Computing and Informatics, Vol. 39, 2020, 622–643, doi: 10.31577/cai_2020_4_622

EUROPEAN HPC LANDSCAPE

Florian Berberich

PRACE aisbl and Jülich Supercomputing Center
Forschungszetrum Jülich GmbH
52428 Jülich, Germany
e-mail: f.berberich@fz-juelich.de

Janina Liebmann, Veronica Teodor

Jülich Supercomputing Center
Forschungszetrum Jülich GmbH
52428 Jülich, Germany
e-mail: {j.liebmann, v.teodor}@fz-juelich.de

Jean-Philippe Nominé

ETP4HPC and Commissariat à l'Énergie Atomique et aux Énergies Alternatives
DAM, DIF
91297 Arpajon, France
e-mail: Jean-Philippe.NOMINE@cea.fr

Oriol Pineda

PRACE aisbl and Barcelona Supercomputing Center
Carrer de Jordi Girona, 29, 31
08034 Barcelona, Spain
e-mail: oriol.pineda@bsc.es

Philippe Segers

PRACE aisbl and Grand Équipement National de Calcul Intensif
6 bis rue Auguste Vitu
75015 Paris, France
e-mail: philippe.segers@genci.fr

Abstract. This paper provides an overview on the European HPC landscape supported by a survey, designed by the PRACE-5IP project, accessing more than 50 of the most influential stakeholders of HPC in Europe. It focuses at Tier-0 systems on the European level providing high-end computing and data analysis resources. The different actors are presented and their provided services are analyzed in order to identify overlaps and gaps, complementarity and opportunities for collaborations. A new pan-European HPC portal is proposed in order to get all information on one place and facilitate access to the portfolio of services offered by the European HPC communities.

Keywords: European Commission, EC, European, high performance computing, HPC, ecosystem, exascale, services, platform, EuroHPC, PRACE, ETP4HPC, CoE

Mathematics Subject Classification 2010: 68-00

1 INTRODUCTION

The European Commission (EC) recognised the need for an EU-level policy in High-Performance Computing (HPC) to optimise the national and European investments in the field and to coordinate the entire HPC ecosystem. To this end, on 15 February 2012 the EC strategy on HPC was published in the communication "High Performance Computing: Europe's place in a Global Race" [1]. Acknowledging the importance of HPC for society, science and industry the communication announced a joint European effort in order to increase the investments in HPC and promoting European HPC technology. This strategy is taking shape, with the creation of the EuroHPC Joint Undertaking (JU) [2].

As no single member state alone has the financial and human resources to develop a sustainable exascale[1] HPC ecosystem, within the European Data Initiative (EDI) subpart of the Digital Single Market (DSM) strategy [3], the EC has step by step increased the investment in HPC significantly [4], supporting with various projects and initiatives the three HPC pillars, as shown in Figure 1: Technologies, Infrastructure and Applications with a strong pan-European coordination. Moreover, a strong HPC ecosystem has been identified as mandatory to leverage the full potential of data in Europe, along with the need for providing more open data, coping with interoperability issues and fragmentation of access to data and digital services.

Back in time, first computers were supercomputers, by definition, the most powerful systems of their time, when computers were huge machines, dedicated to solve a specific industrial or academic problem that could not be addressed without them,

[1] Exascale: HPC systems at the scale of 10^{18} floating-point operation per second. US, Japan and China investments for exascale are of the order of one billion € each, to acquire these systems near 2020.

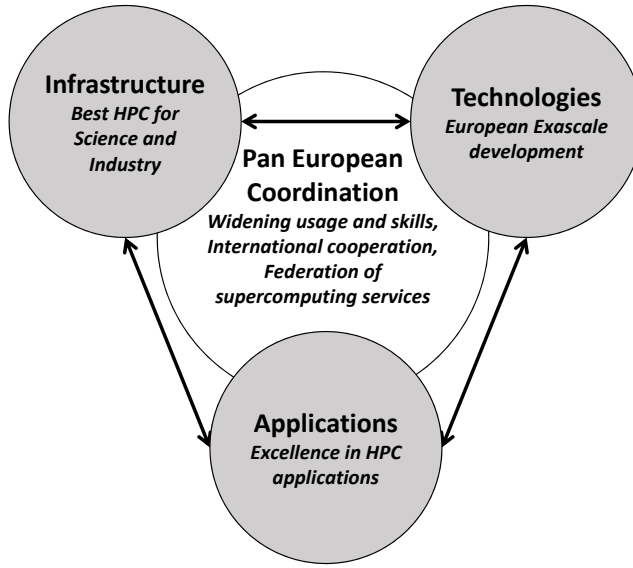

Figure 1. HPC ecosystem pillars

from the first Turing machine to the systems used for the Manhattan project [7] (Oak Ridge National Laboratory [9], one of the leading pre-exascale computing centre being a direct spin-off of this early development of supercomputing). In these early years, the three pillars worked together in each single project, designing the technology and the infrastructure to support it at the same time. The same people worked at the application to solve their problem with the system designed for that. It is only in a second phase that the industry diverged, with one branch that kept addressing the biggest problems of its time, on dedicated systems with specific technologies, a niche but also a strategic market. The second branch, mainstream, evolved to solve problems for a wider market, from industry to office applications, and eventually became the mass market that it is now.

With the rise of the information technology industry, computers becoming a huge mass market, HPC industry partially moved from specific technologies, especially on processor, to general purpose processors, when the number of parallel cores increased and it became more efficient to assemble many general purpose processors than fewer specific ones. Of course, other parts of a supercomputer still needed specific components, with higher performance than mass market components, such as the interconnect, because a supercomputer is much more than just many processors. But from that point on, HPC was not anymore the biggest driver of processor and chips technology, even if the processors used for supercomputers were still the high-end of technology providers, the portfolio of products was not anymore designed for them.

