# EuroHPC JOINT UNDERTAKING

# DECISION OF THE GOVERNING BOARD OF THE EuroHPC JOINT UNDERTAKING No 8/2023

# Approving the Multi-Annual Strategic Programme 2021-2027 (version 2023)

THE GOVERNING BOARD OF THE EuroHPC JOINT UNDERTAKING,

Having regard to Council Regulation (EU) 2021/1173 of 13 July 2021 on establishing the European High Performance Computing Joint Undertaking (hereinafter "EuroHPC, Joint Undertaking") and repealing Regulation (EU) 2018/1488 (hereinafter "Regulation")[1],

Having regard to the Statutes of the EuroHPC Joint Undertaking annexed to the Regulation (thereinafter "Statutes") and in particular to Article 1(o), 7(4)(a), 7(5)(a), 7(6)(a), 7(7)(a) and 18 thereof,

Having regard to Decision of the Governing Board No 24/2021 of 21 November, approving the Multi-Annual Strategic Programme 2021-2027,

Having regard to Decision of the Governing Board No 2/2023 of 7 February 2023, approving the timeline for the production and approval of the EuroHPC Joint Undertaking´s Work Programme and Budget 2024,

WHEREAS

(1) Article 1(o) of the Status provides that the EuroHPC Joint Undertaking shall define the Multi-Annual Strategic Programme.

(2) By Decision No 24/2021 of 21 November, the Governing Board approved the Multi-Annual Strategic Programme 2021-2027.

(3) Pursuant to Article 1 of Decision of the Governing Board No 2/2023, during the 32nd Governing Board meeting of 9 and 10 March 2023, the Executive Director submitted for discussion and adoption the draft Multi-Annual Strategic Programme as amended

[1] OJ L 256, 19.7.2021, p. 3–51

by the Research and Innovation Advisory Group (hereinafter "RIAG") and the Infrastructure Advisory Group (hereinafter "INFRAG") as indicated in Articles 9.4(a), 13.1(a), 14.1(a) and 18 of the Statutes.

(4) Following the 32nd Governing Board, RIAG and the INFRAG added additional input to the Multi-Annual Strategic Programme. In addition, some members of the Governing Board provided comments.

(5) During 33rd Governing Board meeting, the Governing Board agreed the new version of Multi-Annual Strategic Programme and

HAS ADOPTED THE FOLLOWING DECISION:

*Article 1*

The Governing Board approves the Multi-Annual Strategic Programme 2021-2027 (version 2023) annexed to this decision.

*Article 2*

This Decision shall enter into force on the date of its adoption.

Done at Luxembourg, on 15 June 2023.

For the Governing Board

Herbert Zeisel

The Chair

Annex: Multi-Annual Strategic Programme 2021-2027 (version 2023)


# EuroHPC Joint Undertaking

# Multi-Annual Strategic Programme (MASP 2021 -2027)

***Version 2023***

| **Revision Status** | | |
|---|---|---|
| **0.0** | **First Draft, based on Strategic Orientations** | **GB discussion: 3-4 June 2021** |
| **0.1** | **Comments included from CH, DE, ES, SE, DK, IE, FI, EC,** | **July 2021** |
| **0.2** | **Second Draft based on feedback provided** | **August 2021** |
| **0.3** | **Third draft based on feedback provided** | **GB meeting 16/09/2021** |
| **1.0** | **Final version** | **October 2021** |
| **2.0** | **Draft Revision – JU version** | **April 2023** |
| **2.1** | **Comments from INFRAG and RIAG** | **May 2023** |
| **2.2** | **Comments included from DE, FR, SE, DK, NL, NO, IC, EC** | **June 2023** |

# EuroHPC Joint Undertaking

# Multi-Annual Strategic Programme (MASP 2021 -2027)

# 1. Introduction

## 1.1 Context

The EuroHPC Joint Undertaking (JU) was established on 28 September 2018 by Council Regulation No 2018/1488, published in the Official Journal of the EU on 8 October 2018, before entering into force on 28 October 2018.

EuroHPC JU became fully operational in 2018, while still under the auspices of the Commission. It adopted and implemented its first work programme and established itself as a successful model of a public-private partnership involving the European Union, twenty-seven Member States, and four associated countries from outside the EU.

The Executive Director was appointed on 15 May 2020 and took up office on 16 September 2020. The Governing Board confirmed the autonomy of the JU on 23 September 2020, having verified that all autonomy criteria had been met.

To date, the EuroHPC JU has already demonstrated that it is the right legal and financial instrument to address the shortcomings of the European HPC landscape and encourage Member States and EU funds to be pooled to create European value for the Union as whole. Indeed, coordination of the HPC strategies of the Union and the Member States by the JU has already led to:

- Pooling of resources and investments;
- Procurement of ten world-class HPC supercomputers addressing user needs and demands;
- A structured and focused research and innovation agenda aligned with the overall ambition of creating a world-class HPC ecosystem;
- Since 2022, two EuroHPC supercomputers ranked in the top 5 of the TOP 500 list.
- Since 2022, six EuroHPC JU supercomputers are accessible to European scientists.

The approval of a new Council Regulation sets out the updated mission of the EuroHPC JU and adapts the JU's funding streams to be in line with the new multi-annual financial framework (MFF) of the Union (2021 – 2027). As a result, the JU's scope and the variety of its activities has been extended.

## 1.2 Multi-Annual Strategic Programme (MASP 2021-2027)

### 1.2.1 EuroHPC JU's first Multi-Annual Strategic Plan (2021)

This original Plan was developed in 2021 in line with the updated mission set out in the Council Regulation [2] and the Commission Staff Working Document [3] on the new EuroHPC JU.

Input was provided by the JU's Industrial and Scientific Advisory Board, which is made up of the Infrastructure Advisory Group (INFRAG) and the Research and Innovation Advisory Group (RIAG). Both papers are included in the annex to this report.

Input was also provided by the Members of the Governing Board of EuroHPC JU and their experts during a number of discussions organised on the JU's future Strategic Orientations by the staff of the JU between April and June 2021.

The draft Plan was then presented to the EuroHPC JU Governing Board on 3-4 June 2021 for an initial discussion. The consolidated Plan was adopted by the EuroHPC JU Governing Board on 16-17 September 2021.

Once adopted, it formed the basis for the preparation of the updated 2021, 2022 and 2023 Annual Work Programmes.

### 1.2.2 EuroHPC JU updated Multi-Annual Strategic Programme (2023)

This Multi-Annual Strategic Programme has been developed in line with the mission set out in the updated EuroHPC JU Council Regulation.

**Legal base**

Article 1 (o) of the Statutes (Regulation 2021/1173) states: The Joint Undertaking shall define the multiannual strategic programme, draw up and implement the corresponding annual work programmes for their execution and make any necessary adjustments to the multiannual strategic programme;

Articles 7(4); 7(5); 7 (6); 7(7) of the Statutes (Regulation 2021/1173) states: The Governing Board shall discuss and adopt the multiannual strategic programme as referred to in Article 18(1) of these Statutes

[2] Regulation (EU) 2021/1173.

[3] SWD(2020) 179 final.

Article 18 (1) of the Statutes (Regulation 2021/1173) states: 'The Industrial and Scientific Advisory Board shall consolidate the multiannual strategic programme and submit it to the Executive Director. It shall be the basis for the Executive Director to draft the annual work programme.

**Process**

In December 2022, the EuroHPC JU Governing Board asked the Infrastructure Advisory Group (INFRAG) and the Research and Innovation Advisory Group (RIAG) to provide input to update the Plan and ensure it will provide elements to future Annual Programmes during the MFF period (2021-2027).

Input was also provided by the Members of the Governing Board of EuroHPC JU and their experts during several discussions organised between December 2022 and June 2023.

The draft Programme was presented to the EuroHPC JU Governing Board on 9-10 March 2023 for an initial discussion. The consolidated Programme was adopted by the Governing Board in 2023.

Once adopted, it will form the basis for the preparation of future Annual Work Programmes during the remainder of the current MFF period (2024-2027). When appropriate, and in order to reflect the evolving HPC context, this document will be updated.

## 1.3 Mission and Strategy

### 1.3.1 Mission

Supercomputing, numerical simulation, artificial intelligence (AI) and high-performance data analytics (HPDA) are essential and strategic for European countries to understand and respond to the increasing challenges that their citizens will be faced with in the years to come. These technologies will also continue to play an essential role in ensuring continued leadership of European science, industry (including SMEs), security, and economic development.

The European Union is on the way to completing the challenge which it set itself which to deploy current HPC technologies and its associated (human) expertise and making them accessible to all. The challenge now is about future exascale and post-exascale supercomputing technologies, including the emerging domain of quantum computing, as well ensuring connectivity and access to the systems.

Examples of use cases for HPC include early detection and prevention of diseases, new therapies, understanding the functioning of the human brain, forecasting climate change, and accelerating the design of new materials (in particular energy-efficient ones), medicines, airplanes and cars.

Mastering these critical technologies, including modelling in combination with data management (DM) and artificial intelligence (AI), is essential for large-scale simulation as well as processing,

analysing, and using the quintillions of bytes produced every day. These technologies, for example, are key for ensuring that European researchers from both academia and industry reap the full benefits of data-driven science and forge the path to grand scientific discoveries.

They are also essential for a large number of users from the public and private sectors for serving many social, scientific, and industrial domains. For example, at the beginning of the COVID-19 pandemic, HPC resources helped accelerate the search for new drugs and therapies. Access to HPC resources clearly plays a valuable role in quickly identifying solutions to complex societal emergencies and natural disasters.

European citizens are already benefiting from such applications. Personalised medicine, for example, has already used simulations to understand the nature of diseases, diagnose them rapidly, and develop customised treatments. Supercomputing has also a growing impact on industry by significantly reducing product design and production cycles, accelerating the design of new materials, minimising development and manufacturing costs, and increasing resource efficiency.

By 2027, the EuroHPC JU will establish a world-leading hyper-connected and federated HPC service and data infrastructure ecosystem in the Union. It will ensure that the EU is in a position to develop innovative and competitive HPC solutions based on European components, technologies and knowledge. Energy-efficiency and environmental sustainability have become increasingly important, and will also be part of this strategy.

In practice, EuroHPC JU should develop, deploy, maintain, and extend a world leading federated, secure and hyper-connected supercomputing, quantum computing service and data infrastructure ecosystem in the Union; support the development and production of innovative and competitive supercomputing systems based on a supply chain that will ensure components, technologies and knowledge limiting the risk of disruptions and the development of a wide range of applications optimised for these systems; widen the use of this supercomputing infrastructure to a large number of public and private users, and support the twin goals of climate and digital transition as well as the development of key skills for European science and industry.

The JU's approach should take on a demand-orientated and user-driven approach, where appropriate. For example, the JU is setting up an easy-to-use platform to access the EuroHPC systems, and will provide funding to hosting entities to ensure that the available compute resources are made available for academic, public sector and industrial users. It should also be technology driven and provide solutions to computational, engineering or other scientific problems.

