



Invitation to Tender

Destination Earth Programme

Visualisation & Immersive Technologies

Volume II

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1 Introduction

Destination Earth (DestinE) will deploy several high resolution thematic digital replicas (digital twins, DT) of the Earth system to monitor and simulate natural and human activities as well as their interactions, to develop and test scenarios that would enable more sustainable developments and support European policy making. DestinE is intended to unlock the potential of observations and both physics-based and data-driven models for achieving a break-through in the realism of the simulation of Earth-system components.

DestinE's DTs will more realistically represent the Earth system and produce information at precisely those spatial and temporal scales where the impacts of extremes are felt and where key processes are observed thus allowing users from different impact-sectors to access and exploit such information for their specific application.

Innovative visualisation and immersive technologies are expected to connect with DestinE's enhanced simulation systems to provide additional capabilities that may be used for overlaying/mapping/fusing/integrating/distinguishing different geophysical and socio-economic information sources. Such technologies may be used to aid the near real-time quantification of risks of environmental extremes and to support tailored, application specific climate adaptation and mitigation strategies through the ability of contextualising in-situ, impact sector and climate information.

2 Context

DestinE is funded by the European Union's Digital Europe programme and implemented through a partnership between the European Space Agency (ESA), the European Centre for Medium-Range Weather Forecasts (ECMWF) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

The present ITT only relates to ECMWF's contribution to DestinE and focuses on how DT results can be visualised and contextualised with innovative technologies, including overlaying simulation and observational data (including high-resolution satellite images and in-situ local observations or user provided data) but also considering external technology exploitation, e.g. from developments in gaming, virtual (VR) or augmented reality (AR).

The first phase of DestinE, the implementation phase 1, covers the period 15 December 2021 – 14 June 2024. In this phase, the main building blocks of the required infrastructure to reach DestinE's ambitious goals will be configured and deployed and their capability be demonstrated:

- The Core Service Platform (DESP; responsibility ESA) for providing a large number of users with access to observations, simulations and models, evidence-based policy and decision-making tools, applications and services, based on an open, flexible, scalable and evolvable secure cloud-based architecture.
- The Data Lake (DEDL; responsibility EUMETSAT) for handling the storage and access requirements for any input and output DestinE data that is offered to DestinE users via seamless access through the DESP including near-data processing to maximize throughput and service scalability.
- The Digital Twin Engine (DTE; responsibility ECMWF) consisting of generic software infrastructures for workflows, extreme-scale simulation and data fusion, data handling and machine learning that allow exploiting the latest digital infrastructure technology for operating Earth-system digital twins and their integration in the wider digital environment.
- The two high-priority Digital Twins (responsibility ECMWF) for generating high-quality simulations and combining simulations and observations of the Earth system at unprecedented resolution to serve the EU's Green Deal policy priorities:
 - Weather-induced and geophysical extremes DT for providing capabilities for the assessment and prediction of environmental extremes at very high spatial resolution and close to real-

- time decision-making support at continental, country, coastline, catchment and city scales in response to meteorological, hydrological and air quality extremes.
- Climate change adaptation DT for providing capabilities to support climate change adaptation policy and scenario testing at multi-decadal timescales aiming at a real breakthrough in resolution at regional and national levels.

In the following phases of DestinE, these building blocks will further evolve to enhance capabilities, add thematic foci, ingest the latest scientific developments and observational information, and make use of the emerging digital infrastructure ecosystem supported by the Digital Europe programme in Europe.

3 Contract summary

This ITT covers the provision of a technical implementation that demonstrates how DT results can be visualised and contextualised, including overlaying simulation and observational data and the provision of a very specific workflow: a visualisation and rendering service. Under this procurement, the digital twin concept shall be enhanced with immersive technology that blurs the line between the physical world and the digital or simulated world and ideally provides a capability to fully immerse the users in the virtual world. The Tenderer is expected to demonstrate the ability to interact with the DT data output from one or several DTs in a way that illustrates innovative approaches to inspecting information content, augmenting and enhancing information content through fusion of other data sources and demonstrating the value of DT data. The workflow associated with DT data visualisation and rendering should consider the implementation of a service, e.g. involving cloud-native technologies as will be employed in DestinE to facilitate user interactions.