Nowadays, there is a clear distinction between Infrastructure, Application and Technology providers. But for the last miles of the exascale run, with the small leverage HPC could have on the whole information technology market, the co-design is more important than ever. A coordination is needed, especially at the European level missing the same intrinsic coordination as seen in the USA, China, Japan or other key players in the exascale league. Some specific coordination, research and innovation actions are needed at the European level to articulate the interaction of these actors in the most efficient way. Coordination will be also of the upper importance for future quantum computing technologies, which will be closely related to HPC but who will need the development of a new paradigm of the algorithm to solve problems in a way that takes advantage of the specificity of quantum theory, with the strength and weakness of their transposition to the computing industry. Efficiency will ultimately derive from the coordination of these three pillars. This article analyses the current situation, presents the three pillars of the HPC ecosystem, their services, with their overlaps and gaps, complementarity and opportunity for collaborations, and proposes a high-level service architecture.

2 THREE PILLARS OF THE HPC ECOSYSTEM

The European HPC Strategy is based on three pillars: Technologies, Infrastructure and Applications. Each organisation, project or initiative is linked to at least one of those pillars. These three pillars have the objective to serve the European HPC user community through a user-driven approach, with the relevant European HPC communities and user groups adequately represented in each of the pillars. The individual actors are described briefly in this section.

EuroHPC Joint Undertaking (JU) [2] was founded on 28 October 2018. EuroHPC JU will permit the EU and participating countries to coordinate their efforts and share resources with the objective of deploying in Europe a world-class supercomputing infrastructure and a competitive innovation ecosystem in supercomputing technologies, applications and skills. A good overview on the European exascale projects, (FETHPC and Centre of Excellence (CoE)) is provided by the European High-Performance Computing Handbook 2018 with an update 2019 [6].

This schematic view of a complex ecosystem of stakeholders should not be seen as something static, with homogeneous pillars and some formally established relation between them, but more like a dynamic "n-body" interactions, with constantly evolving needs and offers of these pillars. Actors are constantly interacting between these pillars, with some of them playing active roles on more than one pillar. To provide one short example, Technologies are evaluated through benchmarks of Applications, representative of typical workload of HPC Infrastructure, and co-design is part of the HPC culture with overlaps and complementarity among the pillars.

In addition to the three classical pillars also the convergence of simulation and big data workloads – due to the deluge of data coming from next generation scien-

tific instruments (satellites, (radio)telescopes, accelerators, microscopes, sequencers, etc.) – are becoming more and more important. The same development is being monitored in the case of Internet of Things (IoT), social media and large scale simulations (massive 3D simulations, multi-scale and multi-physics coupled simulations, ensemble/optimisation/scenario studies, uncertainties quantification, etc.).

A HPC infrastructure tailored to treat these large amount of data will be also indispensable for machine learning (ML) or artificial intelligence (AI). Data are involved in all three pillars. The Technologies pillar will develop systems designed especially for I/O or AI, the Infrastructure pillar will provide access to systems suitable for AI, and in the Applications pillar ML and AI algorithms will be implemented in codes [19, 26, 28, 30, 31]. Quantum computing, still at an early stage of industrial development, could also be represented by such three pillars, with promising development of technologies providing prototypes of bigger scale at a rapid pace. The work on the application side to reframe problems in a way that can be handled by quantum system is a very new field, in addition to the simulation of future quantum computer (with their specific "speed" of calculation but also their specific "error rate" related to the statistical nature of a quantum computation result). And lastly, the usefulness of such new technologies will be highly dependent on their implementation into existing or new infrastructure to be able to provide access to end-users.

2.1 Infrastructure

2.1.1 Partnership for Advanced Computing in Europe (PRACE)

The development of the European HPC ecosystem was initiated and pursued by the Partnership for Advanced Computing in Europe (PRACE) and its 26 partners in the past ten years. PRACE is supported by the PRACE member states and through the EU by a series of implementation phase (IP) projects [24]. Over the last decade, PRACE and its partners have given national HPC ecosystems a common European umbrella which is recognised as an ESFRI Landmark since 2016. PRACE was founded in 2010 as the European HPC infrastructure, with an investment above 400 million Euros from four hosting members for its first phase (ES, DE, FR, IT), with the objective of developing a persistent and pan-European HPC facility. In the second funding period of PRACE five European countries (with the addition of CH) committed to host leading-edge supercomputers on the highest performance level in Europe. Subsequent investments from all PRACE members (from 26 countries) and contributions from the EC have allowed the infrastructure to provide a continuous set of services, based on a peer-review process assessment of scientific excellence, awarding more than 25 billion core hours more than 700 research projects led by investigators from 40 different countries, from academia and industry. This large computing capacity has been complemented by high-level quality training and strong user support programmes (including support to SMEs), in order to foster the development of a solid HPC community in Europe.

PRACE, with a governance structure that includes the Scientific Steering Committee (SSC) and the Industrial Advisory Committee (IAC), underlined the urgent need for more compute cycles, and huge demands in terms of memory/storage capacities and performance in the recent Scientific Case 2018-2026 [11]. Also the need for new approaches, i.e. scaling via ensembles, deep learning, and statistical models are expressed.

In relation to EuroHPC JU, PRACE published its Position Paper: PRACE in the EuroHPC Era [10] which defines its current and proposed future services for the European HPC ecosystem. The following services encompass the PRACE offer:

1. Peer Review Access to HPC systems,
2. Support for industry (including SMEs),
3. Enabling of HPC applications,
4. Services for universities and user communities,
5. HPC training,
6. Promotion of HPC careers-gender balance,
7. Operational HPC services,
8. HPC procurement and prototyping support,
9. Dissemination and documentation for HPC services.

