

CRUAS 2019 INTERNATIONAL BENCHMARK ON A SEISMIC BASE ISOLATED NPP WHICH EXPERIENCED A REAL EARTHQUAKE

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General outline of the presentation

- Context and objectives
- Cruas building & Recorded data
- The different phases of the benchmark
- Conclusions and recommendation

Steering Committee

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General context & motivation

❑ Which plant?

- Cruas PWR Nuclear Power Plant was designed at the end of the 70's.

❑ Which specificity does this plant have?

- The plant is built on **Seismic Base Isolation** (*laminated steel-neoprene bearing*)
- In view of the seismic risk associated with the **high dynamic modulus of the ground**, the entire **Nuclear Island buildings** of a **pair of units** is **built** on a **raft foundation** resting on **paraseismic supports**, whereas the other buildings are built directly on the ground.
- This system **filters out** seismic movements and thus **maintains an identical design level with slices of the same type**, while retaining the possibility of undergoing higher seismic levels.
- This technology is still challenged by international community and only a few NPP have been built with seismic base isolation.



General context & motivation

☐ Why are we interested in this type of plant?

- New designs such as SMRs, Jules Horowitz research reactor or ITER are willing to apply this kind of technology for both safety and competitiveness of nuclear industry.
- Lack of experience feedback of real earthquakes recorded on such facilities (especially related to in-structure response).

☐ Why a benchmark?

- Benefit from the opportunity of the occurrence of the Teil earthquake in November 2019 and the accelerometric measurements that have been recorded.

☐ What is the main objective of this benchmark?

- To [assess the efficiency of engineering practices](#) to compute in-structure seismic response especially for this specific seismic base isolated NPP.
- To share experience among the largest community.

General context & motivation

❑ What DATA do we have?

- Each facility is equipped with a **seismic safety monitoring system**, installed in Unit 1, called the **EAU system**.
- Its purpose is to **provide warning message** in each of the site's control rooms, and to record movements.
- Exceeding the threshold of **0.01g** on one of the 3 axes of one of the triggering sensors **activates the recording** of all the sensors and the triggering of a category 2 alarm in all the control rooms.

❑ Important to know:

- None of the **reference earthquake spectra for the design basis** of the facilities were exceeded.
- Only the **inspection earthquake fallback threshold**, a fixed threshold unrelated to the design (**0.05g**), **was exceeded** at the level of the basement floor of the ASG tank (outside of the seismic supports).

Recorded data

- ❑ Four triaxial accelerometers, connected to the acquisition console where the recordings are made, located in the following places:

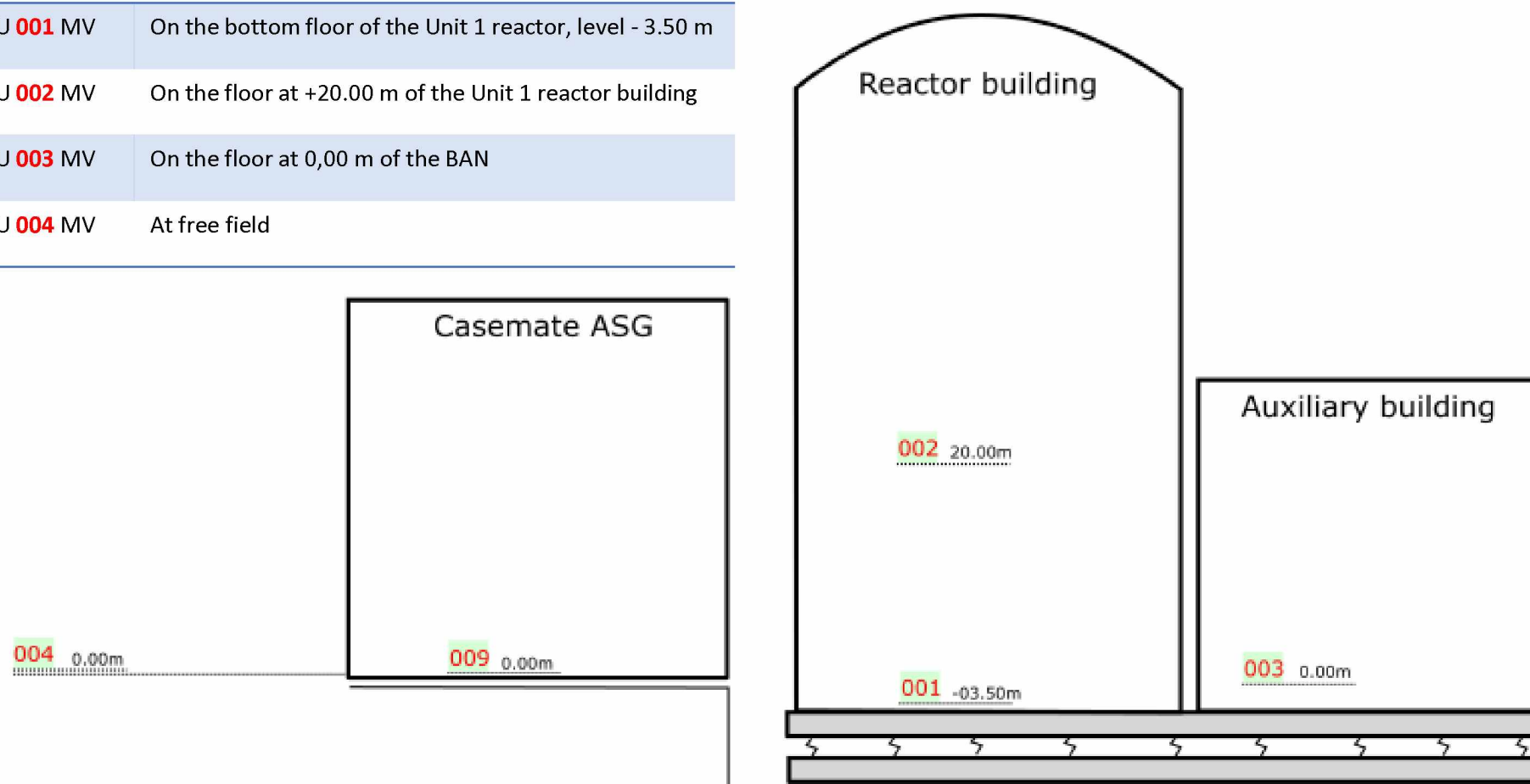
Name	Position
EAU 001 MV	On the bottom floor of the Unit 1 reactor, level - 3.50 m
EAU 002 MV	On the floor at +20.00 m of the Unit 1 reactor building
EAU 003 MV	On the floor at 0,00 m of the BAN
EAU 004 MV	On a small concrete footing at ground level, in free field, (away from heavy buildings)

- ❑ All of these four sensors (the three accelerometers and the free-field sensor) are arranged in such a way that their three respective orthogonal directions coincide with each other, following the axes of the buildings.

Recorded data

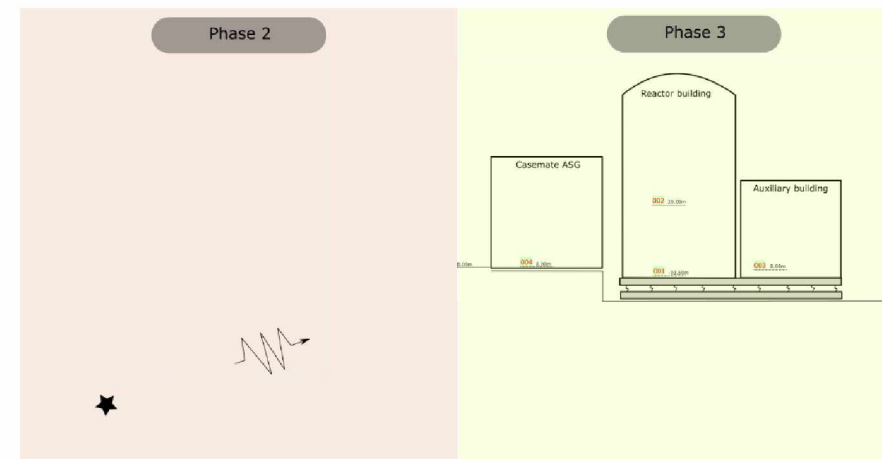


Name	Position
EAU 001 MV	On the bottom floor of the Unit 1 reactor, level - 3.50 m
EAU 002 MV	On the floor at +20.00 m of the Unit 1 reactor building
EAU 003 MV	On the floor at 0,00 m of the BAN
EAU 004 MV	At free field