The workflow to be proposed should consider a range of contributing components, e.g. interpolation and tiling of geospatial data, data cube extraction of output data from one or several DTs through a data-as-a-service, and feeding this into a real-time 4D rendering service, with generic adaptors to e.g. Jupyter notebooks, virtual reality viewing platforms or APIs for easy incorporation into individual user-developed applications. Machine learning tools may potentially aid the process of spatio-temporal gap-filling or adding reality enhancing information, augmenting visual impressions and/or aid the visualisation of rapidly evolving scenes.

An important aspect will be the ability to add/fuse information from a range of sparse or rich data sources (from observations and simulations, potentially sourcing data from the DEDL) to generate infographics and storylines supporting DestinE DT data exploitation. This may involve augmented reality for contextual information on real-world extreme events, e.g. contextualised with climate change information while interactively exploring extreme events at a given location, or integrate evolution and/or adaptation/mitigation suggestions. Reality-enhancing features demonstrating DT data (e.g. a physical exhibition stand) may also involve using hardware to create perceptually-real sensations (e.g. a common task in gaming and flight simulators).

The complex nature of the entire DestinE data production and user interaction workflow and the dependencies on the evolving technical infrastructure – hardware and software – may require making adjustments to development plans as necessary during the period of the contract. Around the end of the first year, a review will take place, for the contractor and ECMWF to analyse such needs and decide on the most effective use of the available resources in the second year of the contract. At this point, amendments to change the priorities, or repurpose developments, will be considered and agreed.

A single contract towards providing and demonstrating the end-to-end rendering service is foreseen, with a strong preference for building on open source components that will facilitate an incorporation into the overall DestinE workflow. DestinE will take ownership of the data products delivered by these contracts, create further data and graphical products with the aim to make them available to the public without charge. The Tenderers are requested to contribute to the generic DTE development led by ECMWF, e.g. interfacing

with distributed high-performance computing sites, cloud and data handling infrastructures, and interfacing with ECMWF's DT data access API.

Tenderers should submit proposals that demonstrate their ability to deliver high-quality visualisation & interactive (immersive) technology capabilities with a strong foundation in digital technology development. The proposals will be evaluated on the basis of criteria related to technology readiness. The technical requirements are described in the following sections.

4 Technical specification

The successful Tenderers selected under this procurement will have a proven track-record in providing interactive rendering and visualisation services with an ability to interface with physically distributed data and distributed computing environments. The proposed solutions are required to fully comply with the DestinE needs as defined in this section.

The required contribution consists of the following components for which further detail is provided in the following sub-sections in support of establishing a novel rendering capability:

1. Define, implement and demonstrate a rendering service that can be integrated into a cloud-native platform and may involve immersive technologies.
2. Define and provide API interfaces/adaptors to either an existing, or provided in response to this invitation to tender, virtual or augmented reality viewing platform.
3. Demonstrate user interaction with DT generated data through flexible interfaces or a collection of micro services that allow to build responsive and reliable user interfaces for data rendering, also considering different usage scenarios across a low and a high latency network.
4. Demonstrate data fusion/overlaying of 4D DT data (e.g. Wedi et al (2020)¹) with at least two other ancillary data information sources (global or regional), where one is a high resolution satellite-derived product (e.g. 10m-100m spatial resolution) and the other represents a collection of pointwise or vertical profile in-situ observations.
5. Develop, in coordination with ECMWF, an (augmented reality) infographic storyline that demonstrates the potential of data from the Extremes and/or Climate DTs for sample applications (e.g. feature highlighting, decision making and policy support).
6. Provide a roadmap for the evolution of such a rendering service.
7. Interface with DTE developments where applicable, e.g. with a software infrastructure framework for workflows, cloud infrastructure integration, simulation and assimilation codes, data analytics and data handling, operated at scale across distributed European large-scale computing and data handling infrastructures (see also Section 4.1).

In addition, Tenderers are invited to propose further developments on visualization and immersive data exploration towards a future improvement of the DestinE capability provision after phase 1:

1. Improvement of the experience when interacting with DestinE data;
2. API developments supporting user friendliness;
3. Developments targeting software/hardware acceleration of the rendering service;
4. Innovative approaches or methods for the visualisation and translation from uncertainty quantification to application specific quality indicators;
5. Other innovative contributions to material for DestinE communication, outreach and education, as agreed with ECMWF.