Many of the PRACE services (1–5) are also reflected in the different fields (see Figure 2) we defined for classification of the European HPC Landscape:

1. HPC Policy,
2. HPC Technology,
3. HPC Computing Services,
4. HPC Training,
5. HPC Application Enabling and User Support,
6. HPC Research.

Only HPC policy and HPC technology are not directly included in the PRACE position paper, because PRACE is not providing HPC policy and direct HPC technology, even if it provides some evaluation of technologies and guidance through a series of white papers and best practice guides [22, 23], illustrating the strong interaction already in place between those pillars.

2.1.2 GÉANT

GÉANT develops, delivers and promotes advanced network and associated e-infrastructure services for research and education, supporting open collaboration and knowledge-sharing amongst its members and the wider research and education community. The GÉANT Association BV [8] is owned by its core membership of the

European National Research and Education Network (NREN) organisations. Since coordinating pan-European research and education (R & E) networking on behalf of Europe's NRENs the GÉANT's role has evolved to that of a true services innovator, incorporating network planning, procurement, building and operation, as well as coordination of research programmes and development of innovative services. Working with NREN partners and the EC, the high-speed networks that they build and operate connect NRENs to each other and to the rest of the world, enabling scientists, academics, innovators and students to collaborate, regardless of their location. HPC current and future new exascale usages highly depend on the integration of core HPC services with data and network services.

2.2 Applications

The importance of a strong HPC applications ecosystem has been periodically highlighted by the PRACE SSC [11] and PRACE User Forum. This has been acknowledged by the EC [1] through the large funding allocated to this pillar. Applications are the core intellectual properties of many communities, a strong asset for European research, both in academic and industrial fields where Europe has often acquired a leading position worldwide. To coordinate the needed effort, Centres of Excellence in computing applications (CoEs) have been designed to address specific needs of communities (weather and climate, material science, medicine, etc.) or transverse needs (industry, algorithm, etc.). After a first selection of CoEs in 2015, the European Commission reviewed the communities supported by awarding a second generation of nine CoEs in 2018 [13], then an additional extra group of four in 2019 [32]. These cover a wide collection of scientific domains, including bioinformatics, biomedical sciences, climate sciences, energy and engineering, materials, social sciences and solid earth, as well as the transversal topic of computing performance, each of them covered by one CoE. The second generation of CoEs builds on the success of the first selection, and will highly contribute to strengthen Europe's leadership in HPC applications through their associated services, such as: developing, optimising (if needed re-designing) and scaling HPC application codes towards peta- and exascale computing; testing, validating and maintaining codes and managing the associated data; quality assurance; co-design of hardware, software and codes; consultancy to industry and SMEs; research in HPC applications; and addressing the skills gap in computational science. The FocusCoE project [33] supports the CoEs to more effectively fulfil their role within the ecosystem and ensure that extreme scale applications result in tangible benefits for addressing scientific, industrial or societal challenges.

This strong contribution to the applications pillar is further enhanced by the highly specific application developments of FETHPC projects and EPI (European Processor Initiative) [8], and with code-enabling activities of PRACE-IP projects and PRACE High Level Application Support Teams (HLSTs) [25]. Beside of that, new usage domains for HPC are developing, such as Humanities or Artificial In-

telligence, with different needs and constraints, requiring innovative ways to access resources.

2.3 Technology

The ETP4HPC Association [14] was created in 2012, to be the voice of the HPC suppliers and promote HPC technologies development, and in particular to prepare input and R & D recommendations to the EC in this area. In 2014 a "contractual Public Private Partnership" in HPC (cPPP) was signed between the EC and ETP4HPC association [13]. A significant fraction of the funding provisioned under this cPPP was assigned to a series of calls on HPC technology R & D [14]: the so-called FETHPC calls (part of the "Future and Emerging Technologies" branch of the successive H2020 Work Programmes). Between 2014 and 2018, 32 FETHPC projects were selected with a total funding of approximately 175 M€. Meant to develop HPC systems hardware and software building blocks in the areas of HPC node architecture, system and middleware, programming environment and tools, the FETHPC projects already produced a number of innovations and prototypes [15, 16], co-developed between technology suppliers (large companies or SMEs), research organisations and end users, sometimes leveraging other innovations dedicated to the wider market of data centres as a whole.

The ETP4HPC Strategic Research Agenda [13], updated every 2 years since 2013, has been the main source of advice and influence regarding the FETHPC calls contents. ETP4HPC also actively participates in the overall EU HPC ecosystem development. ETP4HPC members are technology suppliers and research organisations.

In addition, in 2017–2018 the EC also implemented an important new call to establish a Framework Partnership Agreement on European low-power microprocessor technologies to establish a stable and structured partnership between the EC and committed institutions and organisations. The EPI consortium was selected to co-design, develop and bring to the market a European low-power microprocessor, one of the core elements needed for the development of the European supercomputers with exascale capacity [18, 8]. The co-design aspect of EPI is a key factor to provide a next generation of processors that fully harvest the benefits of energy efficiency for relevant European applications.

Two years after its establishment, the EuroHPC JU [2] is now being implemented and ramping up. EuroHPC JU is taking over from the HPC cPPP to continue the HPC R & D funding towards exascale, from 2019 onward, more strongly coordinating the follow-ups of FETHPC and EPI projects. Members of the EuroHPC JU are the EC, 32 EU member and associated states, and the private members ETP4HPC and the BDVA (Big Data Value Association [30]). ETP4HPC is represented in the EuroHPC Research and Innovation Advisory Group (RIAG).

