# Nuclear Reactor Simulation Hands-On-Training Platform

## Final Announcement

**Lucca, Italy**

16 - 20 April, 2018

To be held at

NINE Headquarters

**Lucca, Italy**

http://www.nnees.sk/nrshot/index.html

## Objective of the Seminar/Training

The NRSHOT Platform provides a set of **parallel Courses Hands-On-Training** to transfer the experience and know-how of recognized code user experts of Thermal-Hydraulics (System and Subchannel) Codes, Reactor Physics Codes (including coupling with Thermal-Hydraulics), Fuel Performance Codes and PSA Codes. Each course consists of 35 hours:

- **RELAP5-Beginner:** The seminar-training is directed toward beginner RELAP5 users without thermal-hydraulics system code experience. The course will provide an overview of the computer codes in Deterministic Safety Analysis, familiarization with the syntax and the input structure of the RELAP5 code and with the use of plotting tools. Hands-on training on simple modelling is then provided.
- **RELAP5-Intermediate:** The seminar-training is directed toward intermediate RELAP5 users with basic thermal-hydraulics system code experience. The course will provide with the features and limitations of System Thermal-Hydraulic Codes and with the procedures for developing nodalizations and qualifying code calculations. Physical models in RELAP5 code are discussed and hands-on training on NPP components and sub-systems models is provided.
- **RELAP5-Advanced:** The hands-on training course is directed toward advanced RELAP5 users with system thermal-hydraulics background. The course will provide information on the nodalization techniques of components in Integral Test Facility (ITF) and on the qualification process of a system thermal-hydraulic calculation, including the qualitative and quantitative evaluation of the accuracy. The so called Kv-scaled calculation of a NPP to the selected test in a ITF is also part of the course as well as the identification of simple and complex errors in a NPP input nodalization.
- **TRACE-Beginner:** The seminar-training is directed toward beginner TRACE users without prior TRACE code experience. The course will provide an overview of the computer codes in Deterministic Safety Analysis, familiarization with the syntax, the input and output structure of the TRACE code, SNAP GUI and the use of post-processing plotting tools. The major part of the course will be spent on hands-on training on the modeling of selected parts of LWRs.
- **COBRA-TF-Beginner:** This is an introductory course on subchannel codes and methods. The course will provide an overview of the computer codes used to perform subchannel analysis in safety and core engineering problems. Participants will learn about the purpose and various uses of subchannel methods. While the training will apply broadly to all subchannel analysis codes, COBRA-TF will be the specific code for the training. The syntax and the input structure of the code and plotting tools will be covered. Hands-on training on simple modeling is provided. In the last day advanced and future capabilities of COBRA-TF are presented.

- **PARCS & 3D NK-TH Coupling-Beginner** The seminar-training is directed toward beginner PARCS users with little or no prior PARCS code experience. The course will provide an overview of the PARCS code and methods, familiarization with the input syntax, and the input and output structure of the code. The course will show the entire process of core modeling, from cross-section generation, input preparation, to coupling with RELAP5 and TRACE and output analysis. The major part of the course will be spent on hands-on modeling of a PWR reactor.
- **PSA-Beginner** The training is directed toward beginners in probabilistic safety assessment (PSA). The training programme is developed in the way that the participants obtain sufficient knowledge on Level-1 PSA basic concepts and methodology and practical experience in the development of the PSA models using selected PSA Software. The major part of the course will be spent on hands-on training on the development of accident sequences and system models for simplified LWR. It is expected that after training participants will be able to continue PSA activity using PSA software themselves.

## Organization

The Network of Nuclear Engineering and Energy Services (NNEES) and Nuclear and INdustrial Engineering (NINE) are **jointly** organizing **parallel Courses Hands-On-Training** directed toward users of Thermal-Hydraulics Codes, Reactor Physics Codes, Fuel Performance Codes and PSA Codes.. The parallel course trainings will take place in **Lucca** (**Italy**) from **16th** to **20th April, 2018** at the **NINE Headquarters.**

The parallel course trainings are open to vendors, utilities, regulatory bodies, national laboratories, consulting companies and universities. A minimum of participants is required to organize each training course. A maximum of 20 persons per course is accepted.

