**PROJECT ARRANGEMENT NE-04**

**between**
**The Department of Energy of the United States of America and**
**The Ministry of Economy, Trade and Industry of Japan**
**under the**
**Implementing Arrangement between the Department of Energy of the United States of America and the Ministry of Economy, Trade and Industry of Japan Concerning Cooperation in the Field of Nuclear Energy-Related Research and Development**
**for**
**Cooperation on Light-Water Reactor Research and Development**

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## 1. Objective

The Department of Energy of the United States of America and, the Ministry of Economy, Trade and Industry of Japan referred to collectively herein as "Participants",

Acting in accordance with Sections 4 and 5 of the "Implementing Arrangement between the Department of Energy of the United States of America and the Ministry of Economy, Trade and Industry of Japan Concerning Cooperation in the Field of Nuclear Energy-Related Research and Development" of May 3, 2013 (hereinafter referred to as the "Implementing Arrangement"),

Have decided to undertake a cooperative effort under this Project Arrangement to perform light-water reactor research and development.

## 2. Scope of Work

The scope of work under this Project Arrangement is:
(1) Severe Accident Code Assessment
(2) Probabilistic Risk Assessment

## 3. Project Management

3.1 Each Participant will designate a Project Coordinator and a Principal Technical Contact. The Project Coordinators will be responsible for detailed management, including technical progress reviews, of the cooperation under this Project Arrangement. The Principal Technical Contacts will serve as the points of contact concerning technical details.

3.2 The specific tasks to be conducted are identified in Appendix I and key personnel are identified in Appendix II of this Project Arrangement. Both Appendix I and Appendix II will be updated as appropriate.

## 4. Financial Management

All costs resulting from the work carried out under this Project Arrangement will be the responsibility of the Participant that incurs them. The ability of the Participants to carry out their specific tasks is subject to the availability of appropriated funds.

## 5. Intellectual Property

With respect to the protection and distribution of intellectual property rights and other rights of a proprietary nature created or furnished in the course of the cooperative activities under this Project Arrangement and the protection of business-confidential information exchanged under this Project Arrangement, the following paragraphs will apply in addition to the paragraphs of the Intellectual Property Annex to the Implementing Arrangement:

5.1 Inventions

For the purpose of this Project Arrangement, "Invention" means any invention made in the course of the cooperative activities under this Project Arrangement which is or may be patentable or otherwise protectable under the laws of the United States of America, Japan, or any third country.
In accordance with paragraph 3.B.(iii)(a) of the Intellectual Property Annex to the Implementing Arrangement, rights to an Invention made as a result of joint research conducted under this Project Arrangement, and allocation of benefits derived therefrom, are provided as follows:

- If an Invention is made solely by a Participant or a contractor (hereinafter referred to as the "Inventor"), the Inventor will obtain all right, title and interest in and to such Invention in all countries.
- If an Invention is made jointly by a Participant/contractor of both Participants, each Participant will obtain all right, title and interest in and to such Invention in its own country. In third countries where both Participants intend to obtain the right to the Invention, the Participants will be joint owners of such rights. The Participants may jointly apply to obtain and/or maintain the relevant rights. The Participants should come to an agreement concerning the costs associated with obtaining and/or maintaining such rights.
- In any country where the Inventor which is entitled to obtain the rights therein decides not to obtain such rights and interests, the other Participant has the right to do so.
- Each Participant will have, in its own country, for its own research and development activities within the scope of work of this Project Arrangement, during the term of this Project Arrangement, a free right of use of Inventions, whether protected or not by intellectual property rights, solely owned by the other Participant and resulting from the joint research performed under this Project Arrangement.

5.2 Copyright

Allocation of rights to an Invention and benefits derived therefrom stipulated in paragraph 5.1 above will be applied *mutatis mutandis* to disposition of rights to copyrighted works created in the course of the cooperative activities conducted under this Project Arrangement.

## 6. General Consideration

This Project Arrangement is pursuant to and subject to the Implementing Arrangement, which is, in turn, pursuant to and subject to the agreement between the Government of the United States of America and the Government of Japan concerning cooperation in the field of nuclear-related research and development, effected by the Exchange of Notes of March 9, 2012.