The outcomes of the cPPP phase – 2014–2018 – have been documented by the annual Progress Monitoring Reports (PMRs [27]). The 2018 PMR (published in the end of summer 2018) summarises this 4-year period of joint support of HPC

technologies and applications by H2020. In particular positive effects are observed regarding job creation (both in research and HPC supply industry in Europe), intellectual property creation, and private companies extra investments – which leverage the public funding effort in initial R & D in order to productise solutions and bring them to the market. A number of European SMEs in particular have been clearly benefitting from H2020 funding and correlatively augmented their staff, business and turnover.

Since the EC funded CoEs as well as FETHPC projects, it also supported the evolution and improvement of many HPC applications, in addition to many innovative hardware and software building blocks for HPC solutions. This helped CoEs contribute to evolutions of community codes (in terms of features and/or portability and/or performance improvement and scaling).

These efforts are now smoothly continued in the EuroHPC Research & Innovation Pillar from 2019 onward.

2.4 Pan-European Coordination

EuroHPC JU already set up two R & I work plans, for 2019 and 2020, the first two years of EuroHPC functioning in the context of Horizon 2020 framework programme. We describe the related calls for projects below. Since EuroHPC R & I Pillar encompasses all aspects not related to Infrastructure procurements and operations, we can find in these work plans a mix of calls that are related to either Technologies or Applications ecosystem pillars: The EuroHPC JU Workplan 2019 [34] encompassed two sets of calls for proposals:

1. Towards Extreme Scale Technologies and Applications which has two facets (a technologies call with support for hardware and software building blocks, and two calls relating to applications).
2. Innovating and Widening the HPC use and skills base has two calls on the users and skills we relate to the Applications pillar.

Regarding the "Towards Extreme Scale Technologies and Applications" call [35]:

- Nine selected projects addressing the topic 1, extreme scale computing and data driven technologies, are expected to address performance and efficiency of future exascale systems.
- Five selected proposals address the call topic 2, HPC and data centric environments and application platforms, and will focus on the development of energy-efficient HPC software. The projects are expected to demonstrate significant use cases and pilot systems.
- Five selected proposals address the call topic 3, industrial software codes for extreme scale computing environments and applications, and are expected to further develop, adapt and optimise HPC software for applications in the European industry.

With funding from the EuroHPC JU, EuroCC and CASTIEL projects will build a European network of 33 national HPC competence centres. The two projects will bridge the existing HPC skills gaps while promoting cooperation and the implementation of best practices across Europe. Each of the 33 national competence centres, which will be part of the EuroCC network, will act locally to map available HPC competencies and identify existing knowledge gaps [38].

The EuroHPC JU work plan 2020 has three main dimensions:

1. Two so-called pilot calls which are clearly related to Technologies pillar, with a system-wide vision, typically meant to integrate building blocks (previously developed or developed in the course of the new projects).
2. An EPI follow-up call, clearly a Technologies pillar aspect, compute hardware oriented.
3. A future call on Education and Training, on the side of Applications pillar addressing widening usage and skills.

EuroHPC work plan 2020 then planned different calls, two of them now being closed [37]:

1. Advanced pilots towards the European supercomputers,
2. A pilot on quantum simulator.

More generally, EuroHPC private members (ETP4HPC and BDVA) are sustaining the development and updates of their research agendas, together with the HPC wider ecosystem and leading stakeholders and representative entities such as PRACE, CoE representatives, AIOTI [28], and also with international collaborations (such as BDEC [30]). Taking into account not only Big Data but also AI and IoT trends in advanced computing is a necessity. The point is to develop HPC both towards extreme scale (exascale and beyond) and also to extend its use and insert it in a digital continuum from edge to cloud and bigger centralised but interconnected HPC centres. ETP4HPC and BDVA help the communities express recommendations and priorities towards EuroHPC Advisory Groups, and it is Governing Board which eventually decides on R & I funding.

3 ANALYSIS OF THE HPC LANDSCAPE

3.1 Summit

An HPC Ecosystem Summit was organised by PRACE on 14 May 2019 during the EuroHPC Summit Week 2019 in Poznan, Poland. The summit was attended by more than 50 representatives from the European Commission, PRACE, GÉANT, CoE and FETHPC projects, EXDCI and ETP4HPC, among others. The objective of this summit was to present current activities and discuss future roles and responsibilities of the key European HPC stakeholders within the landscape. The outcome of this

summit was expected to furnish a vision of the architecture and integration of the HPC services with European Open Science Cloud (EOSC) [29], EDI, data services, etc. for the communities. The discussion during this summit allowed to clarify the results of a preparatory survey and to define further stratification actions.

3.2 Survey

To prepare for the HPC Ecosystem Summit, a dedicated survey with 10 questions was sent to 81 contacts (coordinators of CoEs, FETHPC projects, EuroHPC JU, ETP4HPC, BDVA, GÉANT, FocusCoE, EPI, EOSC, EUDAT, OpenAire, eInfraCentral, EXDCI). For bigger projects or umbrella organisations only the coordinator of the project or organisation was contacted. The contacts were asked in more detail to indicate which of the three pillars they are part of, if they would be able to attend the HPC Ecosystem Summit in order to take part of the discussions, to indicate their specific domain and include a list of their services. Moreover, they were asked to indicate possible overlap and collaboration with other initiatives or organisations. The main part of the survey was the self-evaluation of the current actors concerning their role in the European HPC landscape provided through the answers to the following matrix, as shown in Figure 2.

	Developer	Coordinator	Provider	User/Beneficiary	Enabler
HPC Policy					
HPC Technology (industry, hard & soft)					
HPC Computing Services					
HPC Training					
HPC Application Enabling and User Support					
HPC Research					

- *Developer: institution in charge of preparing materials for the development activity*
- *Coordinator: institution in charge of collecting materials from developers and of coordinating their implementation*
- *Provider: institution in charge of providing the services to execute the activity*
- *User/beneficiary: institution that benefits from the activity*
- *Enabler: institution that enables the activity by providing the necessary services that are not part of the core of the activity*

Figure 2. Self evaluation matrix of the role in the European HPC landscape

3.3 Services

3.3.1 HPC Policy

EuroHPC JU is developing the policy in terms of funding and the main guidelines. The Research and Innovation Advisory Group (RIAG) and the Infrastructure Advisory Group (INFRAG) are the information gathering bodies in the EuroHPC JU. This will include inputs from PRACE, ETP4HPC and from CoE and FETHPC projects, as shown in Figure 3 a).