Further information about participation and registration as well as useful practical information can be obtained from Alessandro Petruzzi at the following email address: **alessandro.petruzzi@nnees.sk** . The Network of Nuclear Engineering and Energy Services (NNEES) is in charge of the financial management of NRSHOT Platform. Special accommodation will be offered on a separate sheet. An internet website with the latest news is available at: **http://www.nnees.sk/nrshot/index.html**

## Expected Products

The Training Courses will provide a transfer of experience and know-how from recognized experts in the respective fields. It will thus contribute to maintaining and increasing technical competence and to ensuring the sustainable development of nuclear technology. All Lectures and Exercises will be distributed to the participants.

# P R O G R A M M E   O U T L I N E

## Organizing Committee

| | |
|---|---|
| A. Petruzzi | Nuclear and Industrial Engineering (NINE), Italy |
| M. Kristof | Network of Nuclear Engineering and Energy Services (NNEES), Slovakia |

## Lecturers and Instructors

| | |
|---|---|
| M. Avramova | North Carolina State University (NCSU) |
| S. Bzuni | Nuclear and Radiation Safety Center (NRSC), Armenia |
| M. Cherubini | NINE, Italy |
| D. De Luca | NINE, Italy |
| V. Giusti | University of Pisa (UNIPI) |
| M. Kristof | Network of Nuclear Engineering and Energy Services (NNEES), Slovakia |
| I. Kuzmina | NINE, Italy |
| A. Lyubarskiy | Atomenergoproekt (AEP), Russia |
| A. Petruzzi | NINE, Italy |

# PROGRAMME OUTLINE

## RELAP5 - Beginner

**Minimum number of Participants: 10**

### Day 1

- Opening, Introduction, Scope and Content of the training
- Introduction to Deterministic Safety Analysis
- Computer codes in Deterministic Safety Analysis
- Overview of Safety Analyses with System Computer Codes: Conservative and BE Approach
- Features and Limitations of System-Thermal-Hydraulic codes
- Overview of the RELAP5 code architecture and structure, models; input, output, rstplt files
- Familiarization with plotting tools (APT plot, Wingraph, etc..)

### Day 2

- Minor Edits, Major Edits and Time Step Controls
- Hydrodynamic Components in RELAP5: Syntax and Models (Part 1)
- Modeling a simple pipe
- Effect of Time Step and Spatial Discretization
- Modeling a multi-tube Heat Exchanger (Part 1)

### Day 3

- Hydrodynamic Components in RELAP5: Syntax and Models (Part 2)
- Modeling a multi-tube Heat Exchanger (Part 2)
- Heat Structure Components in RELAP5
- Modeling a multi-tube Heat Exchanger with secondary side and heat structures

### Day 4

- Logic Trips and Control Variables in RELAP5
- Steady State Controllers and How to Achieve a Steady State
- Modeling a multi-tube Heat Exchanger with Control System
- Edwards Pipe Problem: Description of the Problem and Assignment of the Exercise

### Day 5

- Exercise on Edwards Pipe Problem: Hydrodynamic and Heat Structure
- Exercise on Edwards Pipe Problem: Comparison with Experimental Results and Judgment of the Results
- Validation of system computer codes on integral test facilities
- Questions, Open Issues and Individual Consultations
- Closing of the training and release of the Certificate of Attendance

