IAEA Activities in the Advanced LWR Project of Interest to SMRs: ARIS, Training Simulators and Reactor Technology Assessment

T. Jevremovic, Matthias Krause
IAEA - NPTDS

2nd Meeting of the Technical Working Group for Small and Medium-sized or Modular Reactor (TWG-SMR)
8-11 July 2019
1. WCR Team Activities
2. Data Bases: ARIS, THERPRO
3. Educational Simulators and eLearning Modules
4. Reactor Technology Assessment
5. Summary and Outlook
1. WCR Team Activities
2. Data Bases: ARIS, THERPRO
3. Educational Simulators and eLearning Modules
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5. Summary and Outlook
2019 WCR Team Members

Technology Development for Advanced Reactor Lines

GCR

MSRs

SMR

Fast Reactors

NEApp

WCR

Interns

Staff

https://www.iaea.org/topics/water-cooled-reactors
Modelling & Simulations

Development of Methodologies

Education & Training

Data Bases & Educational Toolkits

Technology Support Safety Systems

Technology development for water cooled reactors

Knowledge Preservation

International Cooperation and Information Exchange
Water Cooled Reactors: Key Activities

**Information Exchange**
- Technical Meetings and publications on topics of programme mandate
- ARIS and THERPRO data bases
- CRPs and publications
- Education courses and corresponding course booklets with hands-on exercises and train-the-trainer approach to human capacity development in Member States

**Knowledge Preservation**
- PC based basic principle simulators learning dais
- Education courses booklets for standardized teaching and instructions on learning-by-doing practices with simulators
- 10 PC based basic principle simulators in supporting education and training courses on physics and technology of WCRs in Member States
- Joint ICTP-IAEA Courses on Scientific Novelties in the Phenomenology of Severe Accidents in Water Cooled Reactors
- eLearning tools

**Education and Training**
- CRPs on simulation codes for NPP designs and severe accidents
- Technical Meetings on severe accidents modelling and simulations codes, spent fuel pools and SAMG-D toolkit
- Joint ICTP-IAEA Courses on Scientific Novelties in the Phenomenology of Severe Accidents in Water Cooled Reactors
- eLearning tools

**Modelling and Simulations**
- CRPs on SCWRs technology development, multi-unit PSA, pipe failure rates estimates for advanced WCRs…

**Technology Support**
- CRPs on SCWRs technology development, multi-unit PSA, pipe failure rates estimates for advanced WCRs…

**Development of Methodologies**
- Reactor Technology Assessment (RTA): Toolkit, interregional and national workshops and training courses, new NES
1. WCR Team Activities

2. Data Bases: ARIS, THERPRO

3. Educational Simulators and eLearning Modules

4. Reactor Technology Assessment

5. Summary and Outlook
What is ARIS?

https://aris.iaea.org/
General Scope of Information

The IAEA Advanced Reactors Information System (ARIS)

Member States interested in having ready access to the most up-to-date information about all available NPP designs, and important development trends.

ARIS is web-accessible database that provides balanced, comprehensive and up-to-date information about advanced NPP designs and concepts: reactors of all sizes and all types from evolutionary NPPs for near term deployment, to innovative concepts still under development.
The Database on Advanced Nuclear Power Reactors

The Advanced Reactor Information System (ARIS) is a database designed and maintained by the IAEA’s Nuclear Power Technology Development Section (NPTDS) since 2009. The most important content of ARIS are the design descriptions of evolutionary and innovative advanced nuclear reactors. ARIS enables users to easily get an overview of the current reactor technologies being developed and deployed by giving people access to the designers’ design descriptions. Read more »

Future of Nuclear Power

The IAEA anticipates that the global demand for electricity will continue to increase as a result of economic development aspirations and energy security concerns, and that expansion of nuclear power will continue at a slow but steady pace particularly in Asia and the Middle East.

