

**ChEESE**

# **Center of Excellence for Exascale in Solid Earth (second phase)**

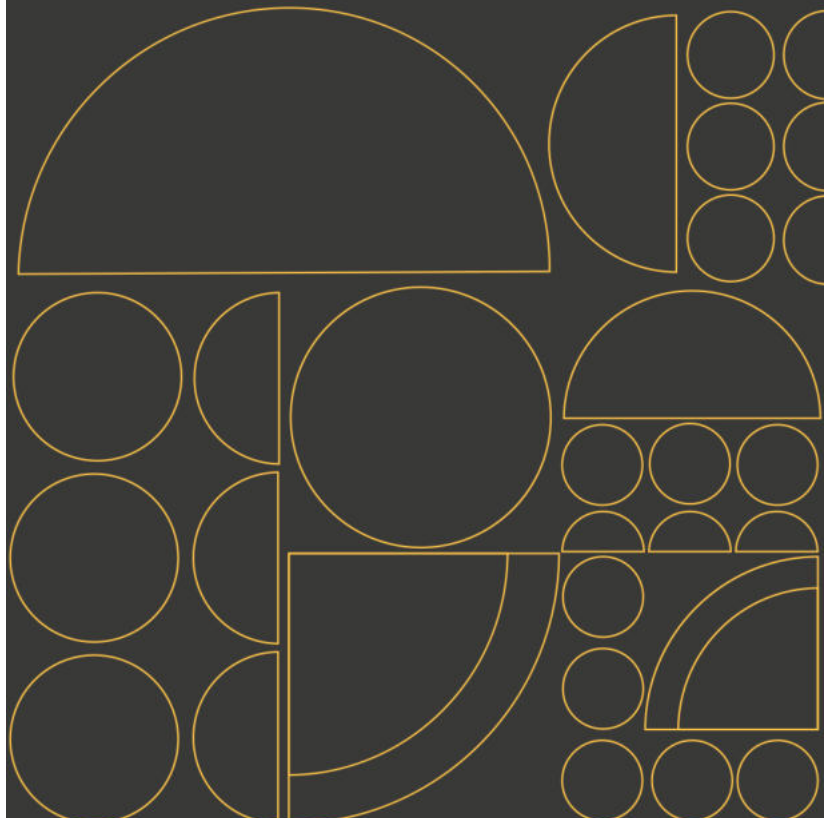
## **Project Overview**

Project kick-off meeting  
Barcelona, 19-20 January 2023

Arnau Folch  
Geociencias Barcelona (GEO3BCN-CSIC)



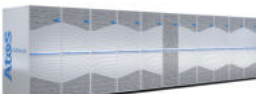
Project funded by EuroHPC under the grant agreement No 101093038.



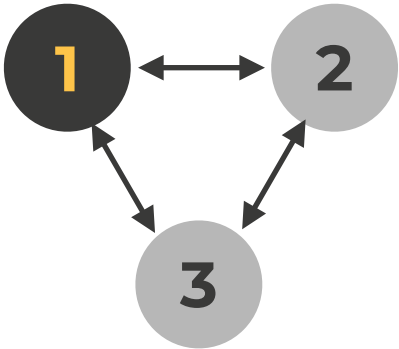
# Project Information

|                     |                                                                                                                                           |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Type of Action      | Horizon-JU-RIA                                                                                                                            |
| Project Name        | Center of Excellence for Exascale in Solid Earth - Second Phase                                                                           |
| Project Acronym     | ChEESE-2P                                                                                                                                 |
| Call                | <b>HORIZON-EUROHPC-JU-2021-COE-01</b><br>(Centres of Excellence for HPC applications)                                                     |
| Topic               | <b>HORIZON-EUROHPC-JU-2021-COE-01-02</b><br>(Centres of Excellence for supporting supercomputing applications for Science and Innovation) |
| Grant Agreement No  | 101093038                                                                                                                                 |
| Start Date          | 1 Jan 2023                                                                                                                                |
| End Date            | 31 Dec 2026                                                                                                                               |
| Budget              | 7,690,590 € (with 50% national co-funding)                                                                                                |
| Person Months (PMs) | 976                                                                                                                                       |
| Partners            | 16                                                                                                                                        |

# The European HPC ecosystem (pillar 1)



**Infrastructure (EuroHPC)**      Applications (CoEs, NCCs)



Technology (EPI, FET, etc)

| tier-0 (pre-exascale) |         |             | T500 |
|-----------------------|---------|-------------|------|
| LUMI                  | Finland | 500 PFlop/s | 3    |
| Leonardo              | Italy   | 330 PFlop/s | 4    |
| MN-5                  | Spain   | 250 PFlop/s | -    |



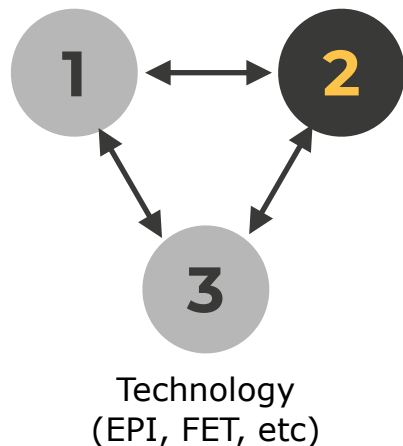
● pre-Exascale      ● Exascale

| tier-1 (petascale) |           |            | T500 |
|--------------------|-----------|------------|------|
| MeluXina           | Luxemburg | 15 PFlop/s | 52   |
| Karolina           | Txequia   | 7 PFlop/s  | 85   |
| Discover           | Bulgaria  | 5 PFlop/s  | 123  |
| Vega               | Slovenia  | 4 PFlop/s  | 140  |
| Deucalio           | Portugal  | 10 PFlop/s | -    |



# The European HPC ecosystem (pillar 2)

Infrastructure (EuroHPC)    **Applications (CoEs, NCCs)**



| H2020-EINFRA-2015-1<br>2016-2019<br>8 CoEs |
|--------------------------------------------|
| BioExcel                                   |
| CompBioMed                                 |
| E-CAM                                      |
| EoCoE                                      |
| ESiWACE                                    |
| MaX                                        |
| NoMaD                                      |
| POP                                        |

| H2020-INFRAEDI-2018-2<br>2019-2022<br>12 CoEs |
|-----------------------------------------------|
| BioExcel-2                                    |
| <b>ChEESE</b>                                 |
| CoEC                                          |
| CompBioMed-2                                  |
| EoCoE-2                                       |
| ESiWACE-2                                     |
| EXCELLERAT                                    |
| HiDALGO                                       |
| MaX-2                                         |
| PerMedCoE                                     |
| POP-2                                         |
| T-REX                                         |

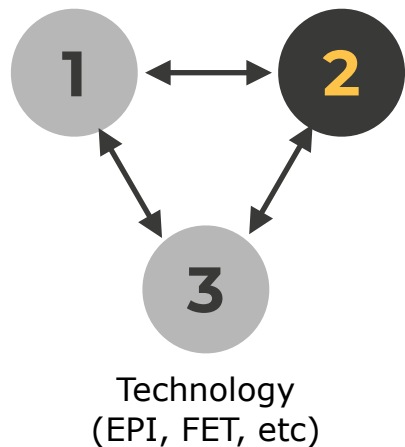
| EUROHPC-JU-2021-COE-01<br>2023-2026<br>10 CoEs |
|------------------------------------------------|
| MaX-3                                          |
| SPACE                                          |
| Plasma-PEPSC                                   |
| CEEC                                           |
| <b>ChEESE-2</b>                                |
| BioExcel-3                                     |
| EXCELLERAT-2                                   |
| HiDALGO-2                                      |
| ESiWACE-3                                      |
| MultiXscale                                    |

| Other calls<br>2022 onwards                           |
|-------------------------------------------------------|
| EuroCC<br>33 National<br>Competence<br>Centers (NCCs) |
| CASTIEL-2<br>CSA                                      |