The JU will ramp-up its activities in HPC soft- and hardware R&D. The vision of the EuroHPC technology pillar is to develop European critical energy-efficient exascale and post-exascale

technologies, architectures and systems technology and their integration in pilot systems, complemented with the deployment of world-class competitive exascale and post-exascale supercomputers based on this technology. This vision is fully in line with the EuroHPC JU regulation's objective of establishing an effective link between technology supply, co-design with users, and future actions involving joint procurement of world-class systems, in order to create a world-class ecosystem in HPC technologies and applications across Europe.

### 1.3.2 Strategy

The Multi-Annual Strategic Programme (MASP 2021-2027) is based on the strategy set out in the updated Council Regulation 2021/1173. By pooling European and national resources, the EuroHPC Joint Undertaking ensures that the EU and EuroHPC participating states (PS) coordinate their investments with the objective of deploying, in Europe, world-class exascale supercomputers and of supporting world leading high performance computing (HPC). The EuroHPC JU seeks to support sustainable, gender-balanced and inclusive European excellence in computing solutions, improving cooperation in advanced scientific research, boosting industrial competitiveness, and ensuring European technological and digital sovereignty.

In the previous Regulation 2018/1488 on establishing the European High Performance Computing Joint Undertaking, the JU was tasked with supporting two main objectives, which it continued to implement in 2022[4]:

- Developing a world-class supercomputing infrastructure: procuring and deploying in the EU three pre-exascale supercomputers (capable of at least $10^{17}$ calculations per second) and five petascale supercomputers (capable of at least $10^{15}$ calculations per second). These supercomputers are located across the European Union and most of them are available to Europe's private and public users, scientific and industrial users throughout Europe; and
- Supporting research and innovation activities: developing and maintaining an innovative European supercomputing ecosystem, stimulating a technology supply industry (from facility infrastructure to low-power processors to software and middleware, and their integration into supercomputing systems), and making supercomputing resources in many application areas available to public and private users, including small and medium-sized enterprises.

[4] JU Activities as set out in Regulation 2018/1488

In addition, since 2021, in accordance with the new Regulation now in force, the JU has new objectives, as follows:

- To contribute to the implementation of Regulation (EU) 2021/695 (Horizon Europe) and in particular Article 3 thereof, to deliver scientific, economic, environmental, technological and societal impact from the Union's investments in research and innovation, so as to strengthen the scientific and technological bases of the Union, deliver on the Union strategic priorities and contribute to the realization of Union objectives and policies, and to contribute to tackling global challenges, including the Sustainable Development Goals, by following the principles of the United Nations Agenda 2030 and the Paris Agreement adopted under the United Nations Framework Convention on Climate Change;
- To develop close cooperation and ensure coordination with other European Partnerships, including through joint calls, as well as to seek synergies with relevant activities and programmes at Union, national, and regional level, with those supporting the deployment of innovative solutions, education, and regional development, where relevant;
- To develop, deploy, extend, and maintain in the Union an integrated, demand-oriented, and user-driven hyper-connected world-class supercomputing and data infrastructure;
- To federate the hyper-connected supercomputing and data infrastructure and interconnect it with the European data spaces and cloud ecosystem for providing computing and data services to a wide range of public and private users in Europe;
- To promote scientific excellence and support the uptake and systematic use of research and innovation results generated in the Union;
- To further develop and support a highly competitive and innovative supercomputing and data ecosystem broadly distributed in Europe contributing to the scientific and digital leadership of the Union, capable of autonomously producing computing technologies, architectures, cooling and energy infrastructures and their integration on leading computing systems, and advanced applications optimized for these systems; and
- To widen the use of supercomputing services and the development of key skills that European science and industry need.

The Joint Undertaking shall enable the acquisition of world-class supercomputers, while safeguarding the security of the supply chain of procured technologies and systems. It shall contribute to the Union's strategic sovereignty, support the development of technologies and applications reinforcing the European High Performance Computing supply chain, and promote

their integration in supercomputing systems that address a large number of scientific, societal, environmental, and industrial needs.

To fulfil its mission and achieve its general and specific objectives as set out in the Council Regulation, the EuroHPC JU will adapt its strategy and put forward a range of measures to address risks identified during the implementation of the Work Programmes 2019-2022.

- **Foster competition in calls for proposals and widen participation**

The competitive evaluation of proposals as foreseen in the Horizon Europe and Digital Europe programmes is critical to ensure the best quality and efficiency for the implementation. Calls for proposals should support inclusiveness and effective collaboration while avoiding cartelization. The JU will adopt appropriate measures such as additional call conditions, limiting the size of consortia, requiring complementary competences and roles of consortium members in grants, defining minimum and maximum contributions and resources for beneficiaries, monitoring participation, and collecting feedback from applicants to promote fair competition, widen participation and improve overall sustainability and impact.

- **Pursue a strategic and results-focused approach to sustainable R&I**

Strategic R&I requires an approach focused on results, with clear focus, targets and commitments in the implementation. The practice of identifying a broad challenge in a call for proposals to identify the best solution among proposals submitted by consortia is often not effective in the current European HPC ecosystem and an approach with focused actions of limited scope is required. This is because the ecosystem is relatively small, with a limited number of closely collaborating main actors. As the competence gap, in particular regarding industrial capability and capacity, between different regions of Europe is evident, and the knowledge transfer and harmonisation of HPC development in Europe represents a key priority of the JU, it is critical for the achievement of the JU's strategic objectives, specifically in the area of technology, to ensure that actions involve the most competent actors in Europe and avoid dissipation and fragmentation. Widening participation and knowledge transfer, on the other hand, should be addressed in targeted actions to attract new stakeholders in technology innovation and development, who typically address academic and low TRL research and development.

The JU will provide, in an open, fair and transparent process, and within the applicable rules of the relevant Framework Programme, support and guidance to applicants in the preparation of their responses to the JU's open calls. Moreover, the JU will strengthen its role in steering projects towards the agreed objectives, adopt measures such as requesting changes during the grant agreement preparation and project lifecycle to ensure projects are focused on the critical path

of development, the introduction of mandatory control points in grant agreements, the termination of unsuccessful development paths within projects and the consolidation of developments to ensure R&I grants focus on the key outcomes of the respective call and that all participants contribute significantly to the results of an action. The JU will further improve the impact and effectiveness of R&I actions by providing more detailed requirements, including on IPR (Intellectual Property Rights) and commercial exploitation, specific mandatory deliverables, milestones, and additional conditions where appropriate. The coherent implementation of actions towards the JU's strategic R&I goals may be supported by additional measures such as payments linked to deliverables and milestones or competitive development streams with subsequent consolidation process, as appropriate.

- **Energy-efficient and environmentally sustainable computing**

In order to improve the energy efficiency of the entire HPC value chain, user skills, technology and infrastructure need further development.

While HPC centres constitute only a subset of the entire datacentre and cloud facilities, they are growing as well and therefore require careful control of their environmental impact.

HPC operations, manufacturing, integration and commissioning of equipment do account for a significant part of this impact. Among this are the use of rare materials and important amounts of water for hardware components production, and transportation footprint.

The decommissioning of equipment and facilities, the recycling of electronic or other waste should be considered as well. A Life Cycle Analysis approach should be used in HPC deployment.

During the active lifetime and operations of a system, the most significant concern is energy optimisation. The best and most energy-efficient technical solution should be sought.

Energy efficient computing aims to maximise energy efficiency. With rising energy prices, energy efficiency gains even more importance and with global warming the environmental impact of large-scale computing must also be considered. The JU aims in cooperation with the hosting entity to develop system level approaches that reduce the cost of exploitation by decreasing power consumption and to optimise the amount of computation achievable under a given energy budget.

Another important element to achieve a more efficient use of resources is a well-educated and energy-aware user base. This requires appropriate training, but also feedback on energy consumption and effective incentives for a responsible and energy-efficient use of HPC (e. g. the development of measure to link scientific impact to energy consumption in HPC). The JU will work on a qualification framework to establish minimum requirements on the skills of end users of

EuroHPC systems while making sure that new user groups get support to be able to gain access to the systems. The JU will also work on development of upstream software development to design performance measurement tools.

From the processor perspective, the more energy effective CPU or GPU per floating point operation is to be preferred. New features like dynamic GPU frequency control allow a dedicated and optimal running of codes to achieve optimal carbon footprint. Improvements at software level could also be considered to improve energy efficiency. Quantum computing and neuromorphic and in memory computing could be used, where appropriate for these tasks.

The data centres, which host EuroHPC JU infrastructure, are already mostly liquid cooled, which make it possible to operate a datacentre at a very low PUE (power utilization efficiency) – a PUE around 1 vs. 2 or more for air cooled solutions. Future EuroHPC Host Entities should whenever it is ecologically worthwhile and economically possible, reuse the waste heat as already done by a number of EuroHPC systems.

While new EuroHPC JU centres might be built in regions with cooler climates, modern high-temperature cooling techniques allow free cooling also at higher environmental temperatures. An important direction of research is the re-use of heat of waste from cooling. Overall, the use of all renewable energy options should/must be studied and increased at best.

- **Promote standardisation and modular design principles**

Standardisation is widely recognised as a catalyst for industrial innovation, providing a competitive advantage for contributors and reducing the risk for technology lock-in. Standardisation and modular design principles allow the easy replacement, reassembly, or rearrangement of components for flexible solutions, a broad participation of the supply industry including SMEs and an overall more resilient supply chain in a competitive European HPC ecosystem. Modularisation further enables joint developments and the effective pooling of skills and resources to develop common parts of technology and applications. The distributed and diverse HPC ecosystem in Europe, with many public organisations, private companies, national and European initiatives which are often focused on specific aspects of HPC technology, requires common standards for interoperability to establish an internationally competitive and resilient supply chain for European HPC and, when mature, quantum computing technology. Beyond standardisation of technology, common standards and certifications in HPC training and education are required to enable the mobility of talents within Europe and between academia, the public and private sectors. The development and promotion of standardised benchmarks for HPC and quantum computing represents another important area for research and development as well as for potential international cooperations. The importance of standardisation has been

acknowledged in the proposal for an EU standardisation strategy and the JU's effort to develop the European HPC ecosystem should be aligned with the overall vision on standardisation in the Union.

The JU will advance pan-European standardisation and modularisation efforts across all relevant pillars of activities. This includes alignment with the activities of established European standardisation bodies, for example the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) and with their relevant working groups, such as the CEN-CENELEC Focus Group on Quantum Technologies. Similarly, the JU will develop a coherent, cross country and modular qualification framework for skills, training, and education in HPC and support the adoption and implementation of common standards by European training providers. To achieve these strategic objectives, the JU will include requirements on standardisation in procurements and calls for proposals where appropriate, to ensure the coherent and effective implementation and to deliver the best possible impact.

European HPC digital sovereignty cannot be done in an isolation from other initiatives. Coordination with other programs like the EU Chips Act and the KDT Joint Undertaking shall contribute to the overall goals and generally benefit from technology trickle down.

Building on this, the Infrastructure Advisory Group (INFRAG) and the Research and Innovation Advisory Group (RIAG) have provided updated and renewed input to the strategy.

