INNOVATIVE AND NEW CONTAINER/CANISTER MATERIALS UNDER DISPOSAL FIELD CONDITIONS: MANUFACTURING FEASIBILITY AND IMPROVED DURABILITY

InCoManD (WP9) – 23/10/24

Co-funded by the European Union under Grant Agreement n° 101166718

InCoManD: A BIT OF SEMANTICS

- **Innovative and new Container/canister materials under disposal field conditions: Manufacturing feasibility and improved Durability**
  - → **Innovative: solutions** (materials and/or processes) **never implemented or tested.**
  - → **New: more traditional solutions** (materials and/or processes) **that need to be optimized, improved, tested in more realistic conditions…**
  - → **Container and canister:** same meaning, can be referred to as **"component"**

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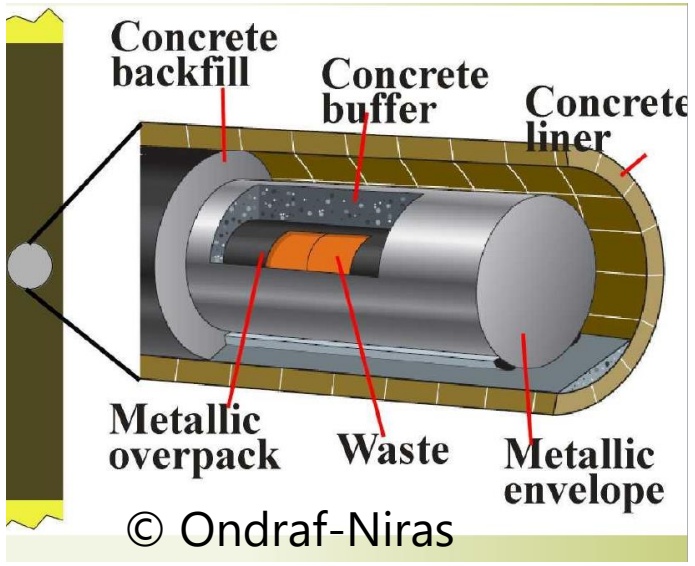

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InCoManD: EXPECTED IMPACT AND ADDED VALUE

- **WP that will be implementation-oriented** (input data about GDF concept already provided)
- **Innovation and/or optimization of material solutions**, including the assessment of the material durability (and analysis of the economical implications)
- **Better description and understanding of material degradation mechanisms** (pushing the state-of-the-art beyond the current one by implementing as realistic as possible conditions), **building of comprehensive predictive models.**
- **Capitalise on ConCorD results**, but also, develop common methodologies, encourage *Round Robin experiments and benchmarking to provide more confidence on the results* produced by each partner.
- **Synergy through a cooperative project** involving several countries across Europe sharing a common goal.
- Significant effort in **attracting and training new scientists** (lectures at the Master and Doctorate levels).

InCoManD: PARTICIPANTS

26 Partners (9 countries)

Short name of participant	Andra (FR)	BAM (DE)	BASE (DE)	CIEMAT (SP)	Galtenco (FR)	GNS (DE)	GRS (DE)	HZDR (DE)	EMSE (FR)
Short name of participant	IRCER (FR)	KIT (DE)	NSC KIPT (UA)	ONDRAF (BE)	Posiva (FI)	SIIEG NASU (UA)	IMT Atlantique (FR)	SÚRAO (CZ)	TUL (CZ)
Short name of participant	UGR (SP)	UJV (CZ)	UW (PL)	LUH (DE)	UPM (SP)	VSCHT (CZ)	VTT (FI)	ZAG (SI)	