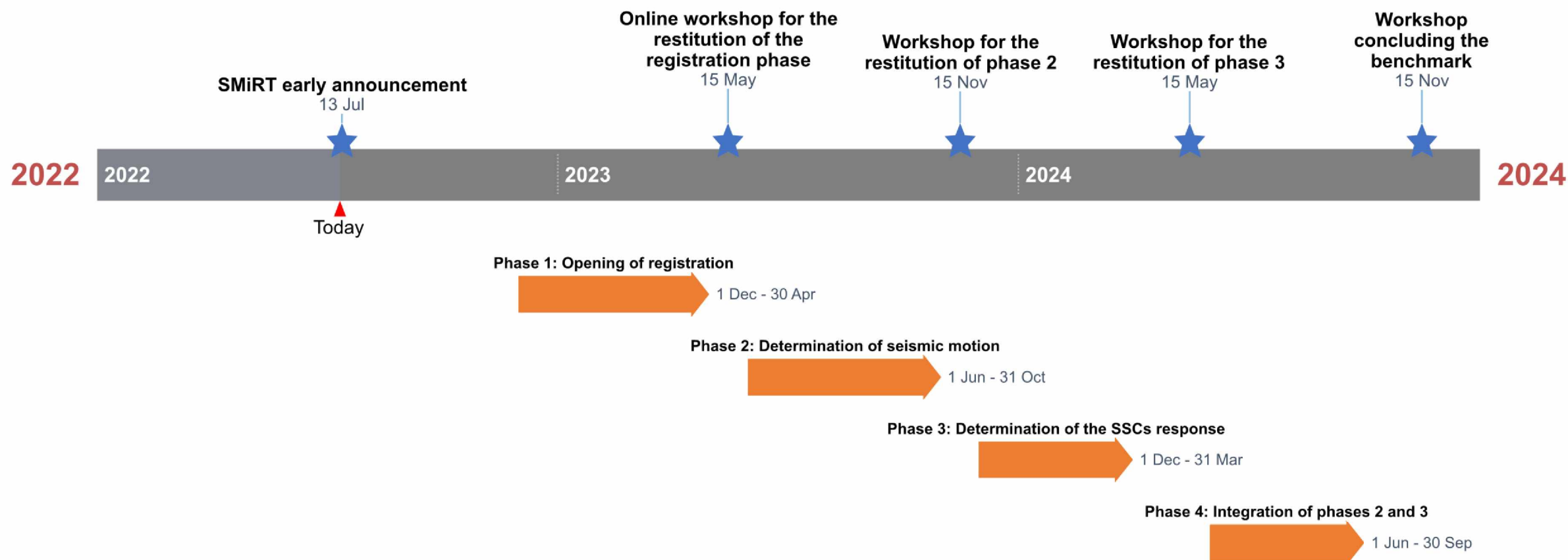


The different phases of the benchmark

- ☐ **Phase 1**: Benchmark announcement and participant registration
- ☐ **Phase 2**: Seismic ground motion characterization at CRUAS site
- ☐ **Phase 3**: Seismic response of CRUAS base isolated NPP
- ☐ **Phase 4**: Integration, synthesis, lessons learnt and recommendations



Agenda of the benchmark



Phase 1: Benchmark announcement and participant registration

- ☐ Announcement of the benchmark
- ☐ Declaration of intention from potential participants
- ☐ Definition of the program, rules and schedule of the benchmark
- ☐ Publication of an exchange and storage platform via a dedicated website
- ☐ Official registration of participants

Phase 2: Characterization of the seismic ground motion at Cruas site

❑ Objective

- Assess the available **engineering practices** related to **seismic ground motion characterization** (including response spectrum and other intensity measures, time histories ...)
- This phase is divided into two stages:
 - Stage 1 : Blind assessment
 - Stage 2 : Calibration and best estimate assessment

❑ Tasks

- Participants will be invited to **simulate the seismic motion at the site** coherently with the 2019/11/11 Le-Teil earthquake characteristics (size, location, fault geometry) and their results will be compared to the recorded ones;
- Additional considerations may be included in the benchmarking activity such as **characterization of sources of uncertainties** and **ground motion variability**;
- Main results and conclusion may be used as an input of phase 3.