¹ <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020MS002192>

To allow efficient negotiations and minimise the complexity of any future adjustments, each development activity should be formulated, as far as possible, as a self-contained module detailed in its own work package including deliverables and milestones and by clearly assigning responsibilities.

The following sections describe specific requirements from several perspectives: technical (in terms of what components shall be delivered), capability demonstration and quality assessment.

4.1 Computing

DestinE relies on a partnership with the EuroHPC Joint Undertaking (JU). The EuroHPC JU allows the European Union and the EuroHPC JU participating countries to coordinate their efforts and pool their resources for reaching new levels of supercomputing in Europe. DestinE relies on the computing centres hosting these HPC systems (e.g. CSC, CINECA, BSC) as well as on computing centres that are organised through the partnership for advanced computing in Europe (PRACE) to create a sustainable, distributed yet well-connected European computing, data production and data exchange framework. This is complemented by the emerging DestinE DEDL and DESP cloud infrastructure once available.

The main allocations for the HPC resources necessary for the DT production will be provided by the EuroHPC JU, also including computing resources for further data processing. The present commitment by the EuroHPC JU for activities of strategic importance for Europe (e.g. DestinE and similar activities) is 10% of the total node-hour budget available to the JU.

The Tenderer shall provide a detailed cost estimate for any required ancillary HPC, networking, cloud computing and storage needs, and detail any in-kind contributions if applicable. In general, the Tenderer is not required to deliver any hardware other than may be needed in the context of accessing the rendered product (e.g. VR glasses, gloves, screens, etc.). The Tenderer shall also describe in detail any other specific requirements, e.g. on software used or data governance (availability, usability, short/medium storage and persistence, etc.) that are important to facilitate the proposed rendering process.

4.2 Additional requirements for software and data

4.2.1 Software

Given the challenging scale of the DestinE computing and data handling tasks, the Tenderer shall provide information on relevant software components, development priorities and a roadmap for implementing rendering workflows that achieve performance and are portable across novel processor, memory and storage technologies. As much as possible, such software infrastructure implementation shall be coordinated with ECMWF as part of the DTE development that aims to implement and sustain a generic framework that will serve present and future DT developments and production. Notwithstanding the aforementioned, the Tenderer should, where possible, rely on open-source solutions.

ECMWF leads the development of the DTE functionality, which will include support for software management, continuous integration and code deployment, and benchmarking for portability and performance assessment. In particular, the DTE will also provide access to a high-performance data production and data access API, supporting DT data access and data governance tasks. The Tenderer shall interface with this API, and add developments and components to the rendering pipeline (e.g. considering tiling and other data processing stages for efficient rendering) and co-develop such functionalities as relevant for the rendering of DT data and develop innovative solutions for data processing as required for the rendering pipeline (e.g. data selection, data compression, interfacing with ML toolkits, interfacing with the proposed rendering engine).

EUMETSAT will host output from DTs and other data sources on the DEDL that may be used in the rendering process. It is from the DEDL that the data will ultimately be made available to users via the ESA DESP. The

Tenderer is asked to use this information as a design constraint for their proposed solution, but assume that other data sources may be used in the demonstration for the purpose of this tender.

4.2.2 Data transfer and data formats

There are different levels of data production and data access anticipated in DestinE. The preferred solution is for DTs to directly make use of an abstraction layer for DT data production and data streaming that is separate from the user data access provided by the DEDL or DESP. The implementation of this abstraction is the responsibility of ECMWF and used by the DTs (as part of the DTE) connecting to the underlying high-performance data handling service. This service will also make an interface available to the DEDL and the DESP for the subsequent dissemination and user data access process. The successful Tenderer of this ITT should interface with DT data through this API. The preferred DestinE internal data format for production is the WMO GRIB edition 2 format (GRIB2). The DestinE high-performance data access service will include options for data cube² access, extraction of partial data and thus supporting rapid visualisation (e.g. for extreme events). Beyond the GRIB2 data produced by the DestinE high-performance data handling service, additional potentially unformatted and user supplied datasets (e.g. derived data, other data sources, pointwise or vertical profile observational data, image data) should be considered and an explicit provision made in the proposal for actions such as reading, reformatting, and/or pre-processing such data.