# The European HPC ecosystem (pillar 2): the 10 CoEs

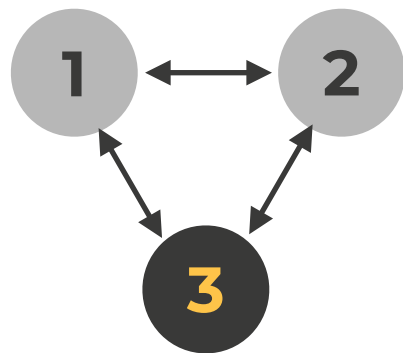
Infrastructure (EuroHPC)    **Applications (CoEs, NCCs)**



|                                                   |                 |               |                          |
|---------------------------------------------------|-----------------|---------------|--------------------------|
| <b>EUROHPC-JU-2021-COE-01-01</b><br><b>4 CoEs</b> | MaX-3           | 8.5 M€        | Materials                |
|                                                   | SPACE           | 8 M€          | Astrophysics             |
|                                                   | Plasma-PEPSC    | 8 M€          | Plasma simulations       |
|                                                   | CEEC            | 7.8 M€        | Fluid Dynamics           |
| <b>EUROHPC-JU-2021-COE-01-02</b><br><b>6 CoEs</b> | <b>ChEESE-2</b> | <b>7.6 M€</b> | <b>Geosciences</b>       |
|                                                   | BioExcel-3      | 6 M€          | Biomedicine              |
|                                                   | EXCELLERAT-2    | 6 M€          | Engineering applications |
|                                                   | HiDALGO-2       | 6 M€          | Big data technologies    |
|                                                   | ESiWACE-3       | 6 M€          | Weather and climate      |
|                                                   | MultiXscale     | 6 M€          | Multiscale use cases     |
|                                                   | CASTIEL-2       | 2 M€          | Link with NCCs           |
| <b>1 CSA</b>                                      |                 |               |                          |

# The European HPC ecosystem (pillar 3): other initiatives

Infrastructure (EuroHPC)      Applications (CoEs, NCCs)



**Technology  
(EPI, FET, etc)**

|                                                          |                            |        |                                                                                                                                                                                                         |
|----------------------------------------------------------|----------------------------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EuPILOT</b>                                           | Dec 2021<br>to<br>May 2025 | 30M€   | <ul style="list-style-type: none"><li>• Design, build, and validate the first EU-based accelerator platform for HPC</li><li>• RISC-V based highly efficient and high performance accelerators</li></ul> |
| <b>EuPEX</b>                                             | Jan 2022<br>to<br>Dec 2025 | 41M€   | <ul style="list-style-type: none"><li>• Design a modular Exascale-pilot system integrating the full spectrum of European HPC technologies, including ARM-based Rhea processor</li></ul>                 |
| <b>Open-Risc-V Framework Partnership Agreement (FPA)</b> | 2024<br>onwards            | >300M€ | <ul style="list-style-type: none"><li>• Procure to EuroHPC at least 1 operational (post-)exascale computer based on Open-Risc-V technology</li></ul>                                                    |



# ChEESE-2P Consortium Composition

| No   | Role | Partner |                                                       | Country | ChEESE-1P |
|------|------|---------|-------------------------------------------------------|---------|-----------|
| 1    | COO  | CSIC    | Consejo Superior Investigaciones Científicas          | Spain   | No        |
| 2    | BEN  | BSC     | Barcelona Supercomputing Center                       | Spain   | Yes       |
| 3    | BEN  | INGV    | Istituto Nazionale di Geofisica e Vulcanologia        | Italy   | Yes       |
| 4    | BEN  | IMO     | Icelandic Meteorological Office                       | Iceland | Yes       |
| 5    | BEN  | HLRS    | High Performance Computing Center Stuttgart           | Germany | Yes       |
| 6    | BEN  | CIN     | CINECA                                                | Italy   | Yes       |
| 7    | BEN  | TUM     | Technical University of Munich                        | Germany | Yes       |
| 8    | BEN  | LMU     | Ludwig-Maximilians Universität München                | Germany | Yes       |
| 9    | BEN  | UMA     | University of Malaga                                  | Spain   | Yes       |
| 10   | BEN  | NGI     | Norwegian Geotechnical Institute                      | Norway  | Yes       |
| 11   | BEN  | CNRS    | National Center for Scientific Research               | France  | Yes       |
| 11.1 | AE   | IPGP    | Institut de Physique du Globe de Paris                | France  | Yes       |
| 12   | BEN  | BA      | Atos Center for Excellence in Performance Programming | France  | Yes       |
| 13   | BEN  | CSC     | CSC – IT Center for Science                           | Finland | No        |
| 14   | BEN  | RBI     | Ruder Boskovic Institute                              | Croatia | No        |
| 15   | BEN  | UM      | University of Mainz                                   | Germany | No        |
| 16   | BEN  | SU      | Sorbonne University                                   | France  | No        |

From 8 different countries

IPGP (affiliated to CNRS)

BSC, CIN, HLRS, CSC

BA, NGI

CSIC, INGV, IMO, CNRS

TUM, LMU, UMA, RBI, UM, SU



# The ChEESE-2P consortium in other projects

|         | Project<br>(GA No)         | CSIC | BSC | INGV | IMO | HLRS | CIN | TUM | LMU | UMA | NGI | CNRS | BA | CSC | RBI | UM | SU | # |
|---------|----------------------------|------|-----|------|-----|------|-----|-----|-----|-----|-----|------|----|-----|-----|----|----|---|
| HORIZON | DT-GEO<br>(101058129)      | C    |     |      |     |      |     |     |     |     |     |      |    |     |     |    |    | 9 |
|         | interTwin<br>(101058386)   |      |     |      |     |      |     |     |     |     |     |      |    |     |     |    |    | 2 |
|         | Geo-INQUIRE<br>(101058518) |      |     |      |     |      |     |     |     |     |     |      |    |     |     |    |    | 9 |
|         | EOSC-synergy<br>(857647)   | C    |     |      |     |      |     |     |     |     |     |      |    |     |     |    |    | 2 |
| EuroHPC | eFlows4HPC<br>(955558)     |      | C   |      |     |      |     |     |     |     |     |      |    |     |     |    |    | 5 |
|         | EuPilot<br>(101034126)     |      | C   |      |     |      |     |     |     |     |     |      |    |     |     |    |    | 1 |
|         | EuPEX<br>(101033975)       |      |     |      |     |      |     |     |     |     |     |      | C  |     |     |    |    | 3 |

C

Coordinator

Beneficiary



# The driving concept: 12 Exascale Computational Challenges (ECCs)

| Area                     | ECC          | Name                                                         | Type of ECC |          |    |
|--------------------------|--------------|--------------------------------------------------------------|-------------|----------|----|
|                          |              |                                                              | Capability  | Capacity | UC |
| Computational Seismology | <b>ECC1</b>  | Full-waveform inversion (FWI) and high-resolution tomography |             |          |    |
|                          | <b>ECC2</b>  | Near real-time seismic scenarios (urgent computing)          |             |          |    |
|                          | <b>ECC3</b>  | Physics-based Probabilistic Seismic Hazard Assessment (PSHA) |             |          |    |
| tsunami modelling        | <b>ECC4</b>  | Near real-time tsunami source inversion and characterization |             |          |    |
|                          | <b>ECC5</b>  | Faster Than Real Time (FTRT) tsunami scenarios               |             |          |    |
|                          | <b>ECC6</b>  | Probabilistic Tsunami Hazard Assessment (PTHA)               |             |          |    |
| Volcanology              | <b>ECC7</b>  | High-resolution atmospheric volcanic dispersal               |             |          |    |
|                          | <b>ECC8</b>  | Volcanic explosions and interactions                         |             |          |    |
|                          | <b>ECC9</b>  | Probabilistic Volcanic Hazard Assessment (PVHA)              |             |          |    |
| MHD                      | <b>ECC10</b> | The dynamo model and the Earth's magnetic field evolution    |             |          |    |
| Geodynamics              | <b>ECC11</b> | Landslide triggering                                         |             |          |    |
|                          | <b>ECC12</b> | Lithospheric stress states and induced seismicity            |             |          |    |