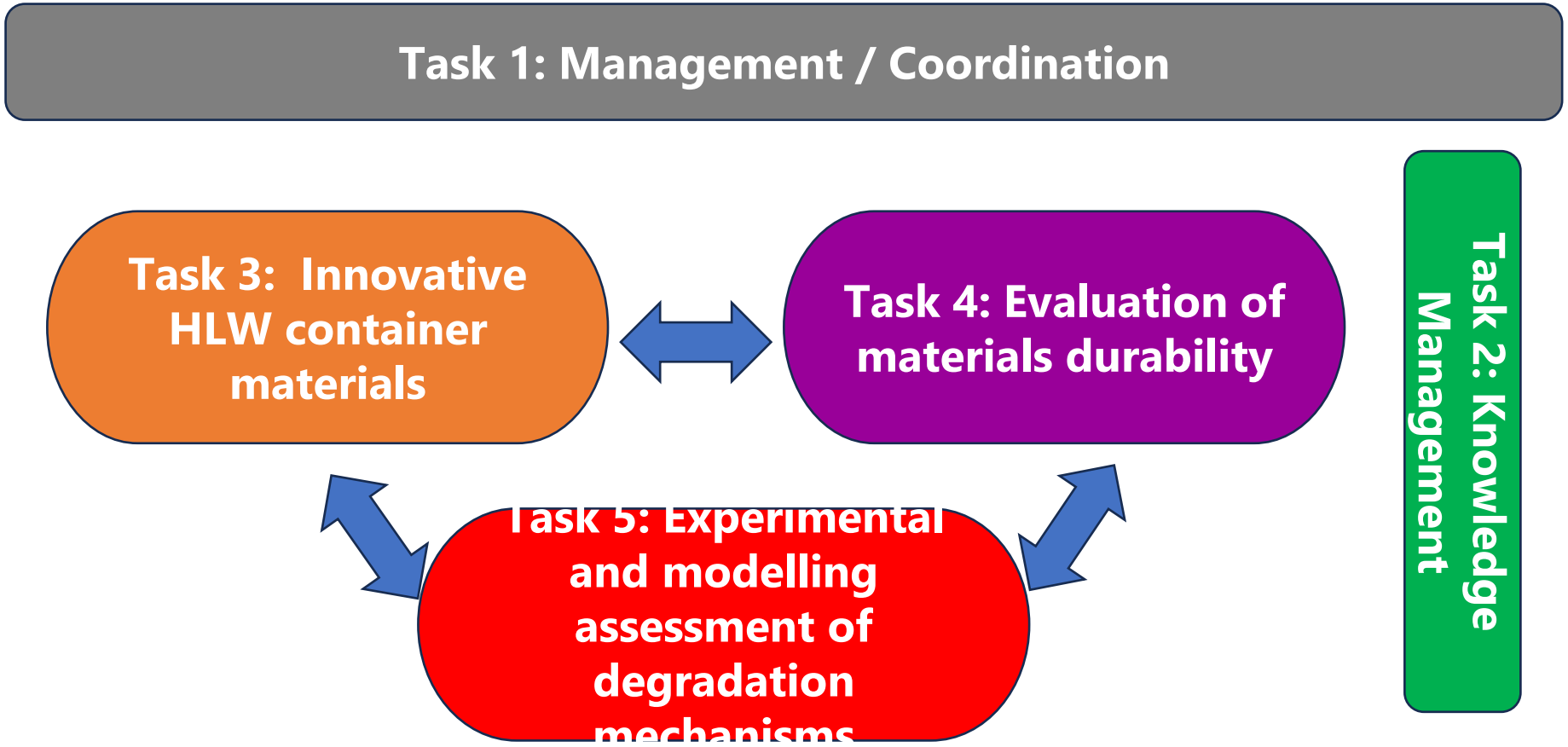
6 Associated Partners (3 countries)

Short name of participant	EPFL (CH)	UBERN (CH)	PSI (CH)	Nagra (CH)	UNIMAN (UK)	Sandia / LBNL (USA)

4 End-users (4 countries)

Short name of participant	BGE (DE)	ENRESA (SP)	NUMO (JP)	PURAM (HU)

