Call for Research Proposals for participation in the New Coordinated Research Project (CRP) sponsored by the International Atomic Energy Agency (IAEA)

<< Advancing the State-of-Practice in Uncertainty and Sensitivity Methodologies for Severe Accident Analysis in Water Cooled Reactors >>

<< **I31033**>>

Summary of the CRP

This CRP was recently approved and will be implemented by the Division of Nuclear Power, Nuclear Power Technology Development Section (NPTDS).

The objective of this CRP is to advance the understanding and characterization of sources of uncertainty and their effects on the key figure-of-merit (FOM) predictions in severe accident codes for water cooled reactors (WCRs). The severe accident codes embody complex multi-discipline physics spanning a variety of phenomena that can often be outside of the users' range of experience and competency. Equally, the code users are sometimes unsure about the correctness or accuracy of their nuclear power plant accident analyses and/or not aware of the importance or impact of uncertainty and variability on predicted code results. Therefore, this CRP is aimed at improving the state of practice in severe accident analyses by examining and characterizing the impact of uncertainty and variability on severe accident analyses. Various widely used severe accident codes (eg. MELCOR, MAAP, ASTEC, etc) will be used to evaluate model form uncertainty by benchmarking them against each other. Monte Carlo sampling methods will be used to assess state-of-knowledge and stochastic sources of uncertainty and narrowed/biased parameter distributions will be used to identify bifurcations. An initial important Phenomena Identification and Ranking Table (PIRT) process for selected accident sequences (benchmark cases) will be essential to determine those uncertain code inputs (and their likelihood distributions) with the largest effect on predicted code results for key FOMs, based on expert elicitation from participating members. Random sampling methods of these input parameter distributions will generate populations of code inputs for these selected accident sequences and, through code calculations, distributions of predicted key FOM. (Example FOMs include in-vessel hydrogen generation or fission product release to containment or environment.) The resultant distributions of FOMs characterize the overall uncertainty of severe accident code predictions for these selected accident sequences.

This CRP will bring together experts from the Member States with water cooled reactor technologies experienced in developing and using the severe accident codes to further advance the state-of-knowledge on uncertainty propagation in severe accident analyses. The newly developed knowledge will be shared with developing MSs through various activities: support of their PhD students, participation in training workshops, and participation in benchmark examples.

Duration

5 years

Expected starting date: 10-2019

Background Situation Analysis

Since the accident at Three Mile Island Unit 2 (TMI-2), severe accident codes have been developed to address the significant lack of understanding of what happened in that accident. The degraded core accident at TMI-2 that reached conditions more severe than design basis accidents prompted new initiatives and subsequent reevaluation of regulatory processes. The United States Nuclear Regulatory Commission (USNRC) initiated, on 2 October 1980, a "long-term rulemaking to consider to what extent, if any, nuclear power plants should be designed to deal effectively with degraded core and core melt accidents" (USNRC, October 2, 1980). The Fukushima accidents stressed the necessity to extend the focus of international R&D efforts also to containment phenomena impacting the source term to the environment (including aerosol and core melt behavior in the containment, risk of combustible gas mixtures, etc.).

One of the first attempts to model the at-the-time poorly understood phenomena and the way that these phenomena interact in the entire system was the Source Term Code Package (STCP). This code was in fact a loosely and explicitly coupled set of individual codes that modeled separate regimes of a severe accident. Feedback between phenomena was largely not treated in any implicit sense. In response to this early attempt at modelling severe accident progression, the MELCOR code project and the MAAP code development were initiated in the United States in the early 1980's by the USNRC and the Industry Degraded Core Rulemaking (IDCOR) programme, respectively. These codes were among the first fully integrated codes applied to severe accident analysis. The codes represented a significant advance over the STCP in that phenomena occurring within the plant accident progression were coupled to account for the decrease in fuel decay as fission products are released from the fuel for example. Following the development of MELCOR and MAAP, other countries initiated other similar integrated code development projects including the ASTEC, ATHLET/CD, SOCRAT in Europe, and more recently the SAMPSON code in Japan.

