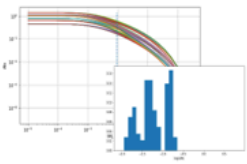
THE METIS PROJECT NEWSLETTER

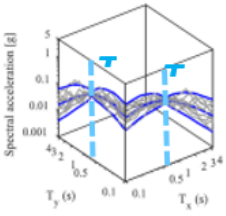
SECOND EDITION

WELCOME TO THE SECOND METIS PROJECT NEWSLETTER

With this newsletter we invite you to learn more about the project's latest developments and the partners' achievements. Please check our recent advances to improve the seismic risk assessment analysis chain, from hazard and ground motion to site response, fragility, and risk quantification.



Seismic hazard at rock



Site response and ground motion

SSCs response and fragility

Risk quantification

METIS
Seismic Risk Assessment for Nuclear Safety

This summer was also very rich in events for the METIS project. This newsletter gives you an overview of the past events and an invitation to join us for upcoming

events in 2023.

Irmela Zentner (project coordinator), the project office & work package leaders

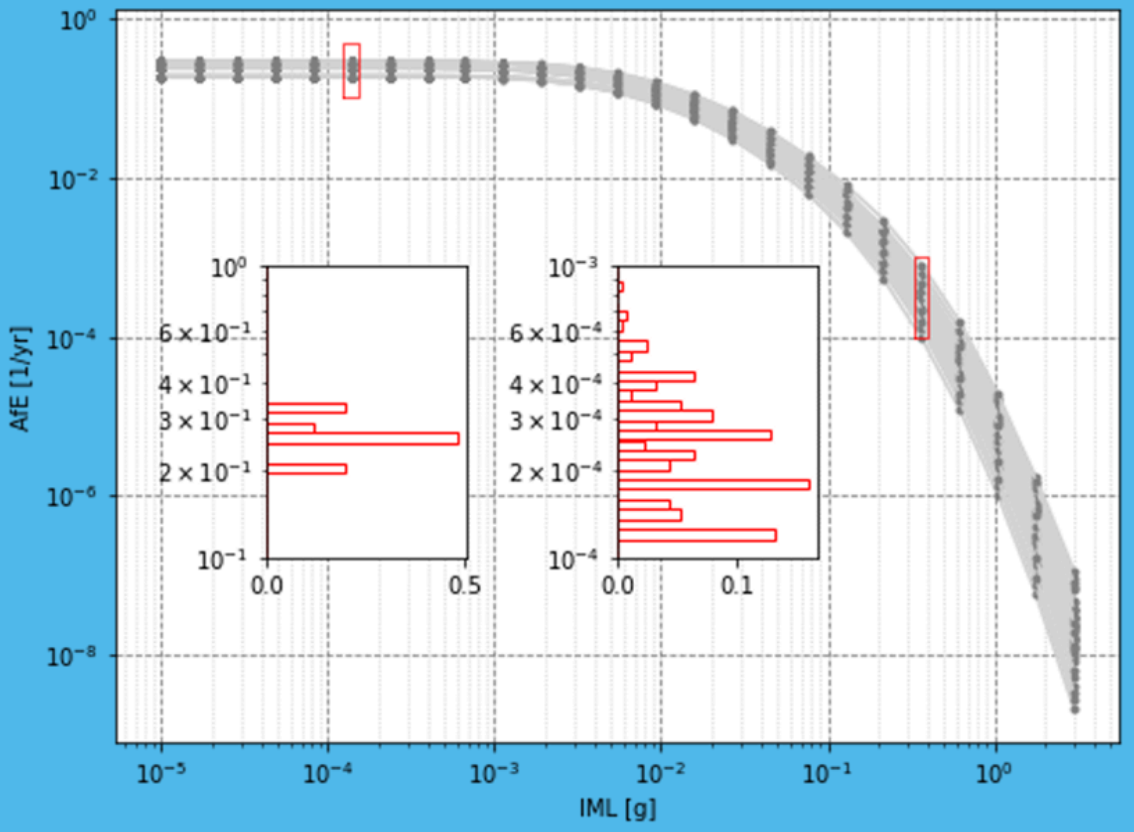
WORK PACKAGE PROGRESS

WP4 - SEISMIC HAZARD ANALYSIS

WP4 deals with new methodologies and tools for probabilistic seismic hazard analysis (PSHA) and their application in the METIS case study.

