High Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy

Final Report

A study prepared for the European Commission
DG Communications Networks, Content & Technology by:
This study was carried out for the European Commission by

![IDC logo]

Contract number: 30-CE-0663100/00-22
SMART number: 2014/0021

DISCLAIMER

By the European Commission, Directorate-General of Communications Networks, Content & Technology.

The information and views set out in this publication are those of the author(s) and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission’s behalf may be held responsible for the use which may be made of the information contained therein.

doi:10.2759/034719
KK-04-15-496-EN-N

© European Union, 2015. All rights reserved. Certain parts are licensed under conditions to the EU.
Reproduction is authorised provided the source is acknowledged.
ABSTRACT

This is the Final Report D3 of the study SMART 2014/0021 High Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy that IDC conducted for the European Commission Directorate-General for Communications Networks, Content & Technology, Unit C1 eInfrastructure. The main goal was to assess progress against the Action Plan in the EC Communication, High Performance Computing (HPC): Europe’s Place in a Global Race (February 2012) and provide recommendations regarding the strategy and its implementation. The findings will support the EC report to the European Parliament and Council on the implementation of the Communication, planned for 2015. The European HPC strategy has made impressive overall progress, especially in organizing Europe’s HPC community to pursue the strategy’s leadership goals, narrowing the gap between the largest European supercomputers and their counterparts elsewhere, and providing fair access to leading supercomputers for scientists and engineers throughout Europe. To achieve the goal of HPC leadership—meaning at minimum parity in HPC capabilities with the best in the world—Europe needs to acquire at least one exascale supercomputer in the same timeframe as the U.S., Japan and China. The current European HPC strategy provides no clear path for doing this. IDC recommends that Europe extends the end date for its HPC strategy from 2020 to 2022, to match the exascale time frames of the U.S., Japan and China, and that Europe plans to acquire two exascale systems, one of which stresses innovative European technologies (such as those being advanced within ETP4HPC). To amass the €1 billion-plus funding needed for the exascale supercomputers, the Member States must find a way to pool funding, and the European Commission must find a way to boost its contribution to the needed funding amount. Rules for collaboration will likely need to change, in order to allow the Commission and Member States to work more closely together. European HPC suppliers face protective barriers in the U.S., Japanese and Chinese HPC markets. These market asymmetries should be addressed at a government-to-government level, preferably by the European Commission. The European Commission and Member States should also collaborate to address the shortage of qualified HPC job applicants, especially by ensuring that HPC competency is required in university scientific and engineering curricula, and that students are aware from an early age of attractive, rewarding HPC careers.
EXECUTIVE SUMMARY

Europe has made impressive progress in areas that are crucial for the goals of the Action Plan, especially organizing the European HPC community to pursue HPC leadership on a unified basis, expanding the scientific and industrial access to and use of supercomputers, and launching initiatives to strengthen the European HPC supply chain.

The IDC assessment of progress in implementing the European HPC strategy, and our related recommendations, are based on the four Action Plan Objectives and the six related Strategic Actions. This ultimate aim is to make Europe stronger in using HPC to advance science and industry, as stated for example in IDC’s 2010 study report for the European Commission¹:

*The EU needs to create and implement a far-reaching vision for high-performance computing (HPC) leadership, and suggests that it be based on this vision: Providing world-class HPC resources to make EU scientists, engineers, and analysts the most productive and innovative in the world in applying HPC to advance their research in the pursuit of scientific advancement and economic growth.*

In particular, Europe has significantly narrowed the wide gap separating the most capable U.S., Chinese and Japanese supercomputers from their European counterparts. In November 2010, 9 of the world’s 50 most powerful supercomputers were located in Europe (www.top500.org). Four years later, Europe hosted 19 of the top 50, including the PRACE tier-0 supercomputers.

European HPC investments are producing excellent returns-on-investment (ROI) for science and industry. IDC captured detailed ROI information on 143 European HPC projects. For projects that generated financial returns, each euro invested in HPC on average returned €867 in increased revenue/income and €69 in profits.

Europe achieved healthy HPC funding growth in 2010, 2011 and 2012, but Europe-wide funding declined heavily in 2013 and 2014. On average, however, the net funding increase over the last five-year period was extremely good for pursuing HPC leadership. Significant investments will be needed, however, for preexascale systems in the period 2019-2020 and exascale systems in 2022 (see the financial section of this report). IDC estimates that the overall European-wide HPC R&D investments, supercomputer purchases, and related services in 2010 amounted to approximately €1.8 billion: €715 million in purchases of supercomputers, plus €90 million (in supporting investments, integration services and professional services); plus ~€850 million (storage, software and repair services purchased with the computers); plus ~€30 million (from the EC); and ~€90 million (R&D by vendors and users). Note that these are IDC estimates, as there is no European tracking of these numbers at this time.