In the decades following the TMI-2 accident the codes were used largely in what is commonly termed a deterministic mode where single representative accidents were modeled to represent classes of accident such as unrecovered large and small break loss of coolant accidents (LOCA's) or station blackout (SBO). During this time the analyses performed with these tools were computationally intensive calculations carried out on much slower computers with much lower memory in comparison to nowadays modern computational platforms. Uncertainty in the operative physics/phenomena and the stochastic aspects of accident conditions in these types of analyses was known to exist but onerous to quantify. For this reason, the deterministic analyses were often biased conservatively in hopes of producing a bounding calculational result which could be compared to the requirements such as for example public exposure limits. The NUREG-1150 study included in the probabilistic risk assessment methodology some estimation of uncertainty in severe accident progression but made heavy use of expert elicitation to estimate uncertainty in key figures of merit such as percent of core metal oxidized. Code analyses were largely impractical at the time of the NUREG-1150 project. Code stability and execution failures were also significant impediments to producing large numbers of analyses that might express the variability in predicted outcomes.

In ensuing years as the severe accident codes improved in robustness and runtime efficiency and as computational platforms significantly increased in speed, sampling-based uncertainty studies began to emerge using sampling methodologies embodied in statistical tools such as DAKOTA, SUSA, SUNSET and MELCOR-Uncertainty Engine. These tools allowed the uncertainties in an analysis to be expressed in terms of variability in the code input and boundary conditions that could be "propagated" through the severe accident analysis producing an ensemble of "answers" from which probability distributions instead of single realization point values. In this way a likelihood distribution of accident figures of merit is obtained that give indications of mean values, central tendencies and dispersion in the answers. Early analyses were heroic owing to the computational challenges and machine limitations.

These days, the codes are significantly more robust and computational platforms are vastly faster in execution and thanks to massively parallel computational resources with thousands of individually addressable processors, sampling-based for these selected accident sequences uncertainty methods are now easily within reach of severe accident analysis efforts. Examples of this include recent uncertainty analysis studies performed by the USNRC and Sandia National Laboratories in the State of Art Reactor Consequence Analyses (SOARCA). Likewise, other uncertainty and sensitivity analysis demonstrations have been accomplished by ASTEC and RELAP/SCDAPSIM on evaluation of the QUENCH-3 and QUENCH-6 experiments.

Scope of the CRP

This CRP will bring together the current state-of-knowledge on uncertainty propagation in severe accident analyses that has been accumulated by experienced analysts with the aim of increasing the sophistication and competency of the practitioners in this field:

- Achieve significant improvement in sophistication and quality of severe accident analyses performed by the participants from Member States with well developed knowledge, adequate simulation capabilities (both software and hardware) and long years of relevant practice

- Enable objective peer review of the benchmark studies with various codes by the participating Member States and thus lead to new knowledge and sharing of research results relevant to evaluation of uncertainties in severe accident analyses

- Foster national excellence and international cooperation through an exercise to elevate the capability and sophistication of global severe accident code users

- Promote sharing of newly developed knowledge and contribute to capacity building in developing countries

Participants in the CRP are expected to have active programmes on severe accidents code development, code uses and benchmark and experimental capabilities. As part of the research proposal, the attached questionnaire must be completed and attached to the research proposal.

This IAEA CRP is coordinated with other parallel international activities to avoid duplication and provide synergies to advance the state-of-the art and widen the knowledge base on severe accident analysis and treatment of uncertainties.

CRP Specific Research Objectives

1) Review of the advancement in methodologies used for uncertainty and sensitivity analysis for severe accident codes across participating Member States

2) Define high level recommendations on uncertainty and sensitivity analysis and methods for severe accident codes with the intent of capturing best practices and lessons learned

3) Training of early-career engineers and scientists, and establishing opportunities for PhD dissertations; develop and conduct workshops and training and education courses on the CRP topical areas

Activities (to be undertaken by the participants)

A) Submission and evaluation of research proposals: 31 May 2019

B) Documentation of in-house expertise and experience 30 September 2019

   - Status and scope of existing severe accident codes used/developed/under development

- Description of uncertainty and sensitivity methods used in severe accident code analyses
- Description of gaps and challenges in severe accident codes development/use and analyses of uncertainty in input parameters
- Etc.

C) Develop initial descriptions of quantitative exercise(s) — 30 September 2019

- Severe accident WCRs model and relevant initiating events
- Discussion on common issues in propagation of severe accident modeling
- Discussion on key uncertain parameters and phenomena
- Etc.