*'EuroHPC should extend its long-term mission and vision for European computing to define a general overarching strategy for all anticipated activities. It should continue to facilitate easy and secure access to an integrated, world-class supercomputing and data infrastructure and to develop and support a highly competitive and innovative high-performance and quantum computing ecosystem encompassing hardware, system and application software, support, and the development of highly qualified personnel. As such, the EuroHPC supercomputing infrastructure should be the strategic instrument for European leadership in the global digital science and economy for the next generation supercomputing and data driven digital era and beyond. The strategy and actions should be based primarily on the requirements of the users. It is important to recognize that the numerous user groups, like academic researchers, scientists working in SMEs or large companies, or researchers in governmental organisations have different requirements with respect to supercomputer hardware, software, support services, and IT security. These divergent needs should be addressed by a federated European supercomputing infrastructure that ensures access to all EuroHPC systems based on the same level of quality. The rapidly increasing demand from data-driven computing applications and technologies including Artificial Intelligence (AI) and Digital Twins requires an agile response from EuroHPC and a*

*sustained engagement with new and emerging communities. The pace and scale of support for HPC and quantum computing education, training and support must be broad and deep to match the investment in hardware and enable a full exploitation of resources. Since the federated supercomputing infrastructure will be essential for the European economy and European industry, science, and society at large, the infrastructure must be resilient, powerful, secure, affordable, and competitive at the international level. EuroHPC should also support potential disruptive innovation supporting global competitiveness in technology development and the retention of skills and expertise in Europe. These are challenges, but also present big opportunities for European suppliers and users who should be empowered to provide appropriate feedback and strategic advice and expertise. The focus of all EuroHPC activities should be on innovation: in science, in industry and in public services to strengthen the collective European economy and society.*

In 2023, RIAG updated its recommendation[5] on the new strategy of the JU:

*'In the last two years, 2021 and 2022, the European HPC ecosystem has improved significantly. Still, it is not yet balanced, with significant European leadership limited to the HPC software stack and major but improving deficiencies in contributions to the HPC hardware stack. To achieve European digital sovereignty soon, EuroHPC JU technology initiatives should be focused on providing a boost to the (re)generation of European HPC technology research and industry, especially in HPC-specific areas where there are clear gaps. One of the fastest ways to achieve this goal is to leverage our strengths and extend those capabilities. We see European technology leadership today, based on open platforms like the Linux OS, toolchain, runtimes, frameworks, and libraries, up to the HPC application layer. This enables rapid development and extension of software systems (...). Combining our European strengths with global trends, we can accelerate the path to digital sovereignty by creating the European Open Stack (EOS), establishing and leveraging an ecosystem based on open source and open standards for computing encompassing both hardware and software and fostering the development of co-designed systems required to advance European and global HPC. This ambitious vision will enable European independence and encourage additional investments. The EOS will produce Intellectual Property (IP) and standards that enable innovation and accelerate the European research and development at all levels in the HPC system stack. To achieve these goals, EOS must include repositories of enabling technologies for the European HPC ecosystem development, from third party hardware IP and tools to system software and applications.'*

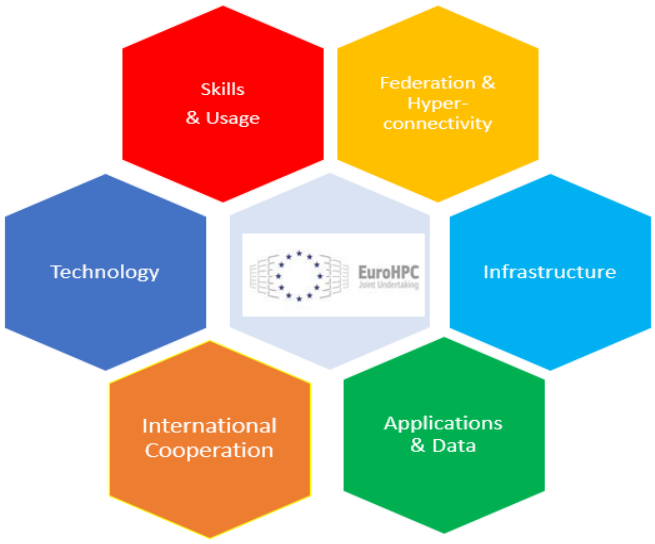
[5] The full 2023 RIAG Recommendations are available in annex to this document.

## 1.4 Funding EuroHPC JU's activities:

### 1.4.1 EU Programmes

The Union's contribution to EuroHPC JU is complemented by national and private member contributions.

In line with the new Regulation, the activities of the Joint Undertaking will be structured in one administrative pillar and six technical pillars that will cover activities in the following areas: infrastructure, federation of supercomputing services, technology-related activities, supercomputing applications-related activities, broadening usage and skills, and international cooperation. Although activities in each pillar will be described separately, it is clear that each pillar is interlinked with the others and that the whole ecosystem needs to be considered. To do this, special actions will be developed to ensure interlinkage between the pillars.




The current Multi-Annual Financial Framework (2021-2027) has allocated funding to implement this strategy in three specific work programmes, with the following indicative budget allocated to EuroHPC JU activities:

Digital Europe (DIGITAL) Programme: EUR 1.981.300.000[6]

- Infrastructure pillar

[6] Due to the proposed Chips Act, operational appropriations of EUR 150 million were reallocated within the Digital Europe Programme. As a result the appropriations from the High-Performance Computing Joint Undertaking (EuroHPC) will be successively reduced during the years 2023 - 2027.

- Connecting and federating of supercomputing services pillar
- Widening usage and skills pillar

DIGITAL is a new programme and will allow for co-funding with Participating States who are signatories to DIGITAL to deploy new and upgrading of new supercomputers, ensuring access to these HPC infrastructure, building on the federation of supercomputing services, and deployment, and usage of the HPC ecosystem. It will also be used to deploy HPC skills and training in the European Union.

DIGITAL will be used to fund the infrastructure pillar, part of the federation of supercomputing services pillar, and the widening usage and skills pillar.

Connecting Europe Facility (CEF): EUR 200.000.000

- Hyper-connectivity
- Data connectivity

The Connecting Europe Facility Programme will be used to fund the remaining activities of the connected and federated supercomputing services pillar, i.e. the high-speed interconnection of high performance computing, quantum computing and data resources, as well as the interconnection with the Union's common European data spaces and secure cloud infrastructures (e.g. GAIA-X). CEF will support connectivity and, where relevant, cybersecurity activities.

Horizon Europe Programme (HE) : EUR 900.000.000

- Technology pillar
- Application pillar
- International Cooperation

HE will continue to focus on R&I activities co-funded with Member States in the areas of technology, applications, and international cooperation. HE will be used to fund the technology pillar, the application pillar, and the international cooperation pillar.

In addition, the newly adopted Recovery and Resilience Facility (RRF) will support the digital transition. Member States are requested by the Commission to ensure a high level of ambition when defining reforms and investments enabling the digital transition as part of their recovery and resilience plans. The Regulation requires that each recovery and resilience plan include a

minimum level of 20% of expenditure related to digital. This includes, for instance, investing in the deployment of HPC and connectivity.

### 1.4.2 National contributions

The Participating States shall make a total contribution that is commensurate to the Union's contribution. Participating States may complement the Joint Undertaking's contribution in different actions, within the applicable maximum reimbursement rate set out in the HE, DIGITAL, and CEF Regulations. The JU shall provide an online platform to ensure that reporting of national financial contributions and in-kind contributions are reported in a transparent and efficient way, in line with the requirements set out in the new Regulation.

### 1.4.3 Private member contributions

The Private Members[7] of the Joint Undertaking provide in-kind contributions from operational (JU-funded) projects (IKOP) in the form of unfunded share of costs on JU projects.

In order to encourage more IKOP contributions, EuroHPC JU has provided support to ensure that reporting of private member in-kind contributions is managed in a transparent and efficient way.

However, as the EuroHPC JU Regulation only allows for IKOP, it will be difficult for Private Members to contribute the target of at least EUR 900 000 000. In consequence, the JU will also explore:

- the use of Innovation Action funding instruments. Innovation Actions will allow for projects to be co-funded with Union, national and private member contributions and will support higher TRL projects in line with the mission of EuroHPC JU.
- the opportunity of procuring an industrial mid-range HPC system in partnership with the private sector (including companies that who have yet to become members of the JU's Private Members associations)
- In the future, the possibility for the JU to collect in-kind contributions to additional activities (IKAA) as defined in the HE rules[8].

[7] In 2023, these are the European Technology Platform for High Performance Computing (ETP4HPC), the Big Data Value Association (BDVA) and the European Quantum Industry Consortium (QuIC).

[8] This is not currently possible under Regulation 2021/1173.

## 1.5 Milestones and Financial Perspectives

In short, the JU's activities shall be coordinated across the different pillars. Each year, the Governing Board of the EuroHPC JU will approve an annual work programme that will implement identified milestones and actions which will form the different outputs of the strategy.

It is important to ensure that the outputs of each R&I call are deployed and disseminated, and that proper usage and take up of the HPC infrastructure, technologies and applications are monitored. Progress on different projects will be presented through events and other communication activities, the EuroHPC JU website, and the JU's Consolidated Annual Activity Report (CAAR).

Under the current Regulation, EuroHPC JU will operate from 2021 until 31 December 2033 to exercise its responsibilities concerning grant implementation, until the last indirect actions launched have been completed, and to finalise the activities related to the operation of the JU supercomputers.

## 1.6 State of Play

### 1.6.1 Infrastructure Procurement

Since 2021, EuroHPC JU has procured several HPC systems which are now operational and accessible to users across Europe. The challenge is to plan for the arrival of future exascale and post-exascale systems and in parallel, to prepare scientists, academics, SMEs, and industry to access them in fast and efficient way.

The other challenge will be to procure quantum computers to provide European scientists the infrastructure to develop new use cases.

In summary, between 2021 and 2023, the following actions were launched by EuroHPC JU:

- The Jupiter exascale system call was launched in 2021, the Hosting Entity Agreement signed in 2022, and the procurement in 2023. The system should be operational by 2024.
- A second HPC exascale system call was published in 2022. The system should be operational by 2025.
- The LUMI pre-exascale procurement took place in 2020 and the system was operational in 2022.
- The Leonardo pre-exascale procurement took place in 2020 and the system will be fully operational in 2023.

- The MareNostrum5 pre-exascale procurement was launched in 2021 and the system will be operational in 2023.
- Four petascale systems (MeluXina, Discoverer, Vega and Karolina) have been operational since 2021.
- Four mid-range HPC hosting entities were selected in 2022.
- The second mid-range hosting entities call was launched in 2022.
- Two HPC systems (Leonardo and Discoverer) were selected for upgrade in 2022.
- Six quantum computer hosting entities selected in 2022.
- One high level application support call launched in 2022.
- In order to implement this strategy and support overall coordination in the implementation, the JU organises regular meetings with HPC and Quantum hosting entities, to ensure good cooperation, spread scientific and operational best practice.

### 1.6.2 Connected and federated Supercomputers

In 2022, the JU launched a call for tender to establish a study to assess what would be the best solution to interconnect EuroHPC systems and provide the related connectivity services. The study will be ready by end of 2023 and a call to procure such a service will be launched in 2024.

Furthermore, a procurement on federation services shall be launched in 2023.

### 1.6.3 Technology

To date, 40 projects in R&I in HPC are being managed by the JU.