Overall, the main actors—the European Commission, PRACE and ETP4HPC, have done an admirable job of coordinating with each other to advance the European HPC strategy, but more needs to be done. To amass the €1 billion-plus in funding needed to acquire preexascale and exascale supercomputers in globally competitive time frames, the Member States will need to find a way to pool resources and the EC will need to find a way to contribute a significant portion of the funding (IDC recommendation: 50%). As IDC stressed in our 2010

report to the Commission, adequate investments in software will be one of the most important determinants of future HPC leadership. In addition, the Commission may need to contribute to the escalating operating expenses associated with PRACE tier-0 supercomputers.

The PRACE peer-review system has enabled fair access to leading supercomputers (infrastructure) by scientists, and more recently industrial engineers, from throughout Europe. Greater outreach is needed to industry, especially SMEs. The PRACE 2.0 financing scheme (not yet defined) will likely aim to spread the burden more equitably among PRACE members but may risk curtailing access for scientists from Member States that are unable or unwilling to make their assigned contributions. HPC procurements in Europe should make greater use of PPI mechanisms, and ETP4HPC and Member States within PRACE should coordinate closely to ensure that the ETP4HPC roadmap reflects the innovations PRACE members and others would like to procure. The aims here are to accelerate HPC innovations by European suppliers (as ETP4HPC is already doing), and also to increase the likelihood that these innovations will be incorporated into supercomputer procurements that enable the European technologies to mature in real-world customer environments.

At the very high end of the supercomputers segment, Europe has significantly narrowed the former wide gap separating the most capable U.S. and Japanese supercomputers from their European counterparts. Spending increased substantially in the EU/EU+ for large supercomputers from 2009 to 2012, but then declined. European overall spending on large supercomputers grew from 112 million euros in 2009, to 658 million in 2012, then down to 362 million euros in 2014. In November 2010, shortly after the founding of PRACE, 9 of the world's 50 most powerful supercomputers were located in Europe (www.top500.org). Four years later, in November 2014, Europe hosted 19 of the top 50, including the PRACE tier-0 supercomputers. The aggregate peak performance of the Europe-based supercomputers rose more than ten-fold during this period, from 4.3 petaflops in November 2010 to 48.9 petaflops four years later. Clearly, Europe's standing as a provider of high-end supercomputing resources advanced in both absolute and relative (worldwide) terms during this period.

From a technical standpoint, Europe's HPC community, building on existing and planned EU-wide HPC development initiatives, is well positioned to exploit a strong base of indigenous and foreign technologies across its commercial, academic and government sectors to assemble exascale HPC capability that could, in some critical application sectors, achieve world-class stature or even global leadership. A clearer path is needed, however, for driving innovation into supercomputer procurements and pooling enough money to deploy pre-exascale and exascale supercomputers in globally competitive time frames.

**Progress on the Four EU HPC Action Plan Objectives**

The overall European HPC strategy is built on a foundation of key objectives that are the source and inspiration for specific strategy actions. IDC has examined progress against these key objectives in detail, and after lengthy discussions with many EU and other HPC technology and policy experts, offers the following assessment.
Assessment of Specific Action Plan Objectives:

1. **Provide a world-class European HPC infrastructure, benefitting a broad range of academic and industry users, and especially SMEs, including a workforce well trained in HPC.**
   - Strong progress was made in deploying large HPC systems across Europe, primarily funded by the Member States, with important secondary funding support by the European Commission through PRACE. Although the overall level of funding was considerably lower than recommended in IDC's 2010 report (as shown in Section 5, Table 5.G), Europe nevertheless made outstanding progress in getting Europe "back in the pack" of top global research areas over the last four years.

2. **Ensure independent access to HPC technologies, systems and services**
   - Hardware technologies from European suppliers today have a very small share and presence in HPC across Europe. Some European software companies are highly successful in Europe and across the world. ETP4HPC collaborations between European and non-European suppliers will benefit European scientists and engineers. A large majority of the European HPC stakeholders IDC interviewed agreed that European scientists and engineers require access to best-in-class HPC technologies and systems, no matter where in the world they come from.