## ChEESE-2P: 4 General Objectives

01

To consolidate the ChEESE CoE as the central HPC hub connecting:

- The scientific Solid Earth (SE) Community,
- The **EuroHPC infrastructures** and National Competence Centers (NCCs),
- The public and private industry parties benefiting from the products and downstream **services on geohazards**

02

To enhance **11 open-source SE community flagship codes** in terms of performance, scalability, deployment, and portability across current pre-exascale systems and emerging hardware architectures

03

To farm a new generation of **9 Pilot Demonstrators** (PDs) and run **15 derived Simulation Cases** (SCs) addressing the ECCs (capability/capacity/UC) and enabling services on socially-relevant aspects of geohazards like urgent computing for disaster response, early warning, and hazard assessment

04

To align and synergize with other domain-specific European projects and longer-term mission-like initiatives like the Digital Agenda and **Destination Earth**



# ChEESE-2P: 15 Specific Objectives

## In terms of exascale software engineering

01

Prepare 11 open-source community **flagship codes** for current/upcoming EuroHPC systems in 6 domains: computational seismology, tsunami modelling, physical volcanology, magnetohydrodynamics, geodynamics, and glacier hazards

02

Perform **audit-driven code optimizations** based upon 2 code audit rounds

03

Co-design with **mini-apps** on OpenSequana (EuPEX) and RISC-V (EuPilot) exascale hardware prototypes ensuring an effective integration of co-design hints back to the main applications

04

Address specific **simulation ecosystem challenges** at large scale

05

Develop and implement 9 new **Pilot Demonstrators** (PD) on different areas of SE addressing 12 SE Exascale Computational Challenges (ECCs)

06

Run 15 **Simulation Cases** (SC): 9 capacity and 6 capability cases, 4 of which can be considered as full-scale Scientific Grand Challenges (SGC)

07

Define a flexible ecosystem to ensure **EOSC-enabled data** (and SW) quality management through an automatic FAIR data validation

## In terms of scientific excellence



# ChEESE-2P: 15 Specific Objectives

In terms of  
geohazard  
services and  
products

08

Raise the Technology Readiness Level (TRL) of the PDs towards enabling downstream service prototypes

09

Foster the **urgent computing access mode** in EuroHPC tier-0/tier-1 systems for emergency management during high-impact geohazardous events

10

Act as an **effective hub** to foster the use of HPC resources and to roadmap the transition to exascale across the SE Community

11

Provide specialised **training** to scientists and end-users on the deployment and use of flagship codes and related services

12

Consolidate and expand the role of the **Industry and Users Board** (IUB) in terms of identifying exploitable outcomes and promoting up-to-date market analyses

13

Align and liaise with other projects, mission initiatives (Destination Earth), Research Infrastructures (EPOS, FENIX), and federated environments (EOSC)

14

**Disseminate** the CoE and the role of under-represented scientists to a wider-public audience, e.g. through the ShEEESE initiative

15

To complement with the CASTIEL-2 CSA

In terms of  
federating  
capabilities



## 7 Work Packages

| WP | WP Title                                                            | Lead Partner | Start Month | End Month | Person Months | Tasks     | Deliverables |
|----|---------------------------------------------------------------------|--------------|-------------|-----------|---------------|-----------|--------------|
| 1  | Project Management                                                  | CSIC         | 1           | 48        | 78            | 5         | 5            |
| 2  | Exascale technical challenges in flagship codes                     | CIN          | 1           | 48        | 247           | 4         | 4            |
| 3  | Co-design with European HPC vendors and technologies                | BA           | 6           | 42        | 86            | 3         | 2            |
| 4  | Simulation ecosystem                                                | HLRS         | 1           | 48        | 95            | 3         | 5            |
| 5  | Farming Pilot Demonstrators                                         | CNRS         | 1           | 42        | 235.5         | 2         | 10           |
| 6  | Simulation cases and service enabling using EuroHPC infrastructures | INGV         | 13          | 48        | 165           | 4         | 12           |
| 7  | Dissemination, outreach and community building                      | BSC          | 1           | 48        | 70.5          | 6         | 8            |
|    | <b>TOTAL</b>                                                        |              |             |           | <b>976</b>    | <b>27</b> | <b>46</b>    |



## WP1: Tasks and key points

| Task          | Task name                                                                                                                                                                                                                                                            | Start | End | Lead |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|------|
| Task 1.1      | Administrative and financial management                                                                                                                                                                                                                              | 1     | 48  | CSIC |
| Task 1.2      | Operational decision making                                                                                                                                                                                                                                          | 1     | 48  | CSIC |
| Task 1.3      | Equality committee                                                                                                                                                                                                                                                   | 1     | 48  | LMU  |
| Task 1.4      | Management of computational resources                                                                                                                                                                                                                                | 1     | 48  | CSIC |
| Task 1.5      | Data management plan and automatic FAIR validation                                                                                                                                                                                                                   | 1     | 48  | CSIC |
| WP1 keypoints | <ul style="list-style-type: none"><li>• Operational project management and reporting</li><li>• Manage computational resources and foster the granting EuroHPC/PRACE resources</li><li>• Implement a DMP and an EOSC-enabled automatic FAIR data validation</li></ul> |       |     |      |

## WP2: Tasks and key points

| Task             | Task name                                                                                                                                                            | Start     | End        | Lead |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|------------|------|
| Task 2.1         | Code audits                                                                                                                                                          | 3<br>(27) | 15<br>(36) | HLRS |
| Task 2.2         | Increasing the performance portability of flagship codes for different accelerators                                                                                  | 1         | 48         | CIN  |
| Task 2.3         | Optimisation for Exascale                                                                                                                                            | 6         | 48         | CIN  |
| Task 2.4         | Continuous Performance Efficiency Monitoring                                                                                                                         | 18        | 48         | BSC  |
| WP2<br>keypoints | <ul style="list-style-type: none"><li>• Code audits (beyond POP)</li><li>• Code acceleration</li><li>• Single-node and multi-node performance optimisation</li></ul> |           |            |      |



## WP3: Tasks and key points

| Task          | Task name                                                                                                                             | Start | End | Lead |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------|-------|-----|------|
| Task 3.1      | Preparation of mini-apps                                                                                                              | 6     | 18  | CIN  |
| Task 3.2      | OpenSequana prototypes (EuPEX)                                                                                                        | 12    | 42  | BA   |
| Task 3.3      | RISC-V prototypes, the European Processor Initiative (EPI) and EuPilot                                                                | 19    | 42  | BSC  |
| WP3 keypoints | <ul style="list-style-type: none"><li>• Implement the 7 mini-apps</li><li>• Test on emerging architectures (EuroHPC Pilots)</li></ul> |       |     |      |



## WP4: Tasks and key points

| Task          | Task name                                                                                                                                                                                                                          | Start | End | Lead         |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|--------------|
| Task 4.1      | Workflow implementation and optimization                                                                                                                                                                                           | 1     | 42  | HLRS         |
| Task 4.2      | Lightweight performance analysis and optimization services for simulation ecosystem components                                                                                                                                     | 25    | 48  | HLRS         |
| Task 4.3      | Development, deployment and quality assessment tools                                                                                                                                                                               | 1     | 48  | CIN/<br>HLRS |
| WP4 keypoints | <ul style="list-style-type: none"><li>• Challenges at workflow level (including time-to-solution)</li><li>• Simulation setup, deployment and data analysis</li><li>• Flagship code deployment targeting EuroHPC machines</li></ul> |       |     |              |