Advanced Designs

The ARIS database includes technical information about Advanced Reactor Designs that is provided by the responsible design organizations and/or reactor plant vendors. According to the definitions established by the IAEA, an advanced reactor design consists of both Evolutionary and Innovative reactor technologies. Evolutionary reactor designs are reactor designs that improve on existing designs through small or moderate modifications with a strong emphasis on maintaining proven design features to minimize technological risk. While innovative reactor designs incorporate radical changes in the use of materials and/or fuels, operating environments and conditions, and system configurations. Advanced reactors can be classified in terms of coolant, neutron spectrum, temperature or purpose. With regards to purpose, the reactors can be sorted in terms of experimental, demonstration or prototype, and commercial.
## 40 SMR Designs in ARIS Database

### Advanced Reactors Information System (ARIS)

**Overview**
- **Type**: All, PWR, BWR, HWR, SCWR, IPWR, GCR, GFR, SFR, LFR, MSR, FR, SMR
- **Country**: All, Canada, China, EU, France, India, Japan, Rep. of Korea, Russia, USA, Other
- **Status**: All, On Hold, Under Design, Licensed, Construction, In Operation
- **Purpose**: All, Commercial, Demonstration, Experimental, Prototype

### Design Details

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full name</th>
<th>Design Org.</th>
<th>Coolant</th>
<th>Moderator</th>
<th>Design Status</th>
<th>Country</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>4S</td>
<td>Super-Safe, Small and Simple Reactor</td>
<td>Toshiba</td>
<td>Sodium</td>
<td>No Moderator</td>
<td>Under Design</td>
<td>Japan</td>
<td>SFR</td>
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<tr>
<td>AHWR</td>
<td>Advanced Heavy Water Reactor</td>
<td>BARC</td>
<td>Light Water</td>
<td>Heavy Water</td>
<td>Under Design</td>
<td>India</td>
<td>HWR</td>
</tr>
<tr>
<td>ALFRED</td>
<td>Advanced Lead Fast Reactor European Demonstrator</td>
<td>Ansaldo Nucleare</td>
<td>Lead</td>
<td>No Moderator</td>
<td>Under Design</td>
<td>EU</td>
<td>LFR</td>
</tr>
<tr>
<td>ALLEGRO</td>
<td>Alpine</td>
<td>EURATOM</td>
<td>Holmium</td>
<td>No Moderator</td>
<td>Under Design</td>
<td>EU</td>
<td>GFR</td>
</tr>
<tr>
<td>ASTRID</td>
<td>Advanced Sodium Technological Reactor for Industrial Demonstration</td>
<td>CEA</td>
<td>Sodium</td>
<td>No Moderator</td>
<td>Under Design</td>
<td>France</td>
<td>SFR</td>
</tr>
<tr>
<td>BREST-OD-300</td>
<td>BREST-OD-300</td>
<td>RDIF</td>
<td>Lead</td>
<td>No Moderator</td>
<td>Under Design</td>
<td>Russia</td>
<td>LFR</td>
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<tr>
<td>CLEAR-I</td>
<td>China Lead-based Research Reactor</td>
<td>Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences</td>
<td>Lead Bismuth Eutectic alloy</td>
<td>No Moderator</td>
<td>Conceptual Design</td>
<td>China</td>
<td>LFR</td>
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<tr>
<td>ELECTRA</td>
<td>European Lead Cooled Training Reactor</td>
<td>KTH</td>
<td>Lead</td>
<td>No Moderator</td>
<td>Under Design</td>
<td>Sweden</td>
<td>LFR</td>
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<tr>
<td>ELFR</td>
<td>European Lead Fast Reactor</td>
<td>Ansaldo Nucleare</td>
<td>Lead</td>
<td>No Moderator</td>
<td>Conceptual Design</td>
<td>EU</td>
<td>LFR</td>
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</table>
Current Booklets

ADVANCED LARGE WATER COOLED REACTORS
A supplement to the IAEA's ADVANCED REACTOR INFORMATION SYSTEM (ARIS)

September 2015

IAEA International Atomic Energy Agency
Atoms for Peace

SMR Booklet is published every 2 years

Large WCR and FR are published as-needed
New ARIS Design & Inputs for Booklet

[Representative Picture of Reactor]

Status Report – SHORT REACTOR NAME (Designer/Vendor)
Country of Origin

This reactor design is an evolution from the previous SHORT REACTOR NAME, of which # units are operating in [LIST OF COUNTRIES and link to PRIS], OR of which # units are under construction in [LIST OF COUNTRIES and link to PRIS], OR which is described in [link to relevant other ARIS Status Report], OR is a new concept with a projected earliest deployment (start of construction) time of YEAR.

The reference plant is [Name of Site and link to PRIS page] and has a net power output of xxx MW, [or xxx MW•h if primary application is non-electric].