3. **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**
   - Pre-commercial procurement (PCP) and public procurement of innovative solutions (PPI) are underutilized in Europe today. PCP and PPI are key mechanisms used by
the governments of the United States, China and Japan (Europe's main rivals for HPC leadership) to drive commercial competitive advantage and to advance suppliers of indigenous technologies. European HPC stakeholders greatly prefer PPI (and related mechanisms) over PCP as a way to advance innovation. There is no central procurement agent in Europe with the financial ability and motivation to exploit PPI or related mechanisms on behalf of Europe, as needed to compete successfully with the U.S., China and Japan.

4. **Ensure the EU's position as a global actor**
   - Advances in highly parallel software will be one of the most important determinants of future global HPC leadership. Europe has world-class strengths in highly parallel software. The de-emphasizing of funding for exascale software development by the U.S. government has created an opportunity for Europe to gain an important advantage. EESI's exceptional work has set the stage for this. The cPPP on HPC, established with the ETP4HPC with €700 million in EC funding, provides a framework for making it happen, especially through the centers of excellence and continued EESI work.

**Assessment of the progress and success of the six Strategy Actions:**

Based on the overarching objectives defined in the European HPC plan, specific policy-related strategy actions were created. For those six strategy actions, IDC offers the following further assessment and recommendations.

*Note: For the sake of clarity, the content of this section will necessarily repeat some of the content of the preceding section.*

1) **Governance at EU level:** seeks adequacy, openness, and efficiency of the current organisations (e.g., PRACE and ETP4HPC) to structure the industrial and scientific stakeholders, to steer the high level objectives and policies on HPC, to pool available HPC resources across the Member States, and to efficiently implement the HPC strategy.

   - The key organizations contributing to the implementation of the European HPC strategy—the European Commission, PRACE and EPT4HPC—have done an admirable job of advancing Europe's position in the few short years since the 2012 Communication. No single European Member State has the financial and related means to compete effectively with the U.S., China and Japan for HPC leadership. If Europe is to be an HPC leader, it will therefore be necessary for Member States to coordinate their HPC strategies more closely, including the pooling of funding, and for the EC and the Member States to coordinate even more closely. This tighter coordination will require some adjustments to existing governance rules and practices by all parties. Tensions already present within Europe's loosely coupled, collaborative HPC governance model will likely grow as the exascale computing era approaches, unless these issues are addressed. Governments of some Member States hosting PRACE tier-0 supercomputers are reluctant to continue funding 100% of the substantial, rising operating expenses associated with these computers. They would like some relief from the Commission and/or from other PRACE members. Access to more of the tier-0 supercomputers' cycles may need to be secured for European, as opposed to national, use.
In carrying out this study, IDC found that even some of the most prominent members of Europe's HPC community did not adequately understand the impact of governance models on the European HPC strategy—or how all the pieces of the strategy fit together. Stronger communications outreach is needed to convey this understanding.

2) **Financial envelope for HPC** spans current investment levels for the acquisition of high-end HPC resources in Europe, and analysis of required levels to meet the Action Plan objectives (including investments for system acquisition, training, HPC software and applications, etc.).

- The European Commission's HPC investment levels have grown substantially, through a range of initiatives including the €700 million, multi-year investment to support the future-oriented cPPP being carried out with the ETP4HPC. But Commission contributions have fallen short of the amounts recommended in IDC's 2010 report, and spending within PRACE has not yet reached the level of commitments. The Commission has contributed to support PRACE, and plans to start helping to support some procurements for large supercomputers in 2016.

3) **The implementation of funding mechanisms**, such as pre-commercial procurement in the public sector (the major buyer of high-end HPC) and pooling of research resources, to support HPC suppliers for developing a leadership-class HPC system about every 2 years.

- As noted earlier, PPI and related mechanisms are crucial for attaining and maintaining HPC leadership. Europe's rivals for HPC leadership—the U.S., China and Japan—regularly employ these mechanisms. These mechanisms are used today only occasionally in Europe. No clear strategy exists for pooling resources to finance the acquisition of pre-exascale supercomputers in 2020 and exascale supercomputers in 2022, in order to Europe to remain competitive with the U.S., China and Japan.

4) **Development of European state-of-the-art supply capabilities** needed for European independent access to key HPC technologies, systems, services and tools for Europe (including level of pre-commercial procurement and other R&D investments, support to European HPC suppliers, jobs in European HPC supply industry, etc.).

