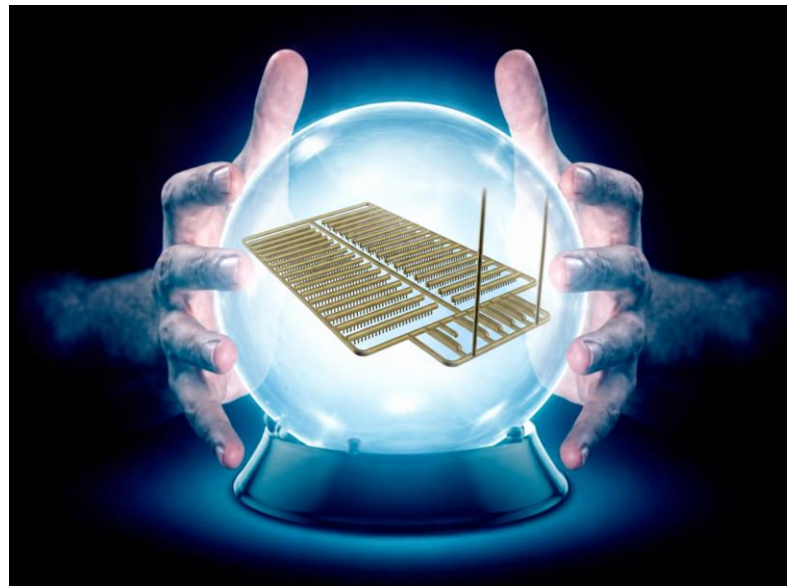


Topical session 7: Repository Digital Twin concepts and developments



or: How to build a crystal ball?



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PROGRAM

- DITOCO2030 / HERMES: Project aims and major achievements – Réka Szőke, Sergey Churakov
- DITOCO2030 White Paper recommendations and outlook – Pablo Cayon, Xavier Pintado
- Surrogate models for acceleration of coupled codes – Nikolaos Prasianakis
- Interactive session – Arto Laikari

Audience:

- Member of DITOCO: 11
- Member of HERMES: 12
- End User: 8
- Never heard about DT: 5

DITOCO2030 – KEY TECHNICAL INSIGHTS & LESSONS LEARNED

- **Vision**

- Build a federated, governed Digital Twin ecosystem creating a continuous digital thread across design → construction → operation → closure.

- **Key challenges**

- Fragmented tools and data silos • inconsistent DT terminology and scope • weak feedback loops between models and field reality • difficult evidence traceability • need to build regulatory and societal trust progressively.

- **Recommended approach**

- Develop an interoperable, modular and technology-agnostic ecosystem connecting BIM/GIS, monitoring data and multi-physics models through open interfaces and shared semantics. Embed governance, cybersecurity, provenance, versioning and traceability from the start, and focus on decision-critical use cases rather than technology itself.

- **Implementation pathway**

- Now: select high-value use cases → define common governance and architecture → launch an auditable MVP → involve TSOs/regulators from day one. Long term: scale toward a Living Safety Case Digital Twin, continuously integrating monitoring data, validated models and evidence for assessment, reporting and stakeholder communication.

THMC coupled processes

Operational period | **Post-closure period**

Emplacement of the package in the cell | Closure of the storage

1 | 10 | 10² | 10³ | 10⁴ | 10⁵ | 10⁶ years

Legend

- Thermal process
- Hydraulic process
- Chemical process
- Mechanic process

Thermal transient

20 °C | 70 °C | 90 °C | 100 °C | 70 °C | 20 °C

Onset of long term effects | Entire steel mass corrosion | Onset of long term effects | Entire steel mass corrosion

Hydraulic transient

Humidity at the long interface | Gas pressure in the cell

0.1 MPa | 0.2 MPa | 0.3 MPa | 0.4 MPa | 0.5 MPa | 0.6 MPa | 0.7 MPa | 0.8 MPa | 0.9 MPa | 1.0 MPa

Water saturation system - drainage | Onset of long term effects | Onset of long term effects | Onset of long term effects

Mechanics transient (lining and container)

Long information period | Loading of the container | Rupture of the container followed by rupture of the lining

Argillites oxidation

0 cm | 10 cm | 20 cm | 30 cm | 40 cm | 50 cm | 60 cm | 70 cm | 80 cm | 90 cm | 100 cm

Alkaline perturbation

0 cm | 10 cm | 20 cm | 30 cm | 40 cm | 50 cm | 60 cm | 70 cm | 80 cm | 90 cm | 100 cm

Corrosion process

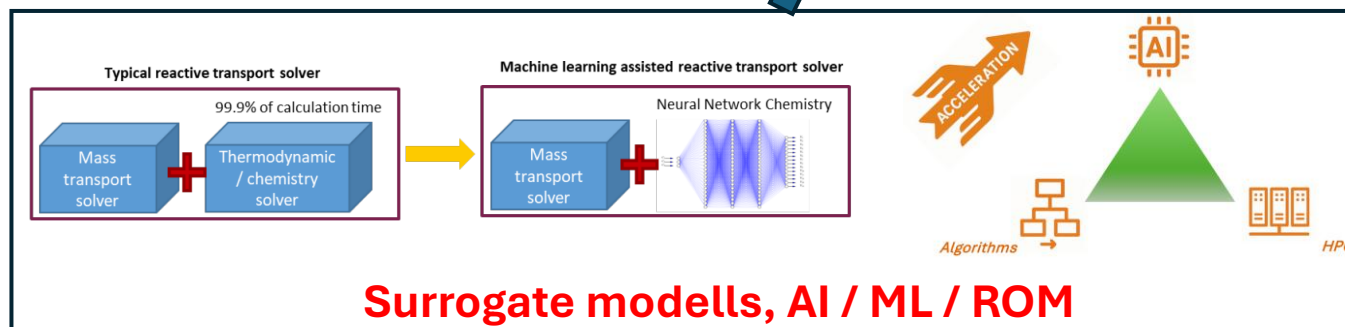
The disposal container is ascertained | The disposal container is not ascertained | The disposal container is not ascertained

Annotations:

- Thermal transient ≈ 1000 years
- Unsaturated conditions during several 10³ years
- Progressive loading of the lining followed by container loading and rupture
- Operating period: argillites oxidation
- Alkaline perturbation which extends: over long time for few decimeters
- Corrosion process linked to 2-phase flow conditions and mechanical loading of disposal cell

Building high fidelity models

Surrogate models, AI / ML / ROM



The figure illustrates the scaling of a geological repository model. It includes a 3D repository scale model (TH) with dimensions 65 m x 142 m x 105 m, a 3D reduced model (THM) with dimensions 6.5 m x 14.2 m x 10.5 m, and a detailed view of rock fractures. Below these are two circular plots showing vertical distance vs. horizontal distance for Mar 21 and Mar 22, with color-coded regions indicating different material properties.

TAKE HOME MESSAGES

- Start small, govern from day one, demonstrate value through auditable use cases, and scale toward a trusted Living Safety Case Digital Twin.
- AI/ML-based surrogate models can make high-fidelity simulations fast enough for Digital Twin applications, provided that accuracy and reliability are demonstrated through validation and benchmarking.
- End-user involvement is essential to ensure that AI/ML surrogate models address real needs and deliver trustworthy, usable Digital Twin solutions.