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COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

High-Performance Computing: Europe's place in a Global Race

{COM(2012) 45 final}

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High-Performance Computing: Europe's place in a Global Race

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Section 1: Problem Definition

The main challenges for High-Performance Computing (HPC)[1] in Europe are:

- Europe spends substantially less than other nations on acquiring high-end computing systems, software and services; as a result, the HPC resources available are diminishing across Europe, while other nations (e.g. China and Russia) are gaining ground
- Fragmentation of efforts across Europe
- Pre-Commercial Procurement (PCP) is not strategically used for developing advanced HPC systems
- Interaction between industry and academia on the exploitation of high-end computing systems and services is rather limited
- Lack of advanced HPC experimental facilities
- Too small workforce that is well trained in super computing
- European HPC vendors experiencing difficulties selling their products to the public sector of the US – while 95% of the European HPC systems are from US vendors

The Rationale for HPC

The case for HPC's importance for Europe can be made from four main perspectives:

- Scientific leadership
- Industrial competitiveness
- National security
- Computing as a key technology, in the context of the global race towards exa-scale

First, the race for leadership-class HPC systems is driven by the need to address societal and scientific grand challenges more effectively, such as fighting Alzheimer's disease,

[1] There's no fixed definition of how powerful a computer needs to be for it to be considered as 'high performance'. This is because the performance of microprocessors has increased exponentially for many years, so any such definition is out of date quickly. It's usual to consider a computer to be high performance if it uses multiple processors (tens, hundreds or even thousands) connected together by a network to achieve the performance well above that of a single processor. Using multiple processors in this way is sometimes called parallel computing. The best performing machines in 2010 use hundreds of thousands of processing cores and are capable of 10^{15} floating point operations per second (this is referred to as a 'peta-flop'). This is 1000 times more than the most powerful machine delivered in 2000, which in turn was 1000 times more powerful than a decade earlier. Experts predict that exa-scale computers (capable of 10^{18} operations per second) will be in existence by 2020.
High Performance Computing FAQ:
www.planethpc.eu/index.php?option=com_content&view=article&id=48#Q1
The term high-performance computing (HPC) refers to technical computing encompassing computers and software used by scientists, engineers, analysts, and other groups using computationally intensive modelling and simulation applications. Technical servers range from small servers costing less than € 5,000 to the large-capability machines that may cost a hundred million Euros. In addition to scientific and engineering applications, technical computing includes related markets/applications areas including economic analysis, financial analysis, animation, server-based gaming, digital content creation and management, business intelligence modelling, and national security applications.
In the context of this report, term supercomputer (or simply HPC system) is used to refer to HPC hardware priced at € 375,000 and above. High-performance computing (HPC) is used in this Impact Assessment as a synonym for capability leadership-class computing, high-end computing, supercomputing, world-class computing, etc. to differentiate it from capacity distributed computing, cloud computing and compute servers that are of a more generic nature and are complementary to HPC systems

understanding how cholesterol is transported in our body, deciphering the human brain, forecasting the evolution of climate, or preventing and managing large-scale catastrophes.

Second, HPC is also driven by the need of industry to innovate in products and services (designing vehicles and airplanes, developing life-saving new drugs, etc.). 97% of the industrial companies that have adopted HPC now consider it indispensable for their ability to innovate, compete, and survive[2]. HPC has enabled producers to reduce the development time (from 60 months to 24 months for a vehicle) and to save on physical prototyping costs (at the level of billions of Euros for Airbus and Boeing), increasing safety and reliability[3]. Hospitals in Germany routinely use HPC to predict which expectant mothers may require surgery for Caesarean births, with the goal of avoiding traditional, riskier last-minute decisions during childbirth. Especially for small and medium sized enterprises, access to HPC consulting, modelling, simulation and product prototyping services is increasingly important.

Third, HPC is strategic in the context of national security applications. Not only in the nuclear area where HPC has become an indispensable tool for simulation and modelling, but also in the context of cyber aspects of conflicts HPC systems play an important analytical role. In the context of this report this aspect is referred to as an important area for HPC, but it is not further explored, and it is handled differently across Member States. The rationale is to acquire and maintain competence in this area of HPC in line with the other areas of HPC identified above.

The increasing tilt toward HPC as an R&D method is related to the fact that the costs of experimental ("live") science and engineering research have skyrocketed in the past decade. This has made HPC increasingly attractive from a financial point of view. IDC carried out a survey[4] with European HPC stakeholders (67 respondents[5]) where every one of the respondents said that HPC is "extremely important" (66%) or "important" (34%) for industrial competitiveness. These stakeholders' survey comments indicate that there is strong support for HPC use by industry, even among non-industrial respondents. Every one of the survey respondents agreed that HPC is "extremely important" or "important" for scientific leadership. Nearly all of the respondents (94%) rated access to leading HPC systems as "extremely important" (94%) for their countries, and the remaining 6% considered it "important". This represents a very strong block vote in favour of making time on large HPC systems widely available in Europe. Similarly, 97% of the survey respondents said that access to leading HPC systems is "extremely important" (84%) or "important" (13%) for the EU's ability to compete in the global market place.

But HPC is a costly undertaking: a single leadership-class supercomputer costs at least € 75 million today, and a US government agency estimated the price for developing an exa-scale supercomputer[6] at more than € 750 million[7].

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2 IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: page 15

3 IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: page 26

4 IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: page 43 onwards

5 Sample composition: 48% from HPC user organizations, 30% from HPC vendors (hardware, software, storage, services), 17% HPC industry experts, 9% from EU member states (overseeing and funding HPC initiatives)

6 The HPC performance advances in these past decades have been remarkable. Gigaflops (billion calculations per second) were achieved in 1985, teraflops (trillion calculations per second) in 1997, and petaflops (a 1 followed by fifteen zeros) in 2008. The HPC community is now aiming for exa-scale computing calculations per second (a 1 followed by eighteen zeros).

Fourth, the move to exa-scale computing requires a complete rethink of the current HPC architectures. However, the challenges faced in this move to exa-scale computing apply equally to all actors around the globe. On the one hand, this provides a unique opportunity for Europe to engage on a level playing field while, on the other, Europe has some unique capabilities and expertise in the area of low power microelectronics and processors, as well as in the area of advanced software tools. Thus, it is well positioned in this race. Another critical resource is human expertise in using HPC systems as well as expertise in developing and designing these systems and their underlying technologies.

Europe has a number of globally successful scientific and engineering software firms, a larger number of nationally and regionally successful software firms, and is strong in many important areas of parallel software development[8]. The majority (64%) of the most important parallel software applications in use at European HPC sites surveyed by IDC have been created and are further developed in Europe.

The software of the next decade will require a root and branch rethink more even fundamental than for hardware; in fact, the growing gap between the state of the art in hardware and in software is already so large that it may even become a block to further progress. New approaches and new tools will be required, perhaps even a new programming paradigm. At the very least, according to IDC, many HPC applications will need to be substantially adapted or wholly rewritten in order to exploit future HPC systems — a major undertaking when half of the top codes of the sites surveyed are more than ten years old

The underlying problem is that modern HPC hardware with large numbers of CPU cores, each with decreasing levels of memory and memory bandwidth, is causing a mismatch with existing application software, driving a need to fundamentally redesign and rewrite HPC application software for greater parallelism. Only about 1% of HPC applications today can exploit 10000 or more processor cores; in a recent survey around 52% were reported to be running on only one node (with an average of 3-4 cores). By contrast, the largest HPC hardware systems already contain more than 200000 cores, and million-core supercomputers will begin to arrive before the end of this decade.