- ETP4HPC is dedicated to expanding and strengthening Europe's HPC supply chain. The European Commission is contributing €700 million to advance the cPPP on HPC in partnership with ETP4HPC. A large majority of the European HPC stakeholders IDC interviewed agreed that European scientists and engineers require access to best-in-class HPC technologies and systems, no matter where in the world they come from. It is especially important that European suppliers not only participate in exascale technology innovation, but also gain experience and feedback in real-world HPC customer environments. For this reason, ETP4HPC roadmaps for indigenous technology development need to be linked as closely as possible to the requirements that will drive supercomputer procurements.

5) **Industrial exploitation of HPC** including regional/national centers for the access of industry (including SMEs) to HPC (HPC Competence Centers), industrial HPC-based development and innovation, education and training in HPC, HPC trained workforce in Europe, and more.
Europe already has some of the world's leading HPC centers for collaborations with industry, including SMEs. Many of the European HPC stakeholders IDC interviewed for this study agreed that European programs supporting industrial access and collaboration, such as PRACE, SHAPE and Fortissimo, have been successful but need to do more. Only a small percentage of European SMEs that could be helped by HPC seem aware of these opportunities, for example. The EC hasn’t done an optimal job of communicating the HPC strategy, resources, plans and contact persons to the broader HPC community, and in particular to industry.

6) **Ensuring a level playing field**, in particular regarding inequalities in HPC market access and exploitation obligations regarding intellectual property rights of HPC results generated in Horizon 2020.

Europe has long been the world's most open HPC market. Government HPC markets in the U.S., Japan and China all present barriers to non-domestic HPC suppliers, although the private-sector markets in these countries are more open and both government and private-sector markets are generally open to non-domestic commercial software. A large majority of European HPC stakeholders IDC interviewed for this study agreed that European scientists and engineers should continue to have access to the world's best supercomputer systems, no matter where in the world they come from. Specific market asymmetries should be address at a government (EC)-to-government level and not made part of Europe's HPC strategy.

**Overall Recommendations**

Based on an examination of the European HPC objectives and related strategy actions, IDC offers the following recommendations, each keyed to one or more of the strategy actions.
In Summary: Recommendations

Recommendations on the Strategic Actions

Based on the progress to-date of the EU's Strategy Actions, IDC makes the following targeted recommendations:

1) **Expand Funding for HPC** (*Financial Envelope & Funding Mechanism, and Needed for Making Europe World Class in HPC*). PRACE members and the EC should agree to provide significant funding support to acquire two pre-exascale supercomputers in 2019-2020 and two additional exascale supercomputers in 2022. One path should stress European pre-commercial technology. The total 5 year cumulative increase in HPC investments (for all parties) from 2016 to 2020 is €3.263 billion. The European Commission should extend the end date of the Action Plan from 2020 to 2022, to match the expected exascale time frames of the U.S., China and Japan and make it easier to amass the funding levels recommended in this study. The Member States and the EC may need to adapt their practices in order to pool the money needed to fund exascale systems.

2) **Improve Communication of the Strategy** (*Supply Ecosystem and Needed for Making Europe World Class in HPC*). The European Commission should create a single website portal enabling access to comprehensive information on the European HPC strategy. There needs to include a single person in charge and as a direct contact for information and for answering questions. This is key for getting more users, ISVs and SMEs involved.
3) Develop the HPC Ecosystem *(European Supply Capabilities and Governance)*. ETP4HPC should continue to support collaborations involving European suppliers and (often much larger) non-European suppliers. This will accelerate the learning curve of some European suppliers who are less experienced. European suppliers will benefit from competing on equal terms with suppliers not based in Europe. Software will be one of the main determinants of future HPC leadership and Europe is very strong in parallel software development. ETP4HPC or another organization in Europe should create a clearinghouse (online storefront) to help disseminate, and in some cases commercialize, innovative European HPC software that is now in limited use.

4) Improve Support for Industry *(Industrial Use of HPC)*. PRACE should consider promoting SME and industry adoption of HPC with a SHAPE initiative that lets SMEs and other industrial firms that are new to HPC try it out without cost, and without needing to show scientific merit. ETP4HPC should ensure that software advances meant to benefit industry have strong, continuous input from industry representatives. Europe already has some of the world's leading HPC centers for collaborations with industry, including SMEs. Centers with strong industrial experience are well positioned to mentor centers with less experience with industry.

5) Improve Skills and Talent *(To Ensure Europe as a Global Actor and Needed for Making Europe World Class in HPC)*. The European Commission should undertake a communications campaign to update the image of HPC as a career choice. The Commission should also establish a task force to develop practical strategies for integrating HPC and related computational science education and training more fully into the scientific and engineering curricula of European universities.