EuroHPC JU took on projects started by the European Commission which have supported the development of European HPC technologies through a large number of projects, including DEEP-SEA, RED-SEA, and IO-SEA, as well as the European Processor Initiative (EPI) and eProcessor which specifically tackled the need for European processor technology for HPC use

The European Processor Initiative (EPI) is a cornerstone of the EuroHPC JU's activities towards strategic autonomy in HPC, chip technologies and infrastructure. The project has completed its first three-year phase (2018-2021), delivering cutting-edge technologies for European sovereignty such as the Rhea General-Purpose Processor (GPP) and a proof-of-concept implementation of European accelerator technology.

The European Processor Initiative project is ongoing, and the results of this project will soon be available to be deployed in the next generation of HPC systems. The second phase of the project

will finalise the development and the bring-up of the first generation of low-power processor units, develop the second generation of the GPP applying technological enhancements targeting the European Exascale machines, develop the second generation of low power accelerator test chips, usable by the HPC community for tests and develop sound and realistic industrialisation & commercialisation paths and enable the long-term economical sustainability with an industrialisation path in the edge computing area, demonstrated in a few well-chosen proofs of concept like autonomous shuttles or video surveillance.

In compliment to the EPI action, a call for a Framework Partnership Agreement (FPA) on RISC-V was launched in 2022. The aim is to support a Framework Partnership Agreement (FPA) establishing a stable and structured long term partnership between the EuroHPC JU and a consortium of industry, research organisations and the institutions in High Performance Computing who commit themselves to establishing, coordinating and implementing a strategic and ambitious R&I initiative contributing to the development of innovative HPC hardware and software technology based on the open RISC-V ecosystem, followed by an ambitious action for building and deploying the exascale and post-exascale supercomputers based on this technology.

The growth in the open-source RISC-V market is having an exponential trajectory. This explosive growth is forecasted to continue over the next years. The increasing adoption of open source is disruptive as it drastically lowers the barrier to chip design. China, the US and India, among others, are already investing heavily in open-source hardware and software in order to develop a competitive advantage in key sectors. It is only a matter of time to see open-source RISC-V solutions entering the HPC market. The benefits and attraction of adoption of open source depends on the type of actor and their role within the value chain. The Staff Working Document accompanying the recently proposed European Chips Act has identified the following benefits from open-source hardware adoption:

- Creating innovative products with lower costs and access barriers.
- Providing a faster path to innovation and smoother cooperation between actors (academic, research, industry, SME, alliances)
- Influencing technical choices and specifications.
- Allowing customization of open-source IP to user needs, delivering differentiating products.
- Sharing development costs.
- Reducing risks related to third-party IP (unbalanced commercial relationship, end of maintenance/ discontinued products, export control and trade wars).

- Building support and design service businesses based on open-source IP
- Better auditing of security and safety, ensuring that solutions can be fully audited and checked/verified.

The EuroHPC JU will work towards putting in place a stable and structured long-term partnership between the JU and industry, research organisations and the institutions in High Performance Computing who commit themselves to establishing, coordinating and implementing a strategic and ambitious R&I initiative contributing to the development of innovative HPC hardware and software technology based on the open RISC-V ecosystem. This should be followed by activities to standardize and ensure interoperability of RISC-V, find RISC-V solutions for SMEs and of course, by building and deploying the exascale and post-exascale supercomputers based on this technology.

The call on algorithms for HPC applications exploiting the capabilities of exascale systems was launched in 2022 and grant agreements will be signed in 2023. This call will develop novel algorithms for the upcoming European exascale supercomputers and the developed proofs of concepts that will demonstrate great potential to solve currently intractable computational challenges, or to improve time-to-solution and energy-to-solution for important use cases.

In 2023, the JU will launch:

- a Pre-Commercial Procurement (PCP) focused on the development of European technology and their integration in pilot systems that demonstrate a significantly reduced energy footprint for typical expected workloads on EuroHPC systems.
- an 'HPC Energy efficiency R&I Call' to develop new technologies that will drastically reduce the energy consumption of future EuroHPC supercomputers. The activities should address the development of pilot systems that demonstrate significantly reduced energy footprint for typical expected workloads on post-exascale EuroHPC systems.
- an Innovation Action in low latency and high bandwidth interconnects will support the R&I technology development of innovative and competitive European HPC inter-node interconnection technology.

### 1.6.4 Applications and Data

A call was launched in 2021 to select Centres of Excellence (CoEs) which will support collaboration between HPC users and experts to ensure that future exascale EuroHPC systems are accessible to European researchers and industries and address current scientific, industrial, and societal challenges.

As a result, Grant Agreements were signed in 2022 creating ten Centres of Excellence, leading to the choice of 10 proposals in science and innovation, or working towards exascale, in many domains, including climate and weather, drug development, astrophysics and cosmology, urgent computing, plasma science and engineering. The most prominent codes, or flagship codes, developed by the Centres of Excellence will be deployed on all EuroHPC supercomputers and will be made available for European scientists and the broader European HPC community.

To fill the gap in some under-served disciplines and services, EuroHPC launched in 2023 an additional call for selecting additional CoEs in the scientific domains of personalized medicine, digital twins, energy, and neuroscience, and performance optimisation of HPC applications.

In addition, in 2023, a call will be launched to start developing Quantum Centres of Excellence.

#### 1.6.5 Usage and Skills

A major focus of the JU's activities has been to ensure that the HPC community is ready for the newly available systems.

- A EuroHPC Master's programme call was launched in 2021 and a grant was signed in 2022 to support a pan-European consortium of universities, led by the University of Luxembourg, to provide a MSc programme in HPC.
- A grant for a pan-European network of National Competence Centres (NCC) was signed (EuroCC2) in 2022. The NCCs were launched in 2023.
- A Coordination and Support Action (CSA) on NCCs and CoEs grant agreement was signed (CASTIEL) in 2022. This project coordinates the activities of EuroHPC CoEs and NCCs, particularly in the field of best practice and training.
- A call on HPC Professional Traineeships and a call on to develop a EuroHPC training platform and summer school were launched in 2022.
- A study was launched under procurement to understand the different user requirements in academia, SMEs, and industry in 2023.

#### 1.6.6 International Cooperation

- An International Cooperation call with Japan was launched in 2022

# 2. Pillars of Action

## 2.1 Infrastructure procurement

In line with the Regulation, EuroHPC JU shall organise activities for the acquisition, deployment, upgrading and operation of the secure, hyper-connected world-class supercomputing, quantum

computing and data infrastructure, including the promotion of the uptake and systematic use of research and innovation results generated in the Union.

Access to the EuroHPC JU infrastructure is provided for free to the European user community and is governed by the EuroHPC Access policy which is available on the EuroHPC JU website.

The following table is indicative and summarises the acquisition strategy for the 2021-2027. Based on the experience to date, the process of acquiring a EuroHPC JU supercomputer takes over two years.

**Indicative overview of HPC acquisitions (2021-2027)**

| | 2020* | 2021* | 2022* | 2023-2024 | 2025 - 2027 |
|---|---|---|---|---|---|
| HPC Infrastructure | 5 peta-scale HPCs<br>and<br>3 pre-exascale HPCs procured | 4 petascale deployed | Two pre-exascale HPCs deployed<br>Hosting Entity for one exascale systems (high end) selected<br>Hosting Entity for four midrange HPC systems selected | 5th petascale deployed<br>Third pre-exascale HPC deployed<br>Hosting Entity for second exascale systems (high end) selected<br>Hosting Entity for additional midrange HPC system to be selected<br>Hosting Entity for industrial mid-range system to be selected<br>Midrange HPC systems deployed | At least two high-end HPC systems (exascale / post-exascale) deployed<br>A number of industrial mid-range systems deployed<br>A number of mid-range HPCs deployed<br>Hosting Entities for post-exascale systems (high end) selected |

(*completed)

**Indicative overview of quantum system acquisitions (2021-2027)**

| | 2020* | 2021* | 2022* | 2023-2024 | 2025 - 2027 |
|---|---|---|---|---|---|
| Quantum Infrastructure | | | 6 Hosting Entities selected | 6 First generation of (experimental) NISQ[9] quantum computers and simulators<br><br>Selection of additional Hosting Entities | Procurement of next Generation NISQ Quantum Computers |

### 2.1.1 HPC infrastructure

Since 2022, the JU has begun to acquire and deploy mid-range supercomputers complementing the top-ranked systems. These supercomputers are co-owned by the EuroHPC JU and Member States. For these supercomputers hosting entities can choose short running innovation partnerships to acquire systems that are tailored to their needs. EuroHPC JU will continue to launch Calls for Expression of Interests to host mid-range supercomputers in each yearly Work Programme.

Starting 2023, the JU will acquire and deploy two top leadership class exascale supercomputing systems owned by the EuroHPC JU. At least one exascale supercomputer should be built with a significant amount of technology based on HPC technology development in Horizon 2020, Horizon Europe, and EuroHPC emerging processor and accelerator technologies

From 2025, the JU will acquire one or more high-end supercomputing systems (exascale /post-exascale) owned by the EuroHPC JU and developed with the most advanced technology available and achieving exascale levels of performance. The EuroHPC JU could act as first user and acquire high-end supercomputers that integrate demand-oriented, user- driven, and competitive technologies primarily developed in the Union.

Subject to support from Industry and SMEs, the JU will also support the acquisition and deployment of industrial supercomputing systems for industrial users in cooperation with and

[9] NISQ: Noisy Intermediate-Scale Quantum

co-funded by private members of EuroHPC JU; adhering to industry specific requirements for increased security, data protection and availability. This initiative should foster collaboration between research and industry in both open and confidential research.

The JU should aim to develop application/community/domain specific systems, that could be optimised for specific use cases and support tools such as artificial intelligence.

### 2.1.2 Quantum computing infrastructure

Quantum computers and quantum simulators have recently evolved significantly and are seen as key future technologies that could change the world. These developments, however, have focused on hardware improvements and design of new quantum or hybrid quantum-classical algorithms. Integrating these systems into HPC environments brings new opportunities, but still requires significant efforts, particularly on the enabling software and the associated interfaces. This new paradigm also calls for investments to further co-design and develop new algorithms and applications, which requires the HPC and quantum computing communities to work together and share knowledge and experience. To achieve this, it is critical to give researchers and the industry access to state-of-the-art quantum systems. It should be emphasized that quantum computing has the potential to be a significant component of the technological sovereignty of the EuroHPC JU Member States. For these reasons, investment in the EuroHPC JU quantum-HPC ecosystem is of high importance.

Looking at current quantum technology developments, the focus is on hardware and algorithm development. Much of this has been driven by public investment, such as via the Quantum Flagship (translated into the Horizon Europe programme) which has concentrated on the development of core aspects of quantum technologies.

Following these efforts, EuroHPC JU shall harness quantum computing systems for European supercomputing.

It is important to highlight that, while industrialized devices are commercially available now, the expectation is that definite scientific and commercial advantage from quantum computers will arrive towards the end of the decade, while quantum simulators might achieve this advantage around the middle of the decade.

Regarding the current quantum computing landscape, the strategic goals of EU are in the digital domain, in the development of key technology and developments around sovereignty. The goal of the EuroHPC JU for quantum computing needs is to extend its HPC infrastructure with quantum computing capabilities in alignment with the Quantum Flagship developments, and to provide access to these machines to European users.

