



GRANT AGREEMENT

Project 101093038 — ChEESE-2P

PREAMBLE

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

European High-Performance Computing Joint Undertaking ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and

on the other part,

1. 'the coordinator':

AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC), PIC 999991722, established in CALLE SERRANO 117, MADRID 28006, Spain,

and the following other beneficiaries, if they sign their 'accession form' (see Annex 3 and Article 40):

2. **BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACION (BSC CNS)**, PIC 999655520, established in CALLE JORDI GIRONA 31, BARCELONA 08034, Spain,

3. **ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA (INGV)**, PIC 999472675, established in Via di Vigna Murata 605, ROMA 00143, Italy,

4. **VEDURSTOFA ISLANDS (IMO)**, PIC 997168343, established in BUSTADARVEGUR 7-9, REYKJAVIK IS-150, Iceland,

5. **UNIVERSITY OF STUTTGART (USTUTT)**, PIC 999974747, established in KEPLERSTRASSE 7, STUTTGART 70174, Germany,

6. **CINECA CONSORZIO INTERUNIVERSITARIO (CINECA)**, PIC 999843409, established in VIA MAGNANELLI 6/3, CASALECCHIO DI RENO BO 40033, Italy,

7. **TECHNISCHE UNIVERSITAET MUENCHEN (TUM)**, PIC 999977463, established in Arcisstrasse 21, MUENCHEN 80333, Germany,

8. **LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN (LMU MUENCHEN)**, PIC 999978433, established in GESCHWISTER SCHOLL PLATZ 1, MUENCHEN 80539, Germany,



9. **UNIVERSIDAD DE MALAGA (UMA)**, PIC 999898311, established in AVDA CERVANTES, NUM. 2, MALAGA 29016, Spain,
10. **STIFTELSEN NORGES GEOTEKNISKE INSTITUTT (NGI)**, PIC 998866522, established in SOGNSV 72, OSLO 0855, Norway,
11. **CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS)**, PIC 999997930, established in RUE MICHEL ANGE 3, PARIS 75794, France,
12. **BULL SAS (BULL)**, PIC 996058081, established in RUE JEAN JAURES 68, LES CLAYES SOUS BOIS 78340, France,
13. **CSC-TIETEEN TIETOTEKNIKAN KESKUS OY (CSC)**, PIC 999645820, established in KEILARANTA 14, ESPOO 02101, Finland,
14. **RUDER BOSKOVIC INSTITUTE (RBI)**, PIC 999875031, established in Bijenicka cesta 54, ZAGREB 10000, Croatia,
15. **JOHANNES GUTENBERG-UNIVERSITAT MAINZ (UM)**, PIC 999978627, established in SAARSTRASSE 21, MAINZ 55099, Germany,
16. **SORBONNE UNIVERSITE (SU)**, PIC 909875521, established in 21 RUE DE L'ECOLE DE MEDECINE, PARIS 75006, France,

Unless otherwise specified, references to ‘beneficiary’ or ‘beneficiaries’ include the coordinator and affiliated entities (if any).

If only one beneficiary signs the grant agreement (‘mono-beneficiary grant’), all provisions referring to the ‘coordinator’ or the ‘beneficiaries’ will be considered — mutatis mutandis — as referring to the beneficiary.

The parties referred to above have agreed to enter into the Agreement.

By signing the Agreement and the accession forms, the beneficiaries accept the grant and agree to implement the action under their own responsibility and in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

The Agreement is composed of:

Preamble

Terms and Conditions (including Data Sheet)

Annex 1	Description of the action ¹
Annex 2	Estimated budget for the action
Annex 2a	Additional information on unit costs and contributions (if applicable)
Annex 2e	Complex funding rate calculator ²
Annex 3	Accession forms (if applicable) ³
Annex 3a	Declaration on joint and several liability of affiliated entities (if applicable) ⁴
Annex 4	Model for the financial statements
Annex 5	Specific rules (if applicable)

¹ Template published on [Portal Reference Documents](#).

² Template published on [Portal Reference Documents](#).

³ Template published on [Portal Reference Documents](#).

⁴ Template published on [Portal Reference Documents](#).

TERMS AND CONDITIONS

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DATA SHEET

1. General data

Project summary:

Project summary
The scientific ambition of ChEESE-2P is to prepare 11 community flagship codes to address 12 domain-specific Exascale Computational Challenges (ECC), enlarging the areas covered during the first implementation phase (computational seismology, magnetohydrodynamics, physical volcanology, and tsunamis) with two additional disciplines (geodynamics and modeling of glacier hazards). Codes will be optimized in terms of performance on different types of accelerators, scalability, deployment, containerization, and portability across current pre-exascale systems and hardware architectures emerging from the EuroHPC Pilots by co-designing with mini-apps. Optimization will also include heterogeneous single-node and multi-node performance, as well as continuous efficiency monitoring using the Performance Optimisation and Productivity (POP) metrics. Emphasis will be given on the uptake by science, public administration and industry, including training and capacity building in cooperation with National Competence Centers (NCCs). Codes and workflows will combine to form a new generation of 9 Pilot Demonstrators (PDs) underpinned by concepts like multi-scale, multi-source, and multi-physics. The PDs will materialise in 15 Simulation Cases (SCs) representing capability and capacity use cases of particular relevance in terms of science, social relevance, or urgency (the capability SCs include 4 potential Scientific Grand Challenges, i.e. cases that can require an extreme-scale access mode). The SCs will produce relevant EOSC-enabled datasets and enable services on aspects of geohazards like urgent computing, early warning forecast, hazard assessment, or fostering an emergency access mode in EuroHPC tier-0/tier-1 systems for geohazardous events (earthquakes, tsunamis and volcanoes), including access policy recommendations. Finally, ChEESE-2P will liaise, align, and synergize with other domain-specific European projects and longer-term mission-like initiatives like Destination Earth.

Keywords:

- Solid Earth, code optimization, services, geohazards, urgent computing

Project number: 101093038

Project name: Center of Excellence for Exascale in Solid Earth - Second Phase

Project acronym: ChEESE-2P

Call: HORIZON-EUROHPC-JU-2021-COE-01

Topic: HORIZON-EUROHPC-JU-2021-COE-01-02

Type of action: HORIZON JU Research and Innovation Actions

Granting authority: European High-Performance Computing Joint Undertaking

Grant managed through EU Funding & Tenders Portal: Yes (eGrants)

Project starting date: fixed date: 1 January 2023

Project end date: 31 December 2026

Project duration: 48 months

Linked action: Linked with other action:

- European Centre of Excellence for Engineering Applications on HPC and associated technologies, EXCELLERAT P2, 101092621, funded by EUROHPC
 - Collaboration agreement: Yes
- Center of excellence for weather and climate phase 3, ESiWACE3, 101093054, funded by EUROHPC
 - Collaboration agreement: Yes
- Plasma Exascale-Performance Simulations CoE - Pushing flagship plasma simulations codes to tackle exascale-enabled Grand Challenges via performance optimisation and codesign, Plasma-PEPSC, 101093261, funded by EUROHPC
 - Collaboration agreement: Yes
- Centre of Excellence in exascale-oriented application co-design and delivery for multiscale simulations, MultiXscale, 101093169, funded by EUROHPC

- Collaboration agreement: Yes
- BioExcel Centre of Excellence for Computational Biomolecular Research, BioExcel-3, 101093290, funded by EUROHPC
- Collaboration agreement: Yes
- Materials design at the eXascale, MaX, 101093374, funded by EUROHPC
- Collaboration agreement: Yes
- Center of Excellence for Exascale CFD, CEEC, 101093393, funded by EUROHPC
- Collaboration agreement: Yes
- Coordination and Support for National Competence Centres and Centres of Excellence on a European Level Phase 2, CASTIEL 2, 101102047, funded by EUROHPC
- Collaboration agreement: Yes
- Scalable Parallel and distributed Astrophysical Codes for Exascale, SPACE, 101093441, funded by EUROHPC
- Collaboration agreement: Yes
- HPC and Big Data Technologies for Global Challenges, HiDALGO2, 101093457, funded by EUROHPC
- Collaboration agreement: Yes

Consortium agreement: Yes

2. Participants

List of participants:

Nº	Role	Short name	Legal name	Ctry	PIC	Total eligible costs (BEN and AE)	Max grant amount
1	COO	CSIC	AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	ES	999991722	943 750.00	470 625.00
2	BEN	BSC CNS	BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACION	ES	999655520	676 103.75	338 051.88
3	BEN	INGV	ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA	IT	999472675	629 416.25	314 708.00
4	BEN	IMO	VEDURSTOFA ISLANDS	IS	997168343	369 478.75	184 739.00
5	BEN	USTUTT	UNIVERSITY OF STUTTGART	DE	999974747	620 958.75	310 479.00
6	BEN	CINECA	CINECA CONSORZIO INTERUNIVERSITARIO	IT	999843409	552 521.25	276 260.63
7	BEN	TUM	TECHNISCHE UNIVERSITAET MUENCHEN	DE	999977463	432 912.50	216 456.00
8	BEN	LMU MUENCHEN	LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN	DE	999978433	484 353.75	242 176.88
9	BEN	UMA	UNIVERSIDAD DE MALAGA	ES	999898311	390 103.75	195 051.88
10	BEN	NGI	STIFTELSEN NORGES GEOTEKNIKE INSTITUTT	NO	998866522	471 855.00	235 927.50
11	BEN	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	999997930	645 515.00	322 757.50
11.1	AE	IPGP	INSTITUT DE PHYSIQUE DU GLOBE DE PARIS	FR	999597417	57 350.00	28 675.00
12	BEN	BULL	BULL SAS	FR	996058081	526 000.00	263 000.00
13	BEN	CSC	CSC-TIETEEN TIETOTEKNIKAN KESKUS OY	FI	999645820	301 896.25	150 948.00
14	BEN	RBI	RUDER BOSKOVIC INSTITUTE	HR	999875031	204 125.00	102 062.50
15	BEN	UM	JOHANNES GUTENBERG-UNIVERSITAT MAINZ	DE	999978627	213 750.00	106 875.00
16	BEN	SU	SORBONNE UNIVERSITE	FR	909875521	170 500.00	85 250.00
Total						7 690 590.00	3 844 043.77

Coordinator:

- AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC)

3. Grant

Maximum grant amount, total estimated eligible costs and contributions and funding rate:

Total eligible costs (BEN and AE)	Funding rate (%)	Maximum grant amount (Annex 2)	Maximum grant amount (award decision)
7 690 590.00	50	3 844 043.77	3 844 043.77

Grant form: Budget-based**Grant mode:** Action grant**Budget categories/activity types:**

- A. Personnel costs
 - A.1 Employees, A.2 Natural persons under direct contract, A.3 Seconded persons
 - A.4 SME owners and natural person beneficiaries
- B. Subcontracting costs
- C. Purchase costs
 - C.1 Travel and subsistence
 - C.2 Equipment
 - C.3 Other goods, works and services
- D. Other cost categories
 - D.2 Internally invoiced goods and services
- E. Indirect costs

Cost eligibility options:

- In-kind contributions eligible costs
- Parental leave
- Project-based supplementary payments
- Average personnel costs (unit cost according to usual cost accounting practices)
- Limitation for subcontracting
- Travel and subsistence:
 - Travel: Actual costs
 - Accommodation: Actual costs
 - Subsistence: Actual costs
- Equipment: depreciation only
- Indirect cost flat-rate: 25% of the eligible direct costs (categories A-D, except volunteers costs, subcontracting costs, financial support to third parties and exempted specific cost categories, if any)
- VAT: Yes
- Country restrictions for eligible costs
- Other ineligible costs

Budget flexibility: Yes (no flexibility cap)**4. Reporting, payments and recoveries**

4.1 Continuous reporting (art 21)**Deliverables:** see Funding & Tenders Portal Continuous Reporting tool**4.2 Periodic reporting and payments****Reporting and payment schedule** (art 21, 22):

Reporting					Payments	
Reporting periods			Type	Deadline	Type	Deadline (time to pay)
RP No	Month from	Month to				
					Initial prefinancing	30 days from entry into force/10 days before starting date – whichever is the latest
					Interim payment	90 days from receiving periodic report
					Interim payment	90 days from receiving periodic report
					Final payment	90 days from receiving periodic report

Prefinancing payments and guarantees:

Prefinancing payment	
Type	Amount
Prefinancing 1 (initial)	2 037 343.20

Reporting and payment modalities (art 21, 22):

Mutual Insurance Mechanism (MIM): Yes

MIM contribution: 5% of the maximum grant amount (192 202.19), retained from the initial prefinancing

Restrictions on distribution of initial prefinancing: The prefinancing may be distributed only if the minimum number of beneficiaries set out in the call conditions (if any) have acceded to the Agreement and only to beneficiaries that have acceded.

Interim payment ceiling (if any): 90% of the maximum grant amount

Exception for revenues: Yes

No-profit rule: Yes

Late payment interest: ECB + 3.5%

Bank account for payments:

ES4490000001200253107033

Conversion into euros: Double conversion

Reporting language: Language of the Agreement

4.3 Certificates (art 24):

Certificates on the financial statements (CFS):

Conditions:

Schedule: only at final payment, if threshold is reached

Standard threshold (beneficiary-level):

- financial statement: requested EU contribution to costs $\geq$ EUR 430 000.00

Special threshold for beneficiaries with a systems and process audit(see Article 24): financial statement: requested EU contribution to costs $\geq$ EUR 725 000.00

4.4 Recoveries (art 22)

First-line liability for recoveries:

Beneficiary termination: Beneficiary concerned

Final payment: Each beneficiary for their own debt

After final payment: Beneficiary concerned

Joint and several liability for enforced recoveries (in case of non-payment):

Individual financial responsibility: Each beneficiary is liable only for its own debts (and those of its affiliated entities, if any)

5. Consequences of non-compliance, applicable law & dispute settlement forum

Suspension and termination:

Additional suspension grounds (art 31)

Additional termination grounds (art 32)

Applicable law (art 43):

Standard applicable law regime: EU law + law of Belgium

Dispute settlement forum (art 43):

Standard dispute settlement forum:

EU beneficiaries: EU General Court + EU Court of Justice (on appeal)

Non-EU beneficiaries: Courts of Brussels, Belgium (unless an international agreement provides for the enforceability of EU court judgements)

6. Other

Specific rules (Annex 5): Yes

Standard time-limits after project end:

Confidentiality (for X years after final payment): 5



Record-keeping (for X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

Reviews (up to X years after final payment): 2

Audits (up to X years after final payment): 2

Extension of findings from other grants to this grant (no later than X years after final payment): 2

Impact evaluation (up to X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

CHAPTER 1 GENERAL

ARTICLE 1 — SUBJECT OF THE AGREEMENT

This Agreement sets out the rights and obligations and terms and conditions applicable to the grant awarded for the implementation of the action set out in Chapter 2.

ARTICLE 2 — DEFINITIONS

For the purpose of this Agreement, the following definitions apply:

Actions — The project which is being funded in the context of this Agreement.

Grant — The grant awarded in the context of this Agreement.

EU grants — Grants awarded by EU institutions, bodies, offices or agencies (including EU executive agencies, EU regulatory agencies, EDA, joint undertakings, etc.).

Participants — Entities participating in the action as beneficiaries, affiliated entities, associated partners, third parties giving in-kind contributions, subcontractors or recipients of financial support to third parties.

Beneficiaries (BEN) — The signatories of this Agreement (either directly or through an accession form).

Affiliated entities (AE) — Entities affiliated to a beneficiary within the meaning of Article 187 of EU Financial Regulation 2018/1046⁵ which participate in the action with similar rights and obligations as the beneficiaries (obligation to implement action tasks and right to charge costs and claim contributions).

Associated partners (AP) — Entities which participate in the action, but without the right to charge costs or claim contributions.

Purchases — Contracts for goods, works or services needed to carry out the action (e.g. equipment, consumables and supplies) but which are not part of the action tasks (see Annex 1).

Subcontracting — Contracts for goods, works or services that are part of the action tasks (see Annex 1).

In-kind contributions — In-kind contributions within the meaning of Article 2(36) of EU Financial

⁵ For the definition, see Article 187 Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council of 18 July 2018 on the financial rules applicable to the general budget of the Union, amending Regulations (EU) No 1296/2013, (EU) No 1301/2013, (EU) No 1303/2013, (EU) No 1304/2013, (EU) No 1309/2013, (EU) No 1316/2013, (EU) No 223/2014, (EU) No 283/2014, and Decision No 541/2014/EU and repealing Regulation (EU, Euratom) No 966/2012 ('EU Financial Regulation') (OJ L 193, 30.7.2018, p. 1): "**affiliated entities** [are]:

- (a) entities that form a sole beneficiary [(i.e. where an entity is formed of several entities that satisfy the criteria for being awarded a grant, including where the entity is specifically established for the purpose of implementing an action to be financed by a grant)];
- (b) entities that satisfy the eligibility criteria and that do not fall within one of the situations referred to in Article 136(1) and 141(1) and that have a link with the beneficiary, in particular a legal or capital link, which is neither limited to the action nor established for the sole purpose of its implementation".

Regulation 2018/1046, i.e. non-financial resources made available free of charge by third parties.

Fraud — Fraud within the meaning of Article 3 of EU Directive 2017/1371⁶ and Article 1 of the Convention on the protection of the European Communities' financial interests, drawn up by the Council Act of 26 July 1995⁷, as well as any other wrongful or criminal deception intended to result in financial or personal gain.

Irregularities — Any type of breach (regulatory or contractual) which could impact the EU financial interests, including irregularities within the meaning of Article 1(2) of EU Regulation 2988/95⁸.

Grave professional misconduct — Any type of unacceptable or improper behaviour in exercising one's profession, especially by employees, including grave professional misconduct within the meaning of Article 136(1)(c) of EU Financial Regulation 2018/1046.

Applicable EU, international and national law — Any legal acts or other (binding or non-binding) rules and guidance in the area concerned.

Portal — EU Funding & Tenders Portal; electronic portal and exchange system managed by the European Commission and used by itself and other EU institutions, bodies, offices or agencies for the management of their funding programmes (grants, procurements, prizes, etc.).

CHAPTER 2 ACTION

ARTICLE 3 — ACTION

The grant is awarded for the action **101093038 — ChEESE-2P** ('action'), as described in Annex 1.

This action is linked to the action(s) set out in the Data Sheet (see Point 1) ('linked actions').

ARTICLE 4 — DURATION AND STARTING DATE

The duration and the starting date of the action are set out in the Data Sheet (see Point 1).

CHAPTER 3 GRANT

ARTICLE 5 — GRANT

5.1 Form of grant

⁶ Directive (EU) 2017/1371 of the European Parliament and of the Council of 5 July 2017 on the fight against fraud to the Union's financial interests by means of criminal law (OJ L 198, 28.7.2017, p. 29).

⁷ OJ C 316, 27.11.1995, p. 48.

⁸ Council Regulation (EC, Euratom) No 2988/95 of 18 December 1995 on the protection of the European Communities financial interests (OJ L 312, 23.12.1995, p. 1).

The grant is an action grant⁹ which takes the form of a budget-based mixed actual cost grant (i.e. a grant based on actual costs incurred, but which may also include other forms of funding, such as unit costs or contributions, flat-rate costs or contributions, lump sum costs or contributions or financing not linked to costs).

5.2 Maximum grant amount

The maximum grant amount is set out in the Data Sheet (see Point 3) and in the estimated budget (Annex 2).

5.3 Funding rate

The funding rate for costs is 50% of the action's eligible costs.

Contributions are not subject to any funding rate.

Individual funding rates and maximum amounts per beneficiary and reporting period are set out in Annex 2e.

5.4 Estimated budget, budget categories and forms of funding

The estimated budget for the action is set out in Annex 2.

It contains the estimated eligible costs and contributions for the action, broken down by participant and budget category.

Annex 2 also shows the types of costs and contributions (forms of funding)¹⁰ to be used for each budget category.

If multiple combinations of complex funding rates are used, Annex 2 will be complemented by Annex 2e, which will specify the individual funding rates that cap the maximum amounts that may be requested for each beneficiary and reporting period.

If unit costs or contributions are used, the details on the calculation will be explained in Annex 2a.

5.5 Budget flexibility

The budget breakdown may be adjusted — without an amendment (see Article 39) — by transfers (between participants and budget categories), as long as this does not imply any substantive or important change to the description of the action in Annex 1.

However:

- changes to the budget category for volunteers (if used) always require an amendment
- changes to budget categories with lump sums costs or contributions (if used; including financing not linked to costs) always require an amendment

⁹ For the definition, see Article 180(2)(a) EU Financial Regulation 2018/1046: ‘**action grant**’ means an EU grant to finance “an action intended to help achieve a Union policy objective”.

¹⁰ See Article 125 EU Financial Regulation 2018/1046.

- changes to budget categories with higher funding rates or budget ceilings (if used) always require an amendment
- changes to Annex 2e always require an amendment
- addition of amounts for subcontracts not provided for in Annex 1 either require an amendment or simplified approval in accordance with Article 6.2
- other changes require an amendment or simplified approval, if specifically provided for in Article 6.2
- flexibility caps: not applicable.

ARTICLE 6 — ELIGIBLE AND INELIGIBLE COSTS AND CONTRIBUTIONS

In order to be eligible, costs and contributions must meet the **eligibility** conditions set out in this Article.

6.1 General eligibility conditions

The **general eligibility conditions** are the following:

- (a) for actual costs:
 - (i) they must be actually incurred by the beneficiary
 - (ii) they must be incurred in the period set out in Article 4 (with the exception of costs relating to the submission of the final periodic report, which may be incurred afterwards; see Article 21)
 - (iii) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2
 - (iv) they must be incurred in connection with the action as described in Annex 1 and necessary for its implementation
 - (v) they must be identifiable and verifiable, in particular recorded in the beneficiary's accounts in accordance with the accounting standards applicable in the country where the beneficiary is established and with the beneficiary's usual cost accounting practices
 - (vi) they must comply with the applicable national law on taxes, labour and social security and
 - (vii) they must be reasonable, justified and must comply with the principle of sound financial management, in particular regarding economy and efficiency
- (b) for unit costs or contributions (if any):
 - (i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2
 - (ii) the units must:



- be actually used or produced by the beneficiary in the period set out in Article 4 (with the exception of units relating to the submission of the final periodic report, which may be used or produced afterwards; see Article 21)
 - be necessary for the implementation of the action and
- (iii) the number of units must be identifiable and verifiable, in particular supported by records and documentation (see Article 20)
- (c) for flat-rate costs or contributions (if any):
- (i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2
 - (ii) the costs or contributions to which the flat-rate is applied must:
 - be eligible
 - relate to the period set out in Article 4 (with the exception of costs or contributions relating to the submission of the final periodic report, which may be incurred afterwards; see Article 21)
- (d) for lump sum costs or contributions (if any):
- (i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2
 - (ii) the work must be properly implemented by the beneficiary in accordance with Annex 1
 - (iii) the deliverables/outputs must be achieved in the period set out in Article 4 (with the exception of deliverables/outputs relating to the submission of the final periodic report, which may be achieved afterwards; see Article 21)
- (e) for unit, flat-rate or lump sum costs or contributions according to usual cost accounting practices (if any):
- (i) they must fulfil the general eligibility conditions for the type of cost concerned
 - (ii) the cost accounting practices must be applied in a consistent manner, based on objective criteria, regardless of the source of funding
- (f) for financing not linked to costs (if any): the results must be achieved or the conditions must be fulfilled as described in Annex 1.

In addition, for direct cost categories (e.g. personnel, travel & subsistence, subcontracting and other direct costs) only costs that are directly linked to the action implementation and can therefore be attributed to it directly are eligible. They must not include any indirect costs (i.e. costs that are only indirectly linked to the action, e.g. via cost drivers).

In-kind contributions provided by third parties free of charge may be declared as eligible direct costs by the beneficiaries which use them (under the same conditions as if they were their own, provided that they concern only direct costs and that the third parties and their in-kind contributions are set

out in Annex 1 (or approved ex post in the periodic report, if their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants; ‘simplified approval procedure’).

6.2 Specific eligibility conditions for each budget category

For each budget category, the **specific eligibility conditions** are as follows:

Direct costs

A. Personnel costs

A.1 Costs for employees (or equivalent) are eligible as personnel costs if they fulfil the general eligibility conditions and are related to personnel working for the beneficiary under an employment contract (or equivalent appointing act) and assigned to the action.

They must be limited to salaries (including net payments during parental leave), social security contributions, taxes and other costs linked to the remuneration, if they arise from national law or the employment contract (or equivalent appointing act) and be calculated on the basis of the costs actually incurred, in accordance with the following method:

{daily rate for the person
multiplied by
number of day-equivalents worked on the action (rounded up or down to the nearest half-day)}.

The daily rate must be calculated as:

{annual personnel costs for the person
divided by
215}.

The number of day-equivalents declared for a person must be identifiable and verifiable (see Article 20).

The actual time spent on parental leave by a person assigned to the action may be deducted from the 215 days indicated in the above formula.

The total number of day-equivalents declared in EU grants, for a person for a year, cannot be higher than 215, minus time spent on parental leave (if any).

For personnel which receives supplementary payments for work in projects (project-based remuneration), the personnel costs must be calculated at a rate which:

- corresponds to the actual remuneration costs paid by the beneficiary for the time worked by the person in the action over the reporting period
- does not exceed the remuneration costs paid by the beneficiary for work in similar projects funded by national schemes (‘national projects reference’)
- is defined based on objective criteria allowing to determine the amount to which the person is entitled

and

- reflects the usual practice of the beneficiary to pay consistently bonuses or supplementary payments for work in projects funded by national schemes.

The national projects reference is the remuneration defined in national law, collective labour agreement or written internal rules of the beneficiary applicable to work in projects funded by national schemes.

If there is no such national law, collective labour agreement or written internal rules or if the project-based remuneration is not based on objective criteria, the national project reference will be the average remuneration of the person in the last full calendar year covered by the reporting period, excluding remuneration paid for work in EU actions.

If the beneficiary uses average personnel costs (unit cost according to usual cost accounting practices), the personnel costs must fulfil the general eligibility conditions for such unit costs and the daily rate must be calculated:

- using the actual personnel costs recorded in the beneficiary's accounts and excluding any costs which are ineligible or already included in other budget categories; the actual personnel costs may be adjusted on the basis of budgeted or estimated elements, if they are relevant for calculating the personnel costs, reasonable and correspond to objective and verifiable information

and

- according to usual cost accounting practices which are applied in a consistent manner, based on objective criteria, regardless of the source of funding.

A.2 and A.3 Costs for natural persons working under a direct contract other than an employment contract and costs for **seconded persons by a third party against payment** are also eligible as personnel costs, if they are assigned to the action, fulfil the general eligibility conditions and:

- (a) work under conditions similar to those of an employee (in particular regarding the way the work is organised, the tasks that are performed and the premises where they are performed) and
- (b) the result of the work belongs to the beneficiary (unless agreed otherwise).

They must be calculated on the basis of a rate which corresponds to the costs actually incurred for the direct contract or secondment and must not be significantly different from those for personnel performing similar tasks under an employment contract with the beneficiary.

A.4 The work of SME owners for the action (i.e. owners of beneficiaries that are small and medium-sized enterprises¹¹ not receiving a salary) or **natural person beneficiaries** (i.e. beneficiaries that are

¹¹ For the definition, see Commission Recommendation 2003/361/EC: micro, small or medium-sized enterprise (SME) are enterprises

- engaged in an economic activity, irrespective of their legal form (including, in particular, self-employed persons and family businesses engaged in craft or other activities, and partnerships or associations regularly engaged in an economic activity) and
- employing fewer than 250 persons (expressed in 'annual working units' as defined in Article 5 of the

natural persons not receiving a salary) may be declared as personnel costs, if they fulfil the general eligibility conditions and are calculated as unit costs in accordance with the method set out in Annex 2a.

B. Subcontracting costs

Subcontracting costs for the action (including related duties, taxes and charges, such as non-deductible or non-refundable value added tax (VAT)) are eligible, if they are calculated on the basis of the costs actually incurred, fulfil the general eligibility conditions and are awarded using the beneficiary's usual purchasing practices — provided these ensure subcontracts with best value for money (or if appropriate the lowest price) and that there is no conflict of interests (see Article 12).

Beneficiaries that are 'contracting authorities/entities' within the meaning of the EU Directives on public procurement must also comply with the applicable national law on public procurement.

The beneficiaries must ensure that the subcontracted work is performed in the eligible countries or target countries set out in the call conditions — unless otherwise approved by the granting authority.

Subcontracting may cover only a limited part of the action.

The tasks to be subcontracted and the estimated cost for each subcontract must be set out in Annex 1 and the total estimated costs of subcontracting per beneficiary must be set out in Annex 2 (or may be approved ex post in the periodic report, if the use of subcontracting does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants; 'simplified approval procedure').

C. Purchase costs

Purchase costs for the action (including related duties, taxes and charges, such as non-deductible or non-refundable value added tax (VAT)) are eligible if they fulfil the general eligibility conditions and are bought using the beneficiary's usual purchasing practices — provided these ensure purchases with best value for money (or if appropriate the lowest price) and that there is no conflict of interests (see Article 12).

Beneficiaries that are 'contracting authorities/entities' within the meaning of the EU Directives on public procurement must also comply with the applicable national law on public procurement.

C.1 Travel and subsistence

Purchases for **travel, accommodation and subsistence** must be calculated as follows:

- travel: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel
- accommodation: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel
- subsistence: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel .

Recommendation) and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.

C.2 Equipment

Purchases of **equipment, infrastructure or other assets** used for the action must be declared as depreciation costs, calculated on the basis of the costs actually incurred and written off in accordance with international accounting standards and the beneficiary's usual accounting practices.

Only the portion of the costs that corresponds to the rate of actual use for the action during the action duration can be taken into account.

Costs for **renting or leasing** equipment, infrastructure or other assets are also eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets and do not include any financing fees.

C.3 Other goods, works and services

Purchases of **other goods, works and services** must be calculated on the basis of the costs actually incurred.

Such goods, works and services include, for instance, consumables and supplies, promotion, dissemination, protection of results, translations, publications, certificates and financial guarantees, if required under the Agreement.

D. Other cost categories

D.2 Internally invoiced goods and services

Costs for internally invoiced goods and services directly used for the action may be declared as unit cost according to usual cost accounting practices, if and as declared eligible in the call conditions, if they fulfil the general eligibility conditions for such unit costs and the amount per unit is calculated:

- using the actual costs for the good or service recorded in the beneficiary's accounts, attributed either by direct measurement or on the basis of cost drivers, and excluding any cost which are ineligible or already included in other budget categories; the actual costs may be adjusted on the basis of budgeted or estimated elements, if they are relevant for calculating the costs, reasonable and correspond to objective and verifiable information

and

- according to usual cost accounting practices which are applied in a consistent manner, based on objective criteria, regardless of the source of funding.

'Internally invoiced goods and services' means goods or services which are provided within the beneficiary's organisation directly for the action and which the beneficiary values on the basis of its usual cost accounting practices.

This cost will not be taken into account for the indirect cost flat-rate.

Indirect costs

E. Indirect costs

Indirect costs will be reimbursed at the flat-rate of 25% of the eligible direct costs (categories A-D,

except volunteers costs, subcontracting costs, financial support to third parties and exempted specific cost categories, if any).

Contributions

Not applicable

6.3 Ineligible costs and contributions

The following costs or contributions are **ineligible**:

- (a) costs or contributions that do not comply with the conditions set out above (Article 6.1 and 6.2), in particular:
 - (i) costs related to return on capital and dividends paid by a beneficiary
 - (ii) debt and debt service charges
 - (iii) provisions for future losses or debts
 - (iv) interest owed
 - (v) currency exchange losses
 - (vi) bank costs charged by the beneficiary's bank for transfers from the granting authority
 - (vii) excessive or reckless expenditure
 - (viii) deductible or refundable VAT (including VAT paid by public bodies acting as public authority)
 - (ix) costs incurred or contributions for activities implemented during grant agreement suspension (see Article 31)
 - (x) in-kind contributions by third parties: not applicable
- (b) costs or contributions declared under other EU grants (or grants awarded by an EU Member State, non-EU country or other body implementing the EU budget), except for the following cases:
 - (i) Synergy actions: not applicable
 - (ii) if the action grant is combined with an operating grant¹² running during the same period and the beneficiary can demonstrate that the operating grant does not cover any (direct or indirect) costs of the action grant
- (c) costs or contributions for staff of a national (or regional/local) administration, for activities that are part of the administration's normal activities (i.e. not undertaken only because of the grant)

¹² For the definition, see Article 180(2)(b) of EU Financial Regulation 2018/1046: '**operating grant**' means an EU grant to finance "the functioning of a body which has an objective forming part of and supporting an EU policy".

- (d) costs or contributions (especially travel and subsistence) for staff or representatives of EU institutions, bodies or agencies
- (e) other :
 - (i) costs or contributions for activities that do not take place in one of the eligible countries or target countries set out in the call conditions — unless approved by the granting authority
 - (ii) costs or contributions declared specifically ineligible in the call conditions.

6.4 Consequences of non-compliance

If a beneficiary declares costs or contributions that are ineligible, they will be rejected (see Article 27).

This may also lead to other measures described in Chapter 5.

CHAPTER 4 GRANT IMPLEMENTATION

SECTION 1 CONSORTIUM: BENEFICIARIES, AFFILIATED ENTITIES AND OTHER PARTICIPANTS

ARTICLE 7 — BENEFICIARIES

The beneficiaries, as signatories of the Agreement, are fully responsible towards the granting authority for implementing it and for complying with all its obligations.

They must implement the Agreement to their best abilities, in good faith and in accordance with all the obligations and terms and conditions it sets out.

They must have the appropriate resources to implement the action and implement the action under their own responsibility and in accordance with Article 11. If they rely on affiliated entities or other participants (see Articles 8 and 9), they retain sole responsibility towards the granting authority and the other beneficiaries.

They are jointly responsible for the *technical* implementation of the action. If one of the beneficiaries fails to implement their part of the action, the other beneficiaries must ensure that this part is implemented by someone else (without being entitled to an increase of the maximum grant amount and subject to an amendment; see Article 39). The *financial* responsibility of each beneficiary in case of recoveries is governed by Article 22.

The beneficiaries (and their action) must remain eligible under the EU programme funding the grant for the entire duration of the action. Costs and contributions will be eligible only as long as the beneficiary and the action are eligible.

The **internal roles and responsibilities** of the beneficiaries are divided as follows:

- (a) Each beneficiary must:
 - (i) keep information stored in the Portal Participant Register up to date (see Article 19)



- (ii) inform the granting authority (and the other beneficiaries) immediately of any events or circumstances likely to affect significantly or delay the implementation of the action (see Article 19)
 - (iii) submit to the coordinator in good time:
 - the prefinancing guarantees (if required; see Article 23)
 - the financial statements and certificates on the financial statements (CFS) (if required; see Articles 21 and 24.2 and Data Sheet, Point 4.3)
 - the contribution to the deliverables and technical reports (see Article 21)
 - any other documents or information required by the granting authority under the Agreement
 - (iv) submit via the Portal data and information related to the participation of their affiliated entities.
- (b) The coordinator must:
- (i) monitor that the action is implemented properly (see Article 11)
 - (ii) act as the intermediary for all communications between the consortium and the granting authority, unless the Agreement or granting authority specifies otherwise, and in particular:
 - submit the prefinancing guarantees to the granting authority (if any)
 - request and review any documents or information required and verify their quality and completeness before passing them on to the granting authority
 - submit the deliverables and reports to the granting authority
 - inform the granting authority about the payments made to the other beneficiaries (report on the distribution of payments; if required, see Articles 22 and 32)
 - (iii) distribute the payments received from the granting authority to the other beneficiaries without unjustified delay (see Article 22).

The coordinator may not delegate or subcontract the above-mentioned tasks to any other beneficiary or third party (including affiliated entities).

However, coordinators which are public bodies may delegate the tasks set out in Point (b)(ii) last indent and (iii) above to entities with ‘authorisation to administer’ which they have created or which are controlled by or affiliated to them. In this case, the coordinator retains sole responsibility for the payments and for compliance with the obligations under the Agreement.

Moreover, coordinators which are ‘sole beneficiaries’¹³ (or similar, such as European research

¹³ For the definition, see Article 187(2) EU Financial Regulation 2018/1046: “Where several entities satisfy the criteria

infrastructure consortia (ERICs)) may delegate the tasks set out in Point (b)(i) to (iii) above to one of their members. The coordinator retains sole responsibility for compliance with the obligations under the Agreement.

The beneficiaries must have **internal arrangements** regarding their operation and co-ordination, to ensure that the action is implemented properly.

If required by the granting authority (see Data Sheet, Point 1), these arrangements must be set out in a written **consortium agreement** between the beneficiaries, covering for instance:

- the internal organisation of the consortium
- the management of access to the Portal
- different distribution keys for the payments and financial responsibilities in case of recoveries (if any)
- additional rules on rights and obligations related to background and results (see Article 16)
- settlement of internal disputes
- liability, indemnification and confidentiality arrangements between the beneficiaries.

The internal arrangements must not contain any provision contrary to this Agreement.

For **linked actions**, the beneficiaries must have **arrangements** with the participants of the other action, to ensure that both actions are implemented and coordinated properly.

If required by the granting authority (see Data Sheet, Point 1), these arrangements must be set out in a written **collaboration agreement** with the participants of the other action or, if the consortium is the same, as part of their consortium agreement, covering for instance:

- the internal organisation and decision making processes
- the areas where close collaboration/synchronisation is needed (e.g. on management of outputs, common approaches towards standardisation, links with regulatory and policy activities, common communication and dissemination activities, sharing of information, access to background and results, etc.)
- settlement of disputes
- liability, indemnification and confidentiality arrangements between the beneficiaries in both actions.

The arrangements with the participants of the other action must not contain any provision contrary to this Agreement.

ARTICLE 8 — AFFILIATED ENTITIES

for being awarded a grant and together form one entity, that entity may be treated as the **sole beneficiary**, including where it is specifically established for the purpose of implementing the action financed by the grant.”

The following entities which are linked to a beneficiary will participate in the action as ‘affiliated entities’:

- **INSTITUT DE PHYSIQUE DU GLOBE DE PARIS (IPGP)**, PIC 999597417, linked to CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS)

Affiliated entities can charge costs and contributions to the action under the same conditions as the beneficiaries and must implement the action tasks attributed to them in Annex 1 in accordance with Article 11.

Their costs and contributions will be included in Annex 2 and will be taken into account for the calculation of the grant.

The beneficiaries must ensure that all their obligations under this Agreement also apply to their affiliated entities.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the affiliated entities.

Breaches by affiliated entities will be handled in the same manner as breaches by beneficiaries. Recovery of undue amounts will be handled through the beneficiaries.

If the granting authority requires joint and several liability of affiliated entities (see Data Sheet, Point 4.4), they must sign the declaration set out in Annex 3a and may be held liable in case of enforced recoveries against their beneficiaries (see Article 22.2 and 22.4).

ARTICLE 9 — OTHER PARTICIPANTS INVOLVED IN THE ACTION

9.1 Associated partners

Not applicable

9.2 Third parties giving in-kind contributions to the action

Other third parties may give in-kind contributions to the action (i.e. personnel, equipment, other goods, works and services, etc. which are free-of-charge) if necessary for the implementation.

Third parties giving in-kind contributions do not implement any action tasks. They may not charge costs or contributions to the action, but the costs for the in-kind contributions are eligible and may be charged by the beneficiaries which use them, under the conditions set out in Article 6. The costs will be included in Annex 2 as part of the beneficiaries’ costs.

The third parties and their in-kind contributions should be set out in Annex 1.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the third parties giving in-kind contributions.

9.3 Subcontractors

Subcontractors may participate in the action, if necessary for the implementation.

Subcontractors must implement their action tasks in accordance with Article 11. The costs for the subcontracted tasks (invoiced price from the subcontractor) are eligible and may be charged by the beneficiaries, under the conditions set out in Article 6. The costs will be included in Annex 2 as part of the beneficiaries' costs.

The beneficiaries must ensure that their contractual obligations under Articles 11 (proper implementation), 12 (conflict of interest), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping) also apply to the subcontractors.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the subcontractors.

9.4 Recipients of financial support to third parties

If the action includes providing financial support to third parties (e.g. grants, prizes or similar forms of support), the beneficiaries must ensure that their contractual obligations under Articles 12 (conflict of interest), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping) also apply to the third parties receiving the support (recipients).

The beneficiaries must also ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the recipients.

ARTICLE 10 — PARTICIPANTS WITH SPECIAL STATUS

10.1 Non-EU participants

Participants which are established in a non-EU country (if any) undertake to comply with their obligations under the Agreement and:

- to respect general principles (including fundamental rights, values and ethical principles, environmental and labour standards, rules on classified information, intellectual property rights, visibility of funding and protection of personal data)
- for the submission of certificates under Article 24: to use qualified external auditors which are independent and comply with comparable standards as those set out in EU Directive 2006/43/EC¹⁴
- for the controls under Article 25: to allow for checks, reviews, audits and investigations (including on-the-spot checks, visits and inspections) by the bodies mentioned in that Article (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.).

Special rules on dispute settlement apply (see Data Sheet, Point 5).

10.2 Participants which are international organisations

¹⁴ Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts or similar national regulations (OJ L 157, 9.6.2006, p. 87).

Participants which are international organisations (IOs; if any) undertake to comply with their obligations under the Agreement and:

- to respect general principles (including fundamental rights, values and ethical principles, environmental and labour standards, rules on classified information, intellectual property rights, visibility of funding and protection of personal data)
- for the submission of certificates under Article 24: to use either independent public officers or external auditors which comply with comparable standards as those set out in EU Directive 2006/43/EC
- for the controls under Article 25: to allow for the checks, reviews, audits and investigations by the bodies mentioned in that Article, taking into account the specific agreements concluded by them and the EU (if any).

For such participants, nothing in the Agreement will be interpreted as a waiver of their privileges or immunities, as accorded by their constituent documents or international law.

Special rules on applicable law and dispute settlement apply (see Article 43 and Data Sheet, Point 5).

10.3 Pillar-assessed participants

Pillar-assessed participants (if any) may rely on their own systems, rules and procedures, in so far as they have been positively assessed and do not call into question the decision awarding the grant or breach the principle of equal treatment of applicants or beneficiaries.

‘Pillar-assessment’ means a review by the European Commission on the systems, rules and procedures which participants use for managing EU grants (in particular internal control system, accounting system, external audits, financing of third parties, rules on recovery and exclusion, information on recipients and protection of personal data; see Article 154 EU Financial Regulation 2018/1046).

Participants with a positive pillar assessment may rely on their own systems, rules and procedures, in particular for:

- record-keeping (Article 20): may be done in accordance with internal standards, rules and procedures
- currency conversion for financial statements (Article 21): may be done in accordance with usual accounting practices
- guarantees (Article 23): for public law bodies, prefinancing guarantees are not needed
- certificates (Article 24):
 - certificates on the financial statements (CFS): may be provided by their regular internal or external auditors and in accordance with their internal financial regulations and procedures
 - certificates on usual accounting practices (CoMUC): are not needed if those practices are covered by an ex-ante assessment

and use the following specific rules, for:



- recoveries (Article 22): in case of financial support to third parties, there will be no recovery if the participant has done everything possible to retrieve the undue amounts from the third party receiving the support (including legal proceedings) and non-recovery is not due to an error or negligence on its part
- checks, reviews, audits and investigations by the EU (Article 25): will be conducted taking into account the rules and procedures specifically agreed between them and the framework agreement (if any)
- impact evaluation (Article 26): will be conducted in accordance with the participant's internal rules and procedures and the framework agreement (if any)
- grant agreement suspension (Article 31): certain costs incurred during grant suspension are eligible (notably, minimum costs necessary for a possible resumption of the action and costs relating to contracts which were entered into before the pre-information letter was received and which could not reasonably be suspended, reallocated or terminated on legal grounds)
- grant agreement termination (Article 32): the final grant amount and final payment will be calculated taking into account also costs relating to contracts due for execution only after termination takes effect, if the contract was entered into before the pre-information letter was received and could not reasonably be terminated on legal grounds
- liability for damages (Article 33.2): the granting authority must be compensated for damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement only if the damage is due to an infringement of the participant's internal rules and procedures or due to a violation of third parties' rights by the participant or one of its employees or individual for whom the employees are responsible.

Participants whose pillar assessment covers procurement and granting procedures may also do purchases, subcontracting and financial support to third parties (Article 6.2) in accordance with their internal rules and procedures for purchases, subcontracting and financial support.

Participants whose pillar assessment covers data protection rules may rely on their internal standards, rules and procedures for data protection (Article 15).

The participants may however not rely on provisions which would breach the principle of equal treatment of applicants or beneficiaries or call into question the decision awarding the grant, such as in particular:

- eligibility (Article 6)
- consortium roles and set-up (Articles 7-9)
- security and ethics (Articles 13, 14)
- IPR (including background and results, access rights and rights of use), communication, dissemination and visibility (Articles 16 and 17)
- information obligation (Article 19)
- payment, reporting and amendments (Articles 21, 22 and 39)

- rejections, reductions, suspensions and terminations (Articles 27, 28, 29-32)

If the pillar assessment was subject to remedial measures, reliance on the internal systems, rules and procedures is subject to compliance with those remedial measures.

Participants whose assessment has not yet been updated to cover (the new rules on) data protection may rely on their internal systems, rules and procedures, provided that they ensure that personal data is:

- processed lawfully, fairly and in a transparent manner in relation to the data subject
- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes
- adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed
- accurate and, where necessary, kept up to date
- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the data is processed and
- processed in a manner that ensures appropriate security of the personal data.

Participants must inform the coordinator without delay of any changes to the systems, rules and procedures that were part of the pillar assessment. The coordinator must immediately inform the granting authority.

Pillar-assessed participants that have also concluded a framework agreement with the EU, may moreover — under the same conditions as those above (i.e. not call into question the decision awarding the grant or breach the principle of equal treatment of applicants or beneficiaries) — rely on the provisions set out in that framework agreement.

SECTION 2 RULES FOR CARRYING OUT THE ACTION

ARTICLE 11 — PROPER IMPLEMENTATION OF THE ACTION

11.1 Obligation to properly implement the action

The beneficiaries must implement the action as described in Annex 1 and in compliance with the provisions of the Agreement, the call conditions and all legal obligations under applicable EU, international and national law.

11.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 12 — CONFLICT OF INTERESTS

12.1 Conflict of interests

The beneficiaries must take all measures to prevent any situation where the impartial and objective implementation of the Agreement could be compromised for reasons involving family, emotional life, political or national affinity, economic interest or any other direct or indirect interest ('conflict of interests').

They must formally notify the granting authority without delay of any situation constituting or likely to lead to a conflict of interests and immediately take all the necessary steps to rectify this situation.

The granting authority may verify that the measures taken are appropriate and may require additional measures to be taken by a specified deadline.

12.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28) and the grant or the beneficiary may be terminated (see Article 32).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 13 — CONFIDENTIALITY AND SECURITY

13.1 Sensitive information

The parties must keep confidential any data, documents or other material (in any form) that is identified as sensitive in writing ('sensitive information') — during the implementation of the action and for at least until the time-limit set out in the Data Sheet (see Point 6).

If a beneficiary requests, the granting authority may agree to keep such information confidential for a longer period.

Unless otherwise agreed between the parties, they may use sensitive information only to implement the Agreement.

The beneficiaries may disclose sensitive information to their personnel or other participants involved in the action only if they:

- (a) need to know it in order to implement the Agreement and
- (b) are bound by an obligation of confidentiality.

The granting authority may disclose sensitive information to its staff and to other EU institutions and bodies.

It may moreover disclose sensitive information to third parties, if:

- (a) this is necessary to implement the Agreement or safeguard the EU financial interests and
- (b) the recipients of the information are bound by an obligation of confidentiality.

The confidentiality obligations no longer apply if:

- (a) the disclosing party agrees to release the other party

- (b) the information becomes publicly available, without breaching any confidentiality obligation
- (c) the disclosure of the sensitive information is required by EU, international or national law.

Specific confidentiality rules (if any) are set out in Annex 5.

13.2 Classified information

The parties must handle classified information in accordance with the applicable EU, international or national law on classified information (in particular, Decision 2015/444¹⁵ and its implementing rules).

Deliverables which contain classified information must be submitted according to special procedures agreed with the granting authority.

Action tasks involving classified information may be subcontracted only after explicit approval (in writing) from the granting authority.

Classified information may not be disclosed to any third party (including participants involved in the action implementation) without prior explicit written approval from the granting authority.

Specific security rules (if any) are set out in Annex 5.

13.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 14 — ETHICS AND VALUES

14.1 Ethics

The action must be carried out in line with the highest ethical standards and the applicable EU, international and national law on ethical principles.

Specific ethics rules (if any) are set out in Annex 5.

14.2 Values

The beneficiaries must commit to and ensure the respect of basic EU values (such as respect for human dignity, freedom, democracy, equality, the rule of law and human rights, including the rights of minorities).

Specific rules on values (if any) are set out in Annex 5.

14.3 Consequences of non-compliance

¹⁵ Commission Decision 2015/444/EC, Euratom of 13 March 2015 on the security rules for protecting EU classified information (OJ L 72, 17.3.2015, p. 53).

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 15 — DATA PROTECTION

15.1 Data processing by the granting authority

Any personal data under the Agreement will be processed under the responsibility of the data controller of the granting authority in accordance with and for the purposes set out in the Portal Privacy Statement.

For grants where the granting authority is the European Commission, an EU regulatory or executive agency, joint undertaking or other EU body, the processing will be subject to Regulation 2018/1725¹⁶.

15.2 Data processing by the beneficiaries

The beneficiaries must process personal data under the Agreement in compliance with the applicable EU, international and national law on data protection (in particular, Regulation 2016/679¹⁷).

They must ensure that personal data is:

- processed lawfully, fairly and in a transparent manner in relation to the data subjects
- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes
- adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed
- accurate and, where necessary, kept up to date
- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the data is processed and
- processed in a manner that ensures appropriate security of the data.

The beneficiaries may grant their personnel access to personal data only if it is strictly necessary for implementing, managing and monitoring the Agreement. The beneficiaries must ensure that the personnel is under a confidentiality obligation.

The beneficiaries must inform the persons whose data are transferred to the granting authority and provide them with the Portal Privacy Statement.

¹⁶ Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC (OJ L 295, 21.11.2018, p. 39).

¹⁷ Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC ('GDPR') (OJ L 119, 4.5.2016, p. 1).

15.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 16 — INTELLECTUAL PROPERTY RIGHTS (IPR) — BACKGROUND AND RESULTS — ACCESS RIGHTS AND RIGHTS OF USE

16.1 Background and access rights to background

The beneficiaries must give each other and the other participants access to the background identified as needed for implementing the action, subject to any specific rules in Annex 5.

‘Background’ means any data, know-how or information — whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights — that is:

- (a) held by the beneficiaries before they acceded to the Agreement and
- (b) needed to implement the action or exploit the results.

If background is subject to rights of a third party, the beneficiary concerned must ensure that it is able to comply with its obligations under the Agreement.

16.2 Ownership of results

The granting authority does not obtain ownership of the results produced under the action.

‘Results’ means any tangible or intangible effect of the action, such as data, know-how or information, whatever its form or nature, whether or not it can be protected, as well as any rights attached to it, including intellectual property rights.

16.3 Rights of use of the granting authority on materials, documents and information received for policy, information, communication, dissemination and publicity purposes

The granting authority has the right to use non-sensitive information relating to the action and materials and documents received from the beneficiaries (notably summaries for publication, deliverables, as well as any other material, such as pictures or audio-visual material, in paper or electronic form) for policy, information, communication, dissemination and publicity purposes — during the action or afterwards.

The right to use the beneficiaries’ materials, documents and information is granted in the form of a royalty-free, non-exclusive and irrevocable licence, which includes the following rights:

- (a) **use for its own purposes** (in particular, making them available to persons working for the granting authority or any other EU service (including institutions, bodies, offices, agencies, etc.) or EU Member State institution or body; copying or reproducing them in whole or in part, in unlimited numbers; and communication through press information services)
- (b) **distribution to the public** (in particular, publication as hard copies and in electronic or digital format, publication on the internet, as a downloadable or non-downloadable file, broadcasting



by any channel, public display or presentation, communicating through press information services, or inclusion in widely accessible databases or indexes)

- (c) **editing or redrafting** (including shortening, summarising, inserting other elements (e.g. meta-data, legends, other graphic, visual, audio or text elements), extracting parts (e.g. audio or video files), dividing into parts, use in a compilation)
- (d) **translation**
- (e) **storage** in paper, electronic or other form
- (f) **archiving**, in line with applicable document-management rules
- (g) the right to authorise **third parties** to act on its behalf or sub-license to third parties the modes of use set out in Points (b), (c), (d) and (f), if needed for the information, communication and publicity activity of the granting authority
- (h) **processing**, analysing, aggregating the materials, documents and information received and **producing derivative works**.

The rights of use are granted for the whole duration of the industrial or intellectual property rights concerned.

If materials or documents are subject to moral rights or third party rights (including intellectual property rights or rights of natural persons on their image and voice), the beneficiaries must ensure that they comply with their obligations under this Agreement (in particular, by obtaining the necessary licences and authorisations from the rights holders concerned).

Where applicable, the granting authority will insert the following information:

“© – [year] – [name of the copyright owner]. All rights reserved. Licensed to the [name of granting authority] under conditions.”

16.4 Specific rules on IPR, results and background

Specific rules regarding intellectual property rights, results and background (if any) are set out in Annex 5.

16.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such a breach may also lead to other measures described in Chapter 5.

ARTICLE 17 — COMMUNICATION, DISSEMINATION AND VISIBILITY

17.1 Communication — Dissemination — Promoting the action

Unless otherwise agreed with the granting authority, the beneficiaries must promote the action and its results by providing targeted information to multiple audiences (including the media and the public), in accordance with Annex 1 and in a strategic, coherent and effective manner.

Before engaging in a communication or dissemination activity expected to have a major media impact, the beneficiaries must inform the granting authority.

17.2 Visibility — European flag and funding statement

Unless otherwise agreed with the granting authority, communication activities of the beneficiaries related to the action (including media relations, conferences, seminars, information material, such as brochures, leaflets, posters, presentations, etc., in electronic form, via traditional or social media, etc.), dissemination activities and any infrastructure, equipment, vehicles, supplies or major result funded by the grant must acknowledge EU support and display the European flag (emblem) and funding statement (translated into local languages, where appropriate):



Funded by the
European Union



Co-funded by the
European Union



Funded by the
European Union



Co-funded by the
European Union

The emblem must remain distinct and separate and cannot be modified by adding other visual marks, brands or text.

Apart from the emblem, no other visual identity or logo may be used to highlight the EU support.

When displayed in association with other logos (e.g. of beneficiaries or sponsors), the emblem must be displayed at least as prominently and visibly as the other logos.

For the purposes of their obligations under this Article, the beneficiaries may use the emblem without first obtaining approval from the granting authority. This does not, however, give them the right to exclusive use. Moreover, they may not appropriate the emblem or any similar trademark or logo, either by registration or by any other means.

17.3 Quality of information — Disclaimer

Any communication or dissemination activity related to the action must use factually accurate information.

Moreover, it must indicate the following disclaimer (translated into local languages where appropriate):

“Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or [name of the granting authority]. Neither the European Union nor the granting authority can be held responsible for them.”

17.4 Specific communication, dissemination and visibility rules

Specific communication, dissemination and visibility rules (if any) are set out in Annex 5.

17.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 18 — SPECIFIC RULES FOR CARRYING OUT THE ACTION

18.1 Specific rules for carrying out the action

Specific rules for implementing the action (if any) are set out in Annex 5.

18.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such a breach may also lead to other measures described in Chapter 5.

SECTION 3 GRANT ADMINISTRATION

ARTICLE 19 — GENERAL INFORMATION OBLIGATIONS

19.1 Information requests

The beneficiaries must provide — during the action or afterwards and in accordance with Article 7 — any information requested in order to verify eligibility of the costs or contributions declared, proper implementation of the action and compliance with the other obligations under the Agreement.

The information provided must be accurate, precise and complete and in the format requested, including electronic format.

19.2 Participant Register data updates

The beneficiaries must keep — at all times, during the action or afterwards — their information stored in the Portal Participant Register up to date, in particular, their name, address, legal representatives, legal form and organisation type.

19.3 Information about events and circumstances which impact the action

The beneficiaries must immediately inform the granting authority (and the other beneficiaries) of any of the following:

- (a) **events** which are likely to affect or delay the implementation of the action or affect the EU's financial interests, in particular:
 - (i) changes in their legal, financial, technical, organisational or ownership situation (including changes linked to one of the exclusion grounds listed in the declaration of honour signed before grant signature)
 - (ii) changes regarding the linked action (see Article 3)
- (b) **circumstances** affecting:
 - (i) the decision to award the grant or
 - (ii) compliance with requirements under the Agreement.

19.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 20 — RECORD-KEEPING

20.1 Keeping records and supporting documents

The beneficiaries must — at least until the time-limit set out in the Data Sheet (see Point 6) — keep records and other supporting documents to prove the proper implementation of the action in line with the accepted standards in the respective field (if any).