**Additional Recommendations**

- **High Performance Data Analysis (HPDA).** This is the market for Big Data workloads that are complex or time-critical enough to require HPC resources. No dramatic shift in the European HPC strategy is needed for HPDA, because most HPDA, today and in the near term, will be data-intensive modeling and simulation (M&S) that HPC sites have been running for decades, but there are many opportunities to expand in this key area.

- **Cloud Computing.** In IDC's worldwide studies of high performance computing (HPC) end-user sites, the proportion of sites employing cloud computing—public or private—has steadily grown from 13.8% in 2011, to 23.5% in 2013, to 34.1% in 2015. As with HPDA, IDC believes that no major change to Europe's HPC strategy is needed to accommodate the growing importance and technical evolution of public and private cloud computing. The challenge is less about educating users about cloud computing and more about the ability of clouds to handle more types of HPC jobs over time.

- **Co-Design.** The EU should initiate an EU-wide exascale test bed program to provide strong support for exascale co-design capabilities. The test bed program would be a natural extension of ETP4HPC’s role. It would require ETP4HPC to collaborate closely with PRACE tier-0 supercomputer hosting members to test hardware and software technologies at large scale.
• **Centers-of-Excellence.** These fall under the cPPP on HPC. The centers should focus heavily on software—not just applications but also the whole HPC software stack (EESI has done an excellent job of laying the groundwork for this). At a minimum, one center should focus on the software requirements of industry, and one center be devoted to HPDA.

**Acronyms Commonly Used in This Report**

The following acronyms appear frequently in this report:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cPPP</td>
<td>Contractual Public Private Partnership</td>
</tr>
<tr>
<td>EESI</td>
<td>European Exascale Software Initiative</td>
</tr>
<tr>
<td>ETP4HPC</td>
<td>European Technology Platform for High Performance Computing</td>
</tr>
<tr>
<td>EU</td>
<td>European Union (of 28 Member States)</td>
</tr>
<tr>
<td>EU+</td>
<td>European Union (28 Member States) plus Norway and Switzerland</td>
</tr>
<tr>
<td>HPC</td>
<td>High Performance Computing</td>
</tr>
<tr>
<td>PCP</td>
<td>Pre-Commercial Procurement</td>
</tr>
<tr>
<td>PPI</td>
<td>Public Procurement of Innovative solutions</td>
</tr>
<tr>
<td>PPP</td>
<td>Public-Private Partnership</td>
</tr>
<tr>
<td>PRACE</td>
<td>Partnership for Advanced Computing in Europe</td>
</tr>
<tr>
<td>SHAPE</td>
<td>SME HPC Adoption Programme in Europe</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium-size Enterprise(s)</td>
</tr>
</tbody>
</table>
# Table of Contents

Abstract .......................................................................................................................... 2  
Executive Summary ...................................................................................................... 4  
  Progress on the Four EU HPC Action Plan Objectives .............................................. 5  
  Overall Recommendations ......................................................................................... 9  
Acronyms Commonly Used in This Report ................................................................. 12  
1. Introduction ............................................................................................................. 15  
1.1. The HPC Communication of the European Commission ....................................... 15  
1.2. The Goal of European HPC Leadership .................................................................. 16  
1.3. Main goal and scope of the study ......................................................................... 17  
1.4. Structure of the Report ......................................................................................... 18  
1.5. Methodological Approach ..................................................................................... 18  
2. The importance OF HPC for EUROPE ................................................................... 20  
  2.1. Examples of Using HPC to Help Society, Make Scientific Discoveries and for Economic Success ................................................................. 23  
3. THE HPC ECOSYSTEM IN EUROPE ................................................................... 25  
  3.1. Evolution of the European HPC Ecosystem .......................................................... 25  
  3.2. Europe and Global Competition for HPC Leadership ........................................... 26  
  3.3. European Consumption of HPC Systems ............................................................... 32  
  3.4. European Production of HPC Systems .................................................................. 40  
  3.5. The Rest of the Ecosystem: Beyond the HPC Servers ........................................... 43  
  3.6. The Rest of the Ecosystem: Deeper Discussion ..................................................... 47  
  3.7. High Performance Data Analysis: Big Data Needing HPC ................................... 50  
  3.8. The European HPC Server Market by Industry/Application Area ....................... 53  
  3.9. The ROI from HPC Investments in Europe ............................................................ 57  
  3.10. HPC Stakeholders Assess Progress in Europe ...................................................... 57  
4. Status of the European HPC Strategy ..................................................................... 63  
  4.1. Overall Progress on the Four EU HPC Action Plan Objectives ............................. 63  
  4.2. Progress in Implementation .................................................................................. 68  
  4.3. Governance ......................................................................................................... 69  
  4.4. Financial Funding for HPC .................................................................................... 74  
5. Analysis of financial progress .................................................................................. 81  
  5.1. 2010 Action Plan Funding Alternatives .............................................................. 81  
  5.2. New Recommended Funding Level Compared to the 2010 Level ....................... 82  
  5.3. The New Recommendation Compared to the Actual Growth in European Spending on Supercomputer Servers ......................................................... 83
1. INTRODUCTION