Any dependencies impacting the timely delivery of an interactive rendering service of DT data (e.g. network latency constraints) shall be clearly described (e.g. by providing a time-to-rendering profile for 4D data, required network speeds, reformatting and pre-processing costs, etc.). These aspects form part of the evaluation process.

4.2.3 Quality control, support and documentation

Quality control procedures (including automatic procedures) shall be established that allow to check the quality of the rendered data and the correct representation of DT data. The precise methods should be proposed by the Tenderer and will be agreed as part of the negotiations. As a minimum, the software development where applicable should follow procedures according to industry standards, e.g. provisions for version control, coherent and uniform code styles, code reviews, issue and bug tracking, branching and merge strategies, continuous unit and acceptance testing followed by continuous integration.

The rendering process needs to be documented to allow users to understand the rendered result, the contributing data sources, and to be informed about configuration and version changes of the rendering engine. In the case of ECMWF detecting possible problems with the rendered results, providers are expected to give timely support to resolve problems quickly. Details of response procedure and time shall be established during contract negotiation.

The Tenderer is asked to document the scope of security and information management aspects to be provided and on the assets to be protected, according to ISO 27001.

4.2.4 IPR

It is a condition of EU funding for DestinE that ownership of any Deliverables (as defined in Volume V Agreement) developed with DestinE funding passes from the suppliers to the European Union via ECMWF. Ownership will pass from the date of creation.

All pre-existing materials (Background IPR; e.g. software and products) used by the successful Tenderer to produce the results (Deliverables) will remain the property of the owner, e.g., the successful Tenderer. The successful Tenderer will have to provide a royalty-free, non-exclusive, worldwide, perpetual and irrevocable license to those pre-existing materials to the EU via ECMWF under the conditions set out in Volume V Agreement.

² https://en.wikipedia.org/wiki/Data_cube

Developments or modifications to pre-existing materials which constitute results or improvements and are created specifically for DestinE purposes will be owned by the European Union via ECMWF.

Modifications to closed-source software should be factored out as software extensions that can be uniquely identified and will be (as Deliverables or Improvements) owned by the EU via ECMWF, with the intention of open sourcing the software extensions subject to approval from the European Commission. If the Deliverables include pre-existing materials, such pre-existing materials will be licensed to the Union unless there is an agreement on the transfer of ownership to the European Union.

Upon request, suppliers may be granted a non-exclusive licence, at the discretion of ECMWF and subject to the approval by the European Commission, to use the results which they have provided to DestinE.

5 General requirements

5.1 Implementation schedule

ECMWF intends to award a single contract for a maximum duration of 20 months, expected to commence by September 2022, and with an end date not later than 30 April 2024.

The successful Tenderer is expected to provide a detailed schedule as part of the tender response. The proposed time plan and schedule shall address the main tasks, inputs, outputs, intermediate review steps, milestones and deliverables. A roadmap of future developments beyond the contracted period is also highly desirable.

5.2 Meetings

Regular progress meetings will be held with ECMWF during the contract to assess contract status, risks and actions. ECMWF will organise annual meetings to bring together all DestinE capability providers, of which the first will be approximately 10 months after kick-off. The successful Tenderer is expected to attend these meetings. The successful Tenderer is also expected to attend monthly (video-conferencing) meetings to discuss progress and other topics that cut across different aspects of DestinE. The cost of attending these meetings shall be covered by each successful Tenderer and shall be included in the tendered price. ECMWF may adjust meeting frequency as needed and considers appropriate two physical meetings during the contract period, to take place in Bonn, to demonstrate progress on this contract.

In addition, the successful Tenderer is expected to participate in a technical working group – which may also include other DestinE partners and relevant collaborators – aimed at discussing issues related to product definition, generation and integration of the overall DestinE infrastructure. These discussions will be convened at regular intervals through video-conferencing.

