Development and Implementation of Nuclear Energy Knowledgebase and Simulation Code Validation System

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To leverage M&S in nuclear energy development, building confidence in M&S outcomes is a MUST.

- Modeling and simulation (M&S) to test nuclear energy solutions promise to provide quick and accurate results.
- Benefits in time- and cost-efficiency from M&S are highly desired for nuclear reactor design, analysis, and licensing.

- Reliability of M&S results must always be scrutinized.
- How to effectively build confidence in M&S outcomes remains a great and controversial challenge.
Rigorous methodologies are required for effective verification & validation of nuclear M&S outcomes.

• Despite controversial opinions in how to build the confidence, the following ideas are commonly accepted:
  ➢ Verification and Validation (V&V), along with uncertainty quantification (UQ), is the way to build the desired confidence.
  ➢ V&V and UQ require systematic collection of evidence data.
  ➢ Relations among data and related knowledge are important as well.

• Collecting data and the interrelations is no easy task, managing the collections for V&V process is challenging.
  ➢ An information framework must be developed to ensure reliability, operability, and repeatability of the process.
  ➢ Rigor of the data collecting and managing process must stand the scrutiny for nuclear licensing.

• Systematically organized long-term efforts are required to achieve successful V&V development and operation.
DOE-NE is planning to develop a centralized resource to foster and organize the V&V efforts. (1)

- The Nuclear Energy Knowledge & Validation Center (NEKVAC)

**NEKVAC Objective**

To develop a centralized resource for supporting efforts within DOE-NE to validate multi-physics modeling and simulation (M&S) tools for modern nuclear power plants and fuel cycle analyses.

- H. Gougar
DOE-NE is planning to develop a centralized resource to foster and organize the V&V efforts. (2)

• Each committee is formed by a group of subject matter experts from government, academia, and industry.

• Each committee is responsible for overseeing specific tasks.
  
  ➢ With industry, DOE program, and international partners.
  
  ➢ A nuclear energy knowledgebase and simulation code validation system will be developed under the Portals Development and Operation task.
NE-KAMS is identified as the framework for NEKVAC Portals Development and Operation.

- Initiated a few years ago as a centralized knowledgebase system under the DOE NEAMS Program to support:
  - V&V and UQ requirements for advanced M&S.
  - Data processing and data quality assessment (QA).
  - Knowledge accumulation and information retrieval.

- To provide the ability to collect, document, qualify, structure, format, integrate, and manage all types of data.

- To serve as important resource for:
  - Technical exchange and collaboration.
  - Enabling credible computational M&S for nuclear energy applications.
A plan was created to expand NE-KAMS to support validation development & operation under NEKVac.

Under this plan, NE-KAMS will be further developed into an online knowledgebase and simulation code validation system to provide global resources networking, benchmarking, and operations that support knowledge management and validation of modeling and simulation (M&S) for safe and efficient development of nuclear science and technology.
Strategy and goals are defined to leverage existing resources and develop new validation tools. (1)

- **Strategy:** to maximize the system capacity by creating a central networking component in NE-KAMS.
  - Accessible domestic and international resources of interest can be conveniently found and utilized by NEKVC users.
  - Involve and activate expertise of existing systems to generate synergy in validation development and operation for common interests.

- The system must achieve the following six **goals:**
  1. Become an authoritative networking resource to effectively locate external resources worldwide for simulation validation, information retrieval, and other related activities.
  2. Provide benchmarking capabilities and benchmarks to conduct validation, knowledge accumulation and management, and other related activities.
Strategy and goals are defined to leverage existing resources and develop new validation tools. (2)

• The system must achieve the following goals (con’t):


4. Promote development of software tools and operation protocols for data contribution, information retrieval, and data quality assessment interpretation.

5. Provide an effective venue for domestic and international collaborations in nuclear energy knowledge and simulation code validation development.

6. Establish a platform for fair peer competition along with collaborations among its networked resources to continuously improve the knowledgebase and simulation code validation technologies.
The development will be focused on both the knowledgebase and the knowledgebase system.

- **Data**: Symbols or signs, representing observations or the product of observations.
- **Information**: Data that are endowed with meaning and purpose for the recipient.
- **Knowledge**: Information in a structured form, consistent with human cognitive processes as opposed to simple lists of data items.
- **Knowledgebase**: An organized collection of information in a structured form with maintenance of relations and logic between information elements consistent with human cognitive processes as opposed to simple lists of data items.
- **Knowledgebase System**: Also called knowledgebase management system, a computer software application that interacts with the user, other applications, and the knowledgebase itself to manage knowledge.
As an advanced knowledgebase system, NE-KAMS must possess several desired characteristics. (1)

- **Preserve** and **manage** data at its **lowest meaningful information element levels** so that it can be computationally processed.

<table>
<thead>
<tr>
<th>Preserve and Manage Data at Its Lowest Meaningful Information Element Levels</th>
<th>PDF Format</th>
<th>DOC Format</th>
<th>XLS Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preserve</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Manage</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- Maintain and manage interrelationships between information elements – from document to data point levels.

- **System modularization** for various schema designs to satisfy structural and managerial requirements of different information domains.