INTRODUCTION

250-300 words describing the reactor’s distinguishing features, target application(s), and overall design philosophy. This will also appear in the ARIS Booklet(s) that are periodically published in hardcopy.

Indicate which booklet(s): [ ] Large WCR [ ] SMR [ ] FR

<table>
<thead>
<tr>
<th>Country</th>
<th>Site Name</th>
<th>No. of Units (operating / under construction)</th>
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Development Milestones (example below is for illustration only)

2010 Previous reactor version – Start of design (changes)
2015 Concept design completed
2016 Start of pre-licensing vendor design review (in country x)
2019 Engineering design complete
2020 Secure necessary licenses (in country x)
2022 Start construction of a first full-scale NPP (in country x)
2025 Commercial operation

Design organization or vendor company (e-mail contact):

Links (www...) to designer/vendor homepage:

Detailed Design Description:

Most Recent Licensing Application Support Document, e.g.:
THERPRO is a web-based on-line database (http://therpro.iaea.org), providing thermo-physical material properties data to the registered users in IAEA Member States since 2009.
HISTORY OF THERPRO DATABASE DEVELOPMENT

1990
- IAEA 1st CRP on ‘Thermo-physical properties of materials for water cooled reactors’ (1990-1994)

1997
- DOS-based THERSYST maintained by the Institute for Nuclear Technology and Energy Systems, University of Stuttgart in Germany (1997-2000)

1999
- IAEA 2nd CRP for data assessment, web-based online database was proposed (1999-2003)

2004
- Web-based THERPRO DB serviced by Center for Nuclear Materials Database (CNMD) at Hanyang University in Seoul, Korea

2009
- Financial support by the Ministry of Science and Technology of the Government of the Republic of Korea (2009-2011)

2012
- New version of THERPRO launched

2015
- Financially supported by the Korean Government (20141201-20170131, 26month)

2018
- Data updated as of 2017
THERPRO database hierarchical structure consists of several levels: element, compound, property, author, report and bibliography.

### Compiled Properties

- Thermal conductivity
- Thermal diffusivity
- Specific heat capacity
- Enthalpy
- Density
- Linear thermal expansion
- Linear expansion coefficient
- Volumetric thermal expansion
- Volumetric expansion coefficient
- Electric resistivity
- Lorentz number
- Absorptance
- Reflectance
- Refractive index
- Emittance
- Extinction coefficient
- Transmittance

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**Thermal conductivity of UO₂**

![Graph showing thermal conductivity of UO₂ over temperature range](image)

**Density of UO₂**

![Graph showing density of UO₂ over temperature range](image)
THERPRO DATABASE USERS

Registered Users by Country

- USA 113
- Austria (IAEA) 25
- Russia Federation 10
- UK 13
- France 14
- India 16
- Canada 17
- China 18
- Republic of Korea 20
- Turkey 7
- Germany 8
- Sweden 8
- Switzerland 7
- Czech Republic 7
- Japan 7
- Spain 6
- Iran 6
- Italy 6
- Indonesia 5
- Poland 5
- Bulgaria 4
- Pakistan 3
- Brazil 4
- Other 46
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Understanding Technology
IAEA Tools & Training Courses

IAEA approach: **basic principle simulators that** provide a thorough learning about general concepts and physical processes in nuclear power plant:

- Operational characteristics
- Reactivity control systems
- Safety systems
- Responses to transients and accidents

**IAEA ARIS data base** provide detailed descriptions about advanced reactor concepts including all reactor designs:

- PWR
- BWR
- SCWR
- PHWR
- VVER
- SMR
- MSR
- FR
The use of the IAEA PC based basic principle simulators in education and training is aimed at enhancing understanding of nuclear technologies through learning-by-doing:

Hands-on experiential training is highly suitable for operators, maintenance technicians, suppliers, regulators and engineers.
Technology development for water cooled reactors

Human Resource Development and Capacity Building in Member States

Active Learning Through Education and Training Courses on Various Topics and with the Use of PC Based Basic Simulators in Understanding Physics and Technology of WCRs/FRs/HTGRs

IAEA's basic principle Simulators:

- Simulate nuclear power plants' operation and responses to various inputs (transients, accidents) with illustrative screens are a state-of-the-art learning tool
- Designed to provide insight and understanding of the general design and operational characteristics of various power reactor systems
- Focus on education and training in classrooms, and not licensing or reactor operator training, or benchmarks of other computer codes and methods