This requires equipping EuroHPC JU Hosting Entities with quantum computers and simulators together with enabling technologies, as well as fostering training and developing use-cases. In order to enhance European HPC capabilities through quantum acceleration, it is critical to develop full software stack based on European solutions that enable the operation of these heterogeneous systems and the execution and management of jobs.

This includes data, workflow and resource management, I/O protocols, signalling, software engineering methods and practices tailored for quantum and hybrid computing, and more. To benefit from these investments, it is also paramount to prepare the EU workforce for quantum technologies.

EuroHPC shall deliver the following actions in Quantum Computing. They will be synchronised to research and development activities on quantum computing to be undertaken within Horizon Europe.

- From 2023, the JU shall acquire state of the art quantum computers and simulators (experimental NISQ systems);
- From 2024, the JU shall start equipping major computing centres with the best available European quantum computers and simulators, some interconnected with high-end HPC machines as accelerators for specific applications, and accessible remotely, via the cloud;
- From 2026, the JU shall deploy state-of-the art quantum computers in the form of hybrid machines accessible via the cloud. The QC/QPU can be physically co-located with the HPC or connected remotely to the HPC via high-speed links, providing efficiently integrated classical-quantum information processing.

## 2.2 Connected and Federated Supercomputers

The JU will develop and deploy a federated, secure, and hyper-connected European HPC and data infrastructures that are accessible to researchers from academia, industry (including SMEs), and the public sector.

The infrastructures will be designed based on user requirements in highly flexible configurations tailored to a wide range of services, applications, and user needs. Associated data infrastructures will also be connected, allowing each category of users to manage its own data storage. It will provide a federated and coordinated access to all EuroHPC supercomputers, quantum computers and simulators, data repositories, knowledge and will also be the place where users will get access to the latest future technology to support innovate solutions.

EuroHPC JU aims to build a fully hyperconnected and federated infrastructure, providing end-to-end connectivity, performance, security and resilience which will underpin the development of a federated ecosystem. As an initial step, EuroHPC JU has commissioned a study on

hyperconnectivity which will provide a clear picture of the future requirements of users, systems and experiments.

By federating the EuroHPC ecosystem, all users, including SMEs, will get appropriate support to access secure services and European HPC expertise, knowledge, and tailored training services provided by Centres of Excellence and National Competence Centres.

The EuroHPC federated ecosystem will also be set up with a view to foster close cooperation with other European activities like EOSC (European Open Science Cloud) for science, GAIA-X, which has a focus on industrial and commercial services, , and in order to build links with future common European data spaces. Special attention will be given to industry friendly HPC federation services that stimulate the utilisation of the EuroHPC JU infrastructures by the private sector, especially SMEs.

### 2.2.1 Hyperconnectivity

In 2023, the JU will procure an independent study on hyper-connectivity for HPC resources. The result of the study should provide an exhaustive analysis of the communication and/or connectivity needs for the EuroHPC HPC (including quantum machines) and other relevant European and national supercomputing and data infrastructures (e.g. European common data spaces), available technology and service providers, and user landscape. It should facilitate an informed view of the implementation options, including the description of services to be provided, network architecture, implementation instruments, and budgeting. Finally, the study should provide the detailed specifications for the provisioning of the hyper-connectivity services to be provided to the EuroHPC JU, and investigate to which extent this may be achieved by extending of already existing infrastructures, such as GEANT and NRENs.

Based on the outcomes of the study, in particular the implementation roadmap and specifications, the JU will procure the deployment of the hyper-connectivity service.

### 2.2.2 Federation of supercomputing resources

EuroHPC JU shall focus on the deployment and operation of a platform for federating HPC and quantum infrastructure and resources providing Union-wide, secure services for a wide range of public and private users across Europe. Also, considering the current exponential increase of HPC use for AI, ML and NLP methods, this is an essential requirement to be able to satisfy the needs of new and emerging users whilst also ensuring ways to reduce the expected growth in the carbon footprint.

In order to achieve a self-consistent European federated and secure HPC service infrastructure ecosystem, EuroHPC JU shall initiate market assessments within European ecosystem which shall

include identifying existing or developing solutions which are aligned to the needs of scientific communities in Europe.

The outcomes of these assessments will be analysed in detailed and from 2023, procurements will be launched. These procurements will take into consideration not only the technical implementation of the federated and hyperconnected solutions (including both HPC and Quantum systems) but these will also include requirements for:

- common policies to use and interact in the infrastructure,
- security standards,
- organisation of coordination activities,
- long term support and services of the federated and hyperconnected solutions
- long term interoperability and sustainability aspect.

The federation of EuroHPC resources envisage to deliver the following services:

- Security and access control: A service that provides secure and controlled access to resources, including user authentication, authorization, and encryption following EU and national regulations.
- Discovery and access: A service that allows researchers to easily discover and access computing resources and data from multiple locations, including metadata search and retrieval;
- Transfer and movement: A service that enables fast and reliable transfer of data between supercomputing resources and data sources/lakes, including data staging, transfer protocols, and data synchronization.
- Carbon footprint: A service that tracks the resulting carbon footprint of these solutions

The JU shall promote these hyperconnected and federated infrastructures to the lower tiers of the national and institutional HPC operators. It shall also consider additional actions that could be performed in order to have more in depth knowledge about which performance, energy use and security of applications running on the systems and explore the use of confidential computing services in order to protect data and applications (while preserving performance).

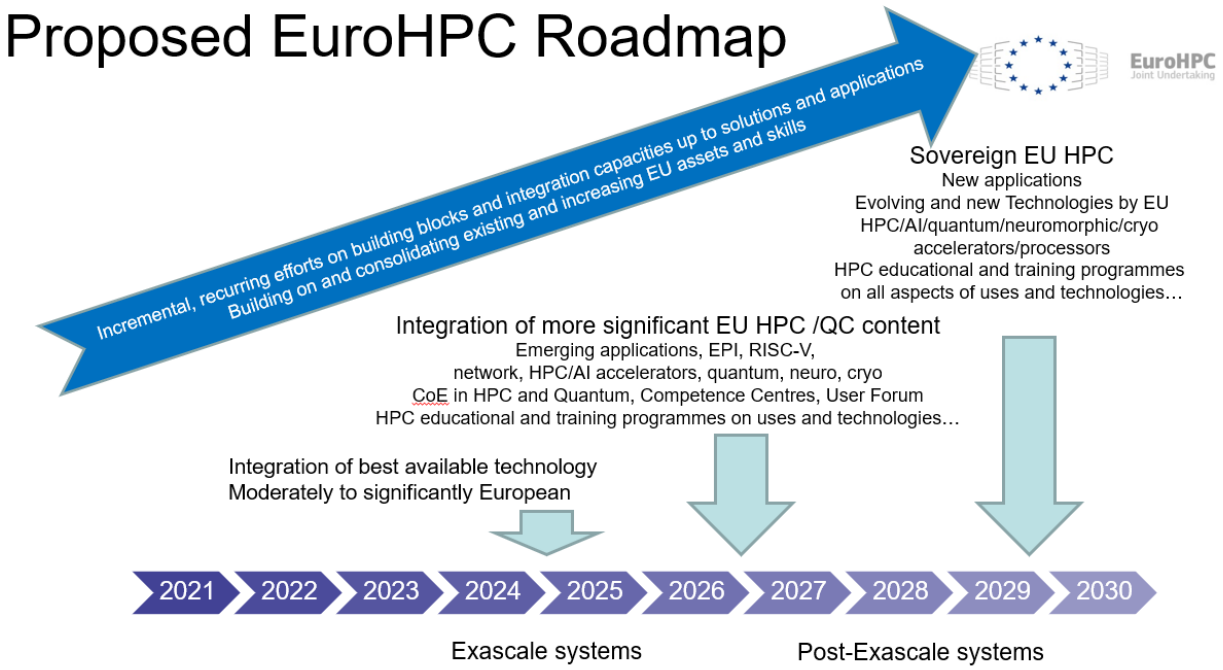
## 2.3 Technology

The competitiveness of the Europe's HPC infrastructure depends on the performance and availability of the most modern technologies. European HPC infrastructure overall performance depends not only on the performance of the supercomputers, but also on the stability and interoperability of each individual component. With large increases in digital networking, data and information are becoming increasingly valuable, in many cases eclipsing raw computing power. It is essential that state-of-the-art cyber security technologies and protocol protect data at all layers and provide secure access and use of the systems.

Technologies research and innovation must be state-of-the art and reinforce strategic sovereignty (as indicated in Council Regulation (2021/1173). Furthermore, they must guarantee early access to European technologies and lead in development of European IP.

Several assumptions were made regarding HPC technologies research and innovation that the JU shall invest in.

- the approach must be based on establishing what end-users need
- technology development should include, where appropriate, the principle of co-design
- technology development must support EU digital sovereignty.
- the approach must consider a resilient supply chain in a competitive European HPC and Quantum Computing ecosystem (supply-chain-readiness-level)




*The roadmap proposed by RIAG has provided a useful contribution to this plan. Progression is foreseen from "Best available technology" to "Integration of more significant European content".*

HPC technologies, including General Purpose Processors, accelerators and networks/interconnects, that are developed through EuroHPC JU calls must pursue energy efficiency goals, be innovative, be able to perform and compete globally, be production ready

and whenever feasible be ready to be deployed in industrial settings. RISC-V based solutions are a key element in the way forward.

These technologies need to take into account new usage models such as hybrid computing and the European Digital Twin initiatives. Technologies should also take into account other R&I activities ongoing in the European ecosystem such as those in big data analytics, AI, and neuromorphic and quantum computing.

A building block approach (see table below) to the whole Research & Development cycle is envisaged. While it is important to leave the door open to non-European suppliers in this process to foster competition and a diverse set of possible solutions, intellectual property (IP) gained in that process must remain in Europe.

EuroHPC JU started an iterative and modular approach where calls should be continuously launched to define building blocks and their interfaces, to develop these building blocks (hardware and software), and to integrate them into innovative HPC architectures for exascale and post-exascale.

The European Open Stack (EOS) is an open ecosystem for computing encompassing both hardware and software and fostering the development of co-designed systems required to advance European and global HPC.

EOS can be represented by a collection of hardware elements or specifications and software pieces such as development tools, system software, middleware, libraries – open source or not. EuroHPC JU calls in 2019, followed by pilot projects call in 2020 led to projects developing some of these elements.

The technology development shall be tied to large scientific and industrial use cases to make sure the development addresses the broader European market and contributes to the digital sovereignty beyond scientific HPC. Close co-design of suppliers with potential customers, as well as the HPC centres acquiring systems and the users of such systems should be encouraged and use-cases should be vertical to the EOS. Further details can be found below in the EOS section.

### 2.3.1 European HPC and Quantum Computing Supply Chain

The HPC supply chain ranges from core digital technologies and components (processors, memory, interconnect, disks, tapes…) to racks or any larger scale integration unit like containers, including thermal, electrical and mechanical equipment (incl. for energy supply and cooling), plus software stack from operating systems to middleware and programming environments and tools.

Attempting to reach a target of 100% European solutions is not realistic, if only regarding some parts or subcomponents, like memories, which are not designed nor manufactured in Europe.