# PROGRAMME OUTLINE

## RELAP5 - Intermediate

**Minimum number of Participants: 7**

### Day 1

- Opening, Introduction, Scope and Content of the Training
- Introduction to Deterministic Safety Analysis
- Physical Models in RELAP5 Code: The Hydrodynamic Model
- Physical Models in RELAP5 Code: Closure Relationships and Other Models
- Overview of the RELAP5 code architecture and structure, models; input, output, rstplt files
- Familiarization with plotting tools (APT plot, Wingraph, etc..)
- General Structure of RELAP5 Input: Hydrodynamic Components
- Exercise 1: Valve Sizing

### Day 2

- Basic Concept on Numerical Methods and RELAP5 Equation
- Solution Algorithms in RELAP5 for Hydrodynamic Model and Heat Conduction
- General Structure of RELAP5 Input: Heat Structures
- Overview of Safety Analyses with System Computer Codes: Conservative and BE Approach
- Exercise 2: Blow-Down Problem

### Day 3

- Numerical Effects in RELAP5 Applications
- Exercise 3: Effect of Time Step and Spatial Dicretization
- General Structure of RELAP5 Input: Control System
- Exercise 4: Steam Generator Modeling

### Day 4

- Procedure for Developing Nodalizations (including Scaling Issues and User Effect)
- Procedure for Nodalization Qualification (at Steady State and On Transient Level)
- Validation of system computer codes on integral test facilities
- Exercise 5: Pressurizer Modeling

### Day 5

- Quantification of Accuracy of a Code Calculation
- Exercise 6: Boiling Channel Problem
- Questions, Open Issues and Individual Consultations
- Closing of the training and release of the Certificate of Attendance

# P R O G R A M M E   O U T L I N E

## ADVANCED RELAP5 TRAINING:<br>ITF AND NPP ANALYSIS

**Minimum number of Participants: 5**

## Day 1

- System Thermal-Hydraulics Codes: Capabilities and Limitations
- Assessment of System Codes
  - The OECD/NEA Computer Code Validation Matrix of Integral Test Facility (ITF)
  - The OECD/NEA Computer Code Validation Matrix of Separate Effect Test Facility (SETF0
- Exercise: working with an Integral Effect Facility (1/4)
  - Description of the ITF
  - Completing the ITF Input Nodalization
    - Developing a Valve Component
    - Developing a Pump Component
    - Developing the Pressurizer

## Day 2

- Exercise: working with an Integral Effect Facility (2/4)
  - Completing the ITF Input Nodalization
    - Developing the Steam Generator
    - Developing the Control System for the Pressurizer and the Steam Generator
- Qualification of a System Code Calculation of a ITF (1/2)
  - Demonstration of Geometrical Fidelity
  - Demonstration of Steady State Achievement
- Exercise: working with an Integral Effect Facility (3/4)
  - Running the Steady State Calculation
  - Demonstration of the Geometrical Fidelity
  - Demonstration of Steady State Achievement

## Day 3

- Qualification of a System Code Calculation of a ITF (2/2)
  - Qualification at On-Transient Level
  - Application of the FFTBM
- Exercise: working with an Integral Effect Facility (4/4)
  - Description of the selected Test in ITF
  - Running the Transient Test
  - Qualification of the Transient Calculation
    - Qualitative Analysis
    - Quantitative Analysis by FFTBM
- Origin of Uncertainties in System Thermal-Hydraulics Calculations
- Approaches to perform Uncertainty Analysis

# PROGRAMME OUTLINE

**ADVANCED RELAP5 TRAINING:**
**ITF AND NPP ANALYSIS**

## Day 4

- Description of a Generic Input Nodalization of a NPP
    - Description of the NPP Nodalization
    - Description of the relevant I&C System
    - Description of the Steady State
    - Description of the Selected Transient
- Exercise: working with a Generic NPP input Nodalization (1/2)
    - Identifying Simple Input Error – Type 1
    - Identifying Simple Input Error – Type 2
    - Identifying Simple Input Error – Type 3
    - Identifying Complex Input Error