## 7. Commencement, Modification, and Discontinuation

7.1 This Project Arrangement will enter into effect upon signature by both Participants, continue for a three (3) year period, unless earlier discontinued in accordance with paragraph 7.2, and may be extended or modified by the Participants' mutual written consent, provided that the Implementing Arrangement remains in effect.

7.2 This Project Arrangement may be discontinued at any time by the Participants' mutual consent in writing. Alternatively, a Participant that wishes to discontinue its participation in this Project Arrangement should endeavor to provide at least sixty (60) days advance notification in writing to the other Participant.

Signed in duplicate.

FOR THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA:

Signature: John E Kelly

Name: John E. Kelly,

Title: Deputy Assistant Secretary for Nuclear Reactor Technologies

Date: Feb 20, 2014

Place: Tokyo

FOR THE MINISTRY OF ECONOMY, TRADE AND INDUSTRY OF JAPAN:

Signature:

Name: Hirobumi Kayama

Title: Director, Office for International Nuclear Energy Cooperation, Agency for Natural Resources and Energy

Date: Feb. 20, 2014

Place: Tokyo

## PROJECT ARRANGEMENT NE-04

## APPENDIX I-1
## Description of Tasks for Severe Accident Code Assessment

### 1. Outline and Responsibility of Tasks

The objective of the Severe Accident Code Assessment activity is to leverage ongoing and emerging programs in the United States and Japan related to lessons learned from the Fukushima accidents and advancing the state of knowledge with respect to severe accidents. In the United States, principal activities center around developing a better understanding of the accidents in the Fukushima reactors and assessing present modeling capabilities in this area. In Japan, similar research is ongoing, in addition to the development of the SAMPSON code. This cooperation presents a significant opportunity for data/information sharing that will be beneficial to both Fukushima decommissioning activities, through developing greater insights into the damaged reactors, and future operation of nuclear power plants through advances in knowledge and modeling of severe accidents.

The scope of work under the Severe Accident Code Assessment activity is as follows:

Task 1: Cooperative assessment of the accidents at Fukushima through comparison of predictions by the MELCOR and SAMPSON codes, as well as other accident analysis activities. This activity will involve both independent analyses performed by each Participant as well as shared analysis activities such as peer-review and cooperative development of modeling best practices.

Task 2: Model enhancement of MAAP and SAMPSON, and analyses of accident progression of Fukushima Daiichi NPP.

Task 3: Fundamental experiments on (1) sea water effect and (2) on debris behavior in BWR lower plenum.

Task 4: Hydrogen explosion analyses for Fukushima Daiichi NPP and experiments for phenomena which were specific to the Fukushima Daiichi NPP accident for code validation

### Task 1: Cooperative Assessment of the Accidents at Fukushima and Shared Development of Uncertainties and Best Modeling Practices

- Subtask 1.1. MELCOR uncertainty analysis on Fukushima Daiichi NPP: This activity will involve the development of uncertain modeling and parameter code inputs with distributions to be used in a Monte-Carlo uncertainty analysis. The majority of this work will be performed by DOE and its laboratories in terms of MELCOR code executions, but input parameter uncertainties will be jointly developed and reviewed by both Participants. The activities under this subtask will benefit both the United States and Japan by the mutual sharing of knowledge concerning best severe accident modeling practices.

- Subtask 1.2. MELCOR analysis of Fukushima Daini, including effectiveness of emergency procedure, and experiment of emergency equipment

    - Subtask 1.2.1. MELCOR analysis of Fukushima Daini: Reactors at Daini were significantly challenged by loss of critical systems. While core damage was avoided in the Daini reactors, important safety systems were challenged. It is equally important for severe accident codes to be able to faithfully replicate the success paths, in order to have greater confidence in the application of measurement guidelines. This activity will consider the SAMPSON modeling of suppression pool thermal stratification and mixing performed by Japan under subtask 2.1.