Manuals and Training Course Series

- PCTRN Generic Pressurized Water Reactor Simulator Exercise Handbook
- Integral Pressurized Water Reactor Simulator Manual
Pressurized Water Reactor (PWR) Simulators

- PCTRAN: Conventional Two-Loop Pressurized Water Reactor
- Advanced PWR: Two-Loop Large PWR (Korean-OPR 1000)
- Russian-type PWR (VVER-1000)
- Advanced Passive PWR (AP-600)
- **Integral Pressurized Water Reactor (SMR)**

Boiling Water Reactor (BWRs) Simulators

- Conventional Boiling Water Reactor with Active Safety Systems (BWR)
- Advanced BWR with Passive Safety Systems (ESBWR)

Pressurized Heavy Water Reactor (PHWR)

- Conventional Pressurized Heavy Water Reactor (PHWR)
- Advanced PHWR (ACR-700)

Part-Task Simulator

- Micro-Physics Nuclear Reactor Simulator

Under Development

- High Temperature Gas Cooled Reactor (HTGR)
- Sodium Cooled Fast Reactor (SFR)

How to Obtain These Simulators

These simulators, including the associated documentation, are distributed at no cost to interested parties in IAEA Member States. Furthermore, the IAEA sponsors training courses and workshops on a regular basis, and would also be willing to support additional training events on this topic at the request of Member States.

Kindly follow these simple steps in order to obtain the complete suite of IAEA PC-Based Simulators:

**Step 1:** Create a Nucleus login ID by registering on the IAEA’s Nucleus website. This is necessary in order to obtain access to our SharePoint website, where all the simulators are hosted.

**Step 2:** Download and fill out this simulator request form.

**Step 3:** Scan and send the completed form to the competent official authority (Ministry of Foreign Affairs, National Atomic Energy Authority, or to the applicant’s Member State Permanent Mission to the IAEA in Vienna, Austria) for their approval and signature (stamp).

After this the Permanent Mission will then forward the approved request to Official Mail, the International Atomic Energy Agency, P.O. Box 100, Vienna International Centre, A-1400 Vienna, Austria. You will then receive an email from the IAEA with instructions on how to download all the simulators from our SharePoint website.
SMR Basic Principle Simulator: Free Distribution

Integral Pressurized Water Reactor Simulator (SMR)

There is continuing global interest in the development of Small Modular Reactors (SMR). One type of SMR currently under the development in a number of countries is the integral Pressurized Water Reactor (iPWR). In this design, primary circuit components are placed within the reactor pressure vessel, eliminating the need for primary circuit pipework, with the intention of enhancing safety and reliability. This simulator is developed by Tecnatom in 2017.

Details on the currently available SMR designs can be found in the IAEA ARIS Database.

The iPWR simulator operational specifics are listed as follows:

- The simulator is designed to examine the primary and balance of plant (BOP) behaviors of the iPWR
- In order to simulate the operation under accident conditions, a variety of safety systems are implemented including Gravity Driven Water Injection System, Pressure Injection System, Passive Decay Heat Removal system (PDHR), and Protection and Control System.
- Severe accidents include a station blackout (SBO): the users can initiate the SBO accident by loading SBO malfunction. It will automatically trip both the reactor and the reactor turbine, and subsequently, actuate Passive Decay Heat Removal System (PDHR). The reactor behavior can be observed during SBO until the reactor becomes stable.

Normal Operation
Technology development for water cooled reactors

2017

- Pilot Training on WCR Technologies and Severe Accidents with Simulators
- IAEA/KAERI Regional Course on WCRs Technologies and Passive Systems: Competence Based Approach with PC-Based Basic Principle Simulators
- Advanced WCRs: Physics, Technology, Passive Safety and Basic Principle Simulators
- Training Course on Reactor Technologies and Severe Accidents: Learning-by-Doing with PC Simulators
- Understanding Technology and Physics of WCRs with PC Simulators
- IAEA/VINATOM National Training Course on PWRS Technologies and Passive Safety Systems