- **Declustering**: During the last semester, we completed the work on the new methodology for declustering earthquake catalogues and we are now working on providing public access to the tools implementing it.

- **Characterising and modelling epistemic uncertainty in PSHA**: Regarding the use of Bayesian approaches for the estimation of logic tree weights, a methodology for updating selected parameters of the GMMs used for a PSHA was devised. Documentation describing the results achieved, and the methodology proposed is under preparation. we completed the first prototype of an alternative approach for propagating epistemic uncertainty based on convolution. We are now extending this approach to different hazard results (e.g., seismic hazard disaggregation). The figure below shows – for a demonstrative example – histograms of the annual frequency of exceedance at different intensity measure levels which are used to propagate uncertainties.



- **PSHA tools and methods**: We improved the implementation of the Lin et al. (2013) method available in the OpenQuake Engine and we completed the code for performing aftershock PSHA. This is available in the `aft` module of the OpenQuake Model Building Toolkit (see https://github.com/GEMScienceTools/oq-mbtk). Documentation is currently in preparation.

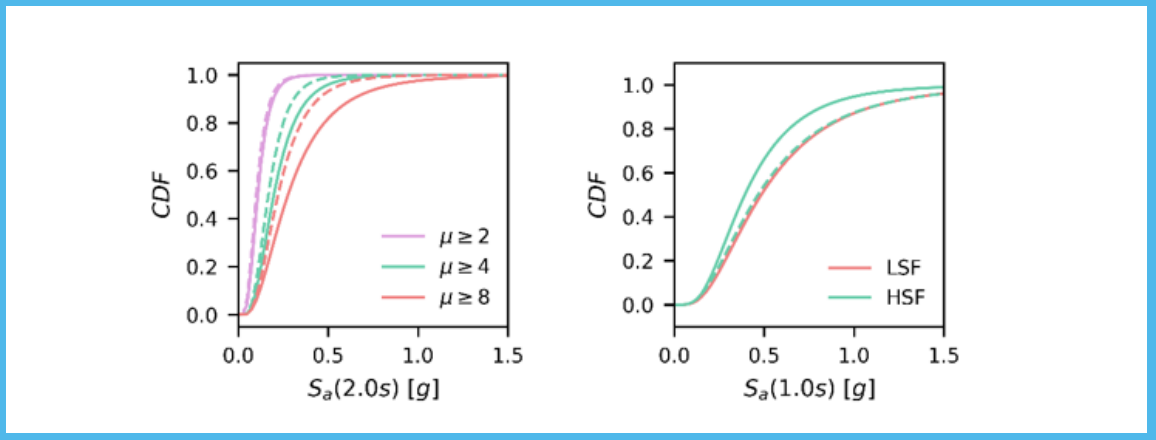
- **Physics-based simulations**: We worked on accounting for epistemic uncertainty when performing simulations using the Otarola method. With this methodology it is now possible to generate a database of synthetic time-histories with a variability that reflects the uncertainty in the parameters controlling the simulation.

