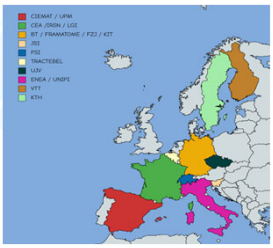
SEAKNOT

SEvere Accident Research and KNOwledge ManagemenT for LWRs

SEAKNOT Project

Luis E. Herranz
Project Coordinator
Research Professor on Nuclear Safety

Luisen.herranz@ciemat.es



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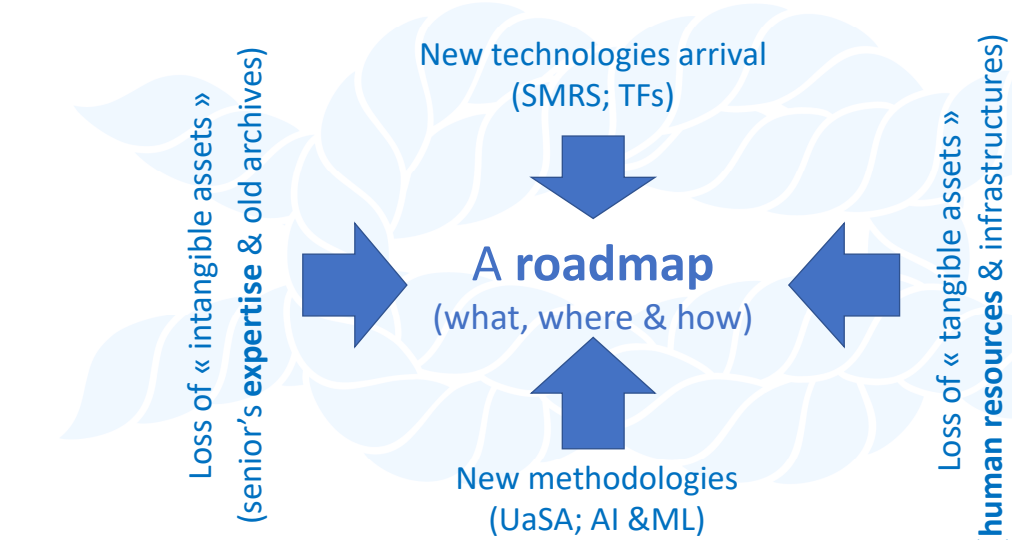
Motivation



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Ambition

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SEAKNOT Distinctive Features

- « Shot » to the entire SA domain.
- Based on ROBUST BACKGROUND.
- Youngsters KNOT « sparkers ».
- « Minimum partners set ».
  - Multi-disciplinary
  - Organization diversity (industry; TSO; RC&U)
- Not a usual research project; other needs apply.
- Cost-effective » (2.3 M€).

- ✓ EURATOM (SARNET2, PASSAM, IVMR, …)
- ✓ H-2020 (MUSA, R2CA, AMHYCO; …)
- ✓ OECD/NEA (ESTER; THEMIS; FACE; …)
- ✓ IAEA/CRPs …
- ✓ Other national & international projects.

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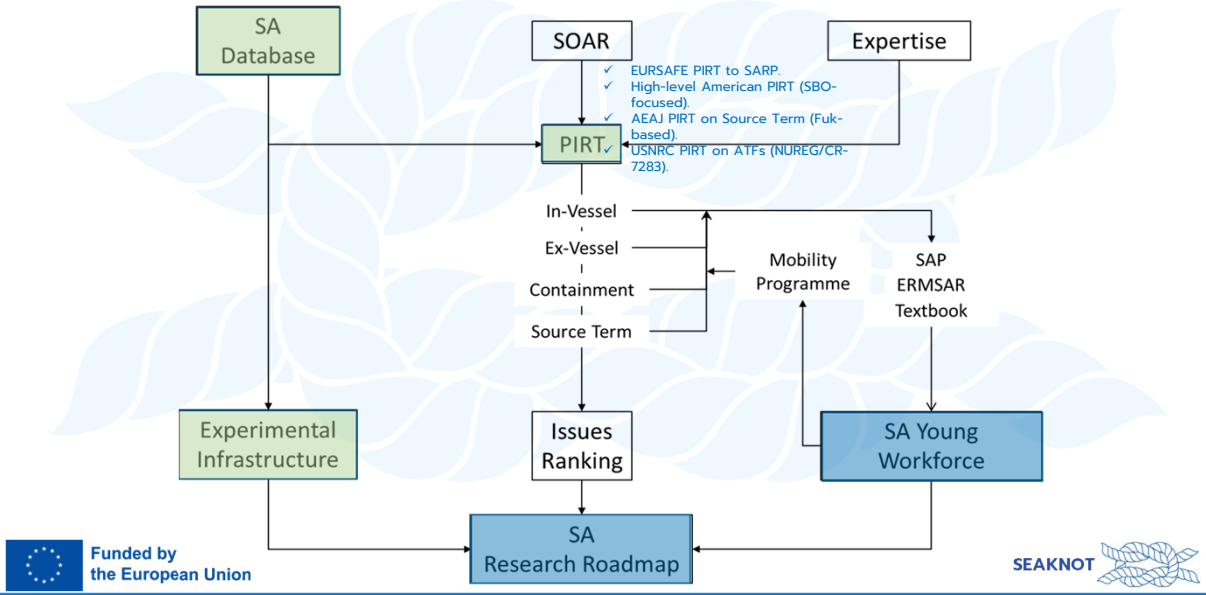
SEAKNOT Methodology