This study evaluates progress to date in implementing the European HPC strategy. The strategy was described in the European Commission’s HPC Communication of 2012 and fully adopted by the Competitiveness Council in May 2013. It is no accident that the strategy passed through the Competitiveness Council. HPC has been firmly linked to scientific and industrial competitiveness in repeated studies, including IDC's pioneering 2008 Study of Innovation, Competiveness and HPC.2

1.1. The HPC Communication of the European Commission

The HPC Communication was adopted by the EC in February 2012, driven by the recognition of HPC as a strategic asset for the EU’s innovation capacity and by the growing awareness of the need for decisive action to overcome the challenges of Europe’s geographic fragmentation and fill the gaps of the European HPC ecosystem. The HPC strategy is coherent with the EU innovation and ICT policies, strongly oriented towards increasing investments in the development of the European research and innovation capabilities. In fact, the Communication on ICT infrastructures for e-Science and the Competitiveness Council in 2009 had already called for “further development of computing infrastructures such as PRACE” recommending to pool investments in high performance computing to strengthen European industry and academia capability to use, develop and manufacture advanced computing products, services and technologies. The Competitiveness Council of May 2013 adopted fully the recommendations and the policy objectives of the HPC Communication and stressed again the strategic relevance of HPC for the EU’s innovation capacity, industrial and scientific capabilities, the achievement of social benefits, and the creation of a Digital Single Market (DSM) within the EU.

1.1.1. The Four Objectives:

The HPC Communication created a strong momentum towards building an integrated HPC community across Europe, raising the role of HPC in the research and innovation agenda at European and national level. The Action Plan designed in the Communication aims at developing both demand and supply in a synergetic manner. The main objectives of the Action Plan examined closely in this study are as follows:

1. Provide a world-class European HPC infrastructure, benefitting a broad range of academic and industry users, and especially SMEs, including a workforce well trained in HPC
2. Ensure independent access to HPC technologies, systems and services for the EU
3. 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
4. Ensure the EU’s position as a global actor

1.1.2. The Six Actions:

To achieve these objectives, the Action Plan outlined a series of actions to be implemented by the Member States, the Commission and the EU industry. This study examined progress in implementing these actions, particularly concerning:

- The quality of governance of the main coordination initiatives established at EU level, that is PRACE for science and the industry-led European Technology platform for HPC (ETP4HPC) for industry;
- The financial envelope, specifically whether the Union, Member States and the industry are on track to double their investments in HPC to approximately €1.2 billion per year, the threshold required to bring Europe back as a major actor in the field;
- The implementation of funding mechanisms, such as pre-commercial procurement in the public sector (the major buyer of high-end HPC) and pooling of research resources, to support HPC suppliers for developing a leadership-class HPC system about every 2 years;
- The development of state-of-the-art European supply capabilities, towards a world-class HPC e-infrastructure driven by PRACE and a network of centers of excellence for the application of HPC in relevant scientific and industrial domains;
- The promotion of industrial use of HPC, particularly by SMEs, also through HPC competence centers and supporting the training and qualification of the required e-skills;
- Finally, efforts to ensure a level playing field that allows the EU industry to compete on an equal basis by gaining access to the main world markets (as international suppliers can access the EU market); and making sure that European R&D investments in the HPC field benefit the EU economy, also if necessary by tweaking the rules of IPR usage in Horizon 2020.