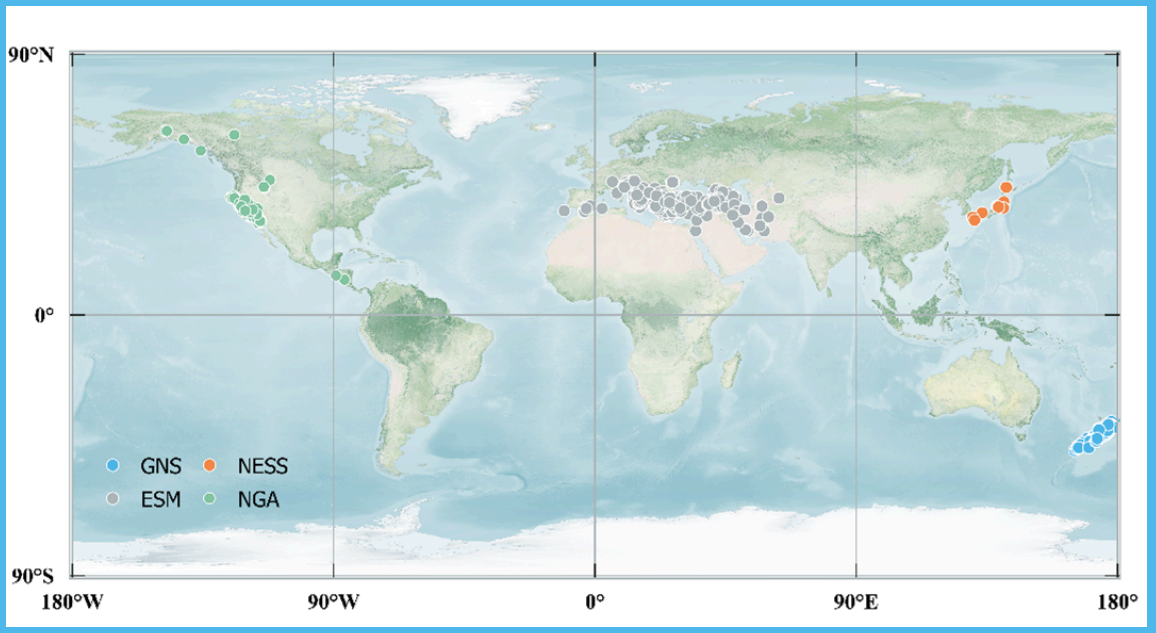
- **PSHA Testing and Validation and Verification**: We constructed a database of ground motion measurements at predictions at several stations located in Europe and analysed residuals. In parallel, initial components of a toolkit for testing PSHA results against observations were developed. Further development and analyses involving the database and the hazard results from ESHM20 and two national hazard models for Germany and France are in progress.

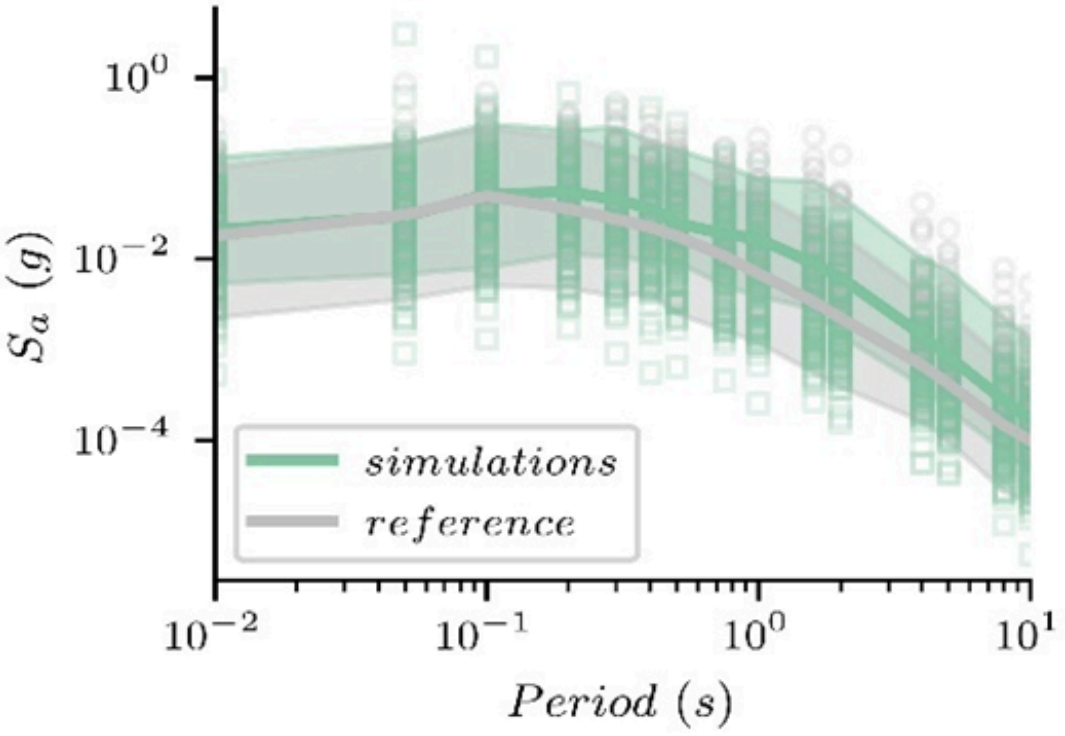
- **METIS case study**: The seismic source characterisation for the METIS test site is located in Central Italy. The model that already took advantage of the new declustering tool will be extended in the following months with a proper ground-motion characterisation and used to produce hazard results valid for the other work packages.