2018

- Workshop on Small Modular Reactors Technology Assessment in Jordan [Video conference from VIC, Vienna to Amman, Jordan, 10 – 12 April, 2018]
- Workshop on Reactor Technology Assessment Training for Large Water Cooled Reactors in Saudi Arabia [Riyadh, Saudi Arabia, 15 – 19 April, 2018]
- Nuclear Infrastructure Training Course [Vienna, 2 - 11 May, 2018]
- Interregional Training Course on Nuclear Power Plant Contract Specifications and Reactor Technology Assessment [Vienna, Austria, 8-12 October, 2018]
- Reactor Technology Assessment: Testing the IAEA’s Reactor Assessment Methodology (12 – 16 November, VIC, 2018)
- Advanced WCRs: Physics, Technology, Passive Safety, and Basic Principle Simulators [Islamabad, Pakistan, 22 – 26 January, 2018]
- Regional Training Course on Pressurized Water Reactor (PWR) Technology Using PC Based Basic Principle and GlassTop Nuclear Power Plant Simulators [Sharjah, UAE, 19 – 23 February, 2018]
- National Training Workshop on Small Modular Reactors Technologies and the IAEA iPWR Basic Principle Simulator [Irbid, Jordan, 8 – 13 September, 2018]
- JOINT ICTP-IAEA 1st COURSE ON SCIENTIFIC NOVELTIES IN THE PHENOMENOLOGY OF SEVERE ACCIDENTS IN WATER COOLED REACTORS [Trieste, Italy, 22 – 26 October, 2018]
- Regional Training Workshop on Phenomenology and Numerical Simulations of Severe Accidents in Advanced WCRs [New Delhi, India, 3 – 7 December, 2018]
<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Event Title</th>
<th>Speaker(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 – 27 February, 2019</td>
<td>University of Sharjah, Sharjah, UAE</td>
<td>Regional Training Course on PWR Technologies Using PC Based Basic Principle and GlassTop NPP Simulators</td>
<td>[M. Krause]</td>
<td>The purpose of the event is to provide a comprehensive training on physics and technology of PWRs using PC based basic principle simulators and the GlassTop simulators</td>
</tr>
<tr>
<td>8 – 12 April, 2019</td>
<td>Wuhan, China</td>
<td>Regional Training Course on WCR Technologies and Educational Simulators</td>
<td>[A. Miassoedov]</td>
<td>The purpose of the event is to provide a comprehensive training on physics and technology of water cooled reactors using educational and training simulators and provide theoretical teaching about various advanced water cooled reactor technologies and design concepts with practical demonstrations of various operation conditions including extensive group exercises and projects designed to assure the understanding of presented concepts</td>
</tr>
<tr>
<td>15 – 19 April, 2019</td>
<td>Beijing, China</td>
<td>National Training Course on Hydrogen Management in Severe Accidents in WCRs</td>
<td>[T. Jevremovic]</td>
<td>The purpose of the event is to provide a comprehensive training on physics and technology of hydrogen generation, propagation, combustion and mitigation processes in WCRs with modern and state-of-the-art simulation tools</td>
</tr>
<tr>
<td>17 – 27 February, 2019</td>
<td>University of Sharjah, Sharjah, UAE</td>
<td>Regional Training Course on PWR Technologies Using PC Based Basic Principle and GlassTop NPP Simulators</td>
<td>[M. Krause]</td>
<td>The purpose of the event is to provide a comprehensive training on physics and technology of PWRs using PC based basic principle simulators and the GlassTop simulators</td>
</tr>
<tr>
<td>24 – 27 September, 2019</td>
<td>Hanyang University, Seoul, Republic of Korea</td>
<td>Regional Training Course on Science and Technology of Water Cooled Reactors and Introduction of Supercritical Water Cooled Reactor Concepts</td>
<td>[T. Jevremovic]</td>
<td>The purpose of the event is to provide a comprehensive overview on physics and technology of water cooled reactors through scientific visits of various facilities, technical tours, discussions and lectures on technology, simulation codes and plant simulators provided uniquely by the host institution</td>
</tr>
<tr>
<td>9 – 13 September, 2019</td>
<td>Raleigh, North Carolina, USA</td>
<td>Regional Scientific Visit on the State of Current Knowledge of Advanced Nuclear Power Reactor Designs with Educational Tools Supporting Regional Human Capacity Development</td>
<td>[M. Krause]</td>
<td>The purpose of the event is to provide a comprehensive overview on physics and technology of water cooled reactors through scientific visits of various facilities, technical tours, discussions and lectures on technology, simulation codes and plant simulators provided uniquely by the host institution</td>
</tr>
<tr>
<td>9 – 13 September, 2019</td>
<td>State College, Texas, USA</td>
<td>Regional Scientific Visit on the State of Current Knowledge of Advanced Nuclear Power Reactor Designs with Educational Tools Supporting Regional Human Capacity Development</td>
<td>[M. Krause]</td>
<td>The purpose of the event is to provide a comprehensive overview on physics and technology of water cooled reactors through scientific visits of various facilities, technical tours, discussions and lectures on technology, simulation codes and plant simulators provided uniquely by the host institution</td>
</tr>
</tbody>
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**2019 Training Courses and Scientific Visits [TC support]**