Europe is already strong in important areas of parallel software development, and a global leader in this area of the supporting Computer Science; some of Europe's best firms are ahead of their international competitors in exploiting HPC for innovation[9]. Thus Europe is also in an excellent position to embrace the software challenge as an opportunity to seize global leadership, the more so as no other nation or region has committed itself to a strategic programme in this area.

Currently, however, it is often difficult for software creators and vendors to make a business case for the major parallelisation initiatives required, in the face of multiple technical and economic uncertainties, and of the cost when improved codes must be proved and re-certified at each update.

At a macroeconomic level, although the HPC market is relatively small (see next section), it has been noted[10,11] that return on investment is high and that companies and countries that

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7 IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: Executive Summary

8 IDC Study "Financing a Software Infrastructure for Highly Parallelised Codes", page 1

9 http://www.compete.org/publications/detail/486/advance/

10 A coordinated and revitalising European effort in the area of HPC would increase industrial growth and an increase in GDP growth for all Europe. (IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: pages 19 and 59 onwards)

invest the most in HPC lead in science and economic success. It can be argued that this is similar to space industry, where the business of manufacturing rockets and launchers is a rather limited one, but the overall impact on our economies and on everyday life is substantial.

The benefits of HPC arise not only from its use as a tool by science and by industry, but also from the know-how generated during the development of HPC systems and software. The development of next-generation HPC systems is motivated by very challenging specifications (e.g. for combinations of performance, power consumption and reliability), which serve as drivers for the development of novel technology. Thus advances made in the area of HPC; such as new computational technologies, software, energy efficiency, storage applications, etc. frequently feed into the consumer mass market and become available in households within about 5 years of their introduction in the HPC area (e.g. file systems and optimisations of the LINUX operating system). Vice-versa, computing components and technologies developed for the mass market (e.g. energy efficient microprocessors) are widely used for the cost-efficient design of HPC systems (e.g. the use of modified PC graphic cards as accelerators in HPC systems).

In summary, HPC is important because it is a substantial multiplier of scientific and economic investments, and a major productivity tool, and a fertile field of research and development.

Base-line data for HPC in Europe

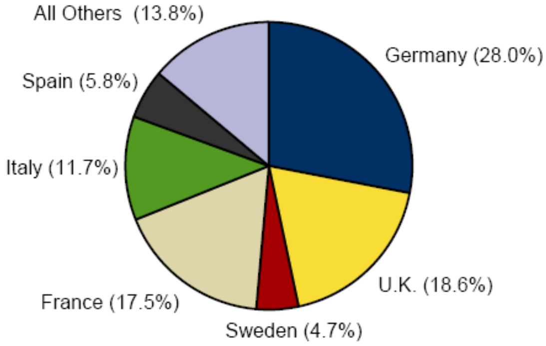
By 2009, the EU's share of the worldwide HPC market (in terms of systems purchase and HPC capacity available in Europe) slipped 10% from the pre-recession 2007 high of 34.4%. During the same period (2007-2009), North America's market share grew nearly 2%, from 47.8% to 49.5%.

In terms of market size, the EU market for high-end computing systems is relatively small: some € 630 million in 2009. It covers three groups: the governmental sector addressing strategic national security issues; the public research and innovation sector consisting of computing centres mainly associated with universities or as a single national entity; and the industry sector. A large part of this market depends on public funding.

In 2009 European spending for HPC systems was distributed over the following main application sectors (according to the IDC split of sectors):

1. University/academic: 23%
2. Bio-sciences: 22%
3. Computer Aided Engineering – CAE: 21%
4. Government labs: 19%
5. Defence: 13%

[11] The [US] High Performance Computing Initiative (HPC) is intended to stimulate and facilitate wider usage of HPC across the private sector to propel productivity, innovation and competitiveness; www.compete.org/hpc



Geographical distribution of HPC system purchases in 2009 (Source IDC)

The broad HPC market is dominated (77%) by three US vendors, who are also the ones who supply the vast majority of systems for the large server farm/data centre/cloud market. Due to re-use of technologies, the two markets are to some extent coupled. In the "supercomputer" segment for HPC systems priced at €375,000 and higher, IBM was most often the EU market share leader in 2005-2009, with HP jumping ahead of IBM only in 2008 and otherwise remaining a close second. Together, IBM and HP captured 78% of the EU market in this price band in 2009. The third-place vendor, Bull, accounted for only about 5% of the market.

EU Countries HPC Revenue (€000) by Vendor in Supercomputing Segment, 2005–2009

Manufacturer	2005	2006	2007	2008	2009
IBM	306,158	268,414	266,886	205,110	275,648
HP	178,527	199,377	260,922	257,471	176,672
Bull	19,125	4,383	13,432	27,301	27,122
NEC	2,941	0	0	1,005	24,533
Dell	10,174	6,022	3,000	3,750	23,690
Cray	15,173	35,953	43,252	12,238	19,237
SGI	21,412	8,312	32,419	14,173	15,465
Sun	11,026	2,224	0	2,464	12,457
Appro	0	0	0	14,280	2,054
Other	0	6,201	13,924	8,320	4,925
Grand Total	564,535	530,886	633,835	546,113	581,803

Source: IDC, 2011

Europe lost 10% of its high-end computing capacity in just 2 years, whereas other nations increased their capacity in this area substantially during the same period, despite the economic crisis. In 2011 China had more computing capacity available than any individual European country (Top500 list[12]) and all European countries put together fell back from the 2nd to the 3rd position after the US and Asia. Furthermore, China and Russia have massively increased their production efforts on HPC and have declared this as an area of strategic priority.

[12] www.top500.org/charts/list/37/countries

Worldwide HPC Supercomputer System Revenue (€000) by Region, 2005–2009

	2005	2006	2007	2008	2009	CAGR (05–09)
Total WW Revenue	2,160,829	1,925,165	2,011,793	2,014,596	2,527,058	4.0%
North America Revenue	1,043,865	903,948	932,183	1,031,201	1,291,493	5.5%
Europe Revenue	614,307	582,989	692,038	592,535	627,732	0.5%
** Percent of WW	28.4%	30.3%	34.4%	29.4%	24.8%	
Asia/Pac Revenue	249,244	204,639	228,972	219,970	226,608	-2.4%
Japan Revenue	231,745	206,965	122,733	137,872	348,448	10.7%
Rest of World Revenue	2,669	8,594	14,464	14,692	13,362	49.6%

Source: IDC, 2010

The HPC condition in the EU

Europe has played an important role since HPC's beginnings and possesses a wealth of HPC-related experience and talent[13]. In recent years however, Europe has been falling behind other regions of the world because it has under-invested in establishing a complete HPC ecosystem: to acquire leadership-class computers, secure its own independent HPC supply, and deploy HPC services to industry and SMEs for simulation, visualisation and prototyping. This has a double negative effect in that there is not enough HPC capacity to cater for the demand of the science, innovation and industrial communities, and there is also not enough European supply industry designing and building these systems. Overall, the European HPC eco-system (including a Europe-based supply of HPC technologies and systems) is underdeveloped; as a consequence, research may need to relocate outside Europe, access to advanced systems is insufficient and software and tools development, especially those linked to hardware, is disadvantaged.