Production facilities of other electronic or mechanical parts can sometimes be found in Europe or their production can be relocated to Europe. The final EU-added value eventually resides in the design and integration know-how of the subsystems, like for cooling, provided by either a supercomputer vendor itself, or by a specialised company providing the technology to a vendor/integrator.

In order to establish an innovative and competitive European HPC value chain, both the supply and the demand side of HPC, including quantum computing technologies, must be strengthened. The strategic EuroHPC JU R&I programme supports the development of HPC hardware such as microprocessors, similar to the European Commission's Quantum Flagship for quantum technologies. As a significant public procurer of HPC and quantum computing infrastructure, the EuroHPC JU will also support a development path up to TRL 8/9 including the deployment of indigenous technology developed in preceding European R&I projects. The coordinated investment in public R&I and public procurement provides an effective driving force towards a vibrant HPC and quantum ecosystem in Europe.

Software has still another status, in the sense it often combines openly available open source (possibly vendor-improved; possibly supported by a third party i.e. not for free) and proprietary pieces. Here again the EU added-value lies a lot in specific optimisations of middleware and in software stack integration know-how.

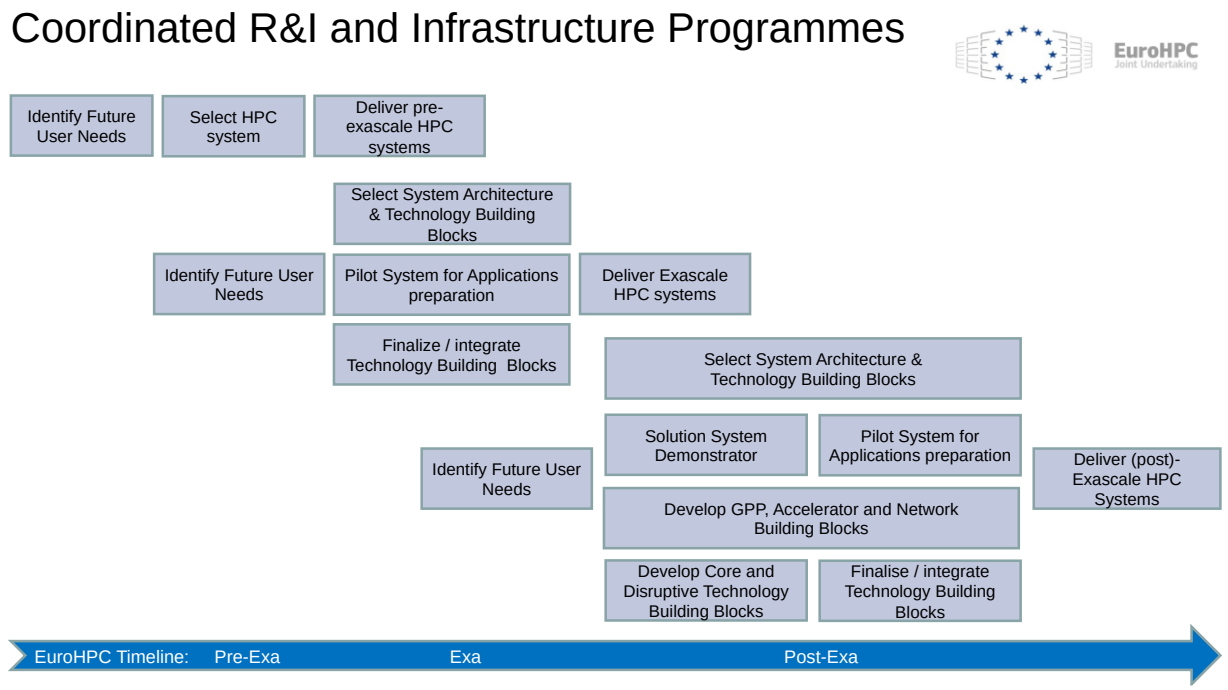
The European HPC supply chain currently consists of one large integrator, plus a number of SME integrators. They all rely on components developed and manufactured outside of Europe, however they all add various levels of European components and intellectual properties to their solutions. Several of them, are particularly strong on advanced cooling technologies. Europe is also the home of a number of independent software vendors (ISVs) developing software for HPC.

The European Commission followed by EuroHPC JU have supported the development of European HPC technologies through a large number of projects, including DEEP-SEA, RED-SEA, and IO-SEA, as well as the European Processor Initiative (EPI) and eProcessor which specifically tackled the need for European processor technology for HPC use. The EPI project has resulted in the development of an ARM-based low power General Purpose Processor (GPP) , which is currently coming to market and which EuroHPC JU expects it will be a key component in future EuroHPC systems.

The EPI project has provided the European HPC ecosystem with valuable experience in designing a General Purpose Processor. The JU will build on this experience when embarking on projects to use the RISC-V ISA as the instruction set for HPC processors.

Since HPC and quantum technology are both key technologies for Europe, developments around tech sovereignty, supply chain management and make-or-buy will have impact on the deployment of HPC, quantum computers and simulators the EU. It will be key to bring this in balance, create and execute a long term joint European strategy that support these developments.

In order to strengthen the supply chain, EuroHPC JU shall consider to provide holistic integration calls for support in the form of pilot technology demonstrators for HPC solutions. Since the elements are not clear at the moment, the strategy is to identify critical elements for the future in a first step and formulate a priority list for strengthening the supply chain in an updated version of the MASP.




### 2.3.2 European Open Stack (EOS)

EuroHPC JU will work with stakeholders to coordinate codesign in the R&I hardware and software activities and ensure that activities meet user requirements and deployment of these technologies. Calls shall be launched which will take each building block in HPC hardware and software from innovation to deployment. This activity shall be closely coordinated with ongoing development of applications.

EuroHPC JU shall also assess the different Technology Readiness Level (TRL) in order to assess which technologies to invest in. Developing the European Open Stack (EOS) whose standards and

interfaces will be part of the requirements in the HPC procurements. It could include actions on operating systems, compilers, runtimes, workflow frameworks, performance/energy analysis tools (as part of the EOS), numerical and I/O libraries. It needs to connect HPC with Quantum Computers and accelerate the development of middleware, including software engineering methods, tools and practices to support industrial take-up

The European Open Stack (EOS) should include:

- Ecosystem for European HPC processors including low-power processors, accelerators, interconnects shall be supported. In particular, the JU in a joint effort with the Key Digital Technologies Joint Undertaking shall support the development of low power General Purpose Processor (GPP) and accelerator technologies. These developments do not only target the state-driven supercomputer-market but primarily broader, industry-driven markets. Processor development shall be driven by industry use cases in cloud and server markets.
- Software Stack from operating systems to libraries as well as AI frameworks so as to foster the ease of use and compatibility of the EuroHPC machines from the user perspective.
- Integration of technology building blocks, based on modular principles, coordinating resource management across layers of the Software Stack into novel HPC architectures Technologies and systems for the interconnection of classical supercomputing systems with other, often complementary computing technologies, such as neuromorphic or quantum computing technologies.
- Technologies for operation and security of HPC systems that take industrial needs into account.
- Emerging computing paradigms and their integration into leading supercomputing systems, including High Performance Computing, AI and quantum computing systems
- Tools for deployment of industrial-oriented HPC infrastructure and associated software environments and service platforms for industrial innovation.
- Tools and procedures forming a minimal common layer of security services that could be a European standard to be implemented by all Hosting Entities.

### 2.3.3 Hardware Technologies

The competitiveness of the European HPC infrastructure depends on the performance and availability of the most modern Hardware technologies. HPC demands hardware compute component designs built in the best silicon technology nodes to provide the highest energy

efficiency and best performance. However, technology intersects many other facets of HPC, from packaging up to large-scale cooling solutions. Mission critical subsystems or components are storage hierarchies as well as high-speed interconnect networks. There are also new upcoming integration paths such as rack-to-container integration.

As HPC systems become more and more heterogenous, larger scale and eventually modular, it is important to focus on related underlying technologies' reliability, availability, serviceability, performance, security and observability. All these underlying technologies are critical for state of the art modular massively parallel systems. The infrastructure's overall performance no longer depends on the performance of just a single supercomputer, but also on the stability, availability, performance, and interoperability of each individual component from board to modules to the entire system. With large increases in digital networking, data and AI engines are becoming increasingly valuable, in many cases eclipsing raw computing power. It is also essential to establish software compatibility and that state-of-the-art hardware enabled cyber security technologies protect data at all layers and provide secure access and use of the systems. The JU will, via its Advisory Groups, monitor the developments in critical hardware where European Leadership is lacking. This may include asking its Advisory Groups to undertake a full analysis of the situation.

- **Ecosystem for European HPC processors**

Hardware technologies such as low-power processors, accelerators, interconnects will be supported by the JU. In particular, the JU in a joint effort with the Key Digital Technologies Joint Undertaking will support the development of low power General Purpose Processor (GPP) and accelerator technologies designed in Europe and taking into account RISC-V based solutions. These developments do not only target the state-driven supercomputer-market but also broader, industry-driven markets.

The development of an ecosystem for European HPC processors will contribute towards European technological sovereignty, by establishing, maintaining and implementing a strategic R&I roadmap that fosters the European capabilities to design, develop and produce the IP related to high-end processors and/or accelerators driven by relevant key performance indicators. The development of European processors and/or accelerators should prepare the technology for its future integration in post-exascale supercomputers to be acquired at a later stage by the EuroHPC JU targeting systems incorporating European technologies.

The RISC-V Instruction Set Architecture (ISA) is an open standard, an abstract model for the design of integrated circuits that defines how a microprocessor is implemented. By adhering to the standard, different implementations provide some degree of software binary compatibility.

The ISA specification with a free licensing model forms the basis for future processor developments, such that effort invested in building the software ecosystem is sustainable.

The RISC-V ISA has reached a level of maturity to demonstrate its viability as the de facto open ISA for future microprocessors and paves the ways for a new software/hardware ecosystem. The development of open hardware requires an ecosystem that supports the development of ideas through implementation in silicon and towards systems made up of different chips. The establishment of such an ecosystem requires careful guidance.

The RISC-V ISA presents two major opportunities for European R&I, both benefit from first-mover advantages. The first is to actively participate in the ISA definition, especially in HPC where there is less focus because there is less RISC-V traction. Second, European R&I can facilitate the development of HPC components and systems based on RISC-V implementations and the associated software ecosystem. Finally, the JU can define projects that facilitate paths from prototype to production and enable a new ecosystem to form and thrive, creating a central repository with well-defined IP rights and a common, business-friendly licensing model that provides a catalyst for European R&I in industry, especially for SMEs.

- **Network and interconnect technologies**

High-speed interconnect networks become of highest importance not only for monolithic architectures but in particular for the fastest possible integration of segregated resources and storage systems, as well as disruptive computing technologies like quantum computers and neuromorphic computers. Such technologies require sustained development and integration effort. High-speed interconnect components represent a significant part of the acquisition costs of state-of-the art supercomputers and are essential for strategic sovereignty in HPC.

EuroHPC JU has run multiple projects funding significant European research into this important field and the JU will continue to support and develop this further.

The world-wide market for HPC interconnect technology is currently dominated by a single non-European actor. There is therefore a real opportunity for European industry to gain market shares, also outside of Europe, if a competitive solutions can be developed.