In addition, the beneficiaries must — for the same period — keep the following to justify the amounts declared:

- (a) for actual costs: adequate records and supporting documents to prove the costs declared (such as contracts, subcontracts, invoices and accounting records); in addition, the beneficiaries' usual accounting and internal control procedures must enable direct reconciliation between the amounts declared, the amounts recorded in their accounts and the amounts stated in the supporting documents
- (b) for flat-rate costs and contributions (if any): adequate records and supporting documents to prove the eligibility of the costs or contributions to which the flat-rate is applied
- (c) for the following simplified costs and contributions: the beneficiaries do not need to keep specific records on the actual costs incurred, but must keep:
 - (i) for unit costs and contributions (if any): adequate records and supporting documents to prove the number of units declared

- (ii) for lump sum costs and contributions (if any): adequate records and supporting documents to prove proper implementation of the work as described in Annex 1
- (iii) for financing not linked to costs (if any): adequate records and supporting documents to prove the achievement of the results or the fulfilment of the conditions as described in Annex 1
- (d) for unit, flat-rate and lump sum costs and contributions according to usual cost accounting practices (if any): the beneficiaries must keep any adequate records and supporting documents to prove that their cost accounting practices have been applied in a consistent manner, based on objective criteria, regardless of the source of funding, and that they comply with the eligibility conditions set out in Articles 6.1 and 6.2.

Moreover, the following is needed for specific budget categories:

- (e) for personnel costs: time worked for the beneficiary under the action must be supported by declarations signed monthly by the person and their supervisor, unless another reliable time-record system is in place; the granting authority may accept alternative evidence supporting the time worked for the action declared, if it considers that it offers an adequate level of assurance
- (f) additional record-keeping rules: not applicable

The records and supporting documents must be made available upon request (see Article 19) or in the context of checks, reviews, audits or investigations (see Article 25).

If there are on-going checks, reviews, audits, investigations, litigation or other pursuits of claims under the Agreement (including the extension of findings; see Article 25), the beneficiaries must keep these records and other supporting documentation until the end of these procedures.

The beneficiaries must keep the original documents. Digital and digitalised documents are considered originals if they are authorised by the applicable national law. The granting authority may accept non-original documents if they offer a comparable level of assurance.

20.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs or contributions insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 27), and the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 21 — REPORTING

21.1 Continuous reporting

The beneficiaries must continuously report on the progress of the action (e.g. **deliverables, milestones, outputs/outcomes, critical risks, indicators**, etc; if any), in the Portal Continuous Reporting tool and in accordance with the timing and conditions it sets out (as agreed with the granting authority).

Standardised deliverables (e.g. progress reports not linked to payments, reports on cumulative expenditure, special reports, etc; if any) must be submitted using the templates published on the Portal.

21.2 Periodic reporting: Technical reports and financial statements

In addition, the beneficiaries must provide reports to request payments, in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2):

- for additional prefinancings (if any): an **additional prefinancing report**
- for interim payments (if any) and the final payment: a **periodic report**.

The prefinancing and periodic reports include a technical and financial part.

The technical part includes an overview of the action implementation. It must be prepared using the template available in the Portal Periodic Reporting tool.

The financial part of the additional prefinancing report includes a statement on the use of the previous prefinancing payment.

The financial part of the periodic report includes:

- the financial statements (individual and consolidated; for all beneficiaries/affiliated entities)
- the explanation on the use of resources (or detailed cost reporting table, if required)
- the certificates on the financial statements (CFS) (if required; see Article 24.2 and Data Sheet, Point 4.3).

The **financial statements** must detail the eligible costs and contributions for each budget category and, for the final payment, also the revenues for the action (see Articles 6 and 22).

All eligible costs and contributions incurred should be declared, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Amounts that are not declared in the individual financial statements will not be taken into account by the granting authority.

By signing the financial statements (directly in the Portal Periodic Reporting tool), the beneficiaries confirm that:

- the information provided is complete, reliable and true
- the costs and contributions declared are eligible (see Article 6)
- the costs and contributions can be substantiated by adequate records and supporting documents (see Article 20) that will be produced upon request (see Article 19) or in the context of checks, reviews, audits and investigations (see Article 25)
- for the final periodic report: all the revenues have been declared (if required; see Article 22).

Beneficiaries will have to submit also the financial statements of their affiliated entities (if any). In case of recoveries (see Article 22), beneficiaries will be held responsible also for the financial statements of their affiliated entities.

21.3 Currency for financial statements and conversion into euros

The financial statements must be drafted in euro.

Beneficiaries with general accounts established in a currency other than the euro must convert the costs recorded in their accounts into euro, at the average of the daily exchange rates published in the C series of the *Official Journal of the European Union* (ECB website), calculated over the corresponding reporting period.

If no daily euro exchange rate is published in the *Official Journal* for the currency in question, they must be converted at the average of the monthly accounting exchange rates published on the European Commission website (InforEuro), calculated over the corresponding reporting period.

Beneficiaries with general accounts in euro must convert costs incurred in another currency into euro according to their usual accounting practices.

21.4 Reporting language

The reporting must be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

21.5 Consequences of non-compliance

If a report submitted does not comply with this Article, the granting authority may suspend the payment deadline (see Article 29) and apply other measures described in Chapter 5.

If the coordinator breaches its reporting obligations, the granting authority may terminate the grant or the coordinator's participation (see Article 32) or apply other measures described in Chapter 5.

ARTICLE 22 — PAYMENTS AND RECOVERIES — CALCULATION OF AMOUNTS DUE

22.1 Payments and payment arrangements

Payments will be made in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2).

They will be made in euro to the bank account indicated by the coordinator (see Data Sheet, Point 4.2) and must be distributed without unjustified delay (restrictions may apply to distribution of the initial prefinancing payment; see Data Sheet, Point 4.2).

Payments to this bank account will discharge the granting authority from its payment obligation.

The cost of payment transfers will be borne as follows:

- the granting authority bears the cost of transfers charged by its bank
- the beneficiary bears the cost of transfers charged by its bank
- the party causing a repetition of a transfer bears all costs of the repeated transfer.

Payments by the granting authority will be considered to have been carried out on the date when they are debited to its account.

22.2 Recoveries

Recoveries will be made, if — at beneficiary termination, final payment or afterwards — it turns out that the granting authority has paid too much and needs to recover the amounts undue.

Each beneficiary's financial responsibility in case of recovery is in principle limited to their own debt and undue amounts of their affiliated entities.

In case of enforced recoveries (see Article 22.4), affiliated entities will be held liable for repaying debts of their beneficiaries, if required by the granting authority (see Data Sheet, Point 4.4).

22.3 Amounts due

22.3.1 Prefinancing payments

The aim of the prefinancing is to provide the beneficiaries with a float.

It remains the property of the EU until the final payment.

For **initial prefinancings** (if any), the amount due, schedule and modalities are set out in the Data Sheet (see Point 4.2).

For **additional prefinancings** (if any), the amount due, schedule and modalities are also set out in the Data Sheet (see Point 4.2). However, if the statement on the use of the previous prefinancing payment shows that less than 70% was used, the amount set out in the Data Sheet will be reduced by the difference between the 70% threshold and the amount used.

The contribution to the Mutual Insurance Mechanism will be retained from the prefinancing payments (at the rate and in accordance with the modalities set out in the Data Sheet, see Point 4.2) and transferred to the Mechanism.

Prefinancing payments (or parts of them) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

22.3.2 Amount due at beneficiary termination — Recovery

In case of beneficiary termination, the granting authority will determine the provisional amount due for the beneficiary concerned. Payments (if any) will be made with the next interim or final payment.

The **amount due** will be calculated in the following step:

Step 1 — Calculation of the total accepted EU contribution

Step 1 — Calculation of the total accepted EU contribution

The granting authority will first calculate the ‘accepted EU contribution’ for the beneficiary for all reporting periods, by calculating the ‘maximum EU contribution to costs’ (applying the funding rate to the accepted costs of the beneficiary), taking into account requests for a lower contribution to costs and CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions (if any). The resulting amount is the ‘total accepted EU contribution’ for the beneficiary.

The **balance** is then calculated by deducting the payments received (if any; see report on the distribution of payments in Article 32), from the total accepted EU contribution:

$$\begin{aligned} & \{\text{total accepted EU contribution for the beneficiary} \\ & \text{minus} \\ & \{\text{prefinancing and interim payments received (if any)}\} \}. \end{aligned}$$

If the balance is **positive**, the amount will be included in the next interim or final payment to the consortium.

If the balance is **negative**, it will be **recovered** in accordance with the following procedure:

The granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to recover, the amount due, the amount to be recovered and the reasons why and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received), it will confirm the amount to be recovered and ask this amount to be paid to the coordinator (**confirmation letter**).

If payment is not made to the coordinator by the date specified in the confirmation letter, the granting authority may call on the Mutual Insurance Mechanism to intervene, if continuation of the action is guaranteed and the conditions set out in the rules governing the Mechanism are met.

In this case, it will send a **beneficiary recovery letter**, together with a **debit note** with the terms and date for payment.

The debit note for the beneficiary will include the amount calculated for the affiliated entities which also had to end their participation (if any).

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

The amounts will later on also be taken into account for the next interim or final payment.

22.3.3 Interim payments

Interim payments reimburse the eligible costs and contributions claimed for the implementation of the action during the reporting periods (if any).

Interim payments (if any) will be made in accordance with the schedule and modalities set out the Data Sheet (see Point 4.2).

Payment is subject to the approval of the periodic report. Its approval does not imply recognition of compliance, authenticity, completeness or correctness of its content.

The **interim payment** will be calculated by the granting authority in the following steps:

Step 1 — Calculation of the total accepted EU contribution

Step 2 — Limit to the interim payment ceiling

Step 1 — Calculation of the total accepted EU contribution

The granting authority will calculate the ‘accepted EU contribution’ for the action for the reporting period, by first calculating the ‘maximum EU contribution to costs’ (applying the funding rate to the accepted costs of each beneficiary), taking into account requests for a lower contribution to costs, and CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions from beneficiary termination (if any). The resulting amount is the ‘total accepted EU contribution’.

Step 2 — Limit to the interim payment ceiling

The resulting amount is then capped to ensure that the total amount of prefinancing and interim payments (if any) does not exceed the interim payment ceiling set out in the Data Sheet (see Point 4.2).

Interim payments (or parts of them) may be offset (without the beneficiaries’ consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

22.3.4 Final payment — Final grant amount — Revenues and Profit — Recovery

The final payment (payment of the balance) reimburses the remaining part of the eligible costs and contributions claimed for the implementation of the action (if any).

The final payment will be made in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2).

Payment is subject to the approval of the final periodic report. Its approval does not imply recognition of compliance, authenticity, completeness or correctness of its content.

The **final grant amount for the action** will be calculated in the following steps:

Step 1 — Calculation of the total accepted EU contribution

Step 2 — Limit to the maximum grant amount

Step 3 — Reduction due to the no-profit rule

Step 1 — Calculation of the total accepted EU contribution

The granting authority will first calculate the ‘accepted EU contribution’ for the action for all reporting periods, by calculating the ‘maximum EU contribution to costs’ (applying the funding rate to the total accepted costs of each beneficiary), taking into account requests for a lower contribution to costs, CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions (if any). The resulting amount is the ‘total accepted EU contribution’.

Step 2 — Limit to the maximum grant amount

If the resulting amount is higher than the maximum grant amount set out in Article 5.2, it will be limited to the latter.

Step 3 — Reduction due to the no-profit rule

If the no-profit rule is provided for in the Data Sheet (see Point 4.2), the grant must not produce a profit (i.e. surplus of the amount obtained following Step 2 plus the action’s revenues, over the eligible costs and contributions approved by the granting authority).

‘Revenue’ is all income generated by the action, during its duration (see Article 4), for beneficiaries that are profit legal entities (— with the exception of income generated by the exploitation of results, which are not considered as revenues).

If there is a profit, it will be deducted in proportion to the final rate of reimbursement of the eligible costs approved by the granting authority (as compared to the amount calculated following Steps 1 and 2 minus the contributions).

The **balance** (final payment) is then calculated by deducting the total amount of prefinancing and interim payments already made (if any), from the final grant amount:

$$\begin{aligned} &\{\text{final grant amount} \\ &\text{minus} \\ &\{\text{prefinancing and interim payments made (if any)}\} \}. \end{aligned}$$

If the balance is **positive**, it will be **paid** to the coordinator.

The amount retained for the Mutual Insurance Mechanism (see above) will be released and **paid** to the coordinator (in accordance with the rules governing the Mechanism).

The final payment (or part of it) may be offset (without the beneficiaries’ consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency,

offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

If — despite the release of the Mutual Insurance Mechanism contribution — the balance is **negative**, it will be **recovered** in accordance with the following procedure:

The granting authority will send a **pre-information letter** to the coordinator:

- formally notifying the intention to recover, the final grant amount, the amount to be recovered and the reasons why
- requesting a report on the distribution of payments to the beneficiaries within 30 days of receiving notification and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received) and the coordinator has submitted the report on the distribution of payments, it will calculate the **share of the debt per beneficiary**, by:

(a) identifying the beneficiaries for which the amount calculated as follows is negative:

$$\left\{ \left\{ \begin{array}{l} \text{total accepted EU contribution for the beneficiary} \\ \text{divided by} \\ \text{total accepted EU contribution for the action} \end{array} \right\} \right.$$

$$\left. \begin{array}{l} \text{multiplied by} \\ \text{final grant amount for the action} \end{array} \right\},$$

$$\text{minus}$$

$$\left\{ \text{prefinancing and interim payments received by the beneficiary (if any)} \right\}$$

and

(b) dividing the debt:

$$\left\{ \begin{array}{l} \text{amount calculated according to point (a) for the beneficiary concerned} \\ \text{divided by} \\ \text{the sum of the amounts calculated according to point (a) for all the beneficiaries identified according to} \\ \text{point (a)} \end{array} \right.$$

$$\left. \begin{array}{l} \text{multiplied by} \\ \text{the amount to be recovered} \end{array} \right\}.$$

and confirm the amount to be recovered from each beneficiary concerned (**confirmation letter**), together with **debit notes** with the terms and date for payment.

The debit notes for beneficiaries will include the amounts calculated for their affiliated entities (if any).

If the coordinator has not submitted the report on the distribution of payments, the granting authority will **recover** the full amount from the coordinator (**confirmation letter** and **debit note** with the terms and date for payment).

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

22.3.5 Audit implementation after final payment — Revised final grant amount — Recovery

If — after the final payment (in particular, after checks, reviews, audits or investigations; see Article 25) — the granting authority rejects costs or contributions (see Article 27) or reduces the grant (see Article 28), it will calculate the **revised final grant amount** for the beneficiary concerned.

The **beneficiary revised final grant amount** will be calculated in the following step:

Step 1 — Calculation of the revised total accepted EU contribution

Step 1 — Calculation of the revised total accepted EU contribution

The granting authority will first calculate the ‘revised accepted EU contribution’ for the beneficiary, by calculating the ‘revised accepted costs’ and ‘revised accepted contributions’.

After that, it will take into account grant reductions (if any). The resulting ‘revised total accepted EU contribution’ is the beneficiary revised final grant amount.

If the revised final grant amount is lower than the beneficiary’s final grant amount (i.e. its share in the final grant amount for the action), it will be **recovered** in accordance with the following procedure:

The **beneficiary final grant amount** (i.e. share in the final grant amount for the action) is calculated as follows:

$$\left\{ \begin{array}{l} \text{total accepted EU contribution for the beneficiary} \\ \text{divided by} \\ \text{total accepted EU contribution for the action} \end{array} \right\} \times \left\{ \begin{array}{l} \text{final grant amount for the action} \end{array} \right\}.$$

The granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to recover, the amount to be recovered and the reasons why and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received), it will confirm the amount to be recovered (**confirmation letter**), together with a **debit note** with the terms and the date for payment.

Recoveries against affiliated entities (if any) will be handled through their beneficiaries.

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

22.4 Enforced recovery

If payment is not made by the date specified in the debit note, the amount due will be recovered:

- (a) by offsetting the amount — without the coordinator or beneficiary's consent — against any amounts owed to the coordinator or beneficiary by the granting authority.

In exceptional circumstances, to safeguard the EU financial interests, the amount may be offset before the payment date specified in the debit note.

For grants where the granting authority is the European Commission or an EU executive agency, debts may also be offset against amounts owed by other Commission services or executive agencies.

- (b) financial guarantee(s): not applicable

- (c) joint and several liability of beneficiaries: not applicable

- (d) by holding affiliated entities jointly and severally liable (if any, see Data Sheet, Point 4.4)

- (e) by taking legal action (see Article 43) or, provided that the granting authority is the European Commission or an EU executive agency, by adopting an enforceable decision under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 100(2) of EU Financial Regulation 2018/1046.

If the Mutual Insurance Mechanism was called on by the granting authority to intervene, recovery will be continued in the name of the Mutual Insurance Mechanism. If two debit notes were sent, the second one (in the name of the Mutual Insurance Mechanism) will be considered to replace the first one (in the name of the granting authority). Where the MIM intervened, offsetting, enforceable decisions or any other of the above-mentioned forms of enforced recovery may be used mutatis mutandis.

The amount to be recovered will be increased by **late-payment interest** at the rate set out in Article 22.5, from the day following the payment date in the debit note, up to and including the date the full payment is received.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2015/2366¹⁸ applies.

For grants where the granting authority is an EU executive agency, enforced recovery by offsetting or enforceable decision will be done by the services of the European Commission (see also Article 43).

22.5 Consequences of non-compliance

¹⁸ Directive (EU) 2015/2366 of the European Parliament and of the Council of 25 November 2015 on payment services in the internal market, amending Directives 2002/65/EC, 2009/110/EC and 2013/36/EU and Regulation (EU) No 1093/2010, and repealing Directive 2007/64/EC (OJ L 337, 23.12.2015, p. 35).

22.5.1 If the granting authority does not pay within the payment deadlines (see above), the beneficiaries are entitled to **late-payment interest** at the rate applied by the European Central Bank (ECB) for its main refinancing operations in euros ('reference rate'), plus the rate specified in the Data Sheet (Point 4.2). The reference rate is the rate in force on the first day of the month in which the payment deadline expires, as published in the C series of the *Official Journal of the European Union*.

If the late-payment interest is lower than or equal to EUR 200, it will be paid to the coordinator only on request submitted within two months of receiving the late payment.

Late-payment interest is not due if all beneficiaries are EU Member States (including regional and local government authorities or other public bodies acting on behalf of a Member State for the purpose of this Agreement).

If payments or the payment deadline are suspended (see Articles 29 and 30), payment will not be considered as late.

Late-payment interest covers the period running from the day following the due date for payment (see above), up to and including the date of payment.

Late-payment interest is not considered for the purposes of calculating the final grant amount.

22.5.2 If the coordinator breaches any of its obligations under this Article, the grant may be reduced (see Article 29) and the grant or the coordinator may be terminated (see Article 32).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 23 — GUARANTEES

Not applicable

ARTICLE 24 — CERTIFICATES

24.1 Operational verification report (OVR)

Not applicable

24.2 Certificate on the financial statements (CFS)

If required by the granting authority (see Data Sheet, Point 4.3), the beneficiaries must provide certificates on their financial statements (CFS), in accordance with the schedule, threshold and conditions set out in the Data Sheet.

The coordinator must submit them as part of the periodic report (see Article 21).

The certificates must be drawn up using the template published on the Portal, cover the costs declared on the basis of actual costs and costs according to usual cost accounting practices (if any), and fulfil the following conditions:

- (a) be provided by a qualified approved external auditor which is independent and complies with Directive 2006/43/EC¹⁹ (or for public bodies: by a competent independent public officer)
- (b) the verification must be carried out according to the highest professional standards to ensure that the financial statements comply with the provisions under the Agreement and that the costs declared are eligible.

The certificates will not affect the granting authority's right to carry out its own checks, reviews or audits, nor preclude the European Court of Auditors (ECA), the European Public Prosecutor's Office (EPPO) or the European Anti-Fraud Office (OLAF) from using their prerogatives for audits and investigations under the Agreement (see Article 25).

If the costs (or a part of them) were already audited by the granting authority, these costs do not need to be covered by the certificate and will not be counted for calculating the threshold (if any).

24.3 Certificate on the compliance of usual cost accounting practices (CoMUC)

Not applicable

24.4 Systems and process audit (SPA)

Beneficiaries which:

- use unit, flat rate or lump sum costs or contributions according to documented (i.e. formally approved and in writing) usual costs accounting practices (if any) or
- have formalised documentation on the systems and processes for calculating their costs and contributions (i.e. formally approved and in writing), have participated in at least 150 actions under Horizon 2020 or the Euratom Research and Training Programme (2014-2018 or 2019-2020) and participate in at least 3 ongoing actions under Horizon Europe or the Euratom Research and Training Programme (2021-2025 or 2026-2027)

may apply to the granting authority for a systems and process audit (SPA).

This audit will be carried out as follows:

- Step 1 – Application by the beneficiary.
- Step 2 – If the application is accepted, the granting authority will carry out the systems and process audit, complemented by an audit of transactions (on a sample of the beneficiary's Horizon Europe or the Euratom Research and Training Programme financial statements).
- Step 3 – The audit result will take the form of a risk assessment classification for the beneficiary: low, medium or high.

Low-risk beneficiaries will benefit from less (or less in-depth) ex-post audits (see Article 25) and a higher threshold for submitting certificates on the financial statements (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3).

¹⁹ Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts or similar national regulations (OJ L 157, 9.6.2006, p. 87).

24.5 Consequences of non-compliance

If a beneficiary does not submit a certificate on the financial statements (CFS) or the certificate is rejected, the accepted EU contribution to costs will be capped to reflect the CFS threshold.

If a beneficiary breaches any of its other obligations under this Article, the granting authority may apply the measures described in Chapter 5.

ARTICLE 25 — CHECKS, REVIEWS, AUDITS AND INVESTIGATIONS — EXTENSION OF FINDINGS

25.1 Granting authority checks, reviews and audits

25.1.1 Internal checks

The granting authority may — during the action or afterwards — check the proper implementation of the action and compliance with the obligations under the Agreement, including assessing costs and contributions, deliverables and reports.

25.1.2 Project reviews

The granting authority may carry out reviews on the proper implementation of the action and compliance with the obligations under the Agreement (general project reviews or specific issues reviews).

Such project reviews may be started during the implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the coordinator or beneficiary concerned and will be considered to start on the date of the notification.

If needed, the granting authority may be assisted by independent, outside experts. If it uses outside experts, the coordinator or beneficiary concerned will be informed and have the right to object on grounds of commercial confidentiality or conflict of interest.

The coordinator or beneficiary concerned must cooperate diligently and provide — within the deadline requested — any information and data in addition to deliverables and reports already submitted (including information on the use of resources). The granting authority may request beneficiaries to provide such information to it directly. Sensitive information and documents will be treated in accordance with Article 13.

The coordinator or beneficiary concerned may be requested to participate in meetings, including with the outside experts.

For **on-the-spot visits**, the beneficiary concerned must allow access to sites and premises (including to the outside experts) and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the review findings, a **project review report** will be drawn up.

The granting authority will formally notify the project review report to the coordinator or beneficiary concerned, which has 30 days from receiving notification to make observations.

Project reviews (including project review reports) will be in the language of the Agreement.

25.1.3 Audits

The granting authority may carry out audits on the proper implementation of the action and compliance with the obligations under the Agreement.

Such audits may be started during the implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the beneficiary concerned and will be considered to start on the date of the notification.

The granting authority may use its own audit service, delegate audits to a centralised service or use external audit firms. If it uses an external firm, the beneficiary concerned will be informed and have the right to object on grounds of commercial confidentiality or conflict of interest.

The beneficiary concerned must cooperate diligently and provide — within the deadline requested — any information (including complete accounts, individual salary statements or other personal data) to verify compliance with the Agreement. Sensitive information and documents will be treated in accordance with Article 13.

For **on-the-spot** visits, the beneficiary concerned must allow access to sites and premises (including for the external audit firm) and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the audit findings, a **draft audit report** will be drawn up.

The auditors will formally notify the draft audit report to the beneficiary concerned, which has 30 days from receiving notification to make observations (contradictory audit procedure).

The **final audit report** will take into account observations by the beneficiary concerned and will be formally notified to them.

Audits (including audit reports) will be in the language of the Agreement.

25.2 European Commission checks, reviews and audits in grants of other granting authorities

Where the granting authority is not the European Commission, the latter has the same rights of checks, reviews and audits as the granting authority.

25.3 Access to records for assessing simplified forms of funding

The beneficiaries must give the European Commission access to their statutory records for the periodic assessment of simplified forms of funding which are used in EU programmes.

25.4 OLAF, EPPO and ECA audits and investigations

The following bodies may also carry out checks, reviews, audits and investigations — during the action or afterwards:

- the European Anti-Fraud Office (OLAF) under Regulations No 883/2013²⁰ and No 2185/96²¹
- the European Public Prosecutor's Office (EPPO) under Regulation 2017/1939
- the European Court of Auditors (ECA) under Article 287 of the Treaty on the Functioning of the EU (TFEU) and Article 257 of EU Financial Regulation 2018/1046.

If requested by these bodies, the beneficiary concerned must provide full, accurate and complete information in the format requested (including complete accounts, individual salary statements or other personal data, including in electronic format) and allow access to sites and premises for on-the-spot visits or inspections — as provided for under these Regulations.

To this end, the beneficiary concerned must keep all relevant information relating to the action, at least until the time-limit set out in the Data Sheet (Point 6) and, in any case, until any ongoing checks, reviews, audits, investigations, litigation or other pursuits of claims have been concluded.

25.5 Consequences of checks, reviews, audits and investigations — Extension of results of reviews, audits or investigations

25.5.1 Consequences of checks, reviews, audits and investigations in this grant

Findings in checks, reviews, audits or investigations carried out in the context of this grant may lead to rejections (see Article 27), grant reduction (see Article 28) or other measures described in Chapter 5.

Rejections or grant reductions after the final payment will lead to a revised final grant amount (see Article 22).

Findings in checks, reviews, audits or investigations during the action implementation may lead to a request for amendment (see Article 39), to change the description of the action set out in Annex 1.

Checks, reviews, audits or investigations that find systemic or recurrent errors, irregularities, fraud or breach of obligations in any EU grant may also lead to consequences in other EU grants awarded under similar conditions ('extension to other grants').

Moreover, findings arising from an OLAF or EPPO investigation may lead to criminal prosecution under national law.

25.5.2 Extension from other grants

Results of checks, reviews, audits or investigations in other grants may be extended to this grant, if:

- (a) the beneficiary concerned is found, in other EU grants awarded under similar conditions, to have committed systemic or recurrent errors, irregularities, fraud or breach of obligations that have a material impact on this grant and

²⁰ Regulation (EU, Euratom) No 883/2013 of the European Parliament and of the Council of 11 September 2013 concerning investigations conducted by the European Anti-Fraud Office (OLAF) and repealing Regulation (EC) No 1073/1999 of the European Parliament and of the Council and Council Regulation (Euratom) No 1074/1999 (OJ L 248, 18/09/2013, p. 1).

²¹ Council Regulation (Euratom, EC) No 2185/1996 of 11 November 1996 concerning on-the-spot checks and inspections carried out by the Commission in order to protect the European Communities' financial interests against fraud and other irregularities (OJ L 292, 15/11/1996, p. 2).



- (b) those findings are formally notified to the beneficiary concerned — together with the list of grants affected by the findings — within the time-limit for audits set out in the Data Sheet (see Point 6).

The granting authority will formally notify the beneficiary concerned of the intention to extend the findings and the list of grants affected.

If the extension concerns **rejections of costs or contributions**: the notification will include:

- (a) an invitation to submit observations on the list of grants affected by the findings
- (b) the request to submit revised financial statements for all grants affected
- (c) the correction rate for extrapolation, established on the basis of the systemic or recurrent errors, to calculate the amounts to be rejected, if the beneficiary concerned:
 - (i) considers that the submission of revised financial statements is not possible or practicable or
 - (ii) does not submit revised financial statements.

If the extension concerns **grant reductions**: the notification will include:

- (a) an invitation to submit observations on the list of grants affected by the findings and
- (b) the **correction rate for extrapolation**, established on the basis of the systemic or recurrent errors and the principle of proportionality.

The beneficiary concerned has **60 days** from receiving notification to submit observations, revised financial statements or to propose a duly substantiated **alternative correction method/rate**.

On the basis of this, the granting authority will analyse the impact and decide on the implementation (i.e. start rejection or grant reduction procedures, either on the basis of the revised financial statements or the announced/alternative method/rate or a mix of those; see Articles 27 and 28).

25.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs or contributions insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 27), and the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 26 — IMPACT EVALUATIONS

26.1 Impact evaluation

The granting authority may carry out impact evaluations of the action, measured against the objectives and indicators of the EU programme funding the grant.

Such evaluations may be started during implementation of the action and until the time-limit set out



in the Data Sheet (see Point 6). They will be formally notified to the coordinator or beneficiaries and will be considered to start on the date of the notification.

If needed, the granting authority may be assisted by independent outside experts.

The coordinator or beneficiaries must provide any information relevant to evaluate the impact of the action, including information in electronic format.

26.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the granting authority may apply the measures described in Chapter 5.

CHAPTER 5 CONSEQUENCES OF NON-COMPLIANCE

SECTION 1 REJECTIONS AND GRANT REDUCTION

ARTICLE 27 — REJECTION OF COSTS AND CONTRIBUTIONS

27.1 Conditions

The granting authority will — at beneficiary termination, interim payment, final payment or afterwards — reject any costs or contributions which are ineligible (see Article 6), in particular following checks, reviews, audits or investigations (see Article 25).

The rejection may also be based on the extension of findings from other grants to this grant (see Article 25).

Ineligible costs or contributions will be rejected.

27.2 Procedure

If the rejection does not lead to a recovery, the granting authority will formally notify the coordinator or beneficiary concerned of the rejection, the amounts and the reasons why. The coordinator or beneficiary concerned may — within 30 days of receiving notification — submit observations if it disagrees with the rejection (payment review procedure).

If the rejection leads to a recovery, the granting authority will follow the contradictory procedure with pre-information letter set out in Article 22.

27.3 Effects

If the granting authority rejects costs or contributions, it will deduct them from the costs or contributions declared and then calculate the amount due (and, if needed, make a recovery; see Article 22).

ARTICLE 28 — GRANT REDUCTION

28.1 Conditions

The granting authority may — at beneficiary termination, final payment or afterwards — reduce the grant for a beneficiary, if:

- (a) the beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed:
 - (i) substantial errors, irregularities or fraud or
 - (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or
- (b) the beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (see Article 25).

The amount of the reduction will be calculated for each beneficiary concerned and proportionate to the seriousness and the duration of the errors, irregularities or fraud or breach of obligations, by applying an individual reduction rate to their accepted EU contribution.

28.2 Procedure

If the grant reduction does not lead to a recovery, the granting authority will formally notify the coordinator or beneficiary concerned of the reduction, the amount to be reduced and the reasons why. The coordinator or beneficiary concerned may — within 30 days of receiving notification — submit observations if it disagrees with the reduction (payment review procedure).

If the grant reduction leads to a recovery, the granting authority will follow the contradictory procedure with pre-information letter set out in Article 22.

28.3 Effects

If the granting authority reduces the grant, it will deduct the reduction and then calculate the amount due (and, if needed, make a recovery; see Article 22).

SECTION 2 SUSPENSION AND TERMINATION

ARTICLE 29 — PAYMENT DEADLINE SUSPENSION

29.1 Conditions

The granting authority may — at any moment — suspend the payment deadline if a payment cannot be processed because:

- (a) the required report (see Article 21) has not been submitted or is not complete or additional information is needed
- (b) there are doubts about the amount to be paid (e.g. ongoing audit extension procedure, queries

about eligibility, need for a grant reduction, etc.) and additional checks, reviews, audits or investigations are necessary, or

(c) there are other issues affecting the EU financial interests.

29.2 Procedure

The granting authority will formally notify the coordinator of the suspension and the reasons why.

The suspension will **take effect** the day the notification is sent.

If the conditions for suspending the payment deadline are no longer met, the suspension will be **lifted** — and the remaining time to pay (see Data Sheet, Point 4.2) will resume.

If the suspension exceeds two months, the coordinator may request the granting authority to confirm if the suspension will continue.

If the payment deadline has been suspended due to the non-compliance of the report and the revised report is not submitted (or was submitted but is also rejected), the granting authority may also terminate the grant or the participation of the coordinator (see Article 32).

ARTICLE 30 — PAYMENT SUSPENSION

30.1 Conditions

The granting authority may — at any moment — suspend payments, in whole or in part for one or more beneficiaries, if:

- (a) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed or is suspected of having committed:
 - (i) substantial errors, irregularities or fraud or
 - (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or
- (b) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant.

If payments are suspended for one or more beneficiaries, the granting authority will make partial payment(s) for the part(s) not suspended. If suspension concerns the final payment, the payment (or recovery) of the remaining amount after suspension is lifted will be considered to be the payment that closes the action.

30.2 Procedure

Before suspending payments, the granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to suspend payments and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the suspension (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

At the end of the suspension procedure, the granting authority will also inform the coordinator.

The suspension will **take effect** the day after the confirmation notification is sent.

If the conditions for resuming payments are met, the suspension will be **lifted**. The granting authority will formally notify the beneficiary concerned (and the coordinator) and set the suspension end date.

During the suspension, no prefinancing will be paid to the beneficiaries concerned. For interim payments, the periodic reports for all reporting periods except the last one (see Article 21) must not contain any financial statements from the beneficiary concerned (or its affiliated entities). The coordinator must include them in the next periodic report after the suspension is lifted or — if suspension is not lifted before the end of the action — in the last periodic report.

ARTICLE 31 — GRANT AGREEMENT SUSPENSION

31.1 Consortium-requested GA suspension

31.1.1 Conditions and procedure

The beneficiaries may request the suspension of the grant or any part of it, if exceptional circumstances — in particular *force majeure* (see Article 35) — make implementation impossible or excessively difficult.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the date the suspension takes effect; this date may be before the date of the submission of the amendment request and
- the expected date of resumption.

The suspension will **take effect** on the day specified in the amendment.

Once circumstances allow for implementation to resume, the coordinator must immediately request another **amendment** of the Agreement to set the suspension end date, the resumption date (one day after suspension end date), extend the duration and make other changes necessary to adapt the action to the new situation (see Article 39) — unless the grant has been terminated (see Article 32). The suspension will be **lifted** with effect from the suspension end date set out in the amendment. This date may be before the date of the submission of the amendment request.

During the suspension, no prefinancing will be paid. Costs incurred or contributions for activities implemented during grant suspension are not eligible (see Article 6.3).

31.2 EU-initiated GA suspension

31.2.1 Conditions

The granting authority may suspend the grant or any part of it, if:

- (a) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed or is suspected of having committed:
 - (i) substantial errors, irregularities or fraud or
 - (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or
- (b) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant
- (c) other:
 - (i) the linked action (see Article 3) has not started as specified in Annex 1, has been suspended or can no longer contribute, and this impacts the implementation of the action under this Agreement
 - (ii) the action has lost its scientific or technological relevance, for EIC Accelerator actions: the action has lost its economic relevance, for challenge-based EIC Pathfinder actions and Horizon Europe Missions: the action has lost its relevance as part of the Portfolio for which it has been initially selected

31.2.2 Procedure

Before suspending the grant, the granting authority will send a **pre-information letter** to the coordinator:

- formally notifying the intention to suspend the grant and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the suspension (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

The suspension will **take effect** the day after the confirmation notification is sent (or on a later date specified in the notification).

Once the conditions for resuming implementation of the action are met, the granting authority will

formally notify the coordinator a **lifting of suspension letter**, in which it will set the suspension end date and invite the coordinator to request an amendment of the Agreement to set the resumption date (one day after suspension end date), extend the duration and make other changes necessary to adapt the action to the new situation (see Article 39) — unless the grant has been terminated (see Article 32). The suspension will be **lifted** with effect from the suspension end date set out in the lifting of suspension letter. This date may be before the date on which the letter is sent.

During the suspension, no prefinancing will be paid. Costs incurred or contributions for activities implemented during suspension are not eligible (see Article 6.3).

The beneficiaries may not claim damages due to suspension by the granting authority (see Article 33).

Grant suspension does not affect the granting authority's right to terminate the grant or a beneficiary (see Article 32) or reduce the grant (see Article 28).

ARTICLE 32 — GRANT AGREEMENT OR BENEFICIARY TERMINATION

32.1 Consortium-requested GA termination

32.1.1 Conditions and procedure

The beneficiaries may request the termination of the grant.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the date the consortium ends work on the action ('end of work date') and
- the date the termination takes effect ('termination date'); this date must be after the date of the submission of the amendment request.

The termination will **take effect** on the termination date specified in the amendment.

If no reasons are given or if the granting authority considers the reasons do not justify termination, it may consider the grant terminated improperly.

32.1.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit a **periodic report** (for the open reporting period until termination).

The granting authority will calculate the final grant amount and final payment on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before the end of work date (see Article 22). Costs relating to contracts due for execution only after the end of work are not eligible.

If the granting authority does not receive the report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

Improper termination may lead to a grant reduction (see Article 28).

After termination, the beneficiaries' obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

32.2 Consortium-requested beneficiary termination

32.2.1 Conditions and procedure

The coordinator may request the termination of the participation of one or more beneficiaries, on request of the beneficiary concerned or on behalf of the other beneficiaries.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the opinion of the beneficiary concerned (or proof that this opinion has been requested in writing)
- the date the beneficiary ends work on the action ('end of work date')
- the date the termination takes effect ('termination date'); this date must be after the date of the submission of the amendment request.

If the termination concerns the coordinator and is done without its agreement, the amendment request must be submitted by another beneficiary (acting on behalf of the consortium).

The termination will **take effect** on the termination date specified in the amendment.

If no information is given or if the granting authority considers that the reasons do not justify termination, it may consider the beneficiary to have been terminated improperly.

32.2.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit:

- (i) a **report on the distribution of payments** to the beneficiary concerned
- (ii) a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, the financial statement, the explanation on the use of resources, and, if applicable, the certificate on the financial statement (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3)
- (iii) a second **request for amendment** (see Article 39) with other amendments needed (e.g. reallocation of the tasks and the estimated budget of the terminated beneficiary; addition of a new beneficiary to replace the terminated beneficiary; change of coordinator, etc.).

The granting authority will calculate the amount due to the beneficiary on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before the end of work date (see Article 22). Costs relating to contracts due for execution only after the end of work are not eligible.

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 21).

If the granting authority does not receive the termination report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

If the granting authority does not receive the report on the distribution of payments within the deadline, it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that
- the beneficiary concerned must not repay any amount to the coordinator.

If the second request for amendment is accepted by the granting authority, the Agreement is **amended** to introduce the necessary changes (see Article 39).

If the second request for amendment is rejected by the granting authority (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the grant may be terminated (see Article 32).

Improper termination may lead to a reduction of the grant (see Article 31) or grant termination (see Article 32).

After termination, the concerned beneficiary's obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

32.3 EU-initiated GA or beneficiary termination

32.3.1 Conditions

The granting authority may terminate the grant or the participation of one or more beneficiaries, if:

- (a) one or more beneficiaries do not accede to the Agreement (see Article 40)
- (b) a change to the action or the legal, financial, technical, organisational or ownership situation of a beneficiary is likely to substantially affect the implementation of the action or calls into question the decision to award the grant (including changes linked to one of the exclusion grounds listed in the declaration of honour)
- (c) following termination of one or more beneficiaries, the necessary changes to the Agreement (and their impact on the action) would call into question the decision awarding the grant or breach the principle of equal treatment of applicants
- (d) implementation of the action has become impossible or the changes necessary for its continuation would call into question the decision awarding the grant or breach the principle of equal treatment of applicants
- (e) a beneficiary (or person with unlimited liability for its debts) is subject to bankruptcy

proceedings or similar (including insolvency, winding-up, administration by a liquidator or court, arrangement with creditors, suspension of business activities, etc.)

- (f) a beneficiary (or person with unlimited liability for its debts) is in breach of social security or tax obligations
- (g) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has been found guilty of grave professional misconduct
- (h) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed fraud, corruption, or is involved in a criminal organisation, money laundering, terrorism-related crimes (including terrorism financing), child labour or human trafficking
- (i) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) was created under a different jurisdiction with the intent to circumvent fiscal, social or other legal obligations in the country of origin (or created another entity with this purpose)
- (j) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed:
 - (i) substantial errors, irregularities or fraud or
 - (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.)
- (k) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (extension of findings from other grants to this grant; see Article 25)
- (l) despite a specific request by the granting authority, a beneficiary does not request — through the coordinator — an amendment to the Agreement to end the participation of one of its affiliated entities or associated partners that is in one of the situations under points (d), (f), (e), (g), (h), (i) or (j) and to reallocate its tasks, or
- (m) other:
 - (i) the linked action (see Article 3) has not started as specified in Annex 1, has been terminated or can no longer contribute, and this impacts the implementation of the action under this Agreement
 - (ii) the action has lost its scientific or technological relevance, for EIC Accelerator actions: the action has lost its economic relevance, for challenge-based EIC Pathfinder actions and Horizon Europe Missions: the action has lost its relevance as part of the Portfolio for which it has been initially selected

32.3.2 Procedure

Before terminating the grant or participation of one or more beneficiaries, the granting authority will send a **pre-information letter** to the coordinator or beneficiary concerned:

- formally notifying the intention to terminate and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the termination and the date it will take effect (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

For beneficiary terminations, the granting authority will — at the end of the procedure — also inform the coordinator.

The termination will **take effect** the day after the confirmation notification is sent (or on a later date specified in the notification; ‘termination date’).

32.3.3 Effects

(a) for **GA termination**:

The coordinator must — within 60 days from when termination takes effect — submit a **periodic report** (for the last open reporting period until termination).

The granting authority will calculate the final grant amount and final payment on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before termination takes effect (see Article 22). Costs relating to contracts due for execution only after termination are not eligible.

If the grant is terminated for breach of the obligation to submit reports, the coordinator may not submit any report after termination.

If the granting authority does not receive the report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

Termination does not affect the granting authority’s right to reduce the grant (see Article 28) or to impose administrative sanctions (see Article 34).

The beneficiaries may not claim damages due to termination by the granting authority (see Article 33).

After termination, the beneficiaries’ obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

(b) for **beneficiary termination**:

The coordinator must — within 60 days from when termination takes effect — submit:



- (i) a **report on the distribution of payments** to the beneficiary concerned
- (ii) a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, the financial statement, the explanation on the use of resources, and, if applicable, the certificate on the financial statement (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3)
- (iii) a **request for amendment** (see Article 39) with any amendments needed (e.g. reallocation of the tasks and the estimated budget of the terminated beneficiary; addition of a new beneficiary to replace the terminated beneficiary; change of coordinator, etc.).

The granting authority will calculate the amount due to the beneficiary on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before termination takes effect (see Article 22). Costs relating to contracts due for execution only after termination are not eligible.

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 21).

If the granting authority does not receive the termination report within the deadline, only costs and contributions included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

If the granting authority does not receive the report on the distribution of payments within the deadline, it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that
- the beneficiary concerned must not repay any amount to the coordinator.

If the request for amendment is accepted by the granting authority, the Agreement is **amended** to introduce the necessary changes (see Article 39).

If the request for amendment is rejected by the granting authority (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the grant may be terminated (see Article 32).

After termination, the concerned beneficiary's obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

SECTION 3 OTHER CONSEQUENCES: DAMAGES AND ADMINISTRATIVE SANCTIONS

ARTICLE 33 — DAMAGES

33.1 Liability of the granting authority

The granting authority cannot be held liable for any damage caused to the beneficiaries or to third parties as a consequence of the implementation of the Agreement, including for gross negligence.

The granting authority cannot be held liable for any damage caused by any of the beneficiaries or other participants involved in the action, as a consequence of the implementation of the Agreement.

33.2 Liability of the beneficiaries

The beneficiaries must compensate the granting authority for any damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement, provided that it was caused by gross negligence or wilful act.

The liability does not extend to indirect or consequential losses or similar damage (such as loss of profit, loss of revenue or loss of contracts), provided such damage was not caused by wilful act or by a breach of confidentiality.

ARTICLE 34 — ADMINISTRATIVE SANCTIONS AND OTHER MEASURES

Nothing in this Agreement may be construed as preventing the adoption of administrative sanctions (i.e. exclusion from EU award procedures and/or financial penalties) or other public law measures, in addition or as an alternative to the contractual measures provided under this Agreement (see, for instance, Articles 135 to 145 EU Financial Regulation 2018/1046 and Articles 4 and 7 of Regulation 2988/95²²).

SECTION 4 FORCE MAJEURE

ARTICLE 35 — FORCE MAJEURE

A party prevented by force majeure from fulfilling its obligations under the Agreement cannot be considered in breach of them.

‘Force majeure’ means any situation or event that:

- prevents either party from fulfilling their obligations under the Agreement,
- was unforeseeable, exceptional situation and beyond the parties’ control,
- was not due to error or negligence on their part (or on the part of other participants involved in the action), and
- proves to be inevitable in spite of exercising all due diligence.

Any situation constituting force majeure must be formally notified to the other party without delay, stating the nature, likely duration and foreseeable effects.

The parties must immediately take all the necessary steps to limit any damage due to force majeure and do their best to resume implementation of the action as soon as possible.

²² Council Regulation (EC, Euratom) No 2988/95 of 18 December 1995 on the protection of the European Communities financial interests (OJ L 312, 23.12.1995, p. 1).

CHAPTER 6 FINAL PROVISIONS

ARTICLE 36 — COMMUNICATION BETWEEN THE PARTIES

36.1 Forms and means of communication — Electronic management

EU grants are managed fully electronically through the EU Funding & Tenders Portal ('Portal').

All communications must be made electronically through the Portal, in accordance with the Portal Terms and Conditions and using the forms and templates provided there (except if explicitly instructed otherwise by the granting authority).

Communications must be made in writing and clearly identify the grant agreement (project number and acronym).

Communications must be made by persons authorised according to the Portal Terms and Conditions. For naming the authorised persons, each beneficiary must have designated — before the signature of this Agreement — a 'legal entity appointed representative (LEAR)'. The role and tasks of the LEAR are stipulated in their appointment letter (see Portal Terms and Conditions).

If the electronic exchange system is temporarily unavailable, instructions will be given on the Portal.

36.2 Date of communication

The sending date for communications made through the Portal will be the date and time of sending, as indicated by the time logs.

The receiving date for communications made through the Portal will be the date and time the communication is accessed, as indicated by the time logs. Formal notifications that have not been accessed within 10 days after sending, will be considered to have been accessed (see Portal Terms and Conditions).

If a communication is exceptionally made on paper (by e-mail or postal service), general principles apply (i.e. date of sending/receipt). Formal notifications by registered post with proof of delivery will be considered to have been received either on the delivery date registered by the postal service or the deadline for collection at the post office.

If the electronic exchange system is temporarily unavailable, the sending party cannot be considered in breach of its obligation to send a communication within a specified deadline.

36.3 Addresses for communication

The Portal can be accessed via the Europa website.

The address for paper communications to the granting authority (if exceptionally allowed) is the official mailing address indicated on its website.

For beneficiaries, it is the legal address specified in the Portal Participant Register.

ARTICLE 37 — INTERPRETATION OF THE AGREEMENT

The provisions in the Data Sheet take precedence over the rest of the Terms and Conditions of the Agreement.

Annex 5 takes precedence over the Terms and Conditions; the Terms and Conditions take precedence over the Annexes other than Annex 5.

Annex 2 takes precedence over Annex 1.

ARTICLE 38 — CALCULATION OF PERIODS AND DEADLINES

In accordance with Regulation No 1182/71²³, periods expressed in days, months or years are calculated from the moment the triggering event occurs.

The day during which that event occurs is not considered as falling within the period.

‘Days’ means calendar days, not working days.

ARTICLE 39 — AMENDMENTS

39.1 Conditions

The Agreement may be amended, unless the amendment entails changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

Amendments may be requested by any of the parties.

39.2 Procedure

The party requesting an amendment must submit a request for amendment signed directly in the Portal Amendment tool.

The coordinator submits and receives requests for amendment on behalf of the beneficiaries (see Annex 3). If a change of coordinator is requested without its agreement, the submission must be done by another beneficiary (acting on behalf of the other beneficiaries).

The request for amendment must include:

- the reasons why
- the appropriate supporting documents and
- for a change of coordinator without its agreement: the opinion of the coordinator (or proof that this opinion has been requested in writing).

The granting authority may request additional information.

If the party receiving the request agrees, it must sign the amendment in the tool within 45 days of receiving notification (or any additional information the granting authority has requested). If it does

²³ Regulation (EEC, Euratom) No 1182/71 of the Council of 3 June 1971 determining the rules applicable to periods, dates and time-limits (OJ L 124, 8/6/1971, p. 1).

not agree, it must formally notify its disagreement within the same deadline. The deadline may be extended, if necessary for the assessment of the request. If no notification is received within the deadline, the request is considered to have been rejected.

An amendment **enters into force** on the day of the signature of the receiving party.

An amendment **takes effect** on the date of entry into force or other date specified in the amendment.

ARTICLE 40 — ACCESSION AND ADDITION OF NEW BENEFICIARIES

40.1 Accession of the beneficiaries mentioned in the Preamble

The beneficiaries which are not coordinator must accede to the grant by signing the accession form (see Annex 3) directly in the Portal Grant Preparation tool, within 30 days after the entry into force of the Agreement (see Article 44).

They will assume the rights and obligations under the Agreement with effect from the date of its entry into force (see Article 44).

If a beneficiary does not accede to the grant within the above deadline, the coordinator must — within 30 days — request an amendment (see Article 39) to terminate the beneficiary and make any changes necessary to ensure proper implementation of the action. This does not affect the granting authority's right to terminate the grant (see Article 32).

40.2 Addition of new beneficiaries

In justified cases, the beneficiaries may request the addition of a new beneficiary.

For this purpose, the coordinator must submit a request for amendment in accordance with Article 39. It must include an accession form (see Annex 3) signed by the new beneficiary directly in the Portal Amendment tool.

New beneficiaries will assume the rights and obligations under the Agreement with effect from the date of their accession specified in the accession form (see Annex 3).

Additions are also possible in mono-beneficiary grants.

ARTICLE 41 — TRANSFER OF THE AGREEMENT

In justified cases, the beneficiary of a mono-beneficiary grant may request the transfer of the grant to a new beneficiary, provided that this would not call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiary must submit a request for **amendment** (see Article 39), with

- the reasons why
- the accession form (see Annex 3) signed by the new beneficiary directly in the Portal Amendment tool and
- additional supporting documents (if required by the granting authority).

The new beneficiary will assume the rights and obligations under the Agreement with effect from the date of accession specified in the accession form (see Annex 3).

ARTICLE 42 — ASSIGNMENTS OF CLAIMS FOR PAYMENT AGAINST THE GRANTING AUTHORITY

The beneficiaries may not assign any of their claims for payment against the granting authority to any third party, except if expressly approved in writing by the granting authority on the basis of a reasoned, written request by the coordinator (on behalf of the beneficiary concerned).

If the granting authority has not accepted the assignment or if the terms of it are not observed, the assignment will have no effect on it.

In no circumstances will an assignment release the beneficiaries from their obligations towards the granting authority.

ARTICLE 43 — APPLICABLE LAW AND SETTLEMENT OF DISPUTES

43.1 Applicable law

The Agreement is governed by the applicable EU law, supplemented if necessary by the law of Belgium.

Special rules may apply for beneficiaries which are international organisations (if any; see Data Sheet, Point 5).

43.2 Dispute settlement

If a dispute concerns the interpretation, application or validity of the Agreement, the parties must bring action before the EU General Court — or, on appeal, the EU Court of Justice — under Article 272 of the Treaty on the Functioning of the EU (TFEU).

For non-EU beneficiaries (if any), such disputes must be brought before the courts of Brussels, Belgium — unless an international agreement provides for the enforceability of EU court judgements.

For beneficiaries with arbitration as special dispute settlement forum (if any; see Data Sheet, Point 5), the dispute will — in the absence of an amicable settlement — be settled in accordance with the Rules for Arbitration published on the Portal.

If a dispute concerns administrative sanctions, offsetting or an enforceable decision under Article 299 TFEU (see Articles 22 and 34), the beneficiaries must bring action before the General Court — or, on appeal, the Court of Justice — under Article 263 TFEU.

For grants where the granting authority is an EU executive agency (see Preamble), actions against offsetting and enforceable decisions must be brought against the European Commission (not against the granting authority; see also Article 22).

ARTICLE 44 — ENTRY INTO FORCE

The Agreement will enter into force on the day of signature by the granting authority or the coordinator, depending on which is later.

SIGNATURES

For the coordinator

For the granting authority



ANNEX 1



Horizon Europe (HORIZON)

Description of the action (DoA)

Part A

Part B

DESCRIPTION OF THE ACTION (PART A)

COVER PAGE

Part A of the Description of the Action (DoA) must be completed directly on the Portal Grant Preparation screens.

PROJECT	
<i>Grant Preparation (General Information screen) — Enter the info.</i>	
Project number:	101093038
Project name:	Center of Excellence for Exascale in Solid Earth - Second Phase
Project acronym:	ChEESE-2P
Call:	HORIZON-EUROHPC-JU-2021-COE-01
Topic:	HORIZON-EUROHPC-JU-2021-COE-01-02
Type of action:	HORIZON-JU-RIA
Service:	EUROHPC
Project starting date:	fixed date: 1 January 2023
Project duration:	48 months

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List of milestones (outputs/outcomes)	34
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JU contributions	37

PROJECT SUMMARY

Project summary

Grant Preparation (General Information screen) — Provide an overall description of your project (including context and overall objectives, planned activities and main achievements, and expected results and impacts (on target groups, change procedures, capacities, innovation etc)). This summary should give readers a clear idea of what your project is about.

Use the project summary from your proposal.

The scientific ambition of ChEESE-2P is to prepare 11 community flagship codes to address 12 domain-specific Exascale Computational Challenges (ECC), enlarging the areas covered during the first implementation phase (computational seismology, magnetohydrodynamics, physical volcanology, and tsunamis) with two additional disciplines (geodynamics and modeling of glacier hazards). Codes will be optimized in terms of performance on different types of accelerators, scalability, deployment, containerization, and portability across current pre-exascale systems and hardware architectures emerging from the EuroHPC Pilots by co-designing with mini-apps. Optimization will also include heterogeneous single-node and multi-node performance, as well as continuous efficiency monitoring using the Performance Optimisation and Productivity (POP) metrics. Emphasis will be given on the uptake by science, public administration and industry, including training and capacity building in cooperation with National Competence Centers (NCCs). Codes and workflows will combine to farm a new generation of 9 Pilot Demonstrators (PDs) underpinned by concepts like multi-scale, multi-source, and multi-physics. The PDs will materialise in 15 Simulation Cases (SCs) representing capability and capacity use cases of particular relevance in terms of science, social relevance, or urgency (the capability SCs include 4 potential Scientific Grand Challenges, i.e. cases that can require an extreme-scale access mode). The SCs will produce relevant EOSC-enabled datasets and enable services on aspects of geohazards like urgent computing, early warning forecast, hazard assessment, or fostering an emergency access mode in EuroHPC tier-0/tier-1 systems for geohazardous events (earthquakes, tsunamis and volcanoes), including access policy recommendations. Finally, ChEESE-2P will liaise, align, and synergize with other domain-specific European projects and longer-term mission-like initiatives like Destination Earth.