InCoManD: ORGANISATION IN 5 TASKS



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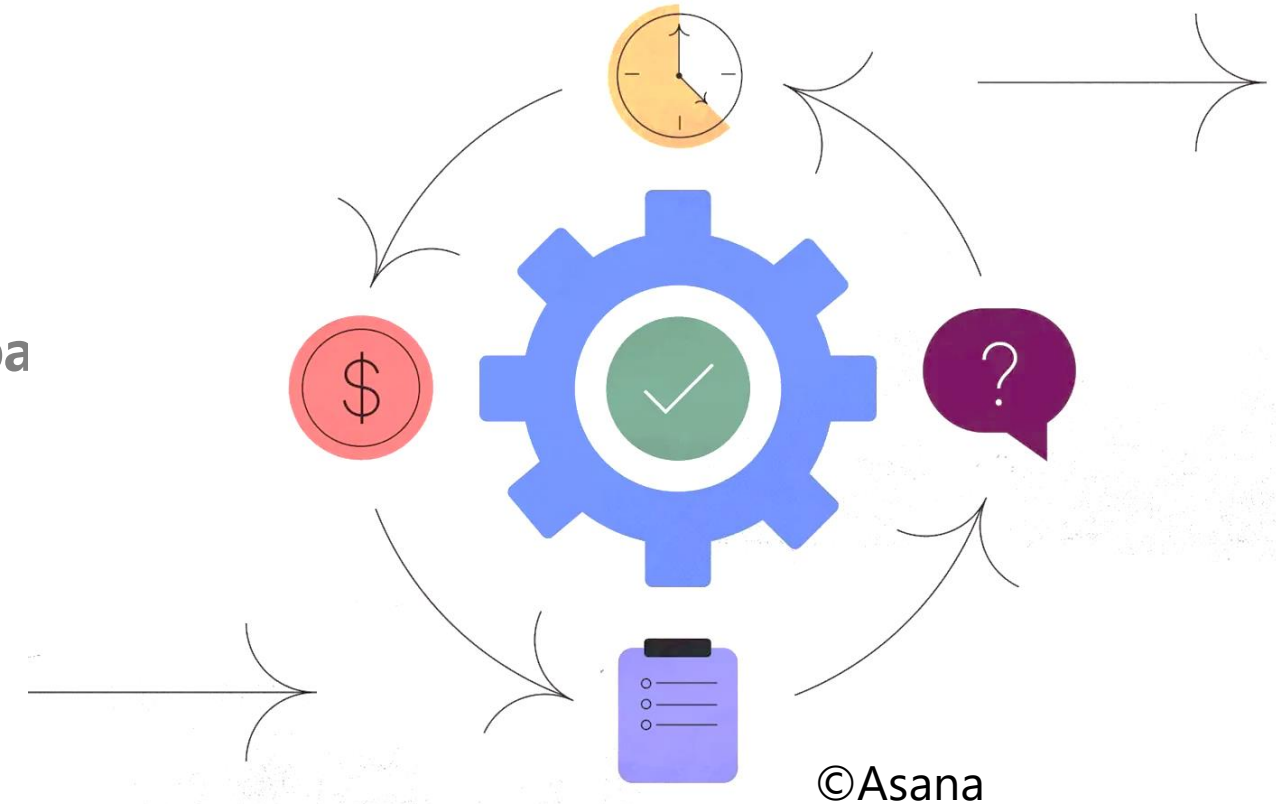
InCoManD: TASK 1 DESCRIPTION

- S&T coordination
- Dissemination / outreach / impa
- Quality control



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InCoManD: BOARD MEMBERS

Task 2: Knowledge Management

8 pm

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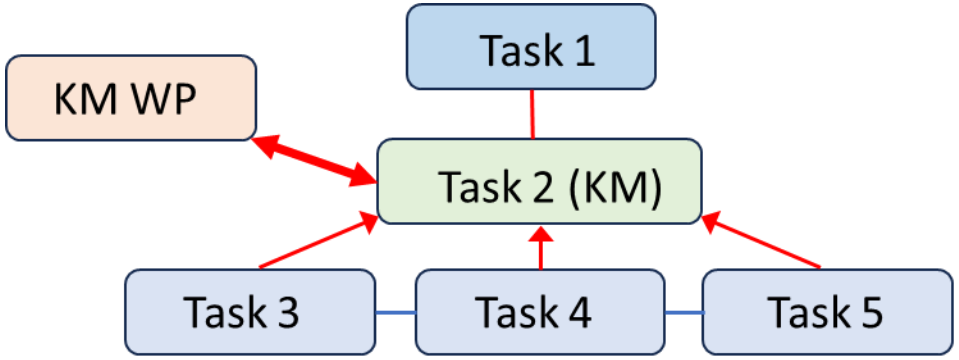
InCoManD: TASK 2 DESCRIPTION

Task 2: Knowledge Management

- **Subtask 2.1: Knowledge capture**
- **Subtask 2.2: Knowledge transfer**
- **Subtask 2.3: Additional KM activities: Summer School in Slovenia in 2027**