On the positive side Europe has world-leading capabilities in power-efficient microelectronics and processor designs, as well as unique software tools and applications.

Key actors in leadership-class have changed many times in recent decades, moving from one country and region to another. Not only the European HPC stakeholders, but also their counterparts in the U.S. and Japan believe that with a differentiated strategy, and sufficient investment and collective political will, Europe can be a global player in HPC.

The causes underlying the HPC decline in Europe

Identified shortcomings and key challenges for HPC in Europe include:

- The interaction between industry and academia on the exploitation of high-end computing systems and services is rather limited, especially regarding the promotion of industrial and service innovation based on the use of HPC. Europe also lacks advanced experimental high-end computation facilities that would allow industry and academia to explore exa-scale technology options.
- In terms of exploitation of HPC research results and technology transfers (also to SMEs) there is still a big gap in Europe.
- There is only a small workforce available that is well trained in super computing. This is a great stumbling block for undertaking major R&D projects in HPC and the exploitation

[13] Distributed European Infrastructure for Supercomputing Applications – DEISA; www.deisa.eu
Enabling Grids for E-sciencE – EGEE; www.eu-egee.org
European Grid Infrastructure – EGI; www.egi.eu
Partnership for Advanced Computing in Europe – PRACE; www.prace-ri.eu
Enabled by the world leading networking resources provided by GÉANT; www.geant.net

of HPC systems and services in research, industry and for society in general. So far HPC is not very attractive for (post-graduate) students as it involves a rather steep learning curve to be able to apply HPC efficiently to a scientific problem.

- Europe lacks a completely autonomous supply of HPC systems. 95% of the HPC systems operated in Europe are from US vendors (Russia and possible China in the future). The main European suppliers active today are system integrators, i.e. they do not control the architecture and the design of HPC systems, but rely on foreign suppliers to give them sufficient information to assemble from components and subsystems.

- Europe spends substantially less than other nations for acquiring high-end computing systems (only half compared to the US, at a similar level of GDP[14]). Consequently, the amount and performance of computing systems available in Europe are simply too low compared to other world regions. In addition, R&D budgets devoted to HPC are also low, in part due to the weakness of the European HPC supply industry.

- There is still a fragmentation of high-performance computing efforts across Europe and within Member States, despite progress made by PRACE. This leads to the inefficient use of resources and allows only for a limited exchange of expertise.

- Almost none of the public procurement budget is devoted to R&D through Pre-Commercial Procurement (PCP) - contrary to the US[15]. This could be due to the difficulties of pooling national resources into a joint international procurement for a novel leadership-class system; and due to the high risks that European enterprises, particularly SMEs, would need to undertake to engage in a PCP exercise where the technical challenges might be too high in the end. Therefore, despite progress made (e.g. by PRACE), fragmentation of HPC efforts across Europe – but also within Member States - persists, in particular concerning public procurement.

- It is very difficult for European HPC vendors to sell their products to the public sector in countries that have national HPC vendors (e.g. in the US, national security issues and the Buy American Act[16] are considered as the main obstacles for European vendors). At the same time, IPR developed in European research projects relevant to HPC often benefits mainly the non-EU parents of participating companies as the Framework Programme imposes few restrictions on the origin of participants or on the transfer of IPR to affiliates in third countries.

Need for public intervention

A large part of the European HPC market (50-65%) depends on public funding[17]. This is the money used to acquire computers and software to address the needs of national security, the public sector, and publicly funded research and innovation. In addition, the development of many HPC applications and associated software is also done through public funding because it is undertaken in academia or in public service organisations such as for weather forecasting or for health.

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[14] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: Table 2 on page 8 onwards

[15] Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe, COM(2007) 799, page 4 onwards: "The US public sector is spending $50Bn per year in procurement of R&D, an amount which is 20 times higher than in Europe and represents approximately half of the overall R&D investment gap between the US and Europe."

[16] Sections 10 (a-d) of Title 41 of the United States Code

[17] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: Table 3 on page 17

Public intervention is already taking place: as much of the HPC market is addressed by the public sector a stronger coordination in terms of procurement and development (e.g. through pre-commercial procurement) and use of HPC systems will make the overall HPC eco-system much more effective. Consequently, the public intervention is very much in the interest of public authorities themselves! In increasing the effectiveness of public spending on HPC (and by also providing more of the currently so much lacking HPC resource) a positive momentum for industry at large will be generated: European-based HPC suppliers will be strengthened, a larger trained workforce will be available, and software up-scaling activities will be carried out widely, enabling the efficient use of large scale HPC systems.

Why intervention at the EU level?

The development of HPC has long been a national affair for the large Member States, often driven by military and nuclear energy applications. In recent years, however, the increasing importance of HPC for researchers and industry, as well as the exponential rise in the investments required to stay competitive at world level, have led to a common understanding that "Europeanisation" of this policy domain would benefit everyone (both small and large Member States).

The Communication on ICT Infrastructures for e-Science COM(2009)108 asks for a "further development of the European High Performance Computing Infrastructure". The Council conclusions (9451/10 RECH 173 COMPET 145 - conclusions of the 2982nd Competitiveness Council) ask for a "pooling of national investments in HPC in order to strengthen the position of European industry and academia in the use, development and manufacturing of advanced computing products, services and technologies". The Commission reacts to this request by proposing the Communication at hand.

The costs of a single leadership-class HPC system are at least € 75 million. To these one has to add the costs for operating and maintaining the system over its lifetime of some 5 years. These costs can double the initial investment costs. Technologies are also rapidly evolving and there exists various types of supercomputer architectures - one specific HPC system does not fit all the needs of the users. Consequently, a complete HPC eco-system has to be put in place that also includes software and services to really support the user community. For any single country to maintain a complete public HPC ecosystem an annual budget of at least € 100 million is necessary. This does not include the R&D budget that would be necessary to also lead in HPC research rather than just making the HPC resources available. This magnitude of investment is beyond the reach of most EU countries, even some of the bigger ones.

Furthermore, no single European country has all the technological know-how and suppliers that are needed to produce a complete state of the art HPC system (hardware and software). Cooperation is a necessity; in particular for medium and small Member States, which find difficulties in creating self-sufficient national HPC infrastructures, but can valuably contribute to and benefit from an EU-level HPC eco-system.

Section 2: Objectives

General Policy Objective

The Council conclusions of the 2982nd Competitiveness Council (December 2009) asked for a further development of the European High Performance Computing Infrastructure and a pooling of national investments in HPC in order to strengthen the position of European industry and academia in the use, development and manufacturing of advanced computing products, services and technologies. This is the high-level objective driving a renewed European HPC strategy.