LIST OF PARTICIPANTS

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
1	COO	CSIC	AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	ES	999991722
2	BEN	BSC CNS	BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACION	ES	999655520
3	BEN	INGV	ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA	IT	999472675
4	BEN	IMO	VEDURSTOFA ISLANDS	IS	997168343
5	BEN	USTUTT	UNIVERSITY OF STUTTGART	DE	999974747
6	BEN	CINECA	CINECA CONSORZIO INTERUNIVERSITARIO	IT	999843409
7	BEN	TUM	TECHNISCHE UNIVERSITAET MUENCHEN	DE	999977463
8	BEN	LMU MUENCHEN	LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN	DE	999978433
9	BEN	UMA	UNIVERSIDAD DE MALAGA	ES	999898311

PARTICIPANTS*Grant Preparation (Beneficiaries screen) — Enter the info.*

Number	Role	Short name	Legal name	Country	PIC
10	BEN	NGI	STIFTELSEN NORGES GEOTEKNISKE INSTITUTT	NO	998866522
11	BEN	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	999997930
11.1	AE	IPGP	INSTITUT DE PHYSIQUE DU GLOBE DE PARIS	FR	999597417
12	BEN	BULL	BULL SAS	FR	996058081
13	BEN	CSC	CSC-TIETEEN TIETOTEKNIKAN KESKUS OY	FI	999645820
14	BEN	RBI	RUDER BOSKOVIC INSTITUTE	HR	999875031
15	BEN	UM	JOHANNES GUTENBERG-UNIVERSITAT MAINZ	DE	999978627
16	BEN	SU	SORBONNE UNIVERSITE	FR	909875521

LIST OF WORK PACKAGES

Work packages						
Grant Preparation (Work Packages screen) — Enter the info.						
Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
WP1	Project Management	1 - CSIC	78.00	1	48	D1.1 – Project Management and Quality Guidelines D1.2 – First Data Management Plan D1.3 – Mid-term report D1.4 – Final Data Management Plan D1.5 – Final report
WP2	Exascale technical challenges in flagship codes	6 - CINECA	247.00	1	48	D2.1 – First code audit report D2.2 – First report on improving code performance at exascale D2.3 – Second code audit report D2.4 – Final report on improving code performance at exascale and Best Practice Guide
WP3	Co-design with European HPC vendors and technologies	12 - BULL	86.00	6	42	D3.1 – Selected set of mini-apps and its requirements D3.2 – SE Community applications on European HPC technologies
WP4	Simulation ecosystem	5 - USTUTT	94.00	1	48	D4.1 – Initial report on workflow setups and workflow auditing D4.2 – Plan for development and deployment tool usage for workflows and software D4.3 – Intermediate report on workflow setups and optimization D4.4 – Final report on workflow implementation and optimization

Work packages						
<i>Grant Preparation (Work Packages screen) — Enter the info.</i>						
Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
						D4.5 – Final report on development and deployment activities
WP5	Farming Pilot Demonstrators	11 - CNRS	235.50	1	42	D5.1 – New version release of flagship codes D5.2 – Demonstrator of PD1 D5.3 – Demonstrator of PD4 D5.4 – Demonstrator of PD6 D5.5 – Demonstrator of PD7 D5.6 – Demonstrator of PD8 D5.7 – Demonstrator of PD2 D5.8 – Demonstrator of PD3 D5.9 – Demonstrator of PD5 D5.10 – Demonstrator of PD9
WP6	SCs and service enabling using EuroHPC infrastructures	3 - INGV	165.00	13	48	D6.1 – Simulation Cases and Trials definition D6.2 – SCs report and datasets from PD1 D6.3 – SCs report and datasets from PD2 D6.4 – SCs report and datasets from PD3 D6.5 – SCs report and datasets from PD4 D6.6 – SCs report and datasets from PD5 D6.7 – SCs report and datasets from PD6 D6.8 – SCs report and datasets from PD7 D6.9 – SCs report and datasets from PD8 D6.10 – SCs report and datasets from PD9 D6.11 – Open Hazard Maps D6.12 – Urgent computing service enabling
WP7	Dissemination, outreach and capacity building	2 - BSC CNS	70.50	1	48	D7.1 – Project website D7.2 – Communication and Dissemination Plan

Work packages <i>Grant Preparation (Work Packages screen) — Enter the info.</i>						
Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
						D7.3 – Collaboration plan with complementary projects D7.4 – Training Plan D7.5 – Preliminary exploitation plan D7.6 – Training Report D7.7 – Exploitation Plan D7.8 – Communication and Dissemination Report

Work package WP1 – Project Management

Work Package Number	WP1	Lead Beneficiary	1. CSIC
Work Package Name	Project Management		
Start Month	1	End Month	48

Objectives

1. Implement an efficient operational project management and give support to administrative and financial reporting, project legal aspects (including IPR), and timely delivery on the scientific and technical objectives of the project within the budget constraints.
2. Establish and enforce effective management and quality procedures for high-quality deliverables.
3. Effective communication between partners and detect project risks promptly, bringing them to resolution.
4. Promote gender and country balance through the Equality Committee (EC) activities.
5. Manage the computational resources according to project needs and foster the granting of additional EuroHPC/ PRACE resources through the different competitive access modes.
6. Implement a Data Management Plan (DMP) and an EOSC-enabled automatic FAIR data validation integrated in the CI/CD pipelines.
7. Produce the 4 deliverables detailed below.

Description

Task T1.1: Administrative and financial management (M1-M48 | Lead: CSIC | Participants: ALL). This task will establish the procedures for project management (quality guidelines defined in D1.1), including: (1) administrative management and periodic financial reporting, (2) coordinate a timely production of deliverables with the corresponding lead participant, organise an internal peer-reviewing procedure for deliverables involving at least 2 partners, and ensure a timely submission of deliverables. The principles guiding these procedures, including the reviewers list, will be agreed during the General Assembly kick-off meeting (M1), (3) organize and manage audits requested by the Commission, (4) ensure clear communication channels between partners (e.g. zoom accounts) and facilitate the exchange of information and documentation by means of internal collaborative tools (set up of a private wiki and a project portal for collaborative sharing), mailing lists, CryptPad or similar for collaborative elaboration of minutes, templates with the project branding for internal reporting, project documents, and presentation templates for meetings and events (docx, pptx, latex, etc), (5) maintain and periodically update an Intellectual Property Register (IPR) of the project assets (codes, methodologies, datasets, etc) in case partners need to agree on potential exploitation terms and, (6) maintain and periodically update the DMP (T1.5) simplifying data curation and sharing among members of the consortium.

Task T1.2: Operational decision making (M1-M48 | Lead: CSIC | Participants: ALL). This task will: (1) organize online monthly Project Executive Committee (PEC) meetings, (2) organize online Project Supervisory Board (PSB) meetings, regularly every 6 months and whenever called by the PC. The written minutes of the PSB meetings will be circulated to the beneficiaries and, (3) organize 3 face-to-face General Assemblies (GA) attended by all partners: the kick-off meeting (M1), the mid-term meeting (M23), and the project final meeting (M47). Members of the Scientific Advisory Board (SAB) and the Industry and Users Board (IUB) will be invited to attend.

Task T1.3: Equality committee (M1-M48 | Lead: LMU | Participants: ALL). A country and gender Equality Committee (EC), composed by delegates of at least 6 partners, will be established at the beginning of the project in order to: (1) prioritize gender equality (e.g. in project WP and task leadership) and favor a gender-balanced recruitment of the personnel hired by the project, (2) promote the ShEESE activities. The name "ShEESE" ("she is") is a combination of the words "She" and "ChEESE", and will centralize all the activities aiming at promoting the participation of women in research professional careers, e.g. general public (scholarship) videos, links with the "Inspiring girls" initiative for national-level contacts in ChEESE countries, activities, campaigns during the International Day of Women and Girls in Science (11th February) and others, (3) coordinate with T7.3 to favor the engagement of EU13 NCCs in the training activities, (4) support the initiative #ScienceForUkraine, an international community group from academic institutions in Europe and around the world to collect and disseminate information about support job opportunities at the university, national, and international level for students and researchers directly affected by the recent situation of Ukraine.

Task T1.4: Management of computational resources (M1-M48 | Lead: CSIC | Participants: ALL). This task will: (1) define and implement an internal ticketing system to manage the computational resources assigned to the CoE (e.g. user access, quota credits) and ensure a rational and equitable distribution of resources among partners aligned with the

project needs and objectives, (2) assist partners in the planification and preparation of EuroHPC access mode proposals on: (i) development and benchmark access (monthly cut-offs) for transversal WP2-WP4 activities and to document the technical feasibility of subsequent submissions to other access modes, (ii) regular access (3 times per year) for execution of SCs and, (iii) extreme scale access (bi-yearly cut-offs, to use 60-90% of pre-exascale systems) for execution of 4 SGC. The 2 largest access modes require a Data Management Plan, which will be consistent with T1.5. In addition, this task will also try to exploit windows of opportunity in the in-house tier-0/tier-1 systems to perform full-scale machine executions, e.g. immediately before or after scheduled machine maintenance stops. Finally, in-house allocation of resources for urgent applications will also be considered, e.g. as occurred with MN-4@BSC during the September 2021 to December 2021 eruption at La Palma, Canary Islands.

Task T1.5: Data management plan and automatic FAIR validation (M1-M24 | Lead: CSIC | Participants: BSC, INGV, IMO, TUM, LMU, UMA, NGI, CNRS, IRB, UM, US). This task will develop a Data Management Plan (DMP) ensuring EPOS-enabled metadata descriptors to be interoperable with the EPOS service catalog. The first version of the DMP, available by M6 (D1.2), will be periodically updated if required. In addition, this task will provide an EOSC-enabled quality-based ecosystem for automatic FAIR data validation. This Software Quality as a Service (SQaaS), resulting from the EOSC-synergy project, can be integrated in the CI/CD pipelines and facilitates the uptake of EOSC services and data repositories by research communities.

Work package WP2 – Exascale technical challenges in flagship codes

Work Package Number	WP2	Lead Beneficiary	6. CINECA
Work Package Name	Exascale technical challenges in flagship codes		
Start Month	1	End Month	48

Objectives

1. Address technical challenges (potentially at exascale) in the 11 flagship codes.
2. Exploit actual accelerators, in particular those targeting EuroHPC pre-exascale machines.
3. Audit the codes and improve single node, multi-node, and I/O performances at scale.
4. Continuously monitor the code performance efficiency during the project.
5. Produce the 4 deliverables detailed below

Description

Task T2.1: Code audits (M3-M15 and M27-M36 | Lead: HLRS | Participants: CSIC, INGV, CIN, TUM, LMU, UMA, CNRS, IPGP, CSC, UM, SU). This task focuses on auditing code performance in order to: (1) identify bottlenecks, (2) set a performance baseline to monitor code evolution through the project and, (3) document the progress of flagship applications (second audit round). Audits will be done using the Performance Optimisation and Productivity Center of Excellence in Computing Applications (POP) tool sets and performance metrics developed by POP2 partners and collaborators. Two levels of audit are envisaged: (i) a performance plan for ChEESE-IP flagship codes already starting from level 1 and, (ii) a general audit for the rest of codes (new codes not audited before and level 2 codes). The general audit consists of an initial analysis measuring a range of performance metrics (POP metrics) to assess quality of performance and identify the issues affecting performance, whereas the performance plan involves further performance evaluations to identify the root causes of the issues found and qualify and quantify approaches to address them. As many applications are now efficiently ported to GPU and completely “hybrid” in their structure, particular care will be given to the use of EuroHPC architectures with emphasis on Leonardo, Lumi, MN5 and similar architectures. Moreover, in strict cooperation with the code owners, a complete set of input data suitable for this analysis will be used and maintained for this task. The task plan includes: (i) a first audit round (M3 to M15) and a first report (D2.1), (ii) a second audit round (M27 to M36) to monitor quantitatively the progress achieved within WP2 and, (iii) the update of the initial report (D2.3).

Task T2.2: Increasing the performance portability of flagship codes for different accelerators (M1-M48 | Lead: CIN | Participants: CSIC, INGV, TUM, LMU, UMA, CNRS, IPGP, CSC, UM). This task will increase the performance and portability of flagship codes in the “accelerators arena”. The activity will be mainly devoted to guaranteeing the efficient use of available hardware (NVIDIA and AMD GPUs in particular) with a clear focus on EuroHPC systems (Leonardo, LUMI, MN-5). This task partially depends on the output of T2.1 and includes: (1) the creation of a development team (composed of one representative for each flagship code and one dedicated mentor from CIN), (2) a first report from the team summarising the actual status of each code in relationship to this technology and further actions (D2.2), (3) porting

and tuning efforts devoted to the most efficient use of NVIDIA and AMD hardware with emphasis on performance portability. This includes accelerators programming tools and libraries with a clear focus on de-facto standards (cross-platform, when available) and software portability layers and, (4) a final report summarizing the experiences done in using accelerators and a Best Practice Guide (D2.4).

Task T2.3: Optimisation for Exascale (M6-M48 | Lead: CIN | Participants: CSIC, BSC, INGV, TUM, LMU, UMA, BA, UM, SU). This task will guarantee technical support to each flagship code to enhance its performance and scalability and achieve best-possible adequacy to exascale technical features, needed to efficiently use current pre- and future exascale architectures. The support will be on-demand and in a strict cooperation between lead developers and CIN. This task will address primarily the following features and properties (not an exhaustive list): (1) single (heterogeneous) node performance, including vectorization, intra-node communication efficiency, and multi-threading, (2) multi-node performance, including mitigation of load-balancing issues and inter-node communication efficiency, (3) implementing or adopting more scalable algorithms and/or algorithms that improve the time-to-solution of simulations (e.g., time-stepping schemes, linear solvers), (4) other exascale features enabling (resiliency, fault-tolerance) in the flagship codes and, (5) I/O performance. The deliverables D2.2 and D2.4 will summarize the experiences done in T2.2 and T2.3 and will foster the adequacy to exascale for future concrete steps in this direction.

Task T2.4: Continuous Performance Efficiency Monitoring (M18-M48 | Lead: BSC | Participants: CSIC, INGV, HLRS, TUM, LMU, UMA, CNRS, IGP, UM). This task aims at providing a lightweight, straightforward, and easy-to-use mechanism to measure the parallel efficiency of flagship codes at exascale. It will cover the need to keep continuous monitoring on the parallel efficiency KPIs of the codes. Low values in the metrics obtained by this task should raise a flag that the code and input must be analyzed in detail in T2.1 or T4.5 to find out the underlying reasons for the low efficiency. T2.4 will rely on TALP to measure well-known and well-established parallel efficiency metrics as defined by POP2. TALP can obtain MPI parallel efficiency metrics using a profiling technique without keeping a detailed trace, this allows for a much more scalable and lightweight approach than tracing. TALP will be extended as necessary by BSC to support the flagship codes and scale up to exascale. In particular, it will be extended to support calculating efficiency metrics over user-defined phases which do not need to correspond to MPI synchronization points

Work package WP3 – Co-design with European HPC vendors and technologies

Work Package Number	WP3	Lead Beneficiary	12. BULL
Work Package Name	Co-design with European HPC vendors and technologies		
Start Month	6	End Month	42

Objectives

1. Extract to mini-apps the most relevant parts of applications according to targeted prototype architecture.
2. Leverage European HPC technologies through the SE Community applications.
3. Foster co-design with HPC vendors and technology and associated ecosystem (EuroHPC Pilots).
4. Produce the 2 deliverables detailed below

Description

Task T3.1: Preparation of mini-apps (M6-M18 | Lead: CIN | Participants: CSIC, TUM, LMU, UMA, CNRS, BA, SU). This task aims at selecting and then preparing the representative set of application parts (also named mini-apps or kernels) which will be used by T3.2 and T3.3 for co-design. Thanks to ChEESE-1P, the legacy mini-apps will form the basis of this selection that includes mini-SeisSol, mini-SPECFEM3D, mini-FALL3D, mini-xSHELLS, and mini-HySEA. These will be complemented with mini-Tandem and mini-pTatin3D (not in ChEESE-1P). The needs for each application and mini-apps in terms of software stack, including compiler toolchain, libraries, and its impact on prototypes will be identified. According to the fact that some mini-apps have already been optimized previously, the relevance of these optimization will be assessed with regards to the two prototypes targeted. This includes the mini-apps already ported to accelerators. The possibility to re-integrate the part mini-apps or kernel into its full application will also be studied in collaboration with WP2.

Task T3.2: OpenSequana prototypes (EuPEX) (M12-M42 | Lead: BA | Participants: CSIC, CIN, TUM, LMU, UMA, CNRS). The EuPEX pilot system will be the first HPC platform integrating the full spectrum of European HPC technologies, including ARM-based Rhea processor, with multiple CPU compute nodes and GPU accelerated ones. This

task will focus on preparing the SE Community applications for this platform from kernels and mini-apps to potentially full applications. Before EuPEX systems availability, first porting and performance analysis will be done on systems with common characteristics such as ARM-based systems with SVE or memory hierarchies with HBM or also BXI based interconnect to anticipate the need for code adaptation. This task will foster collaborations between application developers, HPC scientists, and technology providers. Performance, scalability and potential energy consumption analysis on the EuPEX platform will provide guidance to application developers to take advantage of its characteristics and to technology providers for future generation of HPC systems.

Task T3.3: RISC-V prototypes, the European Processor Initiative (EPI) and EuPilot (M19-M42 | Lead: BSC | Participants: CSIC, TUM, LMU, UMA, CNRS, SU). A promising approach towards HPC accelerator computing is using vector architectures: large vector units can be tightly coupled to lean RISC-V cores and be programmed as stand-alone CPUs as well as devices to offload computational kernels. EPI and EuPilot will deliver vector RISC-V accelerators targeting HPC. While the final chips are developed, users can leverage Software Development Vehicles (SDVs), i.e. software and hardware tools that allow co-design with RISC-V vector architectures. The main focus of this task is studying CHEESE-2P mini-apps on SDVs or other RISC-V compute infrastructure. The co-design cycle will focus on the vectorization of the CHEESE-2P mini-apps and the measurements of their performance. Depending on the maturity of SDV, it will be possible to experiment with a multi-core and multi-node setup. The outcome of this analysis will provide feedback not only to the application developers on how to efficiently exploit HPC EU platforms but also to the EPI/EuPilot architects for next generation EPI architectures and compilers.

Work package WP4 – Simulation ecosystem

Work Package Number	WP4	Lead Beneficiary	5. USTUTT
Work Package Name	Simulation ecosystem		
Start Month	1	End Month	48

Objectives

1. Address challenges at simulation workflow level that go beyond the main application codes.
2. Decrease overall time to solution by adopting a holistic view on the necessary workflow.
3. Exploit new methods of simulation setup, deployment, and data analysis.
4. Improve general usability for codes and workflows in the SE Community.
5. Produce the 5 deliverables detailed below.

Description

Task T4.1: Workflow implementation and optimization (M1-M42 | Lead: HLRS | Participants: CSIC, BSC, INGV, LMU, NGI, CNRS, IPGP, IRB). This task will implement and optimize simulation workflows as a whole, reducing user interaction to a minimum and allowing fast deployment of simulations as well as handling of large ensemble workloads. In terms of workflow optimization, non-obvious bottlenecks beside the main HPC simulation codes (optimized in WP2) will be identified by performing workflow audits and addressed by optimizing the respective parts. Important issues to be identified here will be time-consuming components, inter-component coupling that requires passing large amounts of data between components, and fault tolerance at workflow level (complementary to code fault tolerance, T2.3). Efficient resilience techniques shall be promoted, e.g., using checkpoint/restart at the code level or usage of containers for pre-/post-processing components. With this, the overall overhead will be decreased, something especially important for UC.

Task T4.2: Lightweight performance analysis and optimization services for simulation ecosystem components (M25-M48 | Lead: HLRS | Participants: CSIC, INGV, LMU, UMA, CNRS, IPGP). The wide variety of components in geo-scientific workflows come with many challenges for performance analysis and optimization. Often, workflow components (especially in pre- and post-processing) are not based on the common HPC programming languages (C/C++ and Fortran) and related parallel programming models (MPI, OpenMP, etc.). As a result, the common performance analysis tools can not be applied and established performance metrics to track down issues are hard to obtain (such as the POP metrics, which are addressed for the main codes in T2.1 and T2.4). Therefore, this task will provide a series of lightweight performance analysis services that will help with the identification of performance problems for these components and that can be used for contiguous performance monitoring later. These services target minimal adaptations of the components and try to provide universal solutions that can be applied to multiple components in other disciplines.

Task T4.3: Development, deployment and quality assessment tools (M1-M48 | Lead: HLRS/CIN | Participants: CSIC, BSC, INGV, LMU, UMA, CNRS, IPGP). This task will support and improve code and workflow development and deployment activities. Git-based platforms (github or gitlab) shall be exploited - where not already used - to organize further development and integrate CI (Continuous Integration) and automated testing in the development process, improving feedback between developers and user communities. Codes and scripts will be checked with state of the art tools on potential errors, (e.g., with static code analysis tools like clang-tools or “Looks Good To Me” (LGTM) and Coverity services and dynamic methods using sanitizers) and test harnesses for common use cases shall be set up. As a second part, containerisation of components or whole workflows using docker or singularity shall be exploited to allow fast and reliable setup for simulations – which is especially important for urgent simulation scenarios as well as resilience in case of hardware failures. Further, we target the inclusion of codes into an NVIDIA SE collection to ease the entry for new users and communities as well as to provide installation packages for HPC system software stacks, e.g. via spack. Thirdly, possibilities for tools and new types of user interfaces as well as documentation shall be exploited that help users to set up and deploy their simulations. Here technologies fitting the common simulation environments in different communities shall be exploited, e.g., python/julia jupyter notebooks.

Work package WP5 – Farming Pilot Demonstrators

Work Package Number	WP5	Lead Beneficiary	11. CNRS
Work Package Name	Farming Pilot Demonstrators		
Start Month	1	End Month	42

Objectives

1. Implement novel features and coupling mechanisms in flagship codes for new PD workflows.
2. Develop the new workflows of the PD farm.
3. Produce the 10 deliverables detailed below.

Description

T5.1. Novel features (physics) in flagship codes (M1-M24 |Lead: CNRS | Participants: CSIC, INGV, TUM, LMU, UMA, IPGP, CSC, IRB, UM, SU). This task will implement novel features in flagship codes that are necessary to the new generation of PDs (e.g. couplings for multiphysics, multiscale, multisource, forcing terms, etc). It is important to differentiate conceptually between this task (“model physics”) and subsequent T2.2/T2.3 activities, focussed on “algorithmics, porting, and optimization”. As shown in the Pert diagram, T5.1 actually feeds into T2.2/T2.3. Task T5.1 breaks down as:

T5.1.1. SeisSol (LMU, TUM, US). Couple SeisSol to codes for geodynamics (pTatin3D, LaMEM) and seismic cycling (TANDEM), which simulate Earth’s lithosphere deformation crust from millions of years down to thousands of years of entire seismic cycles. Ability to mix material models (elastic/elastic-anisotropic, acoustic, viscoelastic, poroelastic) for multiphysics simulations. Enable Cybershake capabilities including implementation of reciprocity and optimal "interfacing" between the Cybershake workflow and SeisSol (parameter files, formats of files, and model description).

T5.1.2. SPECSEM3D (CNRS, INGV). Add attenuation and gravity kernels for computing different kinds of gravity anomalies. Extract and separate the computational core of SPECSEM3D, which must be efficient on different exascale platforms, from the various higher-level workflows. To this purpose, a library called SEM-DK (Spectral Element Method - Development Kernel) will be developed in 5 steps: (1) extract the computational kernels already optimized during ChEESE-1P from SPECSEM3D in order to make a version 0.1 of SEM-DK, (2) integrate the new WP2/WP3 developments and optimizations in SEM-DK0.1 or upgraded versions, (3) write an API for SEM-DK considering Fortran and C++ support to produce the version SEM-DK 0.2, (4) write a new version of SPECSEM3D based on SEM-DK0.2 and validate against the up-to-date version of the code and, (5) write a new workflow for inversion (PD2) based on this new version of SPECSEM3D. This will include new algorithms for multi-objective and multi-physics inversion and functionals (seismology and gravimetry) as well as a new inversion scheme based on the Hessian matrix like Truncated Newton method.

T5.1.3. ExaHyPE (TUM). Develop UQ workflows with MUQ (MIT Uncertainty Quantification Library) and ExaSeis towards integration of improved earthquake sourcing (including dynamic rupture) and handling of more complicated geometries, as well as extend shallow water models in the context of landslide tsunamis.

T5.1.4. TANDEM (LMU). New multiphysics coupling, two-way linking to earthquake dynamics and wave propagation

modeling with SeisSol, one way linking to long-term geodynamic modeling (LaMEM, ptatin3D) using stress, temperature, viscosity, density geometry as initial conditions and velocity / stress as boundary conditions.

T5.1.5. xSHELLS (CNRS, IPGP). Implement a dynamic and versatile subgrid-scale flux model based on deep learning to efficiently simulate turbulent geodynamo simulations that have barely been scratched by previous studies.

T5.1.6. HySEA (UMA, IRB). Develop an operational version of the one-layer dispersive/non-hydrostatic version of the code for earthquake generated tsunamis. Implementation of nested domains. Effective coupling of Meteo-HySEA and real atmospheric data (optimization of MeteoT-HySEA).

T5.1.7. FALL3D (CSIC, INGV). Implement a mass-consistent meteorological downscaling and nested domains for multiscale simulations.

T5.1.8. OpenPDAC (INGV). Add new rheological models, modeling of the interaction between volcanic eruption mixture and water, a description of the particle grain size distribution, and the treatment of complex topographies (use of adaptive meshes).

T5.1.9. LaMEM (UM). Implementing a julia interface for LaMEM to rapidly generate model setups of any region of the Earth while using available geophysical data.

T5.1.10. pTatin3D (SU). Add support for Navier-slip type boundary conditions for spherical cap regional model domains using a symmetric Nitsche formulation. Accurate projection of material properties (stress and density) into a field defined on a mesh. Integration of pTatin3D output data formats with ASAGI to enable efficient import of 3D volume data into SeisSol.

T5.1.11. ELMER/ICE (CSC). Implementation of a coupled visco-elastic Reynolds flow type of model able to represent Glacier Outburst Floods (GLOFs).

Task T5.2. Developments in Pilot Demonstrators (M7-M42 | Lead: CNRS | Participants: CSIC,BSC, INGV, IMO,TUM, LMU, UMA, NGI, IPGP, CSC, IRB, UM, IPGP, SU). This task will implement and deliver the 9 PDs. Deliverables D5.2 to D5.10 at M36 will show benchmark results, but the task will continue up to M42 with focus on the production runs (reported in D6.2, D6.3 and D6.4).

Work package WP6 – SCs and service enabling using EuroHPC infrastructures

Work Package Number	WP6	Lead Beneficiary	3. INGV
Work Package Name	SCs and service enabling using EuroHPC infrastructures		
Start Month	13	End Month	48

Objectives

1. Define the 15 Simulation Cases (SCs) leading to capability/capacity production runs generating open EOSC-enabled datasets and hazard maps.
2. Execute 4 Scientific Grand Challenges (if full-scale resources are allocatable).
3. Enable 2 services in EPOS for tsunami and volcano Thematic Core Services (TSU-TCS and VO-TCS).
4. Enable 4 urgent computing services in EuroHPC infrastructures, including policy recommendations.
5. Engage the end-user community in the service co-design activities ensuring that the resulting products are well-suited for the applications and their users, including live demo exercises.
6. Produce the 5 deliverables detailed below.

Description

Task T6.1: Setup of Simulation Cases and trials (M13-M18 | Lead: INGV | Participants: CSIC, BSC, IMO, TUM, LMU, UMA, NGI, CNRS, CSC, IRB, UM, IPGP, SU). This task will define the methodology and precise setup for the production runs and live demo exercises, including collaboration with T1.4 for preparation of EuroHPC/PRACE access calls. It will also define how to test their solutions from a scientific point of view and to verify that they satisfy the interest of end-users, all detailed in deliverable D6.1.

Task T6.2: Exascale capability simulation cases and Scientific Grand Challenges (M19-M48 | Lead: CNRS/LMU | Participants: CSIC, BSC, INGV, IMO, CIN, TUM, UMA, NGI, IRB, UM, SU). This task will run the 6 capability SCs. Among these, the target is to configure 4 of the SCs as Scientific Grand Challenges, i.e. as large-scale pre-exascale executions. However, production of SGCs will depend on the success in obtaining extreme-scale computational resources (see risk mitigation actions). The following SCs will be addressed: (SC1.1) (Lead: CNRS, potential SGC, code: SPECFEM3D) Anthropogenic noise and seismicity, wave propagation at higher frequencies in Rade d'Hyères to

obtain simulation results up to 100Hz; (SC2.1) (Lead: INGV, potential SGC, code: SPECFEM3D) Seismic tomography of the Adriatic-Ionian region to obtain full wave seismic anisotropic tomography of the Adriatic-Ionian lithosphere at 5 km resolution; (SC4.1) (Lead: NGI, potential SGC) Multi-source local high-resolution scenario with emphasis in the 2022 Tonga case for a high resolution coupling of flagship codes for acoustic pressure waves and seismic rupture (SeisSol), landslides (HySEA or ExaHype), and coupled far field tsunami propagation forced by atmospheric pressure waves (HySEA); (SC6.1) (Lead: INGV, code: OpenPDAC) Urgent high-resolution, 3D multiphase flow simulation of phreatic eruptions at Vulcano achieving a spatial resolution at ground in the metric range; (SC8.1) (Lead UM, potential SGC, code: LaMEM) Magmatic systems and induced landslides: the Etna case with a spatial resolution of around 50 meters to resolve the major faults; (SC8.2) (Lead: CNRS, code: pTatin3D) 3D evolution of tectonic deformation and rheology as driver of seismic hazard in the Hellenic arc to simulate the evolution of the tectonic structure of the upper plate of the Hellenic subduction zone in response to subduction dynamics from 35 Ma to the present day with a 1 km spatial resolution.

Task T6.3: Exascale capacity simulation cases (M19-M48 | Lead: INGV | Participants: CSIC, BSC, IMO, TUM, LMU, UMA, NGI, CNRS, IPGP, CSC). This task will run the 9 capacity SCs as ensemble workloads (not needing tight interconnection between runs) that integrate scalable multi-physics/multi-domain models for UC and natural hazard assessment. The following SCs will be addressed: (SC1.2) (Lead: LMU, code: Tandem, SeisSol, pTatin3D, SPECFEM3D) Next generation of earthquake simulators for the Hellenic arc and Iceland to perform hundreds of dynamic rupture earthquake and slip simulations across many cycles of earthquake sequences at the Hellenic Arc and the Southwest Iceland transform zone; (SC1.3) (Lead: LMU, code: SeisSol) Physics-based PSHA and urgent UQ for Iceland for short-term earthquake scenario modeling and ground motion simulations; (SC3.1) (Lead: INGV, code: HySEA) The Global Tsunami Hazard Map built upon 100,000 unit sources carried out on regional to global grids with resolutions of at least 30 arcseconds; (SC5.1) (Lead: INGV, code: FALL3D) The European tephra hazard map at a resolution of less than 10 km for European scale and 2 km at regional scale; (SC5.2) (Lead: CSIC, code: FALL3D) Volcanic gas dispersal at local scale: a reanalysis of the 2021 La Palma case at 1-2 km resolution making use of different observations available for tuning and verifying the model performance; (SC6.2) Long-term probabilistic hazard maps for phreatic eruptions at Vulcano island (Lead: INGV, code: OpenPDAC) considering hundreds to thousands ensemble of uncorrelated high-resolution, 3D numerical simulations of phreatic eruptions at Vulcano; (SC7.1) (Lead: CNRS, code: xSHELLS) MHD turbulence closure models in planetary cores using AI to obtain a catalog of time series and time-dependent 2D maps of the field and flow at the core surface; (SC9.1) (Lead: IMO, code: Elmer/Ice) Eastern Skaftá Cauldron GLOF simulation, Iceland with an estimated horizontal resolution of around 10 m; (SC9.2) (Lead: CNRS, code: Elmer/Ice) Calving glacier hazard in Greenland to quantify the hazard related to iceberg calving near the Bowdoin glacier in terms of generated water waves, sea ice cover and ocean layers perturbation.

Task T6.4: EuroHPC urgent computing service enabling (M25-M48 | Lead: BSC | Participants: CSIC, INGV, HLRS, CIN, LMU, NGI, CSC). This task will enable 4 UC services on target tier-0 EuroHPC pre-exascale architectures (Leonardo, LUMI, MN5) for an emergency access mode. Based on SCs 1.3, 4.1, 5.2, and 6.1, configurations for optimal time-to-solution will be considered and their usefulness for response scenarios evaluated. This will be done in collaboration with IUB members and exemplified by means of exercises. At the same time, a strong focus will be put on the enablement and technical requirements for an EU-level urgent access to HPC resources, including collaboration with the EuroHPC Infrastructure Advisory Group (INFRAG) for UC service certification, deployment, and access (Working Group).

Work package WP7 – Dissemination, outreach and capacity building

Work Package Number	WP7	Lead Beneficiary	2. BSC CNS
Work Package Name	Dissemination, outreach and capacity building		
Start Month	1	End Month	48

Objectives

1. Identify and perform communication and dissemination activities in order to maximize the impact of the project among scientific audiences and target end-user stakeholders.
2. Liaise and coordinate with Research Infrastructures (EPOS), federated environments (EOSC), and other EuroHPC and REA (Horizon Europe) research projects to align and synergize efforts.
3. Identify and perform training activities in cooperation with NCCs in order to engage interested parties in the usage of codes and use cases.

4. Carry out community building and roadmap activities, with the main output being the Galileo Conference already granted by the European Geosciences Union (EGU).
5. Identify the exploitable results of the project and define the potential commercial strategies and services for the ChEESE-2P results (market study, business models, distribution channels and promotional strategy) to reach the market.
6. Produce the 6 deliverables detailed below.

Description

Task T7.1: Dissemination and communication planning and tools (M1-M48 | Lead: CSIC | Participants: ALL). The objectives of this task will be to foster awareness of the project and to engage key stakeholders. The communication team will define the objectives of the communication plan (D7.2), identifying target audiences (e.g. geosciences and HPC scientific communities, policy makers/managers, industrial advisors, potential end-user SMEs and larger companies, and civil society in general) and setting out appropriate channels and messages to communicate with each of them, tailoring the activities and tools to achieve the objectives. The task will define a communication plan including: (1) creation and continuous update/population of the project website (D7.1), with clear information about the project and dissemination of project documents and results, (2) videos about the project for the general-public that will be posted in a dedicated channel, (3) a trimestral newsletter informing about the project progress and results, (4) online and printed materials (flyers, factsheets, booklets) to disseminate information about the project in international conferences and events. Additionally, tailored dissemination materials may be produced for specific relevant events (e.g. the EHPCSW), (5) creation of social media accounts (Twitter and LinkedIn) and continuous posting and activity throughout the project, (6) identifying target events where the project should be presented and peer-reviewed journals or special volumes to which papers can be submitted, (7) identifying outreach activities, such as school visits, roadshows, particularly if aligned with the ShEESE activities (see T1.3), (8) creation and distribution of press releases. All partners will participate in this task by translating and distributing press releases to national and local media, both generic and specialist, (9) a dissemination register will record all dissemination activities of ChEESE-2P partners, including publications. Acknowledgement of the funding sources will be included in all communication materials. The impact of all these activities will be carefully considered and the evolution of relevant KPIs monitored and quantified in a final report (D7.6).

Task T7.2: Liaison activities (M1-M48 | Lead: CSIC | Participants: BSC, INGV, HLRS, CIN, BA, CSC). Liaison officers will be appointed at the beginning of the project to coordinate and align with: (1) the Destination Earth (DestinE) initiative of the Digital Europe Programme and, in particular, with the digital twins on geophysical extremes, atmosphere, and ocean. The project officer has already been appointed as a member of the External Advisory Board (EAB) of DestinE, (2) the currently 33 National Competence Centres (NCCs) set up through the RIA EuroCC project and supported by the CSA CASTIEL. The NCCs have established European-level collaborations between each other through the project CASTIEL (or resulting CSA in the present call), for instance, in the form of mentoring and twinning activities, but also networking in the form of joint events and other collaborative activities. Liaison activities will identify NCCs with interest in the two specific topics of geophysics and emergency management; a survey will be conducted at the beginning of the project. Based on the results, twinning between NCCs on a similar level and mentoring or training between NCCs with different levels will be established. Joint dissemination and collaboration events should accompany these activities to promote the European community in HPC, HPDA and AI within geophysics and emergency management, (3) other EuroHPC and REA (H2020/HE) projects that are particularly relevant to this proposal, e.g. EuPILOT, EuPEX, eFlows4HPC, DT-GEO, Geo-INQUIRE, EsiWACE3 (if funded) and (4) the European Plate Observing System (EPOS) distributed RI and European Open Science Cloud (EOSC).

Task T7.3: Training activities (M6-M42 | Lead BSC | Participants: CSIC, INGV, HLRS, CIN, TUM, LMU, UMA, CNRS, CSC, UM, SU). This task will include identifying the training needs of researchers and other target audiences, as well as the organization and logistical support of the training courses. The target is to organize 8 trainings, including 2 more editions of the successful ChEESE-1P Advanced Training on HPC for Computational Seismology. The courses will be organized in collaboration with the NCCs and the PRACE Advanced Training Centers (PATC) infrastructure, should it still be in operation when the project is granted. While the consortium prefers to organize face-to-face training, online or hybrid versions will also be considered, depending on the need. Reports regarding the satisfaction and feedback of participants will be created after each course and these will be compiled in the Training Report (D7.5), submitted at M48.

Task T7.4: Community building and roadmap activities (M1-M48 | Lead: BSC | Participants: ALL). In order to articulate the SE community around HPC, there is a need to bring together Earth observatories (e.g. monitoring networks, data providers, tsunami warning centres, etc.), research and academia, model developers, model end-users and social agents. One of the main outputs of this task is the organization and execution of the Galileo Conference titled “Solid Earth and Geohazards in the Exascale Era”. This prestigious conference has already been granted by the European Geosciences Union (EGU) and will take place in May 2023. This conference will bring together senior researchers, early career scientists and policymakers in 4 areas: (i) preparation and optimization of HPC codes to Exascale, (ii) edge-to-end data

workflows, (iii) state-of-the-art in computational geosciences and, (iv) Horizon Europe and EuroHPC Policies. The conference will produce a whitepaper (roadmap) for the SE and geohazards community for reaching exascale. This whitepaper will be submitted to various technical press and translated into Spanish for the local media. Besides the Galileo Conference, other events such as seminars will be considered for ChEESE-2P community building activities.

Task T7.5: Sustainability plan (M25-M48 | Lead: BSC | Participants: CSIC). This task will identify all project exploitable outcomes, including interim and final results, with emphasis on the PD and services. It will conclude on potential commercial services, business ideas, exploitation pathways and strategies to ensure the sustainability for most relevant innovations of the project. Through this task, the ChEESE-2P consortium will build a deep understanding of the project market and exploitation context, aiming at providing a solid base for further exploitation actions. The main activities are: (1) Analysis of the exploitation context to find out what is the actual market situation for the different codes and applications covered by the CoE. The potential target markets (or target users) and the early adopters will be identified and analyzed. (2) end-users engagement to identify the various target audiences related to industry (HPC vendors, HPC users and combustion-related industry that covers the SE community), academia, public bodies and policy makers. This task will also orchestrate the IUB, oriented at institutional level, as well as the SAB. (3) Exploitation strategy. Based on the exploitation context analysis, an Exploitation Plan will be produced (D7.4) including the different long-term sustainability options for the outcomes as well as for ChEESE-2P itself (e.g. creation of a non-profit “ChEESE Foundation”). (4) IP strategy. The IP status of the project codes and technologies will be identified and an appropriate protection strategy will be established to ensure an appropriate technology transfer. Initially, an IPR repository will be created in compliance with Horizon Europe and Consortium rules. It will include the type of licensing, user support for the application codes developed and guidelines and recommendations of good practices. This will be provided by ChEESE-2P experts involved in the technical work packages and code developers. This support will be complementary to the general user support provided by HPC infrastructures and to domain-specific user support provided by other Centres of Excellence. (5) Advisory days. The members of the IUB and SAB will be invited to follow-up the outcomes of the project in annual Industry Day meetings held during the 3 GAs (open also to any interested company). (6) Synergies in the field of sustainability with major European projects and initiatives will be coordinated under T7.2 (Liaison Activities) but with the support of T7.4. The interaction with other HPC and SE-related initiatives will not only actively promote joint publications and training, but further joint service-oriented strategies.

Task 7.6: Collaboration task with complementary projects (M1-M48 | Lead: CSIC | Participants: ALL). This task will: (1) actively contribute to the coordination activities with complementary projects, (2) contribute to the knowledge pool and available information to the common portal C2ISS, (3) establish effective collaborations and jointly addressing cross-cutting issues and participate in regular meetings to plan, implement and monitor collaborations and to synchronise research and development activities, (4) participate in benchmarking exercises and share results and best practices as relevant, (5) promote joint publication and dissemination of results and joint events, (6) actively contribute to a common continuous integration of the flagship codes specified in Table A1 (Part B) and application deployment platform with automated testing (e.g., using Special Access scheme in collaboration with CASTIEL 2) at least on all EuroHPC JU systems and, finally (7) establish common best practices for IP management and development including effective measures to ensure code quality, reviews, testing, management and development cycles, (8) actively advancing modularisation: implementation of concrete measures for identification of common routines/algorithms/modules, creation and extension of software libraries used by multiple codes across disciplines.

STAFF EFFORT

Staff effort per participant								
Grant Preparation (Work packages - Effort screen) — Enter the info.								
Participant	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total Person-Months
1 - CSIC	48.00	12.00	6.00	6.00	24.00	12.00	12.00	120.00
2 - BSC CNS	2.00	18.00	12.00	6.00	18.00	18.00	32.00	106.00
3 - INGV	2.00	18.00		6.00	24.00	36.00	2.00	88.00
4 - IMO	2.00				24.00	18.00	2.00	46.00
5 - USTUTT	2.00	18.00		42.00		4.00	2.00	68.00
6 - CINECA	2.00	67.00	12.00	12.00		3.00	2.00	98.00
7 - TUM	2.00	22.00	8.00		12.00	8.00	2.00	54.00
8 - LMU MUENCHEN	3.00	14.00	6.00	6.00	12.00	12.00	2.00	55.00
9 - UMA	2.00	12.00	6.00	6.00	18.00	12.00	2.00	58.00
10 - NGI	2.00			2.00	16.00	12.00	2.00	34.00
11 - CNRS	1.00	28.00	4.00	5.00	33.00	5.60	1.00	77.60
11.1 - IPGP	1.00	1.00		1.00	1.50	2.40	0.50	7.40
12 - BULL	2.00	14.00	30.00				2.00	48.00
13 - CSC	2.00	8.00			16.00	6.00	2.00	34.00
14 - RBI	2.00			2.00	24.00	6.00	2.00	36.00
15 - UM	2.00	8.00			6.00	6.00	2.00	24.00
16 - SU	1.00	7.00	2.00		7.00	4.00	1.00	22.00
Total Person-Months	78.00	247.00	86.00	94.00	235.50	165.00	70.50	976.00

LIST OF DELIVERABLES

Deliverables <i>Grant Preparation (Deliverables screen) — Enter the info.</i> <i>The labels used mean:</i> <i>Public — fully open (🚩 automatically posted online)</i> <i>Sensitive — limited under the conditions of the Grant Agreement</i> <i>EU classified —RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision 2015/444</i>						
Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D1.1	Project Management and Quality Guidelines	WP1	1 - CSIC	R — Document, report	PU - Public	2
D1.2	First Data Management Plan	WP1	1 - CSIC	DMP — Data Management Plan	PU - Public	6
D1.3	Mid-term report	WP1	1 - CSIC	R — Document, report	SEN - Sensitive	25
D1.4	Final Data Management Plan	WP1	1 - CSIC	DMP — Data Management Plan	PU - Public	34
D1.5	Final report	WP1	1 - CSIC	R — Document, report	SEN - Sensitive	48
D2.1	First code audit report	WP2	5 - USTUTT	R — Document, report	PU - Public	12
D2.2	First report on improving code performance at exascale	WP2	6 - CINECA	R — Document, report	PU - Public	24
D2.3	Second code audit report	WP2	5 - USTUTT	R — Document, report	PU - Public	30
D2.4	Final report on improving code performance at exascale and Best Practice Guide	WP2	6 - CINECA	R — Document, report	PU - Public	48
D3.1	Selected set of mini-apps and its requirements	WP3	6 - CINECA	R — Document, report	PU - Public	12
D3.2	SE Community applications on European HPC technologies	WP3	12 - BULL	R — Document, report	PU - Public	42

Deliverables

Grant Preparation (Deliverables screen) — Enter the info.

The labels used mean:

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Sensitive — limited under the conditions of the Grant Agreement

EU classified — RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision [2015/444](#)

Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D4.1	Initial report on workflow setups and workflow auditing	WP4	5 - USTUTT	R — Document, report	PU - Public	18
D4.2	Plan for development and deployment tool usage for workflows and software	WP4	6 - CINECA	R — Document, report	PU - Public	20
D4.3	Intermediate report on workflow setups and optimization	WP4	5 - USTUTT	R — Document, report	PU - Public	30
D4.4	Final report on workflow implementation and optimization	WP4	5 - USTUTT	R — Document, report	PU - Public	42
D4.5	Final report on development and deployment activities	WP4	5 - USTUTT	R — Document, report	PU - Public	44
D5.1	New version release of flagship codes	WP5	7 - TUM	OTHER	PU - Public	24
D5.2	Demonstrator of PD1	WP5	7 - TUM	DEM — Demonstrator, pilot, prototype	PU - Public	30
D5.3	Demonstrator of PD4	WP5	10 - NGI	DEM — Demonstrator, pilot, prototype	PU - Public	30
D5.4	Demonstrator of PD6	WP5	3 - INGV	DEM — Demonstrator, pilot, prototype	PU - Public	30
D5.5	Demonstrator of PD7	WP5	11 - CNRS	DEM — Demonstrator, pilot, prototype	PU - Public	30

Deliverables

Grant Preparation (Deliverables screen) — Enter the info.

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D5.6	Demonstrator of PD8	WP5	15 - UM	DEM — Demonstrator, pilot, prototype	PU - Public	30
D5.7	Demonstrator of PD2	WP5	11 - CNRS	DEM — Demonstrator, pilot, prototype	PU - Public	36
D5.8	Demonstrator of PD3	WP5	9 - UMA	DEM — Demonstrator, pilot, prototype	PU - Public	36
D5.9	Demonstrator of PD5	WP5	4 - IMO	DEM — Demonstrator, pilot, prototype	PU - Public	36
D5.10	Demonstrator of PD9	WP5	13 - CSC	DEM — Demonstrator, pilot, prototype	PU - Public	36
D6.1	Simulation Cases and Trials definition	WP6	3 - INGV	R — Document, report	PU - Public	18
D6.2	SCs report and datasets from PD1	WP6	8 - LMU MUENCHEN	R — Document, report	PU - Public	46
D6.3	SCs report and datasets from PD2	WP6	3 - INGV	R — Document, report	PU - Public	46
D6.4	SCs report and datasets from PD3	WP6	9 - UMA	R — Document, report	PU - Public	46
D6.5	SCs report and datasets from PD4	WP6	14 - RBI	R — Document, report	PU - Public	46
D6.6	SCs report and datasets from PD5	WP6	1 - CSIC	R — Document, report	PU - Public	46
D6.7	SCs report and datasets from PD6	WP6	3 - INGV	R — Document, report	PU - Public	46
D6.8	SCs report and datasets from PD7	WP6	1 - IPGP	R — Document, report	PU - Public	46

Deliverables

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D6.9	SCs report and datasets from PD8	WP6	16 - SU	R — Document, report	PU - Public	46
D6.10	SCs report and datasets from PD9	WP6	4 - IMO	R — Document, report	PU - Public	46
D6.11	Open Hazard Maps	WP6	3 - INGV	DATA — data sets, microdata, etc	PU - Public	47
D6.12	Urgent computing service enabling	WP6	2 - BSC CNS	DEM — Demonstrator, pilot, prototype	PU - Public	48
D7.1	Project website	WP7	1 - CSIC	DEC — Websites, patent filings, videos, etc	PU - Public	2
D7.2	Communication and Dissemination Plan	WP7	1 - CSIC	R — Document, report	PU - Public	3
D7.3	Collaboration plan with complementary projects	WP7	1 - CSIC	R — Document, report	PU - Public	6
D7.4	Training Plan	WP7	2 - BSC CNS	R — Document, report	PU - Public	8
D7.5	Preliminary exploitation plan	WP7	2 - BSC CNS	R — Document, report	PU - Public	30
D7.6	Training Report	WP7	8 - LMU MUENCHEN	R — Document, report	PU - Public	42
D7.7	Exploitation Plan	WP7	2 - BSC CNS	R — Document, report	PU - Public	47
D7.8	Communication and Dissemination Report	WP7	1 - CSIC	R — Document, report	PU - Public	48

Deliverable D1.1 – Project Management and Quality Guidelines

Deliverable Number	D1.1	Lead Beneficiary	1. CSIC
Deliverable Name	Project Management and Quality Guidelines		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	2	Work Package No	WP1

Description
Project's internal management procedures defined in T1.1, detailing the project's quality assurance process as well as a detailed risk evaluation and internal communication tools and mechanisms

Deliverable D1.2 – First Data Management Plan

Deliverable Number	D1.2	Lead Beneficiary	1. CSIC
Deliverable Name	First Data Management Plan		
Type	DMP — Data Management Plan	Dissemination Level	PU - Public
Due Date (month)	6	Work Package No	WP1

Description
A first version of the dynamic DMP analysing the requirements of the science use cases and the data generation and exploitation. Includes identification of state-of-the-art metadata specifications

Deliverable D1.3 – Mid-term report

Deliverable Number	D1.3	Lead Beneficiary	1. CSIC
Deliverable Name	Mid-term report		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	25	Work Package No	WP1

Description
Technical report describing the activities performed during the first half of the project (M24), and a financial report containing the financial statements and explanation of the use of resources per beneficiary

Deliverable D1.4 – Final Data Management Plan

Deliverable Number	D1.4	Lead Beneficiary	1. CSIC
Deliverable Name	Final Data Management Plan		
Type	DMP — Data Management Plan	Dissemination Level	PU - Public
Due Date (month)	34	Work Package No	WP1

Description

Updated (final) version of the DMP.

Deliverable D1.5 – Final report

Deliverable Number	D1.5	Lead Beneficiary	1. CSIC
Deliverable Name	Final report		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	48	Work Package No	WP1

Description

Technical report describing the project activities performed up to the end of the project, and a financial report containing the financial statements and explanation of the use of resources per beneficiary

Deliverable D2.1 – First code audit report

Deliverable Number	D2.1	Lead Beneficiary	5. USTUTT
Deliverable Name	First code audit report		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	12	Work Package No	WP2

Description

First code audit round results and the recommendations arising from the analysis

Deliverable D2.2 – First report on improving code performance at exascale

Deliverable Number	D2.2	Lead Beneficiary	6. CINECA
Deliverable Name	First report on improving code performance at exascale		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	24	Work Package No	WP2

Description

Report on porting, optimisation and tuning for the selected applications on the available hardware

Deliverable D2.3 – Second code audit report

Deliverable Number	D2.3	Lead Beneficiary	5. USTUTT
Deliverable Name	Second code audit report		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP2

Description

Update of D2.1 and further recommendations arising from the analysis
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Deliverable D2.4 – Final report on improving code performance at exascale and Best Practice Guide

Deliverable Number	D2.4	Lead Beneficiary	6. CINECA
Deliverable Name	Final report on improving code performance at exascale and Best Practice Guide		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	48	Work Package No	WP2

Description

Technical report describing the achieved scalability level and related performances obtained for the selected applications on the available hardware including a final Best Practice guide

Deliverable D3.1 – Selected set of mini-apps and its requirements

Deliverable Number	D3.1	Lead Beneficiary	6. CINECA
Deliverable Name	Selected set of mini-apps and its requirements		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	12	Work Package No	WP3

Description

Report presenting the mini-apps selected for co-design with EuPEX, EPI, and EuPilot activities and their software requirements

Deliverable D3.2 – SE Community applications on European HPC technologies

Deliverable Number	D3.2	Lead Beneficiary	12. BULL
Deliverable Name	SE Community applications on European HPC technologies		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	42	Work Package No	WP3

Description

Lessons learnt to use the prototypes from EuPEX and EuPilot, performance evaluation, and analysis for mini-apps and feedback to developers and technology providers.

Deliverable D4.1 – Initial report on workflow setups and workflow auditing

Deliverable Number	D4.1	Lead Beneficiary	5. USTUTT
Deliverable Name	Initial report on workflow setups and workflow auditing		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	18	Work Package No	WP4

Description
Report describing the initial workflows and their set up including audit results for (selected) workflows identifying potential for improvements in components and inter-component interaction.

Deliverable D4.2 – Plan for development and deployment tool usage for workflows and software

Deliverable Number	D4.2	Lead Beneficiary	6. CINECA
Deliverable Name	Plan for development and deployment tool usage for workflows and software		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	20	Work Package No	WP4

Description
Report outlining intended code/workflow development and deployment tools in T4.3, for use with PDs/SCs

Deliverable D4.3 – Intermediate report on workflow setups and optimization

Deliverable Number	D4.3	Lead Beneficiary	5. USTUTT
Deliverable Name	Intermediate report on workflow setups and optimization		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP4

Description
Report summarising changes, improvements and optimisations made to workflows including the adaptation of new deployment methods, e.g., container technologies

Deliverable D4.4 – Final report on workflow implementation and optimization

Deliverable Number	D4.4	Lead Beneficiary	5. USTUTT
Deliverable Name	Final report on workflow implementation and optimization		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	42	Work Package No	WP4

Description
Comparison of final implementations and improvements against the initial workflows. Report on time savings beside main codes (covered by WP2)

Deliverable D4.5 – Final report on development and deployment activities

Deliverable Number	D4.5	Lead Beneficiary	5. USTUTT
Deliverable Name	Final report on development and deployment activities		
Type	R — Document, report	Dissemination Level	PU - Public

Due Date (month)	44	Work Package No	WP4
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Description
Overview of adaptation and use of development and deployment tools in the project

Deliverable D5.1 – New version release of flagship codes

Deliverable Number	D5.1	Lead Beneficiary	7. TUM
Deliverable Name	New version release of flagship codes		
Type	OTHER	Dissemination Level	PU - Public
Due Date (month)	24	Work Package No	WP5

Description
Code version releases with the new functionalities available in the ChEESE-2P Zenodo repository

Deliverable D5.2 – Demonstrator of PD1

Deliverable Number	D5.2	Lead Beneficiary	7. TUM
Deliverable Name	Demonstrator of PD1		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP5

Description
Demonstrator on extreme-scale modeling of seismic hazards

Deliverable D5.3 – Demonstrator of PD4

Deliverable Number	D5.3	Lead Beneficiary	10. NGI
Deliverable Name	Demonstrator of PD4		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP5

Description
Demonstrator on complex multi-source tsunami modeling

Deliverable D5.4 – Demonstrator of PD6

Deliverable Number	D5.4	Lead Beneficiary	3. INGV
Deliverable Name	Demonstrator of PD6		

Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP5

Description
Demonstrator on multiphase 3D volcanic explosion modeling

Deliverable D5.5 – Demonstrator of PD7

Deliverable Number	D5.5	Lead Beneficiary	11. CNRS
Deliverable Name	Demonstrator of PD7		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP5

Description
Demonstrator on the Earth's dynamo model

Deliverable D5.6 – Demonstrator of PD8

Deliverable Number	D5.6	Lead Beneficiary	15. UM
Deliverable Name	Demonstrator of PD8		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP5

Description
Demonstrator on geodynamics to geohazards

Deliverable D5.7 – Demonstrator of PD2

Deliverable Number	D5.7	Lead Beneficiary	11. CNRS
Deliverable Name	Demonstrator of PD2		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP5

Description
Demonstrator on high-resolution seismic inversion and tomography

Deliverable D5.8 – Demonstrator of PD3

Deliverable Number	D5.8	Lead Beneficiary	9. UMA
Deliverable Name	Demonstrator of PD3		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP5

Description
Demonstrator on global probabilistic tsunami hazard and uncertainty quantification

Deliverable D5.9 – Demonstrator of PD5

Deliverable Number	D5.9	Lead Beneficiary	4. IMO
Deliverable Name	Demonstrator of PD5		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP5

Description
Demonstrator on ensemble-based volcanic dispersal across multiple scales

Deliverable D5.10 – Demonstrator of PD9

Deliverable Number	D5.10	Lead Beneficiary	13. CSC
Deliverable Name	Demonstrator of PD9		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP5

Description
Demonstrator on glacial outburst floods

Deliverable D6.1 – Simulation Cases and Trials definition

Deliverable Number	D6.1	Lead Beneficiary	3. INGV
Deliverable Name	Simulation Cases and Trials definition		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	18	Work Package No	WP6

Description
Report on the methodology and precise setup for the production runs

Deliverable D6.2 – SCs report and datasets from PD1

Deliverable Number	D6.2	Lead Beneficiary	8. LMU MUENCHEN
Deliverable Name	SCs report and datasets from PD1		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD1 (SC1.1, SC1.2, SC1.3)

Deliverable D6.3 – SCs report and datasets from PD2

Deliverable Number	D6.3	Lead Beneficiary	3. INGV
Deliverable Name	SCs report and datasets from PD2		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD2 (SC2.1). Lead: INGV

Deliverable D6.4 – SCs report and datasets from PD3

Deliverable Number	D6.4	Lead Beneficiary	9. UMA
Deliverable Name	SCs report and datasets from PD3		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD3 (SC3.1). Lead: UMA

Deliverable D6.5 – SCs report and datasets from PD4

Deliverable Number	D6.5	Lead Beneficiary	14. RBI
Deliverable Name	SCs report and datasets from PD4		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD4 (SC4.1). Lead: IRB

Deliverable D6.6 – SCs report and datasets from PD5

Deliverable Number	D6.6	Lead Beneficiary	1. CSIC
Deliverable Name	SCs report and datasets from PD5		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD5 (SC5.1, SC5.2). Lead: CSIC

Deliverable D6.7 – SCs report and datasets from PD6

Deliverable Number	D6.7	Lead Beneficiary	3. INGV
Deliverable Name	SCs report and datasets from PD6		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD6 (SC6.1, SC6.2). Lead: INGV

Deliverable D6.8 – SCs report and datasets from PD7

Deliverable Number	D6.8	Lead Beneficiary	1. IPGP
Deliverable Name	SCs report and datasets from PD7		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
D6.8: SCs report and datasets from PD7 (SC7.1). Lead: IPGP

Deliverable D6.9 – SCs report and datasets from PD8

Deliverable Number	D6.9	Lead Beneficiary	16. SU
Deliverable Name	SCs report and datasets from PD8		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD8 (SC8.1, SC8.2). Lead: SU

Deliverable D6.10 – SCs report and datasets from PD9

Deliverable Number	D6.10	Lead Beneficiary	4. IMO
Deliverable Name	SCs report and datasets from PD9		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	46	Work Package No	WP6

Description
SCs report and datasets from PD9 (SC9.1, SC9.2). Lead: IMO

Deliverable D6.11 – Open Hazard Maps

Deliverable Number	D6.11	Lead Beneficiary	3. INGV
Deliverable Name	Open Hazard Maps		
Type	DATA — data sets, microdata, etc	Dissemination Level	PU - Public
Due Date (month)	47	Work Package No	WP6

Description
Global Tsunami HM (SC3.1) and European Tephra HM (SC5.1) for EPOS TCS

Deliverable D6.12 – Urgent computing service enabling

Deliverable Number	D6.12	Lead Beneficiary	2. BSC CNS
Deliverable Name	Urgent computing service enabling		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	48	Work Package No	WP6

Description
Report and demonstrators on user-driven UC services and policy recommendations

Deliverable D7.1 – Project website

Deliverable Number	D7.1	Lead Beneficiary	1. CSIC
Deliverable Name	Project website		
Type	DEC — Websites, patent filings, videos, etc	Dissemination Level	PU - Public
Due Date (month)	2	Work Package No	WP7

Description
Creation of the project website with information about the project (first version, continuously updated up to M48)

Deliverable D7.2 – Communication and Dissemination Plan

Deliverable Number	D7.2	Lead Beneficiary	1. CSIC
Deliverable Name	Communication and Dissemination Plan		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	3	Work Package No	WP7

Description
Report detailing activities to be undertaken as part of an overall project communication strategy and provide guidance to ensure that all communications reflect the project's identity

Deliverable D7.3 – Collaboration plan with complementary projects

Deliverable Number	D7.3	Lead Beneficiary	1. CSIC
Deliverable Name	Collaboration plan with complementary projects		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	6	Work Package No	WP7

Description
Collaboration plan with complementary projects defining common objectives and activities, including milestones

Deliverable D7.4 – Training Plan

Deliverable Number	D7.4	Lead Beneficiary	2. BSC CNS
Deliverable Name	Training Plan		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	8	Work Package No	WP7

Description
Outlines the target audiences, topics and learning outcomes of the project's training activities. A timeline with estimated dates of the courses will be included.