5.3 Deliverables and milestones

Deliverables are to be defined by the Tenderer based on the requirements outlined above. They can be in the form of software, documents or reports, datasets and support to users or other related DestinE activities, and a physical demonstration exhibiting the results of this tender in Bonn. Also requirements related to the delivery of software and data have been described above (see Section 4.2). The requirements for all other types are described in the following subsections.

Each deliverable shall have an associated resource allocation (person-months and financial budget). The total of these allocated resources shall amount to the requested budget associated with payroll as detailed in Volume IIIA of this ITT.

Milestones should be designed as markers of demonstrable progress in capability development and/or quality of capability delivery, as applicable. They should not duplicate deliverables.

5.3.1 Documents and reports

All project reports shall be produced in English. Unless otherwise specified in the specific contract, deliverable documents and reports shall be made available to ECMWF in electronic format (Microsoft Word/PDF/Microsoft Excel or compatible), via the DestinE Deliverables Repository portal; the details will be agreed at the negotiation stage.

Please refer to Clause 2.3 and the Annex 5 of the Volume V Agreement for details on Reporting Obligations.

5.3.2 User support

The successful Tenderer is expected to contribute to the delivery of technical support for the data and rendering capabilities they provide. Such technical support shall take the form of a direct response to individual queries from ECMWF as required, as well as potential contributions to FAQs, user guides and knowledge bases. The Tenderer shall cost this as a separate task within the work package action defined in Section 4.2.2.

5.3.3 Other related DestinE activities

The successful Tenderer is required to support the wider DestinE activities, for example the DestinE partnership activities, communication and training and outreach. Sufficient resources for covering these aspects shall be foreseen.

Outreach activities will be organised by ECMWF during the period of the contract. In such instances, the contractors will be approached by ECMWF for support on developing and delivering contents. Similarly, DestinE will require contributions to training material on environmental prediction, and risk management, adaptation and mitigation for the selected use cases from the contractor.

Contractors shall not establish their own brand for the selected projects but rely on and use DestinE and ECMWF branding. A communications package (including guidelines, logos and templates) will be provided by ECMWF at the start of the contract.

6 Tender format and content

General guidelines for the tender are described in Volume IIIB. Specific requirements to prepare the proposal for this particular tender are described in the next sub-sections.

6.1 Page limits

As a guideline, it is expected that individual sections of the Tenderer's response do not exceed the page limits listed below. These are advisory limits and should be followed wherever possible, to avoid excessive or wordy responses.

| <i>Section</i> | <i>Page Limit</i> |
|--|--|
| <i>Executive Summary</i> | 2 |
| <i>Track Record</i> | 2 (for general) and 2 (per entity) |
| <i>Quality of resources to be Deployed</i> | 2 (excluding Table 1 in Volume IIIB and CVs with a maximum length of 2 pages each) |
| <i>Technical Solution Proposed</i> | 30 (Table 2 in Volume IIIB, the section on references, publications, patents and any pre-existing IPR is excluded from the page limit and has no page limit) |
| <i>Management and Implementation</i> | 10 (excluding Table 4 and Table 5 in Volume IIIB) + 2 per each Work package description (Table 3 in Volume IIIB) |
| <i>Pricing Table</i> | No limitation |

Table 1: Page limits

6.2 Specific additional instructions for the Tenderer's response

The following is a guide to the minimum content expected to be included in each section, additional to the content described in the general guidelines of Volume IIIB. This is not an exhaustive description and additional information may be necessary depending on the Tenderer's response.

6.2.1 Executive summary

The Tenderer shall provide an executive summary of the proposal, describing the objectives, team and summarising the proposed technical solution and capability demonstration.

6.2.2 Track record

The Tenderer shall demonstrate for themselves and for any proposed subcontractors that they have experience with relevant projects. ECMWF may ask for evidence of performance in the form of certificates issued or countersigned by the competent authority.

6.2.3 Quality of resources to be deployed

The Tenderer shall propose a team providing the skills required for developing and demonstrating the solutions complying with technical requirements set out in Section 4. The team shall include a dedicated Project Manager with at least 5 years of experience in management of projects of comparable size. The Tenderer shall describe the experience of the Project Manager and the technical project team in performing activities related to the various aspects of this tender.