Specific Objectives

To realise the above general objective, the following specific objectives have been identified:

- Provide a world-class European HPC infrastructure, benefiting a broad range of academic and industry users, and especially SMEs, including a workforce well trained in HPC;
- Ensure independent access to HPC technologies, systems and services for Europe;
- Establish a pan-European HPC governance scheme to pool enlarged resources and increase efficiency including through the strategic use of joint and pre-commercial procurement;
- Ensure Europe's position as an actor on the global scene.

These general objectives are presented in more detail below:

Provision of a world-class European HPC infrastructure

The current investment level of some € 630 million per year for acquiring supercomputing resources across Europe has not been sufficient to sustain computing systems and services available across Europe at a globally competitive level. This investment would need to double to some € 1200 million per year to reach a similar level (in terms of GDP) to the US and revive Europe as an actor in the field of supercomputing. Supplementing the current ongoing efforts in HPC, an additional € 600 million will be needed annually. This amount should be shared between Member States, the European Commission, and industrial users, in part by applying innovative procurement mechanisms.

In addition, a mechanism should be put in place for the joint procurement of systems by several Member States at the same time in cases where it makes sense to pool demand in order to afford a machine with higher performance. Financial incentives should be provided to encourage the joint procurement of HPC systems jointly by Member States, provided that these satisfy EU needs and are open to use by everyone in Europe on the same terms.

The deployment of HPC competence centres will facilitate access of industry and especially SMEs to HPC services (e.g. simulation, visualisation, prototyping) and application software. A network of such competence centres is needed to promote pan-European services, to disseminate best practice and for technology transfer. Such centres can also promote advanced experimentation with new HPC technologies.

The development of skills and an educated work force in HPC are essential for Europe's competitiveness in science and industry. The broad inclusion of HPC skills into curricula is important to increase the number of trained personnel and to fully exploit Europe's innovation capabilities. In this context the cooperation with the European Institute of Innovation and Technology (EIT) is an important component.

The provision and expansion of HPC empowered e-Infrastructures to further facilitate science cooperation addressing global challenges should be stepped up, making Europe the centre for global science cooperation.

Following the setup of the PRACE legal entity in 2010 the research and education sector is pooling its leadership-class computing systems as a single infrastructure and makes them available to all European researchers. In this way critical mass is achieved, training is more effective and access to these top-of-the-range computing systems is provided on the basis of scientific excellence rather than on the country where a researcher is located. PRACE is now extending its services to mid-range HPC systems with the objective to provide a distributed academic computing platform that serves best its users independent of their location and the availability of national resources. The model of PRACE of sharing and pooling systems and expertise makes best use of the limited resources available. At the same time, PRACE has become a platform of exchange and sharing of know-how between the participating supercomputing centres. This has led to a focusing and alignment of the European supercomputing efforts in the academic field.

Europe today has world-class capabilities in the related fields of automotive and aerospace design engineering, including computational fluid dynamics and computational structural analysis expertise and software creation. Europe also has world-class strengths in the bio-life sciences sector. European best-in-class automotive and aerospace companies typically have pushed HPC usage much deeper into their organizations on average than US firms - more frequently extending its use from traditional upstream applications in R&D and design engineering into high-value downstream uses, such as manufacturing and production. European automotive, aerospace and bio-life sciences firms more often require their suppliers (often SMEs) to use HPC than occurs in North America. These European strengths in HPC software are currently challenged in the move from peta- to exa-scale computing: these software packages have been developed and refined over a long time (sometimes over the last 30 years) and are written in the programming languages of that time; this software is often now highly inefficient in today's highly parallel supercomputing systems. A complete re-write, often even a complete new approach on how to model the actual physical problem in software has to be made.

An independent access to HPC for Europe

The objective is to ensure that Europe has access to the technical know how and the industrial base it needs in order to be an acknowledged actor in HPC hardware, software and system supply by 2020, when the next generation of "exa-scale" supercomputers is supposed to come about. Many industrial areas fully depend on the availability of specific HPC resources (e.g. biotechnology, medical, automotive, aerospace, digital manufacturing).

As explained in section 1, the public sector (university/academic, government research centres, defence) is the major buyer of high-performance computers and software in Europe. Some of this budget[18] should be used for helping the development of a native European supply capability in leading edge technologies and systems. Industry should be encouraged to respond to pre-commercial procurement (PCP) actions for the development of advanced computing systems.

Such an approach that links supply, demand and development through PCP to pursue EU leadership in HPC supply has major advantages. First, it spearheads the development of the broader computing sector in Europe by offering a very challenging set of technical problems

[18] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: Table 5 on page 59

on which researchers focus their efforts. Second, it allows co-development of next-generation hardware and software. Third, it stimulates the growth of HPC companies in Europe through coordinated public contracts. Fourth, it increases the leverage of Europe on a global level by making it a powerhouse of HPC developments. Fifth, it increases the state-of-the-art computing capacity available in Europe for industry and research. Sixth, it is strategic in the context of national security.

Europe has technical and human-skills capabilities and strengths (e.g. in applications, interconnects, embedded/low-power computing, systems and integration) that are highly relevant for the next generation of computing. There is now a window of opportunity created by the transition from peta- to exa-scale computing that cannot be missed.

Governance for the efficient use of HPC resources

A strategy aimed at a European HPC renewal requires adequate governance for setting concrete objectives, deciding policies, monitoring progress and efficiently pooling and using resources available across the Member States. Governance should be fair, open, simple and efficient helping to balance and arbitrate on interests, capabilities and resources.

The three main poles of governance should be

(a) an EU-level body that becomes the major EU-level provider of HPC resources for (mainly) academic use,

(b) an industry-led technology platform for European HPC suppliers, and

(c) a coordinated network of competence centres providing expertise and services on HPC software and applications.

Pole (a) should federate national HPC infrastructures into a unified EU infrastructure. In particular, it should be able to:

i) Coordinate national and regional supercomputing centres, including the timing and specifications of their procurement;

ii) Provide computing resources to users in academia following competition at EU level and without national constraints;

iii) Establish centres of excellence addressing key societal challenges through the application of HPC;

iv) Provide services to industry for applications requiring leadership-class computing;

v) Pool national and European funds;

vi) Provide a platform for the exchange of expertise, resources and contributions necessary for the operation of high-performance computing systems;

vii) Set the specifications and carry out joint (eventually pre-commercial) procurements for the development of leadership-class systems;

viii) Support Member States in their preparation of procurement exercises.

PRACE has made significant progress in the last few years and could be in good position to fulfil functions (i) to (viii). It would need to extend its service portfolio to also provide mid-range supercomputing throughout Europe, so that the HPC infrastructure offers a wide range of services and a one-stop-shop for researchers and engineers. Alternatively to PRACE, some of the functions could be jointly executed by a number of other organisations in Europe.

EU-level measures in this area will complement or reinforce Member States’ actions (e.g. Germany and France creating the Gauss Centre for Supercomputing e.V. and GENCI - Grand Equipement National de Calcul Intensif – respectively).

Pole (b) will develop a common industrial vision of where Europe wants to be as a HPC supplier in 10 or 20 years, and produce a joint roadmap for realising this vision. It is the industry-led platform where companies (HPC suppliers and users) and academia discuss and agree the way forward.