Deliverable D7.5 – Preliminary exploitation plan

Deliverable Number	D7.5	Lead Beneficiary	2. BSC CNS
Deliverable Name	Preliminary exploitation plan		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	30	Work Package No	WP7

Description
First version of the exploitation plan (to be updated by a second deliverable)

Deliverable D7.6 – Training Report

Deliverable Number	D7.6	Lead Beneficiary	8. LMU MUENCHEN
Deliverable Name	Training Report		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	42	Work Package No	WP7

Description
Document compiling all the feedback gathered from participants and the actions the project has taken to address them. Recommendations on how to improve courses and training topics to explore will be included

Deliverable D7.7 – Exploitation Plan

Deliverable Number	D7.7	Lead Beneficiary	2. BSC CNS
Deliverable Name	Exploitation Plan		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	47	Work Package No	WP7

Description
Plans for exploiting the project outcomes, market analysis, identifying potential users and early adopters, and plans to work with other EU initiatives. Exploitation plans and reports of partners as well as a reference to the regularly updated IPR Log

Deliverable D7.8 – Communication and Dissemination Report

Deliverable Number	D7.8	Lead Beneficiary	1. CSIC
Deliverable Name	Communication and Dissemination Report		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	48	Work Package No	WP7

Description
Report on all activities undertaken in T7.1 and T7.2 from M1 to M48

LIST OF MILESTONES

Milestones					
<i>Grant Preparation (Milestones screen) — Enter the info.</i>					
Milestone No	Milestone Name	Work Package No	Lead Beneficiary	Means of Verification	Due Date (month)
1	Project setup phase	WP7, WP1	1-CSIC	Internal management and communication tools in place, website operative, communication, data management and training plans defined (D1.1, D1.2, D7.1, D7.2, D7.3)	8
2	Preparation of mini-apps	WP3	6-CINECA	Effective co-design with EuroHPC Pilots can start (D3.1)	18
3	Flagship code functionalities	WP5	11-CNRS	Code version releases with the new functionalities (physics) available repository (D5.1)	24
4	Mid-term review meeting	WP5, WP3, WP6, WP7, WP2, WP4, WP1	1-CSIC	Check of the project program development (D1.3)	25
5	Exascale code preparation	WP2	6-CINECA	Improvements in the flagship codes performance metrics after the second code audit round (D2.2, D2.3)	36
6	Exascale pilot deployment	WP5, WP4	11-CNRS	PDs tested successfully (D4.4, D5.2 to D5.10)	42
7	Production runs	WP6	3-INGV	SCs executed, EOSC-enabled datasets produced (D6.x)	48
8	Community building and Sustainability	WP5, WP6, WP7, WP4, WP1	2-BSC CNS	UC services enabled, evaluation exercises with IUB members done, effective liaison with ecosystem initiatives, training completed	48
9	Complementary Grants	WP7	1-CSIC	Collaboration agreement has been signed	6
10	Application deployment	WP4	5-USTUTT	Applications developed by ChEESE-2P (see Table A1) made available to users of EuroHPC	12

Milestones					
<i>Grant Preparation (Milestones screen) — Enter the info.</i>					
Milestone No	Milestone Name	Work Package No	Lead Beneficiary	Means of Verification	Due Date (month)
				JU systems via automated deployment platform, including documentation for users, required software stack, automated testing and quality checks.	

LIST OF CRITICAL RISKS

Critical risks & risk management strategy			
<i>Grant Preparation (Critical Risks screen) — Enter the info.</i>			
Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
1	New covid-19 outbreaks	WP5, WP3, WP6, WP7, WP2, WP4, WP1	Cancel F2F meetings. Low severity regarding other aspects
2	Delay in recruitment and appointment of new personnel	WP1	Partners already have personnel with required experience. Partners will start recruiting as soon as possible (GA signature or project start)
3	A partner is not collaborating as expected or conflicts among partners	WP1	The PC will call an urgent PSB meeting to take corrective measures
4	POP3 proposal is not funded. This risk has materialised.	WP2	POP metrics are already well defined. BSC, CIN, HLRS and CSC have the skills, personnel and material to perform this task independently
5	Uncertain workload for code performance improving	WP2	Sub-tasks in WP2 that serve to a larger number of codes will be prioritized

Critical risks & risk management strategy <i>Grant Preparation (Critical Risks screen) — Enter the info.</i>			
Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
6	Timeliness of availability and access to hardware prototypes from EuroHPC pilots	WP3	mini-apps can run on the already existing architectures
7	Fortran support for mini-app co-design is not ready yet (EuPilot SDVs)	WP3	This would affect only 2 of the mini-apps in WP3 (mini-SPECFEM3D and mini-FALL3D), kernels can be written in C/C++ alternatively.
8	Unsuccessful/delayed implementation of new code developments	WP5	Extend duration of T5.1. Reduce the coupling ambition of PDs.
9	Insufficient access to EuroHPC (and PRACE) computational resources, production runs and SGCs compromised	WP5, WP6, WP4	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
10	Key milestones or deliverables delayed	WP5, WP3, WP6, WP7, WP2, WP4, WP1	The PC and PEC will foresee problems and take early corrective measures in collaboration with the concerned partners

PROJECT REVIEWS

Project Reviews <i>Grant Preparation (Reviews screen) — Enter the info.</i>			
Review No	Timing (month)	Location	Comments
RV1	12	Luxembourg	
RV2	30	Luxembourg	
RV3	48	Luxembourg	

JU CONTRIBUTIONS

PIC	Legal Name	Membership	IKOP	Non-EU part of IKOP	Financial Contribution	IKAA
909875521	SORBONNE UNIVERSITE	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
996058081	BULL SAS	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
997168343	VEDURSTOFA ISLANDS	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
998866522	STIFTELSEN NORGES GEOTEKNISKE INSTITUTT	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999472675	ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999645820	CSC-TIETEEN TIETOTEKNIKAN KESKUS OY	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999655520	BARCELONA SUPERCOMPUTING CENTER-CENTRO NACIONAL DE SUPERCOMPUTACION	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999843409	CINECA CONSORZIO INTERUNIVERSITARIO	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999875031	RUDER BOSKOVIC INSTITUTE	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999898311	UNIVERSIDAD DE MALAGA	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999974747	UNIVERSITY OF STUTTGART	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999977463	TECHNISCHE UNIVERSITAET MUENCHEN	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999978433	LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999978627	JOHANNES GUTENBERG-UNIVERSITAT MAINZ	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00
999991722	AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	No	€ 19 009.00	€ 0.00	€ 0.00	€ 0.00
999997930	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	No	€ 0.00	€ 0.00	€ 0.00	€ 0.00

Center of Excellence for Exascale in Solid Earth - Second Phase (ChEESE-2P)

Associated with document Ref. Ares(2022)8497838 - 07/12/2022

Grant	Centers of Excellence for supporting supercomputing applications for Science and Innovation
Call ID	HORIZON-EUROHPC-JU-2021-COE-01
Call Topic	02
Proposal ID	SEP-210832925



HISTORY OF CHANGES		
date	Page/section	Nature of change and reason / justification of change proposed (if applicable)
26/09	List of participants	Added partner US as beneficiary No16 (this implies cost breakdown of CNRS partner) and partner IPGP as affiliated of CNRS
24/09	Annex	Added 2 Tables with the flagship applications (Table A1) and the showcases (Table A2)
29/09	Table 3.1a	List of WPs moved to Part A
29/09	Tables 3.1b	Tables with WP description moved to Part A
29/09	Table 3.1c	List of deliverables moved to Part A
29/09	Tables 3.1d	List of milestones moved to Part A
29/09	Tables 3.1f	List of staff effort (per WP) moved to Part A
29/09	staff effort	The former staff effort of partner CNRS (107 PM) has been modified and split between CNRS (77,6 PM), IPGP (7,4 PM), and US (22 PM)
20/10	System	New task 7.6 added to coordinate with CASTIEL2.
20/10	System	New deliverable added (new D4, D7.3)
20/10	System	2 new milestones added for collaboration agreement (M6) and application deployment (M12)
20/10	Section 1.1.2	A new specific objective SO15 added including KPIs for complementary grants
20/10	Ruder Boskovic	Acronym changed from IRB to RBI for consistency with the system

HISTORY OF CHANGES		
	Institute	
20/10	Sorbonne Université	Acronym changed from US to SU for consistency with the system
20/10	Section 3.1.3 and Table 2.3.4a	updated to reflect the changes in deliverables and addition of 1 extra task (T7.6 on complementary grants)
21/10	CNRS tasks	The contribution of CNRS (with 2 labs CNRS-LMA and CNRS-ISTERRE) and its beneficiary entity (CNRS-IPGP) has been made explicit in the system and in Table 3.2.4
16/11	Table 1.1.2	Added 2 more KPIs
16/11	Task 7.6	reformulated according to PO suggestions
16/11	D5.2	Changed to TUM
02/12	D1.4	Added a second deliverable for the DMP at M34
02/12	Budget	Changed equipment and other cost categories to accommodate to the EuroHPC call requirements
02/12	Preamble	Added a Preamble to clarify that activities are constrained to EuroHPC eligible countries only
03/12	Budget	Removed the sentence that included a 10.000€ flat rate for open source publications
03/12	KPIs	KPIs for publications in Table 2.2.2b lowered to 25 because of the budget limitation

Preamble

All activities set out in this Description of Action (DoA) will be performed within the countries eligible for participation in the call HORIZON-EUROHPC-JU-2021-COE-01, including travel, missions, meetings and collaborations.

Participant No.	Participant organization name	Short name	Country
1	Consejo Superior Investigaciones Científicas	CSIC	Spain
2	Barcelona Supercomputing Center	BSC	Spain
3	Istituto Nazionale di Geofisica e Vulcanologia	INGV	Italy
4	Icelandic Meteorological Office	IMO	Iceland
5	University of Stuttgart - High Performance Computing Center	HLRS	Germany
6	CINECA	CIN	Italy
7	Technical University of Munich	TUM	Germany
8	Ludwig-Maximilians Universität München	LMU	Germany
9	University of Malaga	UMA	Spain
10	Norwegian Geotechnical Institute	NGI	Norway
11	National Center for Scientific Research	CNRS	France
11.1	Institut de Physique du Globe de Paris	IPGP	France
12	BULL SAS	BA	France
13	CSC	CSC	Finland
14	Ruder Bošković Institut	RBI	Croatia
15	University of Mainz	UM	Germany
16	Sorbonne Universite	SU	France

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List of acronyms

AI	Artificial Intelligence
CA	Consortium Agreement
CoE	Center of Excellence
CI	Continuous Integration
CD	Continuous Deployment
CERIF	Common European Research Information Format
CRIS	Current Research Information Systems
CS	Computational Seismology
DMP	Data Management Plan
DRR	Disaster Risk Reduction
EC	Equality Committee
ECC	Exascale Computational Challenge
EOSC	European Open Science Cloud
EPOS	European Plate Observing System
EPI	European Processor Initiative
ERIC	European Research Infrastructure Consortium
EGU	European Geosciences Union
ERCC	Emergency Response Coordination Center
EWS	Early Warning System
EuroHPC	European High Performance Computing JU
FAIR	Findable, Accessible, Interoperable and Reusable
FTRT	Faster Than Real Time
FWI	Full-Waveform Inversion
GA	General Assembly. Also Grant Agreement (depending on context)
GLOF	Glacier Outburst Flood
GTM	Global Tsunami Model
HPC	High Performance Computing
HPDA	High Performance Data Analytics
ICS	(EPOS) Integrated Core Services
IUB	Industry and Users Board
IPR	Intellectual Protection Rights
KPI	Key Performance Indicator
MHD	Magnetohydrodynamics
ML	Machine Learning
MN	MareNostrum (machines)
MPI	Message Passing Interface
MUQ	MIT Uncertainty Quantification

NCC	National Competence Centers	 Associated with document Ref. Ares(2022)8497838 - 07/12/2022
NN	Neural Network	
PATC	PRACE Advanced Training Courses	
PC	Project Coordinator	
PD	Pilot Demonstrator	
PEC	Project Executive Committee	
PETSc	Portable, Extensible Toolkit for Scientific Computation	
POP	Performance Optimisation and Productivity	
PSB	Project Supervisory Board	
PSHA	Probabilistic Seismic Hazard Assessment	
PTHA	Probabilistic Tsunami Hazard Assessment	
PVHA	Probabilistic Volcanic Hazard Assessment	
PTF	Probabilistic Tsunami Forecast	
RDA	Research Data Alliance	
RI	Research Infrastructure	
SAB	Scientific Advisory Board	
SC	Simulation Case	
SCEC	Southern California Earthquake Center	
SDV	Software Development Vehicles	
SE	Solid Earth	
SGC	Scientific Grand Challenge	
SO	Specific Objectives	
TCS	(EPOS) Thematic Core Services	
TRL	Technology Readiness Level	
UC	Urgent Computing	
UQ	Uncertainty Quantification	
WMS	Workflow Manager System	
WP	Work Package	
WPL	Work Package Leader	
YATeTo	Yet Another Tensor Toolbox	

Introduction and Motivation

This HORIZON-JTI-EuroHPC-2021-COE-01-02 call proposal aims at implementing the second phase of the Center of Excellence for Exascale in Solid Earth (ChEESE-2P). Solid Earth (SE) sciences address fundamental problems in understanding the formation, composition, and the dynamics of the geosphere from its deep interior to the surface. This encompasses also the study of geohazardous phenomena that originate in the Earth's interior but that manifest at the interface with the atmosphere, the hydrosphere, and the biosphere, causing a variety of natural hazards and geophysical extremes across all spatial and temporal scales. SE is extremely rich in computational challenges, requiring petascale and exascale infrastructures both to address fundamental scientific questions and to anticipate, mitigate, and manage the occurrence of geohazards and their impacts.

Why is a Center of Excellence on Solid Earth and geohazards needed?

There are at least 7 strong reasons that justify the sustainment of the Center of Excellence on SE:

1. SE and related geohazards are a continuous concern to society. Many parts of the world are exposed to geohazards such as earthquakes, tsunamis, landslides, volcanic activity, or geomagnetic variations, all with potential to trigger devastating effects at scales from local to global and to cause huge human and economic impacts due to the interconnected and interdependent nature of our modern society. Geophysical extremes caused at least 10% of the financial loss caused by all kinds of natural disasters worldwide (over 200 billion Euros in 2021, see e.g., the United Nations Global Assessment Reports on Disaster Risk Reduction), and with an increasing trend over recent decades. In Europe, examples of recent deadly earthquakes include the December 2020 6.4 Mw (moment magnitude scale) Petrinja event in central Croatia, the May 2012 5.8 Mw Emilia or the April 2009 6.3 Mw L'Aquila events in the Italian Apennines, and the August 1999 7.6 Mw in Izmit (Turkey), with an estimated toll of 17,000 fatalities. Volcanic activity threatens not only large European metropolises (e.g. Naples with 3 million people at risk from Vesuvius, Campi Flegrei and Ischia) and islands (e.g. Iceland, the Azores and the Canarian archipelagos, Aegean and Aeolian islands, French overseas territories) but the whole European airspace due to the atmospheric long-range dispersal of volcanic ash and aerosols, as demonstrated during the April-May 2010 Eyjafjallajökull eruption in Iceland. In 2021, the March-September and the September-December eruptions of Fagradalsfjall (Iceland) and Cumbre Vieja (La Palma) volcanoes reminded us of the tremendous impact that volcanic eruptions, even if moderate in intensity, can have on the local communities, properties, and infrastructures. The Cumbre Vieja eruption was also very illustrative in showing the tremendous value that urgent computing and HPC infrastructures can have in saving lives and livelihood. Tsunamis can cause oceanwide transnational disasters such as the March 2011 Tohoku event in Japan (20,000 fatalities, 360 billion US\$ cost) and the December 2004 Sumatra–Andaman tsunami (about 230,000 fatalities in 14 different countries across the Indian Ocean). In Europe, the 1755 Lisbon and 1908 Messina Strait tsunamis resulted in tens of thousands of fatalities. These events had complex generation mechanisms involving earthquakes, and for the 1908 event a cascading submarine landslide acted as a primary tsunami source. Recent destructive European tsunamis have also been caused by non-earthquake sources, including large landslides (e.g. a fatal tsunami in Karratfjorden, 2017, Greenland), or tsunamis induced by meteorological pressure fluctuations (e.g. Mediterranean and Black Sea, 2014). These examples indicate that geophysical extremes can be complex and also occur in combination, leading to multi-source and cascading events. To this end, the recent January 2022 Hunga Tonga submarine eruption entailed hydromagmatic explosions sending ash clouds to the stratosphere, atmospheric pressure shockwaves that were recorded across the world, and a volcano-triggered tsunami that reached the Pacific American shoreline, while the 2018 Palu tsunami involved a sequence of complex events from supershear earthquake propagation, liquefaction, landslides, and induced tsunamis. On the other hand, other less hazardous aspects of SE are also of societal concern and relevance. For example, local-scale Earth's subsurface imaging and characterization, e.g. using seismic tomography, has important implications in terms of exploitation and management of georesources and georeservoirs. Applications on geothermal energy, containment of underground waste, or carbon sequestration, among others, are totally aligned with the resource-efficient and competitive economy paradigm promoted by the European Green Deal. Finally, larger-scale regional tomography and geodynamic modeling are also pivotal to study more fundamental aspects like crustal plate tectonics, earthquake cycles over thousands of years, the loci and characteristics of volcanic zones, or the convective mechanisms in the Earth's outer core that yield to the generation and evolution of the Earth's magnetic field.

This proposal wants to continue raising our preparedness to cope with such high-impact events by better understanding/modeling the physical processes and its impacts, using High Performance Computing (HPC) to support informed-based policies on geohazard/georisk mitigation and adaptation and strengthen overall civil protection capabilities to protect citizens from geohazards. All these aspects are amongst the priority areas for action in the United Nations Disaster Risk Reduction Sendai Framework (2030 Agenda).

2. Supercomputers can save lives, but need tailored codes and workflows. Geohazardous phenomena (e.g. earthquakes, eruptions, tsunamis) require emergency simulations presently affordable with current pre-exascale systems (in terms of capability) but that need to be solved under strict time constraints. In these urgent computing applications, exascale resources can reduce substantially the time-to-solution and hence have the potential to substantially transform the way society deals with early warning, short-term forecast and emergency management. In the transition to exascale, scientists will be able to combine capability computing (higher resolution, increase degree of model sophistication, multiscale, multiphysics) and capacity computing (multiple scenarios to deal with uncertainties, data assimilation, fusion of models and observations and hybrids thereof) into products and services delivering to public authorities and decision-makers high-fidelity predictions under strict time constraints, thereby helping to save lives and livelihood. A CoE on SE is essential to promote and leverage an urgent computing access mode in the EuroHPC systems, a clear return to society of the investment that these large infrastructures entail. ChEESE-IP has been exemplary in this regard, e.g. by deploying the tsunami early warning systems or by furnishing operational services to authorities and decision makers during the 2021 eruption at La Palma, Canary Islands.

3. SE sciences require both capability and capacity exascale approaches. Scientific Grand Challenges (SGC) in SE involve multiple spatial scales that span orders of magnitude (from local to global), time ranges, multiphysics with complex couplings, forcings, non-linearities, and large data volumes, all relating to problems that are yet unaffordable by current pre-exascale machines in terms of capability. The solution of these exascale capability problems requires large monolithic executions, often with memory-bound (or IO bound) sub-tasks. On the other hand, SE problems also entail epistemic uncertainties due to the difficulties that we have in observing the current state of the system and in predicting its future behavior and aleatoric uncertainties that are intrinsic to the non-linear nature of the Earth's systems. Such uncertainties and non-linearities force scientists to use large ensembles of model realizations combined in a probabilistic framework, e.g. (1) in ensemble-based data assimilation schemes, (2) to solve inverse problems with large volumes of multi-source observations or, (3) in probabilistic long and short-term hazard assessment that combine many uncertain future scenarios. All these exascale capacity problems make use of complex workflows to orchestrate petascale (or pre-exascale) capability simulations that can aggregate into a final exascale workload (exascale workflow). Depending on the degree of coupling among single model realizations, these capacity workloads can range from tightly coupled, as in the case of ensemble-based data assimilation schemes (e.g. Kalman filters), to loosely coupled as in realizations of hazard scenarios. To this end, large-scale computing and data logistics are integral in SE to increasingly involve machine learning methods and intelligent immersive environments, enabling convergence of HPC and HPDA and the interoperability between programming models and data formats.

4. SE hosts numerous Exascale Computational Challenges (ECCs). Computational challenges in SE span a wide range of scales and disciplines and relate to fundamental scientific problems in understanding the Earth system from its core to the surface environment. A number of ECCs were already identified in ChEESE-IP that will be tackled also by this proposal.

In **Computational Seismology (CS)**, seismic wave simulations span an enormous range of spatial scales (from meters near the seismic source to hundreds/thousands of kilometers across the entire region of interest), timescales, and frequencies (from minutes for the Earth's normal modes up to ~10Hz to resolve frequencies important to civil engineering and impacts on buildings). This poses ECCs, e.g. for:

- **ECC1: Full-waveform inversion (FWI) and high-resolution sub-surface imaging.** Determining the Earth's structure involves thousands of forward wave propagation simulations through iterative inversion (optimisation) schemes to fit observations at thousands of receivers from natural earthquakes or man-made seismic sources. In turn, these forward propagation runs can pose a capability problem because the computational requirements scale with the cube of the characteristic length of the domain (ranging from km scale in local studies to the globe-scale) and with the fourth power of the maximum frequency attainable. ECC1 is also a prerequisite for producing "digital twins" for other ECCs in CS.
- **ECC2. Near real-time seismic scenarios.** Urgent computing simulations shortly after the occurrence of an earthquake can be invaluable for fast impact assessment and deployment of rescue teams on the ground. Ground motions at a given site and related impacts to buildings and infrastructures strongly depend on source, path, and site-specific subsurface geologic structures that must be model-resolved, requiring space-time resolution of tens/hundreds of meters and fractions of seconds in local-scale domains (i.e. a capability challenge case). Urgent seismic computing can also be considered in a probabilistic framework, i.e. as a capacity problem that combines pre-computed scenarios with early surface observations.
- **ECC3. Physics-based Probabilistic Seismic Hazard Assessment (PSHA).** Deterministic earthquake prediction is highly limited by large and inherent uncertainties, i.e., it is currently impossible to forecast where and when the next earthquake will occur and how hazardous it will be, and, therefore, empirical knowledge

and multiple physics-based scenarios have to be evaluated and combined in a probabilistic manner to determine relevant aspects such as estimates of rupture likelihood given seismological and geodetic observations, assessment of which regions will suffer stronger and sustained ground shaking, whether the expected shaking will happen at frequencies critical to building's resistance, or whether large collateral cascading effects such as tsunamis can be triggered.

In **tsunami modeling**, wave simulations also involve a wide range of spatial (from a few meters to thousands of kilometers) and temporal scales, uncertainties in the tsunamigenic source variability, as well as resolving physics related to the source, tsunami generation, and non-hydrostatic wave propagation.

- **ECC4. Near real-time tsunami source inversion and characterization.** Tsunamis can have different triggering mechanisms, e.g. seismic, landslides, volcanic, meteorological forcings (meteotsunamis). Inferring the tsunamigenic source features (e.g. fault slip distribution, slip direction, slip rate, rupture velocity) implies a nonlinear inversion of tsunami waveforms which, similarly to the ECC1, entails a nonlinear joint inversion of different geophysical data and the exploration of a vast parameter space.
- **ECC5. Faster Than Real Time (FTRT) tsunami scenarios.** The simulation of tsunamis in the framework of Early Warning Systems (EWS) is an urgent computing challenge in terms of increasing the size, complexity, and computational requirements of the problem under strict time-to-solution constraints (the target is to evacuate population before the coastal inundation occurs). Similar to the ECC2, a Probabilistic Tsunami Forecast (PTF) can also be contemplated in EWS relying on exascale capacity in order to build a database of pre-computed scenarios to rapidly assess site-specific inundation maps and impacts at different spatial scales (global, regional and local).
- **ECC6. Probabilistic Tsunami Hazard Assessment (PTHA).** Regional and local long-term probabilistic tsunami hazard assessment entails a very large number of scenarios owing to uncertainties in location and characteristics of the tsunamigenic sources. The capacity challenge is posed by the need to simulate the effect of a high number of tsunami sources for regional hazard and perform detailed spatial high-resolution inundation simulations.

In **numerical volcanology**, a myriad of computationally challenging problems exists linked to the several phenomena that can occur in volcanic systems, which display one of the most fascinating examples of multi-hazard and cascading effects.

- **ECC7: High-resolution atmospheric volcanic dispersal.** Volcanic eruptions can disperse particles (tephra), and aerosols at varying distances. Depending on the range, the dispersal and deposition mechanisms are driven by winds and meteorological phenomena ranging from local (e.g. orography and breeze effects) to global (general atmospheric circulation) scales. An urgent computing challenging aspect is how to make the extent of the phenomenon (from local up to thousands of km away from the volcano) compatible with the time-space scales of aircraft operations, which may need to consider in-flight rerouting.
- **ECC8: Volcanic explosions and interactions.** Volcanoes also display complex multiphase and multicomponent flows (e.g. pyroclastic density currents, lahars) that constitute the most dangerous proximal volcanic hazards. Capability challenges exist to model these multiphase thermally-coupled and highly turbulent fluids of compressible mixtures composed of gaseous components and solid particle phases. In turn, volcanic flows generated by explosive eruptions (e.g. phreatic) can further cascade into tsunami generation which entails a coupling between the two phenomena.
- **ECC9: Probabilistic Volcanic Hazard Assessment (PVHA).** As for seismics and tsunamis, volcanic hazard assessment is also a capacity challenge that requires thousands of physics-based model realizations to reduce meteorological and volcanological uncertainties on the hazard analysis and subsequent risk and financial loss estimations.

In **Magnetohydrodynamics (MHD)**, a scientific challenge is to understand the maintenance of the Earth's magnetic field against Ohmic decay, attributed to electric currents generated by convection of an iron alloy fluid surrounding the Planet's solid inner core.

- **ECC10: The dynamo model and the Earth's magnetic field evolution.** The MHD dynamo model couples the Navier-Stokes and the Maxwell equations to obtain the 3D evolution of the thermodynamic variables, the fluid velocity, and the magnetic field. On a longer timescale, a global convective dynamo simulation is a capability challenge not yet affordable in terms of the spatial resolution required to simulate turbulent convection in the Earth's low viscosity liquid core and the conditions that lead to geomagnetic reversals. Related to this, shorter term (decades) geomagnetic forecasts pose also a capability problem in which ensemble-based methods are adopted to predict fluctuations in the Earth's magnetic field that cause an increasing hazard to the ever-growing number of low-Earth orbiting satellites.

Finally, in **geodynamic modeling**, the deformation of the solid Earth is simulated on a wide range of scales, while taking the nonlinear (poro)-visco-elasto-plastic rheology of rocks, complicated geometries and large strains into account. The numerical approaches are applicable to a broad range of problems ranging from fluid flow through

porous rocks, landslides, the long-term safety of underground repositories, stresses within magmatic systems, or large-scale plate tectonic processes. Key challenges involve:

- **ECC11: Landslide triggering.** Large landslides can induce tsunamis (ECC4), but they also become an increasingly urgent problem in a warming climate. Simulating the observed slow ground motion before a catastrophic landslide event requires high-resolution 3D forward simulations that are sufficiently fast to perform sensitivity tests and estimate the effect of uncertainties (in material properties and geometry) on the surface deformation.
- **ECC12: Lithospheric stress states and induced seismicity.** The stress state within the lithosphere is governed by large-scale plate tectonic processes and plays an important role in determining where earthquakes initiate. There is thus a need for new methods that link plate tectonic processes occurring on geological timescales (which requires 3D forward runs with many time steps) with the initiation of earthquakes on seismic timescales (ECC3), while dealing with uncertainties.

5. SE applications (and workflows) are in a prominent position in the exascale roadmaps. SE has been traditionally a key ingredient of supercomputing roadmaps and initiatives in Europe and worldwide including, e.g. the European Extreme Data and Computing Initiative (EXDCI and EXDCI-2), the U.S. Exascale Computing Project (ECP), or the former International Exascale Software Project (IESP) and the Big Data and Extreme-scale Computing (BDEC) initiative. This prominent role is justified because several SE applications, e.g. seismic codes based on explicit time-domain solvers, are extremely scalable and amongst the most efficient parallel applications existing today in any field of science, something that becomes evident by looking at the number of SE applications winning the Gordon Bell prize (e.g. seismics in 2017 and 2003, geodynamics in 2015, dynamo model in 2004), the NVIDIA global impact award (e.g. tsunamis in 2018, earthquakes in 2016), or several Supercomputing Best Paper awards. On the other hand, SE applications have traditionally been considered as excellent candidates for co-design, one of the pillars of the research and innovation programme of the EuroHPC JU to support the development of exascale. Design hints stemming from exercising SE mini-applications on exascale hardware prototypes or candidate architectures, e.g. the European Processor Initiative (EPI), are therefore of utmost importance to design the next generation of architectures and provide co-design feedback back to the full applications. Added to this, resource prospection (e.g. oil and gas) industry is a massive consumer of supercomputer resources. With regard to co-design, this makes SE an important application area for industry users.

6. The European SE community is preparing itself for massive data streams and extreme-scale computing. A rich ecosystem is flourishing in this community, with projects and initiatives that will benefit from (and leverage the use of) current pre-exascale and upcoming exascale EuroHPC infrastructures. Relevant to this proposal are:

- The European Plate Observing System (EPOS), constituted as a European Research Infrastructure Consortium (ERIC) in 2018. EPOS federates European national research infrastructures providing access to data and scientific products, and is also in a transition period to deploy Integrated Core Services Distributed (ICS-D), including HPC-based components. EPOS has been closely linked to ChEESE-1P since the very beginning through its involvement in the Scientific and Industry-Users boards.
- The EuroHPC-funded eFlows4HPC project (2021-2024) that is implementing a workflow software stack integrating HPC simulations with big data analytics and machine learning, with a pillar use-case on natural catastrophes (earthquakes and tsunamis).
- The Horizon Europe Geo-INQUIRE project (2022-2025) that, in strong cooperation with EPOS, will provide virtual and trans-national service access to data and state-of-the-art numerical models and workflows with HPC resources for monitoring and simulation of the dynamic processes in the geosphere at unprecedented levels of detail and precision.
- The Horizon Europe DT-GEO project (2022-2025) that will deploy a prototype Digital Twin (DT) on geophysical extremes consisting of interrelated digital Twin Components (DTCs) dealing with geohazards from earthquakes (natural or anthropogenically induced), volcanoes, and earthquake/landslide-triggered tsunamis, with a long-term vision (2026 onwards) towards Destination Earth.
- The Destination Earth (DestinE) initiative, a decade-long and massive community effort under the Digital Europe Programme (DIGITAL) towards the integration and coupling of Earth system modeling components and data streams in a single digital twin at unprecedented resolution. During the first implementation phase (2024), DestinE will develop the open core digital platform and deploy the first two digital twins on extreme natural (weather-related) events and climate change adaptation. Other twins will be added to progressively converge towards the full digital replica by 2030, with geophysical extremes being in the candidate's list.
- The Galileo conference "Solid Earth and Geohazards in the Exascale Era" (23-26 May 2023) that will bring together some of the world's best minds in various branches of computational geosciences to jointly tackle challenges and issues of Exascale computing and to agree on a community roadmap (2023-2027) for this transition. With the support from 9 European Geosciences Union (EGU) Divisions and promoted by

7. A CoE on Solid Earth (SE) acts as a transversal integrator of EuroHPC infrastructures across the SE ecosystem of scientists and end-users. The SE community is multidisciplinary and transversal, encompassing Earth Observatories (i.e. monitoring networks, data providers, institutions with operational forecast and early warning mandates, etc.), research and academia, model developers, and different typologies of end-users from the public and private domains. A mission of ChEESE-2P is to act as the “gravity center” in this ecosystem facilitating the use of EuroHPC infrastructures and preparation of applications and deployment of downstream services, e.g. on urgent computing access mode. From a scientific point of view, ChEESE-2P will also play a fundamental role in favoring access to HPC to the entire Community at European and National level, in collaboration with the National Competence Centers (NCCs). In this regard, several European and world-wide key Institutions and Associations have manifested their will to continue playing an active role within the Industry and Users Board (IUB) (see Section 2.2.4 for details).

The legacy of ChEESE-1P

The first phase of the Center of Excellence for Exascale in Solid Earth (ChEESE, hereafter referred to in this proposal as ChEESE-1P) has been articulated around 3 pillars: flagship codes, workflows, and service enabling. The overarching concept binding the project was the Pilot Demonstrator (PD), intended as a proof of concept in which codes and workflows were combined to address ECCs in computational seismology, tsunamis, volcanoes and magnetohydrodynamics. Those PDs in ChEESE-1P reaching a Technology Readiness Level (TRL) above 5 were tested in operational service environments on critical aspects of geohazards like hazard assessment, urgent computing, and early warning forecast. This was done in collaboration with members of the Industry and User Board (IUB), which also helped perform a market analysis for exploitation of services.

- **Flagship codes.** 10 SE community flagship codes were included in ChEESE-1P (4 in computational seismology, 2 in MHD, 2 in physical volcanology, and 2 in tsunami modeling). All the applications were audited twice during the project in collaboration with the POP2 CoE and were prepared to pre-exascale systems at single-node level (tackling aspects like porting to accelerators, vectorization, or thread parallelism), multi-node level (internode communication efficiency, load balancing) and in terms of I/O bottlenecks (enabling parallel I/O, asynchrony, and overall efficiency of I/O operations). As a result, and at the end of ChEESE-1P, a first group of codes can already be classified in terms of capability as being “petascale” or above (scalability performance above 1000 nodes) whereas a second group, which started from a lower baseline, has reached “pre-petascale” capability (scalability performance in few 100s of nodes).
- **Pilot Demonstrators and services.** 12 different PDs were implemented in ChEESE-1P to address target ECCs, where codes embedded into complex workflows were integral to obtain exascale capacity. The 8 PDs that reached a TRL above 5 were also deployed and tested in large-scale operational environments and made available to a broader scientific and user community, including “live” exercises in which target use-cases were validated considering user-defined service functional requirements. Some service success stories include the first operational Tsunami Probabilistic Forecast workflow (executed on 3200 NVIDIA V100 GPUs), a seismic urgent computing service (including a full-scale capability execution at MN-4), or the ensemble-based volcanic ash forecast products delivered to Volcanic Ash Advisory Centers and to civil protection authorities (e.g. during La Palma eruption).

ChEESE-1P has been very successful in fostering and leveraging other projects and initiatives that have benefited from and will take over and sustain part of the project developments (eFlows4HPC, Geo-INQUIRE, DT-GEO). Most partners of the ChEESE consortium are also involved in these initiatives. The flourishing of this “ecosystem” is a good indicator of the success that the ChEESE-1P has had in federating the SE community around HPC, and also guarantees the sustainability of key aspects of the project (notably, the access to codes, workflow components and services). However, this scenario has also challenged the way this ChEESE-2P proposal had to be oriented in order to align with these initiatives in a synergistic manner and avoid overlaps and duplication of efforts. These premises have been carefully considered when writing the ChEESE-2P proposal, which shares similarities with its predecessor but also incorporates several novel aspects.

What’s new in ChEESE-2P?

- **Novel applications and domains.** The ChEESE-2P proposal articulates around flagship codes, retaining this first pillar of ChEESE-1P as the main niche of the CoE. ChEESE-2P will continue the preparation and optimization of flagship codes on computational seismology, tsunamis, volcanology, and MHD in order to bring them to the next level. However, it will also adopt new community codes from geodynamics and glacier

hazards, two disciplines that were untapped during the first phase. Enlarging the application domains pursues the engagement of other scientific communities and the attraction of potential users from other countries (e.g. eastern and northern Europe) by widening the spectrum of tackled geohazards.

- **Enabling exascale features.** Despite not explicitly required by the 02 call topic, ChEESE-2P will consider exascale technical challenges not addressed in ChEESE-1P, including code resilience, fault-tolerance, (run-time) load balancing and energy efficiency, including the tagging of the simulation environmental costs (energy/carbon footprint).
- **Explicit targeting to the EuroHPC systems.** ChEESE-2P gives more emphasis on aspects like code performance portability and containerization for deployment on pre-exascale tier-0 (LUMI, Leonardo, MN-5) and tier-1 EuroHPC infrastructures and user uptake. This includes preparation of services and policies for the EuroHPC emergency (urgent computing) access mode in case of geohazards.
- **The concept of Pilot Farm.** ChEESE-2P proposes to farm a new generation of Pilot Demonstrators (PDs) to replace those predecessors that have reached a higher TRL and that, to some extent, have been transferred elsewhere in the ecosystem for further development or downstream service implementation. In this proposal, the new PDs in the farm are underpinned by concepts like multiphysics, multiscale, multisource, multihazard, and integration of phenomena that will require developments in flagship codes in order to incorporate new physics (functionalities), couplings, and forcing terms.
- **Simulation Cases.** Unlike ChEESE-1P, the PDs in ChEESE-2P (see Sec. 1.2.4) will have no direct one-to-one mapping with the simulated use-cases. The new generation of pilots address more generic higher-level concepts (e.g. seismic inversion or volcanic flows) and can result in several capability, capacity, or urgent computing Simulation Cases (SCs) depending on the underlying workflow and model configuration. Capability-oriented use-cases will consider 4 Scientific Grand Challenges (SGC), whereas capacity-oriented use-cases will focus on ensembles of pre- or petascale-level simulations for uncertainty quantification, hazard assessment, urgent computing, or resource prospection among others.
- **A more prominent federation role.** Finally, ChEESE-2P will have a more prominent role on reinforcing the alignment and the liaison activities with other on-going initiatives related to: (1) the EuroHPC ecosystem, e.g. EuPilot and EuPEX for co-design activities, eFlows4HPC, the POP3 and ESiWACE3 CoEs (if funded), the NCCs and, (2) SE domain-specific projects, e.g. DT-GEO, Geo-INQUIRE and ultimately DestinE. Moreover, links with EU13 countries will be enhanced, both in training (in cooperation with NCCs and PATC) and access to codes and products.

Why ChEESE-2P applies to topic call 02 and not to topic call 01?

As mentioned previously, this CoE hosts both exascale capability and capacity cases relevant to call topic 01 (preparing applications in the Exascale era) and call topic 02 (supporting supercomputing applications for Science and Innovation). Actually, ChEESE-2P can be considered as a “1.5” CoE covering the scopes from both topics (see Sec. 2.1.1), but the final choice was motivated by two main reasons:

- Call topic 02 was considered more adequate for the whole SE community in terms of inclusiveness, more possibilities for synergistic applications and exploitation between capability and capacity computing, avoidance of consortium fragmentation, and possibility to effectively attract a wider fraction of the community around HPC and related EuroHPC infrastructures and service use.
- Several flagship applications in ChEESE-1P are used in the day-to-day activities of several institutions in the Consortium and beyond, including not only research but also commitments in operational services. As the transition to true exascale capability (topic 01) can hardly be reached incrementally, it is clear that substantial parts of the applications will need a profound software redesign and refactoring at different levels, implying some sort of coexistence between development and production versions of the codes during a long (several years) transition period. Such duplication of manpower effort was considered too costly and unfeasible by some of the Consortium partners.

1. Excellence

1.1. Objectives and Ambition

The second implementation phase of the ChEESE Center of Excellence (CoE) has 4 high-level general objectives and 14 specific objectives related to scientific, technical, and socio-economic challenges.

1.1.1. General Objectives

1. To consolidate the ChEESE as the central HPC hub connecting the scientific Solid Earth (SE) Community, the EuroHPC infrastructures and National Competence Centers (NCCs), and the public and private industry parties benefiting from the products and downstream services on geohazards.
2. 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.
3. To farm a new generation of 9 Pilot Demonstrators (PDs) and run 15 derived Simulation Cases (SCs) addressing capability/capacity computational challenges and enabling services on socially-relevant aspects of geohazards like urgent computing for disaster response, early warning, and hazard assessment.
4. To align and synergize with other domain-specific European projects and longer-term mission-like initiatives like the Digital Agenda and Destination Earth.

1.1.2. Specific Objectives

ChEESE-2P is underpinned by 14 Specific Objectives (SO), all with clear milestones achievable within 4 years but that can span over a longer-term perspective.

Specific objectives in terms of **exascale software engineering and simulation ecosystem**:

- **SO1**: To prepare 11 open-source community **flagship codes** for current and upcoming EuroHPC systems in the areas of computational seismology, tsunami modeling, physical volcanology, magnetohydrodynamics, geodynamics, and modeling of glacier hazards.
- **SO2**: To perform **audit-driven code optimizations** based upon 2 code audit rounds, one for defining each code baseline and detailing the code optimization plan, and a second for monitoring the performance of the codes along the project using the Performance Optimisation and Productivity (POP) metrics as Key Performance Indicators (KPIs).
- **SO3**: To co-design **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.
- **SO4**: To address specific **simulation ecosystem challenges** at large scale that go beyond the individual codes.

Specific objectives in terms of **scientific excellence**:

- **SO5**: To develop and implement 9 new **Pilot Demonstrators** (PD) on different areas of SE addressing the 12 SE Exascale Computational Challenges (ECCs) and underpinned by the concepts of multiphysics, multiscale, multisource, and multihazard modeling.

Specific objectives in terms of **scientific-technical challenges**:

- **SO6**: To run 15 **Simulation Cases** (SC) derived from running on EuroHPC systems the 9 PDs at sites of particular relevance in Europe and beyond (see Sec. 1.2.5 and 1.2.6). This includes 9 capacity and 6 capability cases, 4 of which can, in turn, be considered as full-scale Scientific Grand Challenges (SGC).
- **SO7**: To define a flexible ecosystem to ensure **EOSC-enabled data** quality management through an automatic FAIR data validation.

Specific objectives in terms of **geohazard services and products addressing socio-economic challenges**:

- **SO8**: To raise the Technology Readiness Level (TRL) of the PDs towards enabling downstream **service prototypes** addressing aspects of geohazards that are socially and economically relevant in Europe: disaster response, early-warning, and physics-based probabilistic hazard assessments.
- **SO9**: To foster the **urgent computing** access mode in EuroHPC tier-0/tier-1 systems for emergency management during high-impact geohazardous events (earthquakes, tsunamis and volcanoes) including related technical challenges and access policy recommendations.

Finally, specific objectives in terms of **federating capabilities and transversal integration around exascale computing and EuroHPC infrastructures**:

- **SO10:** To act as an **effective hub** to foster the use of HPC resources and to roadmap the transition to exascale across the SE Community and related stakeholders.
- **SO11:** To provide **specialized training** to scientists and end-users on the deployment and use of flagship codes and related services in collaboration with the PRACE Advanced Training Courses (PATC) and the National Competence Centers (NCCs).
- **SO12:** To 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.
- **SO13:** To align and **liaise** with other projects (see Sec.1.2.7), mission initiatives (Digital Agenda, Destination Earth), Research Infrastructures (EPOS, FENIX), and federated environments (EOSC).
- **SO14:** To **disseminate** the CoE and the role of under-represented scientists to a wider-public audience, e.g. through the ShEEESE initiative.
- **SO15:** To complement with the CASTIEL2 CSA.

Table 1.1.2a below shows the related target(s), means of verification (KPI), and relationship among the SOs and the project implementation plan (i.e. related WP/Task, see Sec. 3.2.1 for details).

Table 1.1.2a. *Targets and KPIs in relation to the Specific Objectives (SO) and implementation tasks (Sec. 3.1).*

SO	Target(s)	Means of verification (KPI)	Task
1	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
1	Increase the performance portability of codes across tier-0/tier-1 EuroHPC systems	Performance metrics on Leonardo, LUMI and MN5 machines	T2.2 T2.4
1	Perform further single-node optimizations including vectorization, intra-node communication efficiency, and multi-threading. For level 1 codes (Sec. 1.2.2), address also code resilience and fault-tolerance aspects (at MPI level)	Continuous run-time performance efficiency monitoring metrics from the TALP tool (Sec. 1.2.2)	T2.3 T2.4
2	Obtain code performance metrics (and optimize on-demand accordingly)	Increase in the POP metrics after the second audit round (deliverable D2.3)	T2.1
3	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 T3.3
4	Reduce bottlenecks in exascale capacity workflow executions	Increase the workflow audit metrics	T4.1
4	Automate the code deployment process including containerization for code/workflow components	CI, static and dynamic code analysis in place	T4.2 T4.3
5	Farm 9 PDs (2 in CS, 2 in tsunamis, 2 in physical volcanology, 1 in MHD, 1 in geodynamics, and 1 in glacier hazards, see Table 1.2.4a)	Increase the TRL of each PD by at least 2 points (see Sec. 1.2.4 for details)	T5.1 T5.2
6	Run the 9 capacity and 6 capability use cases (see Sec. 1.2.5)	Production runs performed and	T6.2
6	Run 4 SGCs (SC1.2, SC2.1, SC4.1, SC8.1; see Sec. 1.2.5)	EOSC-enabled results/datasets available	T6.3
6	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
7	Ensure FAIR validation of datasets, including EPOS-enabled metadata descriptors	Datasets integrated and/or compatible with EPOS standards	T1.5
8	Deliver a novel, high-resolution and uncertainty-based global tsunami model hazard map and related services	D6.4 (EPOS-TCS) and datasets available	T6.3
8	Deliver the first multi-source European tephra hazard map at scale		
9	Enable resilient UC services and related policies on EuroHPC systems for: (1) urgent seismic simulations, (2) volcanic dispersal at scale, (3) phreatic explosions and, (4) multi-source tsunami scenarios	4 UC service workflows tested and enabled on different tier-0 EuroHPC systems	T6.4
10	Foster the end-user usage and uptake of codes through a containerized application deployment	Zenodo and git-based repositories. NVIDIA collection of ChEESE codes in place	T4.2

10	Organize the Galileo Conference “Solid Earth and Geohazards in the Exascale Era” (May 2023)	Associated with document Ref. Ares(2022)8497838 - 07/12/2022 Publication of the consensual roadmap white paper	T7.4
11	Coordinate with the NCCs and PATC in the organization of open, free, and gender and country-balanced (EU13) 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
12	Engagement of target end-users related to industry, academia, public bodies and policy makers and update the service strategy	Update the market analyses for the new service-oriented use cases	T7.5
13	Coordinate with SE/HPC ecosystem in all phases of the definition, implementation, validation and evolution of ChEESE-2P activities	Successful activity of the liason officers	T7.2
14	Foster awareness of the project and its aims	Quantitative indicators in deliverable D7.6	T7.1
14	Activities of the ShEESE initiative (see Sec. 1.2.9)	(see also Sec. 2.2.1)	T1.3
15	Complementary grants	No of applications deployed to JU systems incl. breakdown by partition (e. g. CPU, GPU).	T7.6
		No of EuroHPC systems supported by application incl. breakdown by partition (e. g. CPU, GPU)	T7.6
		No of errors (failed deployments/regression tests) identified through common platform	T7.6
		Average time from failed application test to deployment of corrected application	T7.6

1.1.3. Progress beyond the State-of-the-Art

First of all, this proposal will prepare flagship codes in SE sciences to be deployed and used efficiently in present and upcoming EuroHPC systems from an early stage, thus boosting the usability of such infrastructures. ChEESE-2P has the ambition of boosting the competitiveness of the EU in the SE area and consolidating the leading role that ChEESE-1P has already taken, including collaboration with other strategic and mission initiatives in matching the needs and capabilities of different stakeholders such as civil protection agencies, universities, HPC centers, and private companies.

In terms of **scientific ambition**, ChEESE-2P covers several domains of SE and geophysics to overcome current shortcomings and challenges represented by the target ECCs, including application domains not considered during the first implementation phase.

- **Earthquakes** are complex multiphysics processes with strong nonlinear dynamics, having substantial societal and economic relevance for large populations worldwide. They are characterized by a wide range of temporal scales (from thousands of years for the tectonic loading to seconds for the fault rupture and generation of seismic waves) and spatial scales (from centimeters-to-meters in the detailed fault rupture nucleation to hundreds of kilometers for the largest tectonic earthquakes). While a new era of seismological instrumentation fundamentally changes current seismic observations, progress is impeded by the lack of quantitative data on timescales capturing multiple large earthquake cycles. ChEESE-2P will progress on physics-based simulations that provide the only path for overcoming the lack of data and elucidating multiscale dynamics and spatio-temporal patterns in seismology.
- In **seismic tomography**, ChEESE-2P will enable progress in sub-surface imaging at local scale, where crust heterogeneities, anisotropies, and attenuation represent big challenges. The novel approach is to use a joint gravity and seismic multi-parameter full waveform inversion including fluid and solid domains, which requires second order methods for robust inversion (in classical first order gradient methods, cross-talks between parameters are detrimental to an accurate imaging). So far, this has been attempted at local scale only for 2D cases due to the tremendous computational cost associated.
- **Tsunamis** can be complex and couple several mechanisms and scales from the generation (e.g. earthquakes, landslides, volcanoes, and meteorological forcing) to wave propagation and inundation. ChEESE-2P proposes a novel set of integrated source models to deal with multiple and multiphysics tsunami sources and propagation at the same time, from earthquakes, acoustic pressure, landslide dynamics, and volcanic crater collapse. Combining existing models and developing new features, a demonstrator will be produced for the

recent 2022 Hunga Tonga case by resolving the source dynamics locally, as well as being further coupled to the global pressure wave and global tsunami propagation.

- **Magnetohydrodynamics** is characterized by a high degree of scale separation between the large-scale magnetic field and the small-scale buoyancy of the highly-turbulent metal liquid in the Earth's core. The ChEESE-2P novel ambition is to embrace the full spectrum of flow motion, which currently represents an untouched full-capability exascale problem.
- In **physical volcanology**, ChEESE-2P will advance the modeling of multiphase 3D volcanic explosions by including important processes such as water phase transitions and plume gas-particle interactions, which are also important for a wide range of scientific applications beyond the CoE. Moreover, it will also address volcanic dispersal at multiple scales, from global to micro.
- In **geodynamics**, ChEESE-2P will perform simulations at unprecedented resolutions required to resolve localized fault zones and connect those with seismic wave propagation and tsunami codes, as well as with observations. This is relevant to estimate seismic or landslide hazards, but the same approaches can also be used for any other problems that involve the stress state in rocks (e.g., drilling-induced risks in sedimentary basins, the stability of caverns in salt domes used to store hydrogen as part of the energy transition, or the long term safety of nuclear waste deposits).
- Finally, for **glacier hazards**, ChEESE-2P will consider the modeling of rapidly rising GLOFs (or Jökulhlaups) and the potential of glacier collapses caused by subglacial lake drainage. To date, no physics-based model of fast rising Jökulhlaups exists. Glacier destabilization by increasing melt-water production is expected to grow in global warming scenarios, rendering those tools to develop towards utilization in hazard assessment (e.g., timings of outburst floods underneath glaciers).

In terms of **new products and service enabling on EuroHPC machines**, the following aspects are relevant:

- Enabling a UC service for earthquakes using AI/ML-based approaches to harvest information from earthquake simulation databases (capacity computing) into readily usable results (urgent computing). The level of maturity starts at TRL 2-3 and is expected to reach TRL 6 during the project.
- Enabling a UC service for volcanic ash/gas dispersal at local scale. The target TRL is 8.
- Enabling a UC service for phreatic eruptions to be potentially used in the framework of a volcanic unrest. It will be tested at Vulcano (Aeolian archipelago) because this island is currently in an unrest state, but potential extension exists to other volcanic areas (e.g., Guadeloupe, Martinique, Solfatara).
- A new tool for probabilistic tsunami hazard analysis based on HPC simulations for earthquakes at the global scale, which is interoperable with seismic hazard models and tools (e.g. Global Earthquake Model Openquake). It will start from TRL 7 (legacy of ChEESE-1P PD7, see Figure 1.2.4) to reach TRL 8-9 at the end of ChEESE-2P for potential distribution through the Thematic Core Service (TCS) Tsunami in EPOS (TSU-TCS). This tool will be demonstrated through the production of a Global Tsunami Model (GTM) tsunami hazard reference map (deliverable D6.4), with unprecedented earthquake slip variability and spatial resolution.
- First step towards a multiscale European volcanic ash hazard assessment in line with the United Nations Office for Disaster Risk Reduction (UNDRR). It will start from TRL 6 (legacy of ChEESE-1P PD6, see Figure 1.2.4) to reach TRL 8 at the end of ChEESE-2P for distribution through EPOS Volcanic Observations TCS (VO-TCS), National civil protection agencies, and European civil aviation stakeholders (e.g. EUROCONTROL).
- In terms of glacier hazards, ChEESE-2P will investigate the subglacial lakes that could endanger populated areas and potential glaciers that could destabilize with respect to the binding to their substrate and impose a hazard in terms of ice avalanches. This has a starting TRL of 3 and a target of 5.