WP5 - GROUND MOTION SELECTION FOR ENGINEERING ANALYSES INCLUDING SITE RESPONSE

WP5 is the link between seismic hazards (WP4) and response assessment (WP6) and deals with the selection of ground motions consistent with the former and appropriate for use in the latter. Most of the WP5 work done to date is related to creating and assembling a large pool of rock ground motion records to be used for hazard-consistent selection. To this end, we explored the adequacy of real but scaled records, synthetic records, and records from soil sites to be used on rock and we defined a battery of tests to evaluate their appropriateness for engineering analysis. Furthermore, to enforce hazard consistency we investigated and developed tools for ground motion selection based on state-of-the-art methodologies, such as the Conditional Spectrum approach and related variants. The results obtained will be summarised in the deliverable that should be submitted in May 2022. In addition, we have started working on the hazard consistent ground motion selection for seismic sequences that will be used in WP6 to derive damage-dependent fragility curves for systems, structures and components (SSC) structures.

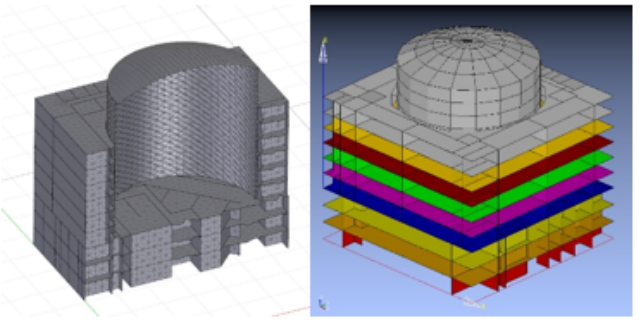




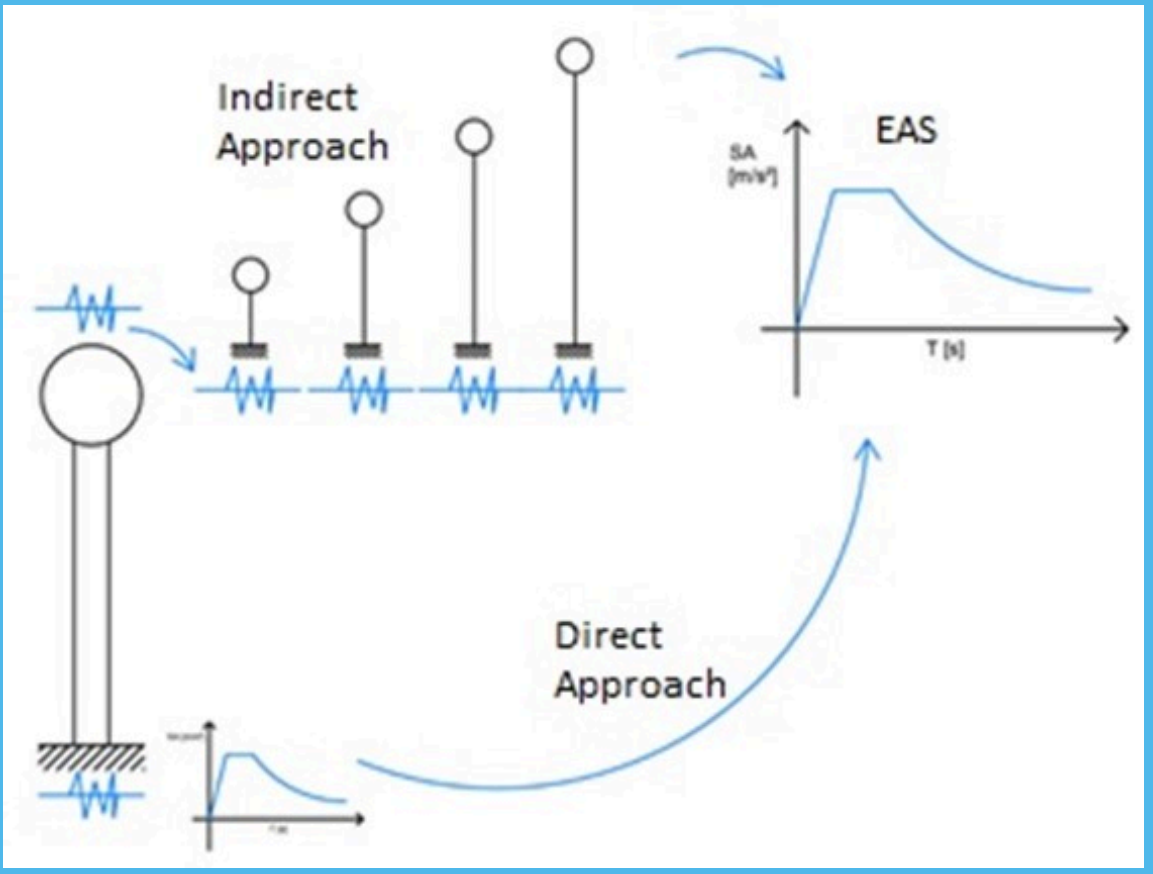


WP6 - BEYOND DESIGN & FRAGILITY ANALYSIS

WP6 deals with the response assessment in the METIS project. The results will be the fragility curves for the SSCs. Within the last year models for the case study have been created. The main structures considered as relevant from the definition and classification scheme of the SSCs are modeled. These are the reactor building and the diesel generator building. Models have been created in OpenSees and Code_Aster to allow the use of open source software within the project. For all nonlinear FE-Models, simplified models with low computational cost for the use in computationally intensive investigations are generated. Additionally, the use of surrogate models is investigated. Hereby the application of machine learning approaches, such as Multilayer perceptron and long short-term memory networks, as surrogates was investigated. This allows the prediction of the engineering demand parameter or the structural displacement time series based on seismic intensity measures or earthquake ground motions.



The influence of nonlinear structural behavior on the resulting floor response spectra of Systems and Components were investigated. In the next step, simplified approaches for the resulting floor response spectra will be proposed. The results will be summarised in the deliverable 6.5.



A methodological framework for the verification and validation of numerical nonlinear models in structural dynamics was presented. The approach allows the assessment of uncertainties whether they originate from the numerical discretisation or input parameters. It also evaluates the model tendencies to overestimate, underestimate, and match reality over the domain covered by the experimental campaign. In case of application outside this domain, objective methods to extrapolate these tendencies are proposed. With this, confidence in the results can be increased and their acceptability assessed. In the next steps, the process is applied to the experimental data and numerical models from the project.