**Courtesy of N. Dinh**
As an advanced knowledgebase system, NE-KAMS must possess several desired characteristics. (2)

- Software tools and functionalities for data comparison on various bases such as numbers, charts, and curves.
- Automated data exchange with modeling and simulation software.
- Version control with automatic data evolution designation to track computational and experimental iterations.
- Access control for different ask management and collaboration.
NE-KAMS must develop capacities for validation of both single and multi-physics simulations.

• The current plan is for NE-KAMS to cover the following areas:
  - Thermal hydraulics
  - Reactor physics (neutronics)
  - Reactor structural mechanics
  - Reactor structural materials and irradiation effects
  - Nuclear system chemistry

Figure 2.8. Physics components and multi-physics interactions. Shown for two scales, respectively described by VERA-BL and VERA-AC codes. Lines relate potential sources of validation data. Mapping available experiments and plant data to the validation of multi-physics capability shows the dramatic paucity of validation base. Even for T/H-CC and RT-T/H couplings, where some experiments and plant data are identified, the data quality is such that they are expected to have a limited value in characterizing the coupling. The number of interface models (estimated to be in the order of 10 to 30) and model parameters (estimated to be in the range of 30 to 100) needed to be calibrated in a CIPS multi-physics problem is too large for a limited number of available tests and the scope of the test data.
In developing the knowledgebase system, two portals will be created to achieve the six goals.

- The existing NE-KAMS will be split into the **Resource Portal** and the **Validation Portal** for further development.
- The **Resource Portal** will strive for Goal 1 to establish an authoritative networking resource.
- The **Validation Portal** will strive for Goal 2 – 5 to support knowledge management and validation development.
- The **two portals together** will reach for Goal 6 to provide a platform for fair peer competition and collaborations to continuously improve the knowledgebase and simulation code validation technologies.
To meet short- and long-term requirements, two conceptual sections will be developed for efficiency.

- **Data File Warehouse and Relational Digital Database.**
  - Data File Warehouse with semantic storage systems.
  - Relational Digital Database with knowledge-based tools.

- **Data File Warehouse** mainly for short-term requirements.
  - Quickly archive original data files of different types and formats for convenient retrieval.

- **Relational Digital Database** mainly for long-term requirements.
  - Efficiently manage data in various digitized information elements and interrelationships.

- **Enabled piecewise growth.**
  - Ensure quality of each development step.
  - Adaptable to funding fluctuations with persistent operation and growth.
The Resource Portal is planned to leverage existing and new resources for V&V development.

The system is modularized with components in a hierarchical order of database, compartment/table, folder, record, heading, and attribute with a network of hypertext links managing the interrelationships.

- **Validation Resources:**
  - Resource networking.
- **Terminology Definitions:**
  - Definition and thesaurus.
- **Operation Instructions:**
  - Help menu for built-in tools.
- **NEKVAC Documents:**
  - Operation documentation.
- **Technical Issues:**
  - Issues identified for solutions.
- **R&D Projects:**
  - NEKVAC project management.
- **User Registrations:**
  - User and access management.
The Validation Portal is planned to facilitate V&V methodology development and operation.

- **Test Data Files:**
  - Electronic files of test data.

- **Experiment Definition:**
  - Experiment methods.

- **Experiment Unit Files:**
  - Experiment facilities.

- **Material Property Files:**
  - Experiment materials.

- **Fluid Property Files:**
  - Experiment fluids.

- **R&D Reports:**
  - R&D result reports.

- **Information Permits:**
  - Data use permits.

- **Quality Assessment:**
  - Data quality documentation.

- **Quality Assurance:**
  - Quality assurance documentation.
To achieve cost-efficiency, the Resource Portal is leveraged to maintain backup through networking.

- Over decades of operation, something might go wrong to result in data loss.
  - Fire, flood, earthquake, lightning strike, or terrorist attack.
- A reliable backup system is required to prevent data loss.
  - A common practice: a second system at least 60 miles away from the main system’s location.
  - High consequent cost and managerial effort.
- An alternative approach:
  - Networked distant database systems as the data preservation backup.
  - The distant systems may not have the advanced tools but should be able to preserve data files as backup.
In FY16, a small case study has been initiated to investigate feasibility of the planned approaches.

- **Task 1:** Evaluate a representative CASL dataset to analyze the data structure of its specific information domain.
  - Develop an ontological understanding of its fundamental variables and interrelationships for custom design of effective knowledgebase schema.

- **Task 2:** Enhance design of the NE-KAMS schema based on Task 1 results.
  - Strive for effective management of the representative dataset.

- **Task 3:** Revise the existing NE-KAMS structure based on the enhanced design from Task 2.

- **Task 4:** Upload the representative dataset and conduct testing operations.
  - Identify structural and functional issues and problems.
  - Refine the schema, and repeat the process until satisfactory results are achieved.
Summary

• To ensure consistent V&V development and operation, an advanced knowledgebase system must be established.

• To support long-term V&V development and operation for nuclear energy modeling and simulation, ORNL has developed a “Nuclear Energy Knowledgebase and Simulation Code Validation System Development and Implementation Plan” for DOE-NE.

• A network will evolve under the plan to include resources and expertise worldwide from governments, academia, and industries for collaborations in V&V development and operation.
Acknowledgments

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QUESTIONS?