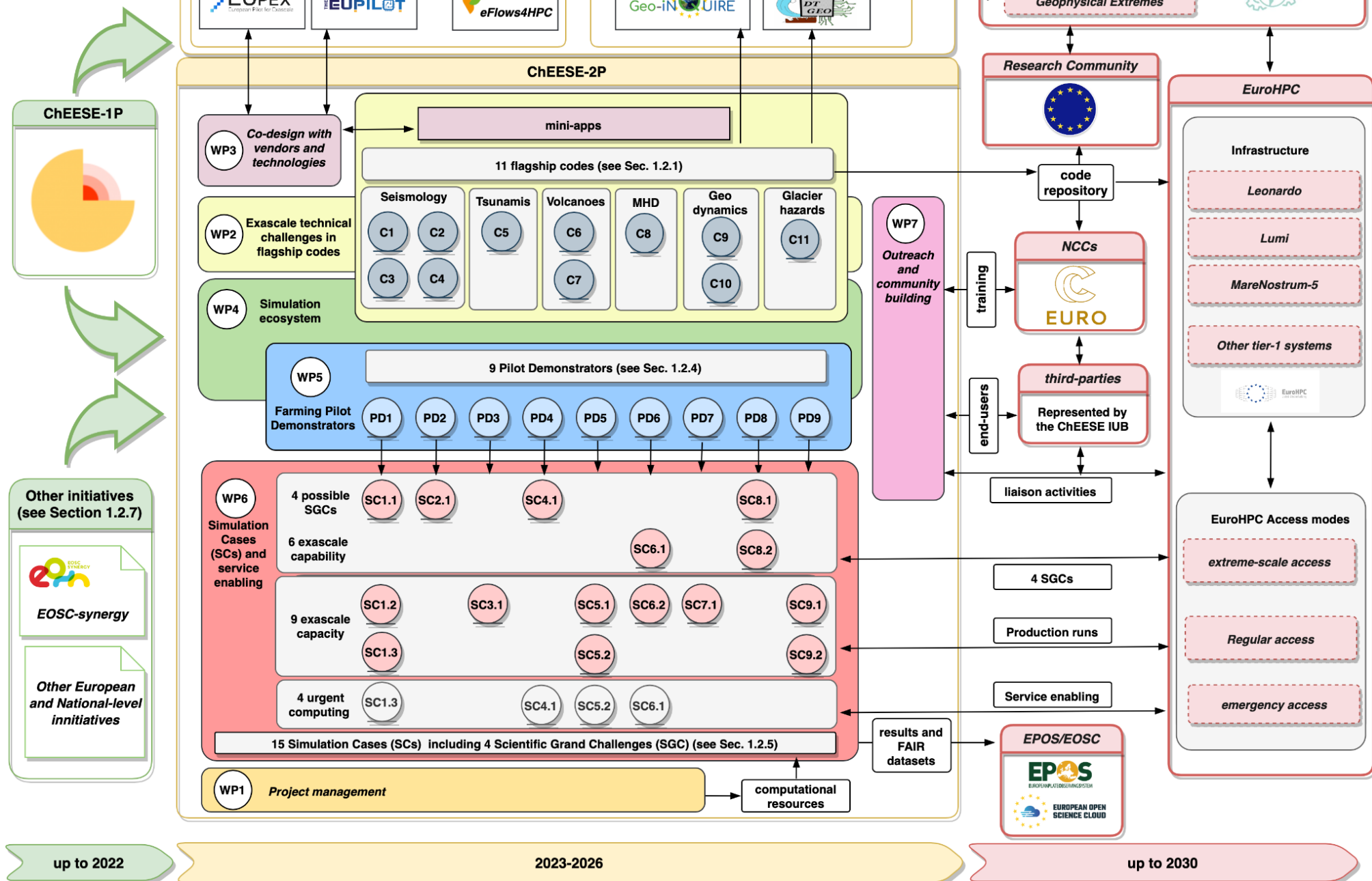
1.2. Methodology

1.2.1. ChEESE-2P in a Nutshell

Figure 1.2.1 (next page) illustrates the ChEESE-2P proposal in a single scheme. The first implementation phase of ChEESE was very successful in leveraging other projects and initiatives (eFlows4HPC, Geo-INQUIRE, DT-GEO) that will take over part of the ChEESE-1P results, notably some PDs that reached a higher TRL (7-9) and related services. ChEESE-2P retains the preparation of flagship codes as the “core business” of the CoE, retaining 6 codes from the first implementation phase and incorporating also 5 new flagship applications and 2 areas previously untapped (geodynamics and modeling of glacier hazards). Placing codes at the core of the CoE, the transversal WP2 and WP3 will deal, respectively, with the exascale technical challenges (including porting, optimization, audit and performance monitoring) and with vendor-driven co-design activities using code mini-apps on hardware prototypes (OpenSequana and RISC-V) furnished by the EuPEX and EuPilot EuroHPC Pilot projects. A third

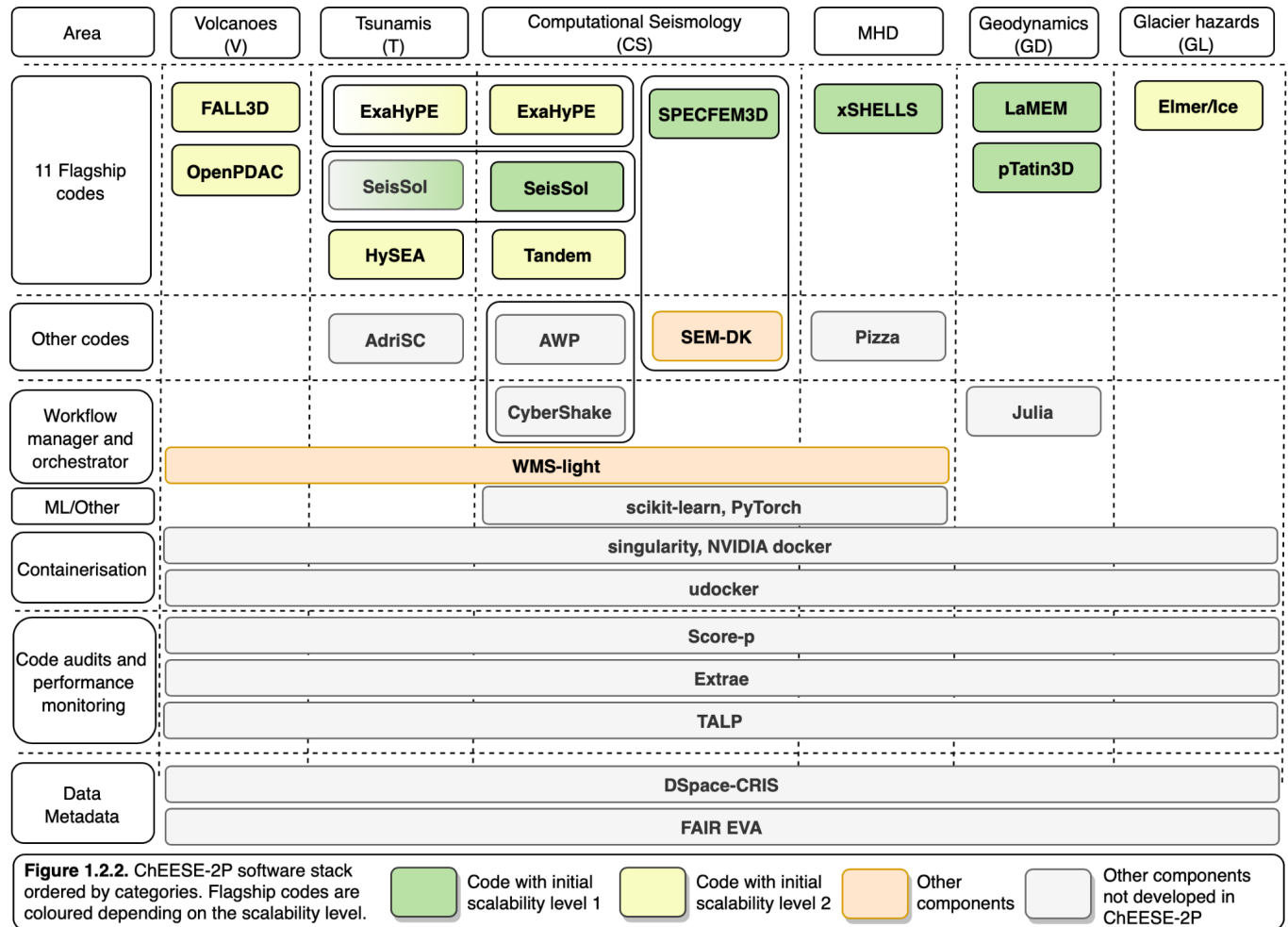
transversal component (WP4) will glue codes with Pilot Demonstrators (PDs) through workflows and simulation ecosystem aspects (including deployment, containerization, and quality assessment tools) that aim at enhancing the uptake of codes by end-users and synergize with DT-GEO and other future projects in upcoming Destination Earth calls (INFRA and Digital Europe Programmes, from 2024 onwards). ChEESE-2P will also farm a new generation of 9 PDs and production runs in 15 site-specific Simulation Cases (SCs) that address the target exascale capability/capacity computational challenges (ECCs). These include 4 large-scale capability Scientific Grand Challenges (SGC). The resulting datasets (e.g. hazard maps) will be EPOS-compliant and follow an EOSC-enabled quality approach (automatic FAIR validation). In addition, 4 PDs will also be exploited for urgent computing service enabling in EuroHPC infrastructures (pre-exascale tier-0 LUMI, Leonardo, and MN-5) for earthquakes, tsunamis and volcanoes. The community building and liaison Officer activities will federate with end-users across the National Competence Centres (NCCs) and IUB members, including training and capacity building to widen the access to codes and fostering transfer of know-how to end-user Communities.

Figure 1.2.1.
ChEESE-2P in a nutshell



1.2.2. Flagship Codes and Software Stack

Figure 1.2.2 below shows the components of the ChEESE-2P software stack ordered by area of application and category.



ChEESE-2P considers 11 flagship codes (see the Tables 1.2.2a and 1.2.2b below for the list and a short description of the flagship codes): 4 in computational seismology, 1 in tsunami modeling, 2 in volcanology, 1 in magnetohydrodynamics, 2 in geodynamics, and 1 in modeling of glacier hazards. In total, 6 codes are legacy from ChEESE-1P (SeisSol, SPECFEM3D, ExaHyPE, xSHELLS, HySEA and FALL3D) and 5 are new ChEESE-2P applications (Tandem, OpenPDAC, LaMEM, pTatin3D and Elmer/Ice), all developed and maintained by Consortium members. In terms of (strong) scalability and parallel performance, we define the following criterion for the “code level”:

- **Level 0 codes.** Codes able to perform full capability runs or capacity workloads on exascale machines (“future tier-0 systems” of the upcoming exascale era). Good scalability (>90% efficiency) proven in more than 10000 nodes (>10⁵-10⁶ cores). No tests at this scale exist yet.
- **Level 1 codes.** Codes able to perform full capability runs or capacity workloads on current pre-exascale machines (“future tier-1 systems” of the upcoming exascale era). Good scalability (>90% efficiency) proven in more than 1000 nodes (>10⁴-10⁵ cores). Up to 5 ChEESE flagship codes are considered to be already at or close to level 1 (SeisSol, SPECFEM3D, xSHELLS, LaMEM and pTatin3D).
- **Level 2 codes.** Codes able to perform full capability runs or capacity workloads on current petascale machines (“future tier-2 systems” of the upcoming exascale era). Good scalability (>90% efficiency) proven in more than 100 nodes (>10³-10⁴ cores). Up to 6 ChEESE flagship codes are considered to be already at or close to level 2 (ExaHyPE, Tandem, HySEA, FALL3D, OpenPDAC and Elmer/Ice).

On the other hand, some tasks will also make use of other open source software stack developed and maintained by Consortium partners (except for the seismic shaking software AWP/CyberShake managed by SCEC):

- **AdriSC** (Type: Code | HPC: no). The Adriatic Sea and Coast (AdriSC) modeling suite is composed of two different modules. The general circulation module couples an atmospheric model at up to 3 km resolution with an ocean-wave model at up to 1 km resolution. The extreme event module further downscales the general

circulation results to 1.5 km in the atmosphere and to an unstructured mesh at up to 10 m resolution along the coasts with a coupled ocean-wave barotropic model. Will be used in PD4 for meteotsunamis.

- **AWP-ODC** (Type: Code | HPC: yes). Code from the U.S. San Diego State University (SDSU) that will be used for reference. Integrated in the CyberShake project of the Southern California Earthquake Center.
- **dislib** (AI | HPC: yes). A machine learning library based on scikit learn and parallelized with PyCOMPSs that can deal with large amounts of data distributed in HPC systems.
- **DSpace-CRIS** (Type: Data and metadata | HPC: no). A system using DSpace but with the richer Common European Research Information Format (CERIF) metadata model for Current Research Information Systems (CRIS). The standard DSpace is used to deal with publications and data sets, whereas DSpace-CRIS involves other CRIS entities.
- **Extrae** (Type: audit tool | HPC: yes). Package to generate Paraver trace-files for a post-mortem application analysis used in the POP audits.
- **FAIR-EVA** evaluator (Type: Data and metadata | HPC: no). FAIR evaluator developed to check the FAIRness level of digital objects from different repositories or data portals.
- **Pizza** (Type: Code | HPC: yes). A high-performance numerical code for quasi-geostrophic and non-rotating convection in a 2-D annulus geometry. Solves for the Navier-Stokes equation including Coriolis force coupled with a temperature equation and/or an equation for the chemical composition under the Boussinesq approximation (to be used in the MDH PD).
- **Score-p** (Type: audit tool | HPC: yes). A highly scalable tool suite for profiling and tracing of HPC applications used in the POP audits.
- **SEM-DK** (Type: library | HPC: yes). The on-going refactoring of SPECfem3D includes to extract and to separate the computational core, which must be efficient on different exascale platforms, from the various higher-level workflows. This is being done through a library called SEM-DK (Spectral Element Method - Development Kernel) which will be interfaced through an API with different languages (see task T5.1).
- **TALP** (Type: Profiler | HPC: yes). A lightweight and user-friendly profiling tool that automatically obtains parallel efficiency metrics as defined by the POP CoE without trace generation and transparently to the user. Additionally, it allows the user to define custom code regions to profile.
- **udocker** (Type: containerization | HPC: yes, GPU-enabled). Enables execution of Linux containers in user space without requiring root privileges. It can be used to enable container execution in HPC clusters, interactive clusters, grid infrastructures and cloud resources.
- **WMS-Light** (Type: Workflow manager | HPC: yes). Workflow Manager System for generic HPC workloads developed in ChEESE-1P (WMS-light v1.0). Based on a JSON-format workflow specification, WMS-L automatically resolves application execution aspects like access policies, submission mechanisms (such as PBS/Torque, SLURM, etc.), and status monitoring options.

Table 1.2.2a. List of Flagship codes including code level, area, accessibility (type of open source license), type of parallelization, existence of mini-apps (see co-design activities in Sec. 1.2.3) and involved PDs. Area codes are: CS computational seismology, T tsunami modeling, MHD magnetohydrodynamics, V volcanology, GD geodynamics, GL glacier hazards.

No	Code	Level	Area	Language	License	Parallelization	Mini-app	Lead	PDs
1	SeisSol	1	CS T	C++, F90	BSD3	MPI, CUDA, OpenACC	yes	LMU	PD1 PD4
2	SPECfem3D	1	CS	C/C++, F90	GNU GPL v3	MPI, CUDA, HIP	yes	CNRS	PD1 PD2
3	ExaHyPE	2	CS T	C++, Python	Modified BSD3	MPI, OpenMP, Intel TBB	no	TUM	PD1 PD4
4	Tandem	2	CS	C++	BSD3-clause new	MPI, AVX, OpenMP	yes	LMU	PD1
5	xSHELLS	1	MHD	C++	CeCILL License (compatible with GNU GPL)	MPI, OpenMP, CUDA	yes	CNRS	PD7
6	HySEA	2	T	C++	Core under CCA ShareAlike 4.0	MPI, CUDA	yes	UMA	PD3 PD4
7	FALL3D	2	V	F90/2008	GNU GPL v3	MPI, OpenACC	yes	CSIC	PD5
8	OpenPDAC	2	V	C++	GNU GPL v3	MPI	no	INGV	PD6
9	LaMEM	1	GD	C/C++	GNU GPL v3	MPI	no	UM	PD8

10	pTatin3D	1	GD	C	GNU GPL v3	AVX, MPI, OpenMP, CUDA	yes	SU	PD8
11	Elmer/Ice	2	GL	C, F90	(L)GPL - solver modules are GPL v2-v3	MPI, OpenMP	no	CSC	PD9

Table 1.2.2b. Short description of the 11 flagship codes.

No	Short flagship code description
1	SeisSol is a high-performance computational seismology software that focuses on the simulation of complex earthquake scenarios. It supports various rheologies (elastic, anisotropic-elastic, acoustic, viscoelastic, poroelastic), boundary conditions and dynamic rupture laws. SeisSol uses high-order discontinuous Galerkin discretisation with an Arbitrary DERivative (ADER) local time stepping on unstructured adaptive tetrahedral meshes.
2	SPECFEM3D solves linear seismic wave propagation (elastic, viscoelastic, poroelastic, fluid-solid) and dynamic rupture problems in heterogeneous 3D models, and also implements imaging and FWI for such complex models based on an L-BFGS (Broyden-Fletcher-Goldfarb-Shanno) algorithm. Based on the high-order spectral-element discretization for unstructured hexahedral meshes, SPECFEM3D was originally (early 2000s) developed to perform wave propagation computation in the Earth and afterwards extended to other application domains; e.g. non-destructive testing, seismic tomography and ocean acoustics.
3	ExaHyPE is an engine to solve hyperbolic PDE systems. It uses high-order discontinuous Galerkin discretisation (DG, with ADER time stepping) on tree-structured dynamically adaptive Cartesian meshes. Within ChEESSE-2P special emphasis is given to ExaSeis, the collection of seismic models in ExaHyPE (in particular seismic wave propagation and dynamic rupture on curvilinear meshes), on shallow-water models and on ExaHyPE's integration with the MIT Uncertainty Quantification (MUQ) library for uncertainty quantification problems.
4	Tandem is a scalable discontinuous Galerkin code on unstructured curvilinear grids for linear elasticity problems and sequences of earthquakes and aseismic slip. Tandem uses the symmetric interior penalty discontinuous Galerkin (SIPG) method to perform seismic cycle simulations accounting for the complex geometries and heterogeneity of the subsurface. Tandem simulates fault behavior over multiple seismic events and the intervening periods of aseismic deformation and considers all phases of earthquake faulting, from slow loading to earthquake nucleation, propagation and termination over time scales of milliseconds to millennia in a unified, self-consistent framework, opening new avenues to pursue extreme scale 3D earthquake cycle simulations.
5	xSHELLS is a high performance simulation code for rotating incompressible flows and magnetic fields in spherical geometries, including geodynamo simulations. Spherical harmonic transforms are combined with Finite Differences in radius to obtain a fast time-stepper.
6	HySEA suite is composed of several codes for tsunami simulations, including seismic sources and landslide generated tsunamis or meteotsunamis, with and without dispersion, and with the hydrodynamic model being a one-layer shallow water model or implementing a multilayer approach in order to capture a more complex vertical structure of the simulated solutions.
7	FALL3D is an off-line Eulerian model for the atmospheric transport and ground deposition of particles, aerosols and radionuclides. The model solves a set of Advection Diffusion Sedimentation (ADS) equations on a structured terrain-following grid using a finite volume (FV) explicit scheme. The model is mainly used for capacity runs (probabilistic hazard assessment) and urgent computing forecasts.
8	OpenPDAC is an offline Eulerian-Lagrangian model for the simulation of volcanic fluids. The model solves the conservation equations of mass, momentum and energy for a Eulerian-Eulerian compressible multiphase mixture of gasses and fine (up to mm size) particles, and the Lagrangian transport equations for coarser solid particles. The solver is based on the equations of the PDAC model, ported and optimized on the open-source OpenFOAM C++ toolbox for Computational Fluid Dynamics (CFD).
9	LaMEM is a parallel 3D numerical code that can be used to model various thermo-mechanical geodynamical processes such as mantle-lithosphere interaction, or the dynamics of magmatic systems, for rocks that have visco-elasto-plastic or (compressible) poroelastic rheologies. The code uses a marker-in-cell approach with a staggered finite difference discretization and is built on top of PETSc. A range of (Galerkin) multigrid and iterative solvers are available, for both linear and non-linear rheologies, using Picard and quasi-Newton solvers. LaMEM has been tested on a massively parallel MPI-cluster with 458,752 cores and has checkpointing/restarting capabilities.
10	pTatin3D is a software package designed for studying long time-scale processes relevant to geodynamics. Unique to this package is that it provides fast, parallel scalable matrix-free definitions for the Stokes operators which are utilized by a hybrid geometric-algebraic multigrid preconditioner. pTatin3D is built upon and heavily utilizes functionality from PETSc. pTatin3D has been used to study continental rifting, subduction and the dynamics of lava domes.
11	Elmer/Ice is based on the multiphysics Finite Element Model (FEM) package Elmer, which is open-source under (L)GPL. Elmer is a established multiphysics package that builds on the MPI/OpenMP parallel paradigm to solve coupled visco-elastic - Reynolds flow types of model able to represent Glacier Outburst Floods (GLOFs)

1.2.3. Flagship Code Preparation Roadmap

The flagship code preparation roadmap is articulated around 3 pillars (see Figure 1.2.3a):

- **Pillar 1: New developments in flagship codes.** First of all, ChEESE-2P is underpinned by concepts like multiphysics, multiscale, multisource, multihazard (cascading effects), and integration of phenomena that will require new developments in flagship codes in order to incorporate new physics (functionalities), couplings, and forcing terms. This will be done in task T5.1 (see WP5 description for details).
- **Pillar 2: Adequacy of flagship codes to EuroHPC heterogeneous hardware.** It is clear that the preparation of flagship codes to exascale must consider node heterogeneity and different levels of parallelism on complex hardware architectures that require a development and optimization methodology to guarantee a full utilization of the HPC resources available. Such methodology is provided by WP2 (see WP2 description for details), a transversal WP that groups the developments in 2 tasks:
 - “The accelerators arena” (T2.2), with a clear focus on EuroHPC hardware (Lumi, Leonardo, MN5) and related GPUs (AMD/NVIDIA) and
 - “generic” audit-driven development and tuning activities (T2.3) addressing known or unexpected code issues, starting from the single-node level and passing through the multi-node scaling and the IO.
- **Pillar 3: Co-design with EPI, EuPEX and EuPilot initiatives.** In parallel, WP3 will consider co-design activities using mini-apps that will extract the most relevant part of applications according to targeted prototype architectures (OpenSequana/RISC-V) furnished by EuroHPC hardware-developing initiatives (see WP3 description for details).

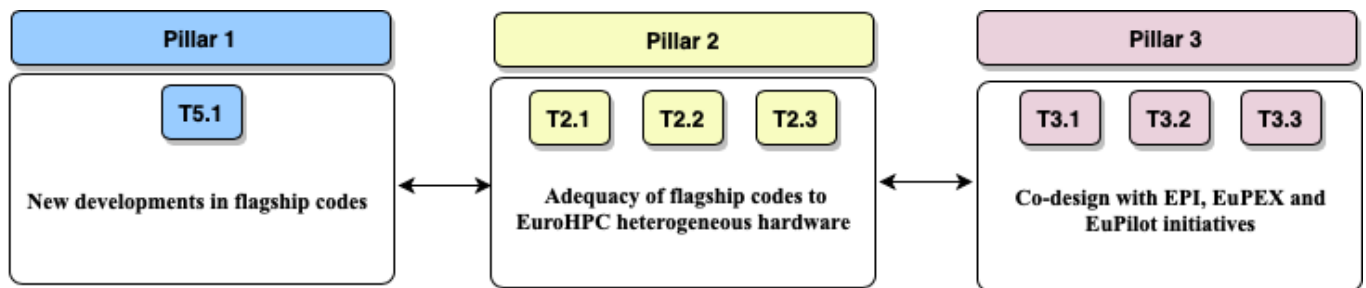


Figure 1.2.3a. Pillars of the ChEESE-2P flagship code preparation roadmap.

Tables 1.2.3a and 1.2.3b below summarize the expected activities and improvements in flagship codes (preparation roadmap). However, it is worth mentioning that the “a priori” strategy for Pillar 2 can vary depending on the results of the first audit round (T2.1), particularly for those codes that were not audited under the umbrella of ChEESE-1P.

Table 1.2.3a. Initial estimation of the effort required by the codes. Flagship code number: (1) SeisSol, (2) SPECFEM3D, (3) ExaHyPE, (4) Tandem, (5) xSHELLS, (6) HySEA, (7) FALL3D, (8) OpenPDAC, (9) LaMEM, (10) pTatin3D, (11) Elmer/Ice. (*) vectorization, and intra-node communication efficiency. (**) mitigation of load-balancing issues and inter-node communication efficiency. (***) e.g. time-stepping schemes, linear solvers.

Pillar	Code preparation activity	1	2	3	4	5	6	7	8	9	10	11
1	New code physics, couplings and forcing terms (T5.1)											
2	Code audit(s) and related POP metrics (T2.1)											
	GPU porting and fine tuning of already-porting components (T2.2)											
	Single heterogeneous node performance (*) (T2.3)											
	Multi-node performance (**)(T2.3)											
	Algorithmic improvements (***) (T2.3)											
	Resilience and fault tolerance (T2.3)											
	IO performance (T2.3)											
3	Co-design with mini-apps (T3.1, T3.2 and T3.3)											

Table 1.2.3b. Expected improvements in the 11 flagship codes after ChEESE-2P. Associated with document Ref. Ares(2022)8497838 - 07/12/2022

No	Expected improvements in flagship codes after ChEESE-2P
1	SeisSol. After ChEESE-2P, SeisSol shall be a multi-physics earthquake simulation code that can run fully-coupled simulations between all supported rheologies in a performance portable way on CPU/GPU architectures. It will be coupled to codes for geodynamics (pTatin3D, LaMEM) and seismic cycling (Tandem), which simulate Earth's crust from millions of years down to thousands of years of entire seismic cycles and provide improved initial and boundary conditions for earthquake simulations. In terms of code performance, ChEESE-2P will further improve portability of SeisSol and the scalability and time-to-solution of the local-time-stepping scheme.
2	SPECFEM3D. Improvements in terms of model physics are to add attenuation (visco-elasticity is currently used with classical memory-bound and poorly vectorizable approaches) and gravity kernels for computing different kinds of gravity anomalies. In terms of code performance, ChEESE-2P will address inter-node optimization on GPU using CUDA-aware MPI, the implementation of new schemes in time, and load balancing between the different MPI processes for unstructured meshes of the order of a few billion elements and related problem of distributing the elements between the different MPI processes and, especially, balancing the load correctly.
3	ExaHyPE. In terms of code functionality, ChEESE-2P will develop workflows with MUQ (MIT Uncertainty Quantification Library) and ExaSeis towards integration of improved earthquake sourcing (including dynamic rupture) and handling of more complicated geometries, as well as extent shallow water models in the context of landslide-induced tsunamis. Regarding code performance, ChEESE-2P will address the optimisation of ExaSeis based on ExaHyPE-2/Peano4 (exploiting a recent major rewrite of the Peano framework), porting ExaSeis to GPU architectures, and evaluate the use of SeisSol's YATeTo code generator in ExaHyPE (possibly using a mini-app).
4	Tandem. In terms of code functionality, improvements include adding viscoelasticity, new multiphysics coupling to earthquake dynamics and wave propagation (with SeisSol), and linking to long-term geodynamic modeling (LaMEM, ptatin3D). Regarding code performance, ChEESE-2P will explore GPU support provided by PETSc, single-node performance improvement via YATeTo, optimize the evaluation of discrete Green's functions via re-partitioning for improved load balance and matrix compression algorithms, and optimization of checkpointing (fault tolerance).
5	xSHELLS. In terms of code functionality and model physics, ChEESE-2P will implement a dynamic and versatile subgrid-scale flux model based on deep learning (a first short run with full resolution to adjust the subgrid-scale model, followed by a long run on the coarse grid, with the subgrid-scale model). This will take a large part in the work on the xSHELLS code. Regarding code performance, targets are the implementation of mixed-precision (the non-linear evaluation is expected to be accurate enough in single precision, while double-precision can be kept in the linear solver), better scaling of performance for a large number of nodes, and continuation of CUDA porting (initiated in ChEESE-1P).
6	HySEA. In terms of code functionality, ChEESE-2P will develop an operational version of the one-layer dispersive/non-hydrostatic version of the code for earthquake generated tsunamis, the implementation of nested domains, and an effective coupling of Meteo-HySEA and real atmospheric data. In terms of code performance, the main task will be optimization of multi-GPU multilayer in non-hydrostatic codes.
7	FALL3D. In terms of code functionality and model physics, the goal is to embed a meteorological downscaling system (to include, e.g. topography, breeze, and blocking effects) to cover local-scale dispersal phenomena and to enable multiple nesting domains. In terms of code performance, fine-tune solver kernels to GPUs (about 90% of the main FALL3D kernel is ported to the accelerators after ChEESE-1P), intra-node communication efficiency, and overall parallel IO efficiency.
8	OpenPDAC. In terms of code functionality and model physics, ChEESE-2P will add new rheological models, interaction between eruptive mixtures (volcanic gasses and pyroclasts) and water, a description of the particle grain size distribution, and the treatment of complex topographies (use of adaptive meshes). In terms of code performance, activities will focus on improving parallelization and load balancing of Lagrangian libraries and developing a parallel library for NetCDF IO.
9	LaMEM. The plan for ChEESE-2P is to implement matrix-free, geometric multigrid solvers, porting much of the current code (or solvers) such that it can use the recently added GPU-functionality in PETSc, implement BFBt solvers (which may converge better under some conditions), and implement coarse grid solvers strategies that only run on a subset of the processors to allow scalability on >16k processors.

10	pTatin3D. In terms of code functionality and model physics, ChEESE-2P will add support for Navier-slip type boundary conditions for spherical cap regional model domains using a symmetric Nitsche formulation, the extraction of surfaces defining material interfaces, and an accurate projection of material properties (stress and density) into a field defined on a mesh. The precise code performance roadmap is unclear and will depend on the first audit results.
11	Elmer/Ice. In terms of code functionality and model physics, ChEESE-2P will consider the implementation of a coupled visco-elastic Reynolds flow type of model to represent Glacier Outburst Floods (GLOFs). On the computational side, will enable cross-platform matrix solution offload to GPUs as well as the offload of matrix assembly step to accelerators, either by OpenMP offload or in parts by CUDA/HIP kernels. Apart from GPU implementation, improving on threading and vectorization using OpenMP (threading + SIMD), eventually even on the new platforms that are part of the project.

1.2.4. Farming a new Generation of Pilot Demonstrators

As in ChEESE-1P, the PDs in ChEESE-2P must be understood as proofs of concept to address the 12 target ECCs (see the Introduction for details), and can result in several capability, capacity, or urgent computing SCs depending on the underlying workflow and model configuration. The project will farm a new generation of 9 PDs underpinned by concepts like multiscale, multiphysics and multisource. This will require developments in flagship codes in order to incorporate new physics (functionalities), couplings, and forcing terms (T5.1).

Table 1.2.4a. List of Pilot Demonstrators (PDs) showing the corresponding area, involved flagship codes, and associated Exascale Computational Challenge (ECC). Area: CS computational seismology, MHD magnetohydrodynamics, V volcanology, T tsunami, GD geodynamics, GL glacier hazards.

No	PD name	Area	Related flagship codes	Initial TRL	Target TRL	Underpinning concept	ECC
1	Extreme-scale modeling of seismic hazards	CS	All CS codes	5	7	multiphysics multiscale	ECC2 ECC3
2	Joint seismic inversion and tomography	CS	SPECFEM3D	4	6	multisource	ECC1
3	Global tsunami hazard and uncertainty quantification	T	HySEA	6	8-9	multiscale	ECC6
4	Complex multi-source tsunami modeling	T	HySEA, ExaHyPE, SeisSol	3	5	multisource multiphysics	ECC4 ECC5
5	Ensemble-based volcanic dispersal at multiple scales	V	FALL3D	5	7-8	multiscale	ECC7 ECC9
6	Multiphase 3D volcanic explosion modeling	V	OpenPDAC	4	7	multiphysics multiscale	ECC8
7	The Earth's dynamo model	MHD	xSHELLS	3	5	multiscale	ECC10
8	Geodynamics to geohazards	GD	LaMEM, pTatin3D	3	5	multiscale	ECC11 ECC12
9	Glacial outburst floods	GL	Elmer/Ice	2	4	multiphysics	none

Two thirds of the PDs in ChEESE-2P are a natural evolution of their ChEESE-1P predecessors whereas the other third (PD6, PD8 and PD9) start from scratch addressing new types of phenomena and geohazards (see Figure 1.2.4). Note that the final TRLs of ChEESE-1P PDs does not necessarily match the starting TRL of their ChEESE-2P evolution (Table 1.2.4a). This is because ChEESE-2P PDs are not just a continuation of their predecessors but extend their functionality and/or model complexity.

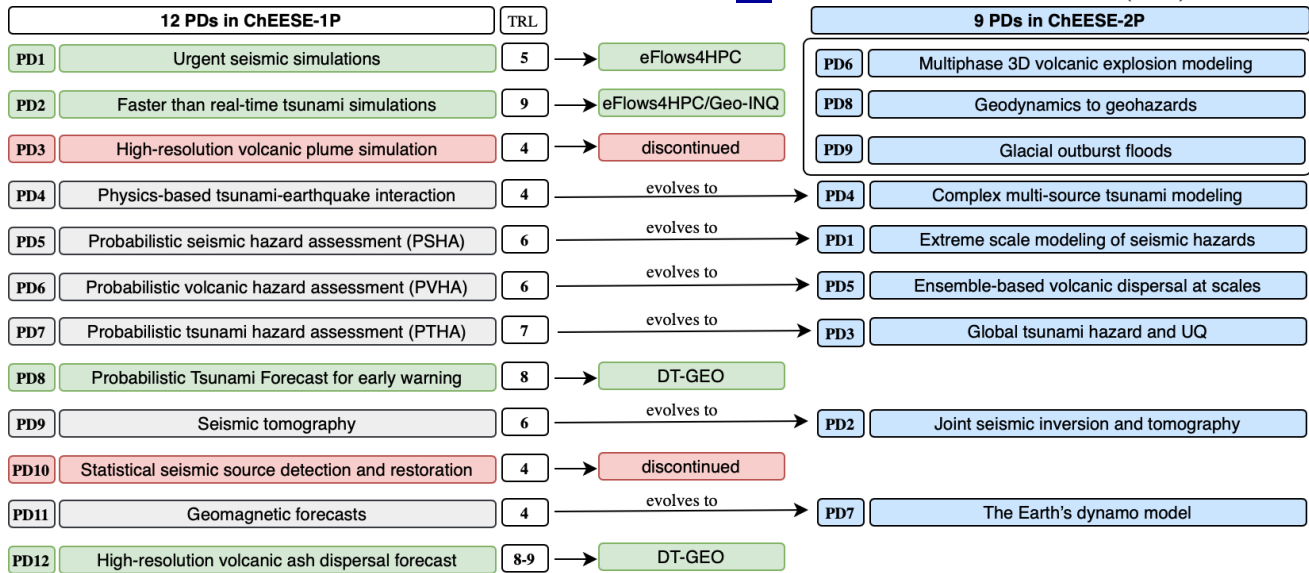


Figure 1.2.4. Evolution of the PDs from ChEESE-1P to ChEESE-2P. The color code indicates PDs discontinued, transferred elsewhere, and evolved to ChEESE-2P.

PD1	Extreme-scale modeling of seismic hazards				
PD leader	LMU	Partners	IMO, TUM, CNRS, BSC	Derived SCs	SC1.1, SC1.2, SC1.3
Problem description: This PD combines high-fidelity earthquake and seismic wave simulations performed with 4 ChEESE-2P flagship codes in order to catapult seismic simulations to bridge spatial and temporal scales by enabling the efficiency, versatility and flexibility required to allow the integration of multiphysics simulations, physics-based probabilistic hazard assessment, rapid response urgent earthquake and shaking simulations and modeling the highly complex seismic wavefield at high-frequencies, such as ubiquitous anthropogenic “noise”. PD1 will allow combining simulations that are well validated with available data with probabilistic frameworks and uncertainty quantification towards next generation physics-based hazard assessment. Using a physics-based description of earthquakes, modern numerical methods as well as hardware-specific optimisation will shed light on the dynamics, severity and cascading hazards of earthquake behavior and enable an unparalleled degree of realism exploiting high-performance computing. As a complement to forward HPC modeling, PD1 will also explore ML-based solutions that can obtain fast analogs to seismic simulations, fundamental for parameter exploration and early assessment of hazard. Objective: The objective of this PD is to improve the scalability and time-to-solution of the earthquake modeling and seismic wave propagation codes SeisSol, ExaHyPE, SPECFEM3D and Tandem. These flagship codes will be enhanced with respect to new features in model physics (such as viscoelasticity), IO including capabilities for importing and exporting 3D volume data for one-way or two-way multiphysics coupling, and mesh generation. The developed multiphysics, probabilistic and data-integration capabilities will be tailored towards future DestinE integration in digital twin components, such as those developed in DT-GEO, and specific models and data will be prepared to be shared via EPOS, utilizing synergies with Geo-INQUIRE, and inform rapid response simulations.					

PD2	High-resolution seismic inversion and tomography				
PD leader	CNRS	Partners	CSIC, BSC, INGV	Derived SCs	SC2.1
Problem description: High-resolution subsurface imaging entails high-frequency computations up to 20Hz to achieve a resolution of a few tens of meters. Given the very strong heterogeneity and anisotropy of the upper crust and the strong attenuation effect at the considered frequencies, the complete anisotropic tensor and the material attenuation need to be inverted, requiring second order optimization methods such as Newton or Gauss-Newton to perform multi-parameter inversions in a more robust way. Objective: The objective of this PD is to define a complete and flexible workflow for seismic inversion in conjunction with other methods such as gravimetry (density is an important physical parameter that is not well-resolved yet by seismic tomography). This implies: (1) Joint inversion with gravimetric data defining a multi-objective functional that contains both the seismic and gravity data. (2) Computation of the initial guess model using methods based on the Eikonal equation to make a tomography of the first arrival times. (3) Add new parameters in the inversion to account for upper crust heterogeneity, anisotropy and attenuation. (4) Use a 2nd-order optimization method (gradient+Hessian) to address the shortcomings of the classical adjoint method. These 2nd-order methods are not used yet in 3D and in time-domain solvers because of the 10-100 times cost increase compared to the classical (gradient) method. This PD is an evolution of the ChEESE-1P PD9 (seismic tomography, final TRL 6) to focus on the local scale, i.e. on areas of a few kilometers to a few tens of kilometers using local seismicity/gravity data. Challenges at-scale concerning the local seismicity include locating the					

hypocenters, inverting the moment tensor, and computation of the source time function. For these reasons the start TRL has been lowered to 4.

PD3	Global probabilistic tsunami hazard and uncertainty quantification				
PD leader	INGV	Partners	UMA, NGI, TUM, LMU	Derived SCs	SC3.1
Problem description: The developments in ChEESE-1P included an earthquake-based PTHA model for simulating local tsunami hazard in the Mediterranean Sea, focusing on the inundation process. The novelty of the ChEESE-1P PTHA model was the combination of unprecedented numbers (order 10^5-10^6) and high-resolution inundation simulations in capacity workloads. This PD will further expand these previous developments with the following new functionalities: (1) allowing users to carry out local PTHA analysis at high resolution at any location worldwide, (2) add a new module to upload user-defined source treatment, from probability and rates, to fault data and earthquake source models, including heterogeneous and dynamic slip, (3) provide interoperability with the Global Earthquake Models (GEM) OpenQuake engine and, (4) include generators for tsunami initiation from dynamic and stochastic slip processes, using available services distributed by the EPOS-TCS Tsunami, and tsunami propagation using the shallow water version of HySEA. Objectives: The main objectives of this PD are: (1) Provide a workflow for carrying out PTHA capacity workloads that can exploit tier-0 and tier-1 machines. (2) Provide enhanced capacity of carrying out multiscale (from global to local) PTHA at any location worldwide. (3) make it interoperable with seismic hazard tools (enabling a link between the Global Tsunami Model and GEM); make it compatible and interoperable with other relevant tools that will be developed in the Horizon project DT-GEO aiming at DestinE, and with the EPOS-TCS Tsunami service delivery framework also through compatibility with products available through the Horizon project Geo-INQUIRE (D6.4).					

PD4	Complex multi-source tsunami modeling				
PD leader	NGI	Partners	UMA, INGV, TUM, LMU, CNRS, RBI, UM	Derived SCs	SC4.1
Problem description: This PD will combine multiphysics processes from earthquakes, landslides, volcanoes, and acoustic pressure and atmospheric forcing to tsunami generation and propagation in a single workflow that allows coupling of different flagship codes. Particular attention is given to modeling processes that are not being tackled so far in other related projects (e.g. in the DT-GEO project towards DestinE). Several recent tsunami events worldwide have involved different geophysical processes that took place at the same time. For instance, the 2018 Palu tsunami involved both earthquake supershear and slope failure and landslides, while the 2022 Hunga Tonga eruption involved a range of processes from volcano explosion, earthquakes, landslides, and atmospheric pressure wave, all coupled to tsunami generation. Present tsunami prediction capabilities in use today use a single source representation. This restriction limits the understanding of the tsunami generation processes and our possibility of coupling them. It is hence necessary to develop a coupled approach where all the different physics can be tied together, including complex earthquake rupture, landslides, volcanic explosions, acoustic pressure and explosions, as well as meteorological tsunami sources (meteotsunamis). Objectives: The main objectives of this PD are: (1) integrate advanced source multiphysics with tsunami propagation models at both unprecedented resolution at the source and widespread regional coverage through capability modeling aiming towards exascale, in a complementary way to DT-GEO towards DestinE, (2) prepare the models to be later available through the EPOS TCS Tsunami both as Virtual Access or TransNational Access, as in Geo-INQUIRE, and specifically for UC applications that may be needed in the event of a future catastrophic event, (3) enable higher degree of complexity and diversity in source representation in tsunami generation modeling than what is available today through state-of-the-art modeling and, (4) obtain, through models that can capture more advanced physics and higher resolution, the basis for providing insight into solving potential SGC phenomena that are intrinsically multi-source of nature.					

PD5	Ensemble-based volcanic dispersal across multiple scales				
PD leader	CSIC-IMO	Partners	INGV	Derived SCs	SC5.1, SC5.2
Problem description: Volcanic eruptions emit aerosols and particles of sizes ranging from centimeters to microns that impact at varying distances. Depending on the range, the atmospheric dispersal and deposition mechanisms are controlled by winds and meteorological phenomena occurring at scales from local (e.g. orography and breeze effects) to global (general atmospheric circulation). The developments in ChEESE-1P included a PVHA workflow and a forecast strategy generally valid in the mesoscale range. This restriction presents shortcomings when volcanoes are in or very close to populated areas. For example, during the eruption at La Palma, the air quality forecasts were very challenging and often failed due to complex local-scale wind patterns not well captured by the models, including wind convection phenomena caused by the presence of widespread lava flows at high temperatures. Objectives: The main objectives of this PD are: (1) include a wind downscaling strategy to capture local-scale effects and make volcanic forecasts realistic below km-scale resolutions and, (2) enable a model nesting strategy for telescopic PVHA, thereby leading to high-resolution accurate forecasts. This aspect is pivotal for a proper response during crises and prompt early-warning of severe pollution conditions expected in populated regions around volcanoes (SC5.2). On the other hand, the multiscale approach will allow for the first European tephra hazard map at scale covering, simultaneously, long-range					

PD6	Multiphase 3D volcanic explosion modeling				
PD leader	INGV	Partners	CIN, CSIC	Derived SCs	SC6.1, SC6.2
Problem description: Recent events at Mt. Ontake (Japan, 2014) and Whakaari/White Island (New Zealand, 2019) showed that the hazard associated with small-scale, potentially frequent, phreatic explosions has been underestimated, partly due to the general lack of long/medium term precursory geophysical signals and of numerical models specifically designed to simulate these processes. These aspects require high-resolution simulations of explosions associated with water flashing (phreatic explosions) typical of magmatic and hydrothermal systems in volcanic islands and calderas, the quantification of their hazards (particularly, pyroclastic flows and ballistic ejection) and the development of UC procedures to produce maps of hazardous actions from phreatic eruptions during volcanic unrests. Objectives: The main objectives of this PD are: (1) develop a multiscale simulation capability (from sub-meter scale for the initial water flashing phase to kilometer scale for the flow and ballistic impacted area) of explosive processes, improving unstructured mesh discretization methods (potentially including adaptive meshes) and sub-grid scale modeling, (2) develop physical models for mechanical and thermal non-equilibrium multiphase eruptive mixtures and for the temperature evolution of ballistic blocks and, (3) exploring two- and four-way coupling of coarse Lagrangian ballistic particles with Eulerian fine ash and gas phases in the eruptive mixture. This will result in the development of an UC workflow (pre- syn- and post-processing and visualization) for deterministic scenario definition and probabilistic hazard mapping workflow for phreatic eruptions on volcanic islands and calderas, including uncertainty quantification.					

PD7	The Earth's dynamo model				
PD leader	CNRS	Partners	IPGP	Derived SCs	SC7.1
Problem description: The Earth's magnetic field is generated and maintained by turbulent flow of liquid metal in the Earth's outer core. Its variability exhibits a wide range of time and length scales, from interannual pulses of secular acceleration to the occasional reversal of the geomagnetic field. This system is characterized by a high degree of scale separation: the magnetic field is large-scale while flow and buoyancy (which is of thermo-chemical origin) are small-scale, on the account of their smaller diffusivity coefficients. The developments in ChEESE-1P were constrained to a limited time span and an arguably limited range of spatial scales, which may be detrimental to the quality of short-term geomagnetic forecasts. This PD will extend the previous developments by embracing the full spectrum of flow motion at stake and enabling a longer time integration by using a handful of very high-resolution simulations (over short time spans) to train dedicated neural networks for subgrid-scale modeling. The work plan consists of 3 successive steps: 1) use AI to infer the free parameters of standard subgrid-scale models using Neural Networks (NN). This should work well for hydrodynamic simulations (no magnetic field), and also for realistic dynamo simulations with scale-separation (a feature of the real Earth core) if the subgrid-scale model operates below the magnetic dissipation scale. 2) use AI to infer the subgrid-scale contribution, in a fully data-driven way. No explicit models are assumed. This will require more data to train the model, but should allow more accurate subgrid-scale models. The NN will take advantage of physical invariants and symmetries, and 3) the final step will be to implement end-to-end training that requires a fully differentiable code. Objectives: The main objectives of this PD are: (1) simulate the geodynamo process with an unprecedented level of realism, most notably by acknowledging that the fluid flow is highly turbulent and small-scale, while the magnetic field is large-scale, (2) assess the impact of turbulent flow on the short and long term working of the geodynamo, and propose an AI-based parameterization of subgrid-scale fluxes that is physics-informed and, (3) include the effect of double-diffusive convection on the geodynamo model, through its impact on the subgrid-scale fluxes and on the overall dynamics.					

PD8	Geodynamics to geohazards				
PD leader	UM	Partners	CNRS, CSIC, LMU, SU	Derived SCs	SC8.1, SC8.2
Problem description: The slow deformation of the solid Earth takes place over long timescales, involves large strains and non-linear viscoelastoplastic rheologies. This deformation governs processes on a wide range of scales, from fluid flowing through porous rocks on a micrometer scale to the motion of tectonic plates on thousands of kilometers, and controls the stress state of the lithosphere, affects where earthquakes occur, or how magma migrates through the crust. It also affects stresses within sedimentary basins and geothermal reservoirs and thus plays a key role for the long-term safety of nuclear waste deposits. Whereas existing geodynamic codes are typically applied to more basic scientific questions (such as how mountain belts form), they can equally well be used to simulate geohazards such as landslides or coupled geodynamic/seismic simulations. This PD focusses on these topics, which requires work to couple geodynamic with seismic codes. Objectives: The main objectives of this PD are: (1) improve the workflow of geodynamic codes to such an extent that they can be rapidly deployed to simulate any part of the Earth and model output can be compared with observations, (2) export					

and project material properties and state of stress to other codes for multiphysics modeling purposes and, (3) prepare geodynamic codes for the next generation GPU machines, by improving multigrid strategies, implement matrix free solvers and as well as novel BFBt preconditioners.

PD9	Glacial outburst floods				
PD leader	CSC	Partners	IMO, CNRS	Derived SCs	SC9.1, SC9.2
Problem description: Glacial lake outburst flood (GLOF) and jökulhlaups (a type of GLOF where water results from melting and subsequent overflowing of the hosting glacier) imply massive displacements of water contained in glacial reservoirs and can be triggered by multiple processes (e.g. water level increase, sub-glacier eruptions, earthquakes). Modeling the glacier failure process requires to couple subglacial-hydrology and ice-deformation models, typically consisting of a 2D horizontal solution for the subglacial water-flux/pressure distribution and a fully 3D visco-elastic model describing the glacier deformation in reaction to the pressurization by the subglacial flood. Objectives: The main objective of this PD is to numerically describe a traveling pressure-wave underneath a visco-elastic plate, where ice viscosity is a function of the strain-rate (i.e., the temporal derivative of the deformation itself). To that end, a two-dimensional elliptic equation describing the temporal evolution of the subglacial water pressure (or piezometric height) needs to be formulated in a Manning-type of water sheet flow strongly coupled to the overlying visco-elastically deforming ice-body. This PD will explore techniques like artificial compressibility and/or matrix block preconditioning techniques in order to achieve a stable solution procedure.					

1.2.5. Simulation Cases and Service Enabling

The PDs will materialize in 15 Simulation Cases (SCs) that target 6 capability (T6.2) and 9 capacity (T6.3) use cases. The different SCs have been defined based on scientific interest, social relevance, window of opportunity (hazardous events that have occurred recently or are likely to occur in the near future, e.g. during the on-going unrest episodes at Vulcano Island and Solfatara), and homogeneous geographic coverage across Europe and beyond. SCs will run in production on EuroHPC tier-0/tier-1 using ChEESE-2P in-kind resources (see Sec. 1.2.6) and, especially, making use of different EuroHPC access modes though competitive call resources. ChEESE-1P has been successful in obtaining PRACE competitive resources (up to 217M core hours in 3 years) and the plan is to adopt a similar strategy in ChEESE-2P with the support of T1.4 to prepare several calls on regular and extreme-scale access modes. If possible, the ambition is to run up to 4 of the capability SCs as Scientific Grand Challenges (SGCs), i.e. as “full-scale” executions (60-90% of pre-exascale machines). SCs will produce FAIR and EPOS-compliant (i.e. identified by appropriate metadata) open datasets and, in higher-reaching TRL cases, will also serve as service prototypes for EPOS-TCS and to enable urgent computing services in EuroHPC systems (T6.4). This will be done in cooperation with the IUB members for the definition of functional requirements and through participation in live demo exercises. The Tables and Figure 1.2.5 below detail, respectively, the 15 SCs (description and expected results) and their geographic location.

Table 1.2.5. List of the Simulation Cases (SC) resulting from executing PDs in production runs and expected results. Nomenclature: SC1.2 means second SC derived from PD1, SC6.1 means first SC derived from PD6, and so on.

No	SC name	Type of run	SGC	Task(s)	Expected outcome
SC1.1	Anthropogenic noise and seismicity, wave propagation at higher frequencies in Rade d'Hyères	capability	yes	T6.2	open datasets
SC1.2	Next generation of earthquake simulators for the Hellenic arc and Iceland	capacity	-	T6.3	open datasets (earthquake catalogs)
SC1.3	Physics-based PSHA and urgent UQ for Iceland	capacity	-	T6.2 / T6.3	UC service enabling
SC2.1	Seismic tomography of the Adriatic-Ionian region	capability	yes	T6.2	open datasets
SC3.1	The Global Tsunami Hazard Map	capacity	-	T6.3	TCS-TSU service in EPOS
SC4.1	Multi-source local high-resolution scenario with emphasis on the 2022 Tonga case	capability	yes	T6.2 / T6.3	UC service enabling
SC5.1	Towards the European tephra hazard map	capacity	-	T6.3	TCS-VO service in EPOS
SC5.2	Volcanic dispersal at local scale: a reanalysis of the 2021 La Palma case	capacity	-	T6.2 / T6.3	UC service enabling
SC6.1	Urgent high-resolution, 3D multiphase flow simulation of phreatic eruptions at Vulcano	capability	-	T6.2 / T6.3	UC service enabling

SC6.2	Long-term probabilistic hazard maps for phreatic eruptions at Vulcano island	capacity	-	T6.3	open datasets
SC7.1	MHD turbulence closure models in planetary cores using AI	capacity	-	T6.3	open datasets
SC8.1	Magmatic systems and induced landslides: the Etna case	capability	yes	T6.2	open datasets
SC8.2	3D evolution of tectonic deformation as driver of seismic hazard in the Hellenic arc	capability	-	T6.2	open datasets
SC9.1	Eastern Skaftá cauldron GLOF simulation, Iceland	capacity	-	T6.3	open datasets
SC9.2	Calving glacier hazard in Greenland	capacity	-	T6.3	open datasets

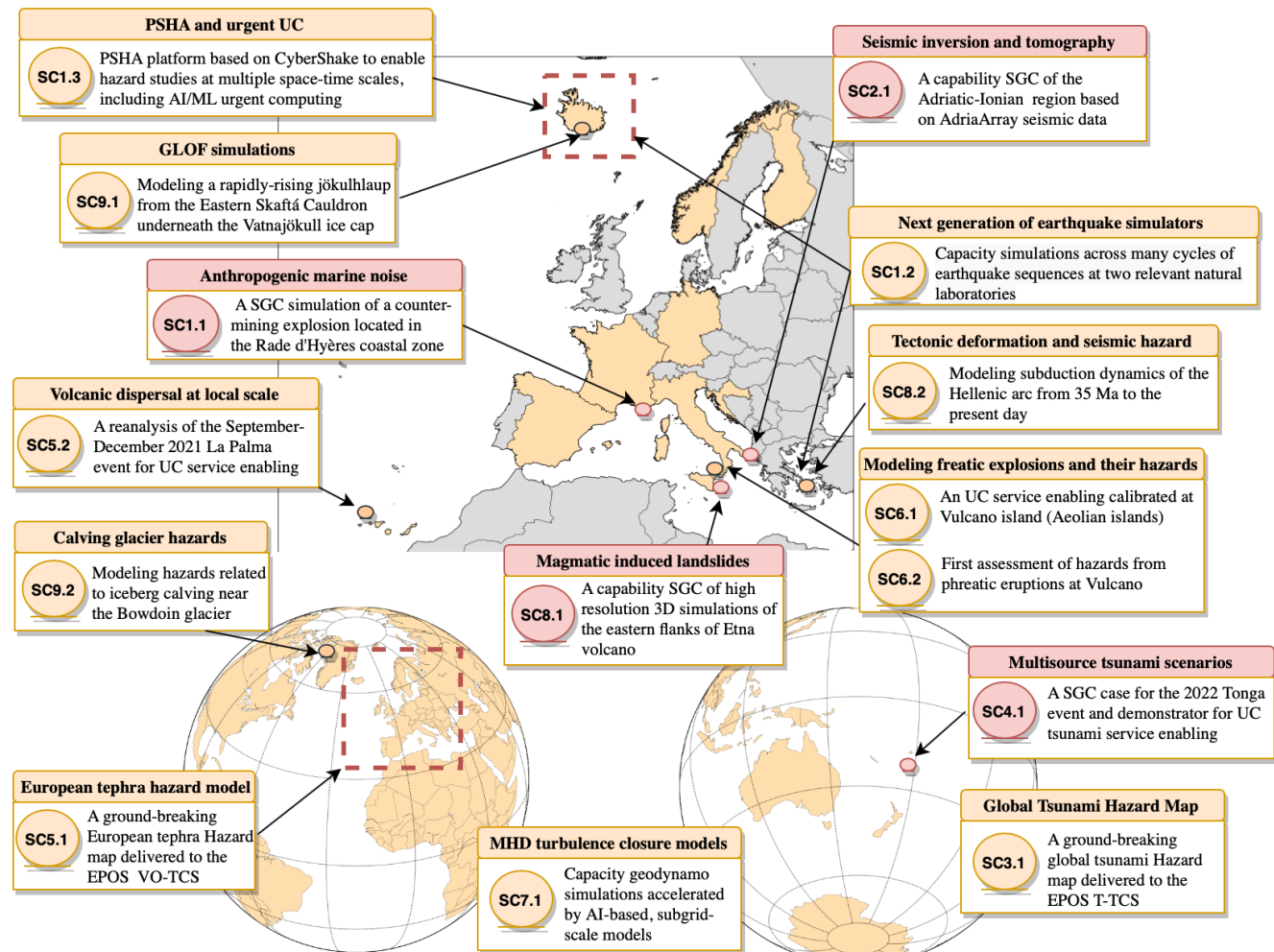


Figure 1.2.5. Location of the 15 Simulation Cases (SCs) and target Scientific Grand Challenges (SGCs, shown in red).

SC1.1	Anthropogenic noise and seismicity, wave propagation at higher frequencies in Rade d'Hyères				
SC leader	CNRS	Partners	CSIC	Type	Hazard assessment
Description: The upstream assessment of noise pollution generated by anthropogenic activities in the coastal zone (e.g. offshore civil engineering works, disposal of historical explosive devices) is a crucial issue with respect to the European Marine Strategy Framework Directive (MFSF) which advocates that the “introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment”. In addition, specific anthropogenic activities may induce seismic risks. The goal of SC1.1 is then to pave the way for reliably assessing both the noise pollution in the marine environment and the risks of damage to buildings on the shore, induced by the detonation of WWII Unexploded Ordnance (UXO) of large weights in variable shallow water environments with a water depth less than 50 m. The aim of the run is to model the full seismo-acoustic wave propagation (i.e. both in water and in unconsolidated sediments and bedrock) generated by an underwater explosion located in the coastal zone a few kilometers offshore, in the same					

conditions as for the UXO counter-mining campaigns usually carried out in the Rade d'Hyères in the Mediterranean Sea (south-east of France).

Expected results: Previous simulations were performed at 30Hz with a mesh size of 100 million elements running SPEC3D on 1024 V100 GPUs. This new capability (and potential for SGC) run expects to increase by at least a factor of 50-100, which means computations reaching up to 100Hz. In this range and for a computational area of 20x20x5 km a mesh comprising 3.7B elements is needed, with a mesh size of 3m on the surface and in the sediment in order to represent the topography and the different sedimentary layers. Once the bedrock is reached, the mesh size will be multiplied by 3 and 9 depending on the depth.