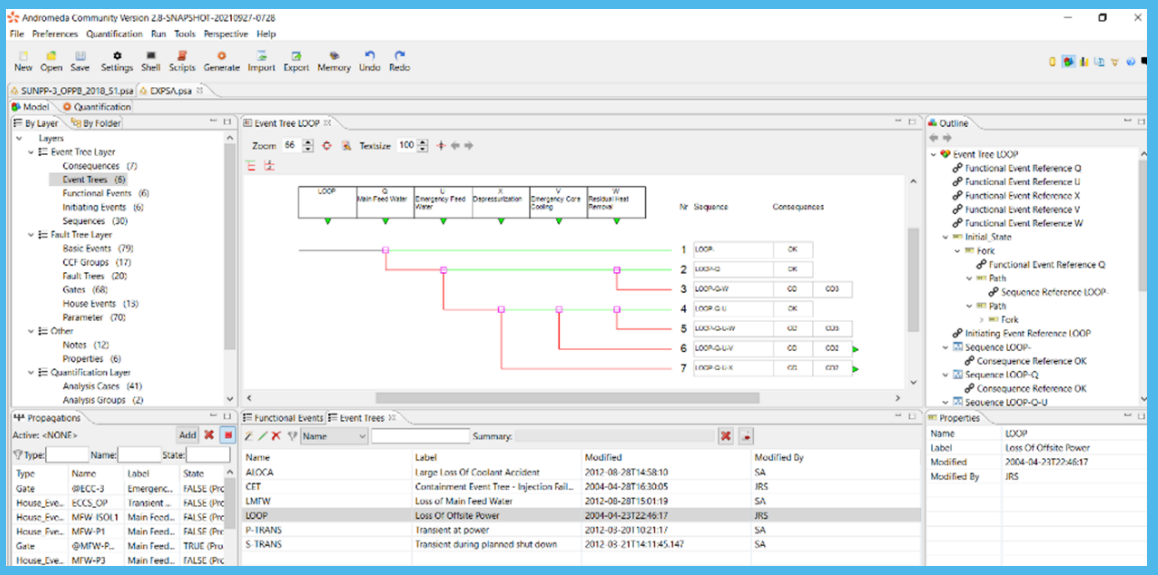
WP7 - PSA TOOLS & METHODOLOGY

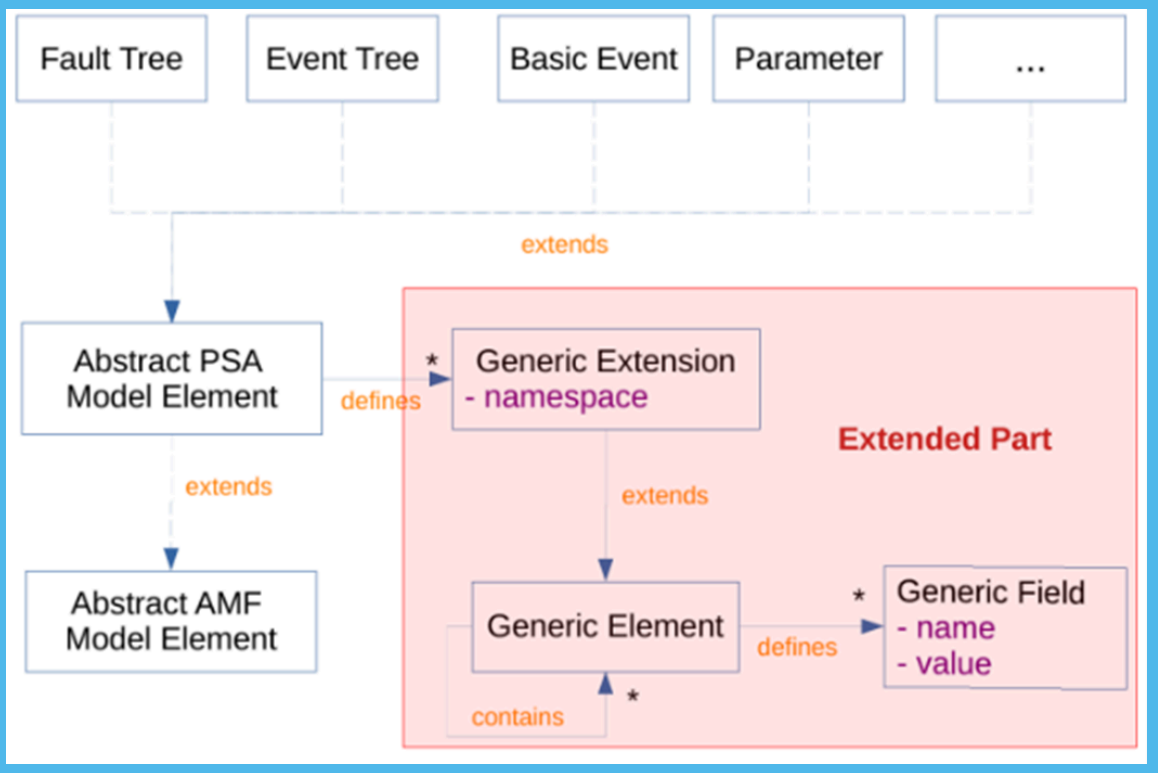
The first deliverable of WP7, D7.1, has been completed. It deals with technical requirements and specifications for the new seismic PSA tool. Main activities were related to the development of the open-source PSA tool for seismic PSA, which is the main goal of WP7.

The METIS PSA tool consists of the coupled Andromeda-SCRAM tool and the Seismic Data Base tool. Coupled Andromeda-SCRAM is a tool for developing probabilistic models and quantifying the results for Seismic PSA, while Seismic Data Base tool is dedicated to calculating failure probabilities of structures and components due to seismic activity.

- Coupled Andromeda-SCRAM uses open source PSA model exchange format and is under development and debugging. Graphical user interface of Andromeda-SCRAM is below. In the coupled Andromeda-SCRAM tool, Andromeda functionalities are applicable for the development of logic models (seismic event trees, functional and seismic fault trees), visualisation, and reliability data manipulations, while SCRAM provides solving functionalities on computing minimal cutsets and quantifying risk metrics (e.g. conditional core damage probability). A generic approach introducing generic elements into the existing AML modelling framework domain for PSA models

was chosen. It supports the philosophy on ensuring modularity and extensibility of PSA software. The generic elements could serve to represent seismic information by the means of generic expressions that are themselves non seismic specific. Ongoing activities on the tool development are related to the extension of the user interface to integrate seismic related modelling and seismic data preparation, as well on improving of quantification of seismic PSA results.