## Day 5

- Qualification of a System Code Calculation of a NPP
    - The Kv Scaled Calculation
- Exercise: working with a Generic NPP input Nodalization (2/2)
    - Developing the Kv NPP Scaled Input Nodalization respect to the selected ITF and selected Transient
    - Qualitative Analysis of the Results
- Evaluation of the Training Course

# PROGRAMME OUTLINE

## TRACE - Beginner

**Minimum number of Participants: 10**

### Day 1

- Opening, Introduction, Scope and Content of the training
- Introduction to Deterministic Safety Analysis
- Computer codes in Deterministic Safety Analysis
- Features and Limitations of System-Thermal-Hydraulic codes
- Exercise: Familiarization with pre- and post-processing tools (SNAP and AptPlot).

### Day 2

- Overview of the TRACE code architecture and structure, models; input and output files
- Hydrodynamic Components in TRACE
- Exercise 1: modeling of a simple pipe (part 1).
- Defining Boundary and Initial Conditions in TRACE
- Exercise 1: modeling of a single pipe with a valve (part 2).

### Day 3

- Heat Structure and Power Components in TRACE
- Exercise 2: modeling of a single BWR fuel assembly (part 1).
- Exercise 2: modeling of a single BWR fuel assembly and analysis of the post CHF conditions (part 2).

### Day 4

- Control system: signal variables, control variables and trips in TRACE
- Exercise 2: modeling of a single PWR fuel assembly (part 3)
- Exercise 2: modeling of a single PWR fuel assembly to reproduce the reflood phase of a LOCA scenario (part 4).

### Day 5

- Exercise 2: modeling of a single BWR and PWR fuel assembly (part 5): analysis of the different heat transfer modes and flow regimes.
- Questions, Open Issues and Individual Consultations
- Closing of the training and release of the Certificate of Attendance

# COBRA-TF - Beginner

**Minimum number of Participants: 7**

## Day 1

- Opening, Introduction, Scope and Content of the training
- COBRA General Overview and Formulation
- COBRA Usage
  - Subchannel analysis
  - LOCA analysis
- Analysis examples
- COBRA manuals/documentation
- Building a Model – General Overview

## Day 2

- Building a model – Geometry Data
- Channel, Sections and Gaps
- Merging and splitting of subchannels
- Advection of momentum at section boundary
- Form losses setting
- Exercise 1: Start modeling a bundle (RBHT) – Two-Channel with single hot channel
- Exercise 2: Run hydro problem (single-phase adiabatic)

## Day 3

- Building a model – Rods and Unheated Conductors Data
- Heat transfer package
- Exercise 3: Upgrade bundle model by adding heat structure

## Day 4

- Simplified sub-channel analysis
- Exercise 4: Run and analyze simplified sub-channel analysis

## Day 5

- LOCA reflood analysis
- Quench front models
- Exercise 5: Run and analyze reflood transient
- Closing of the training and release of the Certificate of Attendance

# PROGRAMME OUTLINE

## PARCS and 3D NK-TH Coupling - Beginner

**Minimum number of Participants: 7**

### Day 1

- Opening, Introduction, Scope and Content of the training
- Features and Limitations of nodal core simulator codes
- Overview of the PARCS code models; input and output files
- Exercise 1: modeling of static core with internal feedback

### Day 2

- Nodal cross-section generation
- PAMXS and table formats
- Exercise 2: Generating PMAXS cross-sections

### Day 3

- Exercise 3: modeling of transient PWR core (control bank withdrawal)
- Exercise 4: Using PMAXS stand-alone steady-state calculations
- Exercise 5: Using PMAXS for transient calculations

### Day 4

- Coupling to RELAP5
- Exercise 6: coupling PARCS to RELAP5 PWR model
- Coupling to TRACE
- Exercise 7: coupling PARCS to TRACE PWR model