- **2nd course on June 24-28, 2019**
- **Joint ICTP-IAEA 1st Course on Scientific Novellities in Phenomenology of Severe Accidents in Water Cooled Reactors (WCRs)**
- **[A. Miassoedov]**
- **10 – 14 June, 2019**
- VIC, Vienna
- Regional Training Course on RTA for SMRs
  - [T. Jevremovic, F. Reitsma]**
Technology development for water cooled reactors
Technology development for water cooled reactors

Submodule 3: History
This submodule describes the history of boiling water reactor technology. This includes a description of initial prototypes, summaries of major reactor and containment designs, and discusses major developments.

Submodule 4: Global Deployment
This submodule describes the global deployment of boiling water reactors, including advanced technologies. This submodule details the relevant information which can be found on two IAEA databases: the Power Reactor Information System (PRIS) [https://pris.iaea.org/PRIS/home.aspx] and the Advanced Reactors Information System (ARIS) [https://aris.iaea.org/].
Technology development for water cooled reactors

ELSA: E-Learning Module on Severe Accidents

**Module 1**
Accidents in nuclear installations
1.1 Classification of accidents
1.2 Historical overview: TMI-2, Chernobyl, Fukushima

**Module 2**
Early and late in-vessel phases
2.1 Reflood phenomena
2.2 Zirconium oxidation
2.3 Loss of rod-like geometry
2.4 Vessel failure modes
2.5 Corium release

**Module 3**
Ex-vessel phase
3.1 Fuel-coolant interaction (FCI) and steam explosion
3.2 Corium melt spreading
3.3 Direct containment heating
3.4 Molten core-concrete interaction (MCCI) and basement behavior
3.5 Modes of containment failure

**Module 4**
Hydrogen and source term
4.1 Hydrogen generation
4.2 Hydrogen distribution and burn
4.3 Physics and chemistry of Source term (ST)
4.4 Fission products (FP) behavior and transport

**Module 5**
Mitigation of accident consequences
5.1 In-vessel melt retention
5.2 Ex-vessel melt retention
5.3 Hydrogen mitigation
5.4 Mitigation of FP release
5.5 IAEA SAMG-D toolkit

**Module 6**
Severe accident R&D
6.1 Severe accident R&D priorities
6.2 Experimental R&D
6.3 Severe accident codes

Overview QUIZ
### Hub for Open-Source Nuclear Power Plant Part-Task Simulators (HOPS)

**Purpose**
Develop a hub for open source nuclear power plant part-task simulators in support of nuclear power programmes development in Member States.

**Activities**
- Collect the nuclear power plant part-task simulators that are open-source based from the developers in Member States and provide detailed description on their applications and use.
- Synchronise the collected nuclear power plant open-source part-task simulators with standardized approach and GUI.
- Systematise an expanded range of training and demonstration activities on nuclear power plant fundamentals (systems and subsystems operational performances and their roles in overall operation of a nuclear power plant) with open-source part-task nuclear power plant simulators.
- Create a forum in which expert’s advice and technical guidance may be provided on the Agency’s programme in the area.

**Outcome**
Strengthened national capabilities on hands-on education and training programmes on nuclear power plant operations.