## WP5: Tasks and key points

| Task                 | Task name                                                                                                                                                   | Start | End | Lead | Contributor  |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|------|--------------|
| <b>Task 5.1</b>      | Novel features (physics) in flagship codes                                                                                                                  | 1     | 42  | CNRS |              |
| <b>5.1.1</b>         | SeisSol                                                                                                                                                     | -     | -   |      | LMU, TUM, US |
| <b>5.1.2</b>         | SPECFEM3D                                                                                                                                                   | -     | -   |      | CNRS, INGV   |
| <b>5.1.3</b>         | ExaHyPE                                                                                                                                                     | -     | -   |      | TUM          |
| <b>5.1.4</b>         | TANDEM                                                                                                                                                      | -     | -   |      | LMU          |
| <b>5.1.5</b>         | xSHELLS                                                                                                                                                     | -     | -   |      | CNRS, IPGP   |
| <b>5.1.6</b>         | HySEA                                                                                                                                                       | -     | -   |      | UMA, IRB     |
| <b>5.1.7</b>         | FALL3D                                                                                                                                                      | -     | -   |      | CSIC, INGV   |
| <b>5.1.8</b>         | OpenPDAC                                                                                                                                                    | -     | -   |      | INGV         |
| <b>5.1.9</b>         | LaMEM                                                                                                                                                       | -     | -   |      | UM           |
| <b>5.1.10</b>        | pTatin3D                                                                                                                                                    | -     | -   |      | SU           |
| <b>5.1.11</b>        | ELMER/ICE                                                                                                                                                   | -     | -   |      | CSC          |
| <b>Task 5.2</b>      | Developments in Pilot Demonstrators                                                                                                                         | 7     | 42  | CNRS |              |
| <b>WP5 keypoints</b> | <ul style="list-style-type: none"> <li>• Novel model physics (couplings)</li> <li>• Pilots including multi-physics, multi-scale and multi-hazard</li> </ul> |       |     |      |              |

## WP6: Tasks and key points

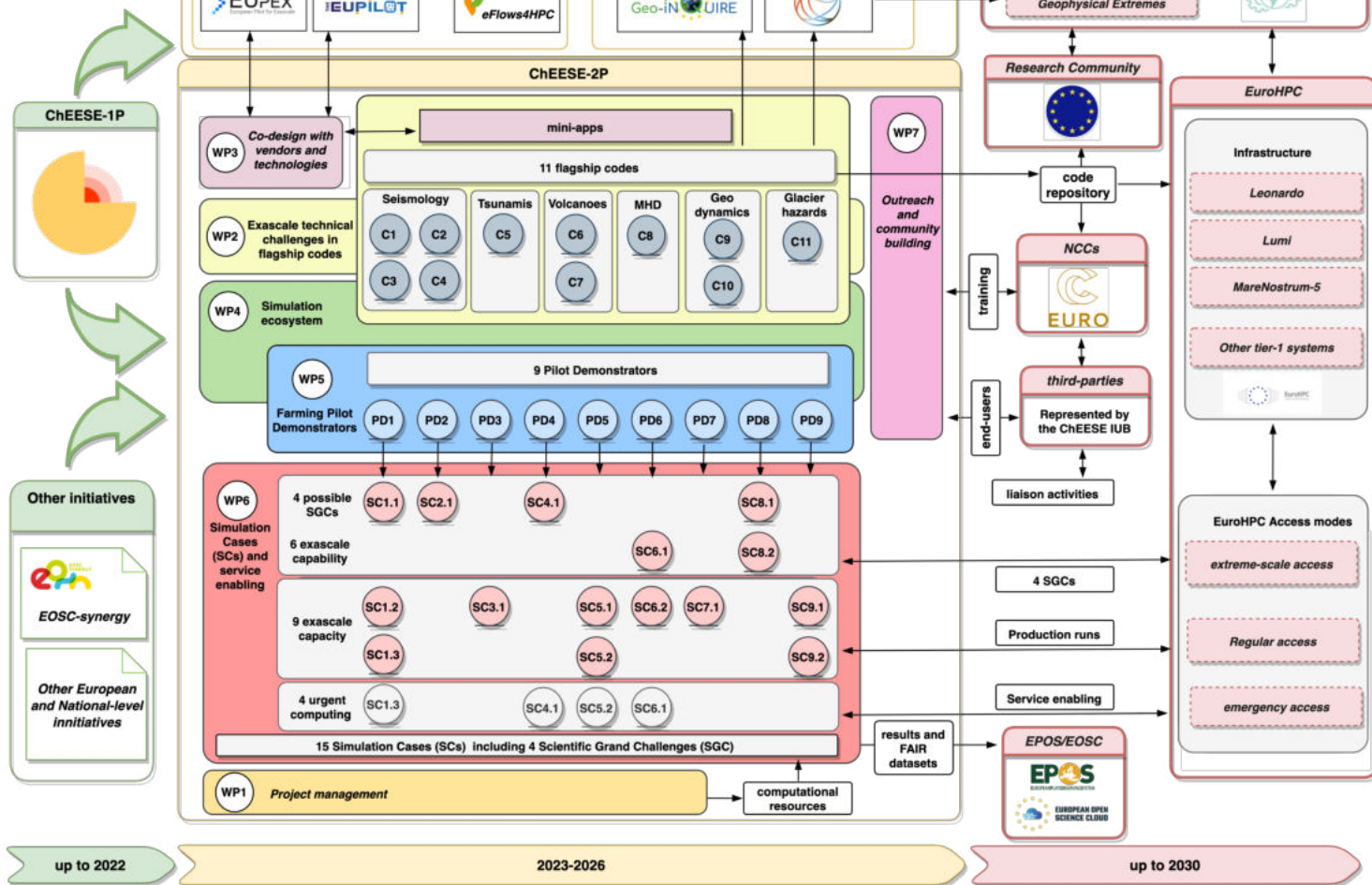
| Task             | Task name                                                                                                                                                                                                                                                                                                              | Start | End | Lead         |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|--------------|
| Task 6.1         | Setup of Simulation Cases and trials                                                                                                                                                                                                                                                                                   | 13    | 18  | INGV         |
| Task 6.2         | Exascale capability simulation cases and Scientific Grand Challenges                                                                                                                                                                                                                                                   | 19    | 48  | CNRS/<br>LMU |
| Task 6.3         | Exascale capacity simulation cases                                                                                                                                                                                                                                                                                     | 19    | 48  | INGV         |
| Task 6.4         | EuroHPC urgent computing service enabling                                                                                                                                                                                                                                                                              | 25    | 48  | BSC          |
| WP6<br>keypoints | <ul style="list-style-type: none"><li>• Run Simulation cases (including 4 Scientific Grand Challenges in EuroHPC extreme-scale access mode)</li><li>• Enable 2 services in EPOS for tsunami and volcano Thematic Core Services (TCS)</li><li>• Enable 4 urgent computing services in EuroHPC infrastructures</li></ul> |       |     |              |