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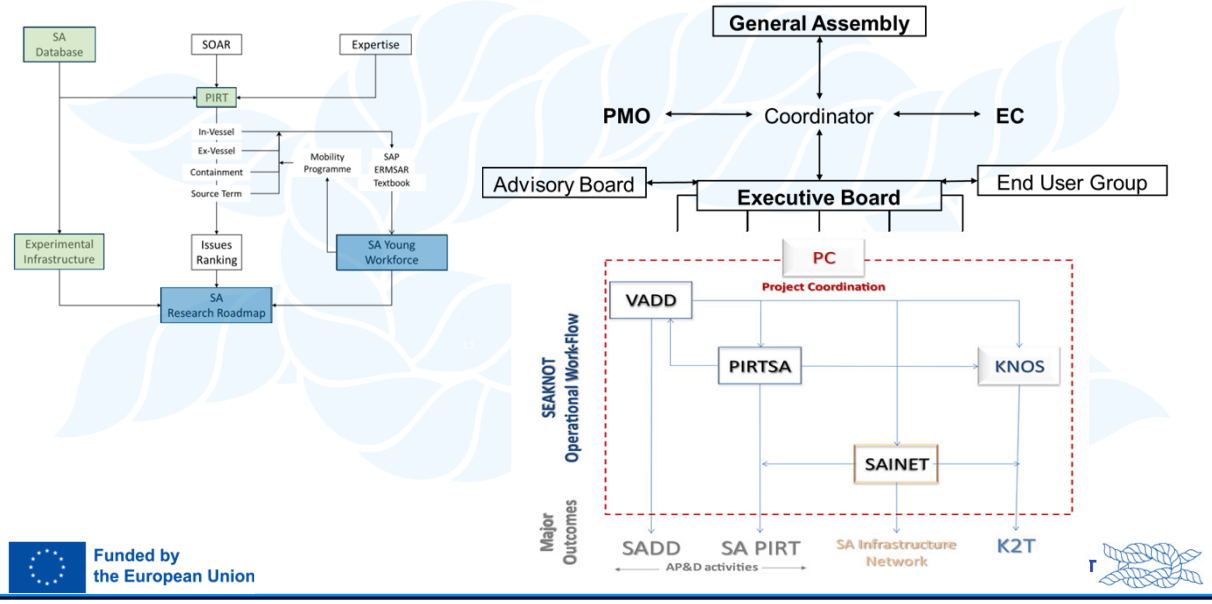
SEAKNOT Methodology



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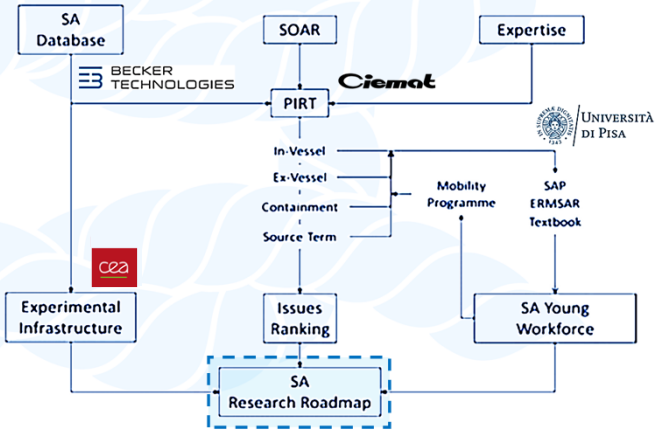
SEAKNOT Major Outcomes