**Outputs**
- Variety of open-source part-task nuclear power plant simulators on specific plant characteristics of interest to Member States.
- Hands-on learning tools on nuclear power plant systems and subsystems.
- Interactive educational approaches addressing fundamentals of nuclear power plant operation with the use of these open-source part-task nuclear power plant simulators.
- Training course series addressing the specifics of the collected open-source part-task nuclear power plant simulators with examples and exercises.
- A strong community of developers in the field of simulators for nuclear engineering applications.
International HOPS School
Enhancing Human Resource Development with Hands-on Learning-by-Doing Nuclear Power Plant Part-Task Simulators

NPTDS Proposal to 2022-23 TC Project [PCMF, January 2020]
Area: Education and Training, Capacity Building

Overall Objective:
Supporting Member States with less advanced education and training nuclear power programmes, by making available the relevant skills, knowledge, programmatic training approaches and educational hands-on tools

Overview
1. Theoretical lectures provided by NPTDS and external experts (developed countries) on different advanced reactor technologies, passive safety systems, severe accidents, ...
2. Using IAEA’s PC based basic principle simulators to teach the complete system engineering with hands-on exercises and new TCSs
3. FOAK training and education approach: International HOPS School
   Using IAEA’s part task simulators (HOPS), to simulate each system/sub-system with hands-on exercises:
   - participants to develop their own part-task simulator during the course [develop new TCSs]
SANIS: Simulation and experimental Analyses Network Information System

The SANIS system will contain information on the world’s experimental facilities and analytical tools related to operation of water cooled reactors:
- Addresses phenomena from normal operation to design extension conditions with core melt
- May include reference data for code development and assessment
- Provide supporting information and documentation, news, activities and links

Within the system, the database will be structured into sections, dedicated to specific phenomena, e.g.
- Reactor physics
- Fuel behavior
- Thermal hydraulics
- Hydrogen distribution, deflagration and detonation
- Codes used for plant analysis
- Learning tools

The information in the system will be periodically updated directly by facility provider or code developer, reviewed and accepted by the IAEA.

The system will be used as a collaborative platform to allow infrastructure and facility operators as well as code developers to better identify the resources available to them.
SANIS
Simulation and experimental Analyses Network Information System
Technology development for water cooled reactors

- **Codes**
  - Codes for analysis of plants in normal operation and accident conditions
  - Reactor physics, fuel behavior, containment analysis
  - Reference data for code development and assessment
  - Supporting information and documentation, news, activities and links

- **Facilities**
  - Integral and separate-effects test facilities to study conditions from normal operation to design extension conditions with core melt
  - Thermal hydraulics
  - Containment behavior
  - Corium behavior
  - Fission products
  - Hydrogen distribution, deflagration and detonation
  - Accident management

- **Learning Tools**
  - eLearning Modules *(WCR Technology and link to SAMG-D)*
  - Part task and basic principle simulators
  - Links to ARIS and THERPRO databases
1. WCR Team Activities
2. Data Bases: ARIS, THERPRO
3. Educational Simulators and eLearning Modules
4. Reactor Technology Assessment
5. Summary and Outlook
OBJECTIVE: RTA methodology as a training tool supporting capacity building in Member States

PURPOSE: RTA as a decision making approach providing comprehensive information on complexity of required facts & figures for an unbiased assessment of reactor technologies

RTA Toolkit reflecting the RTA methodology:
- Applicable to training case studies
- Used in the training courses

National RTA (WCRs and SMRs) Training Workshops with Exercises, PC Simulators & ARIS Database

Preparing the new comer countries in supporting their national human resource development toward reactor technology assessment.
International RTA (WCRs and SMRs) Training Workshops with Exercises, PC Simulators & ARIS Database

2012
- First Interregional Training Course on Tools and Methodologies for Nuclear Reactor Technology Assessment, 11-13 July, VIC

2013
- Technical Meeting on Technology Assessment for Embarking Countries, 24-28 Jun, VIC

2015
- Interregional Training Course on Nuclear Power Plant Contract Specifications and Reactor Technology Assessment, 8-12 October, VIC

2018
- Nuclear Infrastructure Interregional Training Course (RTA on SMRs), 2 - 11 May, VIC

2019
- SMR Workshop (RTA for SMRs) European region 15-19 June, VIC
New RTA Methodology

- Training Approach -

**Retasland**
Fictitious country providing framework for the RTA training
describing the national goals, site specifics, grid, …

**ARIS Database Reactor Descriptions**
As input for RTA training tables

**RTA Training Tables**
15 Key Elements and Key Topics with justifications
Retasland
Fictitious country providing framework for the RTA training
describing the national goals, site specifics, grid, …
Retasland
Fictitious country providing framework for the RTA training describing the national goals, site specifics, grid, …
IAEA RTA IT-Toolkit

Under development

Reactors type
Number of reactors to assess
Selected reactor designs
IAEA RTA IT-Toolkit

Under development

SITE SPECIFIC CONSIDERATIONS

INFORMATION FOR SITE SPECIFIC CONDITIONS

Most of the information in this survey was extracted from:
- Nuclear Reactor Technology Assessment for Near Term Deployment, No. NES NP-T-1.10, Section 4.1.1 (pages 29-30)

Description: Site specific parameters affecting the plant design.