3.3.2 HPC Technology

The provision of HPC technology should be driven by the FETHPC projects and the European Processor Initiative (EPI) with the goal to develop European technology for exascale computing. Surprisingly, only some FETHPC projects see themselves as HPC technology provider. However, 80 % of the FETHPC projects declared to develop HPC technology. Some CoEs also indicated a contribution to the HPC technology, since there are some of them with a co-design approach, see Figure 3 b). A detailed analysis has been done by the EXDCI-2 project [5].

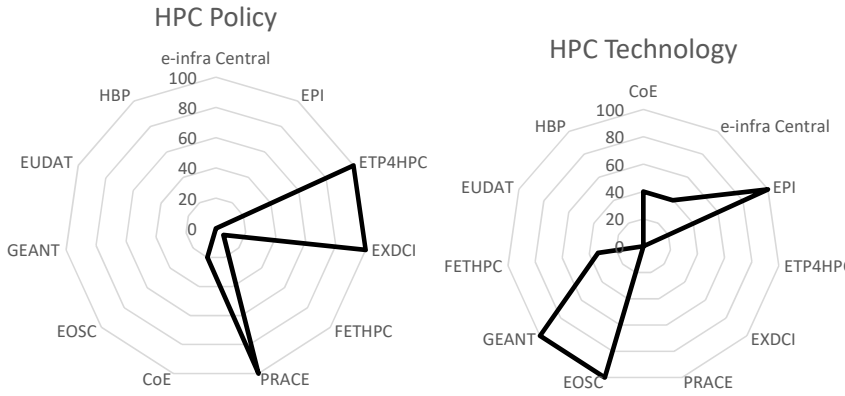

Figure 3. Provision of a) HPC Policy and b) HPC Technology in % of positive responses in the respective stakeholder groups

3.3.3 HPC Computing Service

The provision of HPC Computing Service refers to making available HPC resources for testing, scaling and production. PRACE via its members is the major European HPC resources provider, as shown in Figure 4 a). Additionally, EOSC and Human Brain Project (HBP) also presented themselves as resource providers. Indeed, EOSC provides access to existing services that are compliant with EOSC rules, though at a lower scale compared to PRACE resources. The FENIX [40] federated set of e-infrastructure services also provides access to HPC resources infrastructure via the ICEI project (Interactive Computing E-Infrastructure for the Human Brain Project – HBP), funded by the EC in the context of the Framework Partnership Agreement of the flagship project HBP. The distinguishing characteristic of this e-infrastructure is that data repositories and scalable supercomputing systems are in close proximity and well integrated, providing a generic e-infrastructure for HPC, driven by its scientific use-cases and usable by other scientific communities, such as the ones from EOSC, but also future ones such as the one from the Square Kilometer

Area telescope project SKA [42]. This is also a good example of coordinated action, using state of the art HPC, storage and network technologies to build an application layer that helps user to access a portfolio of HPC services in a convenient way.

3.3.4 HPC Training

The results from the survey showed a significant number of contributors to HPC Training services, including PRACE, HBP, EOSC, CoE and FETHPC projects. In Figure 4 b) the percentage of the received positive answers is shown. While the trainings from HBP, EOSC and FETHPC were identified as independent and complementary, a potential overlap was identified between the training offer of PRACE and that of the CoEs. This had been already identified in previous discussions and through the FocusCoE coordination action, where a decision was taken to focus PRACE training on general and cross-disciplinary HPC topics, while CoEs would focus on topical trainings.

In order to make all training offers well-known, they are collected and will be made available in a centralised European portal [41]. This will be based on a joint training database, to be fed with training offers from all national and European actors; this database will be shared and will include categories to allow searching for specific trainings.

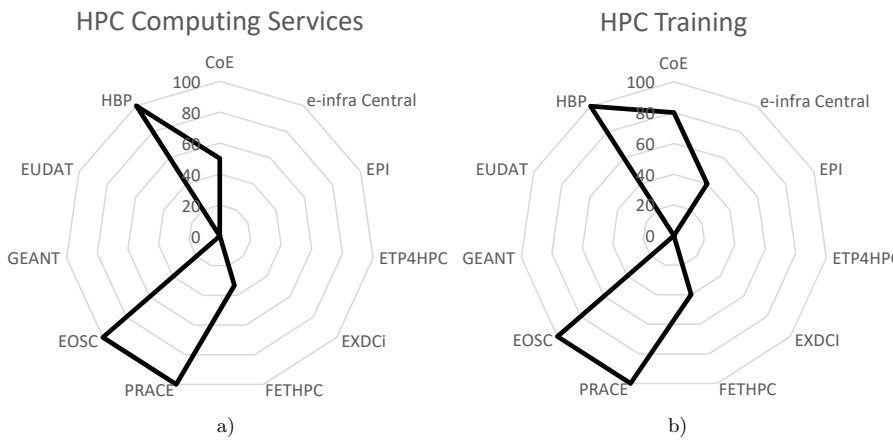

Figure 4. Provision of a) HPC Computing Service and b) HPC Training in % of positive responses in the respective stakeholder groups

3.3.5 HPC Application Enabling and User Support

The survey showed again a significant number of actors contributing to HPC Application Enabling and User Support activities, as presented in Figure 5 a). After the

discussion, it was concluded that this item required further stratification according to the additional dimensions of support levels and targeted users.