Pole (c) coordinates the carrying out of a number of services that are of particular importance to industry: providing expertise on the scaling of legacy codes and their use; offering services for simulation and prototyping, possibly also through clouds; ensuring the evolution and availability of tools and of major application software in areas that are important for Europe, from computational fluid dynamics to genomics; and executing training, outreach and communication activities.

Europe - a global actor

Actions with global scope are needed to match the global challenges ahead of us. These challenges exist in the area of HPC itself — the move to exa-scale — but also in the science and societal domains where HPC is the essential tool available to tackle them (e.g. climate change, biomedical research).

On an academic level Europe is fully engaged in the International Exa-scale Software Project (IESP) via the joint European Exa-scale Software Initiative (EESI)[19]. On the global scale, the emergence of Global Virtual Research Communities and HPC-empowered e-Infrastructures paved the way to efficiently pool resources (human, technological, computational). Concrete examples are in radio-astronomy where telescopes around the globe are linked to a central computer in the Netherlands; or computational structural biology investigating the functioning of molecules and cells. The G8 countries have agreed to set aside funds for high-performance computing software development projects. These efforts support the joint global work towards exa-scale computing software and should continue.

However, a strategy towards a European HPC renewal requires keeping in mind Europe's interests in terms of intellectual property in this strategic area. Intellectual property developed in European R&D projects often benefits mainly the participating companies from 3rd countries as the Framework Programme projects impose very few restrictions on the origin of participants or on the management of IPR. A more balanced arrangement concerning the technology transfer to third countries needs to be found.

Overall, a level-playing field for the European HPC industry and expertise as suppliers has to be ensured. Results of European HPC research and development results should be exploited as much as reasonably possible in Europe.

[19] IESP: www.exascale.org and EESI: www.eesi-project.eu

Section 3: Envisaged Measures

This section puts forward a range of measures addressing the objectives highlighted previously. To make HPC a strategic priority for Europe, coordinated and joint efforts between EU, Member States and industry in terms of industrial policy, innovative procurement mechanisms, and substantial financial commitments are needed to ensure Europe's place in global HPC efforts. The section starts with a summary of the current state of affairs so that comparison with what is proposed next becomes easier.

The current state of affairs

Following the setup of PRACE in 2008 and the commencement of services in 2010, the research sector is pooling its leadership-class computing systems into a single infrastructure and makes them available to all European researchers. In this way critical mass is achieved, training is more effective and access to these top-of-the-range computing systems is provided on the basis of scientific excellence and the needs of a given R&D effort rather than on the country where a researcher is located. PRACE has become a platform for the provision of pan-European HPC services, the coordination of national HPC system acquisitions and for sharing know-how between the participating supercomputing centres. This has led to a focusing and alignment of the European supercomputing efforts in the academic field.

Despite these (recent) efforts of PRACE in the academic field, Europe's overall share in the globally available HPC capacity has gone down from more than 30% in 2008 to 20% in 2011; while Asia's share has gone up to 34%. Europe continues to be an appealing sales market for the US – and probably in the future for Chinese, Japanese and Russian - HPC system vendors. European HPC software and services are adapted and tuned to these HPC systems and this in turn further benefits their vendors from 3rd countries.

Commission investment levels are around € 50 million annually (some 10% of the current total European HPC public expenditure) in support of the PRACE infrastructure, a small R&D and experimentation effort towards next-generation exa-scale HPC, and limited coordination in the acquisition of supercomputer systems. The purchase of (mostly small scale) HPC systems continues to be done at national level. The R&D work launched on exa-scale is a very good start but would need significant ramping up to bring it on a par with anticipated investments by the US, Japan, Russia and China and to achieve a sustained impact on the European HPC supply industry.

Act in a decisive way to ensure Europe's competitiveness in and through HPC

To let European industry and academia benefit fully from HPC, more and better resources and services would need to be made available. Additional resources would be needed to acquire more HPC systems; to adapt and up-scale software packages allowing them to fully exploit the new and advanced computing architectures; to complete the European HPC ecosystem, providing a HPC service infrastructure including HPC consulting, modelling, simulation and computing services, also for industry and SMEs; and to reinforce training. In addition, decisive actions are needed to ensure Europe's independent access to HPC as a strategic matter for competitiveness. A Europe-based supply of HPC systems and services should be reached by 2020.

Europe strategically needs to ensure native HPC capabilities to remain competitive and position itself as a centre of innovation, a hub of scientific excellence and a global partner. Gaining independent access to HPC systems and services would support growth and competitiveness also in ICT industry and the economy in general. Most importantly, Europe would be able to address societal challenges more efficiently, ranging from climate change, to the working of the human brain, or to the treatment of diseases with a large impact on citizens like Alzheimer's. Europe will be able to invest in HPC centres of excellence that design and build dedicated HPC systems with specific features optimised for addressing a given societal challenge (e.g. simulating the human brain needs a different computing architecture then designing and simulating a more efficient battery for electric cars). If Europe does not feature centres of excellence with dedicated and top-of-the-range HPC systems, leading research and innovation would be carried out at locations where such resources are made available (outside Europe). Thus, native HPC capabilities would be needed to provide a flexible HPC eco-system tuned to the needs of the European user community.

The additional financial resources needed are estimated at around € 600 million per year[20]. They would be provided by the Commission (e.g. Horizon 2020 – e-Infrastructures, cohesion policy instruments), Member States (individually and through Joint Programming), and industry (suppliers and users). This amount is well reachable if one considers that PRACE has already 20+ partner countries participating. Overall, this would double the European HPC market to some € 1200 million per year.

These resources would stimulate the entire sector and would increase demand for a HPC trained workforce. Sufficient resources would be available to provide the required training in many HPC areas. HPC competence centres would be launched as clusters of expertise that bridge between academia and industry in terms of HPC development and use for simulation, visualisation, product prototyping and modelling. The setup of HPC experimentation centres (e.g. on exa-scale technologies) would allow industry to exploit much better the opportunities offered by novel HPC.

Joint and coordinated procurement of HPC systems and provision of HPC services would free – to some extent - HPC system acquisition from national budget limitations. This should be supported by a strengthened pan-European HPC governance scheme. Stimulus funding from the EU is necessary to encourage the pooling of resources between Member States. In addition, a strong support of Pre-Commercial Procurement (PCP) will foster the development of advanced and leadership-class HPC systems. PCP is seen as a strategic tool to stimulate research and innovation in HPC and strengthen the HPC industry in Europe. Pre-commercial procurement undertaken on an annual or biannual basis with some € 100 million per PCP activity would amount to about 4-8% of the overall annual HPC expenditure, or 6-12% of the public annual expenditure. Such an amount is modest in the sense that it would not disrupt normal public procurement of HPC systems, yet sufficient for stimulating a native EU technology development and supply. PRACE is in a good position to facilitate the pooling of resources between Member States and matching funding from the European side, in order to support the (pre-commercial) procurement of HPC systems and R&D&I efforts with a European dimension.