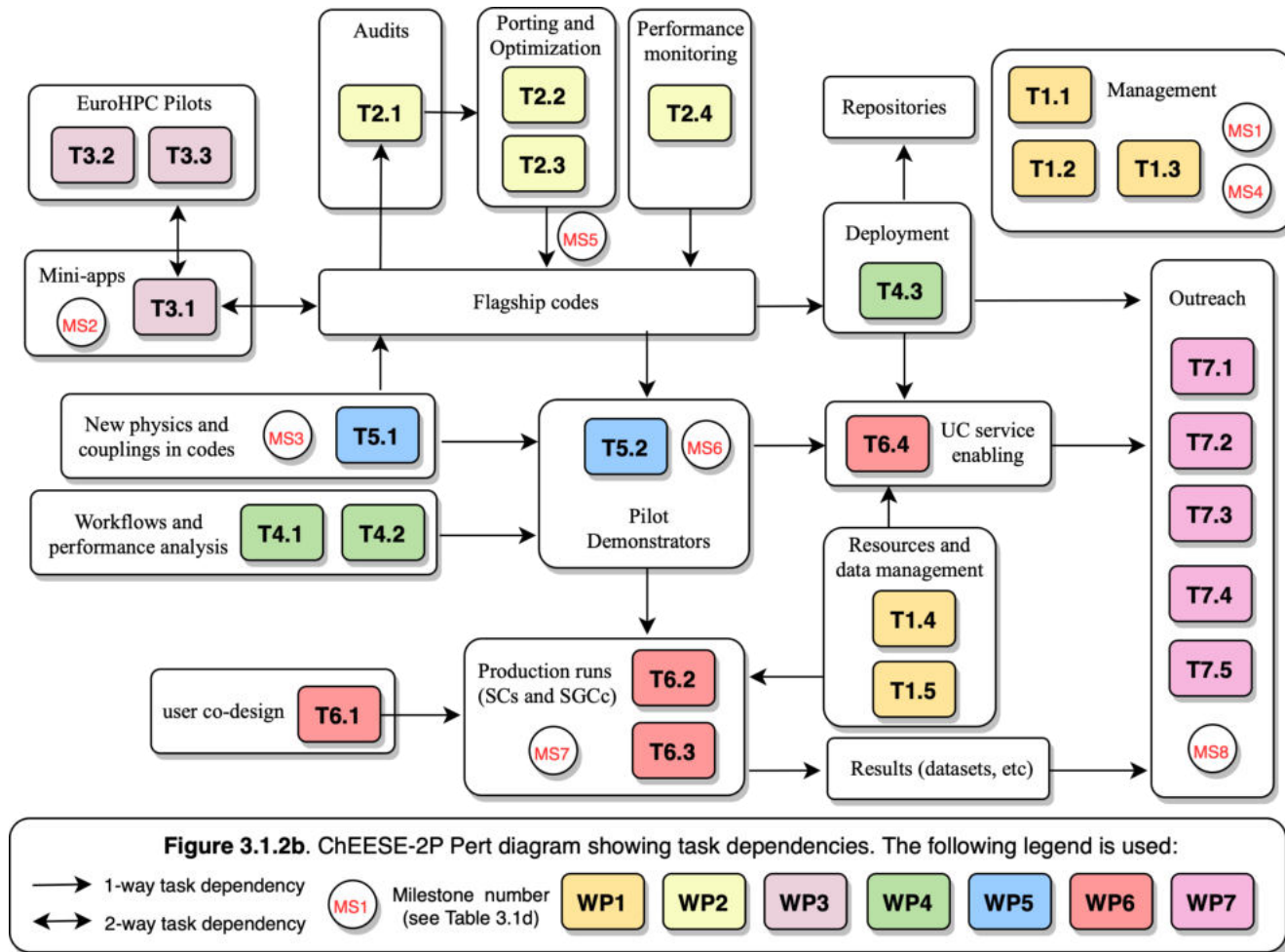
## WP7: Tasks and key points

| Task          | Task name                                                                                                                                                                                                            | Start | End | Lead |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|------|
| Task 7.1      | Dissemination and communication planning and tools                                                                                                                                                                   | 1     | 48  | CSIC |
| Task 7.2      | Liaison activities                                                                                                                                                                                                   | 1     | 48  | CSIC |
| Task 7.3      | Training activities                                                                                                                                                                                                  | 6     | 42  | BSC  |
| Task 7.4      | Community building and roadmap activities                                                                                                                                                                            | 1     | 48  | BSC  |
| Task 7.5      | Sustainability plan                                                                                                                                                                                                  | 25    | 48  | BSC  |
| Task 7.6      | Collaboration task with complementary projects                                                                                                                                                                       | 1     | 48  | CSIC |
| WP7 keypoints | <ul style="list-style-type: none"><li>• Communication, dissemination and training</li><li>• Liaison activities and community building</li><li>• Exploitation (renew the concept of the ChEESE Foundation?)</li></ul> |       |     |      |

# ChEESE-2P in a nutshell



# Task Dependencies



# 46 Deliverables (by WP and lead partner)

| WP    | CSIC | BSC | INGV | IMO | HLRS | CIN | TUM | LMU | UMA | NGI | CNRS | IPGP | BA | CSC | RBI | UM | SU |    |
|-------|------|-----|------|-----|------|-----|-----|-----|-----|-----|------|------|----|-----|-----|----|----|----|
| WP1   | 5    |     |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    | 5  |
| WP2   |      |     |      |     | 2    | 2   |     |     |     |     |      |      |    |     |     |    |    | 4  |
| WP3   |      |     |      |     |      | 1   |     |     |     |     |      |      | 1  |     |     |    |    | 2  |
| WP4   |      |     |      |     | 4    | 1   |     |     |     |     |      |      |    |     |     |    |    | 5  |
| WP5   |      |     | 1    | 1   |      |     | 2   |     | 1   | 1   | 2    |      |    | 1   |     | 1  |    | 10 |
| WP6   | 1    | 1   | 4    | 1   |      |     |     | 1   | 1   |     |      | 1    |    |     | 1   |    | 1  | 12 |
| WP7   | 4    | 3   |      |     |      |     |     | 1   |     |     |      |      |    |     |     |    |    | 8  |
| TOTAL | 10   | 4   | 5    | 2   | 6    | 4   | 2   | 2   | 2   | 1   | 2    | 1    | 1  | 1   | 1   | 1  | 1  | 46 |



# Task to partner mapping

| Task               | CSIC | BSC | INGV | IMO | HLRS | CIN | TUM | LMU | UMA | NGI | CNRS | IPGP | BA | CSC | RBI | UM | SU |
|--------------------|------|-----|------|-----|------|-----|-----|-----|-----|-----|------|------|----|-----|-----|----|----|
| Task 1.1, 1.2, 1.4 | L    |     |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 1.3           |      |     |      |     |      |     |     | L   |     |     |      |      |    |     |     |    |    |
| Task 1.5           | L    |     |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 2.1           |      |     |      |     | L    |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 2.2           |      |     |      |     |      | L   |     |     |     |     |      |      |    |     |     |    |    |
| Task 2.3           |      |     |      |     |      | L   |     |     |     |     |      |      |    |     |     |    |    |
| Task 2.4           |      | L   |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 3.1           |      |     |      |     |      | L   |     |     |     |     |      |      |    |     |     |    |    |
| Task 3.2           |      |     |      |     |      |     |     |     |     |     |      |      | L  |     |     |    |    |
| Task 3.3           |      | L   |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 4.1           |      |     |      |     | L    |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 4.2           |      |     |      |     | L    |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 4.3           |      |     |      |     | L    | L   |     |     |     |     |      |      |    |     |     |    |    |