- **Roadmap for SA research over the next decade**
- SA Phenomena Identification Ranking Table (SA PIRT)
- Validation SA Database Directory (SADD)
- Experimental infrastructure network (SAINET)
- Strengthening of young work-force (SA Textbook, SAP Course, ERMSAR, mobility grants…)



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WP1 PIRTSA Objective

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Identify the major SA issues worth new R&D activities

- Developed by a critical assessment of existing SA knowledge
- Assess the knowledge gaps (data & models)
- Evaluate the safety significance

Bases

- AEAJ PIRT on Source Term (Fukushima based)
- High-level American PIRT (SBO-based)
- From EURSAFE PIRT to SARP
- PIRT on SFP accidents (CSNI/WGAMA)
- running projects under several frameworks…

PIRT focus on LWRs but including SMLWRs and ATFs related aspects

- In-Vessel
- Ex-Vessel
- Containment
- Source Term

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WP2 VADD Objectives

BECKER TECHNOLOGIES

Review of SA experimental data used to develop and validate codes presently used to model SAs and support SAMGs

- Critical analyses of database (incl. OECD, EU reports, etc.)

Creation of a SA Database Directory (SADD)

- SADD will be a website analytical tool
- Future share outside the project also using external Knowledge Transfer Platforms, i.e., SNETP, IAEA or NEA
- Target: future expansions to accommodate new experimental data sources

VADD focus on LWRs but including SMLWRs and ATFs related aspects

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WP3 SAINET Objectives

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Assessment of EU experimental SA Facilities activities 2022-2030

- Mapping of EU experimental facilities in operation
- Identification of EU experimental able to answer to experimental key needs
- Identify forthcoming needs

Creation of SAINET (Severe Accident Infrastructure NETwork)

- Outline means, recommendations and framework for the future research

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WP4 KNOS Objectives

- **Strengthen EU leadership on SA E&T**
- **Efficiently foster C&D activities of the whole project**
  - Two consolidated NUGENIA TA2 events:
    - **Severe Accident Phenomenology (SAP) Course**
    - **European Review Meeting on Severe Accident Research** (ERMSAR)
  - New edition of SARNET **SA Textbook**, with substantial additions from EU expertise and WP1 - WP3 activities
  - **Internal mobility program** for young researchers & students
- **Articulate means to update SA R&D agenda according to SEAKNOT outcomes**

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The ROADMAP Core

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PIRT: Background

- PIRT: Step 3 in CSAU (Code Scaling, Applicability and Uncertainty) Methodology.
  (BEPU application in safety analysis; USNRC,1988).

- PIRT: A way to set technical basis for experimental programs.
- PIRT: A means to establish computer codes phenomenological requirements.
- PIRT: A methodology broadly used in SA (… but adaptation required!).
  - "Development of the source term PIRT based on findings during Fukushima Daiichi NPPs accident", 2015.
  - "PIRT: R&D Priorities for Loss-of-Cooling and Loss-of-Coolant Accidents in Spent Nuclear Fuel Pools", 2018.
  - "Elaboration of a PIRT for the modelling of In-Vessel Retention", 2020.

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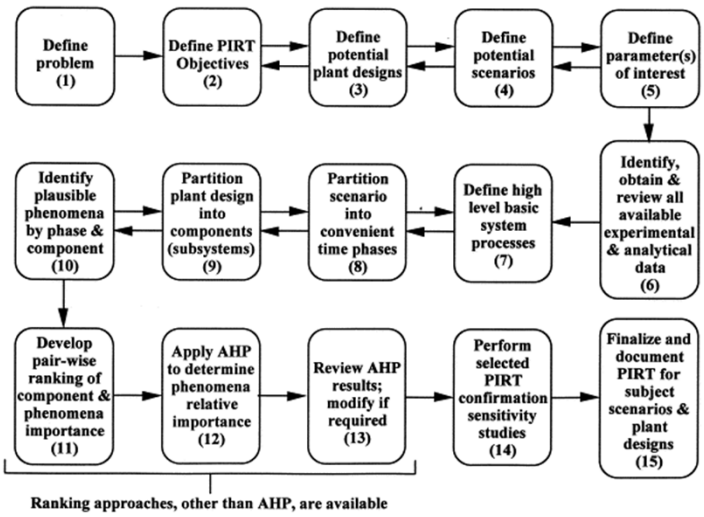
PIRT: Process Description



(1) Resources vs. efforts!
What problem must be solved to what level!