HPC support is classified in four levels depending on the scope of the support provided, which ranges from short helpdesk support to long-term refactorization support, including horizontal performance analysis by the POP CoE. While some overlap could initially be identified in medium-term support (level 2 and level 3) between the PRACE HLST [25] programme and CoEs, this was discriminated through their target users.

Similarly to training, the available support catalogue will be collected and made available in a centralised EU portal managed by PRACE. Further analysis on this service will be carried out by the PRACE-6IP project.

3.3.6 HPC Research

The survey showed that research in HPC is mainly executed by the actors in the HPC pillar of applications, that is CoE and FETHPC projects. This would include also EPI when one considers research in HPC technology. However EPI indicated HPC Research as Developer and not as Provider.

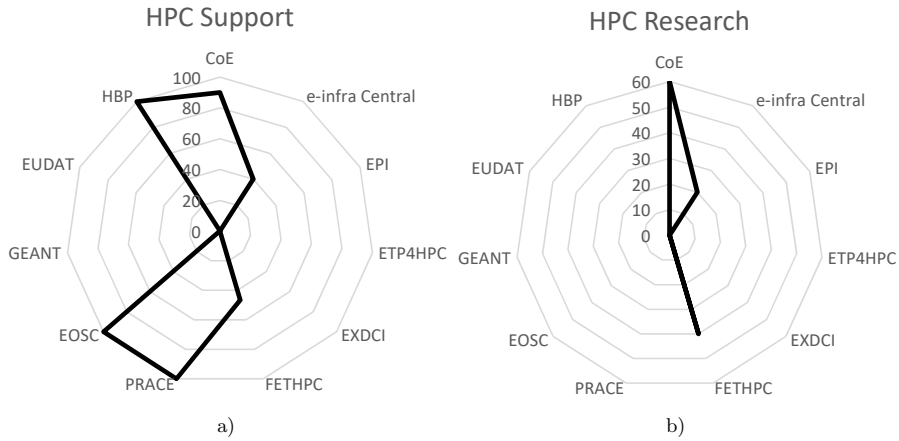

Figure 5. Provision of a) HPC User Support and b) HPC Research in % of positive responses in the respective stakeholder groups

3.4 Link to Other e-Infrastructures

PRACE is preparing for the use of HPC and data resources by other infrastructures and e-infrastructures. With the increasing amount of data traditional workflows will have to be changed in order to cope with the data. This is especially true for large scale scientific instruments, e.g. CERN or the SKA telescope. In order

to tackle this aspect, CERN, SKAO, GÉANT and PRACE formed a pioneering collaboration (officially signed in July 2020 [39]) that works to help realise the full potential of the coming new generation of HPC technology. During the initial period of 18 months, the collaboration is developing a benchmarking test suite and a series of common pilot "demonstrator" systems such as training, authenticated workflows, benchmarking and data access. The activity of these demonstrators has been kicked-off in September 2020 with a joint meeting of all the four leading research organisations.

The European Open Science Cloud (EOSC) has been designed to increase the value of scientific data assets by making them easily available to a greater number of researchers, across disciplines (interdisciplinarity) and borders (EU added value), and to reduce the costs of scientific data management, while ensuring adequate protection of information/personal data according to applicable EU rules. EOSC is one of the major actions of the Communication on a "European Cloud Initiative" of April 2016 [3]. The European Open Science Cloud will offer 1.7 million European researchers and 70 million professionals in science and technology a virtual environment with open and seamless services for storage, management, analysis and re-use of research data, across borders and scientific disciplines by federating existing scientific data infrastructures, today scattered across disciplines and member states. Part of EOSC's mission is to join the existing and emerging data infrastructures. To be part of EOSC, the infrastructure should comply with the rules of participation that define the rights, obligations and accountability of its various actors.

As one of its underlying layers, PRACE is not formally part of the EOSC but is compliant with main rules of participation, working on a referenced joint service catalogue, enabling users to find and access the HPC resources also in the EOSC. While new complementary ways to access converged HPC and AI resources in Europe are foreseen (such as AI4EU [19]) to respond to new usage models, the allocation of large resources in HPC and also in other fields of science will probably still be based on a peer-review process assessing scientific excellence, which is not contradictory with EOSC rules. In addition, it is planned also to integrate EOSC training in the HPC in Europe portal (see the next section) and make the training offers accessible also for EOSC and HPC ecosystem.

4 NEXT STAGE – HPC PORTAL

In order to facilitate the access to HPC resources and other linked services, the conclusions from the analysis of the HPC landscape have been used to shape a new European HPC services portal. This portal will serve as a central HPC services database gathering the offers and services of all European HPC actors. The new HPC in Europe portal will classify the elements collected according to three different criteria:

- Service nature: HPC Access, Training and Events, Support, Applications, Tech-

nology and Documentation.

- Target: Research, Industry (with a dedicated section for SMEs), Skills development, HPC Communities and General Public (including stakeholders and policy makers).
- Maturity level: from basic/beginner to advanced/experienced.

This structure will facilitate the navigation through the entire European HPC services catalogue and provide a clear access to all of them. The objective of the portal is to collect and display the first level of information, that is, a short but clear description of each service and the most relevant constrains (e.g.: dates, eligibility), in order to guide HPC users to the services that meet their needs. The portal will also include import and fetching capabilities, in order to feed and fetch the services from all other HPC European providers. The descriptors and categories of each service will be agreed with the major stakeholders.