Task 2: Knowledge Management

InCoManD: WORKPLAN FOR THE FIRST 2 YEARS

- **Subtask 2.1 Knowledge capture:** Initial SotA/SoK report (based on final ConCorD-SotA)
- **Subtask 2.2 Knowledge transfer**
  - Indication of and **interaction with relevant target groups** and interested parties for the WP9 topics and tasks in collaboration with the KM WP.
  - **Indication of relevant international conferences** where to present and publish major outcomes of the WP and its tasks.
  - **Identification of potential seminars and lectures at universities** about the topics and outcomes from the WP to reach students and young researchers.
- **Subtask 2.3 Additional activities**
  - **Concept and structure of the planned summer school**, organized by ZAG in 2027. Identification of location, date, topics and contributions.
  - **First Workshop on both experimental and computational techniques** within the scope of the WP tasks (in early 2025).

Task 3: Innovative HLW container materials

255 pm

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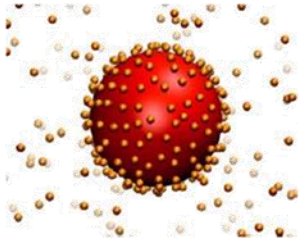
InCoManD: TASK 3 DESCRIPTION

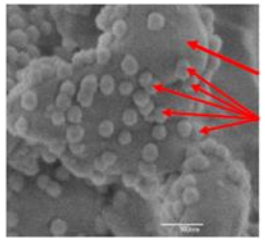
Task 3: Innovative HLW container materials

InCoManD

- **Subtask 3.1: *Improve* recently selected** (within ConCorD) **innovative, bulk and coating materials, and seek for new options** (e.g. multilayered materials, ceramic-metal composites)
- **Subtask 3.2: For selected materials, *define and optimize* elaboration or fabrication processes**
- **Subtask 3.3: A first LCC/LCA approach** will also be tackled **to *identify* the critical points in the upscaling strategy**



3D illustration of alumina/silica heteroaggregation Orange : Silica particles Red : Alumina particle



SEM micrograph of alumina/silica heteroaggregation

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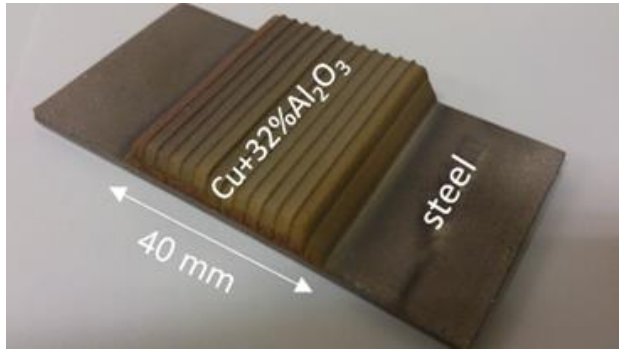
institut de recherche sur les céramiques



MINES Saint-Étienne

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Task 3: Innovative HLW container materials

InCoManD

INCOMAND: WORKPLAN OF THE FIRST 2 YEARS

- Subtask 3.1: Identification & improvement of innovative materials
- Subtask 3.2: Development of fabrication methods
- Subtask 3.3: Life Cycle Assessment and Life Cycle Costing (LCA/LCC) approaches

		Year 1	Year 2	
Bulk	Al_2O_3	**Manufacturing and characterizations** (mechanical/physical) of the chosen ceramics Development of sealing materials	Preparation of assembled coupons	Galtenco IRCER EMSE
	SiC	Improvement of Cr-doped SiC	Joining process for SiC-based ceramic parts by brazing with complex metallic and ceramic fillers	KIPT
	Cu	**Study of the hardening behavior**, cyclic/dynamic mechanical behavior of the materials		VTT
Coatings	Cold Spray	Elaboration/improvement of samples and various thermal post-treatments aimed at reducing porosity and improving adhesion between copper particles		EMSE
	Electrochemical deposition	Selection of metals/alloys	Deposition and qualification	Univ. Warsaw
	PVD	**Selection and qualification** (adhesion, porosity, corrosion resistance) **of a few relevant coating materials**, including metals, ceramic and composites of those such as CrN/CrON, Ti/TiO_2, Ti/Cu and associated potential multilayers		KIPT

InCoManD: BOARD MEMBERS

Task 4: Evaluation of materials durability

342 pm

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InCoManD: TASK 4 DESCRIPTION