(2) Plant behavior! ⇐ Guidance ⇒
- SETs; IETs
- Code devlopment
- Code uncertainty

(3&4) Relative importance = f (design; scenario)
(5) Primary evaluation criteria!
(6) Collective knowledge of SOA understanding.
(7) "Saving time".
(8&9) Need to accommodate to SA (AM).
(10) Completeness ("what the team doesn't know").
(11-13) Ranking – Focused on (5) using (2).
(14) Confirmation of validity! (LongT Mob.)
(15) Documentation!

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PIRT: SEAKNOT Adaptation

(1) Definition: **SA Research to be done** in the coming 10 years.
From the SOARS, PIRTs and SARPs + input from recent projects

(2) Objectives: **External radiological impact** (external measures excluded) ⟶ Source Term
- FP release
- Barriers impairment
  - Cladding (In-V)
  - RPV (In-V)
  - RCB (ExV; Cont.)

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PIRT: SEAKNOT Adaptation

(3) Plant designs: **PWR-W/VVER/BWR/WC-SMRs (SASPAM-Types I, II)**
(ATFs – near term; cross cutting considerations; high Bup & enrich.)

(4) Scenarios: Generic approach to phenomena: phenomena ⟶ Key scenarios (prf).

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PIRT: SEAKNOT Adaptation

(5) Parameters: Main RN in terms of radiological consequences (I131; Cs137; Ru106; xxx?).
Onset time; release activity rates; composition.

(6) Data: Collective expertise (6) – deep on subject; broad in approach (expt.; model; appls.)
AB – Supplementary role (feedback).

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PIRT: SEAKNOT Adaptation

(7) High level features: Bifurcation/disruption of accident progress.
(Phasing / AMgmt).

(8) Accident phases: Alternate to the WP structure ... In-V + containment + Source Term
Ex-V + containment & Source Term

(adopting this approach might require to check with EC PO; WP2)

(9) Partition in components: Attention in accidents phasing.
Ex. Ex-V Containment
- Sprays
- Spools
- PARs
- Fan coolers
- FCVS

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PIRT: SEAKNOT Adaptation

(10) Phenomena identification: Based on "team satisfaction" from SOARs+PIRTS+Projects; plausibility!

(11) Phenomena ranking: Collective expertise (6)
ABs – Supplementary role (feedback).

(12) Sensitivity studies: Inspiration for long-term mobility grants.

(13) Documentation: Full traceability: defensible/scrutinizable/complete.
Feedback from EUG highly recommended (AB welcome)

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PIRT Ranking

- **Safety significance** – Referred to the primary parameters of interest (5)

  Three levels: L/M/H

  L: Low
  M: Medium
  H: High

- **Knowledge/Understanding** – Data/Models/Uncertainties

  a. Data: Existing & QVD (H); Existing, but no direct application VD (M); Non-existing (L)

  b. Models: Existing in codes (H); Existing but highly uncertain (M); Non-existing (L)

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PIRT Knowledge Ranking

MODEL \ DATA	L	M	H
L	L (Unknown)	L (Qualitative understaning)	M (Bases for "known" set)
M	L (Uncertain approximation)	M (Qualitatively assessed app.)	M (Soundly assessed app.)
H	L (Uncertain model)	M (Qualitatively assessed model)	H (Known)

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PIRT Ranking

KNOWLEDGE \ SAFETY	L	M	H
L	L	M_2	H
M	L	M_3	M_1
H	L	L	L

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The PUSH for K2T

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SAP 2023 Course

- Held in Madrid at ETSII - Universidad Politécnica de Madrid (UPM)
- **27** professional + **33** Students participants
- **13** Lecturers + **2** UPM staff
- Organizations from 14 countries / 20 nationalities

Country	Professionals	Students	Lecturers
Belgium	1		1
Canada	2		
Czech Republic	3	2	
Finland	2	1	
France	4	1	4
Germany	4	8	2
Iran		2	
Italy	1	3	2
Mexico	1		
The Netherlands	1		
Slovenia			1
South Korea	4		
Spain	4 (+ 2 UPM staff)	15	3
Sweden		1	