SC1.2	Next generation of earthquake simulators for the Hellenic arc and Iceland				
SC leader	LMU	Partners	TUM, CNRS, UM	Type	Basic research, hazard assessment
Description: This capacity SC will perform dynamic rupture, earthquake and slip simulations across many cycles of earthquake sequences at two relevant natural laboratories for which interdisciplinary geo- and hazard-data was acquired and unified for HPC applications in ChEESE-1P: the Hellenic Arc and the Southwest Iceland transform zone. While historical and geological records (extending over several thousands of years) have been used to construct catalogs of major earthquakes on known natural fault systems, constructing seismic hazard maps and estimating probabilities of aftershocks in the aftermath of large earthquakes are challenged by the lack of space-time complete, quantitative data on fundamental observables of the seismic cycle (e.g. magnitude and recurrence interval of large earthquakes). Also, the mechanics and feedback of earthquake fault networks throughout the seismic cycle remains poorly understood. The Hellenic Arc case will integrate novel high-resolution 3D structures developed using SPEC3D in PD2 (SC2.2) with earthquake-tsunami modeling capabilities of SeisSol to the developments in complex multi-source tsunami modeling of PD4. The model region is large and complex; the Hellenic Arc subduction zone itself extends over an area of 860km x 625km x 90km, including a complex slab geometry. Tsunami generating earthquakes may involve secondary splay fault activation. Time scales under consideration span from 35 Ma (starting point of SC8.2's geodynamic modeling of the evolution of the tectonic structure of the upper plate) to the seconds of seismic wave propagation. The modeling of the seismic cycle of the Southwest Iceland transform zone (~130x50 km), that poses the largest threat to the majority of the population, will be constrained in the long-term by the historical earthquake catalog (~1000 years) and in the short-term by the deformation measurements and earthquake hypocentral locations of recent decades, including the high-resolution measurements of the ongoing volcano-tectonic episode (since 2019). The modeling results will directly feed into SC1.3 where earthquake scenarios consistent with seismic cycle modeling will be simulated using physics-based approaches leading to non-ergodic hazard assessment and urgent shaking scenarios. The SC's physics-based results for aftershock sequences and short-term seismic hazard will be verified by independent, Southwest Iceland regional-specific ETAS statistical modeling. Expected results: Enhance our fundamental understanding of earthquake faulting and crustal deformation on different space-time scales. The developments in ChEESE-2P will allow the direct comparison of our findings to data (validation) in the Hellenic Arc region and Southwest Iceland and enable monitoring and mitigation of the effects of potential large earthquakes with current and future observational networks and statistical modeling. SC1.2 is of highly integrative character as well, it links several ChEESE flagship codes: Tandem, SeisSol, pTatin3D, SPEC3D and several PDs (PD1, PD2, PD4, PD8). The simulated earthquake catalogs will be prepared to be made available within the Geo-INQUIRE infrastructure, and the workflows complement digital twin components developed in DT-GEO, to readily inform operational hazard assessment from physics-based modeling.					

SC1.3	Physics-based PSHA and urgent UQ for Iceland: next generation hazard map				
SC leader	LMU	Partners	IMO, BSC, TUM	Type	Hazard assessment, urgent computing
Description: This capacity SC brings together state-of-the-art physics-based probabilistic seismic hazard analysis (PB-PSHA) with physics-based earthquake scenario forecasting (SC1.2) and strong ground shaking simulations that shall be launched immediately after seismic and/or deformation events in the Southwest Iceland transform zone to more accurately predict which areas are affected, and to what extent (UC service). In ChEESE-1P, the first PB-PSHA was carried out using time-independent finite-fault earthquake catalogs simulated on the basis of the 3D fault system model, for which earthquake rupture modeling and ground motion simulations were carried out using the fully probabilistic Southern California Earthquake Center (SCEC) CyberShake framework. Here, the seismic cycle modeling (SC1.2) is expected to directly inform on the likely hot-spots of tectonic loading along the zone in the short-term. It will thus serve as the gateway to the seamless migration from time-independent PB-PSHA to urgent and short-term earthquake scenario modeling and ground motion simulations for time-dependent forecasting, with important implications for expected impact and risk for those modern society's systems that are vulnerable to strong seismic motions. To this end, SC1.3 will unify the range of physics-based forward and ensemble simulations constrained by regional observations to which a seismic cycle model is calibrated for Southwest Iceland (SC1.2), thus ensuring consistency of all required geophysical information to enable modeling based hazard assessment. Expected results: Enable the open-source, multi-physics software SeisSol as a plugin within CyberShake, thus adding versatility to the platform. A SeisSol-enabled CyberShake model can introduce novel features such as topography or thin sedimentary basins to Iceland's PSHA models, while benefiting from future developments in SeisSol both within ChEESE-2P and elsewhere. This novel PSHA platform will then enable hazard studies at multiple space-time scales that help					

bridging fundamental issues with existing PSHA models (e.g. recurrence models, wave physics). This SC will also utilize the MUQ capabilities of ExaHyPE and SeisSol in a rapid response setting and use ML/AI models, trained from HPC simulation results and observations, able to reproduce with substantial accuracy the outcomes of full-field HPC simulations.

SC2.1	Seismic tomography of the Adriatic-Ionian region				
SC leader	INGV	Partners	CNRS	Type	Subsurface imaging
Description: This capability SC (and potential SGC candidate) plans to build a high-resolution full wave seismic anisotropic tomography for the Adriatic-Ionian lithosphere, targeting a resolution of 3s/5km. Enhanced accuracy is enabled by state-of-the-art 3D wavefield simulations using the code SPECFEM3D in combination with an iterative adjoint-state method. The SC will focus on a region encompassed between longitude 11°E-25°E and latitude 34.5°N-46.5°N, with an emphasis on coastal and marine regions. In this area, during the last 22 years more than 800 seismic events have been recorded by more than 400 seismic stations (AdriaArray Seismic Network). The SC will start from the adjoint tomography of the Italian lithosphere recently published, increasing its resolution and extending its coverage. Expected results: Despite the important role of the Adriatic-Ionian region in the geodynamics of the central Mediterranean, its lithospheric structure is poorly known in term of seismic velocity profile, due to a lack of seismic stations, poor earthquake location quality (large observational gaps), and the consequent lack of coverage by classical seismic tomography methods. SC2.1 will increase the scientific knowledge of this region with an important impact in terms of seismic hazard.					

SC3.1	The Global Tsunami Hazard Map				
SC leader	INGV, UMA	Partners	NGI, TUM	Type	Hazard assessment
Description: This capacity SC aims at providing a global seismic tsunami hazard map at unprecedented resolution, both in terms of increased source variability exploration and spatial output. The model aims at a full coverage of both global tsunamigenic earthquake zones and global coastlines. It will exploit previous global tsunami hazard analysis and it will substantially extend the resolution and uncertainty treatment to provide a new global benchmark. The key for providing a substantial advancement is exploiting the functionality developed in PD3 for resolving extensively the earthquake source uncertainty treatment in PTHA combined with high resolution tsunami modeling. Expected results: Capacity simulations will be carried out for about 100,000 unit sources carried out on regional to global grids with resolutions of at least 30 arcseconds to simulate about 40 h of tsunami propagation. Complementary scenarios (combining many unit sources) will be carried out as input to the local-scale inundation simulations. About 0.5M of GPU hours for the offshore tsunami simulations and up to 5M of GPU hours for the inundation simulations are expected to encompass several tens of millions of tsunami scenarios covering the entire globe and high resolution inundation maps for at least 10-20 hotspot locations. This global benchmark, which will be distributed through the TCS Tsunami in EPOS, will prototype possibilities for increased utilization of EuroHPC resources for local hazard and risk analysis, and form the background for a unique service, to be added to those distributed by Geo-INQUIRE.					

SC4.1	Multi-source local high-resolution scenario with emphasis on the 2022 Tonga case				
SC leader	NGI	Partners	TUM, INGV, UMA, LMU, RBI, CNRS	Type	EWS, urgent computing
Description: This capability SC (and potential SGC) will simulate coupled tsunamigenic geohazard phenomena that involve a variety of phenomena encompassing different physical processes, such as complex earthquake rupture physics, landslides and volcanic explosions. A prominent example of such a case is the 2022 Tonga eruption and tsunami, which involved a series of events, from seismic precursors, explosion, landslides, atmospheric pressure, and tsunami generation. The atmospheric pressure wave induced a tsunami that traveled faster than the locally generated tsunami. Another complex event is the 2018 Palu event involving supershear earthquake dynamics and contemporaneous slope failures and landslides, both generating tsunamis. The seismo-volcanic crisis in Mayotte related to the birth of a new submarine volcano in 2018 is also an ideal and timely case study since tsunamis generated by submarine volcanic explosions, caldera collapse, earthquakes and landslides are present threats for the population and infrastructures. The complexity of these events implies that coupled multiphysics simulations are needed to gain insight about the events, and ideally explain which phenomena contribute how much to the generated tsunami hazard, and assess the importance of each modeled process on the generated tsunami hazard. Expected results: The Tonga case will involve high-resolution coupling of flagship codes for acoustic pressure waves and seismic rupture (SeisSol), landslides (HySEA or ExaHyPE), and coupled far field tsunami propagation forced by atmospheric pressure waves (HySEA). HySEA will be updated to take into account atmospheric forcing in PD4 (T5.1). A fine-resolution local simulation resolving the acoustic pressure wave, landslide dynamics, as well as a heuristic modeling of the caldera collapse and local tsunami generation will need to be coupled to a global-scale propagation model for the atmospheric pressure wave and tsunami. Combined, this will require very large computational resources to resolve a single simulation, which implies a push towards testing the simulation using pre-exascale computational resources. On the other hand, through the capacity simulations, the SC will also gain new insight into complex multiphysics phenomena (e.g. high resolution atmospheric pressure wave, earthquake dynamics, landslides, all coupled to tsunami generation) that cannot be described only by single source models and will establish one potential service for UC applications in the EuroHPC context.					

SC5.1	Towards the European tephra hazard model  Associated with document Ref. Ares(2022)8497838 - 07/12/2022				
SC leader	INGV	Partners	CSIC, IMO	Type	Hazard assessment
Description: This capacity SC aims at paving the road for the first homogeneous multi-volcano probabilistic hazard model for volcanic tephra in Europe. As there is a highly variable degree of knowledge among the different volcanoes and volcanic districts, the main challenge is to include multiple sources (i.e. volcanoes or volcanic districts) and, for each of them, multiple eruptive scenarios. Where the knowledge of volcanic sources is at sufficient detail in terms of eruptive record and possible scenarios (e.g. Italy), this SC will do a first attempt of National tephra hazard model at high resolution, considering all the key and best-known explosive active volcanoes in the territory (e.g. Vesuvius, Campi Flegrei, Ischia and Etna). Such a model will show those areas in the country statistically more likely to receive tephra fallout. On the other hand, at European scale, a similar approach will be used to provide a European hazard model for airspace areas prone to be contaminated by dangerous concentrations at cruise Flight Level (FL550). Dispersion model results for eruptions in several volcanic districts in Europe (e.g. Iceland, Italy, Canaries, Jan Mayen, Greece and Azores) will be integrated to create a single probabilistic model. Eruptive scenarios for these volcanic districts will be designed by using the database already available through the European Catalog of Volcanoes (EUROVOLC product). Expected results: First step towards a European volcanic ash hazard assessment in line with the United Nations DDR policy. The analysis will be performed over a domain including the densest air traffic regions in Europe, which spans over a 2000 x 5000 km area at a resolution of less than 10 km for European scale and 2 km at regional scale. The final datasets will be accessible through the TCS Volcano Observations service in EPOS for their usage and distribution.					

SC5.2	Volcanic dispersal at local scale: a reanalysis of the 2021 La Palma case				
SC leader	CSIC	Partners	INGV	Type	EWS, urgent computing
Description: Recent volcanic eruptions in Europe (La Palma in the Canaries and Fagradalsfjall in Iceland) did bring attention to events characterized by sustained low-intensity gas (mainly SO₂) and ash release in the lowest part of the atmosphere, causing serious concerns for public health as well as for environmental impact. In common, these events also had the specificity of occurring in small islands/peninsulas with sensitive targets (towns, villages, infrastructures, airports) within distances shorter than 30 km from the emitting source. Reproducing numerically the ongoing dynamic and forecasting the transport of volcanic emissions over complex and small domains has been challenging due to interactions between the atmosphere and the eruption dynamics (e.g. micrometeorology induced by the lava field, conversion of SO₂ in sulfates when the gas particles are interacting with the water droplets and solar radiation in the atmosphere). Expected results: This SC will do a reanalysis of the September-December 2021 La Palma event at 1-2 km resolution making use of different observations available for tuning and verifying the model performance for a more reliable and robust forecast. This will showcase a potential UC service for volcanic dispersal forecasts at local scale.					

SC6.1	Urgent high-resolution 3D multiphase flow simulation of phreatic eruptions at Vulcano				
SC leader	INGV	Partners	CIN	Type	Urgent computing
Description: The objective of this capability SC is to run OpenPDAC for urgent simulation of phreatic eruptions to be potentially used in the framework of a volcanic unrest. The specific application will be calibrated on Vulcano (Aeolian islands, Italy) which, since September 2021, is in an unrest state potentially leading to a phreatic event. Expected results: Functional requirements will be defined with the potential stakeholders at the beginning of the project. As an indication, the goal is to achieve a spatial resolution at ground <1m, domain size ~5×5×5 km³ (covering the whole island) potentially requiring >10⁸ elements and >10⁹ degrees of freedom solved on O(10⁴) cores. The time-to-solution for a single explosive event lasting 5 to 10 minutes should remain below about 10-15 min. Outputs will include maps of maximum temperature, dynamic pressure, ash concentration, ballistic fall landing time, density and energy. Video animations will be generated for dissemination and outreach, including the organization of a UC “live” exercise involving potential stakeholders (Italian Civil Protection, Lipari Municipality, DG-ECHO). The case has potential extension to other volcanic areas (e.g., Guadeloupe, Martinique, Solfatara) through Transnational Access.					

SC6.2	Long-term probabilistic hazard maps for phreatic eruptions at Vulcano island				
SC leader	INGV	Partners	CSIC	Type	Hazard assessment
Description: The objective of this capacity SC is to exploit the parallel workflow developed in PD6 to perform, for the first time, a wide (hundreds to thousands) ensemble of uncorrelated high-resolution, 3D numerical simulations of phreatic eruptions at Vulcano (Aeolian islands, Italy). This will be provided to the Italian and local authorities in charge of evaluating the medium-to-long term hazard at Vulcano, which is in an unrest state (since September 2021) potentially leading to a phreatic event. The probabilistic study will consider and assess the uncertainty on the possible vent location, volume and energy of the eruption, gas/liquid ratio, rock porosity and temperature. The size of the ensemble adopting a Latin Hypercube sampling strategy should be of the order of several hundreds. Expected results: General open-source workflow and numerical engine for ensemble simulation of phreatic eruptions on volcanic islands and probabilistic hazard maps in standard netCDF format provided to the stakeholders (Italian Civil					

SC7.1	MHD turbulence closure models in planetary cores using AI				
SC leader	CNRS	Partners	IPGP	Type	Basic research
Description: This SC will run capacity geodynamo simulations accelerated by AI-based, subgrid-scale models and prototype first the Neural Network (NN) on a series of 2D turbulent simulations of rotating convection using the pizza code, which is a pseudo-spectral code whose solution strategy is similar to the one used in the xSHELLS code. In order to implement and validate the NN, the level of rotating turbulence will be gradually increased until a Reynolds number equals 10^5, with a Rossby number equal to 10^{-4}, amounting to DNS 1200^3. At each step, upon successful validation of the NN framework with the prototype, we will next couple it with the xSHELLS code and assess its accuracy using a high-fidelity simulation run with 3 resolutions DNS: 200^3, 500^3 and 1200^3. For each resolution, about 100 (at coarse resolution), 30 (at medium resolution) and 10 (at large resolution) runs will be made to explore a variety of regimes with and without subgrid-scale models: some runs without magnetic field, some with magnetic field but no scale separation, some with scale separation for the magnetic field, some with separate chemical and temperature fields and scale separation. The idea is to simulate the Earth's core at the equivalent of a DNS with resolution 4000^3 or more, at about 1/1000 of the cost. The scientific gain is important, such a subgrid-scale model could be applied to many geophysical and astrophysical models, resulting in a speed-up of current and future calculations by orders of magnitude. Expected results: In the case the model is relevant for other parameters (as suggested by the "path theory" for the Earth's core), one could readily simulate the Earth's core at its nominal parameters. Orders of magnitude improvement in time-to-simulation is also what is needed to explore the magnetic field reversals at realistic parameters, and to perform realistic parametric studies. The numerical datasets produced will be made available to the community, each comprising a catalog of time series of the quantity of interest, time-dependent 2D maps of the field and flow at the core surface, and a number of full 3D snapshots for more detailed post-processing.					

SC8.1	Magmatic systems and induced landslides: the Etna case				
SC leader	UM	Partners	CNRS, INGV, SU	Type	Hazard assessment
Description: A significant risk related to volcanic eruptions is that the flank of a volcano can collapse before or during an eruption, which can induce tsunamis or generate even larger eruptions. A particularly relevant case is the southern flank of Etna, which is currently sliding seawards with several cm's per year. It is crucial to create numerical models of these processes, in order to estimate whether future changes in the magmatic system may cause the sliding to become catastrophic (and induce a major eruption/tsunami). This capability SC (and potential SGC) will run high resolution 3D viscoelastoplastic forward simulations of the eastern part of Etna over a region $\sim 50 \text{ km}^3$ in size, with a spatial resolution of around 50 meters to resolve the major faults. It requires time-dependent simulations (~ 100-1000 timesteps) to simulate fault formation, and to create model setups that take ongoing seismicity and 3D seismic tomography into account to construct the internal structure of the Etna volcano. Expected results: The SC will provide the first 3D models of the ongoing deformation at Etna to determine the slide plane that can explain the ongoing deformation. In addition, it will test the sensitivity of the deformation to the thermal and magmatic structure, as well as to material parameters. The most successful 3D simulations will be made available and can also be used to estimate volumes of rock mass that may induce tsunamis. Ultimately, this should be embedded in an inversion framework, but in our experience with performing such geodynamic inversions, it is crucial to have good starting models (and fast forward simulations) which will be obtained here.					

SC8.2	3D evolution of tectonic deformation as driver of seismic hazard in the Hellenic arc				
SC leader	CNRS	Partners	UM, LMU, TUM, CSIC, SU	Type	Basic research
Description: Dynamic rupture propagation of an earthquake and whether it will potentially cause a tsunami depends not only on the subduction megathrust properties but also largely on the structure of the upper plate and on the heterogeneity of the state of stress related to the long-term tectonic evolution. Fault slip and inelastic deformation in the frontal wedge are intensely debated causes of large coseismic seafloor displacement and resulting tsunami heights of megathrust earthquakes. The Mw 8.3 AD 365 Crete earthquake, which resulted in a tsunami that destroyed cities and drowned thousands of people in coastal regions from the Nile Delta to modern-day Dubrovnik did not occur on the subduction interface but on a splay fault. The recurrence of earthquakes happening on these secondary faults is poorly understood, and a better understanding of the long term context that leads to their formation would allow such faults to be identified in the field, subsequently mapped and accounted for in seismic and tsunami hazard assessment. This capability SC targets to model the self-consistent evolution of the tectonic structure of the upper plate of the Hellenic subduction zone in response to subduction dynamics from 35 Ma to the present day with a 1 km spatial resolution in the upper plate over a domain that covers $1000 \text{ km} \times 1000 \text{ km} \times 670 \text{ km}$ using pTatin3D which requires thousands of timesteps. Expected results: Analyze the state of stress and geomorphologic signature of these potential tsunamigenic splay faults which will help to identify locality of other potential splay faults along the arc. The complex, self consistent state of stress					

obtained at the last stage will be used as an input to the rupture propagation code(s) (see SC1.2). The entire evolution of the upper plate is of interest for many geologists in Europe, who work on the Aegean, and therefore the simulation results would be of interest to many scientists outside of this project. The approach developed in this case study will be used for other regional case studies in the future.

SC9.1	Eastern Skaftá cauldron GLOF simulation, Iceland				
SC leader	IMO	Partners	CSC	Type	Hazard assessment
Description: The goal of this SC is to simulate a rapidly-rising jökulhlaup from the Eastern Skaftá Cauldron underneath the Vatnajökull ice cap in Iceland. It will investigate a domain of the glacier that at least covers an area of $10 \times 40 = 400 \text{ km}^2$ with an estimated horizontal resolution in the order of magnitude of 10 m. Vertical movements of the glacier certainly demand a similar resolution as horizontal, leading to at least 10 vertical layers. Given the aforementioned resolutions, that will lead to a coupled system of several 10s of Million DOFs. Additionally - implied by a CFL condition - we expect a needed high temporal resolution of time-step sizes below minutes over the stretch of the whole event that usually lasts a few days. Expected results: There exists a wider interest in the glaciological community on glacier hazard modeling, in particular on glacier outburst floods (GLOFs). Jökulhlaups/GLOFs can lead to flood hazards in areas close to glaciers, so improved scientific understanding is relevant for hazard management in Iceland and several other countries such as Norway, Greenland and regions in the Himalayas.					

SC9.2	Calving glacier hazard in Greenland				
SC leader	CNRS	Partners	CSC	Type	Hazard assessment
Description: This SC aims to quantify the hazard related to iceberg calving at the terminus of the Greenland marine glaciers based on coupled numerical simulation of iceberg calving and capsizing, glacier flow and ocean motion on one hand and on analysis of the generated seismic signals on the other hand. Indeed iceberg calving and generated water waves and sea ice cover strongly impacts the life of inhabitants of nearby villages, by making it difficult and sometimes extremely dangerous for the small boats to move within the fjord. Furthermore, iceberg calving and overturning of sea ice affects the water layer and the wildlife in the fjord. The relation between iceberg calving and glacier stability is also an open question potentially related to climate change and to the associated ice mass loss. SC9.2, will simulate the glacier flow at Bowdoin nearby village of Qaanaaq using Elmer/Ice and simulate iceberg calving using simple models and finite element methods coupling iceberg capsizing simulation with a Computational Fluid Dynamics code (ISISCFD) to calculate the water waves (potentially tsunamis for large icebergs) generated by iceberg calving as well as the ocean motion that has been shown to affect the water column at depth. In a complementary way we will analyze the seismic waves generated by the calving events that can be recorded far from the glacier and compare them to numerical simulation of iceberg calving to recover the iceberg volume. Full simulation of the glacier flow, iceberg calving and ocean motion may help interpret these seismic data, making it possible to constrain the basal friction law, the iceberg volume and the water perturbation generated by calving. Seismic analysis could also help rapidly detect iceberg capsizing and could be ultimately used for hazard assessment for the local population. Expected results: Quantification of the hazard related to iceberg calving near the Bowdoin glacier in terms of generated water waves, sea ice cover and ocean layers perturbation. Seismic based detection of large iceberg calving that will be applicable near other marine terminating glaciers. Constrain on glacier stability and basal friction laws based on innovative coupling of seismic analysis and numerical modeling of the physical processes.					

1.2.6. HPC and co-design Infrastructure

Multiple in-kind architectures from ChEESE-2P partners will be available for testing/running PDs on pre-exascale systems and exascale architecture prototypes including:

- **Leonardo@CIN**, the 250 Pflops pre-exascale supercomputer expected by late 2022 and based on Atos BullSequana XH2000 technology and having 14,000 NVIDIA Ampere architecture-based GPUs. Leonardo has been available since April 2020 to public and industrial researchers.
- **MareNostrum-5@BSC**, the 200 Pflops pre-exascale supercomputer expected by early 2023, precise GPU-based characteristics still under procurement.
- **LUMI@CSC**, the HPE Cray EX supercomputer with 2560 nodes, each with 64 core AMD Trento CPU and 4 AMD MI250X GPUs. The first deployment phase (March 2022) peaks 140 Pflops, up to 550 Pflops planned for general availability by late 2022.
- **MARCONI100@CIN**, the 32 Pflops GPU-based tier-0 accelerated cluster based on IBM POWER9 architecture and Volta NVIDIA GPUs. Marconi100 is equipped with 980 nodes, each composed of 32 P9 CPUs and 4 NVIDIA Volta V100 GPUs.
- **HAWK@HLRS**, the 26 Pflops CPU-based tier-0 cluster with 5632 nodes, each with 128 AMD EPYC Rome cores.

- **MareNostrum-4@BSC**, the 11 Pflops CPU-based tier-0 cluster equipped with 3456 nodes, each with 48 Intel Xeon Platinum chips.
- **Galileo100@CIN**, a CPU-based tier-1 cluster with 605 computing nodes, each consisting of 2 x CPU Intel Cascade Lake 8260, with 24 cores each.
- **CTE-Power@BSC**, the 1.5 Pflops cluster consisting of IBM POWER9 processors and NVIDIA Volta GPUs.
- **CTE-AMD@BSC**, the 0.45 Pflops cluster made up of AMD EPYC processors and Infiniband interconnect, boasting 2 AMD MI50 Instinct GPUs per node
- **CTE-ARM@BSC**, the 0.65 Pflops cluster formed of 64 bit ARMv8 processors in a prototype machine, using state-of-the-art technologies from the Japanese Post-K supercomputer.
- **Vulcan@HLRS**, the system with ~750 nodes of different types (Memory, CPU, Disk, Accelerators), SandyBridge, Haswell, CascadeLake Processors, Nvidia Tesla P100 + V100, NEC Aurora TSUBASA vector Accelerators

On the other hand, the following exascale architecture prototypes will be available:

- The **EPI accelerator** (EPAC), a RISC-V-based chip, including, among others, a RISC-V vector accelerator able to handle vector operands of up to 256 double-precision elements. The architecture behaves as a general-purpose computing platform and is supported by a complete system software tool-chain including a standard Linux, an LLVM-based compiler enabling intrinsics and auto-vectorization, and vectorized scientific libraries.
- **Software Development Vehicles** (SDVs), software and hardware tools that allow experimentation with the EPAC architecture. Even with little knowledge of the underlying architecture, scientists can compile and test their codes and collaborate with EPI experts in analyzing the outcome. The resulting study is a co-design effort providing feedback to the domain scientist who plans to efficiently run on long-vector architectures and architects and system software developers.

1.2.7 Related Initiatives

ChEESE-2P will benefit from a number of initiatives and projects:

- **AdriaArray** (www.orfeus-eu.org | (2021-2023) | GA na). A multidisciplinary and international project aimed to better understand geodynamics and the driving forces of geohazards in the Adriatic plate and surrounding region. The base of the seismological part of AdriaArray is the AdriaArray Seismic Network composed of the permanent seismic stations installed in the region and ~300 temporary broadband stations that will be installed starting from fall 2022.
- **eFlows4HPC** (<https://eflows4hpc.eu> | (2021-2023) | GA No 955558). EuroHPC project coordinated by BSC that implements a European workflow platform enabling the design of complex applications that integrate HPC processes, data analytics and artificial intelligence, making use of the HPC resources in an easy, efficient and responsible way as well as enabling accessibility and reusability of applications to reduce time to solution. One of the eFlows4HPC pillars, urgent computing for natural hazards, is based on ChEESE-1P flagship codes and workflows.
- **EOSC-synergy** (www.eosc-synergy.eu | (2019-2022) | GA No 857647). Expanded the capacity and capabilities of EOSC by leveraging the experience, effort and resources of national publicly-funded digital infrastructures. ChEESE-2P will benefit from the EOSC-synergy automated tool for FAIR assessment that relies on Research Data Alliance (RDA) indicators.
- **EPI** (www.european-processor-initiative.eu | since 2017 | FPA: 101036168). Led by BA and participated by CIN and BSC, the European Processor Initiative (EPI) aims to design and develop the first European system-on-chip and accelerator processors for high-performance computing.
- **EUDAT** (<https://eudat.eu> | since 2016 | Contract No 654065). Collaborative Data Infrastructure Agreement committed to develop, maintain and deploy pan-European research data services and to promote harmonization of research data management practices across centres. ChEESE-2P will benefit from EUDAT data services.
- **EuPEX** (<https://eupex.eu> | (2022 | 2025) | GA No 101033975). EuroHPC project led by BA that will build and validate the first EU platform for HPC including a modular OpenSequana-compliant platform and a corresponding HPC software ecosystem. ChEESE-2P will co-design mini-apps with EuPEX OpenSequana prototypes.
- **EuPilot** (<https://eupilot.eu> | (2021-2025) | GA No 101034126). EuroHPC project led by BSC that will deliver the first all-European integrated HPC system by creating an autonomous set of accelerators. ChEESE-2P will co-design mini-apps with EuPilot RISC-V prototypes.
- **EuroCC** (www.eurocc-access.eu | (2022-2022) | GA No 951732). Has set up the network of National Competence Centres (NCCs) in HPC across Europe in 31 participating, member and associated states.

- **EUROVOLC** (<https://eurovolc.eu> | (2018-2021) | GA No 31670). The European Network of Observatories and Research Infrastructures for Volcanology project facilitated communication and integration within the European volcanological community, bringing together the wide range of disciplines necessary for effective volcanic research. ChEESE-2P will benefit from volcano databases.
- **ExaFOAM** (<https://exafoam.eu> | (2021-2024) | No 956416). Funded by EuroHPC, will introduce improvements on the open-source CFD software OpenFOAM towards exascale. Participated by INGV.
- **FENIX** (<https://fenix-ri.eu> | since 2018). E-infrastructure consisting of data repositories and scalable supercomputing systems in close proximity and well integrated. Federates 6 European supercomputing centres, BSC (Spain), CEA (France), CINECA (Italy), CSC (Finland), CSCS (Switzerland) and JSC (Germany). Provide access to resources following the peer review principles established by PRACE.
- **Geothermie Allianz Bayern** (<https://geothermie-allianz.de/en/news/> | (2020-2024)). A Bavarian State Ministry for Science and the Arts funded collaborative research on deep geothermal energy. Participated by LMU.
- **MAGMA** (<https://magma.uni-mainz.de> | (2018-2023) | GA No 771143). MAGMA is a Consolidator Grant research project funded by the ERC to create new computer models to simulate two-phase flow through a deforming thermo-mechanical visco-elasto-plastic lithosphere. ChEESE-2P brings in the LaMEM code for geodynamics.
- **POP** (<https://POP-coe.eu> | (2018-2021) | GA No 824080). The Performance Optimisation and Productivity CoE provides performance optimisation and productivity services. If POP3 is funded, ChEESE-2P will perform the code audit rounds in collaboration.
- **SPIN** (<https://spin-itn.eu> | (2021-2025) | GA No 955515). A Marie Skłodowska-Curie Innovative Training Network (ITN) to improve seismological parameters and instrumentation. Participated by LMU.
- **TEAR** (www.tear-erc.eu | (2019-2024) | GA No 852992). A Starting Grant research project funded by the ERC to model earthquake dynamics faults slip, a grand challenge of computational seismology and geophysics. ChEESE-2P brings in the Tandem code for geodynamics.

On the other hand, ChEESE-2P results will feed in the following initiatives and projects:

- **DT-GEO** (n.a. | (2022-2025) | No 101058129). An HORIZON-INFRA-2021-TECH-01-01 call project lead by CSIC that will deploy a prototype Digital Twin (DT) on geophysical extremes dealing with geohazards from earthquakes (natural or anthropogenically induced), volcanoes, and earthquake/landslide-triggered tsunamis. Based on ChEESE flagship codes, DT-GEO will benefit from the code optimization and performance portability (on FENIX infrastructure) activities in ChEESE-2P, with long-term ambition to Destination Earth.
- **EPOS-ERIC** (<https://www.epos-eu.org> | ERIC since 2018). The European Plate Observing System, is a multidisciplinary, distributed research infrastructure that facilitates the integrated use of data, data products, and facilities from the solid Earth science community in Europe. EPOS is a member of the ChEESE IUB and 4 members of the Consortium (CSIC, INGV, IMO, CNRS) are national EPOS representatives. Produced datasets will be EPOS-enabled. Tsunami services potentially distributed through the Thematic Core Service tsunami in EPOS.
- **Geo-INQUIRE** (n.a. | (2022-2025) | No 101058818). An HORIZON-INFRA-2021-SERV-01-07 call project that will provide and enhance access to selected key data, products, and services, enabling the dynamic processes within the geosphere to be monitored and modeled at new levels of spatial and temporal detail and precision. This includes virtual and trans-national access to several ChEESE-2P flagship codes that will benefit from the project activities.
- **GTM** (<http://globalsunamimodel.org>). The Global Tsunami Model, initiated by NGI and INGV, is a network that comprises more than 30 organizations worldwide. The partners in GTM will be important end users of HPC tsunami products resulting from ChEESE-2P.

1.2.8. Research and Data Management

Task T1.5 (Data management and automatic FAIR validation) is devoted to ensuring the implementation of open science practices by means of an EOSC-enabled quality approach. ChEESE-2P will make use of observational data from geophysical monitoring and datasets from different Research Infrastructures (e.g. EPOS, Copernicus, etc.), all relying on well-established data standards and strictly following the FAIR principles, license handling, recognition and security. Table 1.2.8a below summarizes the handling of data and other research outputs (except for publications):

Table 1.2.8a. FAIR aspects of project outputs.

	Project data outputs	Software (codes)	Other project outputs
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Type	Datasets from SCs (including SGCs)	flagship codes and related tools (e.g. WMS-light workflow)	Reports and deliverables
Findability	Stored in a proper data repository, including an accepted persistent identifier and described by rich metadata. Codes in ChEESE (version releases) already have assigned doi through Zenodo.		Website and mechanisms for consistent findability across distributed nodes
Accessibility	Open access	All with open source licenses (see Table in Sec. 1.2.1)	All public
Interoperability	Based on ENVRI-hub and EPOS formats and metadata catalogs. Formats should support controlled vocabularies and include reference to any other kind of resources (datasets, software, papers, et.).	not applicable	not applicable
Reusability	Open Data Commons	not applicable	not applicable
Curation	Curation processes description will be included in the metadata.	Lead developers	Defined in the DMP

Assessment of data and software quality and FAIRness. ChEESE-2P contemplates an automatic assessment of the FAIRness of the data and other research outputs with quantitative indicators of level of FAIR fulfillment. Conventional FAIR assessment is usually done manually, e.g. by answering defined questionnaires. In contrast, based on EOSC-synergy project results, ChEESE-2P will provide an open source automated tool for FAIR assessment that relies on Research Data Alliance (RDA) indicators. Dockerized versions of these validation tools exist for easier deployment and testing in integrated environments, and can be connected to software repositories and services to perform the FAIR assessment.

1.2.9. Equal Opportunities

All the members of the Consortium (research centers, academia and private enterprises) have implemented gender-equality policies, including policies to promote recruitment and ensure personal career development. All beneficiaries follow the EU and national laws on Gender Equality and truly believe that diversity constitutes a benefit to the working environment. The beneficiaries facilitate a flexible environment in which both men and women can achieve an appropriate work-life balance. The objective is to create a workplace where the best talent can flourish, in line with the Strategic Vision of the European Research Area (adopted in 2010) that points out the objective for the year 2030 that half of all scientific personnel in all disciplines and, at all levels of the scientific system, are women. A strong enforcement of gender balance will be pursued by ChEESE-2P in order to offer the same opportunities for both genders in the research teams. In particular:

- An Equality Committee (EC), composed by delegates of at least 6 beneficiary partners, will be set at the start of the project (Task T1.3) in order to prioritize gender equality in all project activities (including WP leadership, liaison activities, and Boards) and ensure the maximum possible gender-balance recruitment.
- Continue with the ShEESE initiative (created during ChEESE-1P). The name "ShEESE" ("she is") is a combination of the words "She" and "ChEESE", and gathers all the activities aiming at promoting the participation of women in research professional careers, e.g. general public (scholarship) videos, links with the "Inspiring girls" initiative for national-level contacts in ChEESE countries, activities, campaigns during the International Day of Women and Girls in Science (11th February), and others.
- Ensure a 50-50 ratio in all training activities (Task T7.3) and conferences. For example, the scientific programme committee of the EGU Galileo Conference promoted by ChEESE already has a gender balanced composition and the keynote speakers and attendees will be selected among candidates considering the gender balance dimension.
- Finally, ChEESE-2P will continue to ensure equal opportunities for EU13 participants in all training and outreach activities of the project.

2. Impact

2.1. Project's Pathways towards Impact

2.1.1. Fulfillment of the Scopes of the Call

With the focus on the specific area of SE, the ChEESE-2P proposal addresses the challenges and scopes of the call HORIZON-JTI-EuroHPC-2021-COE-01-02 (topic 02) as follows:

Scope 1. *“Developing, maintaining, porting, optimizing and scaling HPC application codes, addressing the full scientific and industrial workflow, particularly covering data aspects; testing and validating codes and quality assurance”*

- ChEESE-2P hosts 11 well-established SE Community codes, all developed and maintained by members of the consortium (Sec. 1.2.2). All codes will benefit from transversal WP2 activities on porting to accelerators (NVIDIA and AMD), audit-driven tailored performance optimizations, portability, and scaling. Solutions will be provided for code development cycle and deployment (including containerization of components) and ease application setup and usage for new users and communities (T4.3). Codes will run in production at 15 site-specific Simulation Cases (SCs, see Sec. 1.2.5), including an automatic EOSC-enabled FAIR data validation (T1.5).

Scope 2. *“Enhancing HPC applications and ensembles of coupled applications towards highly scalable, optimized codes”*

- The SE community is amongst those best-positioned to succeed in the exascale endeavor, with several existing codes already scaling up to full-petascale. In ChEESE-2P, flagship applications and underlying workflows combine in 9 Pilot Demonstrators (PDs) that, in turn, define capability or capacity Simulation Cases (SCs), the latter involving large (hundreds/thousands) ensembles of model realizations combined in probabilistic frameworks. Scalability and optimization are also considered at a workflow level, i.e. addressing simulation bottlenecks that go beyond the main codes (T4.1).

Scope 3. *“Streamline development, collaboration, automated testing and deployment processes throughout the application development and maintenance cycle, for example, by provisioning and using state-of-the-art development tools, platforms and software management models”*

- Most flagship codes are actually maintained by a reduced group of scientists and IT teams, and do not yet apply formal software development models besides limited adoption of agile methodologies (e.g. Scrum or Kanban). However, all codes make use of git-based collaborative tools (GitHub, GitLab) for branching and “continuous” version release. Promotion of the adoption of “community codes” by ChEESE-2P will ease future code maintenance and development. On the other hand, ChEESE-2P will provide fast deployment techniques and solutions using containerization for components, as well as workflow microservices for some of the PDs.

Scope 4. *“Fostering pre-exascale-oriented codes and innovative algorithms that address societal challenges and/or are important for key scientific and industrial applications”*

- Codes and workflows in ChEESE-2P deal with geohazards which cost the EU hundreds of lives and billions of Euros each decade. Code improvement and provision and related services can translate into benefits to industry (e.g. insurance and reinsurance, georesource exploration, industrial risk assessment and investment planning) and to society in general (e.g. hazard mitigation, early warning, crisis management, etc.) as demonstrated by several ChEESE-1P success stories, e.g. the operational volcanic ash forecast service delivered to the civil protection during the eruption at La Palma (Nov-Dec 2021). From the scientific point of view, ChEESE-2P will address 12 ECCs identified by several HPC-community roadmaps, some of which will require the implementation of novel features and algorithms (T5.1). From the computational point of view, ChEESE-2P SCs will achieve unprecedented spatial/time/frequency resolutions, larger domains, and larger amounts of assimilated data.

Scope 5. *“Provision of codes aimed at capacity pre-exascale systems for ensemble workloads that might not need tight interconnection between runs”*

- ChEESE-2P considers 9 capacity SCs that combine ensembles of model realizations to solve inverse problems (with large volumes of multi-source observations) or to explore many possible scenarios in probabilistic long and short-term hazard assessments (T6.2). All these capacity problems use complex workflows to orchestrate loosely coupled simulations that can aggregate into a final (pre-)exascale workload, e.g. to generate seismic, tsunami, volcano, or glacier hazard maps at unprecedented model accuracy and resolutions and coping with different sources of uncertainty.

Scope 6. “Collaboration with EuroHPC JU systems and infrastructure federation initiatives to implement a robust and reliable automated deployment process for applications, in order to make novel developments timely available to the EuroHPC JU user communities”

- The ChEESE-2P Consortium includes all 3 supercomputing centers hosting pre-exascale EuroHPC systems (CIN, CSC and BSC), all being also leading members of the FENIX RI. Task T2.2 will increase the performance of flagship codes in these tier-0 architectures and T4.3 will address its deployment process (including containerization) and updated Community access through repositories (e.g. git-based, Zenodo, NVIDIA collection). Also, versions of the flagship codes will be enabled as "modules" in the HPC systems involved (e.g. “module load SeisSol” and then having the possibility to run a simple example). On the other hand, ChEESE-2P will enable different typologies of Urgent Computing (UC) services on EuroHPC systems following a service co-design approach with relevant IUB members (T6.4) and with the objective of having a portfolio of validated (and EuroHPC certified) services in place.

Scope 7. “Involvement in co-design activities (hardware, software, codes), including the collaboration with HPC vendors and the identification of suitable applications relevant to the development of European HPC technologies towards exascale”

- A full WP lead by Bull Atos (hardware integrator and vendor) is devoted to co-design activities on OpenSequana and RISC-V prototypes from EuroHPC Pilots (EuPEX and EuPilot) using mini-apps built upon kernels of 5 selected flagship codes (see T3.1). The coordinators of EuPEX and EuPilot (BA and BSC) are also members of the ChEESE-2P Consortium. The SPECfem3D code is already in the EuPEX benchmark suite.

Scope 8. “Enlarging and expanding HPC applications development and use, in particular for new user communities in EU countries and countries associated to Horizon Europe that are members of the EuroHPC”

- The ChEESE-2P IUB includes public stakeholders, large academic associations, and private companies that, during the first implementation phase, have collaborated actively in the design, configuration and deployment of services and in monitoring their potential exploitation. This ever growing community of users will be further expanded thanks to the enlargement of the CoE with new domains (geodynamics and glacier hazards) and associated countries. A Project Innovation Manager (PIM, see Section 3.2.1) will coordinate with the IUB to elaborate an Exploitation Plan (D6.5) for services.

Scope 9. “Ensure wider access to codes and foster their uptake by user communities, in particular industry and SMEs”

- ChEESE-2P will foster the end-user usage and uptake of codes through a containerized application deployment (see the specific objective SO10), including the Zenodo and git-based repositories and an NVIDIA collection of flagship codes. Several codes in ChEESE-2P are also in Geo-INQUIRE together with EPOS-ERIC, which will facilitate virtual and trans-national access mechanisms to different user communities. For example, in terms of “user communities”, ChEESE-1P had two super-successful seismology training (with ~100 participants each), plus further training in the other fields.

Scope 10. “Federating capabilities and integrating communities around exascale computing in Europe”

- This coincides with the General Objectives 1 and 4. ChEESE-2P codes will feed in other large initiatives like Geo-INQUIRE and DT-GEO. The former will provide virtual and trans-national access to codes and workflows, the latter has a longer-term vision on Destination Earth (digital twin on geophysical extremes). ChEESE-2P will also interact strongly with EPOS towards the construction of the ICS-D (Integrated Core Services - Distributed), and through the provision of workflows through the TCS VO and TSU (see D6.4 in Table 3.1c). Tasks T7.2, T7.3 and T7.4 will consider liaison activities, training (in cooperation with PATC and NCCs) and community building and roadmap activities (including a Galileo conference).

Scope 11. “Address the skills gap in the targeted domain by specialized training and capacity building measures to develop the human capital resources for increased adoption of advanced HPC in industry and academia”

- ChEESE-2P will provide specialized training and capacitation to scientists and end-users on deployment and use of applications in collaboration with PATC and the National Competence Centers (NCCs). A minimum of 8 training events will be organized, including capacitation courses for all flagship codes (T7.3). Different webinars will also be considered and defined in the Training Plan (T7.3). Finally, it is worth mentioning that a partner of the Consortium (HLRS) has led EuroCC and the Coordination and Support for National Competence Centres on a European Level (CASTIEL) and will also lead the EuroCC-2 proposal. In addition, several Consortium partners are also NCCs (e.g. BSC, CIN).

Scope 12. “Complementarity and synergy with National HPC Competence Centres and EU projects”

- In addition to the point above, ChEESE-2P aligns with the EuroHPC eFlows4HPC project, with Geo-INQUIRE and DT-GEO, two large initiatives starting in 2022 and, on a longer term, with the Destination Earth mission (see 1.2.7 for details).

Scope 13. “Include clear KPIs on the optimal employment of current and/or emerging HPC technologies, allowing the assessment of the progress towards the objectives, both in terms of outputs and ultimate impact”

- Code progress monitoring will be done using the hybrid POP metrics (deliverables D2.1 and D2.3). The progress of PDs is measured by the TRL, with the goal to increase the TRL of all PDs by at least 2 points. The overall impact of the project will be measured by the KPIs explained in this proposal and will be detailed in D7.6.

In addition to the 13 points above, ChEESE-2P will also tackle 3 extra scopes that are exclusive of the call HORIZON-JTI-EuroHPC-2021-COE-01-01 (topic 01) and that are not explicitly required in topic 02 CoEs:

Scope 14. *“Addressing the exascale and post exascale related technical challenges, such as load balancing; resilience; heterogeneity programming models, in particular accelerator-based architecture programming; run-time systems; workflow management tools; development environments and production environments”*

- Task T2.2 will increase the performance portability of all flagship codes for different accelerators (with focus on NVIDIA and AMD). Moreover, T2.3 will also consider exascale features enabling (resiliency, fault-tolerance) in selected level 1 codes that were not addressed in the first implementation phase. These are amongst the most scalable codes and have already reached good pre-exascale scalability levels during ChEESE-1P (full-scale executions on several thousands of computing nodes). On the other hand, T4.1 and T4.3 will face non-obvious bottlenecks beside the main HPC simulation codes using workflow management tools (WMS-L) and the definition of environments for development, deployment and quality assessment tools.

Scope 15. *“Demonstrable advances of the targeted HPC applications towards highly scalable, optimized flagship codes and exascale performance (both computing and extreme data)”*

- ChEESE-2P will address 6 capability SCs (T6.2). Among these, 4 are Scientific Grand Challenges candidates, i.e. cases demonstrable in full pre-exascale executions. The exact number will depend on the success in allocating EuroHPC extreme scale resources (T1.4).

Scope 16. *“Activities to improve the energy efficiency of applications, algorithms, methods, libraries and/or tools”*

- This scope will be partially covered T3.2 considering an energy consumption analysis on the EuPEX platform to provide guidance to application developers and to technology providers for future generation of HPC systems. This is more uncertain in RISC-V (T3.3) because it is unclear yet if EuPilot will develop specific monitoring tools for this purpose (at present, energy efficiency is contemplated from a drastic time-to-solution reduction point of view).

2.1.2. Short-term Project Impacts

Specific impacts. First and foremost, ChEESE-2P ambition focuses on exascale-orienting 11 European flagship codes that are already referents for the SE community and beyond. This guarantees the European leadership in this domain regarding HPC, as well as cross-discipline reinforcement of the European RIs (EuroHPC, FENIX, EPOS) and of the European hardware co-design. In the short-term, the project will reinforce and develop further our to-date capabilities to model highly complex geophysical processes and, in this regard, the most relevant scientific impacts include:

- In computational seismology, ChEESE-2P will enhance the extreme-scale modeling of seismic hazards by bridging spatial (complex geometries and heterogeneity of the subsurface) and temporal (simulations across many cycles of earthquake sequences) scales, including also new features in model physics (such as viscoelasticity) and probabilistic and data-integration capabilities. The combination of scales will allow for a seamless migration from present time-independent Probabilistic Seismic Hazard Assessment (PSHA) to short-term earthquake scenario and ground motion simulations built upon time-dependent forecasting of spatially varying ground motion wavefield characteristics, with important implications for expected impact and risk for the modern society’s systems that are vulnerable to strong seismic motions. As a complement to forward modeling, it is also expected that novel ML-based solutions will also provide fast analogs to seismic simulations, fundamental for parameter exploration and early (urgent) assessment of seismic hazards.
- In terms of Earth’s subsurface imaging (tomography), scientific progress is expected by considering joint seismic and gravimetric data inversion at unprecedented resolutions (hundreds of meters) and frequencies, with overall impact on geophysical exploration. Tomographic imaging has a broad range of economically relevant applications, e.g. tapping of natural resources, hazard assessments, or understanding mantle dynamics and related surface processes. In particular, ChEESE-2P will obtain a full wave seismic anisotropic tomography of the Adriatic-Ionian lithosphere, a region of particular relevance in terms of seismic hazard.
- In tsunami modeling, ChEESE-2P will overcome the present single-source tsunami prediction capabilities by developing a coupled approach where complex earthquake rupture, landslides, volcanic explosions, acoustic pressure, as well as meteorological tsunami sources (meteotsunamis) can be tied together. The characterization of tsunami source uncertainties combined with high-resolution tsunami modeling is expected to gain new insights into complex multiphysics phenomena that cannot be described only by current single source models.

Moreover, ChEESE-2P will advance current PTHA, exemplified in Global Tsunami Model and its interoperability with seismic hazard models and tools.

- In physical volcanology, ChEESE-2P will address the modeling challenge of phreatic explosions that occur in magmatic and hydrothermal systems of volcanic islands and calderas (e.g. Vulcano, Guadeloupe, Martinique, Solfatara). In addition, it will also focus on multiscale volcanic dispersal, with emphasis on still poorly understood local-scale (km size or less) effects that difficult operational forecastings within distances shorter than tens of kilometers from the emitting source. In recent eruptions, this limitation has caused serious concerns for public health as well as for evaluation of environmental impacts. The multiscale approach will also be combined with a multisource hazard assessment to obtain the first European-scale tephra hazard map.
- In magnetohydrodynamics, the scientific gain will be on modeling geodynamo process across scales, from interannual pulses of secular acceleration to the occasional reversal of the geomagnetic field, with an unprecedented level of realism and by using a handful of very high-resolution simulations (over short time spans) to train dedicated neural networks for subgrid-scale modeling. The scientific gain is potentially very relevant, as such a subgrid-scale model could be applied to many geophysical and astrophysical models, resulting in a speed-up of current and future calculations by several orders of magnitude.
- In geodynamics, structure of the upper crust and the state of stress resulting from the long-term tectonic evolution dictate how its dynamic rupture occurs, as well as the subsequent propagation of seismic waves. A short-term scientific contribution of ChEESE-2P will be to model a self-consistent state of stress and couple it with the rupture propagation codes. This will be exemplified by considering the tectonic evolution of the Hellenic subduction zone (from 35 Ma to the present day) and to characterize the fault formation underneath Etna volcano. This is relevant because the southern flank of Etna volcano is currently sliding seawards several cm per year, and future changes in the magmatic system may cause this sliding to become catastrophic, e.g. by inducing a major eruption and/or triggering a mega-tsunami.
- Finally, the project will contribute to better understanding the processes leading to floods from glacial lake outbursts and jökulhlaups (a type of outburst common in Iceland in which water comes from sudden melting of the hosting glacier, e.g. due a subglacial eruption), relevant for hazard management in Iceland and several other countries such as Norway, Greenland, and regions in the Alps and Himalayas. In addition, simulations will also quantify iceberg calving and capsizing from marine glaciers and subsequent ocean motion and generation of seismic signals. Iceberg calving and overturning of sea ice affects the water layers and the wildlife in fjords, and the relation between iceberg calving and glacier stability is also an open question potentially related to climate change and to the associated ice mass loss.

Technological advances and products. In terms of technology, ChEESE-2P will equip computational infrastructures across Europe with geohazards' software that utilize their HPC resources to full capability and capacity. ChEESE-2P will also extend the HPC potential of EuroHPC systems by using pre-exascale platforms (Leonardo, LUMI, MN5), thereby serving as a prototype to develop an exascale-class service-oriented architecture. In terms of products, ChEESE-2P will provide enhanced services to the SE community by means of a co-design approach with the IUB members, fostering the adoption of the outcomes by the decision-makers, as it has been successfully done in ChEESE-1P.

Socio-economic impacts. ChEESE-2P will contribute to an informed forecast of the Earth behavior, creating new services and business opportunities at European and global levels, measured by the involvement of the private and public sectors using/exploiting products/services (e.g. exploration of resources in general, hazard assessment, aviation security, (re-)insurance companies, etc). For society, ChEESE-2P will improve policies and decision making practices related to management of geohazards such as earthquakes, volcanic eruptions, tsunamis, and glacial lake outbursts by enabling applications and services at EuroHPC/EPOS RIs, treating uncertainties, and enriching models with data streams. To this end, the goal is to establish a Working Group with the EuroHPC Infrastructure Advisory Group (INFRAG) to promote a service certification mechanism and related access policies. On the other hand, ChEESE-2P will also allow the science-industry-society community to make a step-change concerning geo-resource and geo-reservoir exploitation (tomography), as well as scientific applications to the environment and to human welfare. Table 2.1.2a below summarizes the societal value and the significance of the project outcomes to the target groups.

Table 2.1.2a. Societal impact (value) of project outcomes and target groups.

Project outcomes / societal value	Target groups and impact scale
PSHA and ML-based solutions for urgent seismic computing for fast ground shaking mapping after earthquakes and earthquake short-term forecasting (including aftershocks)	Civil protection agencies, insurance sector. More than 170 million people in Europe are potentially exposed to earthquakes, almost a quarter of the total population. In

	Associated with document Ref. Ares(2022)8497838 - 07/12/2022 Italy, Romania, Greece, and Turkey the share reaches over 80% of the population.
Seismic (and gravity) inversion and related high-resolution subsurface imaging	Private companies and the public sector. Prospecting of geological storage sites for energy, hazardous waste, or CO2 storage monitoring operations
Global PTHA and integration of physics-based models for tsunamis and earthquakes including UC applications	Communities in critical coastal areas, e.g. around 40% of the EU population
Multiscale PVHA and hazard from phreatic explosions including an UC workflow for deterministic scenario definition	Civil protection agencies. Products benefit communities around active volcanoes. In Europe, it affects eastern Sicily, Naples area, Iceland, Canary, Aeolian and the Azores archipelagos, and the U.K./France oversea volcanic islands, exceeding 10 millions of inhabitants in total
Volcanic dispersal forecasts across multiple scales	Civil aviation sector. Savings on rerouting and engine maintenance (airspace disruptions cause millionaire costs)
Glacier hazards (GLOF and iceberg calvin)	Communities in critical areas, e.g. Iceland, Norway, Greenland, Alps. Several thousands on inhabitants at risk

Ecosystem leverage and other synergies. Short-term impacts are expected across the ecosystem through synergies and collaborations, including:

- Collaboration with other CoEs and NCCs. If funded, ChEESE-2P will interact with POP3 for code audits and with the NCCs for training, capacity building, and provisions of codes. To this end, a co-shared hackathon has also been agreed with ESIWACE3. Finally, ChEESE-2P will also participate in HPC3 Council as an active member.
- Alignment with DT-GEO, which will deploy prototype Digital Twin Components (DTCs) on geophysical extremes with long-term ambition to Destination Earth. It is very important to stress the complementarity of these two initiatives. DT-GEO will deploy digital twin components (TRL 6-7) as workflows that combine massive real-time data streams (including data lakes) and model-data fusion, but will not consider any improvement/optimization in the codes beyond ChEESE-1P developments (these are treated as “black boxes”). In contrast and complementary, further developments of such applications are the “core business” of ChEESE-2P. The synergy of the two initiatives is of paramount importance for the integration of this Digital Twin in DestinE and its execution on EuroHPC systems.
- ChEESE-2P will cooperate with EPOS and Geo-INQUIRE to provide seamless access to codes and workflows, HPC Infrastructures and innovative HPC services for SE. ChEESE and EPOS have already been acting synergistically to build scientific and societal capacities for new generations measured by stakeholders’ engagement. This guarantees a boost in the software uptake and a broader geographic distribution of impact (downloads) because EPOS engages 141 research institutions, 256 research infrastructures, and thousands of seismic stations, GPS receivers and other data sources. This partnership fosters scientific, engineering and information technology innovation for a better risk management of geo and environmental hazards, measured by contributions to increase resilience to hazards.
- ChEESE-2P is a capacity building enterprise, including training, workshops, and dissemination activities to fulfill community building aspects of the project. It will involve around 150 researchers and young post-docs, a significant pool of human resources developing skills.
- Finally, international scientific associations present in the IUB will promote synergies with the SE community and disseminate the project results internationally. For example, the International Association of Seismology and Physics of the Earth’s Interior (IASPEI) and the International Association of Volcanology and Chemistry of the Earth’s Interior (IAVCEI), both under the umbrella of the International Union of Geodesy and Geophysics (IUGG), that host thousands of individual memberships globally.

2.1.3. Long-term Project Impacts

Destination Earth. The DG-CNECT Destination Earth initiative (2021-2030), is implementing a game-changer high-precision digital model of the Earth to monitor the green transition, environmental changes, mitigate impacts from extreme events, and adapt policies to the ever-growing climate challenges providing a digital environment to analyze the past, monitor the present, and predict the future. The initiative evolves around 3 pillars led by

corresponding world-leading European agencies: models and twin engines (ECMWF), federated and distributed data lake(s) (EUMETSAT), and provision of downstream services (ESA). During the first implementation phase (up to 2024), two digital twins will be deployed on prediction of weather-induced extremes and climate change adaptation. A second implementation phase (2024 up to 2030) will follow to incorporate other twins, e.g. on the Ocean (European Digital Twin of the Ocean, EDITO), anthropogenic, and likely on geophysical extremes (Digital Twin on Geophysical Extremes, DT-GEO). A key element of DestinE is to have better simulations based on more realistic models and relaying on EuroHPC (and FENIX) RIs. The long-term ambition of ChEESE-2P is the integration, in alignment with DT-GEO, in DestinE.

Operational urgent computing services. In parallel, ChEESE-2P will enable UC services in EuroHPC systems. The EuroHPC Governing Board has already identified the need for urgent access for emergency and crisis management and committed to allocate resources to support public or private decision making in urgent situations under two distinctive cases of UC: (1) registered applications that are ready to run on the EuroHPC infrastructures for which hosting supercomputing centers will provide access within a short period of time and, (2) emergency computing cases for which relevant applications have not gone through a technical evaluation before (see the Decision of the Governing Board of the EuroHPC JU No 06/2021). ChEESE-1P has been a key actor in pushing this new access mode, and long-term impacts can be expected from ChEESE-2P on, (i) enabling a UC service for earthquakes using AI/ML-based approaches, (ii) enabling a UC service for volcanic ash/gas dispersal at scale and, (iii) enabling a UC service for phreatic eruptions to be potentially used in the framework of a volcanic unrest.