The HPC in Europe portal [41] has been designed to be complementary to the classification of HPC services and related activities according to different target audiences (i.e. researchers, students, industry and projects) available in the EXDCI portal [21]. The difference between both portals is the scope of the services and the level of information provided. Both portals might be merged in the future. The details and current status of the portal strategic development is summarised herein:

- The elements within the different service natures have been further categorised based on the feedback received from the HPC stakeholders during the workshops organised to this effect. The category tree is being tested with real services provided by these same stakeholders.
- A number of highlights have been selected to appear on the front page of the portal to give a direct access to the related services.
- A dedicated Training section will offer a joint catalogue of HPC trainings provided by all training providers in Europe including PRACE, CoEs, EOSC, FETHPC projects and HBP, and also national training offers; this will be further enhanced with training materials for different user levels and links to other related training portals worldwide.
- Likewise, all European HPC Application Enabling and User Support services will also be collected and displayed in a dedicated section, including different categories for support levels and target users.
- An interactive map will display in a graphical manner all European HPC systems, CoEs and Competence Centres and training opportunities. This will allow the users of the portal to find easily the resources and competences needed based on their location across Europe.
- The portal will incorporate a light and independent branding, not directly related to any of the HPC stakeholders. All contributors will be equally acknowledged in a dedicated section. These two measures will illustrate the neutral position of this portal towards the European HPC ecosystem.

- FocusCoE and CASTIEL recently joined PRACE in making all their services visible on the HPC in Europe portal while still maintaining the projects identities.

Figure 6. HPC portal

The portal will be complemented with information related to the three European HPC pillars of Infrastructure, Applications and Technologies, and further enhanced with related use cases and other HPC documentation.

The final structure of the portal includes 33 categories to further stratify the services in the six natures defined, as follows:

- HPC access: Access to HPC systems, Cloud computing, Complementary HPC access, Development and benchmark access, Prototype HPC Access and European HPC systems.
- Training and events: Training events, HPC events, On-demand training offers, Online training, Training materials, Academic programmes, Mobility and mentoring.
- Support: High-level HPC support, Domain-specific support, Support to Industry.
- Applications: European Centres of Excellence in HPC, Simulation services, Consulting services, Prototyping services, Benchmarking services.
- Technology: Software developments, Hardware developments, HPC prototyping.
- Documentation: Map of HPC systems, White Papers and BPGs, Use cases and Success Stories, HPC Media, ETP4HPC, European Processor Initiative, FETHPC projects results, Artificial Intelligence, Deep Learning, Machine Learning, Quantum Computing, Quantum Communication Initiative, Cyber Security.

A test version of the portal, including the work design is already available to facilitate the fine tuning and final improvements before its final release. Figure 6 shows this design and structure.

5 CONCLUSIONS

After the analysis of the services of the different actors in the European HPC ecosystem, it is clear that further coordination is needed at European level to leverage the strong, but scattered, skills of European players, in order to compete with united effort from USA, China or Japan on the race to exascale. To that end, the following high-level service architecture is proposed:

- European HPC technologies will be developed by the FETHPC projects and EPI. CoEs and PRACE will collaborate by providing user requirements and co-designing the new technologies. In addition, PRACE will support in providing access to the FETHPC prototypes and give the related infrastructure feedback while CoEs and other users will provide end-user feedback.
- Access to HPC and AI resources of EuroHPC JU will be provided mainly by PRACE through peer-review process for Grand-Challenge level of computation or through EOSC portal for smaller computations, while network connectivity will be provided by GÉANT. Other, more specific computing services, such as Interactive Computing, scalable computing or virtual machine and data services, along with authentication and authorisation services will be provided through a federated way using FENIX.
- The wide offer of training in HPC will be provided by many actors, where PRACE will focus on the general and cross-disciplinary training, leaving topical training to the specialised communities and CoEs.

- Application enabling will be provided by PRACE as the first contact point, along with high-level support to implementation through PRACE HLSTs. Long-term support and specific support for codes of general interest will be provided by the relevant CoEs. The POP CoE will provide transverse performance analysis services.

This high-level provision of HPC services by PRACE, GÉANT, CoEs, EPI and FETHPC projects will be complemented by the pool of national HPC services, to be integrated within this architecture. The new HPC in Europe portal will collect in this way the complete catalogue of HPC services throughout Europe, with a special emphasis in computing, training and support services. Following a user-driven approach, this will significantly increase the awareness for European HPC resources and services, and strongly facilitate their access by all European audiences. The important role of the EuroHPC JU will be acknowledged in the portal as well.

The Infrastructure Advisory Group (INFRAG) and Research and Innovation Advisory Group (RIAG), two advisory groups of the Industrial and Scientific Board of EuroHPC JU received the mission to work on the European HPC landscape. This overview and analysis will be helpful in the discussion and definition.

Acknowlegment

This work was supported by the PRACE-5IP and PRACE-6IP projects co-funded by the EUs Horizon 2020 research and innovation programme under grant agreements EINFRA-730913 and 823767.

REFERENCES

[1] High Performance Computing: Europe's Place in a Global Race. COM(2012), 45 Final.

[2] Council Regulation (EU) 2018/1488. Available at: `https://eurohpc-ju.europa.eu/`.

[3] European Cloud Initiative – Building a Competitive Data and Knowledge Economy in Europe. COM(2016), 178 Final.

[4] Proposal for a Council Regulation on Establishing the European High Performance Computing Joint Undertaking. COM(2020), 569 final, 18.9.2020.

[5] EXDCI-2 Deliverable D2.4: Report on Coordination of the Technology Research Action in Europe. May 2020.

[6] European High-Performance Computing Handbook 2018. ETP4HPC and EXDCI, 2018. ISBN 9789082169492. Update available at: `https://www.etp4hpc.eu/pujades/files/ETP4HPC_Handbook_2019_web.pdf`.

[7] Kelly, C. C.—Rhodes, R.: Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians. Black Dog & Leventhal, 2009.