    - Subtask 1.2.2. Experimental activities of emergency equipment: RCIC stream-driven turbine and safety relief valves are based mostly on design basis conditions. Their performance under severe accident conditions is poorly known and largely based on conservative assumptions. Large-scale testing could provide world-class testing capability to evaluate real-world response of critical equipment: SRVs, RCIC, seal performance, pump seal failures, piping ruptures. This activity will provide critical information on real-world performance of critical safety equipment, useful to MELCOR, MAAP and SAMPSON, needed for advancing accident management practices.

**Task 2: Model enhancement of MAAP and SAMPSON, and analyses of accident progression of Fukushima Daiichi NPP**

- Subtask 2.1. MAAP code improvement: Development of improved models for the main drawbacks identified by latest MAAP5 version. New models focus on: core support region, lower plenum for molten fuel relocation, fuel spreading and interaction with concrete in the pedestal region. Finally, more detailed subdivision of suppression chamber will be developed. Accident progressions in Fukushima Daiichi NPP Units 1-3 will be analyzed with the improved MAAP code. Critical comparisons of MELCOR, MAAP and SAMPSON predictions will help clarify severe accident modeling uncertainties and areas where improvement in phenomenological understanding is needed and can be gained. The MELCOR/MAAP crosswalk activity currently underway in the United States is expected to provide valuable insights for this activity.

- Subtask 2.2. SAMPSON code improvement: Improvement of physical models and testing of geometrical inputs. Geometrical inputs regard core and core region structures description in the code. New models include: steel oxidation, lower plenum design, ex-vessel corium interactions. SAMPSON activity will gain advantage from funded fundamental experiments and detailed computational fluid dynamics simulations. Accident progressions in Fukushima Daiichi NPP Units 1-3 will be analyzed with the improved SAMPSON code. Critical comparisons of MELCOR, MAAP and SAMPSON

predictions will help clarify severe accident modeling uncertainties and areas where improvement in phenomenological understanding are needed and can be gained.

**Task 3: Fundamental experiments on (1) sea water effect and (2) on debris behavior in BWR lower plenum with simulant**

- Subtask 3.1. Sea water effect: Investigation of sea water effect on the reactor core cooling capabilities during alternative water injection. Experiments will be performed for heat transfer modalities, corrosion process, and structure interactions in the core region. MELCOR, MAAP and SAMPSON codes can benefit from expanded understanding of the implications of emergency use of raw water to cool the reactor fuel. The impact of material deposits on fuel rods and grid spacers and their influence on heat transfer and fuel coolability can be assessed by this activity.

- Subtask 3.2. Debris behavior in BWR lower plenum: Investigation of detailed phenomena of debris falling into the lower plenum. Experiments will be performed with a simulant. Main points aimed to be learned are behavior of debris dispersion, adhesion of debris particles on the Control Rod Drive and In Core Monitor housings, and composition of debris bed on the floor. All codes can benefit from advances in phenomenological processes investigated under this task. Code comparison activities can inform data needs.

**Task 4: Hydrogen explosion analyses for Fukushima Daiichi NPP and experiments for phenomena which were specific to Fukushima Daiichi NPP accident for code validation**

These activities will provide needed improvements in practical modeling aspects of hydrogen transport, mixing and combustion, building on a large previously existing database of hydrogen combustion behavior. Specifically, these tasks will provide a basis for evaluating the current modeling practices with severe accident analysis codes regarding compartmentalization and nodalization in order to capture essential mixing and combustion behavior.

- Subtask 4.1. Computational Fluid Dynamic (CFD) analysis of hydrogen explosion: Hydrogen explosions at units 1 and 3 are one of the major consequences of the severe accidents at the Fukushima Daiichi NPP. Explosions caused light fission products spreading, soil contamination, and possibly disrupted containment integrity. Detailed computational analyses are now possible, providing capability to quantify source terms for light fission products spreading, stress on buildings, and new in-plant safety systems design. An important outcome of this work will be an assessment of the ability of severe accident analysis codes to model significant combustion events, important to MELCOR, MAAP and SAMPSON.