- The Seismic Data Base tool makes it possible to express the relation through mathematical laws between SSC failure probability and upstream parameters used in these laws. The draft tool has been developed and is under review by the METIS partners.

LEARN MORE ABOUT METIS

THE THIRD PLENARY MEETING

The 3rd METIS plenary meeting, hosted by partner NTUA, took place from 6-7 June in Athens, Greece. The first day of the meeting, the WP leaders presented their updates and milestones while the second day was dedicated to working meetings and technical focus sessions on site response analysis, aftershocks in PRA and the METIS case study.

The meeting and the perfect dinner locations in Athens where the occasion for interesting face-to-face discussions within the consortium and with the Advisory Board and End Users Group members.

PAST EVENTS

5 - 6 APRIL / 13 - 14 JUNE - Code_Aster Training

Code_Aster is an opensource finite element software developed by EDF. The first part of the training was organized by UKC Manchester in April with an introduction to Code_Aster and the salome_meca platforms. The second part of the training included lectures and practical applications for the generation of spectrum compatible ground motion, 1D site response by soil column analysis, and soil structure interaction (SSI) analysis.

8 - 9 JUNE / METIS SUMMER SCHOOL ON SEISMIC FRAGILITY

The plenary was followed by two days of summer school with lectures and practical sessions on seismic fragility analysis. It was organised by the Institute of Steel Structures at the Zografou Campus of the National Technical University of Athens. The first day focused on methodologies and approaches for seismic fragility assessment, especially as it pertains to high-importance infrastructure, such as nuclear power plants. Issues of record and intensity-measure selection, as well as industry-standard approaches were discussed. The second day was comprised of practical sessions with hands-on training via Excel, Matlab, and Python, using simple tools to perform data-fitting and derive fragilities.

20 - 23 JUNE / METIS SUMMER SCHOOL ON SEISMIC HAZARD ANALYSIS

The Global Earthquake Model (GEM) Foundation and Scuola Universitaria Superiore (IUSS) di Pavia – in the context of the METIS project – jointly organised a summer school on probabilistic seismic hazard analysis (PSHA). The school, tailored to PhD and postdoctoral students, took place at the GEM premises in Pavia from 20-23 June 2022. About twenty students from European (e.g., Croatia, France, Germany, Greece, Italy, North

Macedonia, Portugal, Spain, United Kingdom) and overseas universities (e.g., Saudi Arabia, Canada) successfully attended the event.

The school focused on introducing the students to the main functionalities of the OpenQuake Engine, the open-source seismic hazard and risk calculation software developed by GEM, GEM's tools for building components of PSHA tools, and recent methods for time-history selection and calculation of PSHA accounting for the contribution of aftershocks. These topics are currently investigated within work packages 4 and 5 of the METIS project. During training, the students had the chance to briefly visit one of the shaking tables operated by the Eucentre Foundation, the organisation hosting the GEM Headquarters.

21 OCTOBER / METIS PRA METHODS AND TOOLS WORKSHOP

The workshop included a general presentation of METIS tools, invited technical presentations on improved methods for seismic PRA and was concluded by a tutorial for the use of the METIS tools.

CONFERENCES

- METIS particpcated in the FISA EURADWASTE conference in Lyon, France 31 May
- METIS was presented at the SIGMA2 Closing Symposium 31 May - 2 June
- METIS was present at the Third European Conference on Earthquake Engineering and Seismology (ECEES) 4-9 September with contributions from NTUA, IUSS and TUK

UPCOMING EVENTS

15-16 November 2022 - The next METIS plenary meeting in Paris

- The fourth plenary meeting, organised by partner IRSN, will take place on the 15th and 16th of November at the Maison de la Recherche, in the city center of Paris. Day 1 will include presentations of WP progress. Day 2 will be dedicated to technical and working meetings.

Happening in 2023

- June 2023 - Plenary Meeting (location TBD)
- Summer 2023 - Summer School in Slovenia
- November 2023 - Plenary Meeting + Workshop on site specific PSHA and ground motion in Italy

OUR PARTNERS

THANKS FOR READING!

DON'T HESITATE TO CONTACT US.

E-mail: contact@metis-h2020.eu
Website : www.metis-h2020.eu

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