Task 4: Evaluation of materials durability

InCoManD

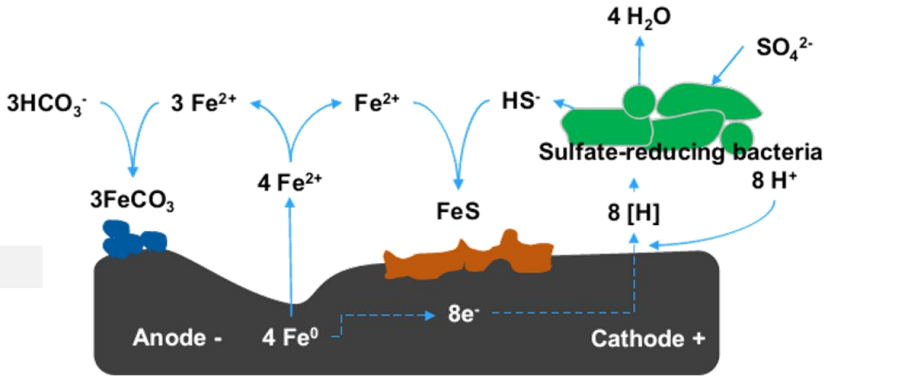
- **Subtask 4.1: *Evaluate* the durability** (*i.e.*, corrosion resistance under transients) **of the materials**, identified in Task 3 or previously recognized as reference materials, implementing lab-scale experiments, in systematic and parametric studies (irradiation, pH, temperature,…) , **to *identify* the main degradation mechanisms** and associated important parameters
- **Subtask 4.2: *Development* of dedicated complex (even *in situ*) experiments to mimic accelerated field conditions** (necessity to build devices with which stress factors can be coupled)

Copper tube

MX-80 bentonite

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

LOT: SKB TR-20-11



Scheme of iron corrosion by SRB based on reactions as suggested by the cathodic depolarization theory [7]

DRESDEN concept HZDR

^{137}Cs

Subatech

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Task 4: Evaluation of materials durability

InCoManD: WORKPLAN OF THE FIRST 2 YEARS

Subtask 4.1: Corrosion and durability of innovative and container materials

➢ Metals & alloys

- **C-steel**
- **Cast -Fe**
- **Cu and OF-Cu**
- **Ni & Ti alloys**

- **Localized corrosion under mechanical loac**
- Galvanic corrosion in scratch
- Repassivation studies
- **Combined effect of temperature and chemical attac**
- Welding effect
- Electrochemical analyses: temperature

➢ Metallic coatings

- **Materials fabricated in Task 3**
- **Ti/Cu & Ti/Cr**
- **Cu/Al_2O_3**

- Influence of aqueous medium on corrosion
- **Effect of irradiation and temperature on corrosio**
- Comparative corrosion resistance of single and multi-laye structure metallic PVD coatings on steel substrates

➢ Ceramics

- **Al_2O_3**
- **Multilayers ($CrN/CrON/TiO_2$)**

- **Durability under corrosive environme**
- Corrosion resistance

Task 4: Evaluation of materials durability

InCoManD: WORKPLAN OF THE FIRST 2 YEARS

Subtask 4.2: *Ad hoc* experiments to mimic accelerated conditions

➢ Temperature

- C-steel
- Cast -Fe
- Cu, Ti, Ni

Effect of temperature on canister corrosion:

- **Including bentonite or cement contact**
- Varying water chemistry

➢ Irradiation

- Materials fabricated in Task 3
- C-steel /Cu

- **Corrosion under coupled stress factors, including irradiation**

➢ Microbial activity

- C-steel
- TiO_2
- Novel materials developed in Task 3

- **Durability studies**
  - **Including bentonite**
  - **Including Fe powders**
- Diffusion studies

Task 5: Experimental and modelling assessment of degradation mechanisms

155 pm

InCoManD: BOARD MEMBERS

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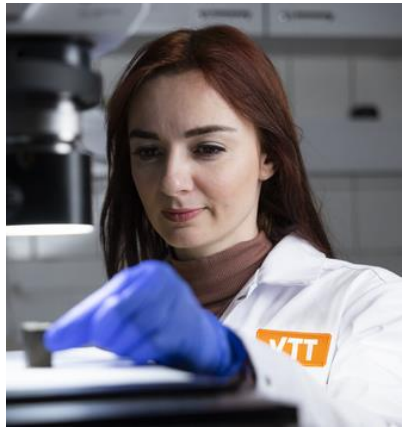