At the same time, the pooling of national funds for PCP is expected to be politically and organisationally challenging because of the partial loss of control over the procurement process by individual countries and their supercomputing centres, but also because some of the countries may perceive that they have no national interest in funding an R&D&I

[20] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: Table 4 on page 58

programme in advanced HPC through their procurement budgets. It is therefore important that PRACE defines a governance scheme for PCP investments which is variable in geometry, is perceived by all as fair, and motivates investments both by countries that aspire to be major HPC market players as well as by those that limit themselves to a lesser role.

Europe's strengths in embedded and mobile computing, in energy efficiency, in microelectronics and software will be the basis for innovative and efficient European designed and developed HPC systems. Together with Europe's strength in HPC applications, EU industry possesses all necessary know-how and skills across the full technology spectrum to be able to develop leadership class HPC systems. Industrial efforts in HPC can be coordinated by a European Technology Platform in this area.

With such efforts in place, Europe can play a strong role in the global race for the next generation of HPC systems – the exa-scale computing challenge. The extra effort required to move to exa-scale computing could have enormous returns: mastering extreme-performance technologies (use and supply) would not just put European technologies back at the forefront of supercomputing, but it would also be crucial for maintaining and improving the competitiveness of European industries in many areas, for key advances in fundamental and applied research and for tackling global challenges such as energy, climate change, etc.

Section 4: Analysis of Proposed Measures

This analysis is based on the scenarios developed in the Final Report of the IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020" and on the consultations with HPC stakeholders (industry, academia and Member States, see Annex).

Investments in R&D and HPC are critical for economic growth in many sectors, but growth will normally lag these investments by five years or more. The GDP impacts are in 2020 values based on today's investments. This impact is based on increased expenditures on HPC, which triggers more expenditure in R&D, generating more innovative products and services in the longer term. Innovative products and services are generating healthy businesses with growing revenues. Finally these revenues generate overall economic growth and contribute to the GDP. Thus, investments in HPC contribute to economic growth in the long run. The relationships between the various steps have been modelled by IDC and integrated in an overall model linking investment in HPC and economic growth. IDC is using this model in their studies and in providing advice to governments around the globe. Evidence in Europe (e.g. automotive, pharmaceutical and aerospace industry) indeed supports such a relationship between HPC investment and global competitiveness.

According to one IDC study carried out in this context, an investment into HPC today can contribute as much as 3 % to GDP growth in 2020. The widespread use of HPC will improve the business environment, especially for SMEs, and will foster the development of a strong and sustainable industrial base able to compete globally.

European GDP improvements will come from a number of different areas:

- Directly from industries that use the improved HPC infrastructure and tools to make better and more competitive products and services
- Directly from European HPC suppliers of the targeted new technology areas (and for related HPC suppliers)
- Indirectly from scientific advances, although these take longer to show up in economic terms (and are not included in this evaluation)

Is continuing the Status Quo an option?

Despite the gains achieved by PRACE in recent years, maintaining the status quo would lead to additional scientific and economic ground lost to foreign competitors by 2020. Minimal investment increases in HPC could even cause a negative effect on GDP by 2020. Other countries (in addition to the US and to some extent Japan, especially China and Russia, potentially India and Brazil) are increasing their efforts and investments in HPC and by 2020 Europe would clearly be seen as a follower.

In the field research IDC conducted for the Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", survey respondents from national funding agencies, HPC centres and research programs, and vendor companies in Europe clearly articulated the consequences if Europe does not take steps to develop native HPC capabilities. The respondents almost universally portrayed the consequences as dire for both Europe as a region and the EU Member States, especially the smaller ones.

The main foreseeable consequences were as follows:

- Europe would lose ground as a scientific and research powerhouse. The HPC capacity available through PRACE in 2011 is oversubscribed by a factor of 6 in terms of CPU hours requested for R&D. At the same time Asia has increased installed HPC capacities further. According to the Top500 list Europe had at the end of 2011 only 19% of the world's HPC capacities (in terms of aggregated performance) while the Americas had 45% and Asia 36%. Europe would become inferior to the USA and Asia in scientific capability. Smaller EU Member States would likely suffer most.

- Europe and the EU Member States could lose industrial competitiveness and jobs. The existing EU HPC strategy already lags the US and Japan in providing industry with access to world-class HPC resources. If nothing is done to remedy this situation, Europe and the Member States could fall seriously behind these and other nations in industrial innovation and economic competitiveness.

- The European ICT industry has some unique strength in the areas of low-power electronics, system integration, energy efficiency and innovative cooling, HPC system components, HPC system operational tools and software analysis techniques. Not exploiting the synergies between these within a European initiative will make some of these suppliers valuable targets for foreign takeovers and an opportunity will be lost in combining these efforts to stimulate the European HPC supply industry.

- Exa-scale HPC computing systems require a complete new approach to software programming. Without direct access and interaction during the development of these new computers it would be impossible to have scientific and industrial software packages ready in time so that they are able to fully exploit these new systems. A decoupling of these co-design and development processes would either lead to an inefficient utilisation of the HPC systems in Europe or provide other nations with a window of opportunity to come up with alternative software packages replacing the European ones.

- Europe and the EU Member States could experience an escalating brain drain to the US and Asia, along with great difficulty in attracting talented scientists and engineers. The Europe-to-US brain drain in HPC is already occurring, including scientists relocating to work at US national laboratories with the best HPC resources available. This brain drain would likely escalate if Europe failed to keep its HPC resources on a par with those of the US and Asia.

- Europe and the Member States could become increasingly reliant on the US and Asia for scientific, industrial, and technological advances. If Europe fails to keep pace in HPC with the US, Japan, and others, Europe might be forced to import scientific, industrial, and technological advances from other areas of the world — without having much to offer in exchange.

- National security concerns may not be able to be addressed in an independent way.

- The smaller and less affluent EU Member States could lose the ability to access and benefit from large HPC systems. This would widen the digital divide in Europe, to the detriment of the smaller countries. Unlike Europe's wealthier Member States, the smaller Member States typically cannot afford to fund world-class HPC systems on their own and rely to a greater extent on access to HPC systems in other countries.

- The lack of HPC competence centres severely hampers the access of SMEs to this key tool as an efficient means for simulation, visualisation, modelling and prototyping.

- Europe's existing world-class skills in HPC related technologies would also erode without continuing access to world-class HPC systems.

Expected impact of proposed measures

A comprehensive HPC strategy such as the one proposed has the potential to substantially impact in many economy sectors and increase GDP in many EU countries. Many companies in Europe would see direct benefits from the better use of HPC, including automotive, aerospace, energy, bio-life sciences, climate, finance, movie design, pharmaceuticals, IT, and chemicals. In addition, a critical mass of PCP for leadership-class computers would directly grow the broader HPC supply sector (systems and services) across Europe.

Approximately 27% of overall EU GDP is currently in industry (if services and agriculture are considered the other sectors). A strong European HPC strategy could increase industry growth by 6%–8% in 2020 and potentially as much as 10% in 2025. This would result in an increase in GDP growth for all Europe by 2% in 2020 and 3% in 2025 as the strategy and investment impacts materialize.[21]

The additional investment of € 600 million in combination with the use of PCP would provide the best chance of reaching all or at least most of the strategic leadership goals by 2020. It would also provide sufficient HPC resources and tools to increase the rate of scientific advancement across Europe. It would ensure the establishment of a dynamic HPC ecosystem where the encouraging environment and the large and well trained workforce in HPC would attract (including foreign) HPC actors to carry out their work in Europe.