1.1.3. The Three Pillars:

From the point of view of the current context of the R&I landscape for HPC, the main resources will be channelled by the EC through the Horizon 2020 Programme through the Directorate Excellence in Science with three main strands of research:

- Developing the next generation of HPC technologies, applications and systems towards exascale
- Providing access to the best supercomputing facilities and services for both industry including SMEs and academia (PRACE)
- Achieving excellence in HPC application delivery and use

1.2. The Goal of European HPC Leadership

IDC understands the goal of HPC leadership to mean that European attains overall HPC capabilities that are on a par with the best in the world, with Europe standing as number one in the world in certain targeted areas of using HPC. As noted earlier, the U.S., Japan, and China have extended their timetables for the arrival of the first exascale systems out to 2020-2022. IDC recommends that Europe do that same.
1.3. Main goal and scope of the study

The main goal of this study is to assess the level of progress of the Action Plan presented by the EC Communication, *High Performance Computing (HPC): Europe’s Place in a Global Race*, of February 2012. The focus is not only the evaluation of the achievement of the specific goals of the Action Plan, but also the assessment of progress toward the ultimate policy objective of the Communication, which is to ensure European leadership in the supply and use of HPC (high performance computing) systems and services by 2020. The results of this study will support the EC reporting to the European Parliament and Council on the implementation of the Communication, planned for 2015.

1.3.1. Definitional Scope: HPC

IDC uses the term high performance computing (HPC) to encompass the entire market for computer server systems and related software, storage, networking and services employed by scientists, engineers, analysts and others to address computationally intensive and data intensive simulation and analytics problems. HPC activities can be found in industry and commerce, government and academia. Industrial/commercial activities include automotive and aerospace product development, oil and gas exploration, drug discovery, weather prediction and climate modeling, complex financial modeling, consumer product design and optimization, advanced 3D animation, advance business analytics and others. HPC systems range from sub-€10,000 commodity clusters to €100 million-plus, one-of-a-kind supercomputers (a continuous spectrum from entry-level to high-end machines). HPC is in contrast to enterprise computing as used for business operations such as accounting, payroll, sales, customer relations, transaction processing, human resources, and purchasing. HPC may be carried out on premise in dedicated HPC data centers, or in private, public or hybrid cloud environments. HPC methodologies include modeling and simulation, advanced data analytics, visualization, and others. (For more details, see Appendix 7.6, HPC Applications Workloads)

1.3.2. Geographical Scope

For the purposes of this study, IDC assumed that the term Europe includes the 28 EU Member States (designated in tables as “EU”), along with Norway and Switzerland (these two countries plus the 28 Member States are designated in tables as “EU+”). IDC assessed European progress toward HPC leadership not only in relation to the goals of the European HPC strategy and Action Plan but also in relation to the status of HPC in areas of the world that are also competing for HPC leadership, especially the U.S., Japan, and China.

1.3.3. Temporal Scope

IDC assumed that the primary timeframe within which HPC progress should be evaluated extends from the 2009-2010 era of IDC’s first report to the Commission, continuing through the 2012 adoption of the EU HPC strategy and Action Plan to the present day, and that the Commission is also interested in forecast data. In most cases, IDC shows five-year forecast data extending to 2018. Our experience shows that HPC market forecasts for periods longer than this are far less useful.
1.4. Structure of the Report

Following the introduction and executive summary, the report describes and evaluates the status of the European HPC ecosystem, especially progress in implementing the Action Plan. The report then presents IDC’s recommendations for refining the strategy to increase the chances to attain the goals outlined in the Action Plan.

1.5. Methodological Approach

IDC’s methodological approach combined extensive desk research, field research (quantitative and qualitative interviews and analysis), an online consultation leveraging the HPC User Forum run by IDC, as well as economic modeling and in-depth analysis and assessment of the main policy issues.

1.5.1. In-Depth Interviews with Key Individuals

IDC conducted in-depth interviews with key European HPC stakeholders, including PRACE center directors, ETP4HPC officials, officials of national scientific research programs, senior representatives of HPC vendor firms, and leading scientific and industrial users of HPC. In addition, IDC interviewed leading figures in the North American and Asian HPC communities to obtain non-European perspectives on the status and recent progress of HPC in Europe. To date, 30 such interviews have been completed and others have been scheduled. The countries of individuals who agreed to be interviewed are as follows:

- Germany 9
- France 8
- UK 5
- U.S. 3
- Netherlands 2
- Switzerland 2
- Poland 1

The interviews were deliberately far-ranging and covered all of the main topical areas of the study project, as well as related topics. The chief objectives of these interviews were to obtain a range of well-informed, qualitative assessments of HPC in Europe, and to help ensure key stakeholders that their perspectives will have an important influence on the findings and recommendations of the study.