- Subtask 4.2. Experimental activity: Modalities of vessel and control rod tubes failure in BWRs are still today not clearly known. As a consequence, occurrence of reactor pressure vessel failure in Fukushima Daiichi units 1, 2 and 3 is still not directly confirmed. In addition, while fission products scrubbing knowledge in the suppression pool is based on design basis conditions, in all units measured quantities differed widely from expected values. For such problems integral experiments, employing reactor materials and real scale facilities, will provide insights on unknown critical phenomena necessary to support decommissioning activities. Severe accident analysis codes will benefit from these experimental activities that provide data for improved model development and validation.

2. **Sites**

The tasks will be conducted at:

1. Sandia National Laboratory
2. Institute of Applied Energy

3. **Schedule**

| | | 2013 CY* | 2014CY | | | | 2015CY | | | | 2016CY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity | | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Task 1 | MELCOR uncertainty analysis | | | X | X | X | | | | | | | | |
| | MELCOR Daini Analysis | | | | | | X | X | X | X | | | | |
| | Critical Equipment Function Testing | | | | | | | | | | X | X | X | X |
| Task 2 | MAAP code improvement | | X | X | X | X | X | X | X | X | X | X | X | X |
| | SAMPSON code improvement | | X | X | X | X | X | X | X | X | X | X | X | X |
| Task 3 | Investigation of sea water effects | | X | X | X | X | X | X | X | X | X | X | X | X |
| | Investigation of debris effects | | X | X | X | X | X | X | X | X | X | X | X | X |
| Task 4 | CFD analysis of hydrogen explosion | | | | | | | X | X | X | X | X | X | X |
| | Modalities of vessel and control rod tubes failure in BWRs | | | | | | | X | X | X | X | X | X | X |

* "CY" is Calendar Year, Q1: January-March, Q2: April-June, Q3: July-September, Q4: October-December

## 4. Deliverables

The exchanged data under this activity will be used by the Participants to support the future research described in the task. Data exchanged meetings will be conducted on a semi-annual basis as bilateral meetings. Pre-published data may be exchanged to help in ongoing research by the Participants.

**PROJECT ARRANGEMENT NE-04**

**APPENDIX II-1**
**Key Personnel List**

**U.S. Department of Energy**

**1. DOE Headquarters**

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**2. National Laboratories**

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**Ministry of Economy, Trade and Industry**

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**PROJECT ARRANGEMENT NE-04**

**APPENDIX I-2**
**Description of Tasks for Probabilistic Risk Assessment**

## 1. Outline and Responsibility of Tasks

The U.S. has seen a growing use of probabilistic risk assessment (PRA) tools and technologies in nuclear power plant (NPP) applications over the last three decades. Comprehensive use of risk information has become one of the key means for U.S. nuclear power plants to improve overall reactor safety. Japan is exploring means to better apply PRA techniques. The objective of this collaboration is to help initiate the expansion of the application of PRA methodologies to plant operations, maintenance, and decision-making in Japan through a roundtable of U.S. and Japanese experts in PRA applications. Participation in this roundtable by U.S. nuclear industry experts and U.S. industry's subsequent support of Japan's efforts would facilitate successful expansion of the use of risk management in Japan It is expected that this effort will be informed by U.S. experience in encouraging the acceptance and application of risk insights to managing nuclear safety, by both industry and its regulator.

The scope of work under the Probabilistic Risk Assessment activity is as follows:

**Task 1: Participate in a PRA experts roundtable wherein U.S. participants discuss how PRA is applied in the U.S. and the resulting benefits and Japanese participants discuss the issues associated with PRA application in Japan.**

## 2. Schedule

| | | 2013 CY | 2014CY | | | | 2015CY | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Activity | | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Task 1 | | | X | | | | | | | |

CY" is Calendar Year, Q1: January-March, Q2: April-June, Q3: July-September, Q4: October-December

## 3. Deliverables

Specific deliverables will be identified during the early phase of the collaboration. The exchanged data under this activity will be used by the Participants to support the future research described in the tasks. Data exchange meetings will be conducted on a annual basis as bilateral meetings. Pre-published data may be exchanged to help in ongoing research by the Participants.

**PROJECT ARRANGEMENT NE-04**

**APPENDIX II-2**

**Key Personnel List**

**U.S. Department of Energy**

**1. DOE Headquarters**

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**2. National Laboratories**

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