On an international level, US[22,23], Japan[24], Russia[25], China and Korea[26] all are increasing their investments in HPC and are ready to invest heavily for their independent access to this key technology recognising its strategic nature and the prestige it carries; they are also ready to cooperate with Europe in addressing some of the major challenges in software and applications. Europe simply cannot afford to stay out of this race.

Other benefits would include:

- Europe would gain an independent and native access to HPC technology from a European supplier base.
- A pan-European HPC governance scheme would ensure the efficient utilisation of resources available for the acquisition and the provision of HPC systems and services.

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[21] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report: pages 59 and 60. The underlying model is based on the assumption that today's investments in HPC trigger more research, which causes more revenues, which result in higher GDP in 2020 and beyond.

[22] In his 2011 State of the Union address, US President Obama noted China's HPC achievements and countered that the Department of Energy's Oak Ridge National Laboratory is "using supercomputers to get a lot more power out of our nuclear facilities."

[23] The US has put aside $126 million alone for exa-scale computing in 2012, to overtake China's Tianhe-1A supercomputer as the fastest computing platform

[24] From 2002 to 2004, Japan's "Earth Simulator" supercomputer topped the Top 500 list, sparking concern that motivated the US Government to substantially bump up funding for high performance computing in order to recapture the lead. In 2011 Japan's K computer took the lead again.

[25] In 2009, Russian President Dmitry Medvedev warned that, without more investment in supercomputer technology, Russian products "will not be competitive or of interest to potential buyers."

[26] In June 2010, Rep. Chung Doo-un of South Korea's Grand National Party raised that topic: "If Korea is to survive in this increasingly competitive world, it must not neglect nurturing the supercomputer industry, which has emerged as a new growth driver in advanced countries."

- Pre-Commercial Procurement activities would pool national funding resources in an efficient way for the development of leadership-class innovative HPC systems. This would give Europe a boost in the race towards exa-scale systems.
- Europe would be recognized as a hotbed for new science and engineering research.
- Europe's leadership in specific areas of HPC (e.g. application software, tools, energy efficiency, system design) would create many new jobs in science and industry, and could result in faster growth in the national economies.
- HPC Intellectual Property (IPR) generated in Europe with public funds would benefit Europe and its economy.
- National security aspects of HPC could be well catered for.

The successful implementation of this strategy requires establishing a level-playing field for the European HPC industry on a global level, ensuring that EU companies have access to foreign markets and that IPR generated from European HPC investments first and foremost benefit Europe. This will require proper use of the rules on protection, transfer and exploitation of IPR in European programmes for research and innovation (Horizon2020) as well as judicious selection of the selection and award criteria in pre-commercial procurements – by PRACE or other entities. Proper use of these instruments would also encourage (foreign) HPC actors to locate more of their R&D in Europe. Overall, this will allow the achievement of the set objectives from a position of strength and increased international influence.

Additional observations

The administrative impact of the proposed measures has been assessed and found to be negligible: PRACE and its governance structures have been setup; the e-Infrastructures Policy Forum with the Member States exists already too; a European Technology Platform on HPC has been announced and is in the process of being setup. No new structures need to be created. Eventually existing structures might need more staff in the longer run. Again, this will not create significant extra burdens to any of the actors.

Energy consumption is a clear barrier that has to be overcome. The recent advances in leadership-class computing have shown a halving of power consumption over the last 6 years while the performance increased by a factor of 250 in the same timeframe. Overall the electricity bill in HPC is a significant factor (some € 2-3 million per centre per year for electricity is quite common). HPC vendors and users are very much aware of this factor and already now there are many very promising activities ongoing to reduce the energy consumption (and the associated electricity bill). This is in the very (economic) interest of all of the stakeholders and no particular additional requirements need to be assessed.

IDC has carried out a survey with European HPC stakeholders gathering their input on the options listed above. Their main comments and suggestions are provided in the Annex.

Section 5: Monitoring and Evaluation

A full review of the progress achieved should be carried out by 2015. This assumes that the proposed strategy will be implemented from 2013 onwards. Thus, after some 3 years concrete effects should be visible. In 2015 one should also have already a good idea on the progress towards exa-scale and the overall impact of HPC on Europe's innovation and competitiveness.

In the meantime various indicators are available measuring the progress towards the objectives. For each of the specific objectives a set of indicators is provided (the progress towards the general policy objective is measured via the entire range of indicators given below):

Specific Objectives

- Encourage the industrial and academic use of HPC through the provision of a world-class European HPC infrastructure

  The growth of a functioning European HPC eco-system can be monitored via PRACE: the number of user communities it is serving, the amount of computing cycles available and the services provided to users (e.g. number of up-scaled software packages).

  The number of centres of excellence, the number and profile of their users are good indicators on how well SMEs and industry in general can access HPC resources and services.

  The investment level of HPC resources can be measured by the total volumes of annual HPC system sales in Europe. IDC is one of the organisations monitoring such sales on a global basis. In this way the amount of HPC resources available to academia and industry can be measured effectively. The actual use of such systems is difficult to measure, especially when it comes to industrial use.

  The level of joint pre-commercial procurement activities in HPC can be measured via the annual reporting provided by PRACE and its partners on their activities carried out in this context. The financial incentives fostering the joint-procurement can be measured via the same mechanism.

  The amount of training provided and the number of people trained can be readily measured. However, the overall impact of having a sufficiently large HPC trained workforce has to be measured via stakeholder consultations and surveys.

- The level of independent access to HPC technologies, systems, services and tools for Europe can be monitored through the number of patents registered in Europe in HPC and the number of people employed by European HPC suppliers.

- The effectiveness of a pan-European HPC governance scheme can be measured by the number of joint and/or pre-commercial procurement actions carried out through PRACE versus the number of such activities done outside PRACE. The amount of money pooled is a further indicator of the preparedness of Member States to join resources in this field. The establishment and functioning of an ETP on HPC can be measured via the number of participants in it and its annual reporting. The network of competence centres and centres of excellence can be measured by the number of centres established and the number of users served.

- Europe's share of the world's total available HPC capacity can be measured to some extent via the 6-monthly published Top500 ranking. However, most industrial and national security-related systems are absent from that list. Nevertheless, it still gives a good relative picture on how Europe is performing vis-à-vis other nations and regions.

Surveys and studies will be also carried out for specific topics (e.g. the needs for HPC software up-scaling and applications, etc.) and this will feed into the overall assessment of the state of HPC in Europe. The gathered information will be shared with all actors (as far as this does not concern any national security-related issues or commercially sensitive topics).

Many of these monitoring and consultation activities are already ongoing and they will be continued. Thus, no significant extra efforts will be needed to maintain the current level of monitoring. The launching of special studies will be done on a case by case basis and following a clear assessment of the needs and their cost effectiveness.