6.2.4 Technical solution proposed

The Tenderer shall give an introduction to the overall proposed technical solution to demonstrate their understanding of the DestinE context and the specific requirements of the present tender. This section shall also include information on other third-party suppliers or solutions that are proposed for delivering the technical solution.

6.2.4.1 Existing capabilities

Tenderers should present information outlining the strength of their present capabilities in the following form:

- A brief description of the technological heritage of the proposed components.
- Publications or internal documentation describing the system's performance.
- Rendering examples, in a similar or other context.
- A brief description of experience with large HPC systems and supporting software stacks, and developing and running complex systems at scale.
- A brief description of the capacity to handle big data.

6.2.4.2 Provision of technical capabilities

Tenderers shall describe in detail their proposed technical approach to develop, implement and demonstrate the technical solution in compliance with the technical requirements laid out in Section 4. The description shall include information on how the proposed solution maps onto the requirements formulated throughout this document.

Tenderers shall describe their plan to maintain and update existing capabilities in the course of the contract. If any new, technical or scientific developments are considered necessary during this period, these shall also be described, for context, even if they may not qualify for funding under this contract. Where insufficient information does not allow the fully compliant description of a technical solution, such case shall be highlighted to facilitate discussions at the negotiation stage.

6.2.4.3 Computing and data handling resources

Tenderers should provide information about the computer systems expected to be used to provide the rendering service. DT data will be produced on (different) EuroHPC platforms, with dedicated access to HPC computing resources. Needs with respect to HPC and ancillary needs in terms of cloud computing, processing and data handling, data formats, data storage and data transmission are to be specified separately (see also Section 4.1).

If other computing or hardware resources (guaranteed in-kind, subject-to-proposal in-kind, or charged to this contract) are provided, the estimate of the associated computing and data handling cost needs to be accompanied by information on the nature of the anticipated resource and the elements included in this cost, in as much detail as possible.

6.2.5 Management and implementation plan

The Tenderer shall provide a detailed implementation plan of proposed activities for the duration of the contract. Deliverables should be consistent with the technical requirements specified in Section 4.

The Tenderer is requested to include management and implementation activities within a dedicated work package (WPO). The number of milestones is not prescribed, but they should be designed as markers of demonstrable progress in capabilities development and/or quality of capability delivery to keep progress monitoring manageable.

Adjustments to the proposed implementation plan can be proposed by the successful Tenderer, depending on the needs for the evolution of the technical solution, changed user requirements, or other requirements, but must be agreed to by ECMWF.

As part of the general project management description the Tenderer shall consider the following elements (this is not an exhaustive list):

- Semestrial, annual and final reports shall be provided in accordance with the Volume V Agreement Clause 2.3 and Annex 5.
- An annual work plan is expected to be agreed at negotiation for 2023. The annual work plan for 2024 shall be provided in July of 2023.
- Monthly video-conferencing with ECMWF and a proposal for involvement of ECMWF in major project reviews shall be provided as part of the management plan. The contractor is responsible for the organisation of such meetings, including provision of minutes.
- If relevant, a list of sub-contractors and details of their contribution, key technical personnel involved in the contract, legal names and addresses shall be provided. The tenderer shall describe how the Volume V Agreement, in particular Clause 2.9, has been communicated to all their sub-contractors.
- The Tenderer shall describe in the Proposal the management of personal data and how this meets the requirements of Clause 2.8 and Annex 6 of Volume V Agreement.

The table below provides the template to be used by the Tenderer to describe the complete list of deliverables, milestones and schedules for this work package. All milestones and deliverables shall be numbered as indicated. All document deliverables shall be periodically updated and versioned as described in the table. Tenderers shall provide preliminary versions of the completed tables as part of their bid.