Phase 2: Characterization of the seismic ground motion at Cruas site

❑ Stage 1 : Blind assessment

- For a given seismic scenario, participants will **calculate the corresponding ground motion** in terms of response spectra and accelerograms.
- The ground motion must be provided with different **intensity measures** (IM).
- All simulation strategies are allowed, **uncertainties** must be considered and propagated.

❑ Stage 2 : Calibration and best estimate assessment

- The organizers will **provide** the participants with the **recordings**.
- Participants are asked to address **discrepancies** between the blind results of stage 1 and the seismic recordings to improve the assessment of seismic ground motion.
- Prepare the input for Phase 3.

Phase 2: Characterization of the seismic ground motion at Cruas site

Stage 1

Input data for stage 1

- Hypocentral location with uncertainties
- Moment magnitude with uncertainties (Mw)
- Focal mechanism (strike, dip, rake)
- Georeferenced image InSAR
- 1D velocity profiles at RAN et EAU seismic stations
- Geological information (deep structure and velocity model)
- The coordinates of the reference station (in free field)



Output data for stage 1

- Three-component accelerograms
- Response spectra
- Intensity measures

Phase 2: Characterization of the seismic ground motion at Cruas site

Stage 2

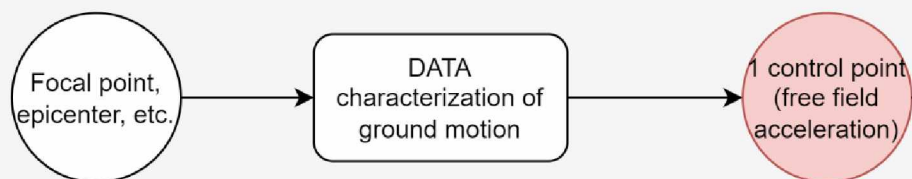
Input data for stage 2

- Recorded accelerograms in free field conditions
- Characterization of the discrepancies between observed and simulated ground motions
 - Response spectra discrepancies
 - IM discrepancies for each component (with the organizers methods)

Output data for stage 2

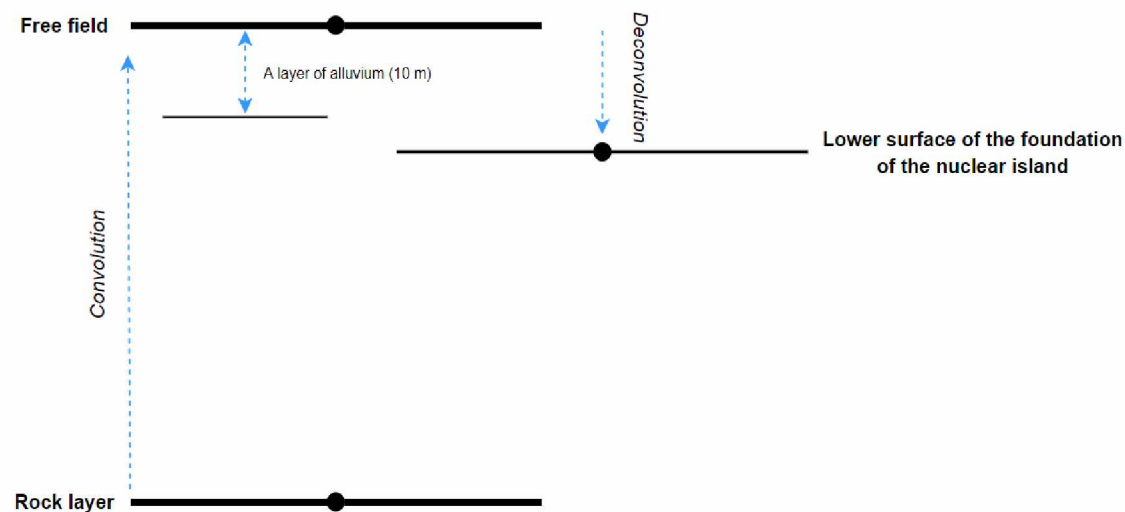
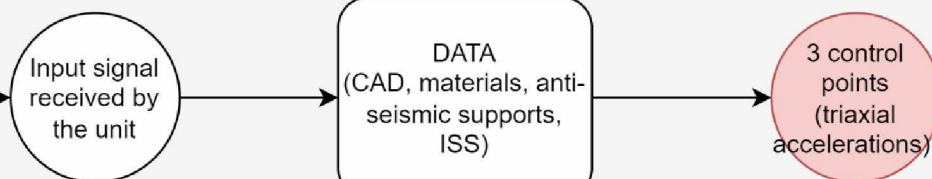
- Characterization of the discrepancies between observed and simulated ground motions (with the participant methods);
- Modify/adapt the seismic ground motion assessment to provide an updated best estimate of ground motion;
- Definition of the ground motion at the foundation of the nuclear island;
- Definition and integration of the spatial variability of the propagation medium at the scale of the nuclear island foundation.