### Day 5

- Exercise 8: using PMAXS for coupled calculations (Control Rod Ejection)
- Fuel cycle analysis capabilities of the PARCS
- Exercise 9: using PMAXS for depletion calculation (Core Loading Analysis)
- Questions, Open Issues and Individual Consultations
- Closing of the training and release of the Certificate

# PROGRAMME OUTLINE

## PSA - Beginner

**Minimum number of Participants: 5**

### Day 1

- Brief overview of the Training Curriculum
- Overview of the Main Terms and Concepts of PSA
  - Concept of Risk, Typical PSA Scope, Terms and Definitions used in PSA, Introduction to Boolean Algebra, Brief overview of Typical Level-1 PSA Tasks
- Initiating Events (IE) Analysis
  - Definition of an Initiating Event in PSA, Initiating Events Selection, Initiating Events Grouping, Initiating Events Frequency Assessment, Typical Lists of IEs for Different Reactor Types, IEs Frequencies Assessment
- Presentation on the Design of the Facility to be Used for the Case Study on PSA Model Development
  - Presentation of the Main Design Features of a Simplified Nuclear Installation to be used during training
    - Main Safety Systems
    - Main Support Systems
- Accident Sequence Models Development
  - Safety Functions and Modelling Functions in the Accident Sequence Models, Successful and Non-Successful End States, Typical definition of End States in Accident Sequence Models, Success Criteria Definition, Supporting Analyses, Mission Time and Cliff-Edge Effects, Typical Formats of Accident Sequence Models, Approach for Construction of Small Event Tree - Large Fault Tree PSA Models
  - Example of Event Trees Construction Process
- Introduction to PSA Software and Construction of Event Trees
  - Brief description of the PSA Software Used (SAPHIRE or RISKSPECTRUM)
  - Work in working groups: each group develops one ET (later to be integrated in one PSA model)
    - Each working group construct one ET (Large LOCA, Medium LOCA, Small LOCA, Loss of Off-Site Power)
    - Experts provides advices at request and reviews the work done

### Day 2

- System Models Development
  - Typical Methods for System Models Development
  - Fault Tree (FT) Method
    - Structure of FT, Typical Elements of FT, Typical Basic Events in FT
    - Types of Components, Components Failure Modes and Related Probabilistic Models
    - Components Boundaries and Link with Existing Reliability Data
  - Methods to Control the Logic of System Models in FTs (house events, boundary condition sets, etc.)
  - Typical Coding Scheme for Naming Basic Events in the PSA Model
  - Failure Modes and Effects Analysis (FMEA)
  - Example of a FT Development Process, Breaking Logic Loops
- Exercise: Construction of Fault Trees. Development of the Coding Scheme to be used in the PSA Model Development Process. Performing and Documenting FMEA
  - Construction of System Models in the Form of FT (using PSA Software). Defining Reliability Models for Basic Events and Introduction of “Dummy” Values. System Models Quantification. Analyses of Minimal Cutsets (MCSs) obtained.

## Day 3

- PSA Data Analysis
  - Overview of Data required for PSA. Component Reliability Data Collection and Treatment Process. Initiating Events Data Collection and Treatment.
  - Methods for Reliability Parameters and IEs Frequencies Estimation (Classical Statistic Methods, Bayesian Updating Process)
  - Introduction to Human Error Probability (HEP) Evaluation
- Exercises on data assessment. Assessment of the Data Needed for their part of the PSA Model. Treatment of the Raw Data (data to be provided by experts). Estimation of Reliability Parameters for the Components and Failure Modes to be used in the PSA Model Under Development. Entering the Data obtained in the PSA Model. Quantification of MCSs with the Data obtained (replacement of “dummy” values).

## Day 4

- Modelling Dependencies in PSA (including Common Cause Failures [CCF])
  - Types of Dependencies to be modelled in the PSA
  - Common Cause Failures (CCF): CCF Models, CCF Parameters and Sources of Data, CCF Groups.
  - Inclusion of CCF Events in the PSA Model (depending on the software to be used)
- Exercise: Modelling of the CCF in the PSA model. CCF Analyses for the Equipment Modelled in their part of the Model. Defining CCF Groups. Introduction of CCF Groups in the PSA Model. Re-Quantification of the Model with CCF Data.