- **Container technologies: a new option for HPC infrastructures and systems**

Integration of container-based supercomputing hardware technology, in addition to faster and more flexible deployment of systems (of small, medium, or large size), can help overcome energy-efficiency limitations, and create new redundancy and residency approaches.

The containers provide supercomputer building blocks one step further than racks: with pre-installed technical equipment – including power supply and cooling elements – for a full row of

pre-wired compute or storage racks, they can be assembled and connected to make up a full fledge system.

### 2.3.4 Software Technologies

The development of software technologies for HPC, including for quantum computing, will address a system software stack which connects low-level interfaces at the operating system level with HPC user and application programming interfaces. While the important role of open source and public domain software is acknowledged, the impact of open source software on a sovereign European value chain is often limited due to the lack of specific knowledge, capacity and control of the development. The competences for the independent development, maintenance and support of many critical software components for the operation of supercomputing environments are currently not available in Europe.

In line with the general R&I strategy of the EuroHPC JU, developments on a European HPC software stack for HPC will be guided by the principles of modularity, interoperability and open standards. The promotion of common interfaces on the basis of open standards is critical to develop an innovative, competitive, resilient and more autonomous HPC ecosystem. It will enable developers to select and implement possibly competing alternative solutions, the seamless substitution of software components and the rapid composition of new solutions.

Activities to support the development of a system software stack will account for the diversity of the European software ecosystem which involves many contributors from academic institutions, public organisations, independent software vendors, hardware suppliers and integrators. By pursuing a modular approach with focused grants on specific software developments with limited scope, the JU will build on preceding work and address the challenges of the evolving European HPC ecosystem, while maintaining inclusive and balanced funding support. Enforcing interoperability and promoting the adoption and contribution to open standards represent key elements for the implementation by the JU. Accordingly, the JU will structure calls for proposals to ensure individual grants will respect to a well-defined scope with clear boundaries to other software components.

The uptake of best practices for professional software development is a cornerstone for the implementation of JU's strategy on software technologies. Within JU funded actions, this will include requirements on the adoption of effective project monitoring and management, the automation of development and deployment, as well as the establishment of feedback loops with application developers and users. Activities supported by the JU should also include requirements for measures to increase the quality, reliability and security of the developed software as an integral part of the development cycle, and include well-defined, quantitative and measurable

KPIs, milestones and deliverables which allow swift and effective adjustments during the project lifecycle.

Priority domains for software technologies include the development and deployment of

- Dynamic elastic resource allocation mechanisms and effective resource management software for future exascale and hybrid HPC and quantum computing environments
- Software for monitoring and analysing usage (as part of the EOS), performance monitoring, energy and resource consumption patterns
- Relevant common benchmarks
- System software components contributing to the federation of the European HPC infrastructure
- Software for security related monitoring, protection, incident detection and response for the EuroHPC JU's infrastructure
- An effective common development and deployment mechanism for end user software such as a central continuous integration/continuous deployment platform and software container technologies

## 2.4 Applications and Data

The success of any technological infrastructure is determined by its impact on science, industry, and society. Performance indicators such as theoretical flop performance, synthetic benchmarks or scaling behaviour of individual jobs to an entire HPC system may help to guide developments but do not reflect the impact of these investments. The impact is measured by the outputs and results of innovative, efficient applications that fully exploit available HPC technology for real use cases. To date, Europe has an enviable record in application development and is world-leading in many academic and industrial domains. To maintain these leading positions constant efforts are needed as applications need to adapt to new hardware technologies, incorporate new algorithm, adaptable codes and scientific methods, and improve their efficiency and scaling on existing and future systems. In addition, scientific workflows often require combining different applications and associated data flows which is a great challenge for the implementation of effective resource allocation mechanisms on supercomputers and the optimal use of available resources.

European HPC users are not a homogeneous body, but span a broad spectrum of skills, knowledge, and experience in developing and using HPC and quantum applications. The challenges now faced are centred around preparing existing applications (academic and commercial) for the known EuroHPC architectures and designing new algorithms, methods, and applications that run and scale to match future hardware developments and are fit to tackle upcoming scientific challenges. Application software development is a long-term effort and constant improvements are needed to maintain the relevance of applications.

The JU has already funded several Centres of Excellence (CoEs) for HPC Applications and launched a call to support algorithm development to prepare for the post-exascale era.

To address the challenges associated with the increasing complexity of software development on heterogeneous HPC architectures, the general shortage of skilled developers and the general objective of achieving more modular, sustainable, reusable, reliable and higher quality software, the JU shall:

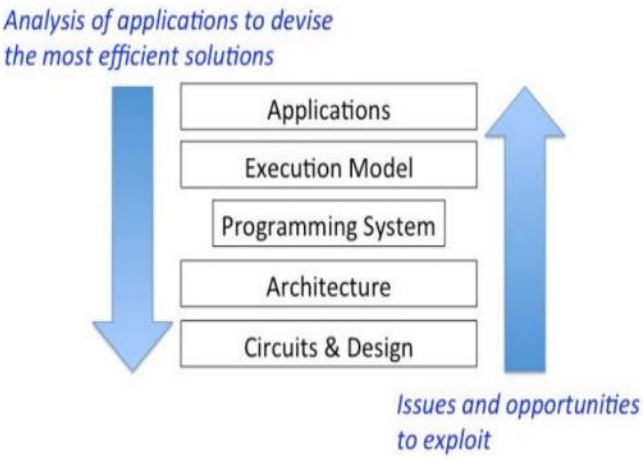
- Provide continuous support to the development and improvement of important applications in a wide range of scientific and industrial areas
- Prioritise the usability and accessibility to the EuroHPC systems, in particular for new users and key areas such as Artificial intelligence and Digital Twins, with tools and methods aimed at widening the access to different systems and architectures while ensuring performance and portability of the applications.
- Promote modularisation of applications by identifying common software building blocks and supporting their redesign using specialised software libraries to exploit synergies between applications and simplify the development of new applications
- Prioritise the development of software libraries for applications to accelerate application readiness for new architecture and address horizonal and cross-cutting elements, such as artificial intelligence and energy efficiency.
- Support new usage methodologies for interactive execution and elastic scheduling for dynamic allocation of resources based on workloads, in particular for AI workloads.
- Support the harmonisation of programming models and concepts, quality standards as well as best practices in software engineering.
- Address the challenges and limitations arising from legacy code present in many applications

### 2.4.1 HPC Applications

Through this pillar of activity, EuroHPC JU aims at achieving excellence and maintain European world-leadership in HPC and quantum applications that are key for European science, industry, and the public sector. Scientific and industrial HPC codes, applications, and software packages in key areas for Europe shall be codesigned, developed, ported, and optimised to fully exploit the performance of current and future computing systems. They will also need to integrate the worlds of simulation and AI to facilitate hybrid workloads, such as AI-enabled simulations or larger workflows consisting of alternating AI/ML and HPC steps.

- Support for HPC-powered codes, applications, and tools in all phases (such as in co-design, development, porting, re-structuring, optimisation, up scaling, interoperability, re-engineering, etc.) in critical domains for extreme scale computing and data performance.

- New methods and tools for facilitating and widening the access to different systems and architectures while ensuring performance and portability of the applications, and energy efficiency
- Novel approaches combining HPC, AI and HPDA for cybersecurity applications, for example preventing or responding in real-time to cyberattacks.
- Development of quantum computing testbeds and platforms for quantum applications and services. The availability of quantum computer emulators on top of the existing HPC infrastructure could help to accelerate the development of applications for quantum computers.
- Identification of applications areas that need additional support to meet the diverse European user community needs.
- Development of common APIs that allow the interoperability of Big Data and AI workloads, which are typically deployed in public clouds (e.g. GAIA-X), with HPC infrastructures.




The JU shall continue the development of HPC and quantum applications, exploit synergies and, develop novel algorithms, codes and tools optimised for future generations of supercomputers. Further development and sharing of methodologies for analysis and parallelisation should constitute a transversal spine to sustain a holistic multi-domain applications scope.

### 2.4.2 Growing the quantum applications ecosystem

To unlock the potential of quantum computing, there is a strong need not only to develop advanced quantum hardware but also to bring European users of quantum technologies together and facilitate the development of quantum applications and use cases. European Quantum Excellence Centres (QECs) shall play a key role in this. They shall foster the development of an

ecosystem of quantum programming facilities, application libraries, and a skilled workforce, the discovery of new applications for quantum computers and software engineering principles, fostering knowledge and uptake for these technologies.

These Quantum Centres of Excellence should develop quantum applications that can solve real-world problems. This could involve collaboration between Quantum Excellence Centres and industry partners to identify challenges that can be addressed using quantum computing and then developing applications that can solve those challenges. Developing quantum programming facilities and application libraries that can support the development of quantum applications, involving the establishment of open-source libraries and platforms that can be used by developers to build quantum applications. The EuroHPC quantum hardware can support the development of quantum applications and software for integration (middleware), as well as the establishment of testbeds for quantum technologies.

In order to foster collaboration between HPC and Quantum communities toward hybrid HPC/QC, the JU should explore the development of novel hybrid quantum algorithms and setup tailored programmes to engage and support end users communities through concrete PoCs (proof-of-concepts) gathering experts from QC startups, academia and end users (including SMEs and large-companies).

### 2.4.3 Data and Artificial Intelligence

Data and Artificial Intelligence (AI) communities in Europe also need to be included quickly in the HPC ecosystem to respond to the exponential increase in HPC usage of AI. Actions dedicated to integrate the HPC and Data Space ecosystems should be considered addressing industrial and scientific use cases, including HPDA and AI use cases. Furthermore, actions dedicated to the scaling out of AI models (e.g. in natural language processing, vision or toward multi modal approaches), should be considered, fostering the use of leading edge HPC facilities and access to large datasets, and optimised frameworks and support services. At the time of writing, it is broadly known that new requirements of efficiently using AI on HPC systems are not to be underestimated. The JU will work with its Advisory Committee to establish the areas of actions that could be considered. It is clear that cutting-edge Machine Learning (ML), Deep Learning (DL), and the use of Large Language Models (LLM) can significantly benefit from HPC systems. Actions dedicated to integrating the HPC and data-driven communities (e.g., Common European Data Spaces[10]) ecosystem could be considered addressing industrial, governmental, and scientific use cases, including HPDA and AI use cases. The following key actions will need to be taken into

[10] Common European Data Spaces, Online: http://dataspaces.info/common-european-data-spaces

consideration to ensure a broader uptake of HPC/AI methods across a wide range of communities:

- Access to EuroHPC systems with specific HPC/AI tooling
- Deploy and advance HPC workflow tools for AI and HPDA, including MLOps
- Provide advanced expertise in using efficient HPC/AI methods at scale
- Sharing AI/HPC methods scalability findings in the light of energy constraints in Europe. Specific actions dedicated to the scaling out of AI models (e.g. in natural language processing, vision, sequence, or toward multi-modal approaches), should be considered, fostering the use of leading edge HPC facilities and access to large datasets, and optimised frameworks and support services.