Phase 2



Signal transposition
at the bottom of the
nuclear unit
(+characterization of
the spatial variability if
necessary)

Phase 3



Phase 3: Assessment of the seismic response of Cruas base-isolated NPP

❑ Objective

- Assess the available engineering practices related to **seismic response** calculation of a **NPP built on base isolation** (including seismic input, calculation model and methods and in-structure seismic response).

❑ Main task

- Participants will be invited to predict the **seismic response** on the NPP and their results will be compared to the actual recorded in-structure response.

Phase 3: Assessment of the seismic response of Cruas base-isolated NPP

☐ **Stage 1 : Blind assessment**

- Participants will calculate the **response** of **Cruas base isolated NPP** in terms of response spectra and accelerograms.
- All simulation strategies are allowed, **uncertainties** must be considered and propagated.

☐ **Stage 2 : Calibration and best estimate assessment**

- The organizers will **provide** the participants with the **recordings**.
- Participants are asked to address **discrepancies** between the blind results of stage 1 and the seismic recordings to improve the assessment of seismic response of Cruas base isolated NPP.

Phase 3: Assessment of the seismic response of Cruas base-isolated NPP

Stage 1

Input data for stage 1

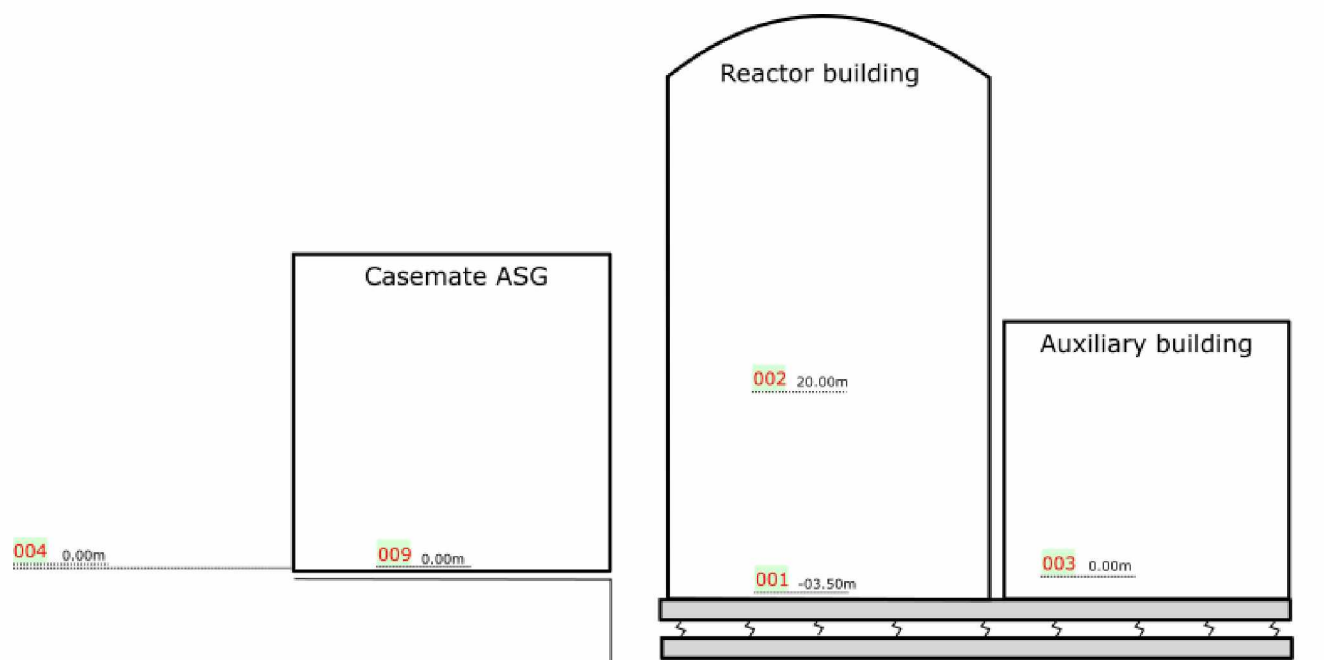
- Geometry of BR/BAN in 3D in STEP format + material properties
- Lumped-mass stick models for BK1, BEE1, RRI, BL, as well as Unit 2 buildings since Units 1 and 2 rest on the same isolated base :
 - *key information on the stiffnesses of the concrete beams and the masses*
 - *location of these lumped-mass stick models on the common base*
 - *main modal characteristics under embedded conditions to ensure the dynamic behavior of the main modes of these buildings*
- Possibility of providing participants with an optional mesh in MED format of BR/BAN
- Data about seismic supports
 - *number and height of supports*
 - *location/position of each support*
 - *stiffness evolution curves (considering their aging)*
 - *the curves of the cyclic tests at the design stage and those up to date*

Phase 3: Assessment of the seismic response of Cruas base-isolated NPP

Stage 1