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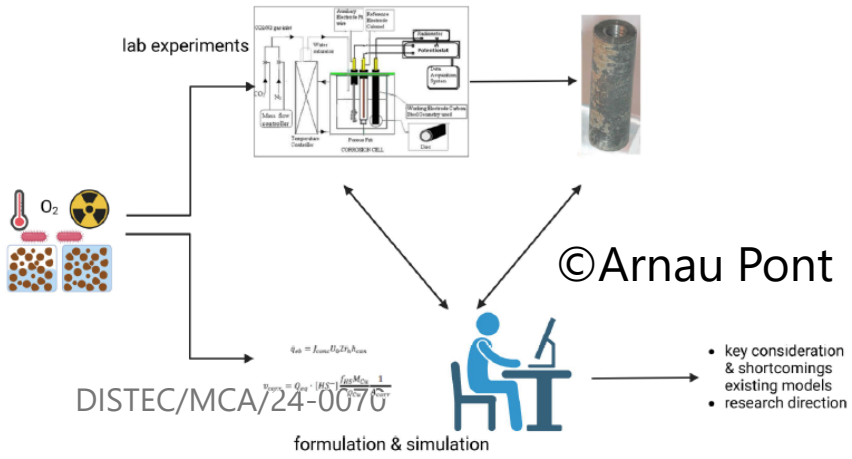
InCoManD: TASK 5 DESCRIPTION

Task 5: Experimental and modelling assessment of degradation mechanisms

InCoManD

- **Subtask 5.1: *Evaluate and study* joint mechanical-corrosion degradation modes, and *determine* the threshold stresses for SCC and stress intensity factors** (as a function of material properties and of the corrosive environment)
- **Subtask 5.2: *Develop* a modelling of the geochemistry and of time-dependent transients**

❑ 2 dedicated workshops between all partners of the WP to have the exp. vs model. communities discussing together (share of needs, description of outcomes…)



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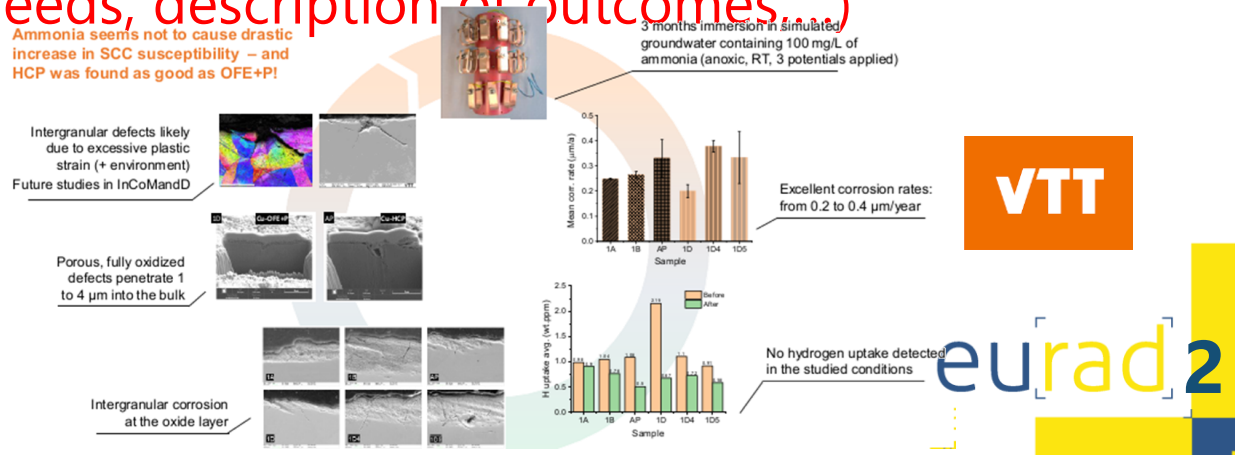

VTT

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InCoManD: WORKPLAN FOR THE FIRST 2 YEARS

Task 5: Experimental and modelling assessment of degradation mechanisms

InCoManD

- **Subtask 5.1: Evaluate and study joint mechanical-corrosion degradation modes, and determine the threshold stresses for SCC and stress intensity factors**