D) Participation in 1st Research Coordination Meeting (RCM): — 14–17 October 2019

E) Develop the PhD thesis programme — October 2020

F) Implement the PhD programme in developing MSs — from January 2021

G) Participation in 2nd RCM — October 2020

H) Develop and agree on the benchmark exercise — October 2020

I) Participation in 3rd RCM — October 2021

J) Submission of benchmark results — 30 September 2021

K) Participation in 4th RCM — October 2022

L) Submission of methods for uncertainty and sensitivity analyses — 30 September 2022

M) Develop and conduct training workshops — 2022, 2023

N) Written submissions to Final Report (TECDOC, NES) — 2022, 2023

O) Technical review of Final Report (TECDOC, NES) — January 2023

CRP Outputs

- IAEA NES on state of practice with lessons learned on best practices in uncertainty and sensitivity methodologies for the severe accidents analyses in WCRs
- IAEA TECDOC on uncertainty methods and tools for severe accidents codes with relevant benchmark results
- Relevant training workshops and courses and supporting lecture materials to be published as the IAEA Training Series Documentations
- Publications in conference proceedings and peer reviewed journals
- PhD training programme to strengthen promotion of research on severe accidents simulation and modelling in developing Member States through pair building between agreement holders and contract holders institutes

CRP Outcomes

- Improve capabilities and expertise in Member States to perform state-of-the-art uncertainty and sensitivity analysis with severe accident codes
- More defensible application of severe accident codes
- Establish best practise for uncertainty and sensitivity analyses in the realm of severe accident analysis
- Increase depth and breadth of severe accident analysis and uncertainty/sensitivity analysis using integral severe accident codes by Member States

- Elevate ability and sophistication of global severe accident code users with improved characterization of the effect of various sources of uncertainty and variability in the predictive output of relevant codes for advanced WCRs
- Foster a common understanding of uncertainty and sensitivity methodologies and tools among Member States

Funding

The IAEA will contribute €3000 per year towards each contract and support financially the attendance of CRP participants that have made substantial contributions (through contract or agreement) in the four research coordination meetings (RCM) planned to be held during the CRP lifetime.

Application Procedures

Interested scientists should submit their research contract or research agreement proposal that cover part(s) or all of the scope of the CRP, along with the completed questionnaire attached (*the scope of the coverage of a proposal is to be determined by the Project Officer after evaluating the proposal and the capacity of the scientist(s) involved and the capability of the institute)*. The standard research contract/agreement proposal form is available at http://cra.iaea.org/cra/forms.html.

Research proposals should be submitted by email to Official.Mail@iaea.org by 31 May 2019.

Any administrative question should be addressed to the Research Contracts Administration Section (NACA) via research.contracts@iaea.org.

Technical enquiries should be addressed to the project officer for this CRP, Ms Tatjana Jevremovic (T.Jevremovic@iaea.org).

Further general information relating to the participation in CRPs and the Coordinated Research Activities in general is available on http://cra.iaea.org.

Questionnaire on the Status and Prerequisites Related to Severe Accidents Simulations in WCRs and Uncertainties and Sensitivity Analyses

No.	Question	Your Answer	Comments
1	**Country**		
2	Name of applicant(s) and organization wishing to participate in the CRP		One person must be designated as “Chief Scientific Investigator (CSI)”, plus one (optional) Alternate.
3	Organization, which develops the severe accidents codes Or Organization that has proven record of the application and use of severe accident codes		
4	Other organizations involved in the development and/or application of severe accident codes		
5	**Severe accident codes developed**		Brief description (name, version) plus list of relevant publications
6	**Severe accident codes in use**		Brief description (name, version) plus list of relevant publications
7	**WCR severe accident scenarios modeled** List the most relevant journal publications in last 5 years		Brief description of reactor type(s) and scenario(s) plus list of relevant publications
8	**Codes used to model Fukushima accident** List the most relevant journal publications and/or reports in last 5 years		Brief description (name, version) plus list of relevant publications

No.	Question	Your Answer	Comments
9	**Methods used for uncertainty assessment in severe accident OR in other analyses** List the most relevant journal publications and/or reports in last 5 years		Brief description plus list of relevant publications
10	**Involvement in related international or national projects**		Brief description plus relevant publications or websites
11	Access to or possession of experimental facilities providing data of interest to the scope of this CRP List the most relevant journal publications and/or reports in last 5 years		Please specify the facilities and data generated as well as the level of sharing the data within the scope of this CRP
12	Please provide any additional information, which you consider helpful or important in the context of your related activities within the scope of the CRP		