EPOS TCS/ICS. ChEESE-2P will cooperate actively with EPOS for the building of the ICS-D, which will permit access to distributed core services to fully exploit the cross-TCS multidisciplinary data and scientific products offered by the ICS-C. This paves the road to a myriad of potential service products both for facilitating the research around fundamental scientific challenges, but also to make high-TRL services available to, e.g.:

- Consolidate Early Warning Systems (EWS) for Geophysical extreme events based on reliable physical modeling.
- Perform operational forecasting of geohazards.
- Enhance Tsunami Early Warning Systems (TEWS) by embedding a probabilistic description of a wide range of source mechanisms in numerical modeling.
- Study surface deformation induced by geo-resource exploitation by fostering full use of the data acquired from the integrated monitoring set-ups. This integration will improve images of ground deformation processes that can be studied in the framework of local to regional-scale deformation processes due to the various technological human activities.

Fostering Open-Science. ChEESE-2P will result in a robust framework enabling researchers to ensure the quality, reliability, and verifiability of the outputs and will be made available through the Common European Data Spaces and the European Open Science Cloud (EOSC). ChEESE-2P high-level products (such as the outputs from the SCs and their elaboration) will be made available through the Common European Data Spaces and the European Open Science Cloud, where their quality, reliability and verifiability will be ensured.

Disaster Risk Reduction. Finally, ChEESE-2P will initiate a technical discussion with UN Global Platform for Disaster Risk Reduction, a flagship product of the European Commission's Disaster Risk Management Knowledge Center (DRMKC) to compile the state-of-the-art in disaster risk management and review progress on the implementation of the Sendai Framework for Disaster Risk Reduction.

2.1.4. Potential Barriers

- Effective integration of flagship codes (and workflows) in an eventual Destination Earth twin on geophysical extremes may go beyond the duration of the project. Two potential barriers can be foreseen in this endeavor: (1) some extra funds will be needed and, at this stage, it is uncertain which precise funding mechanisms will be available in Horizon Europe, European Green Deal (European Strategy for Data action), EuroHPC, or others and, (2) the precise common infrastructure of DestinE is not yet defined (particularly for geophysical extremes), and some technological challenges may appear in this regard when coupling with the other components and layers of DestinE.
- The long-term commitment of target RIs, e.g. Thematic Core Services and Distributed Core Services in EPOS, may evolve with time, implying use of other resources. However, as codes and components will be deployed as self-contained and containerised entities, the adaptation to such a changing environment should not be a major barrier.

- Policies, e.g. country membership, regulatory framework, etc., may put some limitations/restrictions to access data, digital components and services required.

2.2. Measures to Maximize Impact - Dissemination, Exploitation and Communication

2.2.1. Dissemination

The project results will be shared with the scientific community, stakeholders, and other end-users, while dissemination activities will seek to raise awareness among policy makers, civil protection agencies, society, and the general public about the key role the project will play. ChEESE-2P will maximize dissemination through the following actions:

- Taking advantage of the well-established **links with key end-users and scientific networks** that the ChEESE-2P Consortium already possesses (see, e.g. Sec. 2.2.4). The leadership of scientific partners and private companies in the Consortium ensures efficient channels towards the exploitation of results (e.g. through EPOS and projects from the ecosystem) while the strong presence of academia ensures a proper dissemination through scientific means. On the other hand, tasks T6.1 and T6.4 will also define the production runs and urgent computing exercises (including service prototype setups) following a “co-design” collaborative approach with IUB members, thereby contributing also to dissemination of interim results.
- Setting up a detailed **Communication and Dissemination Plan** (deliverable D7.2) and Report (D7.6). The plan will be developed by M3 and will include a list of Key Performance Indicators (KPIs) such as number of papers published (in scientific venues and journals), keynote talks, events attended or organized, number of press clippings, website visitors and their location, social media followers, attendees to training workshops (including gender balance), etc.
- **Liaison activities.** Liaison officers (task T7.2) will be nominated at the beginning of the project to disseminate and coordinate with RIs (EuroHPC, FENIX, EPOS) and their Communities, federated environments (EOSC), parallel EuroHPC and REA (H2020/HE) projects that are particularly relevant to this proposal (Pilots, DT-GEO, Geo-INQUIRE) and, especially, the Destination Earth (DestinE) initiative of the Digital Europe Programme. This initiative is a main long-term goal of ChEESE-2P and, consequently, a dedicated and effective dissemination and outreach program is needed to ensure that ChEESE-2P reaches the broadest research Community in Earth System science and in other fields for interdisciplinarity cross-fertilization, public and private beneficiaries, and key stakeholders. The coordinator of this proposal has already been appointed as a member of the External Advisory Board (EAB) of DestinE. On the other hand, liaison activities will also identify National Competence Centres (NCCs) with interest in the two specific topics of geophysics and emergency management. A survey will be conducted at the beginning of the project and, based on the results, twinning between NCCs on a similar level and mentoring or training between NCCs with different levels will be established. Joint dissemination and collaboration events shall accompany these activities to promote the European community in HPC, HPDA and AI within geophysics and emergency management (including links with the RAISE CoE). The liaison activities will inform about the project and its results, promote capacity building among young technicians and researchers in the field, and push for outreach among science players, key stakeholders, and policy makers.
- Last but not least, the Equality Committee (EC, task T1.3) and the **ShEESE activities** will disseminate activities of female researchers. The name “ShEESE” (“she is”) is a combination of the words “She” and “ChEESE”, and will centralize all the activities aiming at promoting the participation of women in research professional careers, e.g. general public (scholarship) videos, links with the “Inspiring girls” initiative for national-level contacts in ChEESE countries, activities, campaigns during the International Day of Women and Girls in Science (11th February) and others. This will also include school-level dissemination activities to inspire and motivate a new generation of scientists (particularly girls).

2.2.2. Communication

Effective communication is essential to ensure that ChEESE-2P reaches its intended beneficiaries and to promote the value of its research to key stakeholders and to the wider public. To achieve this, it is necessary to define a clear communication and dissemination strategy at the outset of the project, identifying target audiences and selecting the appropriate means of communicating with each of them (see Table 2.2.2a).

Table 2.2.2a. *Target audiences and dissemination channel.*

Target audience	Dissemination channel	Value to audience
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Scientific community	ChEESE website and social media. Networks and International Associations in the IUB. Deliverables and white papers. Papers, conference proceedings, symposia, and workshops.	Understand ChEESE-2P approach and its benefits, including code and data access, training and services. To be able to contribute and build upon it.
Industrial stakeholders and policy makers (e.g. civil protection)	GA meetings and active participation in the IUB. Channels of partners. Events and conferences. Training. LinkedIn discussion groups.	Understand the potential benefits of ChEESE-2P and inclusion of related services in their roadmap.
Young researchers	Training courses and activities (T7.3), social media channels.	Understand ChEESE-2P approach and the potential benefits it offers, potentially devising a promising research area of interest.
General public	Press releases and interviews, videos, website, leaflets and factsheets, ShEESE activities.	Understand how ChEESE will benefit European (and world) society, particularly in assessment and mitigation of geohazards.
Other related projects and initiatives	Liaison activities, invited talks in other project meetings, meetings, social media channels.	Identify potential ways in which ChEESE-2P and other projects can synergize.

Communication activities will seek to raise awareness about the project and its results, updating key stakeholders on the project progress, and help building the Community.

- A **brand identity** (including logo and style, font, project templates, poster, etc) will be created for the project based on that of ChEESE-1P but with distinctive features. Branding will be applied consistently across all project dissemination materials and templates in order to reinforce awareness of the project.
- The project **website** (D7.1) will centralize the dissemination activities, inform about publications and the project agenda (activities, training, events, etc.), and provide access to public reports, evolution of KPIs, published manuscripts, flyers, posters, whitepapers, webinars, presentations, press releases, videos, and other promotion materials. The ChEESE website will be built using Drupal (open source CMS) and comply with the technical requirements of performance and security. In addition, the website will link to the project's Wiki, which will serve as the internal repository, allowing effective management by the dissemination team and seamless access by all consortium members.
- A strong presence of ChEESE-2P on **social media** will help foster a digital community and complement face-to-face networking activities such as training and conferences. Taking into account the aim to connect with industry stakeholders and researchers, the professional networks **LinkedIn** (378 followers at the end of ChEESE-1P) and **Twitter** (1035 followers at the end of ChEESE-1P) will continue offering useful platforms for encouraging participation, debating key themes and obtaining feedback. As part of a social media strategy, influential spokespeople such as industry and decision making experts who are active on social media and blogs will be identified as a possible means of reaching a wider audience of potential beneficiaries.
- With the aim of disseminating ChEESE software development and results to European industry beyond the project, the social media strategy will be complemented with the production of **white papers**, webinars and tutorials, fostering interactive learning of project knowledge and tools. White papers, webinars are useful to disseminate technical results targeting industry. On the other hand, **Leaflets and factsheets** are a useful and attractive way of providing the key facts about the project at a glance, and can be easily distributed at events. All Consortium members have a solid success record and a long list of contributions to international conferences or exhibitions.
- **Press releases** will be prepared and released as required to disseminate project results to either the specialists and general press in different languages. Special effort will be dedicated to Pilot Demonstrators and Simulation Cases (including service enabling), as these feature the highest impact. The objective of the ChEESE-2P communication activities are summarized in Table 2.2.2b, including dissemination and communication KPIs.

Table 2.2.2b. Objectives, audience, activities and target KPIs of the communication activities.

Objective	Audience	Activity	Target KPI
Project start	Consortium, SAB, IUB	1st General Assembly (KoM)	-
Reinforce project awareness	Consortium, scientific community, end-users, general public, policy makers	Branding, website	3,000 website sessions per year (based on Google Analytics)
Present ChEESE-2P and milestones	Consortium, scientific community, end-users, general public, policy makers	Press releases	2 press releases, obtain at least 10 press mentions
Publicize scientific outcomes; results	Scientific community	Presentations, international conferences and exhibitions	50 abstracts and keynotes in events
		Peer-review journal publications	25 publications, at least 80% in Q1 journals
Publicize outcomes, debate key themes and obtain feedback	Scientific community, end-users, general public	Social Media, Twitter, LinkedIn	2,000 Twitter followers, 600 on LinkedIn
Community building	SE scientific community	White papers and webinars	1 white paper (roadmap), 2 webinars
Capacity building (promote discussion and new visions)	Project consortium, SAB, IUB	Project General Assemblies, Galileo conference	-
Training	Scientific community, early-stage career (including EU13 and gender balance)	Internal/external workshops and training courses, presential and/or online	8 training courses
Sustainability of project products, provide general access to ChEESE-2P outcomes	Consortium, scientific community, end-users, general public, policy makers	Exercises, integration within RI's (EPOS-ERIC)	3 service demo exercises, at least 2 integrated in EPOS-TCS

2.2.3. Exploitation

Exploitation from a scientific and industrial perspective is a major commitment for ChEESE-2P, as testified by the balanced consortium including a diversity of organizations and the liaison with EPOS-ERIC and the Destination Earth initiative. With the objective of maximizing exploitation possibilities, the following 6 activities will be considered:

1. **Identification of project exploitable outcomes**, including interim and final results, as to conclude on potential downstream services, business ideas and exploitation pathways.
2. **Intellectual Property Rights (IPR) protection** of the individual components (codes, tools, etc.) developed in ChEESE-2P. In order to ensure a smooth execution of the project, the project partners will define the details concerning the access rights for exploitation to background and results in the Consortium Agreement (CA). Note that some of the high-level outputs of the Demonstrators might have restricted access because of specific sensitive data issues (e.g., related to Civil Protection aims).
3. **Identification and analysis of the target users** that may benefit from the project findings and achievements. Initially identified target users are civil protection organizations, (re)insurance companies, and companies providing services in evaluation of natural or anthropogenic hazards, or geophysical reservoir exploitation.
4. **Analysis of the exploitation context and business opportunities** to find out what is the actual market situation for the different applications covered in the project and discuss new emerging business models.
5. **Assessment of the competitive environment** of the project including technology readiness, integration, standardization and regulatory, policy framework at the targeted markets, and future trends at the social, business and policy levels.
6. **Dissemination activities** related to the exploitation of the results, such as publications in international conferences and journals, and presentation of results in trade fairs, workshops and related events or press releases in technical media.

These activities will be identified and included in the Communication and Dissemination Plan (D7.2) and the Exploitation Plan (D7.5). The latter will gather the feedback from the consortium interaction and discussions with

the IUB and other key external stakeholders and experts. It will be crucial to address strengths (benefits), weaknesses (drawbacks and prerequisites), opportunities (existing conditions suitable to promote the wide adoption of results) and threats, and will constitute the basis for planning a successful exploitation. For an effective exploitation of the project results it is necessary to establish already at the proposal stage the main aspects of the methodology that will be further developed on Intellectual Property Rights (IPR). IPR management will be based on the following principles:

- Background knowledge and Access Rights. Each Consortium partner will own the background that it brings to the project. In order to ensure a smooth execution of the project, the project partners will define the details concerning access rights for exploitation to background and results in the Consortium Agreement.
- Patents. In case a partner wants to submit a patent application, it will communicate to the Project Coordinator to determine if it is a joint foreground or not and initiate, if deemed, the appropriate patentability study. All required measures will be taken to guarantee that there is no disclosure that can ruin the patent possibility. Therefore, all partners will be communicated and special measures to confidentiality will be taken. Information of patent applications will be made available to the EU through regular management reports. The costs of the patent applications will be covered by the submitters.
- Foreground knowledge and IP ownership. Results will be owned by the project partner(s) carrying out the work leading to such results, independently of whether they can be protected or not. If any results are created jointly by at least two project partners and it is not possible to distinguish between the contributions of each of the project partners, such results, including inventions and all related patent applications and licenses, will be jointly owned by the contributing project partners. Each partner may use the results and material produced within the project for project purposes provided that such use does not come into conflict with the terms of the project Grant Agreement or the European legislation. Further details concerning jointly owned results, joint inventions and joint patent applications will be addressed in the Consortium Agreement.

2.2.4. The Industry and Users Board (IUB)

One of the most successful aspects of ChEESE-1P in terms of impact has been the creation (and the active involvement) of an Industry and Users Board (IUB), which has followed the progress of the project not only during the face-to-face and remote meetings but also through continuous feedback and validation of the PDs and related services in an operational environments and exercises. Starting from a reduced group of 12 members, the IUB grew progressively up to 29 members during the project, a clear indicator of the impact of the CoE. The IUB members of ChEESE-1P (see Table 2.2.4a and Figure 2.2.4) were composed of organizations from all around the world of diverse typologies, e.g. governmental bodies and institutions, scientific associations with thousands of individual memberships, networks, industry (large companies and SMEs), European projects, and non-profit Foundations. The IUB used the project's flagship codes and improved them by giving valuable feedback. Furthermore, many of them were involved in the live demos that ChEESE-1P organized.

Table 2.2.4a. *List of the ChEESE-1P IUB members.*

#	Name	Type	Country / Region
1	Italian Civil Protection Department (DCP)	Governmental	Italy
2	Icelandic Civil Protection	Governmental	Iceland
3	Spanish Geographic National Institute (IGN)	Governmental	Spain
4	International Association of Seismology and Phys. Earth's Interior (IASPEI)	Association	Global
5	International Association of Volcanology and Chem. Earth's Interior (IAVCEI)	Association	Global
6	European Plate Observing System (EPOS)	ERIC	Europe
7	GW4 ISAMBARD	Alliance	U.K.
8	Geohazard Supersites and Natural Laboratory (GEO-GSNL)	Network	Global
9	REPSOL	Industry	Multinational
10	Schlumberger	Industry	Multinational
11	INTEL	Industry	Multinational
12	MITIGA Solutions	SME	Spain
13	Global Parametrics	SME	Multinational
14	ARM	Industry	Multinational

15	FAULT2SHA	Associated with document Ref. Ares(2022)8497838 - 07/12/2022	Working Group	Global
16	Modeling Collaboratory for Subduction (MCS)		Network	Global
17	VECMA		H2020 project	Europe
18	ARISTOTLE		H2020 project	Europe
19	Norwegian Water Resources and Energy Directorate (NVE)		Governmental	Norway
20	AuScope		Governmental	Australia
21	National Computational Infrastructure Australia (NCI)		Governmental	Australia
22	International Center for Earth Simulation (ICES)		Foundation	Global
23	NVIDIA		Industry	Multinational
24	Global Earthquake Modeling Foundation (GEMF)		Foundation	Global
25	Mexican National Seismic Institute (ISN)		Governmental	Mexico
26	The Buenos Aires Volcanic Ash Advisory Center (VAAC)		Governmental	Argentina
27	Norwegian Meteorological Institute		Governmental	Norway
28	CAT-INGV		Governmental	Italy
29	Centro PLINIVS		Governmental	Italy

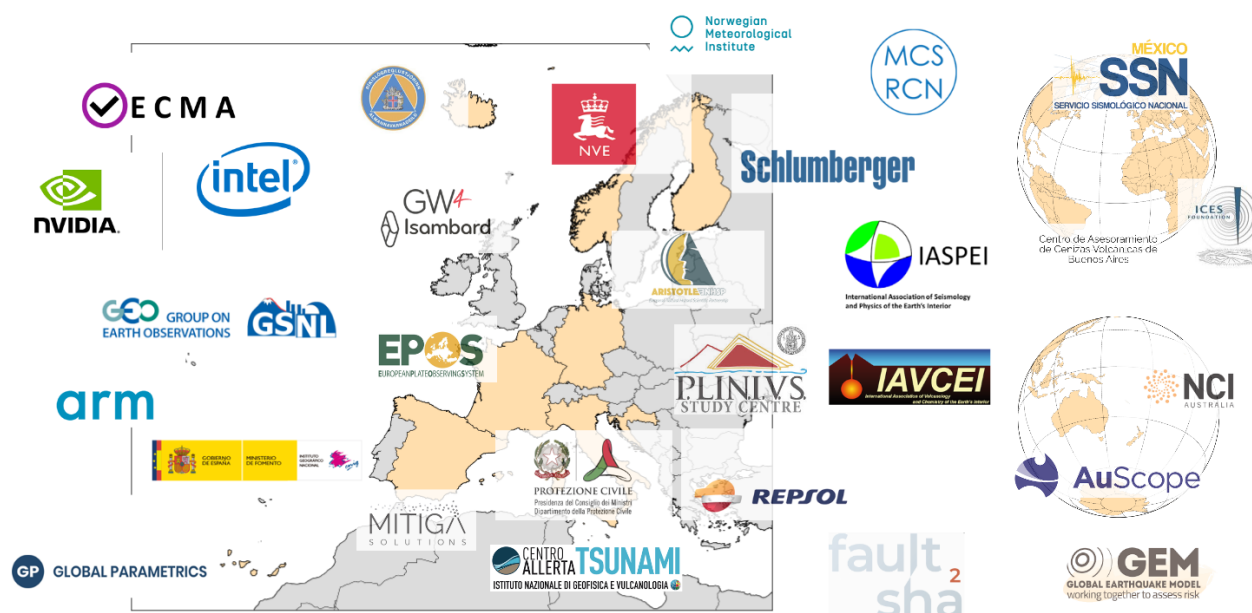


Figure 2.2.4. Members of the Industry and Users Board (IUB)

With few exceptions (e.g. projects like VECMA, which ended recently), almost all IUB members have already declared their interest to renew the membership for ChEESE-2P, including an update and new signature of the Non-Disclosure Agreement (NDA) with the ChEESE-2P Consortium members. Among those, the most prominent and relevant members include:

- The **European Plate Observing System (EPOS)** ERIC that integrates the diverse and advanced European RI for Solid Earth Science relying on new e-science opportunities to monitor and unravel the dynamic and complex Earth system. The EPOS ultimate goal is to enable innovative multidisciplinary research for a better understanding of the Earth's physical processes that control earthquakes, volcanic eruptions, ground instability, tsunamis, and all those processes driving tectonics and Earth surface dynamics. EPOS integrates those research infrastructures provided and supported by national organizations, and aims at providing an interoperable platform where specific scientific services can be presented in a uniform and harmonized manner, facilitating cross- disciplinary access and utilization.
- The **Italian Civil Protection Department (DPC)**, which coordinates the response to natural disasters, catastrophes or other events that must be faced with extraordinary powers and means. Moreover, also in

agreement with the regional governments and local authorities, DPC works in the drafting of legislation on the prevention of risks and regulatory measures needed to cope with disasters and minimize damage to people and property. It promotes national and international training projects and activities that contribute to spreading the culture of civil protection through its Competence Centres, such as PLINIVS (see below).

- The **Icelandic Civil Protection**, delegated to the National Commissioner of the Icelandic Police (NCIP). The NCIP runs a Department of Civil Protection and Emergency Management which is responsible for daily administration of Civil Protection matters, maintains a national coordination/command center which can be activated at any time and is also responsible for operating the center in emergency situations. The NCIP is also responsible for monitoring and supporting research and studies related to risk factors and natural catastrophes, and to coordinate and support measures aimed at reducing risks of bodily harm. The NCIP operates a National Crisis Coordination Center in Reykjavik.
- The **Spanish Geographic National Institute (IGN)**, a Governmental Institute with more than 500 employees, holds a long experience in designing and maintaining operative infrastructures and derived applications related to geodetic and geophysical purposes. It is officially responsible for the Seismic, Tsunami and Volcano Monitoring Early Warning System and associated risks assessment. It is also responsible for the installation, maintenance and data analysis from the Seismic, Geodetic, Gravimetric and Geomagnetic networks of Spain, as well as the drafting and updating of the Earthquake Resistant Building Design Code.
- The **PLINIVS Study Centre** (Study Centre for Hydrogeological, Volcanic and Seismic Engineering), a structure of LUPT Research Interdepartmental Centre, University of Naples Federico II, in the field of seismic, volcanic and hydrogeological risk modeling and assessment. PLINIVS is also a National Competence Center on Volcanic Risk for the Italian Civil Protection.
- The **International Association of Seismology and Physics of the Earth's Interior (IASPEI)**, a non-governmental and nonprofit organization aimed at facilitating multidisciplinary research related to earthquake science, internal structure, properties and processes of the Earth, and to initiate and coordinate the conduct and communication of related research which depends on cooperation between different countries.
- The **International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)**, a non-governmental and non-profit organization aimed at research in volcanology, efforts to mitigate volcanic disasters, and research into closely related disciplines, such as igneous geochemistry and petrology, geochronology, volcanogenic mineral deposits, and the physics of the generation and ascent of magmas in the upper mantle and crust.
- **INTEL**, a corporation that designs, manufactures, and sells computer, networking, data storage, and communication platforms worldwide. Approximately 85% of the supercomputers listed on the current Top500 list are based on Intel CPUs.
- **Global Parametrics**, a company whose principal objective is the design, development and implementation of financial disaster risk management solutions in respect of the risk of natural disasters (e.g. drought, tropical cyclone, flood, earthquake, etc.) occurring in emerging countries thereby seeking to build resilience to, and to provide financial protection to mitigate the impact of, natural disasters.
- **ARM**, a world-leading supplier of semiconductor intellectual property (IP) that designs energy-efficient processors and related technologies to deliver the intelligence in applications ranging from sensors to servers, including smartphones, tablets, enterprise infrastructure and the Internet of Things (IoT). Headquartered in Cambridge, U.K., are now part of the SoftBank Group Corp (SBG). Fugaku, the currently world-wide fastest supercomputer is based on Arm CPUs.
- **ARISTOTLE-2**, the second phase of ARISTOTLE that aims at continuing strengthening the monitoring and analysis functions of the Emergency Response Coordination Center (ERCC) and its Situational Awareness Sector (SAS) by delivering unique multi-hazard advice service at global level and on a 24/7 operational basis.
- **Norwegian Water Resources and Energy Directorate (NVE)** mandate is to ensure an integrated and environmentally sound management of the country's water resources, promote efficient energy markets and cost-effective energy systems and contribute to efficient energy use. They also have a national responsibility for landslide-induced tsunami hazards in Norway.
- The **National Computational Infrastructure Australia (NCI)**, the nation's most highly integrated high-performance research computing environment, provides world-class services to government, industry, and researchers.
- **NVIDIA**, an American multinational technology company which designs graphics processing units (GPUs) for the gaming and professional markets, as well as system on a chip units (SoCs). At present, 14 of the 20 fastest supercomputers in the latest Top500 list use NVIDIA GPUs.

2.2.5. Letters of Support

In accordance with Horizon Europe Programme application procedures, Letters of Support (LoS) are not attached to this proposal. However, the following Letters of Support (LoS) are available upon request:

- LoS from NVIDIA and commitment to provide support from NVIDIA specialists in HPC performance optimization and applied Deep Learning, engaging in co-design initiatives, and collaboration to enable ChEESE-2P flagship applications to be hosted on the NVIDIA GPU Cloud registry (NGC).
- LoS from the Partnership for Advanced Computing in Europe (PRACE).
- LoS from the LUMI Consortium.
- LoS from the IUB members (see detailed list in Table 2.2.4a).

2.3. Summary

Specific Needs
• Geophysical extremes are responsible for at least 10% of the losses caused by all kinds of natural disasters worldwide. In Europe, around 40% of the population lives in coastal areas, 30% is potentially exposed to earthquakes (up to 80% in some countries), and over 10 million people live around active volcanoes. The associated risks show a growing trend, in some cases exacerbated by global warming (e.g. glacier hazards), and an urgent demand exists to better understand and anticipate the occurrence of these natural disasters and their impacts. • Proper utilization of supercomputer resources can save lives, but need tailored codes and workflows. In emergency situations time-to-solution is of paramount importance and HPC RIs are becoming extremely valuable for early warning, short-term forecast, and emergency management (urgent computing). • SE hosts numerous capability/capacity Exascale Computational Challenges (ECCs) and ChEESE-2P can act as a transversal integrator of RIs (EuroHPC/FENIX/EPOS) across the ecosystem of scientists and end-users. • The Destination Earth initiative under the Digital Europe Programme has identified geophysical extremes as a key Earth system component together with extreme weather, climate, and oceans.
Expected Results
• Enhance 11 open-source flagship codes in terms of performance, scalability, deployment, and portability across current pre-exascale systems and emerging hardware architectures for its uptake by other initiatives of the ecosystem (including DestinE). • A new generation of 9 Pilot Demonstrators (PDs) on different areas of SE and 15 capability/capacity production runs (Simulation Cases) yielding to EOSC-enabled datasets and hazard assessments. • Foster the urgent computing access mode in EuroHPC tier-0/tier-1 systems by enabling the deployment of 4 services and related access policies in co-design with end-users and IUB members. • Foster the end-user usage and uptake of codes and products through a containerized application deployment, training and roadmapping activities.
Dissemination, Exploitation and Communication measures
• Dissemination: scientific networks, Galileo conference, 100+ presentations in scientific meetings, 50+ Q1-Q2 publications, 8 training courses, workshops and live exercises with potential end-users for co-design, activities of liaison officers to foster integration in DestinE, Equality Committee activities (including ShEESE and EU13 engagement). • Exploitation and sustainability: feasibility analysis to set up a “ChEESE Foundation”, which may be linked to the different EU initiatives (e.g. DestinE) as an asset provider while fostering scientific research in the SE community. Development of services into EPOS Thematic Core Services (TCS), public and private third parties building added value downstream services on PDs. • Communication: dedicated branding identity, website, public reports, flyers, posters, white papers, press releases, videos for general public, social media (LinkedIn for industry and Twitter for scientists)
Target Groups
• The Earth science research community will benefit from development and uptake of a leading-edge innovative research framework to study and forecast geohazards and their interactions with other Earth components. • The computer science community will benefit from hardware co-design with one of the more exascale-oriented research communities.

- **European RIs** (EuroHPC, EPOS, FENIX). Overall enhanced competitiveness of target RIs (data providers and supercomputing facilities), including staff developing skills.
- **Public sector**. National and European (i.e. the Directorate-General for European Civil Protection and Humanitarian Aid Operations) civil protection agencies, local municipalities, risk management practitioners, civil aviation stakeholders (e.g. regulators, air traffic controllers, volcanic ash advisory centers, airport operators), tsunami service providers.
- **Private sector**. EPOS ERICs, hardware developers (NVIDIA, INTEL, ARM), SMEs, and spin-offs.
- **Other EU and national Research projects** and initiatives in the Earth System science ecosystem (e.g. DT-GEO, Geo-INQUIRE projects, DestinE, ARISTOTLE, etc.).

Outcomes

- UC service for earthquakes using AI/ML-based approaches, UC service for volcanic ash/gas dispersal at local scale, UC service for phreatic eruptions to be potentially used in the framework of a volcanic unrest.
- A Global Tsunami Model and the first multiscale European volcanic hazard map for potential distribution through the EPOS Thematic Core Service (TCS) and a hazard assessment from subglacial lakes that could endanger populated areas.
- Private sector builds downstream services on early warning, hazard assessment, hydrocarbon and energy resource exploration, etc.

Impacts

- Informed forecast of the Earth behavior, creating new business opportunities at European and global levels, measured by the involvement of the private and public sectors using/exploiting products/services.
- Breakthrough in realism for modeling cascading and coupled phenomena across disciplines to improve policies and decision making practices related to management of geohazards.
- Establish the basis for an emergency access mode as adaptive, objective, based on high quality data, reliable physical modeling and forecasting tools using integrated communication systems and HPC capabilities.
- Bridge the gap between operational warning and hazard analysis, provide changes to how land use planning and insurance risk are carried out.

3. Quality and Efficiency of the Implementation

3.1 Work Plan and Resources

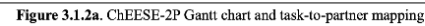
3.1.1. Overall Structure

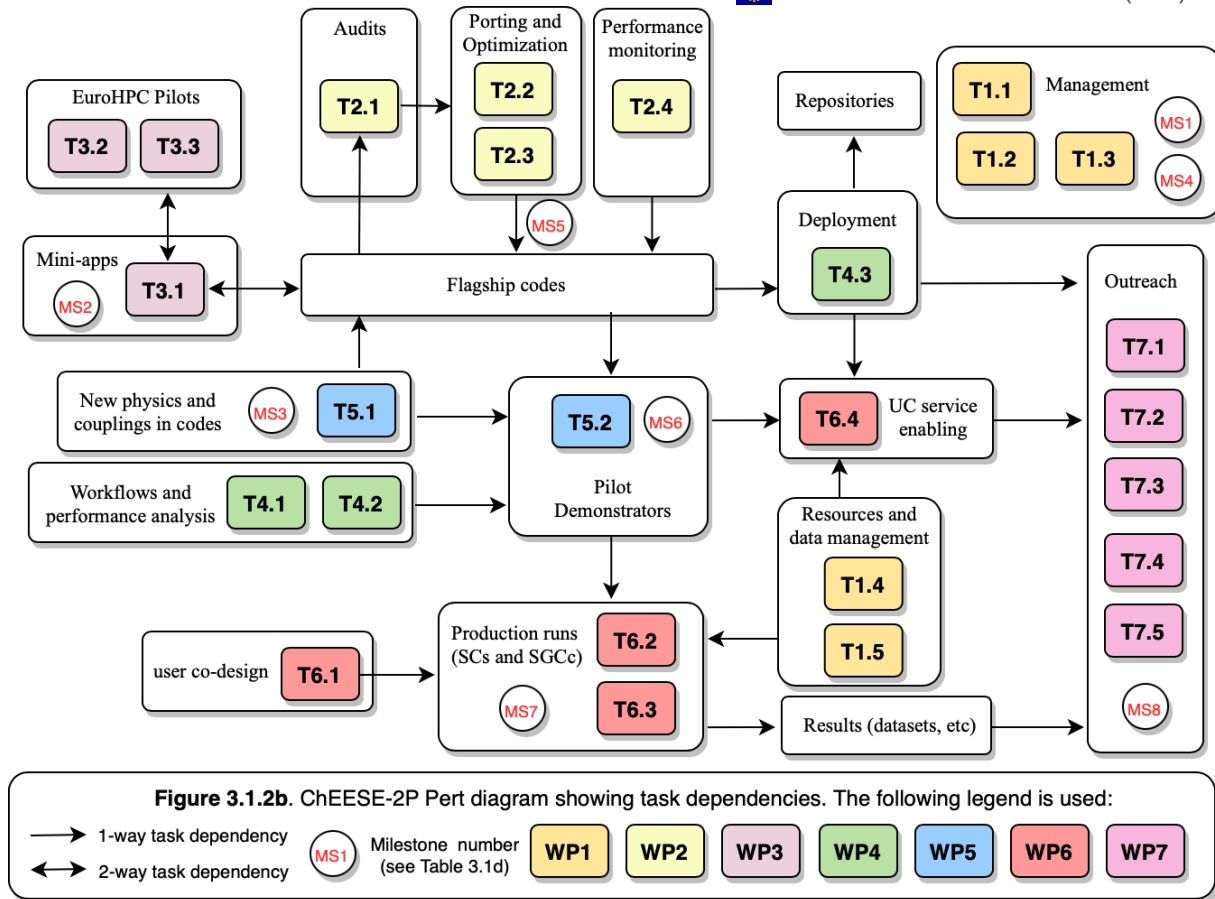
ChEESE-2P articulates around 26 tasks grouped in 7 WPs (see List of WPs in Part A). These include project management (WP1), 3 transversal WPs (WP2, WP3 and WP4), 2 vertical pillars (WP5 and WP6), and a final WP for dissemination, outreach and capacity building (WP7). **WP1** (project management, 5 Tasks) deals with the administrative and financial management of the project, including the monitoring and assessment of the quality of the project outcomes, gender and inclusive country balance activities, access and management of computational resources, and data management and FAIR data validation. **WP2** (exascale technical challenges in flagship codes, 4 Tasks) is the foremost transversal WP that groups the code audits, code performance portability and porting to accelerators, single and multi-node performance optimizations, continuous code performance monitoring, and testing efforts for the 11 flagship codes. **WP3** (co-design with European HPC vendors and technologies, 3 Tasks) focuses on preparing selected code mini-apps and testing on exascale hardware prototypes in synergy with the two major EuroHPC Pilot initiatives. **WP4** (simulation ecosystem, 3 Tasks) addresses challenges at large scale that go beyond the main application codes, including workflow implementation and organization, support tools to code/workflow development, validation, and deployment using containerization for components and a series of lightweight performance analysis services. **WP5** (farming Pilot Demonstrators, 2 Tasks) is the main vertical component and will farm the new generation of 9 PDs, including implementation in flagship codes of new physics and coupling terms, and the development of the PDs. **WP6** (simulation cases and service enabling using EuroHPC infrastructures, 4 Tasks) will define and execute the 15 SCs in cooperation with the community of users and enable 4 urgent computing services on EuroHPC infrastructures. Finally, **WP7** (dissemination, outreach and capacity building, 5 Tasks) will perform communication and dissemination activities, liaison actions, training activities in cooperation with PATC and the NCCs, community roadmap activities (including the Galileo conference), and identify all project exploitable outcomes, including interim and final results, with emphasis in the PDs and the services. The total person effort (976 PMs) can be grouped in 3 broad “categories”:

- Transversal activities (WP2 to WP4, 427 PMs, i.e. a 43.75% of the total person effort) for HPC software engineering and hardware co-design.
- Vertical activities (WP5 and WP6, 401 PMs, i.e. a 41.08% of the total person effort) for SE domain-specific science, production runs, and related outcomes and services.
- Other non strictly scientific-technical activities (WP1 and WP7, 148 PMs, i.e. a 15.17% of the total person effort) grouping the rest of activities.

3.1.2. Detailed WP Description

The 7 Panels in Part A show all WP descriptions. The panels below show the corresponding Gantt chart (, including also a task-to-partner mapping,) and a Pert diagram showing the relations and dependencies among the 26 tasks. The participants involved in each WP and their staff efforts are shown in Part A.





3.1.3. Deliverables

The total number of deliverables is 44 (see Table in Part A): 4 in WP1, 4 in WP2, 2 in WP3, 5 in WP4, 10 in WP5, 12 in WP6, and 7 in WP7. The delivery months consider both the dependencies among different tasks and a balanced distribution of effort throughout the project: 12 deliverables are expected after the mid-term (one third of the total) and around 50% delivery is achieved at M36. This will allow the PEC (and the Project Officers) to have a good indicator of the project evolution during the mid-term review and, if necessary, adopt timely corrective measures. ALL partners have a deliverable lead role with the following distribution: CSIC(9), BSC(4), INGV(6), IMO(2), HLRS(6), CIN(4), LMU(2), UMA(1), NGI(1), CNRS(3), BA(1), CSC(1), RBI(1), UM(1), IPGP(1) and SU(1).

3.1.4. Milestones and Risks

Tables in Part A includes the list of milestones (8 in total) and the critical risks for implementation including likelihood and level of severity is shown in the Table below.

Table 3.1e. Expected risks and proposed mitigation measures.

Quantification of risk			WP	Risk-mitigation measures
Description	Likelihood	Severity		
New covid-19 outbreaks	low	low	all	Cancel F2F meetings. Low severity regarding other aspects
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
POP3 proposal is not funded	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

The project will elaborate (during the first months) a risk assessment and management strategy including planned contingency measures. It will be based on a continuous risk analysis methodology involving all Consortium members. Such a risk management strategy will be described in detail in deliverable D1.1. Addressing potential risks will be part of the normal operation of the project, being addressed in the PEC and PSB meetings. This regular review of potential concerns will ensure the early warning of potential risks and ample time to employ the necessary corrective actions. Risks considered being of importance, in particular risks associated with partners not performing or conflicts between partners will be closely monitored by the PC. In general, risk management will be the responsibility of the PC and the status of any risk situations will be informed to the EC via the yearly reports, except when there is a clear need for earlier EC intervention upon decision of the PSB.

3.1.5. Resources

NOTE: The ChEESE-2P total budget is around 25% larger than the 6 M€ suggested maximum for topic 02 CoEs but less than the topic 01 suggested maximum. This is justified because ChEESE-2P is actually a “1.5” CoE that covers the scopes of both calls, preparing some applications for true exascale capability use and, simultaneously, considering high-impact use-cases from world-leading Community codes/workflows that aggregate to pre-exascale workloads. The reasons for applying to topic 02 have been detailed in the Introduction.

- **Personnel (staff) costs.** Part A contains the staff effort distribution among the different WPs by beneficiary (WP leaders are highlighted). Around 15% of the staff effort is dedicated to management, communication, dissemination and outreach activities (WP1+WP7), and the remaining 85% is dedicated to R&D activities (WP2 to WP6). The total PMs are 976.
- **Subcontracting costs.** No partner has subcontracting costs (Table 3.1g not needed).
- **Purchase costs.** Budget for purchase costs (travel + other goods) has been carefully considered to ensure that they are deemed necessary for ensuring the effective consecution of the work planned and, as a consequence, the successful achievement of the project goals. Table 3.1h is not necessary because no partner exceeds the

percentage of 15% of personnel costs. The partner with a higher percentage is CSIC (the project Coordinator, 14.39%), the rest of beneficiary partners are all below 10%. For all partners (except the Coordinator), the other goods category includes a 3.000€ for auditing if the total EU-requested partner budget exceeds 430.000€.

- **Other costs.** No partner declares costs under other costs categories (Table 3.1i is not needed).
- **In-kind contributions provided by third parties** (associated). The ChEESE-2P consortium has no third parties (Table 3.1j is not needed).

3.2. Capacity of Participants and Consortium as a Whole

3.2.1. Consortium

The ChEESE-2P Consortium is composed of 16 Partners from 8 EU member and associated states (Croatia, Finland, France, Germany, Iceland, Italy, Norway, and Spain) and, with respect to ChEESE-1P, incorporates 4 new beneficiaries (CSC, RBI, UM, and SU). The expertise and background of the Consortium is strong enough to achieve ambitious objectives in due time. All partners are organizations with a deep background on the technologies to be developed and deployed, with an experience and expertise that includes:

- The 3 supercomputing centers (CIN, BSC and CSC) which will host the 3 EuroHPC pre-exascale machines (Leonardo, LUMI and MN5) plus a fourth tier-0 center (HLRS). The Consortium hosts also 5 petascale machines (Marconi100, MN4, HAWK, Galileo100, CTE-Power) plus federated e-infrastructure services (e.g. FENIX RI for service-oriented provision of resources).
- The coordinator of the EuroCC project and the CASTIEL Coordination Support Action (CSA) that have established the NCCs (HLRS).
- The coordinators of EuPEX and EuPilot, the 2 major EuroHPC initiatives for European exascale hardware sovereignty (BA and BSC).
- The 4 largest institutions in charge of geophysical monitoring networks in Europe (INGV, IMO, CNRS and CSIC for Italy, Iceland, France and Spain respectively).
- Internationally recognized scientists and institutions (CSIC, BSC, INGV, TUM, LMU, UMA, CNRS, CSC, RBI, UM, SU) that are experts in the different areas of SE and develop and maintain the 11 flagship codes.
- Industry hardware and software providers (BA) and private research non-profit foundations that carry out both research and consulting (NGI), which brings an added value to the Consortium in terms of Industrial outreach, using cutting-edge science developments to increase their competitiveness.
- The coordinator of DT-GEO (CSIC) and a substantial part of the DT-GEO and Geo-INQUIRE consortiums.
- National representatives of the EPOS-ERIC RI and some of its key data-provider members (INGV, CSIC, IMO, CNRS).
- In terms of research and academia, almost all partners are top geophysical research institutions in Europe and worldwide, with experts in the different target areas. They have multidisciplinary teams covering both the knowledge of transversal components (workflows, computing, data) and vertical pillars (volcanoes, tsunamis, earthquakes, etc).
- Finally, representatives of industry, governance bodies (e.g civil protections), scientific networks and associations will participate through the IUB, including EPOS (see Sec. 2.2.4). The industry side of these stakeholders participates in international projects and is interested in cutting-edge science developments to increase their competitiveness. All consortium beneficiaries have a long history of technological collaboration with industrial partners, which guarantees the required common language and work style.

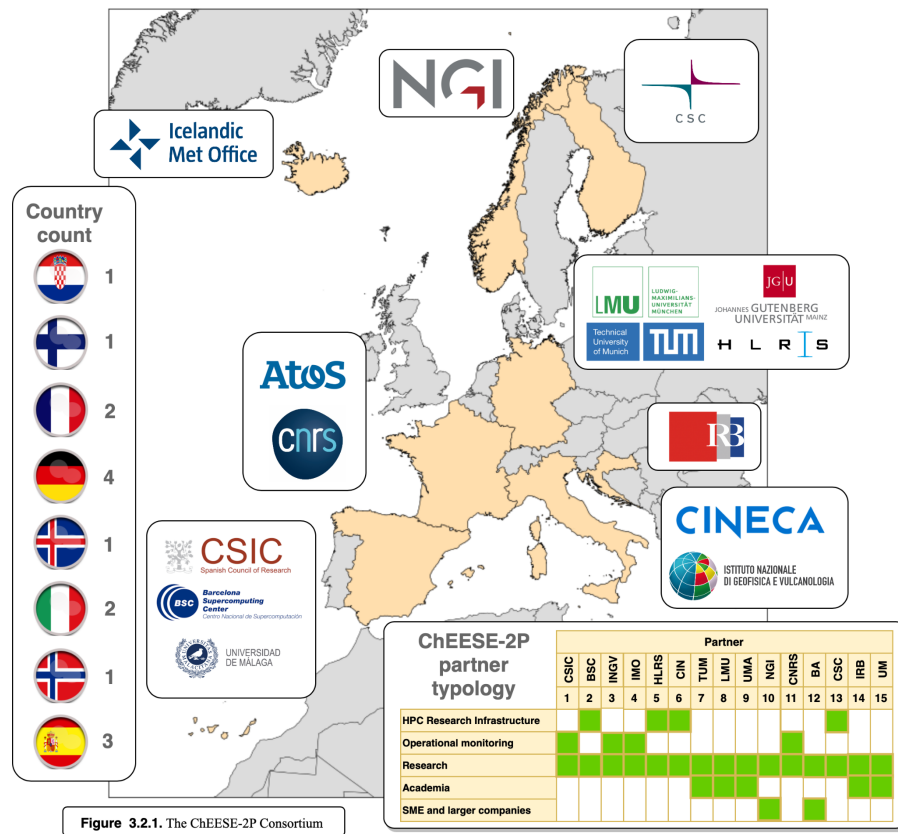


Figure 3.2.1. The ChEESE-2P Consortium

3.2.2. Management Structure

The ChEESE-2P management structure has been designed to ensure coherent and effective strategic, administrative, and financial coordination and to provide participants with the necessary support and management tools to achieve the project goals. The main purposes of the management structure are: (i) to define procedures that ensure timely completion of quality project deliverables while staying within budget, (ii) to provide an efficient organization structure that ensures the involvement of all partners and, (iii) to provide mechanisms for the management of knowledge and intellectual property and the resolution of conflicts. The project organizational structure includes the following components:

Project Coordinator (PC). The PC (Prof. Arnau Folch, CSIC) is responsible for the day-to-day execution of the project. The PC will ensure the timely delivery of project objectives and deliverables by continuously monitoring the project progress against the plan of record. The PC will identify and track issues as well as propose suitable corrective actions (e.g. resource reallocation, task force creation, etc.) that might require a formal decision by the Project Supervisory Board (PSB). The PC will also be responsible for calling the PEC, PSB and GA meetings and reviews, as well as compiling and distributing meeting minutes and actions. The PC will define the procedures for change control (proposed changes to the plan of record), risk management, quality assurance, and IPR management. The administrative and financial management of the project is also the responsibility of the PC, including internal use of resources monitoring on a 6-month basis, the provisioning of Periodic Reports and Financial Statements, and ensuring an efficient distribution of funding. The PC will also act as the official point of contact between the Commission and the Beneficiaries.

Project Innovation Manager (PIM). As explained in the Impact Section, the PIM (Dr. Joan Farnós, BSC) will fulfill a key role in the coordination of the various exploitation activities. The PIM, with the contribution of the whole consortium, will be responsible for the development of a rolling Exploitation Plan and for setting up the exploitation strategies. The PIM will be deeply involved in linking activities with the IUB.

Work Package Leaders (WPLs). The WPLs will be responsible for the scientific and technical work of their respective WP. This includes the planning and control of all activities within each WP, the preparation of deliverables and the collection of the contributions from other partners participating in the respective WP for internal and external reports. Each WPL will be appointed by the organization responsible for the respective WP, trying to keep gender balance as much as possible.

Project Executive Committee (PEC). The PEC will be composed of the PC, the PIM and the 7 WPLs (9 members). The PEC is responsible for the day-to-day execution of the project and will meet regularly (every 1-2

months) via teleconference or in coincidence with the 3 face-to-face meetings. The PEC is expected to raise critical issues to the PSB and GA and to support the PC in coordinating cross-work package relationships within the appropriate activity area. They must actively participate in the regular project-related meetings as well as in preparing technical and status presentations as required.

Project Supervisory Board (PSB). The PSB will be responsible for the overall management and running of the project and is the decision-making body of the project that holds the highest level of authority. The board will be chaired by the PC and involve 1 representative from each of the 16 partners (i.e. 17 PSB members in total) with one vote each to make strategic decisions during the PSB meetings. If no consensus can be reached, decisions will be approved by a simple majority of members. The PSB will be in charge of making all decisions affecting more than one Beneficiary, including: resolution of conflictive situations among the consortium partners; approval of significant changes of the project content; exploitation, dissemination and communication of the project results; or decide on an efficient implementation of the project. Only the PSB has the authority to alter the project work plan significantly. Conflicts, if any, will be solved in accordance with the Consortium Agreement. The PSB will meet regularly every 6 months in face-to-face meetings called by the PC. However, in case of urgent conflicts or issues affecting the general project advancement, conference calls will be organized immediately to ensure no delay in the project implementation.

General Assembly (GA). The GA will host general face-to-face meetings attended by all participants plus the Scientific Advisory Board (SAB) and, if possible, the Industry and Users Board (IUB). Three meetings are planned: a kick-off meeting (M1), a mid-term meeting (M23) and a final project meeting (M47).

Industry and Users Board (IUB). The IUB will provide an independent, industry-based mechanism for obtaining feedback on project interim results. Moreover, and in collaboration with the Project Innovation Manager (PIM), it will facilitate industry and project end-user communities direct participation in identifying and pursuing exploitation opportunities. The IUB will meet (physically or virtually) during the 3 project General Assemblies and will review the project evolution and provide feedback. After ChEESE-1P, the IUB consists of the 26 members detailed in Section 2.2.4.

Scientific Advisory Board (SAB). The SAB initially consists of 4 external relevant scientists, 2 male and 2 female, in the fields of SE and Computer Sciences that will contribute their expertise to support ChEESE-2P in attaining its goals. The main role of the SAB will be to provide constructive criticism on the project development and its scientific direction. They will also provide strategic support to WPLs in the periodic General Assemblies, at which the SAB members shall be invited. The composition of the SAB includes European and non-European scientists in order to provide a global perspective to the project. The SAB may be extended to one or two more scientists as the project develops. The SAB consists of the following 4 advisors:



Lesley Wyborn. Honorary Professor at the Research School of Earth Sciences and the National Computational Infrastructure at the Australian National University. She previously had 42 years' experience from 1972 to 2014 in Geoscience Australia in scientific research and in geoscientific data management. She is currently project leader of the 2030 Geophysics Collection Project which seeks to make national Geophysics Data Assets FAIR and machine actionable for use in 2030 Exascale environments.



Kim Olsen is the Rollin & Caroline Eckis Chair in Seismology, and Professor of Geophysics, at the Department of Geology and Geophysics at the San Diego State University, San Diego, CA, USA. His expertise ranges from rupture dynamic modeling for earthquake sources, simulation of wave propagation in visco-elastic and visco-plastic media, to high performance computing.



Jean-Pierre Vilotte is Professor at the Institut de Physique du Globe de Paris (IPGP) where he has been (1997-2020) director of the high-performance computing and analysis centre. He is Scientific Deputy at the Institut National des Sciences de l'Univers (INSU) of the French CNRS for high-performance computing, data and information technology, and a member of the steering committee of the CNRS interdisciplinary centre: AI for Sciences and Sciences for AI the Sciences.



Lilli Freda is the Executive Director of EPOS Eric, committed to enabling excellent science through the integration, accessibility, use and re-use of solid Earth science data, research products and services, as well as by promoting physical access to research facilities. As Executive Director, Lilli Freda is the legal representative and overall coordinator of the Research Infrastructure.

3.2.3. Management Procedures and Tools

Internal Communication Tools. In order to support the cooperation among all partners and encourage participation in the decision-making process, a set of internal collaboration tools will be set up. The CSIC, as leader of WP1, will be responsible for providing the project with the necessary internal collaborative tools, including: a Project Portal (shared workspace) to facilitate the exchange of critical project documentation and news, an issue tracking system, and a set of distribution mailing lists for working sub-groups as appropriate (e.g. by WP).

Progress Monitoring. The ChEESE-2P project work plan structure has been defined in order to ease charting the progress of the project. The PC will ensure that monitoring the work progress and the use of resources is done on a

6-month basis in order to ensure the detection of errors and deviations as early as possible in the project's life cycle. This will enable the Consortium to apply systematically corrective actions or contingency plans, if necessary. During the PEC meetings, WPLs will report to the PC the effort spent by their work packages, status of achievement of milestones, production of deliverables, and completion of tasks within their respective WP.

Quality Control and Assurance. A Quality assurance process will be defined in order to ensure accurate documentation, reporting and justification of the work being carried out. An internal peer-review process will be set up, including a well-defined set of criteria, to guarantee the project deliverables meet the minimum quality standards before being sent to the European Commission as official outcomes of the project. The high level principles guiding these procedures will be agreed to at the start of the project during the kick-off meeting. The quality assurance process will be also documented in the deliverable D1.1.

Emergency and Conflict Resolution. Any event that may jeopardize the overall completion date of the project should be reported immediately to the PC. The PC will call an emergency PSB meeting or teleconference as required. Each party involved in the issue will have to present a short document describing their respective understanding of the conflict that includes at least one proposed solution. The PSB will resolve by votation following the procedures with the PC casting the tie-breaking vote if necessary. The formal procedure to deal with such conflicts will be detailed in the Quality Plan (D1.1).

3.2.4. Role of Partners

Tables 3.2.4a and 3.2.4b below show the main roles of partners, including WP/task lead and participation. Table 3.2.4b also reflects the diversity and complementarity of the Consortium members.

Table 3.2.4a. *Role of each beneficiary partner.*

CSIC	WP/T lead	WP1 and 7 tasks (T1.1, T1.2, T1.4, T1.5, T7.1, T7.2, T7.6)
	Participates	All 26 tasks
	Main roles	Project coordinator, FALL3D flagship code, co-design, lead PD5 and SC8.2, UC service enabling, training
BSC	WP/T lead	WP7 and 6 tasks (T2.4, T3.3, T6.4, T7.3, T7.4, T7.5)
	Participates	15 tasks (T1.1 to T1.5, T2.3, T4.1, T4.3, T5.2, T6.1 to T6.3, T7.1, T7.2, T7.6)
	Main roles	performance monitoring, EuPilot prototype, communication, sustainability, training, UC service enabling
INGV	WP/T lead	WP6 and 2 tasks (T6.1, T6.3)
	Participates	19 tasks (T1.1 to T1.5, T2.1 to T2.4, T4.1 to T4.3, T6.2, T6.4, T7.1 to T7.4, T7.6)
	Main roles	OpenPDAC flagship code, lead PD3 and PD6, lead SC2.1, SC3.1, SC5.1, SC6.1, SC6.2, UC service enabling
IMO	WP/T lead	No
	Participates	13 tasks (T1.1 to T1.5, T5.2, T6.1 to T6.3, T7.1 to T7.4, T7.6)
	Main roles	PSHA in Iceland, lead SC9.1, UC service enabling
HLRS	WP/T lead	WP4 and 4 tasks (T2.1, T4.1, T4.2, T4.3)
	Participates	11 tasks (T1.1 to T1.4, T2.4, T6.4, T7.1 to T7.4, T7.6)
	Main roles	code audit, workflows, performance analysis, containerization, deployment
CIN	WP/T lead	WP2 and 4 tasks (T2.2, T2.3, T3.1, T4.3)
	Participates	13 tasks (T1.1 to T1.4, T2.1, T3.2, T6.2, T6.4, T7.1 to T7.4, T7.6)
	Main roles	code audit, porting (Leonardo), optimization, monitoring, portability, UC service enabling
TUM	WP/T lead	No

	Participates	21 tasks (T1.1 to T1.5, T2.1 to T2.4, T3.1 to T3.3, T5.1, T5.2, T6.1 to T6.3, T7.1, T7.3, T7.4, T7.6)
	Main roles	ExaHyPE flagship code, performance optimization and scalability of SeisSol and ExaHyPE, multiphysics, coupled PDs, training
LMU	WP/T lead	2 tasks (T1.3, T6.2)
	Participates	23 tasks (T1.1, T1.2, T1.4, T1.5, T2.1 to T2.4, T3.1 to T3.3, T4.1 to T4.3, T5.1, T5.2, T6.1, T6.3, T6.4, T7.1, T7.3, T7.4), T7.6
	Main roles	SeisSol and TANDEM flagship codes, lead PD1, lead SC1.2 and SC1.3, training, EC committee, UC service enabling
UMA	WP/T lead	No
	Participates	23 tasks (T1.1 to T1.5, T2.1 to T2.4, T3.1 to T3.3, T4.2, T4.3, T5.1, T5.2, T6.1 to T6.3, T7.1, T7.3, T7.4, T7.6)
	Main roles	HySEA flagship code, training, UC service enabling
NGI	WP/T lead	No
	Participates	23 tasks (T1.1 to T1.5, T4.1, T5.2, T6.1 to T6.4, T7.1, T7.4, T7.6)
	Main roles	Lead PD4, lead SC4.1, multisource tsunami modeling
CNRS	WP/T lead	WP5 and 2 tasks (T5.1, T6.2)
	Participates	22 tasks (T1.1 to T1.5, T2.1 to T2.4, T3.1 to T3.3, T4.1 to T4.3, T6.1, T5.1, T5.2, T6.1, T7.1, T7.3, T7.6)
	Main roles	SPECFEM3D, xSHELLS and flagship codes, lead PD2 and PD7, lead SC1.1, SC7.1 and SC8.2, training
BA	WP/T lead	WP3 and 1 tasks (T3.2)
	Participates	10 tasks (T1.1 to T1.4, T2.3, T3.1, T7.1, T7.2, T7.4, T7.6)
	Main roles	EuPEX prototype, co-design, optimization
CSC	WP/T lead	No
	Participates	16 tasks (T1.1 to T1.4, T2.1, T2.2, T5.1, T5.2, T6.1, T6.3, T6.4, T7.1 to T7.4, T7.6)
	Main roles	porting (LUMI and AMD), portability, ELMER/ICE flagship code, lead PD9, UC service enabling, training
RBI	WP/T lead	No
	Participates	13 tasks (T1.1 to T1.5, T4.1, T5.1, T5.2, T6.1, T6.2, T7.1, T7.4, T7.6)
	Main roles	HySEA flagship code, meteotsunamis
UM	WP/T lead	No
	Participates	17 tasks (T1.1 to T1.5, T2.1 to T2.4, T4.1, T5.1, T5.2, T6.1, T6.2, T7.1, T7.3, T7.4, T7.6)
	Main roles	LaMEM flagship code, lead PD8 and SC8.1, training
SU	WP/T lead	No
	Participates	13 tasks (T1.1, T1.5, T2.1, T2.3, T3.1, T3.3, T5.1, T5.2, T6.1, T6.2, T7.1, T7.3, T7.4)
	Main roles	ptatin3D flagship code, training
IPGP	WP/T lead	No

Participates	13 tasks (T1.1, T2.1, T2.2, T2.4, T3.1, T4.1, T4.2, T4.3, T5.1, T5.2, T6.1, T7.1, T7.6)
Main roles	Participation in PD7 and SC7.1

Table 3.2.4b. *Type of activity of each beneficiary partner. Beneficiary number: (1) CSIC, (2) BSC, (3) INGV, (4) IMO, (5) HLRS, (6) CIN, (7) TUM, (8) LMU, (9) UMA, (10) NGI, (11) CNRS, (12) BA, (13) CSC, (14) RBI, (15) UM, (16) SU*

Type of activity / Beneficiary number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project management																
Communication, dissemination, engagement																
Provision of research and tech. infrastructure																
Co-definition of research and market needs																
Research performer																
Technology developer																
Testing/validation of approaches and ideas																
Prototyping and demonstration																
IPR management + tech.transfer																
Education and training																

Annex

Table A1: Applications in ChEESE-2P. Area codes are: CS computational seismology, T tsunami modelling, MHD magnetohydrodynamics, V volcanology, GD geodynamics, GL glacier hazards.