Institution	2-year planning
VTT	**Sample preparation tested in autoclaves with different environments** (ammonia, acetate and sulfide) with static load. "Disturbed groundwater" (accelerated conditions) to induce SCC.
ZAG	**Stress-threshold determination using tapered specimens**; SCC process initiation & crack growth monitoring at const. tensile load.
PSI	**Pre-characterization of samples by laboratory-based techniques to ultimately select appropriate synchrotron techniques. Writing of beamtime proposals for different techniques at synchrotron light sources.**

- **Subtask 5.2: Develop a modelling of the geochemistry and of time-dependent transients**

Institution	2-year planning
VTT	**Organization of a workshop to ensure efficient collaboration between experimental and computational work.**
TUL	**Collect ideas for corrosion and reactive transport modelling from partners.** Adjust the current reaction-transport model. Evaluate the stress/deformation model of steel outer and inner waste package.
PSI	**Thermodynamic and kinetic reaction model setup for the iron-cement system. Coupling with reactive transport solvers.** Development of a machine learning model to emulate the geochemical solver, which should allow to accelerate geochemical calculations by a factor of 1000.

InCoManD: EXPERT REVIEW GROUP

- **Missions:**
  - **Guiding** the development of the experimental and modelling tasks **to ensure that the results are relevant with respect to an actual GDF concept**
  - Participating in project meeting and WP annual meetings
  - **Reviewing progress** of the various tasks
  - Reviewing of milestones and deliverables
  - **Assisting in organising training activities**

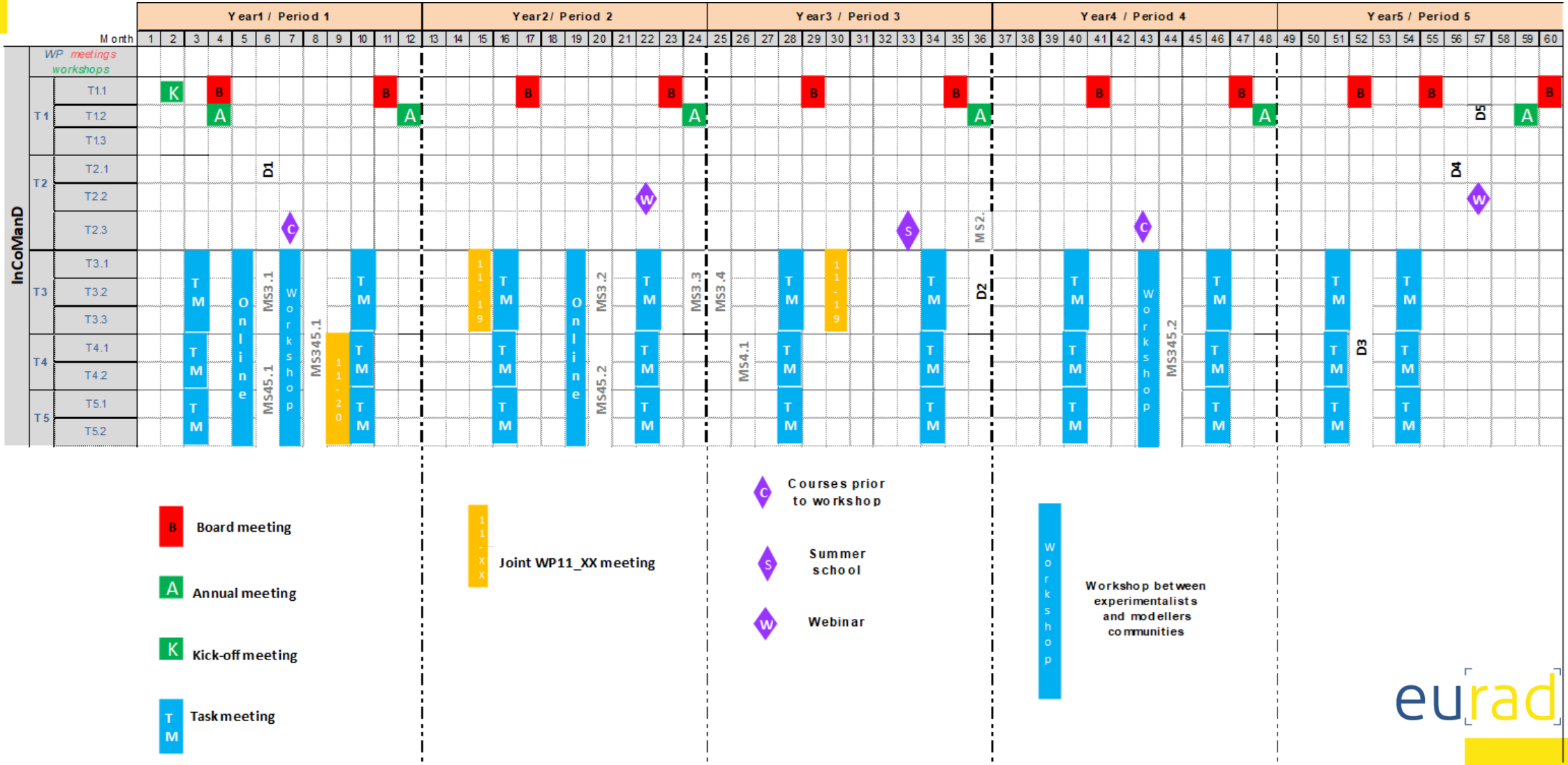
InCoManD: EXPERT REVIEW GROUP (ERG)