## Day 5

- PSA Model Quantification and Analysis of the Results
  - Typical Results from Level-1 PSA
  - Analysis of MCSs and Dominant Accident Sequences
  - Importance Measures Quantification and Analysis: Types of Importance Measure, Typical Insights from Importance Measures
  - Uncertainty Analyses and Types of Uncertainties in PSA: Parametric Uncertainty, Modelling Uncertainty, Incompleteness Uncertainty
  - Sensitivity Studies: Sensitivity Studies to Address Uncertainties, Sensitivity Studies to Assess the Impact of Modifications, Other Sensitivity Studies
- Exercise: PSA Model Quantification and Analysis of the Results. Quantification of the Model and review MCSs obtained, review of the Results of Importance Measures Quantification and Uncertainty of the Results, definition of Sensitivity Cases including Model Adjustment and Model.
- Discussion on the Final Results achieved
- High-Level overview of Internal and External Hazards Level-1 PSA, Level-2 PSA and use of PSA Results
  - High-Level overview of Internal and External Hazards Level-1 PSA
  - High-Level overview of Level-2 PSA Tasks
  - High-Level overview of Use and Application of PSA
- Evaluation of the Training Course

N.IN.E. — Network of Nuclear Engineering and Energy Services

# NRSHOT 2018

## Nuclear Reactor Simulation – Hands-on Training Platform

### NINE Headquarters, Lucca, Italy

### 16 – 20 April 2018

**REGISTRATION FORM**

To be returned by 23 March 2018

Last name: ........................................................................ First name: ..................................................................Sex.................

Title:................Organization:....................................................................................... .................... V.A.T #.................................

Organization Address:.......................................................................................................................................................

City: .......................................... State: ................................... Zip Code: ..……..………  Country ……..…………………..

Phone:…………………………..….. Fax: ………………………… Email: ……………………..………………………………...

(Please type all information as you wish it to appear on your name badge)

**Registration Fees** (Include proceedings, lunches, one dinner and coffee breaks)

Please select ONE of the course here below

| Course | Payment by March 2 | Payment after March 2 |
|---|---|---|
| **1.** RELAP5-Beginner | ☐ **€ 2400** | ☐ **€ 2600** |
| **2.** RELAP5-Intermediate | ☐ **€ 2600** | ☐ **€ 2800** |
| **3.** RELAP5-Advanced | ☐ **€ 2800** | ☐ **€ 3000** |
| **4.** TRACE-Beginner | ☐ **€ 2400** | ☐ **€ 2600** |
| **5.** COBRA-TF-Beginner | ☐ **€ 2600** | ☐ **€ 2800** |
| **6.** PARCS & 3D NK-TH Coupling-Beginner | ☐ **€ 2400** | ☐ **€ 2600** |
| **7.** PSA-Beginner | ☐ **€ 2400** | ☐ **€ 2600** |

**** Bank charges to be added to registration fees***

**In case your course is NOT activated, please select THREE alternatives options (indicate the course number from 1 to 8)**

1st Option: ___________ 2nd Option: ___________ 3rd Option: ___________ I do not want any other course ☐

**In case you need a laptop, please inform the organizer. No laptop is provided for the hands-on training.**

**Payment Terms and Cancellation Policy**

- ☐ No cancellation fee applies if cancellation of the registration occurs before March 2, 2018
- ☐ 50% cancellation fee applies if cancellation of the registration occurs up to 4 weeks before the starting of the course
- ☐ 100% cancellation fee applies if cancellation of the registration occurs 4 weeks or less before the starting of the course

The Registration Form should be sent to:

Alessandro Petruzzi : **email: a.petruzzi@nineeng.com**