# Task to partner mapping

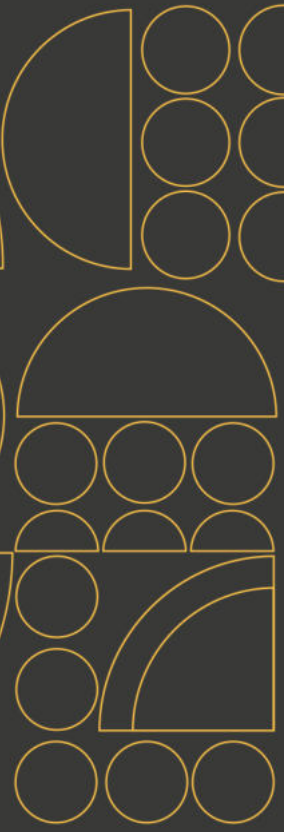
| Task     | CSIC | BSC | INGV | IMO | HLRS | CIN | TUM | LMU | UMA | NGI | CNRS | IPGP | BA | CSC | RBI | UM | SU |
|----------|------|-----|------|-----|------|-----|-----|-----|-----|-----|------|------|----|-----|-----|----|----|
| Task 5.1 |      |     |      |     |      |     |     |     |     |     | L    |      |    |     |     |    |    |
| Task 5.2 |      |     |      |     |      |     |     |     |     |     | L    |      |    |     |     |    |    |
| Task 6.1 |      |     | L    |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 6.2 |      |     |      |     |      |     |     | L   |     |     | L    |      |    |     |     |    |    |
| Task 6.3 |      |     | L    |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 6.4 |      | L   |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 7.1 | L    |     |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 7.2 | L    |     |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 7.3 |      | L   |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 7.4 |      | L   |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 7.5 |      | L   |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |
| Task 7.6 | L    |     |      |     |      |     |     |     |     |     |      |      |    |     |     |    |    |



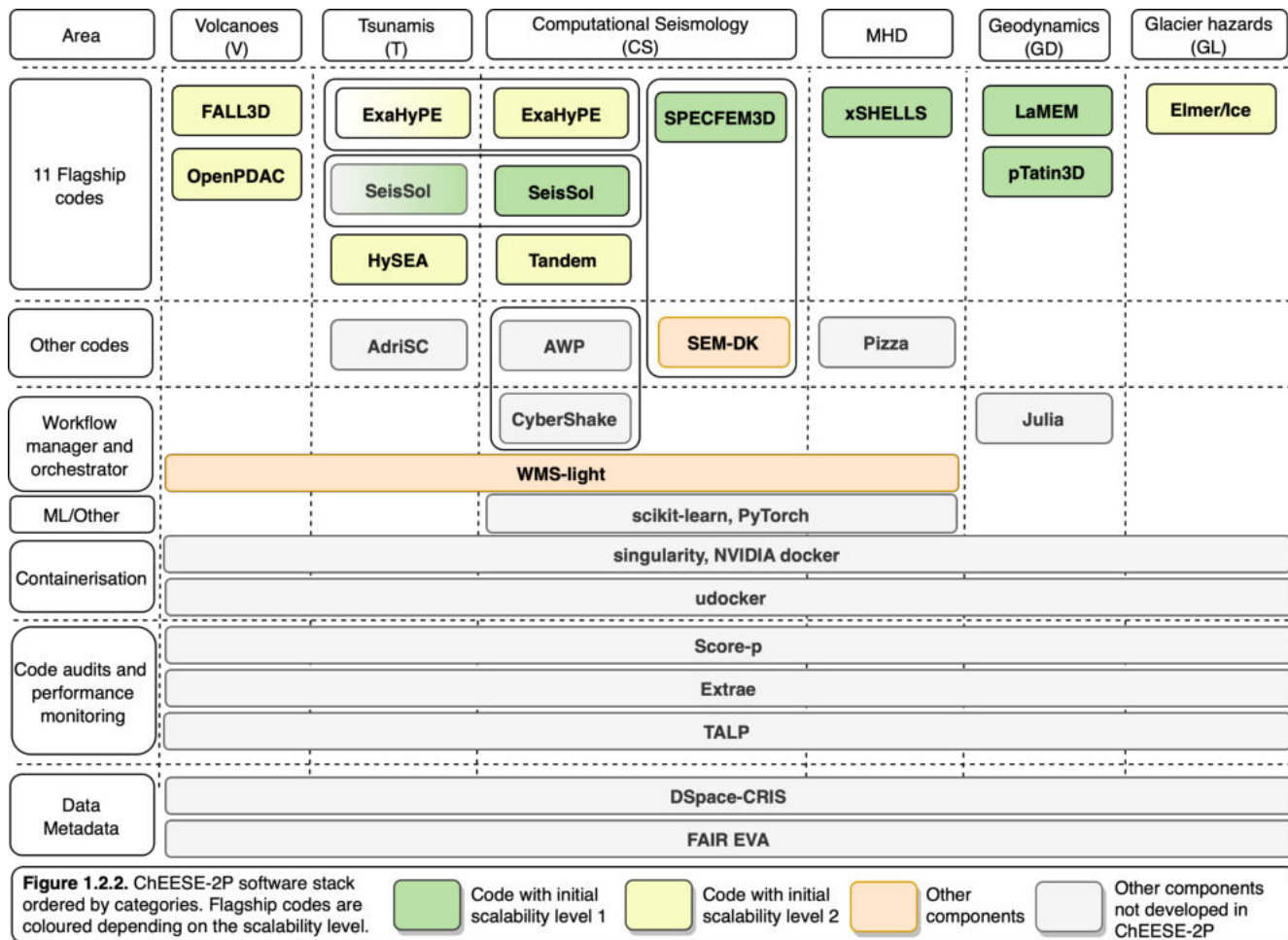
# 11 Flagship codes

| Area | No        | Code      | Lead | Licence         | ChEESE-1P | Accelerated | Mini-app | PDs     |
|------|-----------|-----------|------|-----------------|-----------|-------------|----------|---------|
| CS   | <b>1</b>  | SeisSol   | LMU  | BDS3            | yes       | CUDA        | yes      | PD1,PD4 |
|      | <b>2</b>  | SPECFEM3D | CNRS | GNU GPL v3      | yes       | CUDA, HIP   | yes      | PD1,PD2 |
|      | <b>3</b>  | ExaHyPE   | TUM  | Modified BSD3   | yes       | no          | no       | PD1,PD4 |
|      | <b>4</b>  | Tandem    | LMU  | BSD3-clause new | no        | no          | yes      | PD1     |
| MHD  | <b>5</b>  | xSHELLS   | CNRS | CeCILL          | yes       | CUDA        | yes      | PD7     |
| T    | <b>6</b>  | HySEA     | UMA  | Core under CCA  | yes       | CUDA        | yes      | PD3,PD4 |
| V    | <b>7</b>  | FALL3D    | CSIC | GNU GPL v3      | yes       | OpenACC     | yes      | PD5     |
|      | <b>8</b>  | OpenPDAC  | INGV | GNU GPL v3      | no        | no          | no       | PD6     |
| GD   | <b>9</b>  | LaMEM     | UM   | GNU GPL v3      | no        | no          | no       | PD8     |
|      | <b>10</b> | pTatin3D  | SU   | GNU GPL v3      | no        | CUDA        | yes      | PD8     |
| GL   | <b>11</b> | Elmer/ICE | CSC  | GNU GPL v2-v3   | no        | no          | no       | PD9     |

## An abstract geometric pattern composed of yellow lines on a dark background. The pattern includes a large semi-circle on the left, a row of three circles in the top right, a large semi-circle in the middle, a row of three circles below it, a row of three semi-circles below that, a large quarter-circle on the right, and a row of three circles at the bottom.