- **Members: Fraser KING** (Chairperson), **Christina LILJA** (SKB, Vice-chairperson), **Reddy BARTHI** (NWS), **Mehran BEHAZIN** (NWMO), **Benoit COCHEPIN** (Andra), **Gyula DANKÓ** (PURAM), **Nikitas DIOMIDIS** (Nagra), **Birgitta KALINOWSKI** (SKB), **Peter KEECH** (NWMO), **Valérie MAILLOT** (Andra), **Vanessa MONTOYA** (SCK CEN), **Tassilo MORITZ** (Fraunhofer Institute for Ceramic…), **Yosuke OSEGAWA** (NUMO) → ***all topics tackled within InCoManD covered by the members expertise***

	Task 3 Innovative container materials	Task 4 Evaluation of materials durability	Task 5 Joint mechanical-corrosion/modelling
ERG Lead	Bharti Reddy (NWS)	Birgitta Kalinowski (SKB)	Valérie Maillot (Andra) (Task 5.1) Vanessa Montoya (SCK-CEN) (Task 5.2)
ERG members	Mehran Behazin (NWMO) Gyula Dankó (PURAM) Tassilo Moritz (IKTS) Nikitas Diomidis (Nagra) Peter Keech (NWMO) Fraser King (ICC Ltd)	Mehran Behazin (NWMO) Gyula Dankó (PURAM) Valérie Maillot (Andra) Bharti Reddy (NWS) Vanessa Montoya (SCK-CEN) Christina Lilja (SKB) Tassilo Moritz (IKTS) Yosuke Ogawa (NUMO) Benoît Cochepin (Andra) Fraser King (ICC Ltd)	Nikitas Diomidis (Nagra) Christina Lilja (SKB) Benoît Cochepin (Andra) Mehran Behazin (NWMO) Birgitta Kalinowski (SKB) Yosuke Ogawa (NUMO) Peter Keech (NWMO Fraser King (ICC Ltd)

InCoManD: TIMELINE

- Online kick-off meeting: November 18 and 19 (2024)
- 1st f2f meeting: January 20-22 (2025)



InCoManD: SUMMARY

- 5 Tasks, comprising 3 S&T Tasks (Innovative materials, Materials under transients, Coupled effects, Experiments and modelling)
- Capitalise on ConCorD results
- WP that will be implementation-oriented (ERG will assist the partners!)
- Synergy, benchmarking, and skills upgrading through a cooperative project
- Attracting and training new scientists

InCoManD: ERG CHAIR

Task 3: Innovative HLW container materials

Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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InCoManD: ERG MEMBER, ERG CO-CHAIR

Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 3: Innovative HLW container materials

Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 3: Innovative HLW container materials

Task 4: Evaluation of materials durability

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Task 3: Innovative HLW container materials

Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 3: Innovative HLW container materials

Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 5: Experimental and modelling assessment of degradation mechanisms

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Task 3: Innovative HLW container materials

Task 4: Evaluation of materials durability

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Task 4: Evaluation of materials durability

Task 5: Experimental and modelling assessment of degradation mechanisms

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