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SAP 2023 Course. Contents

- Severe Accidents (SA) in Nuclear Power Plant (NPP) Safety
- Historical Severe Accidents: TMI-2, Chernobyl, Fukushima-Daiichi
- In-vessel core degradation phenomena: early and late phases
- Early containment failure. Direct Containment Heating (DCH)
- Hydrogen risk
- Fuel coolant interaction (FCI) and steam explosions
- Ex-vessel phase. Corium spread; molten core concrete interaction (MCCI); coolability
- Source term: FP Transport in RCS and Containment. Source term chemistry
- Severe Accident computer codes & uncertainty quantification
- Safety assessment (PSA)
- Post-Fukushima safety improvements in Spanish NPP. Impact in SA phenomenology
- Radiological impact of SA
- Long-term Accident Management
- Decommissioning of SA damaged reactors
- New Design Features for Severe Accident Mitigation in Gen-III NPPs
- SA considerations in Advanced and Small Modular Reactors: Issues, challenges and opportunities

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SAP & SA Summer Camp 2025 at FZJ

June 23-27 (SAP) and June 30-July 4 (SASCamp), 2025

❖ SAP technical content similar to the SAP 2023

❖ FZJ on the logistics of both events (rooms & technical means available)

❖ **SA Summer Camp (SASCamp)→**

- One topic per day (in-V; Ex-V; containment; ST; uncertainties).
- "Instructors" pose a SA assignment to participants (agreed with SAP lecturers)
- "Instructors" support the groups while "solving" the assignment.
- **Not another SAP course or a SA code training**

Tentative day structure

09:00 – 10:00 h – Fast topic review (20') and assignment proposal (25' – Q&A included).
10:00 – 13:00 h – Group work to work out the assignment
13:00 – 14:00 h – Lunch time
14:00 – 15:00 h – Work on material presentation
15:00 – 16:30 h – Joint Session & discussion (5 groups of 3-4 people)
16:30 – 17:00 h – Final discussion of the day (topic wrap-up)

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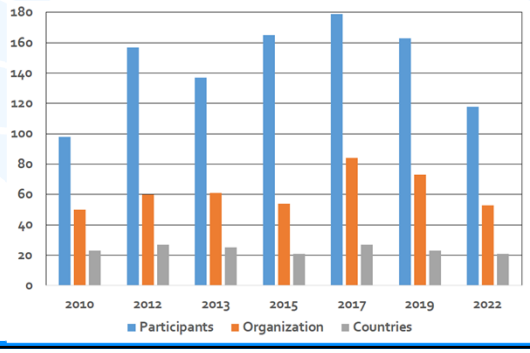
EUROPEAN REVIEW MEETING on SA RESEARCH
(ERMSAR)

- **Unique international forum focused only on SA research**
- **Ten editions since 2005 – Next XI edition in 2024**
- **2005 (CEA, Aix-en-Provence), 2007 (FZK, Karlsruhe), and 2008 (NRNE, Nesseber)** - FP6 SARNET
- **2010 (ENEA, Bologna)** - 98 participants; 23 countries (8 non-EU countries)



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EUROPEAN REVIEW MEETING ON SA RESEARCH
(ERMSAR)

- **2012 (GRS, Cologne)** **The first edition open to the international community**
  157 participants; 60 organizations; 27 countries
  Recent progress & needs (Fukushima)
- **2013 (IRSN, Avignon)** 137 participants; 61 organizations; 25 countries
  Syntheses of issues & R&D perspectives
- **2015 (CEA, Marseille)** 165 participants; 54 organizations; 21 countries (Japan, Russia, USA and Korea)
- **2017 (NCBJ, Warsaw)** 179 participants (25% non-EU) ; 84 organizations; 27 countries
- **2019 (ÚJV Řež, Prague)** 163 participants (19% non-EU) ; 73 organizations; 23 countries

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THE 10th EUROPEAN REVIEW MEETING ON SA RESEARCH (ERMSAR-2022)

- **First edition co-organized with NEA and IAEA.**
- **Locally organized by KIT:** An astonishing success!
- **Round numbers:** 120 participants; > 20 countries; > 50 organizations
  60 papers; 10 posters
- **Plenary sessions:**
  - International programs (NEA; IAEA; EC)
  - Fukushima XI years after (NEA)
  - New elements in the SA research domains
- **Dissemination:**
  - Proceedings (freely available)
    (snetp.eu/technical-area-2-severe-accidents)
    (DOI: 10.5445/IR/1000151444)
  - VSI: ANUCENE (since 2013 edition)
  - Summary report (WGAMA)