# Software stack (beyond codes)



# Farming a new generation of 9 PDs

| No | PD name                                              | Area | Initial TRL | Target TRL | Codes                   | Lead     |
|----|------------------------------------------------------|------|-------------|------------|-------------------------|----------|
| 1  | Extreme-scale modeling of seismic hazards            | CS   | 5           | 7          | All CS codes            | LMU      |
| 2  | Joint seismic inversion and tomography               |      | 4           | 6          | SPECFEM3D               | CNRS     |
| 3  | Global tsunami hazard and uncertainty quantification | T    | 6           | 8-9        | HySEA                   | INGV     |
| 4  | Complex multi-source tsunami modeling                |      | 3           | 5          | HySEA, ExaHyPE, SeisSol | NGI      |
| 5  | Ensemble-based volcanic dispersal at multiple scales | V    | 5           | 7-8        | FALL3D                  | CSIC IMO |
| 6  | Multiphase 3D volcanic explosion modeling            |      | 4           | 7          | OpenPDAC                | INGV     |
| 7  | The Earth's dynamo model                             | MHD  | 3           | 5          | xSHELLS                 | CNRS     |
| 8  | Geodynamics to geohazards                            | GD   | 3           | 5          | LaMEM, pTatin3D         | UM       |
| 9  | Glacial outburst floods                              | GL   | 2           | 4          | Elmer/Ice               | CSC      |

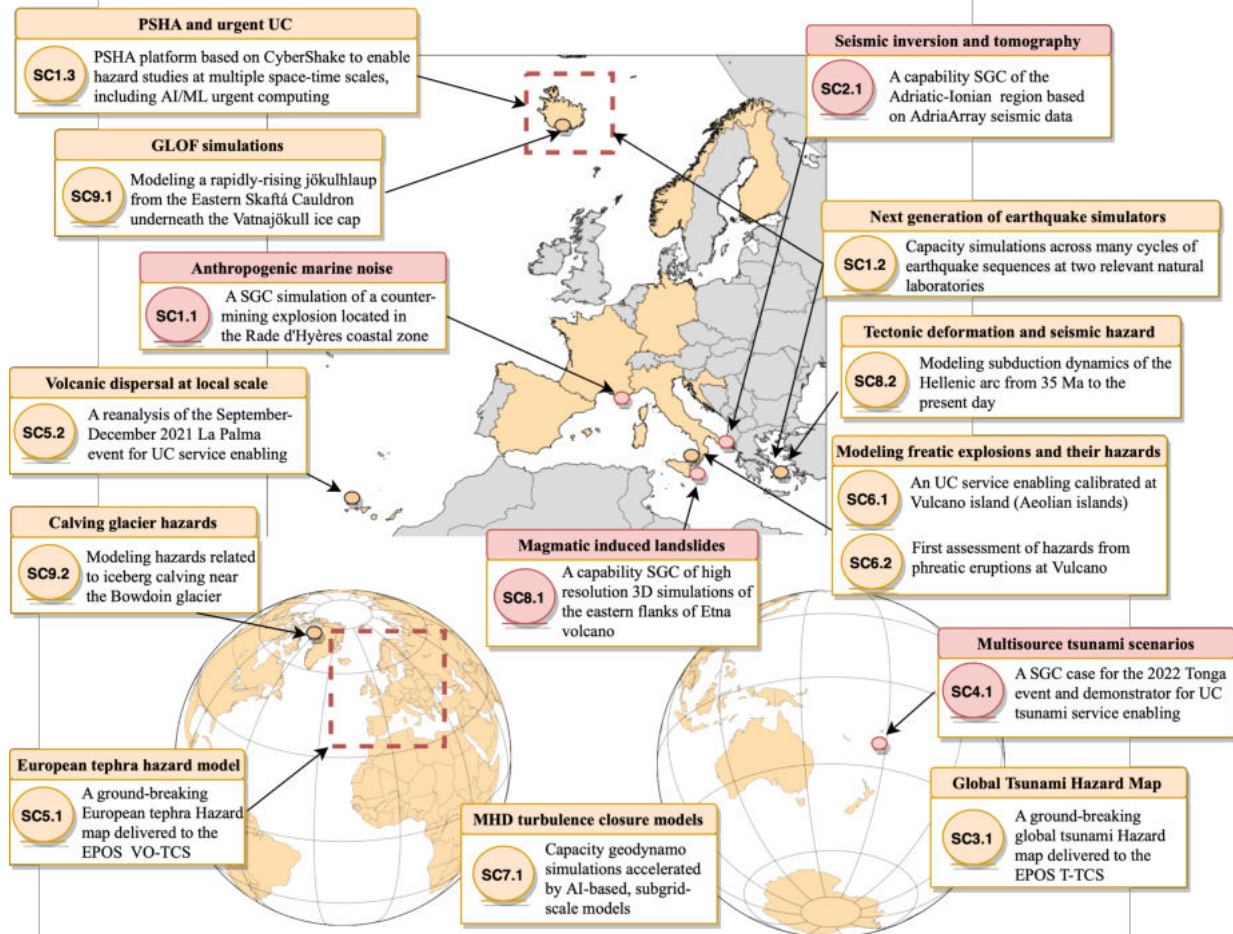


# 15 Simulation cases (4 Scientific Grand Challenges)

| PD  | No    | SC name                                                                                     | Type       | SGC | Expected outcome        |
|-----|-------|---------------------------------------------------------------------------------------------|------------|-----|-------------------------|
| PD1 | SC1.1 | Anthropogenic noise and seismicity, wave propagation at higher frequencies in Rade d'Hyères | capability | yes | open datasets           |
|     | SC1.2 | Next generation of earthquake simulators for the Hellenic arc and Iceland                   | capacity   | -   | earthquake catalogs     |
|     | SC1.3 | Physics-based PSHA and urgent UQ for Iceland                                                | capacity   | -   | UC service enabling     |
| PD2 | SC2.1 | Seismic tomography of the Adriatic-Ionian region                                            | capability | yes | open datasets           |
| PD3 | SC3.1 | The Global Tsunami Hazard Map                                                               | capacity   | -   | TCS-TSU service in EPOS |
| PD4 | SC4.1 | Multi-source local high-resolution scenario with emphasis on the 2022 Tonga case            | capability | yes | UC service enabling     |
| PD5 | SC5.1 | Towards the European tephra hazard map                                                      | capacity   | -   | TCS-VO service in EPOS  |
|     | SC5.2 | Volcanic dispersal at local scale: a reanalysis of the 2021 La Palma case                   | capacity   | -   | UC service enabling     |
| PD6 | SC6.1 | Urgent high-resolution, 3D multiphase flow simulation of phreatic eruptions at Vulcano      | capability | -   | UC service enabling     |
|     | SC6.2 | Long-term probabilistic hazard maps for phreatic eruptions at Vulcano island                | capacity   | -   | open datasets           |
| PD7 | SC7.1 | MHD turbulence closure models in planetary cores using AI                                   | capacity   | -   | open datasets           |
| PD8 | SC8.1 | Magmatic systems and induced landslides: the Etna case                                      | capability | yes | open datasets           |
|     | SC8.2 | 3D evolution of tectonic deformation as driver of seismic hazard in the Hellenic arc        | capability | -   | open datasets           |
| PD9 | SC9.1 | Eastern Skaftá cauldron GLOF simulation, Iceland                                            | capacity   | -   | open datasets           |
|     | SC9.2 | Calving glacier hazard in Greenland                                                         | capacity   | -   | open datasets           |



# 15 Simulation cases (4 Scientific Grand Challenges)



# Service enabling

## Urgent Computing (UC) service enabling at EuroHPC systems (emergency access mode)

*Collaboration with IUB members (exercises) and EuroHPC Infrastructure Advisory Group (INFRAG) for UC service certification, deployment, and access*

|            |       |                                                     |                                     |
|------------|-------|-----------------------------------------------------|-------------------------------------|
| <b>PD1</b> | SC1.3 | Physics-based PSHA and urgent UQ                    | LMU, BSC, IMO, TUM                  |
| <b>PD4</b> | SC4.1 | Multi-source high-resolution tsunamigenic scenarios | NGI, TUM, INGV, UMA, LMU, RBI, CNRS |
| <b>PD5</b> | SC5.2 | Volcanic dispersal at multiple scales               | CSIC, INGV                          |
| <b>PD6</b> | SC6.1 | Multiphase flow simulation of phreatic eruptions    | INGV, CIN                           |