The JU could also develop an understanding of new HPC/AI requirements needs to engage in Digital Twins and other AI models that support different applications in the field of sustainable energy production (e.g.: wind farms), healthcare, climate research, etc. It is important to note the increased importance of digital twins in research and industry. Thus, this is another area where the development of applications should be supported for these end users' communities. Priority should be given to the following topics:

- Tools enabling HPC workflows for AI and large data analytics workloads, e.g., with software containers
- Techniques for supporting the interactive access to large datasets and their management in HPC systems.
- Reusable methodologies and tools for the development of a wide range of digital twins involving the coupling of traditional HPC simulation and modelling with computationally intensive artificial intelligence training processes and access to large datasets. While this is the case for digital twins, the use of coupling is also considered in other traditional HPC communities (e.g., computational fluids dynamics).

## 2.5 Usage and Skills

To enhance Europe’s competitiveness, boost its technological and data sovereignty, and strengthen European innovation, the European HPC ecosystem made up of the JU, Member States, HPC research institutes, the Centres of Excellences (CoEs) and the National Competence Centres (NCCs) need to work together to a generate a highly knowledgeable, world-leading scientific and industrial community.

EuroHPC JU has launched two calls in support these objectives: the EuroHPC Professional Traineeships and EuroHPC Training Platform and Summer School. In addition, the EUMaster4HPC project is ongoing to educate the next generation of HPC experts.

EuroHPC JU will support the development of digital skills, professional training and education, attracting engineering knowledge and human resources to HPC and increasing Europe's workforce skills.

More actions will be considered to develop and retain a European talent pool in HPC and develop viable and rewarding career paths for research software engineers and other key roles. Support to increase EuroHPC competences will come with the Competence Centres nationally and will support the European ecosystem of users and developers.

To facilitate constructive dialogue with existing and new users, the JU will explore the establishment of two consultative groups which are a User Forum and a Scientific Advisory Committee. These groups should support RIAG and INFRAG and provide reliable, sustainable feedback to the governance bodies of the EuroHPC JU on current and future infrastructure requirements and strategic advice for the development of targeted use cases and a renewed scientific and industrial case. They will also serve to disseminate the range and availability of EuroHPC infrastructure, training, and skills to new and existing user communities.

### 2.5.1 National Competence Centres (NCCs)

It is essential to extend the use of supercomputing to a wider range of scientific and industrial users, for instance by helping SMEs develop innovative business cases using supercomputers and providing them with training opportunities and critical HPC skills they need. Investment in HPC National Competence Centres is promoting a wide coverage of HPC activities and expertise in the EU and is providing specific services and resources for industrial innovation (including SMEs);

The HPC National Competence Centres were created by the Commission in 2020 and were strengthened in 2022 to prioritise and support exchange of best practices, the sharing of existing libraries of HPC codes and access to upgraded HPC application codes.

The National Competence Centres facilitate access to the best HPC and data intensive codes and tools and innovative scientific and industrial applications in collaboration with Centres of Excellence and Digital Innovation Hubs. This includes federating capabilities, exploiting available competences, and ensuring that application knowledge and expertise has the widest geographical coverage in the Union. HPC Competence Centres and HPC Hosting Entities work together to facilitate access to large-scale High-Performance Computing enabled pilot demonstrators and testbeds for big data applications and services in a wide range of scientific and industrial sectors.

In addition, ongoing collaboration with HPC National Competence Centres work and HPC Centres of Excellence is providing user input into the development of HPC technologies and applications.

Furthermore, in order to strengthen the ongoing deployment of first quantum simulators and computers by EuroHPC, JU could setup projects that would pull together QC Hosting Entities and National Competence Centres with the objective of fostering collaboration between HPC and Quantum communities toward hybrid HPC/QC.

### 2.5.2 HPC Skills

The development of a skilled workforce is one of the most sustainable investments in HPC with the potential for long lasting impact in a rapidly changing environment. Europe needs skills in highly specialised hardware and software development in order to support HPC infrastructure, federated resources and services, technologies, and applications. Europe needs an increase in HPC skilled workforce who can compute sustainably, that is diverse and gender balanced. This workforce is critical to support the design of emerging European HPC technologies and applications, the running of existing HPC and quantum systems and the provision of support to users.

Training, skills, and support are cross-cutting topics relevant to technologies, applications and chip design.

EuroHPC JU shall consider actions in the following domains:

- specialised training for HPC specialists, application developers, advanced users of HPC applications and related topics should be offered
- short-term, industry-specific training schemes, for example combined with consultancy and trial use of HPC infrastructures through hosting entities and competence centres
- SME-tailored courses and support offerings like staff exchange programmes with research and academia. For end-user SMEs, this could include hands-on training and solving real use cases, developed in cooperation with the competence centres and the European Digital Innovation Hubs.
- Encourage mobility and supporting training projects that also include the opportunity to study/train in another European Participating State
- skills for emerging technologies such as quantum computing should be considered
- skills to support development or energy efficient and sustainable solutions in HPC technology and application design

EuroHPC JU has launched two calls in support these objectives: the EuroHPC Professional Traineeships and EuroHPC Training Platform and Summer School. In addition, the EUMaster4HPC project is ongoing, with the goal of educating the next generation of HPC experts. Furthermore, the CoEs shall offer specialised training for HPC specialists as well as IT and data professionals, application developers, and advanced users of HPC applications.

In 2023, the EuroHPC Virtual Academy Call shall be launched. It shall seek to develop a European HPC training framework which shall set out a common HPC skills-tree where all levels of users and skills need to be carefully defined and classified. The Virtual Academy shall also develop a catalogue of training programmes and courses which are made available in Europe through EuroHPC Hosting Entities, CoEs, Competence Centres and EDIHs, industry and SME partners, PRACE and other recognised HPC training organisations.

The EuroHPC Virtual Academy learning framework shall identify different 'learning tracks' depending on whether the person is seeking to be trained to be a 'designer of HPC Technology, 'a user' 'or 'a provider of HPC Services', and whether they need specific skills specific to a type of HPC or Quantum Technology, application, or use case.

A first step shall be to build an inventory of existing training portfolios across Europe. Existing HPC training courses shall be classified and modified in accordance with the established framework standardised skills tree.

In parallel to these activities, a portfolio of common European HPC training material should be established and a EuroHPC portal developed where the currently existing HPC training material as well as future new material for teaching the advances of the future technology developments that do not exist now can be accommodated.

In order to exploit and leverage the European HPC training materials developed in the EU projects, a suitable repository is needed. As a result, a EuroHPC shall create, implement and maintain a reliable and long term EU repository that can safely store all the training materials developed within the EU projects (e.g. all the EU CoEs and CCs) and then make it available through internet to the EU Citizens. This facility could also serve as repository for the HPC training material provided by the Participating States.

EuroHPC JU shall also consider a training certification scheme which could be adopted by all European actors and should be embedded with the digital identity of the user giving possibility to access the European HPC systems based on the level of knowledge the person obtained.

All the above activities focused on EU Citizen participation, need to implement the State-of-the-Art of Learning Methodologies, including alternative forms of learning methodologies — such as student-centred instruction, participatory learning, hands-on learning, open learning etc. - should be implemented.

### 2.5.3 Users

**User Forum:** A EuroHPC User Forum will be created in 2023 by the EuroHPC JU. It shall promote knowledge exchange, professional development, and collaboration within the European HPC and Quantum communities. It shall be open, inclusive, independent, transparent, and responsive to the needs of its members. The Forum shall be made up of users from academic, industrial and public sector sectors. It is an open group where discussions cover updates from EuroHPC, current

developments in the European HPC community and report on difficulties and issues they face using the EuroHPC JU infrastructure. It is not however a forum for vendors.

The creation of the EuroHPC User Forum shall have the following aim, support, and governance:

- The aim of the User Forum is to foster structured, coherent, and regular communication and exchange with all user communities and stakeholders;
- The mission and goals of the User Forum should be clear, concise, and relevant;
- The User Forum shall facilitate open consultation with user and scientific communities that also serves to highlight the EuroHPC vision;
- The User Forum shall have dedicated administrative support from the JU to ensure its sustainability and effectiveness;
- The JU shall establish a governance structure responsible for overseeing the Forum's activities and to collate and communicate feedback on user requirements to the Advisory Groups of EuroHPC as necessary;

**Scientific Advisory Committee:** the EuroHPC JU also needs the coherent, independent expertise and strategic vision of a world leading high-level scientific advisory committee. Indeed, a large amount of the available compute resources in Europe are requested and used by scientific groups from universities and public research centres on daily basis.

As far as research and innovation is concerned, these academic users are an indispensable source of guidance. They work on a wide range of different scientific disciplines (astrophysics, particle physics, climate, weather, earth science, life science, energy or engineering)[11] and also from scientific fields not traditionally acquainted with HPC (e.g., social sciences, digital humanities). These academic users could provide advice to INFRAG, RIAG and EuroHPC JU and be part of the User Forum.

The JU shall consider the creation of a specific Scientific Advisory Committee (SAC) with a consultative role, which would be composed of recognised world high-level experts from across domains to provide coherent, independent expertise and strategic vision to EuroHPC. The Committee should, for example, propose scientific cases for post-exascale supercomputing.

## 2.6 International Cooperation

In line with the external policy objectives and international commitments of the Union, Europe should define, implement, and participate in international collaboration on supercomputing to

[11] see PRACE scientific case 2018-2026 ISBN: 9789082169492)

foster research which addresses global scientific and societal challenges, while promoting competitiveness of the European HPC supply of technologies and user ecosystem.

The EuroHPC JU shall support international cooperation in supercomputing between European and Non-European partners in the following topics: scientific cooperation, EuroHPC JU Research and Development projects, reciprocal exchange of access time between EU and non-EU systems, exchange of young HPC professionals and EuroHPC JU supercomputer procurements. It will also monitor closely activities related to the HPC sector as well as evolving user needs outside the European Union.

The JU will implement, with guidance from the European Commission, the different types of HPC cooperation with likeminded third countries and regions, including those with existing or future Digital Partnership and cooperation agreements. Each activity will need to be approved by the Governing Board based on external EU foreign and public policy considerations, in particular, the HPC and Quantum Computing related aspects of the Digital Partnerships signed by the Union.

## 3. Activities with other Joint Undertakings and EU activities

EuroHPC JU shall work very closely with the European Commission to ensure that its activities are undertaken in close cooperation and coordination of other activities organised by the Commission including the EU Chip Act, the EU Quantum Flagship and shall monitor development in EOSC, GAIA-X, etc.

Furthermore, EuroHPC JU shall work closely with our sister JU, the newly created 'Chips' JU (formerly Key Digital Technologies JU) and the newly created Cybersecurity Competence Centre.

## 4. Annexes

### Regulation 2021/1173

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R1173&from=EN

### Infrastructure Advisory Group (INFRAG) Input (2019)


EuroHPC INFRAG - Multiannual Strategic

## INFRAG MASP: Updated Topics and Recommendations (February 2023)

2023MASP_UpdateTopics_and_Rationale_

## Research and Innovation Advisory Group (RIAG) Input (2020)

EuroHPC JU RIAG MSRIA 2021-2022 v11

## RIAG proposal for MASP 2023-2027 (February 2023)

RIAG Proposal for MASP 2023-2027.pdf

## Commission Staff Working Document (attached to Regulation 2021/1173)

4Annex2part2pdf (4) Staff.pdf