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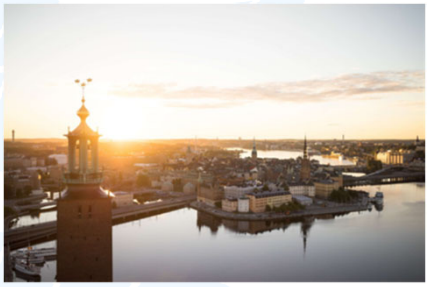
THE 11th EUROPEAN REVIEW MEETING ON SA RESEARCH (ERMSAR-2024)



- Framed within **EU SEAKNOT project** (SNETP/NUGENIA/TA2)
- **NEA** and IAEA expected to join as co-organizers
- May 13-16, 2024, Royal Institute of Technology (KTH), Sweden
- **Key dates**
  - Abstract submission: September 30, 2023
  - Abstract acceptance notification: November 1, 2023
  - Full paper submission: December 30, 2023
  - Full paper notification: February 22, 2024
  - Full paper final submission: March 12, 2024

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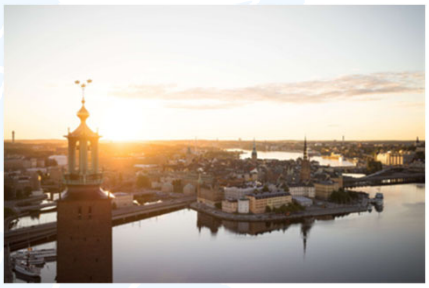
THE 11th EUROPEAN REVIEW MEETING ON SA RESEARCH (ERMSAR-2024)



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THE 11th EUROPEAN REVIEW MEETING ON SA RESEARCH (ERMSAR-2024)

- **Technical Tracks**
  - In-vessel corium and debris coolability
  - Ex-vessel corium interactions and coolability
  - Containment behavior including H2 explosion risk
  - Source term issues
  - AM & consequences of SA for Gen II/III reactors
  - SA in innovative reactors, including SMRs
  - Other applications (fusion, interim storage, etc.)

11TH CONFERENCE ON
SEVERE ACCIDENTS RESEARCH
May 13-16, 2024 – Stockholm, Sweden
ERMSAR 2024

- 20' presentations PLUS 10' for Q&A ("discussion driven").
- **"Open floor spirit"** in plenary sessions, round tables, sessions and conference wrap-ups – Discussing findings, brainstorming ideas & visions.
- **Current status (07.09.2023):** > 120 abstracts submitted!
- **Registration fee:** < 500 € (400 € for students).

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THANK YOU!

Get in touch for more information

All of the reports of the project will be available for download on the SEAKNOT website: **www.seaknot-project.eu**

Project coordinator: Luis Enrique Herranz, CIEMAT
Contact us: **contact@seaknot-project.eu**

Follow us on LinkedIn!
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Source Term

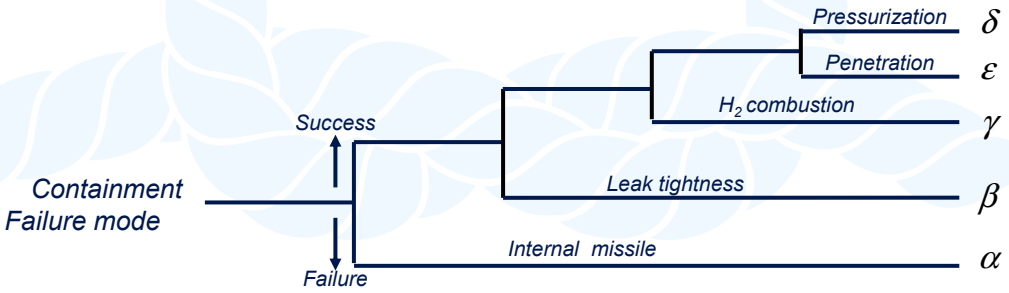
The Source Term Integral

$$J_i(t) = \int_0^{t_f} e(t)\cdot dt \cdot l \cdot F \cdot F_i \cdot \int_0^{t} s(t')\cdot dt' \cdot \exp\left[-\int_{t'}^{t} \varepsilon(t'')\cdot dt''\right]$$

Leak function

Release mode

Probability of remaining airborne



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