Section 6: Stakeholder Consultations

Key public consultation documents and summaries of replies

HPC in Europe Taskforce (HET) white paper: “Scientific Case for Advanced Computing in Europe”
www.hpcineuropetaskforce.eu/files/Scientific case for European HPC infrastructure HET.pdf

Online Consultation (until 20 May 2011): Green Paper on a Common Strategic Framework for future EU Research and Innovation Funding – Question 25: How should research infrastructures (including EU-wide e-infrastructures) be supported at EU level?
ec.europa.eu/research/csfri/index_en.cfm

> 81.4 % of the 719 respondents considered Research Infrastructures (including EU-wide e-infrastructures and HPC) important or of high importance and that this should be further supported at EU level.
> One of the main messages of the respondents was: "Computational resources (HPC and PRACE in particular) have become necessary to tackle scientific challenges and the EU should promote and facilitate computing infrastructures".

Key studies and work carried out by external consultants

International Data Corporation (IDC) Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report
http://www.hpcuserforum.com/eu/downloads/IDCWP12S_12.10.2010v2_webInterim.pdf

IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Final Report
http://www.hpcuserforum.com/eu/downloads/SR03S10.15.2010.pdf

IDC Study "Financing a Software Infrastructure for Highly Parallelised Codes", Final Report
http://www.hpcuserforum.com/EU/downloads/IDCEUsoftwaresurveyguide.zip

US High Performance Computing Initiative (HPC)
www.compete.org/hpc

Conclusions from HPC expert consultation meetings

2 September 2010

The main and unanimous conclusion of the meeting is that there is no choice: a European-wide effort should and must be engaged to develop autonomous technology (covering the whole spectrum from processor architectures to applications) to build exa-scale systems in ~10 years. Europe has the technical and human-skills capabilities to tackle this big challenge. Even if currently Europe is very weak compared to other regions in terms of supplying High Performance Computing systems, there are strengths (e.g. in applications, embedded/low-power computing) that are highly relevant for the next generation of computing. These strengths can and must be exploited in order to get European industry back in the computing scene as technology leading-edge supplier. There are new opportunities created from the transition from peta to exa-scale computing as this will not be achieved by an evolution or extrapolation but by a revolution in computing technologies (all the way from hardware, programming, algorithms etc. to applications). There is a window of opportunity that cannot be missed, as the social, economic and scientific impacts are enormous compared to the investment for this effort.

30 March 2011

Now it's the time to act. 2011 is a critical year in which important decisions will be taken for the future of the development of supercomputing capabilities in Europe including the efforts towards producing exa-scale systems. The three main areas where timely action should be taken are:

(a) Structuring the European stakeholders: a European Technology Platform (ETP) was receiving strong support

(b) Applications supporting science, supporting industrial co-design processes, but also supporting socio-economic analysis in political and economic decision making processes

(c) Sustainability in terms of supporting the necessary R&D, engineering and application (re-)coding effort for exa-scale systems, and of market and industrial strategy considerations.

Europe has the required technical and human-skills capabilities to tackle the exa-scale challenge, but in addition to the current weaker position of the technology supply in supercomputers the European R&D, organisational and political landscape is much more complex than in US, China or Japan. However, the extra effort required to coordinate the European efforts can have enormous returns: mastering extreme-performance technologies (use and supply) is not just to put European technologies back at the forefront of supercomputing, but is also crucial for maintaining and improving the competitiveness of European industries in many areas, for key advances in fundamental sciences, engineering and technology, and for tackling global challenges such as energy, climate change etc. Solid and quantified arguments integrated in a convincing story and a comprehensive plan on how to carry out the efforts must be developed in order to get the necessary support of EU and national decision-makers.

Stakeholder Survey Results

IDC carried out a survey[27] with European HPC stakeholders where the most popular choice for the EU's HPC strategy to focus on was HPC software applications and application scaling (mentioned by 71% of the respondents). Becoming stronger in "the use of HPC to solve important scientific problems" (62%) was the second most popular choice, followed by "the use of HPC to solve important engineering problems" (46%). Furthermore, the issue of staffing/training was raised as there is always a shortage of workforce in HPC.

A sizeable majority of the respondents (72%) did not favour having the EU attempt to change the market structure or business models for HPC in Europe, such as for instance might happen if the EU were to adopt a protectionist policy in competitive procurements or provide direct funding support for EU-based vendors' commercial (as opposed to pre-competitive) technology and product development.

What Are the Most Important Approaches for EU HPC Leadership?

Approach	Number of Responses	Percentage of Responses
Having many very large supercomputers, e.g., being at or near the top of the Top500 list of the world's most powerful supercomputers (www.top500.org)	25	41.0%
Making world-class HPC resources more widely available to the EU scientific and engineering communities	57	93.4%
Making HPC more readily available for the first time to small and medium-size businesses (including industrial supply chains, small educational sites, etc.)	33	54.1%
Advancing scientific leadership by using HPC to solve some of the world's most challenging problems	50	82.0%
Building an EU-based HPC vendor community with world-class capabilities in important areas (hardware, software, storage, networking, etc.)	24	39.3%

Note: Multiple responses were allowed. 61 sites responded.

Additional Comments:

"Encourage the constitution of strong user communities; such communities will be in the best position to advocate and to request funding for the long term effort."

Source: IDC, 2010

The survey respondents see the areas of expertise most needed from HPC user organizations as falling into these main categories[28]:

- Expertise in parallel programming for highly parallel HPC systems
- Expertise in creating advanced software algorithms
- Expertise in writing highly scalable application software
- The ability to port and optimize applications for new hardware architectures, including heterogeneous architectures that include newer processor types
- The ability to communicate and collaborate well with scientists

The main recommendations from the survey respondents on what the EU should do help develop and obtain critical HPC skills were the following[29]:

- Make HPC leadership a higher priority in the EU

[27] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: page 54 onwards and page 93 onwards
[28] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: page 111 onwards
[29] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: page 114 onwards

- Ensure that HPC leadership becomes a long-term commitment with sustained funding
- Focus the EU HPC strategy on solving important problems
- Focus on algorithm and software development
- Strengthen HPC education and access in European colleges and universities

The main recommendations from the survey respondents on what they would like to see the EU do to make Europe stronger in HPC were the following[30]:

- Make HPC a higher priority on the EU's research agenda
- Provide substantial EU funding and not just coordination and direct funding more toward software development and skills training
- Ensure broad access to leadership-class HPC systems by users in all Member States
- Actively promote the benefits of HPC for science and industry
- Create a central EU HPC organization, possibly by expanding the mission of PRACE and also borrowing from the CERN model
- Drive toward EU leadership in peta-scale and exa-scale computing
- Include support for industrial initiatives and promote public-private partnerships
- Avoid funding a large number of small projects instead of a limited number of larger projects
- Avoid protectionism in procurements

The main recommendations from the survey respondents on actions that are needed at the national level to improve to improve the European position in HPC were the following[31]:

- Improve and unify HPC resources and access at the national level
- Increase national funding for HPC-enabled science and engineering
- Expand university programs in HPC at the national level
- Promote an understanding of the value and contributions of HPC

[30] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: page 117 onwards, page 125 onwards and page 136 onwards

[31] IDC Study "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020", Interim Report: page 122 onwards

Annexes

Technical background material:

The Communication on ICT Infrastructures for e-Science - COM(2009)108
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