Deliverables for this work package shall include the following reports:

| WPO Contractual Obligations Template | | | |
|---|--------|--|-------------------|
| # | Nature | Title | Due |
| D0.y.z-YYYY | Report | Semestrial Implementation Report (January-June YYYY) YYYY being the Year n This includes a specific Financial Report | Annually on 15/07 |

| | | | |
|-------------|--------|---|-------------------------------|
| D0.y.z-YYYY | Report | Annual Implementation Report YYYY YYYY being the Year n-1 This includes a specific Financial Report | Annually on 15/01 |
| D0.y.z | Report | Final Implementation Report | 60 days after end of contract |
| D0.y.z-YYYY | Report | Annual Work Plan YYYY YYYY being the Year n+1 | Annually on 31/08 |
| D0.y.z-YYYY | Other | Copy of prime contractor's general financial statements and audit report YYYY YYYY being the Year n-1 | Annually (no-cost associated) |

6.2.6 Key performance indicators

Contractors shall report to ECMWF on a set of Key Performance Indicators (KPIs) suitable for monitoring various aspect of service performance, including (but not limited to):

- Capability development
- Capability demonstration
- Output quality
- Technical performance
- User support

The KPIs, to be defined by the Tenderer, are subject to review by ECMWF and may be updated if necessary. The Tenderer should propose KPIs such that the overall DestinE KPIs (see below) can be reported upon where applicable.

| KPI | Method | Unit | Applicable Phase |
|---|---|---------|------------------|
| Partnerships | | | |
| Hydrology Applications | Agreement implementation | Number | I-IV |
| Energy Applications | Agreement implementation | Number | I-IV |
| Food Applications | Agreement implementation | Number | II-IV |
| Health Applications | Agreement implementation | Number | II-IV |
| Trans-continuum | Agreement implementation | Number | I-II |
| Others | Agreement implementation | Number | II-IV |
| Digital Twin capabilities | | | |
| Spatial resolution/coverage of monitoring and prediction DT Extremes datasets | Monitor system usage/evolution; define DT improvement over existing systems | km/area | I-IV |
| Spatial resolution/coverage of monitoring and prediction DT Climate datasets | Monitor system usage/evolution; define DT improvement over existing systems m | km/area | I-IV |
| Temporal availability/timeliness of DT output for continuous production mode | Monitor system usage/evolution; define DT improvement over existing system | hours | I-IV |
| Temporal availability/timeliness of DT output for on-demand production mode | Monitor system usage/evolution; define cost-benefit of DT set-up improvement over existing systems | hours | I-IV |
| Availability of decision-ready information derived from DT output | Monitor DT output uptake per impact sector | % | II-IV |
| Digital Twin data uptake | | | |
| Number of (service-level) applications using DT-Extremes output | Monitor the actively running applications on core platform using output (simulations, observations) | Number | II-IV |

| | | | |
|---|---|----------------|-------|
| Number of (service-level) applications using DT-Climate output | Monitor the actively running applications on core platform using output (simulations, observations) | Number | II-IV |
| Number of (service-level) applications using full-resolution, high-frequency output | Monitor the actively running applications on core platform using output (simulations, observations) | CPU Hours | II-IV |
| Number of (service-level) applications using critical-path output | Monitor the actively running applications on core platform using output (simulations, observations) | Number | II-IV |
| Number of applications producing candidate models to be added to DT Engine | Monitor and evaluate the number of applications suitable for integration | Number | II-IV |
| Number of new datasets created from DT output | Monitor the datasets made available from core platform relative to original portfolio | Number | II-IV |
| Computing and data handling performance | | | |
| Amount of data sets pushed into the Data Lake(s) | Monitor the overall data flow across bridges | Number, TB | I-IV |
| Ingestion, access & usage of Earth observation data | Monitor the overall data flow across bridges and uptake by DT Engine | Number, TB | I-IV |
| Actual HPC node allocation for continuous production mode | Monitor the node-hour allocation on test systems and EuroHPC platforms | Node-hours/day | I-IV |
| Actual HPC node allocation for on-demand product mode | Monitor the node-hour allocation on test systems and EuroHPC platforms | Node-hours/day | I-IV |
| Sustained vs peak performance | Assess application specific sustained performance on test systems and EuroHPC platforms | % | I-IV |
| Digital Twin Engine | | | |
| Extreme-scale software component uptake | Monitor number of models/data assimilation systems employing DTE modules | Number | II-IV |
| Machine-learning software component uptake | Monitor number of models/data assimilation systems employing DTE modules | Number | II-IV |
| HPC efficiency gains in DT production | Monitor the change in time-to-solution/reduction of node allocations | % | II-IV |
| Data exploitation gains in DT production and use in applications | Monitor the change in data touched and actively used | % | II-IV |