Output data for stage 1

- Three-component accelerograms at EAU sensor positions (001, 002, 003)
- Response spectra
- Transfer functions



Participants are required to submit a descriptive document along with their results.

Phase 3: Assessment of the seismic response of Cruas base-isolated NPP

Stage 2

Input data for stage 2

- Input data for stage 1
- Measures of the EAU system (001, 002, 003)

Output data for stage 2

- Input signal (*signal transposition at the bottom of the nuclear unit*)
- Damping ratio
- Stiffness calibration of seismic supports
- Linear or non-linear behavior

Phase 4: Synthesis, lessons learnt and recommendations

- ☐ **Integration** of phases 2 and 3: additional considerations may be included such as **significance of**
 - seismic ground motion incoherency and variability,
 - estimated engineering demand parameters vs intensity measures,
 - issues related to the transposition to higher intensity seismic ground motions

- ☐ Main results and conclusions will be **shared** among participants (bridging phase 2 – seismic ground motion and phase 3 – seismic response of the plant)

- ☐ Identify **best practices** especially dedicated to the **seismic assessment** of **base-isolated NPPs**

- ☐ The final outcome will be a **synthesis report** providing Member States with the **lessons learnt** and **recommendations** from this benchmarking exercise

Next steps

- ☐ Writing a technical specification note regarding the benchmark (under progress)
- ☐ Preparation and setting up of the Benchmark roadmap
- ☐ Organization, screening and harmonization of the recorded data to be used in the benchmark
- ☐ Detailed definition of the exercises that will be requested from Benchmark participants
- ☐ Preparation of phase 1 and start of participants' registration from January 2023

Outcome of the benchmark

- ☐ The final outcome will be a synthesis report providing Member States with the lessons learnt and recommendations from this benchmarking exercise

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*If you want to stay informed about the next steps or if you are
interested in participating in the benchmark, I invite you to send me a
message by email to add you to the mailing list under creation.*

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THANK YOU