Importance factor rational: Note that the interaction between site characteristics and the features of the proposed design may be strong differentiators (e.g., design features that have been included in the standard nuclear power plant for external events).

Site parameters compared with the site parameters envelope offered by the technology holder for the proposed (standard) plant, for example:
- Soil conditions (soft, medium, rock);
- Site seismic level ground acceleration (e.g., safe shutdown earthquake ground motion, operating basic earthquake ground motion);
- Wind velocity;
- Snow load;
- Environmental conditions (barometric pressure, temperature, relative humidity, etc.);
- Cooling water temperatures (for non-safety related cooling systems and safety related cooling systems, and ultimate heat sink considerations);
- Site ambient temperatures and relative humidity for HVAC (heating, ventilation, air conditioning) system design (non-safety and safety related HVAC systems);
- Condenser cooling water source;
- Heat sink temperature (note: this impacts the design of heat exchangers, pumps and the safety analyses. The resultant designs of the heat exchangers and pumps impact the plant electrical output);
- Condenser temperature rise (note: this is determined by the circulating water and service water flows, which in turn affect plant performance);
- Seismic design basis and site differences, including impact on structures and embedment given soil interaction analysis for the site spectra, seismic requirements for the turbine island;
- Water resources required for plant make-up, blowdown and margin required for operation.

Key questions: Questions for the owner/operator:
1. What is the range of acceptable plant ratings for this procurement?

Questions for the technology holder:
1. What is the size of your largest component, and how do you propose to transport it to the site?
2. What site specific issues could affect the site preparation schedule and costs?
3. What is the footprint of the major facilities on the site?
4. What is the impact of local temperature variation on plant performance and MWe output?

Evaluation expectations and relative comparisons: Ensure that each technology holder’s plant design and site configuration and characteristics are consistent with the site specific characteristics.

Additional references:

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<th>Reactor#1</th>
<th>Reactor#2</th>
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<tbody>
<tr>
<td>Summary</td>
<td>Ambient site environmental conditions and ecology, including seismic, flooding, wetlands, population density</td>
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<td>Heat sink temperature, condenser cooling water source and extent of water resources</td>
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<td>Predicted magnitude and frequency of all external events (design and safety considerations)</td>
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<td>Site size requirements, boundary conditions, population, neighbours and environs</td>
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<td>Transportation routes/facilities and access to required infrastructure for construction and operation</td>
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<td>Site development and preparation requirements</td>
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<td>Site structure plan, single- or multi-unit site requirements</td>
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Comments (Optional)
Refinement of the RTA methodology through Consultancy Meetings including feedbacks from national and interregional RTA training workshops and experts.

BOOKLETS on Training Case Studies to publish in 2019
- S/M Retasland and SMR technologies
- L Retasland and AWCR technologies

IAEA RTA methodology refinement

1st CM
28 – 31 May 2019

2019

Refining the clarity of key elements and key topics with examples and explanations

New RTA Methodology
IAEA NE Series 2021/2022

2020

Refine the RTA methodology to include the effect of non-electric applications on assessment

2nd CM
Q2 2020

Refine the key elements and key topics and their suggested importance for SMRs with examples and explanations

Refine the RTA methodology to include the effect of integrated renewables with nuclear energy systems
1. WCR Team Activities
2. Data Bases: ARIS, THERPRO
3. Educational Simulators and eLearning Modules
4. Reactor Technology Assessment
5. Summary and Outlook
Summary / Outlook

WCR Team Activities of Interest to SMRs:

- ARIS Database
- THERPRO Database

Training and Education:
- Basic Principle Simulators
- Training Courses
- Training Course Series: Booklets and Exercises

Reactor Technology Assessment:
- Training Courses
- Training Course Materials for SMRs