[8] https://www.european-processor-initiative.eu/.
[9] https://www.ornl.gov/.
[10] PRACE Position Paper: PRACE in the EuroHPC Era. 2019, available at: http://wwws.prace-ri.eu/about/positionpapers.
[11] The Scientific Case for Computing in Europe 2018–2026. PRACE Scientific Steering Committee, 2018. ISBN: 9789082169492. Available at: https://prace-ri.eu/about/scientific-case/.
[12] https://www.geant.org.
[13] https://ec.europa.eu/digital-single-market/en/high-performance-computing-contractual-public-private-partnership-hpc-cppp.
[14] https://www.etp4hpc.eu and https://www.etp4hpc.eu/cppp.html.
[15] https://www.etp4hpc.eu/news/156-2017-handbook-of-european-hpc-projects.html.
[16] https://www.etp4hpc.eu/pujades/files/ETP4HPC_Annueal-Report-2018_web.pdf.
[17] https://www.etp4hpc.eu/sra.htm.
[18] https://ec.europa.eu/digital-single-market/en/news/european-processor-initiative-consortium-develop-europes-microprocessors-future-supercomputers.
[19] https://www.ai4eu.eu/.
[20] http://www.hpc-portal.eu.
[21] https://exdci.eu/about-exdci/exdci-at-a-glance.
[22] https://www.prace-ri.eu/best-practice-guides/.
[23] https://www.prace-ri.eu/white-papers/.
[24] https://www.prace-ri.eu/public-deliverables.
[25] PRACE High Level Support Teams. Available at: http://www.prace-ri.eu/HLST.
[26] https://www.prace-ri.eu/IMG/pdf/D5.2_5ip.pdf.
[27] https://www.etp4hpc.eu/cppp-monitoring.html.
[28] https://aioti.eu.
[29] https://www.eosc-portal.eu/.
[30] http://www.bdva.eu/.
[31] https://www.exascale.org/bdec/.
[32] https://exdci.eu/collaboration/coe.
[33] https://www.focus-coe.eu/.
[34] https://eurohpc-ju.europa.eu/documents/.
[35] https://ec.europa.eu/digital-single-market/en/news/19-proposals-selected-develop-world-class-supercomputing-ecosystem-europe.
[36] https://eurohpc-ju.europa.eu/closed_calls.html.
[37] https://eurohpc-ju.europa.eu/participate.html.
[38] https://ec.europa.eu/digital-single-market/en/news/eurocc-and-castiel-two-new-projects-boost-european-hpc-knowledge-and-opportunities.

[39] https://prace-ri.eu/cern-skao-geant-and-prace-to-collaborate-on-high-performance-computing/.
[40] https://fenix-ri.eu/.
[41] https://www.hpc-portal.eu.
[42] https://www.skatelescope.org.

Florian Berberich works for the PRACE Project Management Office at Jülich Supercomputing Centre (JSC) since 2008. He obtained his Ph.D. in physics at the Technical University of Dresden in 2002. He had worked as Post-Doc at the European Synchrotron Radiation Facility, France before he became the assistant to the Board of Directors at Forschungszentrum Jülich in 2004. Currently he is the project manager of the PRACE-6IP project, PRACE Council Secretary and a member of the Board of Directors of PRACE aisbl.

Janina Liebmann works for the PRACE Project Management Office as Project Assistant for the PRACE-6IP project at JSC since 2017. She finished her education as an industrial business management assistant at the EWE TEL GmbH, Germany, in June 2011. In 2016 she worked as a secretary at the Foundry Institute, RWTH Aachen.

Veronica Teodor is working for the PRACE Project Management Office at JSC, since 2012. She finished her law studies at the University of Transylvania Brasov, Romania in June 2004 and multilingual communications at the University of Applied Science Cologne, Germany in January 2009. Currently, she is the task leader for the organisational support for PRACE 2 development in the PRACE-6IP project.

Jean-Philippe Nominé joined CEA HPC division in 1992, where he held different managing positions in HPC software development. He has been involved in PRACE since its preparation in 2007 and has coordinated CEA efforts in all PRACE PP/IP projects. He was a member of PRACE aisbl Board of Directors in 2010–2011. He was then ETP4HPC Office Manager between 2012 and 2019 and now he is a member of ETP4HPC Steering Board, and of EuroHPC Research and Innovation Advisory Group (RIAG). At CEA he manages HPC strategic collaborations (EU and international). He graduated from Ecole Polytechnique (engineer degree) and obtained his Ph.D. from Université Pierre-et-Marie-Curie (Paris, 1991).

Oriol Pineda is Director of Peer Review in PRACE, the Partnership for Advanced Computing in Europe, and Senior Project Manager at the Barcelona Supercomputing Center in Spain. He is responsible for monitoring the review process to access PRACE HPC resources and for the management of the impact assessment methodology of PRACE. He has an academic background, with a degree in organic chemistry, an M.Sc. in experimental chemistry and a Ph.D. in computational chemistry, from the University of Barcelona, Spain.

Philippe Segers is overseeing GENCI's contributions to the PRACE Implementation Projects, he is a member of the Board of Director of PRACE aisbl, Management Board of PRACE-nIP and PPI4HPC, and Technical Board of PRACE-nIP. He holds an Executive MBA from NEOMA Business School and has an academic background in numerical modeling of theoretical physics (University Paul Sabatier, Toulouse and University of Quebec at Montreal – UQAM). He began his career at the EC Joint Research Centre (Ispra, Italy) in 1999, moved to the scientific software industry and spent ten years in Program Management of R & D for EC and NATO projects. He was leading PRACE-3IP work-package on Pre-Commercial Procurement (PCP), he is a co-leader of PRACE-nIP work-package on the organisation of infrastructure and stakeholder management. He was representing PRACE within EOSCpilot project, and he is leading the GENCI contribution to the Connecting Europe Facilities (CEF) project AQMO on air quality.