## Services integrated in EPOS Tematic Core Services (TCS)

*TCS-TSU and TCS-VO*

|            |       |                                |                     |
|------------|-------|--------------------------------|---------------------|
| <b>PD3</b> | SC3.1 | Global Tsunami Hazard Map      | INGV, UMA, NGI, TUM |
| <b>PD5</b> | SC5.1 | The European tephra hazard map | INGV, CSIC, IMO     |



# 10 Project Milestones

| MS   | Milestone name                | Month | Lead | Means of verification (KPI)                                                                                                       |
|------|-------------------------------|-------|------|-----------------------------------------------------------------------------------------------------------------------------------|
| MS1  | Project setup phase           | 8     | CSIC | D1.1, D1.2, D7.1, D7.2, D7.3                                                                                                      |
| MS2  | Preparation of mini-apps      | 18    | CIN  | Effective co-design with EuroHPC Pilots can start (D3.1)                                                                          |
| MS3  | Flagship code functionalities | 24    | CNRS | Code version releases with the new functionalities (physics) available repository (D5.1)                                          |
| MS4  | Mid-term review meeting       | 25    | CISC | Check of the project program development (D1.3)                                                                                   |
| MS5  | Exascale code preparation     | 36    | CIN  | Improvements in the flagship codes performance metrics after the second code audit round (D2.2, D2.3)                             |
| MS6  | Exascale pilot deployment     | 42    | CNRS | PDs tested successfully (D4.4, D5.2 to D5.10)                                                                                     |
| MS7  | Production runs               | 48    | INGV | SCs executed, EOSC-enabled datasets produced (D6.x)                                                                               |
| MS8  | Community building            | 48    | BSC  | UC services enabled, evaluation exercises with IUB members done, effective liaison with ecosystem initiatives, training completed |
| MS9  | <b>Complementary Grants</b>   | 6     | CSIC | CASTIEL-2 collaboration agreement has been signed                                                                                 |
| MS10 | <b>Application deployment</b> | 12    | HLRS | Codes available to users of EuroHPC via automated deployment, documentation, testing and quality checks                           |



# Relevant KPIs

| Target(s)                                                                                                            | Means of verification (KPI)                                                    | Task            |
|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-----------------|
| Port to accelerators (e.g. NVIDIA/AMD) and fine-tune the codes already accelerated in the first project phase        | All codes accelerated at the end of the project                                | T2.2            |
| Increase the performance portability of codes across tier-0/tier-1 EuroHPC systems                                   | Performance metrics on Leonardo, LUMI and MN5 machines                         | T2.2<br>T2.4    |
| Obtain code performance metrics (and optimize on-demand accordingly)                                                 | Increase in the POP metrics after the second audit round (deliverable D2.3)    | T2.1            |
| Engage with the EuroHPC EuPEX and EuPilot projects to test on the available prototypes                               | The 7 mini-apps tested and with feedback integrated to main codes              | T3.1 to<br>T3.3 |
| Automate the code deployment process including containerization for code/workflow components                         | CI, static and dynamic code analysis in place                                  | T4.2 T4.3       |
| Farm 9 PDs (2 in CS, 2 in tsunamis, 2 in physical volcanology, 1 in MHD, 1 in geodynamics, and 1 in glacier hazards) | Increase the TRL of each PD by at least 2 points                               | T5.1<br>T5.2    |
| Run the 9 capacity and 6 capability use cases                                                                        | Production runs performed and EOSC-enabled results/datasets available          | T6.2<br>T6.3    |
| Apply to EuroHPC (and PRACE if not discontinued) for competitive project access resources                            | Obtain 3 regular and 1 extreme scale EuroHPC competitive access projects       | T1.4            |
| Global tsunami and European tephra hazard maps and related services                                                  | D6.4 (EPOS-TCS) and datasets available                                         | T6.3            |
| Enable UC services and related policies on EuroHPC systems                                                           | 4 UC service workflows tested and enabled                                      | T6.4            |
| Organization of open, free, training events and seminars on the specific domains of SE                               | Organize 8 training events, including at least 1 course for each flagship code | T7.3            |



# Implementation Risks

| Quantification of risk                                                                                    |            |          | WP      | Risk-mitigation measures                                                                                                                     |
|-----------------------------------------------------------------------------------------------------------|------------|----------|---------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Description                                                                                               | Likelihood | Severity |         |                                                                                                                                              |
| Delay in recruitment and appointment of new personnel                                                     | medium     | medium   | 1 (all) | Partners already have personnel with required experience. Partners will start recruiting as soon as possible (GA signature or project start) |
| A partner is not collaborating as expected or conflicts among partners                                    | low        | medium   | all     | The PC will call an urgent PSB meeting to take corrective measures                                                                           |
| <b>POP3 proposal is not funded</b>                                                                        | low        | low      | 2       | POP metrics are already well defined. BSC, CIN, HLRS and CSC have the skills, personnel and material to perform this task independently      |
| Uncertain workload for code performance improving                                                         | medium     | medium   | 2       | Sub-tasks in WP2 that serve to a larger number of codes will be prioritized                                                                  |
| Timeliness of availability and access to hardware prototypes from EuroHPC pilots                          | low        | low      | 3       | mini-apps can run on the already existing architectures                                                                                      |
| Fortran support for mini-app co-design is not ready yet (EuPilot SDVs)                                    | medium     | low      | 3       | affects only 2 of the mini-apps in WP3 (mini-SPECFEM3D and mini-FALL3D), kernels can be written in C/C++                                     |
| Unsuccessful/delayed implementation of new code developments                                              | low        | high     | 5       | Extend duration of T5.1. Reduce the coupling ambition of PDs.                                                                                |
| Insufficient access to EuroHPC (and PRACE?) computational resources, production runs and SGCs compromised | medium     | high     | 4, 5, 6 | Find alternatives based on in-kind and national resources. Reduce the ambition of T6.2 and T6.3. Limit the quantity (and extend) of the SGCs |
| Key milestones or deliverables delayed                                                                    | low        | low      | all     | The PC and PEC will foresee problems and take early corrective measures in collaboration with the concerned partners                         |



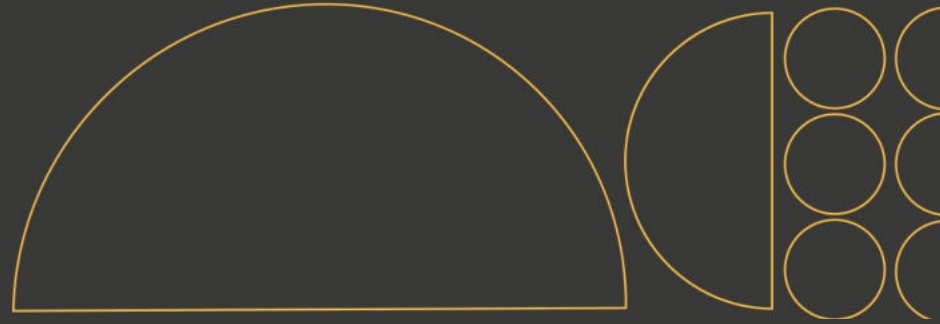
# Galileo Conference



|               |                                                                  |
|---------------|------------------------------------------------------------------|
| <b>Day 0</b>  | Master Classes (10 grants of 500€)                               |
| <b>Day 1</b>  | Session 1: Preparation and optimization of HPC codes to Exascale |
|               | Session 2: Edge-to-end data workflows                            |
| <b>Day 2</b>  | Session 3: State-of-the-art in computational geosciences         |
|               | Session 4: Horizon Europe and EuroHPC Policies                   |
| <b>Day 3</b>  | Discussion on the the consensual documents                       |
| <b>14 Nov</b> | Opening of abstract submissions                                  |
| <b>29 Jan</b> | Deadline of abstract submissions (extended)                      |
| <b>21 Mar</b> | Registration opens                                               |
| <b>21 Apr</b> | Registration closes                                              |



# Thank you!



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