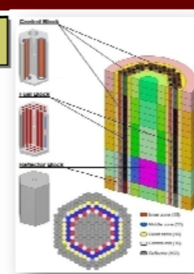




Benchmarking

- LEU-HTR PROTEUS
- HTTR Program
- HTR-10 Program
- FSV Data
- Other (History Data)

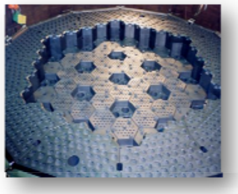


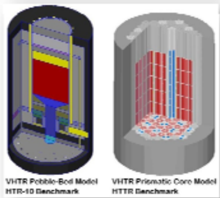
Validation and Verification

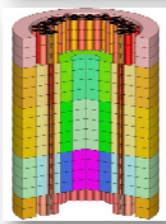
- Experiment-to-Code
- Code-to-Code

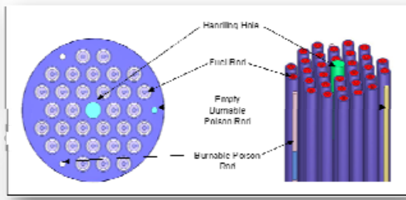
- Uncertainty Quantification
- Modeling Reliability

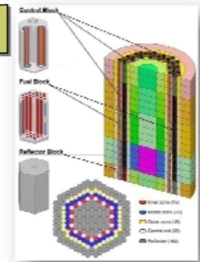
Benchmarking







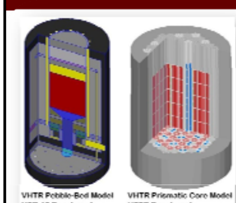


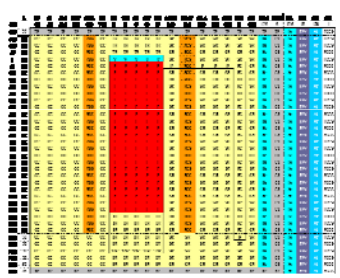


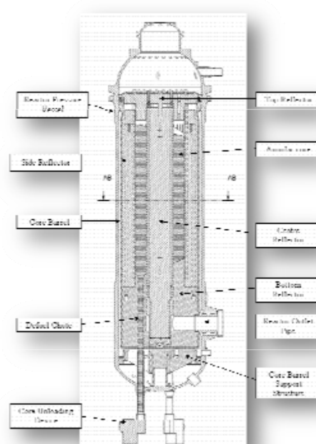
HTTR Hexagonal Block Configuration

Benchmark		VHTR model (calculated)	HTTR (experimental)	Error (%)
Control Rods Fully Withdrawn	k_{eff}	1.137 ± 0.002	1.14 ± 0.04	0.044
Control Rods Fully Inserted	k_{eff}	0.686 ± 0.002	0.69 ± 0.01	0.117
Critical Insertion Depth (core temperature 300K)	cm	177.1	177.5 ± 0.5	0.225
Critical Insertion Depth (core temperature 418K)	cm	189.9	190.3 ± 0.5	0.210
Temperature Coefficient	1/K	-1.45E-04	-1.42E-04	2.113

Benchmarking

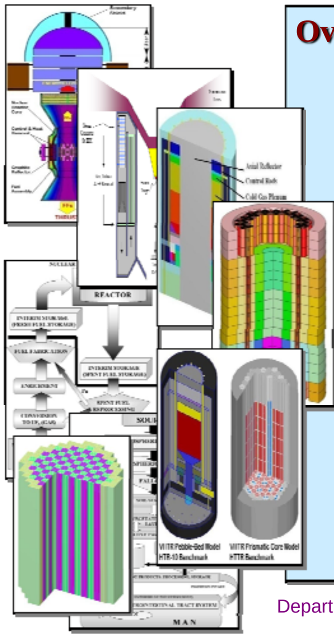






- Acceptance of the PBMR-400 benchmark
- Defined system specifications
- Benchmark fidelity
- Broad participation in benchmark evaluations and availability of results
- Existing experience with the benchmark for PARCS

OECD/NEA PBMR-400 Benchmark for MELCOR/PARCS



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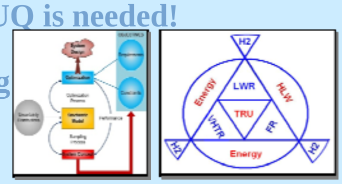
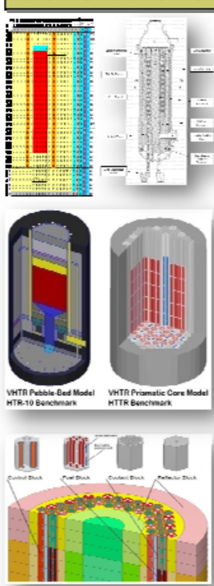
- **Conclusions**



Conclusions



Path forward – FY09 efforts

- MELCOR HTR model assessment
- Assessment and quantification of MELCOR/PARCS coupling architectures
- Assessment and quantification of material data storage and passing options for MELCOR/PARCS coupling architectures
- OECD/NEA PBMR-400 benchmark for selected MELCOR/PARCS coupling architectures

$$PARCS\,/\,PK \xrightarrow[\boxed{\text{MELCOR TH\&PK solvers}}]{\text{PARCS PK}\Rightarrow\text{MELCOR}} MELCOR$$