Application name	Methods	Application area	Programming language	Access/ License	IP rights/ Code owner	Link for further information
SeisSol	Simulation of complex earthquake scenarios using high-order discontinuous Galerkin discretisation with an Arbitrary DERivative (ADER) local time stepping on unstructured adaptive tetrahedral meshes.	CS T	C++, F90	BSD3	LMU	doi: 10.5281/zenodo.7038298
SPECFEM3D	Solves linear seismic wave propagation (elastic, viscoelastic, poroelastic, fluid-solid) and dynamic rupture problems in heterogeneous 3D models, and also implements imaging and FWI for such complex models based on an L-BFGS algorithm.	CS	C/C++, F90	GNU GPL v3	CNRS	doi: 10.5281/zenodo.6394675
ExaHyPE	Engine to solve hyperbolic PDE systems using high-order discontinuous Galerkin discretisation (DG, with ADER time stepping) on tree-structured dynamically adaptive Cartesian meshes	CS T	C++, Python	Modified BSD3	TUM	https://exahype.eu
Tandem	A scalable discontinuous Galerkin code on unstructured curvilinear grids for linear elasticity problems and sequences of earthquakes and aseismic slip	CS	C++	BSD3-clause new	LMU	https://github.com/TEAR-ERC/tandem
xSHELLS	Code for rotating incompressible flows and magnetic fields in spherical geometries, including geodynamo simulations.	MHD	C++	CeCILL License (compatible with GNU GPL)	CNRS	https://nschaeff.bitbucket.io/xsells/
HySEA	Suite composed of several codes for tsunami simulations, including seismic sources and landslide generated tsunamis or meteotsunamis	T	C++	Core under CCA ShareAlike 4.0	UMA	doi: 10.5281/zenodo.6400825 doi: 10.5281/zenodo.6400815

FALL3D	Model for the atmospheric transport and ground deposition of particles, aerosols and radionuclides using a finite volume (FV) explicit scheme	V	F90/2008	GNU GPL v3	CSIC/INGV	doi: 10.5281/zenodo.6343786
OpenPDAC	Model for the simulation of volcanic fluids ported and optimized on the open-source OpenFOAM C++ toolbox for Computational Fluid Dynamics (CFD)	V	C++	GNU GPL v3	INGV	http://vmmsg.pi.ingv.it/index.php/en/software/show/sw_id/3
LaMEM	Code for thermo-mechanical geodynamical processes such as mantle-lithosphere interaction, or the dynamics of magmatic systems, for rocks that have visco-elasto-plastic or (compressible) poroelastic rheologies.	GD	C/C++	GNU GPL v3	UM	https://bitbucket.org/bkaus/lamem/src/master/
pTatin3D	Software package designed for studying long time-scale processes relevant to geodynamics	GD	C	GNU GPL v3	SU	https://bitbucket.org/ptatin/ptatin3d/security/learn-more
Elmer/Ice	Code based on the multiphysics package Elmer to solve coupled visco-elastic - Reynolds flow types of model able to represent Glacier Outburst Floods (GLOFs)	GL	C, F90	(L)GPL - solver modules are GPL v2-v3	CSC	http://elmerice.elmerfem.org

Table A2: Showcases (SC) in ChEESE-2P. Area codes are: CS computational seismology, T tsunami modeling, MHD magnetohydrodynamics, V volcanology, GD geodynamics, GL glacier hazards.

No	Showcase name	Application area	Codes involved
SC1.1	Anthropogenic noise and seismicity, wave propagation at higher frequencies in Rade d'Hyères	CS	SPECFEM3D
SC1.2	Next generation of earthquake simulators for the Hellenic arc and Iceland	CS	Tandem, SeisSol, pTatin3D, SPECFEM3D
SC1.3	Physics-based PSHA and urgent UQ for Iceland	CS	SeisSol, ExaHype
SC2.1	Seismic tomography of the Adriatic-Ionian region	CS	SPECFEM3D
SC3.1	The Global Tsunami Hazard Map	T	HySEA
SC4.1	Multi-source local high-resolution scenario with emphasis on the 2022 Tonga case	T, CS	SeisSol, HySEA, ExaHype
SC5.1	Towards the European tephra hazard map	V	FALL3D
SC5.2	Volcanic dispersal at local scale: a reanalysis of the 2021 La Palma case	V	FALL3D

SC6.1	Urgent high-resolution, 3D multiphase flow simulation of phreatic eruptions at Vulcano	V	 Associated with document Ref. Ares(2022)8497838 - 07/12/2022 OpenPDAC
SC6.2	Long-term probabilistic hazard maps for phreatic eruptions at Vulcano island	V	OpenPDAC
SC7.1	MHD turbulence closure models in planetary cores using AI	MHD	xSHELLS
SC8.1	Magmatic systems and induced landslides: the Etna case	GD	LaMEM
SC8.2	3D evolution of tectonic deformation as driver of seismic hazard in the Hellenic arc	GD, CS	pTatin3D, Tandem, SeisSol, ExaHype
SC9.1	Eastern Skaftá cauldron GLOF simulation, Iceland	GL	Elmer/Ice
SC9.2	Calving glacier hazard in Greenland	GL	Elmer/Ice

ANNEX 2

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible ¹ costs (per budget category)									Estimated EU contribution ²				
	Direct costs								Indirect costs	Total costs	EU contribution to eligible costs			Maximum grant amount ⁶
	A. Personnel costs		B. Subcontracting costs	C. Purchase costs			D. Other cost categories	E. Indirect costs ³	Funding rate % ⁴		Maximum EU contribution ⁵	Requested EU contribution		
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons	A.4 SME owners and natural person beneficiaries	B. Subcontracting	C.1 Travel and subsistence	C.2 Equipment	C.3 Other goods, works and services	D.2 Internally invoiced goods and services	E. Indirect costs						
	Forms of funding	Actual costs	Unit costs (usual accounting practices)	Unit costs ⁷	Actual costs	Actual costs	Actual costs	Actual costs	Unit costs (usual accounting practices)	Flat-rate costs ⁸				
	a1	a2	a3	b	c1	c2	c3	d2	e = 0,25 * (a1 + a2 + a3 + c1 + c2 + c3)	f = a + b + c + d + e	U	g = f * U%	h	m
1 - CSIC	695 000.00	0.00	0.00	0.00	20 000.00	0.00	40 000.00	0.00	188 750.00	943 750.00	50	471 875.00	470 625.00	470 625.00
2 - BSC CNS	527 633.00	0.00	0.00	0.00	13 250.00	0.00	0.00	0.00	135 220.75	676 103.75	50	338 051.88	338 051.88	338 051.88
3 - INGV	492 533.00	0.00	0.00	0.00	11 000.00	0.00	0.00	0.00	125 883.25	629 416.25	50	314 708.13	314 708.00	314 708.00
4 - IMO	289 833.00	0.00	0.00	0.00	5 750.00	0.00	0.00	0.00	73 895.75	369 478.75	50	184 739.38	184 739.00	184 739.00
5 - USTUTT	488 267.00	0.00	0.00	0.00	8 500.00	0.00	0.00	0.00	124 191.75	620 958.75	50	310 479.38	310 479.00	310 479.00
6 - CINECA	421 600.00	0.00	0.00	0.00	20 417.00	0.00	0.00	0.00	110 504.25	552 521.25	50	276 260.63	276 260.63	276 260.63
7 - TUM	335 080.00	0.00	0.00	0.00	11 250.00	0.00	0.00	0.00	86 582.50	432 912.50	50	216 456.25	216 456.00	216 456.00
8 - LMU MUENCHEN	0.00	380 608.00	0.00	0.00	6 875.00	0.00	0.00	0.00	96 870.75	484 353.75	50	242 176.88	242 176.88	242 176.88
9 - UMA	304 833.00	0.00	0.00	0.00	7 250.00	0.00	0.00	0.00	78 020.75	390 103.75	50	195 051.88	195 051.88	195 051.88
10 - NGI	370 400.00	0.00	0.00	0.00	7 084.00	0.00	0.00	0.00	94 371.00	471 855.00	50	235 927.50	235 927.50	235 927.50
11 - CNRS	497 120.00	0.00	0.00	0.00	19 292.00	0.00	0.00	0.00	129 103.00	645 515.00	50	322 757.50	322 757.50	322 757.50
11.1 - IPGP	45 880.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11 470.00	57 350.00	50	28 675.00	28 675.00	28 675.00
12 - BULL	414 800.00	0.00	0.00	0.00	6 000.00	0.00	0.00	0.00	105 200.00	526 000.00	50	263 000.00	263 000.00	263 000.00
13 - CSC	0.00	237 267.00	0.00	0.00	4 250.00	0.00	0.00	0.00	60 379.25	301 896.25	50	150 948.13	150 948.00	150 948.00
14 - RBI	158 800.00	0.00	0.00	0.00	4 500.00	0.00	0.00	0.00	40 825.00	204 125.00	50	102 062.50	102 062.50	102 062.50
15 - UM	168 000.00	0.00	0.00	0.00	3 000.00	0.00	0.00	0.00	42 750.00	213 750.00	50	106 875.00	106 875.00	106 875.00
16 - SU	133 300.00	0.00	0.00	0.00	3 100.00	0.00	0.00	0.00	34 100.00	170 500.00	50	85 250.00	85 250.00	85 250.00
Σ consortium	5 343 079.00	617 875.00	0.00	0.00	151 518.00	0.00	40 000.00	0.00	1 538 118.00	7 690 590.00		3 845 295.04	3 844 043.77	3 844 043.77

¹ See Article 6 for the eligibility conditions. All amounts must be expressed in EUR (see Article 21 for the conversion rules).

² The consortium remains free to decide on a different internal distribution of the EU funding (via the consortium agreement; see Article 7).

³ Indirect costs already covered by an operating grant (received under any EU funding programme) are ineligible (see Article 6.3). Therefore, a beneficiary/affiliated entity that receives an operating grant during the action duration cannot declare indirect costs for the year(s)/reporting period(s) covered by the operating grant, unless they can demonstrate that the operating grant does not cover any costs of the action. This requires specific accounting tools. Please immediately contact us via the EU Funding & Tenders Portal for details.

⁴ See Data Sheet for the funding rate(s).

⁵ This is the theoretical amount of the EU contribution to costs, if the reimbursement rate is applied to all the budgeted costs. This theoretical amount is then capped by the 'maximum grant amount'.

⁶ The 'maximum grant amount' is the maximum grant amount decided by the EU. It normally corresponds to the requested grant, but may be lower.

⁷ See Annex 2a 'Additional information on the estimated budget' for the details (units, cost per unit).

⁸ See Data Sheet for the flat-rate.

ANNEX 2a

ADDITIONAL INFORMATION ON UNIT COSTS AND CONTRIBUTIONS

SME owners/natural person beneficiaries without salary (Decision C(2020) 7115¹)

Type: unit costs

Units: days spent working on the action (rounded up or down to the nearest half-day)

Amount per unit (daily rate): calculated according to the following formula:

{EUR 5 080 / 18 days = **282,22**}
multiplied by
{country-specific correction coefficient of the country where the beneficiary is established}

The country-specific correction coefficients used are those set out in the Horizon Europe Work Programme (section Marie Skłodowska-Curie actions) in force at the time of the call (see [Portal Reference Documents](#)).

HE and Euratom Research Infrastructure actions²

Type: unit costs

Units³: see (for each access provider and installation) the unit cost table in Annex 2b

Amount per unit^{*}: see (for each access provider and installation) the unit cost table in Annex 2b

* Amount calculated as follows:

For trans-national access:

$$\frac{\text{average annual total access costs to the installation (over past two years}^4\text{)}}{\text{average annual total quantity of access to the installation (over past two years}^5\text{)}}$$

For virtual access:

$$\frac{\text{total virtual access costs to the installation (over the last year}^6\text{)}}{\text{total quantity of virtual access to the installation (over the last year}^7\text{)}}$$

Euratom staff mobility costs⁸

Monthly living allowance

Type: unit costs

¹ Commission [Decision](#) of 20 October 2020 authorising the use of unit costs for the personnel costs of the owners of small and medium-sized enterprises and beneficiaries that are natural persons not receiving a salary for the work carried out by themselves under an action or work programme (C(2020)7715).

² [Decision](#) of 19 April 2021 authorising the use of unit costs for the costs of providing trans-national and virtual access in Research Infrastructure actions under the Horizon Europe Programme (2021-2027) and the Research and Training Programme of the European Atomic Energy Community (2021-2025).

³ Unit of access (e.g. beam hours, weeks of access, sample analysis) fixed by the access provider in proposal.

⁴ In exceptional and duly justified cases, the granting authority may agree to a different reference period.

⁵ In exceptional and duly justified cases, the granting authority may agree to a different reference period.

⁶ In exceptional and duly justified cases, the granting authority may agree to a different reference period.

⁷ In exceptional and duly justified cases, the granting authority may agree to a different reference period.

⁸ [Decision](#) of 15 March 2021 authorising the use of unit costs for mobility in co-fund actions under the Research and Training Programme of the European Atomic Energy Community (2021-2025).

Units: months spent by the seconded staff member(s) on research and training in fission and fusion activities (person-month)

Amount per unit*: see (for each beneficiary/affiliated entity and secondment) the unit cost table in Annex 2b

* Amount calculated as follows from 1 January 2021:

{**EUR 4 300** multiplied by
country-specific correction coefficient** of the country where the staff member is seconded}⁹

**Country-specific correction coefficients as from 1 January 2021¹⁰

EU-Member States¹¹

Country / Place	Coefficient (%)
Bulgaria	59,1
Czech Rep.	85,2
Denmark	131,3
Germany	101,9
Bonn	95,8
Karlsruhe	98
Munich	113,9
Estonia	82,3
Ireland	129
Greece	81,4
Spain	94,2
France	120,5
Croatia	75,8
Italy	95
Varese	90,7
Cyprus	78,2
Latvia	77,5
Lithuania	76,6
Hungary	71,9
Malta	94,7
Netherlands	113,9
Austria	107,9
Poland	70,9
Portugal	91,1
Romania	66,6
Slovenia	86,1

⁹ Unit costs for living allowances are calculated by using a method of calculation similar to that applied for the secondment to the European Commission of seconded national experts (SNEs).

¹⁰ ⚠ For the financial statements, the amount must be adjusted according to the actual place of secondment.
The revised coefficients were adopted in the Decision authorising the use of unit costs for the Fusion Programme co-fund action under the Research and training Programme of the European Atomic Energy Community 2021-2025. They are based on the 2020 Annual update of the remuneration and pensions of the officials and other servants of the European Union and the correction coefficients applied thereto (OJ C 428, 11.12.2020) to ensure purchasing power parity. The revised coefficient are applied as from 1 January 2021 through an amendment to the grant agreement.

¹¹ No correction coefficient shall be applicable in Belgium and Luxembourg.

Slovakia	80,6
Finland	118,4
Sweden	124,3

Third countries

Country/place	Coefficient (%)
China	82,2
India	72,3
Japan	111,8
Russia	92,7
South Korea	92,3
Switzerland	129,2
Ukraine	82,3
United Kingdom	97,6
United States	101,4 (New-York) 90,5 (Washington)

Mobility allowance

Type: Unit costs

Units: months spent by the seconded staff member(s) on research and training in fission and fusion activities (person-month)

Amount per unit: **EUR 600** per person-month; see (for each beneficiary/affiliated entity and secondment) the unit cost table in Annex 2b

Family allowance

Type: unit costs

Units: months spent by the seconded staff member(s) on research and training in fission and fusion activities (person-month)

Amount per unit: **EUR 660** per person-month; see (for each beneficiary/affiliated entity and secondment) the unit cost table in Annex 2b

Education allowance

Type: Unit costs

Units: months spent by the seconded staff member(s) on research and training in fission and fusion activities (person-month)

Amount per unit*: see (for each beneficiary/affiliated entity and secondment) the unit cost table in Annex 2b

*Amount calculated as follows from 1 January 2021:
{**EUR 283.82** x number of dependent children¹²}

¹² For the estimated budget (Annex 2): an average should be used. ( For the financial statements, the number of children (and months) must be adjusted according to the actual family status at the moment the secondment starts.)

Participant type	EU base rates (%)
Other	50%
Profit	50%
Non-profit	50%
SME	50%
[other]	50%

Country	Participant type	National top-up rate
Spain	Non-profit	0%
Italy	Non-profit	0%
Germany	Non-profit	0%
France	Non-profit	0%
Finland	Non-profit	0%
Croatia	Non-profit	0%
Iceland	Non-profit	0%
Norway	Non-profit	0%

Individual funding rates per participant											Grant breakdown	
No	Short name	Country	Participant type	EU base rate	National top-up rate	Total funding rate	Total costs	Maximum EU contribution	Requested EU contribution		EU funding	National contribution top-up
1	CSIC	Spain	Non-profit	50%	0%	50%	943.750,00	471.875,00	470.625,00		471.875,00	0,00
2	BSC CNS	Spain	Non-profit	50%	0%	50%	676.103,75	338.051,88	338.051,88		338.051,88	0,00
3	INGV	Italy	Non-profit	50%	0%	50%	629.416,25	314.708,13	314.708,00		314.708,13	0,00
4	IMO	Iceland	Non-profit	50%	0%	50%	369.478,75	184.739,38	184.739,00		184.739,38	0,00
5	USTUTT	Germany	Non-profit	50%	0%	50%	620.958,75	310.479,38	310.479,00		310.479,38	0,00
6	CINECA	Italy	Non-profit	50%	0%	50%	552.521,25	276.260,63	276.260,63		276.260,63	0,00
7	TUM	Germany	Non-profit	50%	0%	50%	432.912,50	216.456,25	216.456,00		216.456,25	0,00
8	LMU MUENCHEN	Germany	Non-profit	50%	0%	50%	484.353,75	242.176,88	242.176,88		242.176,88	0,00
9	UMA	Spain	Non-profit	50%	0%	50%	390.103,75	195.051,88	195.051,88		195.051,88	0,00
10	NGI	Norway	Non-profit	50%	0%	50%	471.855,00	235.927,50	235.927,50		235.927,50	0,00
11	CNRS	France	Non-profit	50%	0%	50%	645.515,00	322.757,50	322.757,50		322.757,50	0,00
11.1	IPGP	France	Non-profit	50%	0%	50%	57.350,00	28.675,00	28.675,00		28.675,00	0,00
12	BULL	France	Non-profit	50%	0%	50%	526.000,00	263.000,00	263.000,00		263.000,00	0,00
13	CSC	Finland	Non-profit	50%	0%	50%	301.896,25	150.948,13	150.948,00		150.948,13	0,00
14	RBI	Croatia	Non-profit	50%	0%	50%	204.125,00	102.062,50	102.062,50		102.062,50	0,00
15	UM	Germany	Non-profit	50%	0%	50%	213.750,00	106.875,00	106.875,00		106.875,00	0,00
16	SU	France	Non-profit	50%	0%	50%	170.500,00	85.250,00	85.250,00		85.250,00	0,00
Consortium total							7.690.590,00	3.845.295,00	3.844.043,77		3.845.295,00	0,00

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACION (BSC CNS), PIC 999655520, established in CALLE JORDI GIRONA 31, BARCELONA 08034, Spain,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA (INGV), PIC 999472675,
established in Via di Vigna Murata 605, ROMA 00143, Italy,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'),
under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement,
in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in
accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

VEDURSTOFA ISLANDS (IMO), PIC 997168343, established in BUSTADARVEGUR 7-9, REYKJAVIK IS-150, Iceland,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSITY OF STUTTGART (USTUTT), PIC 999974747, established in KEPLERSTRASSE 7, STUTTGART 70174, Germany,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

CINECA CONSORZIO INTERUNIVERSITARIO (CINECA), PIC 999843409, established in VIA MAGNANELLI 6/3, CASALECCHIO DI RENO BO 40033, Italy,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

TECHNISCHE UNIVERSITAET MUENCHEN (TUM), PIC 999977463, established in Arcisstrasse 21, MUENCHEN 80333, Germany,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN (LMU MUENCHEN), PIC 999978433, established in GESCHWISTER SCHOLL PLATZ 1, MUENCHEN 80539, Germany,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSIDAD DE MALAGA (UMA), PIC 999898311, established in AVDA CERVANTES, NUM. 2, MALAGA 29016, Spain,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

STIFTELSEN NORGES GEOTEKNISKE INSTITUTT (NGI), PIC 998866522, established in SOGNSV 72, OSLO 0855, Norway,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS), PIC 999997930,
established in RUE MICHEL ANGE 3, PARIS 75794, France,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'),
under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement,
in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in
accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

BULL SAS (BULL), PIC 996058081, established in RUE JEAN JAURES 68, LES CLAYES SOUS BOIS 78340, France,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

CSC-TIETEEN TIETOTEKNIKAN KESKUS OY (CSC), PIC 999645820, established in KEILARANTA 14, ESPOO 02101, Finland,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

RUDER BOSKOVIC INSTITUTE (RBI), PIC 999875031, established in Bijenicka cesta 54, ZAGREB 10000, Croatia,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

JOHANNES GUTENBERG-UNIVERSITÄT MAINZ (UM), PIC 999978627, established in SAARSTRASSE 21, MAINZ 55099, Germany,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

SORBONNE UNIVERSITE (SU), PIC 909875521, established in 21 RUE DE L'ECOLE DE MEDECINE, PARIS 75006, France,

hereby agrees

to become beneficiary

in Agreement No 101093038 — ChEESE-2P ('the Agreement')

between AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC) **and European High-Performance Computing Joint Undertaking** ('granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 4 HORIZON EUROPE MGA — MULTI + MONO

FINANCIAL STATEMENT FOR [PARTICIPANT NAME] FOR REPORTING PERIOD [NUMBER]

	Eligible ¹ costs (per budget category)															EU contribution ²				Revenues		
	Direct costs															Indirect costs	Total costs	EU contribution to eligible costs			Total requested EU contribution	Income generated by the action
	A. Personnel costs		B. Subcontracting costs	C. Purchase costs			D. Other cost categories							E. Indirect costs ²	Funding rate % ³	Maximum EU contribution ⁴		Requested EU contribution				
	A.1 Employees (or equivalent)	A.4 SME owners and natural person beneficiaries	B. Subcontracting	C.1 Travel and subsistence	C.2 Equipment	C.3 Other goods, works and services	D.1 Financial support to third parties	D.2 Internally invoiced goods and services	D.3 Transnational access to research infrastructure unit costs	D.4 Virtual access to research infrastructure unit costs	[OPTION for HE PCP/PPPI: D.5 PCP/PPPI procurement costs]	[OPTION for Euratom Programme Cofund Actions: D.6 Euratom Cofund staff mobility costs]	[OPTION for HE ERC Grants: D.7 ERC additional funding]	[OPTION for HE ERC Grants: D.8 ERC additional funding (subcontracting, FSTP and internally invoiced goods and services)]	E. Indirect costs							
	A.2 Natural persons under direct contract																					
	A.3 Seconded persons																					
Forms of funding	Actual costs	Unit costs (usual accounting practices)	Unit costs ⁵	Actual costs	Actual costs	Actual costs	Actual costs	/ Actual costs	Unit costs (usual accounting practices)	/ Unit costs ⁵	/ Unit costs ⁵	/ Actual costs	/ Unit costs ⁵	/ Actual costs	/ Actual costs	Flat-rate costs ⁶						
	a1	a2	a3	b	c1	c2	c3	/ d1a	d2	/ d3	/ d4	/ d5	/ d6	/ d7	/ d8	e = 0,25 * (a1 + a2 + a3 +a+ c1 +c2 + c3 +d1a+d2+d3 +d4 +d5)+d6+ / +d7 +d8)	f = a+b+c+d+e	U	g = f*U%	h	m	n
XX – [short name beneficiary/affiliated entity]																						

The beneficiary/affiliated entity hereby confirms that:

The information provided is complete, reliable and true.

The costs and contributions declared are eligible (see Article 6).

The costs and contributions can be substantiated by adequate records and supporting documentation that will be produced upon request or in the context of checks, reviews, audits and investigations (see Articles 19, 20 and 25).

For the last reporting period: that all the revenues have been declared (see Article 22).

① Please declare all eligible costs and contributions, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Only amounts that were declared in your individual financial statements can be taken into account lateron, in order to replace costs/contributions that are found to be ineligible.

¹ See Article 6 for the eligibility conditions. All amounts must be expressed in EUR (see Article 21 for the conversion rules).

² If you have also received an EU operating grant during this reporting period, you cannot claim indirect costs - unless you can demonstrate that the operating grant does not cover any costs of the action. This requires specific accounting tools. Please contact us immediately via the Funding & Tenders Portal for details.

³ See Data Sheet for the reimbursement rate(s).

⁴ This is the *theoretical* amount of EU contribution to costs that the system calculates automatically (by multiplying the reimbursement rates by the costs declared). The amount you request (in the column 'requested EU contribution') may be less.

⁵ See Annex 2a 'Additional information on the estimated budget' for the details (units, cost per unit).

⁶ See Data Sheet for the flat-rate.

ANNEX 5

SPECIFIC RULES

CONFIDENTIALITY AND SECURITY (— ARTICLE 13)

Sensitive information with security recommendation

Sensitive information with a security recommendation must comply with the additional requirements imposed by the granting authority.

Before starting the action tasks concerned, the beneficiaries must have obtained all approvals or other mandatory documents needed for implementing the task. The documents must be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they must be submitted together with an English summary.

For requirements restricting disclosure or dissemination, the information must be handled in accordance with the recommendation and may be disclosed or disseminated only after written approval from the granting authority.

EU classified information

If EU classified information is used or generated by the action, it must be treated in accordance with the security classification guide (SCG) and security aspect letter (SAL) set out in Annex 1 and Decision 2015/444¹ and its implementing rules — until it is declassified.

Deliverables which contain EU classified information must be submitted according to special procedures agreed with the granting authority.

Action tasks involving EU classified information may be subcontracted only with prior explicit written approval from the granting authority and only to entities established in an EU Member State or in a non-EU country with a security of information agreement with the EU (or an administrative arrangement with the Commission).

EU classified information may not be disclosed to any third party (including participants involved in the action implementation) without prior explicit written approval from the granting authority.

ETHICS (— ARTICLE 14)

Ethics and research integrity

The beneficiaries must carry out the action in compliance with:

- ethical principles (including the highest standards of research integrity)

¹ Commission Decision 2015/444/EC, Euratom of 13 March 2015 on the security rules for protecting EU classified information (OJ L 72, 17.3.2015, p. 53).

and

- applicable EU, international and national law, including the EU Charter of Fundamental Rights and the European Convention for the Protection of Human Rights and Fundamental Freedoms and its Supplementary Protocols.

No funding can be granted, within or outside the EU, for activities that are prohibited in all Member States. No funding can be granted in a Member State for an activity which is forbidden in that Member State.

The beneficiaries must pay particular attention to the principle of proportionality, the right to privacy, the right to the protection of personal data, the right to the physical and mental integrity of persons, the right to non-discrimination, the need to ensure protection of the environment and high levels of human health protection.

The beneficiaries must ensure that the activities under the action have an exclusive focus on civil applications.

The beneficiaries must ensure that the activities under the action do not:

- aim at human cloning for reproductive purposes
- intend to modify the genetic heritage of human beings which could make such modifications heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed)
- intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer, or
- lead to the destruction of human embryos (for example, for obtaining stem cells).

Activities involving research on human embryos or human embryonic stem cells may be carried out only if:

- they are set out in Annex 1 or
- the coordinator has obtained explicit approval (in writing) from the granting authority.

In addition, the beneficiaries must respect the fundamental principle of research integrity — as set out in the European Code of Conduct for Research Integrity².

This implies compliance with the following principles:

- reliability in ensuring the quality of research reflected in the design, the methodology, the analysis and the use of resources
- honesty in developing, undertaking, reviewing, reporting and communicating research in a transparent, fair and unbiased way

² European Code of Conduct for Research Integrity of ALLEA (All European Academies).

- respect for colleagues, research participants, society, ecosystems, cultural heritage and the environment
- accountability for the research from idea to publication, for its management and organisation, for training, supervision and mentoring, and for its wider impacts

and means that beneficiaries must ensure that persons carrying out research tasks follow the good research practices including ensuring, where possible, openness, reproducibility and traceability and refrain from the research integrity violations described in the Code.

Activities raising ethical issues must comply with the additional requirements formulated by the ethics panels (including after checks, reviews or audits; see Article 25).

Before starting an action task raising ethical issues, the beneficiaries must have obtained all approvals or other mandatory documents needed for implementing the task, notably from any (national or local) ethics committee or other bodies such as data protection authorities.

The documents must be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they must be submitted together with an English summary, which shows that the documents cover the action tasks in question and includes the conclusions of the committee or authority concerned (if any).

VALUES (— ARTICLE 14)

Gender mainstreaming

The beneficiaries must take all measures to promote equal opportunities between men and women in the implementation of the action and, where applicable, in line with the gender equality plan. They must aim, to the extent possible, for a gender balance at all levels of personnel assigned to the action, including at supervisory and managerial level.

INTELLECTUAL PROPERTY RIGHTS (IPR) — BACKGROUND AND RESULTS — ACCESS RIGHTS AND RIGHTS OF USE (— ARTICLE 16)

Definitions

Access rights — Rights to use results or background.

Dissemination — The public disclosure of the results by appropriate means, other than resulting from protecting or exploiting the results, including by scientific publications in any medium.

Exploit(ation) — The use of results in further research and innovation activities other than those covered by the action concerned, including among other things, commercial exploitation such as developing, creating, manufacturing and marketing a product or process, creating and providing a service, or in standardisation activities.

Fair and reasonable conditions — Appropriate conditions, including possible financial terms or royalty-free conditions, taking into account the specific circumstances of the request for access, for example the actual or potential value of the results or background to which access is requested and/or the scope, duration or other characteristics of the exploitation envisaged.

FAIR principles — ‘findability’, ‘accessibility’, ‘interoperability’ and ‘reusability’.

Open access — Online access to research outputs provided free of charge to the end-user.

Open science — An approach to the scientific process based on open cooperative work, tools and diffusing knowledge.

Research data management — The process within the research lifecycle that includes the organisation, storage, preservation, security, quality assurance, allocation of persistent identifiers (PIDs) and rules and procedures for sharing of data including licensing.

Research outputs — Results to which access can be given in the form of scientific publications, data or other engineered results and processes such as software, algorithms, protocols, models, workflows and electronic notebooks.

Scope of the obligations

For this section, references to ‘beneficiary’ or ‘beneficiaries’ do not include affiliated entities (if any).

Agreement on background — Background free from restrictions

The beneficiaries must identify in a written agreement the background as needed for implementing the action or for exploiting its results.

Where the call conditions restrict control due to strategic interests reasons, background that is subject to control or other restrictions by a country (or entity from a country) which is not one of the eligible countries or target countries set out in the call conditions and that impact the exploitation of the results (i.e. would make the exploitation of the results subject to control or restrictions) must not be used and must be explicitly excluded in the agreement on background — unless otherwise agreed with the granting authority.

Results free from restrictions

Where the call conditions restrict control due to strategic interests reasons, the beneficiaries must ensure that the results of the action are not subject to control or other restrictions by a country (or entity from a country) which is not one of the eligible countries or target countries set out in the call conditions — unless otherwise agreed with the granting authority.

Ownership of results

Results are owned by the beneficiaries that generate them.

However, two or more beneficiaries own results jointly if:

- they have jointly generated them and
- it is not possible to:
 - establish the respective contribution of each beneficiary, or
 - separate them for the purpose of applying for, obtaining or maintaining their protection.

The joint owners must agree — in writing — on the allocation and terms of exercise of their joint ownership ('joint ownership agreement'), to ensure compliance with their obligations under this Agreement.

Unless otherwise agreed in the joint ownership agreement or consortium agreement, each joint owner may grant non-exclusive licences to third parties to exploit the jointly-owned results (without any right to sub-license), if the other joint owners are given:

- at least 45 days advance notice and
- fair and reasonable compensation.

The joint owners may agree — in writing — to apply another regime than joint ownership.

If third parties (including employees and other personnel) may claim rights to the results, the beneficiary concerned must ensure that those rights can be exercised in a manner compatible with its obligations under the Agreement.

The beneficiaries must indicate the owner(s) of the results (results ownership list) in the final periodic report.

Protection of results

Beneficiaries which have received funding under the grant must adequately protect their results — for an appropriate period and with appropriate territorial coverage — if protection is possible and justified, taking into account all relevant considerations, including the prospects for commercial exploitation, the legitimate interests of the other beneficiaries and any other legitimate interests.

Exploitation of results

Beneficiaries which have received funding under the grant must — up to four years after the end of the action (see Data Sheet, Point 1) — use their best efforts to exploit their results directly or to have them exploited indirectly by another entity, in particular through transfer or licensing.

If, despite a beneficiary's best efforts, the results are not exploited within one year after the end of the action, the beneficiaries must (unless otherwise agreed in writing with the granting authority) use the Horizon Results Platform to find interested parties to exploit the results.

If results are incorporated in a standard, the beneficiaries must (unless otherwise agreed with the granting authority or unless it is impossible) ask the standardisation body to include the funding statement (see Article 17) in (information related to) the standard.

Additional exploitation obligations

Where the call conditions impose additional exploitation obligations (including obligations linked to the restriction of participation or control due to strategic assets, interests, autonomy or security reasons), the beneficiaries must comply with them — up to four years after the end of the action (see Data Sheet, Point 1).

Where the call conditions impose additional exploitation obligations in case of a public emergency, the beneficiaries must (if requested by the granting authority) grant for a limited period of time specified in the request, non-exclusive licences — under fair and reasonable

conditions — to their results to legal entities that need the results to address the public emergency and commit to rapidly and broadly exploit the resulting products and services at fair and reasonable conditions. This provision applies up to four years after the end of the action (see Data Sheet, Point 1).

Additional information obligation relating to standards

Where the call conditions impose additional information obligations relating to possible standardisation, the beneficiaries must — up to four years after the end of the action (see Data Sheet, Point 1) — inform the granting authority, if the results could reasonably be expected to contribute to European or international standards.

Transfer and licensing of results

Transfer of ownership

The beneficiaries may transfer ownership of their results, provided this does not affect compliance with their obligations under the Agreement.

The beneficiaries must ensure that their obligations under the Agreement regarding their results are passed on to the new owner and that this new owner has the obligation to pass them on in any subsequent transfer.

Moreover, they must inform the other beneficiaries with access rights of the transfer at least 45 days in advance (or less if agreed in writing), unless agreed otherwise in writing for specifically identified third parties including affiliated entities or unless impossible under the applicable law. This notification must include sufficient information on the new owner to enable the beneficiaries concerned to assess the effects on their access rights. The beneficiaries may object within 30 days of receiving notification (or less if agreed in writing), if they can show that the transfer would adversely affect their access rights. In this case, the transfer may not take place until agreement has been reached between the beneficiaries concerned.

Granting licences

The beneficiaries may grant licences to their results (or otherwise give the right to exploit them), including on an exclusive basis, provided this does not affect compliance with their obligations.

Exclusive licences for results may be granted only if all the other beneficiaries concerned have waived their access rights.

Granting authority right to object to transfers or licensing — Horizon Europe actions

Where the call conditions in Horizon Europe actions provide for the right to object to transfers or licensing, the granting authority may — up to four years after the end of the action (see Data Sheet, Point 1) — object to a transfer of ownership or the exclusive licensing of results, if:

- the beneficiaries which generated the results have received funding under the grant
- it is to a legal entity established in a non-EU country not associated with Horizon Europe, and

- the granting authority considers that the transfer or licence is not in line with EU interests.

Beneficiaries that intend to transfer ownership or grant an exclusive licence must formally notify the granting authority before the intended transfer or licensing takes place and:

- identify the specific results concerned
- describe in detail the new owner or licensee and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or licence on EU interests, in particular regarding competitiveness as well as consistency with ethical principles and security considerations.

The granting authority may request additional information.

If the granting authority decides to object to a transfer or exclusive licence, it must formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information it has requested).

No transfer or licensing may take place in the following cases:

- pending the granting authority decision, within the period set out above
- if the granting authority objects
- until the conditions are complied with, if the granting authority objection comes with conditions.

A beneficiary may formally notify a request to waive the right to object regarding intended transfers or grants to a specifically identified third party, if measures safeguarding EU interests are in place. If the granting authority agrees, it will formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information requested).

Limitations to transfers and licensing due to strategic assets, interests, autonomy or security reasons of the EU and its Member States

Where the call conditions restrict participation or control due to strategic assets, interests, autonomy or security reasons, the beneficiaries may not transfer ownership of their results or grant licences to third parties which are established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) — unless they have requested and received prior approval by the granting authority.

The request must:

- identify the specific results concerned
- describe in detail the new owner and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or license on the strategic assets, interests, autonomy or security of the EU and its Member States.

The granting authority may request additional information.

Access rights to results and background

Exercise of access rights — Waiving of access rights — No sub-licensing

Requests to exercise access rights and the waiver of access rights must be in writing.

Unless agreed otherwise in writing with the beneficiary granting access, access rights do not include the right to sub-license.

If a beneficiary is no longer involved in the action, this does not affect its obligations to grant access.

If a beneficiary defaults on its obligations, the beneficiaries may agree that that beneficiary no longer has access rights.

Access rights for implementing the action

The beneficiaries must grant each other access — on a royalty-free basis — to background needed to implement their own tasks under the action, unless the beneficiary that holds the background has — before acceding to the Agreement —:

- informed the other beneficiaries that access to its background is subject to restrictions, or
- agreed with the other beneficiaries that access would not be on a royalty-free basis.

The beneficiaries must grant each other access — on a royalty-free basis — to results needed for implementing their own tasks under the action.

Access rights for exploiting the results

The beneficiaries must grant each other access — under fair and reasonable conditions — to results needed for exploiting their results.

The beneficiaries must grant each other access — under fair and reasonable conditions — to background needed for exploiting their results, unless the beneficiary that holds the background has — before acceding to the Agreement — informed the other beneficiaries that access to its background is subject to restrictions.

Requests for access must be made — unless agreed otherwise in writing — up to one year after the end of the action (see Data Sheet, Point 1).

Access rights for entities under the same control

Unless agreed otherwise in writing by the beneficiaries, access to results and, subject to the restrictions referred to above (if any), background must also be granted — under fair and reasonable conditions — to entities that:

- are established in an EU Member State or Horizon Europe associated country
- are under the direct or indirect control of another beneficiary, or under the same direct or indirect control as that beneficiary, or directly or indirectly controlling that beneficiary and

- need the access to exploit the results of that beneficiary.

Unless agreed otherwise in writing, such requests for access must be made by the entity directly to the beneficiary concerned.

Requests for access must be made — unless agreed otherwise in writing — up to one year after the end of the action (see Data Sheet, Point 1).

Access rights for the granting authority, EU institutions, bodies, offices or agencies and national authorities to results for policy purposes — Horizon Europe actions

In Horizon Europe actions, the beneficiaries which have received funding under the grant must grant access to their results — on a royalty-free basis — to the granting authority, EU institutions, bodies, offices or agencies for developing, implementing and monitoring EU policies or programmes. Such access rights do not extend to beneficiaries' background.

Such access rights are limited to non-commercial and non-competitive use.

For actions under the cluster 'Civil Security for Society', such access rights also extend to national authorities of EU Member States for developing, implementing and monitoring their policies or programmes in this area. In this case, access is subject to a bilateral agreement to define specific conditions ensuring that:

- the access rights will be used only for the intended purpose and
- appropriate confidentiality obligations are in place.

Moreover, the requesting national authority or EU institution, body, office or agency (including the granting authority) must inform all other national authorities of such a request.

Additional access rights

Where the call conditions impose additional access rights, the beneficiaries must comply with them.

COMMUNICATION, DISSEMINATION, OPEN SCIENCE AND VISIBILITY (— ARTICLE 17)

Dissemination

Dissemination of results

The beneficiaries must disseminate their results as soon as feasible, in a publicly available format, subject to any restrictions due to the protection of intellectual property, security rules or legitimate interests.

A beneficiary that intends to disseminate its results must give at least 15 days advance notice to the other beneficiaries (unless agreed otherwise), together with sufficient information on the results it will disseminate.

Any other beneficiary may object within (unless agreed otherwise) 15 days of receiving notification, if it can show that its legitimate interests in relation to the results or background would be significantly harmed. In such cases, the results may not be disseminated unless appropriate steps are taken to safeguard those interests.

Additional dissemination obligations

Where the call conditions impose additional dissemination obligations, the beneficiaries must also comply with those.

Open Science

Open science: open access to scientific publications

The beneficiaries must ensure open access to peer-reviewed scientific publications relating to their results. In particular, they must ensure that:

- at the latest at the time of publication, a machine-readable electronic copy of the published version or the final peer-reviewed manuscript accepted for publication, is deposited in a trusted repository for scientific publications
- immediate open access is provided to the deposited publication via the repository, under the latest available version of the Creative Commons Attribution International Public Licence (CC BY) or a licence with equivalent rights; for monographs and other long-text formats, the licence may exclude commercial uses and derivative works (e.g. CC BY-NC, CC BY-ND) and
- information is given via the repository about any research output or any other tools and instruments needed to validate the conclusions of the scientific publication.

Beneficiaries (or authors) must retain sufficient intellectual property rights to comply with the open access requirements.

Metadata of deposited publications must be open under a Creative Commons Public Domain Dedication (CC 0) or equivalent, in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: publication (author(s), title, date of publication, publication venue); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the publication, the authors involved in the action and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for any research output or any other tools and instruments needed to validate the conclusions of the publication.

Only publication fees in full open access venues for peer-reviewed scientific publications are eligible for reimbursement.

Open science: research data management

The beneficiaries must manage the digital research data generated in the action ('data') responsibly, in line with the FAIR principles and by taking all of the following actions:

- establish a data management plan ('DMP') (and regularly update it)
- as soon as possible and within the deadlines set out in the DMP, deposit the data in a trusted repository; if required in the call conditions, this repository must be federated in the EOSC in compliance with EOSC requirements
- as soon as possible and within the deadlines set out in the DMP, ensure open access — via the repository — to the deposited data, under the latest available version of the Creative Commons Attribution International Public License (CC BY) or Creative

Commons Public Domain Dedication (CC 0) or a licence with equivalent rights, following the principle ‘as open as possible as closed as necessary’, unless providing open access would in particular:

- be against the beneficiary’s legitimate interests, including regarding commercial exploitation, or
- be contrary to any other constraints, in particular the EU competitive interests or the beneficiary’s obligations under this Agreement; if open access is not provided (to some or all data), this must be justified in the DMP
- provide information via the repository about any research output or any other tools and instruments needed to re-use or validate the data.

Metadata of deposited data must be open under a Creative Commons Public Domain Dedication (CC 0) or equivalent (to the extent legitimate interests or constraints are safeguarded), in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: datasets (description, date of deposit, author(s), venue and embargo); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the dataset, the authors involved in the action, and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for related publications and other research outputs.

Open science: additional practices

Where the call conditions impose additional obligations regarding open science practices, the beneficiaries must also comply with those.

Where the call conditions impose additional obligations regarding the validation of scientific publications, the beneficiaries must provide (digital or physical) access to data or other results needed for validation of the conclusions of scientific publications, to the extent that their legitimate interests or constraints are safeguarded (and unless they already provided the (open) access at publication).

Where the call conditions impose additional open science obligations in case of a public emergency, the beneficiaries must (if requested by the granting authority) immediately deposit any research output in a repository and provide open access to it under a CC BY licence, a Public Domain Dedication (CC 0) or equivalent. As an exception, if the access would be against the beneficiaries’ legitimate interests, the beneficiaries must grant non-exclusive licenses — under fair and reasonable conditions — to legal entities that need the research output to address the public emergency and commit to rapidly and broadly exploit the resulting products and services at fair and reasonable conditions. This provision applies up to four years after the end of the action (see Data Sheet, Point 1).

Plan for the exploitation and dissemination of results including communication activities

Unless excluded by the call conditions, the beneficiaries must provide and regularly update a plan for the exploitation and dissemination of results including communication activities.

SPECIFIC RULES FOR CARRYING OUT THE ACTION (— ARTICLE 18)

Implementation in case of restrictions due to strategic assets, interests, autonomy or security of the EU and its Member States

Where the call conditions restrict participation or control due to strategic assets, interests, autonomy or security, the beneficiaries must ensure that none of the entities that participate as affiliated entities, associated partners, third parties giving in-kind contributions, subcontractors or recipients of financial support to third parties are established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) — unless otherwise agreed with the granting authority.

The beneficiaries must moreover ensure that any cooperation with entities established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) does not affect the strategic assets, interests, autonomy or security of the EU and its Member States.

Recruitment and working conditions for researchers

The beneficiaries must take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers³, in particular regarding:

- working conditions
- transparent recruitment processes based on merit, and
- career development.

The beneficiaries must ensure that researchers and all participants involved in the action are aware of them.

Specific rules for access to research infrastructure activities

Definitions

Research Infrastructures — Facilities that provide resources and services for the research communities to conduct research and foster innovation in their fields. This definition includes the associated human resources, and it covers major equipment or sets of instruments; knowledge-related facilities such as collections, archives or scientific data infrastructures; computing systems, communication networks, and any other infrastructure, of a unique nature and open to external users, essential to achieve excellence in research and innovation. Where relevant, they may be used beyond research, for example for education or public services, and they may be ‘single-sited’, ‘virtual’ or ‘distributed’⁴:

When implementing access to research infrastructure activities, the beneficiaries must respect the following conditions:

- for transnational access:

³ Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

⁴ See Article 2(1) of the Horizon Europe Framework Programme Regulation 2021/695.

- access which must be provided:

The access must be free of charge, transnational access to research infrastructure or installations for selected user-groups.

The access must include the logistical, technological and scientific support and the specific training that is usually provided to external researchers using the infrastructure. Transnational access can be either in person (hands-on), provided to selected users that visit the installation to make use of it, or remote, through the provision to selected user-groups of remote scientific services (e.g. provision of reference materials or samples, remote access to a high-performance computing facility).

- categories of users that may have access:

Transnational access must be provided to selected user-groups, i.e. teams of one or more researchers (users).

The majority of the users must work in a country other than the country(ies) where the installation is located (unless access is provided by an international organisation, the Joint Research Centre (JRC), an ERIC or similar legal entity).

Only user groups that are allowed to disseminate the results they have generated under the action may benefit from the access (unless the users are working for SMEs).

Access for user groups with a majority of users not working in a EU Member State or Horizon Europe associated country is limited to 20% of the total amount of units of access provided under the grant (unless a higher percentage is foreseen in Annex 1).

- procedure and criteria for selecting user groups:

The user groups must request access by submitting (in writing) a description of the work that they wish to carry out and the names, nationalities and home institutions of the users.

The user groups must be selected by (one or more) selection panels set up by the consortium.

The selection panels must be composed of international experts in the field, at least half of them independent from the consortium (unless otherwise specified in Annex 1).

The selection panels must assess all proposals received and recommend a short-list of the user groups that should benefit from access.

The selection panels must base their selection on scientific merit, taking into account that priority should be given to user groups composed of users who:

- have not previously used the installation and
- are working in countries where no equivalent research infrastructure exist.

It will apply the principles of transparency, fairness and impartiality.

Where the call conditions impose additional rules for the selection of user groups, the beneficiaries must also comply with those.

- other conditions:

The beneficiaries must request written approval from the granting authority for the selection of user groups requiring visits to the installations exceeding 3 months (unless such visits are foreseen in Annex 1).

In addition, the beneficiaries must:

- advertise widely, including on a their websites, the access offered under the Agreement
 - promote equal opportunities in advertising the access and take into account the gender dimension when defining the support provided to users
 - ensure that users comply with the terms and conditions of the Agreement
 - ensure that its obligations under Articles 12, 13, 17 and 33 also apply to the users
 - keep records of the names, nationalities, and home institutions of users, as well as the nature and quantity of access provided to them
- for virtual access:
 - access which must be provided:

The access must be free of charge, virtual access to research infrastructure or installations.

‘Virtual access’ means open and free access through communication networks to digital resources and services needed for research, without selecting the users to whom access is provided.

The access must include the support that is usually provided to external users.

Where allowed by the call conditions, beneficiaries may in justified cases define objective eligibility criteria (e.g. affiliation to a research or academic institution) for specific users.

- other conditions:

The beneficiaries must have the virtual access services assessed periodically by a board composed of international experts in the field, at least half of whom must be independent from the consortium (unless otherwise specified in Annex 1). For this purpose, information and statistics on the users and the nature and quantity of the access provided, must be made available to the board.

The beneficiaries must advertise widely, including on a dedicated website, the access offered under the grant and the eligibility criteria, if any.

Where the call conditions impose additional traceability⁵ obligations, information on the traceability of the users and the nature and quantity of access must be provided by the beneficiaries.

These obligations apply regardless of the form of funding or budget categories used to declare the costs (unit costs or actual costs or a combination of the two).

Specific rules for JU actions

JU actions must contribute to the long-term implementation of the JU partnership, including the JU Strategic Research and Innovation Agenda, the JU objectives and the exploitation of research and innovation results.

Moreover, when implementing JU actions, the members and contributing partners of the Joint Undertaking must fulfil their obligations regarding contributions to the Joint Undertaking:

- the description of the action in Annex 1 must include, for beneficiaries, affiliated entities, associated partners or other participants or third parties which are members or contributing partners, the estimated contributions to the action, i.e.:
 - in-kind contributions to operational activities ('IKOP'; if applicable)
 - in-kind contributions to additional activities linked to the action ('IKAA'; if applicable)
 - financial contributions ('FC'; if applicable)
- the contributions must be reported during the implementation of the action in the Portal Continuous Reporting tool
- at the end of the action, the members and contributing partners that have not received funding under the grant must ensure that financial and in-kind contributions of EUR 430 000 or more (see Article 21) are supported by statements of contributions (CS) and certificates on the statements of contributions (CCS) which fulfil the following conditions:
 - be provided by a qualified approved external auditor which is independent and complies with Directive 2006/43/EC (or for public bodies: by a competent independent public officer)
 - the verification must be carried out according to the highest professional standards to ensure that the statements of contributions comply with the provisions under the Agreement and the applicable JU Regulation, that the contributions cover activities that are part of the action and that they have not been reimbursed by the grant
- contributions must comply with the following conditions:

⁵ According to the definition given in ISO 9000, i.e.: "Traceability is the ability to trace the history, application, use and location of an item or its characteristics through recorded identification data." The users can be traced, for example, by authentication and/or by authorization or by other means that allows for analysis of the type of users and the nature and quantity of access provided.

- costs covered by financial contributions cannot be claimed for reimbursement under the JU grant
- for Clean Aviation JU, SNS JU, Europe's Rail JU, CBE JU grants: if provided in the call conditions, a certain percentage of the total costs of the action must be covered by contributions (IKOP, IKAA or FC)
- for IHI JU grants: at least 45% (or another amount set out in the call conditions) of the total costs of the action and of the related IKAA must be covered by contributions (IKOP, IKAA or FC)
- for IHI JU grants: non-EU costs must not exceed 20% (or other percentage set out in the call conditions) of IKOP provided by members and contributing partners.

The beneficiaries must comply with the additional IPR, dissemination and exploitation obligations set out in the call conditions (Article 16 and Annex 5), in particular:

- for all JU grants: the granting authority right to object to transfers or licensing also applies to results generated by beneficiaries not having received funding under the grant
- for SESAR 3 JU and Clean Aviation JU grants: in view of the long innovation cycles:
 - the granting authority right to object to transfers or licensing (if any) can be exercised for up to 10 years after the end of the action (see Data Sheet, Point 1)
 - the beneficiaries must comply with their best effort obligation to exploit the results and any additional exploitation obligations imposed by the call conditions for up to 10 years after the end of the action (see Data Sheet, Point 1)
- for IHI JU and Global Health EDCTP3 JU grants (if applicable): the beneficiaries must ensure that the products and services that they develop based or partially based on the results of clinical studies undertaken as part of the grant are affordable, available and accessible to the public at fair and reasonable conditions.

In addition to the obligations set out in Article 17, communication and dissemination activities as well as infrastructure, equipment or major results funded under JU actions must moreover display the Joint Undertaking's special logo:





and the following text:

“The project is supported by the [insert JU name] and its members *[OPTION for actions with national contribution top-ups: (including top-up funding by [name of the national funding authority])]*.”

For EuroHPC JU and KDT JU grants, the beneficiaries must respect the following conditions when implementing actions with national contribution top-ups from Participating States:

- the beneficiaries must ensure visibility of the national contributions (see below)
- the payment deadlines for prefinancing, interim or final payments are automatically suspended if a national funding authority is late with its payments to the Joint Undertaking for the national contribution top-up
- the European Anti-Fraud Office (OLAF), European Public Prosecutor's Office (EPPO), European Court of Auditors (ECA), the National Court of Auditors and other

national authorities can exercise their control rights on the project implementation and costs declared, including for the national contribution top-up.

For SNS JU grants, where imposed by the call conditions for digital infrastructure projects the beneficiaries must ensure that the network technologies and equipment (including software and services) funded by the action comply with the security requirements and assessments as reflected in the applicable EU, international and national law on cybersecurity and on data protection.

Moreover, where the call conditions impose wholesale access obligations, the beneficiaries must provide wholesale access to the digital infrastructure funded by the action, under fair and reasonable conditions, in a non-discriminatory manner and in accordance with the call conditions.

For Global Health EDCTP3 JU fellowship grants, the beneficiaries must respect the following conditions when implementing them through financial support to third parties:

- avoid any conflict of interest and comply with the principles of transparency, non-discrimination and sound financial management
- take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers⁶ and ensure that the researchers and all participants involved in the action are aware of them
- ensure that the researchers enjoy at the place of the implementation at least the same standards and working conditions as those applicable to local researchers holding a similar position
- ensure that the other direct contract or fixed-amount-fellowship agreement specifies:
 - the name of the supervisor(s) and/or mentor(s) for the research and training activities
 - the starting date and duration of the research and training activities
 - the monthly support for the researcher under this Agreement (in euro and, if relevant, in the currency in which the remuneration is paid)
 - the obligation of the researcher to work exclusively for the action, unless part-time has been approved and not to receive, for activities carried out in the frame of the action, other incomes than those received from the beneficiary or other entities mentioned in Annex 1)
 - the working pattern of the researcher
 - the arrangements related to the intellectual property rights (during implementation of the action and afterwards), in particular full access — on

⁶ Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

- a royalty-free basis — for the researcher to background and results needed for their activities under the action
- the obligation of the researcher to inform as soon as possible about events or circumstances likely to affect the implementation of the action or the compliance with requirements under the Agreement (see Article 19)
- the obligation of the researcher to maintain confidentiality (see Article 13)
- the obligation of the researcher to ensure the visibility of the EDCTP Association and EU funding in communications or publications and in applications for the protection of results (see Articles 17)
- where set out in the call conditions, the obligation of the researcher to carry out a mandatory return period of 12 months
- assist the researchers in the administrative procedures related to the recruitment
- inform the researchers about:
 - the description, conditions, location and timetable for the implementation of the research and training activities
 - the rights and obligations toward the researchers under this Agreement
 - the obligation of the researchers to complete and submit — at the end of the research training activities — the evaluation questionnaire and — two years later — follow-up questionnaire provided by the granting authority
- ensure full access — on a royalty-free basis — for the researchers to background and results needed for their activities under the action
- ensure that the researchers do not have to bear any costs for the implementation of the action as described in Annex 1
- provide training, infrastructure and the necessary means for implementing the action (or ensure that such training and means are provided by other participants in the action)
- ensure that the researchers are adequately supervised and receive appropriate career guidance
- ensure that personalised career development plans are established, support their implementation and update in view of the needs of the researchers
- ensure an appropriate exposure to the non-academic sector (if applicable)
- respect the maximum limit for secondments set out in the call conditions (if applicable)
- respect the conditions for the outgoing and return phases set out in the call conditions (if any)
- ensure that the researchers are informed that they are ‘Global Health EDCTP3 JU fellows’

- ensure that the researchers do not receive, for activities carried out in the frame of the action, other incomes than those received from the beneficiaries (or other entities mentioned in Annex 1)
- host the researchers at their premises (or at the premises of other participants in the action).



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