To encourage candor, IDC assured interviewees that none of their statements would be associated with them or their organizations in the Interim Report or Final Report. A list of the organizations whose representatives were invited to participate in interviews appears in Appendix 7.1.
1.5.2. **Broad Survey of European HPC Stakeholders**

To get a more representative reading of European HPC stakeholders' opinions on the study topics, IDC emailed a brief questionnaire to a pre-qualified list of 832 members of the European HPC community. There were 143 responses. The list included government officials, managers of HPC centers of all sizes, scientists representing many disciplines and European countries, executives and product designers in industrial firms of many sizes, leaders and ordinary workers in HPC vendor/supplier companies, and other categories.

The deliberately brief, multiple-choice survey instrument asked respondents what has happened in the past 2-3 years with the following things. The full survey results appear in Section 5.3 of this report. A complete copy of the questionnaire is in Appendix 7.4):

- Europe's overall HPC capabilities
- Access by **scientists** to supercomputers at PRACE centers
- Access by **industry** to supercomputers at PRACE centers
- Europe's ability to develop **HPC software**
- Europe's ability to develop **HPC hardware**
- Europe's position in the worldwide HPC market

The questionnaire also invited respondents to provide comments, and most of them did.

1.5.3. **External Reviewers: European HPC Experts**

IDC also recruited the following European HPC leaders to review the draft versions of the Interim Report and the Final Report. In addition, IDC conducted in-depth interviews for the study with each of these individuals, as part of the larger group of key individuals we targeted for these interviews.

1. Dr. Jean-Yves Berthou, Director of the Department for Information and Communication Science and Technologies, L'Agence Nationale de la Recherche (French National Research Agency)
2. Dr. Arndt Bode, Director, Leibniz Computing Center of the Bavarian Academy of Sciences
3. Terry Hewitt, Delivery Project Executive for the Hartree Center, UK Science & Technology Facilities Council (STFC)
4. Jean-Philippe Nominé, le Commissariat à l’énergie atomique et aux énergies alternatives (CEA), France
5. Dr. Michael Resch, Director, HPC Center Stuttgart (HLRS) and Dean of the Faculty for Energy, Process and Biotechnology at the University of Stuttgart
2. THE IMPORTANCE OF HPC FOR EUROPE

The use of high performance computing (HPC) has contributed significantly and increasingly to scientific progress, industrial competitiveness, national and regional security, and the quality of human life. HPC-enabled simulation is widely recognized as the third branch of the scientific method, complementing traditional theory and experimentation. HPC is important for national and regional economies—and for global ICT collaborations in which Europe participates—because HPC, also called supercomputing, has been firmly linked to accelerating innovation. HPC is also an important element for creating a Digital Single Market (DSM) within the EU.

Increased HPC use can directly help to improve the situation described in the European Commission's ICT Research and Innovation Strategy:

*Europe continues to under-invest, fragment its efforts, under-use the creativity of SMEs and fails to convert the intellectual advantage of research into the competitive advantage of market-based innovation. Moreover, society calls for solutions to key European and global challenges ranging from demographic change to resource efficiency. We need to build on the talent of our researchers to deliver a European innovation ecosystem that maximizes the economic and social potential of ICT. In a globalized world, this ecosystem cannot disregard the opportunities offered by international collaboration in ICT R&I.*

Consider these facts regarding sectors where HPC is especially important:

- European scientists play a vital role in HPC-enabled scientific endeavors of global importance, including CERN (European Organization for Nuclear Research), IPCC (Intergovernmental Panel on Climate Change), ITER (fusion energy research collaboration), and the newer Square Kilometer Array (SKA) initiative. NOTE: Investments needed for exascale computing are very minor in comparison with investments in these scientific initiatives, even though exascale capability may be no less important for Europe.

- In addition, scientists from throughout Europe increasingly rely on HPC resources to carry out advanced research in nearly all disciplines.

- Industry accounted for 25.2% of EU GDP in 2013. Studies by IDC and others firmly established the link between HPC and industrial competitiveness. In a global IDC study, 97% of companies that had adopted HPC said they could no longer compete or survive without it.

- Manufacturing contributed about 30 million jobs and 16% of EU GDP (€6,500 billion) in 2013, and the European Commission aims to increase that figure to 20% by

---


4 CIA World Factbook. 2014

5 HPC Use in Industry. IDC study for Council on Competitiveness. 2004
Manufacturing represents two-thirds of EU exports and two-thirds of EU private-sector R&I investment but Europe lost seven million manufacturing jobs between 2000 and 2013. HPC enables smart manufacturing that could create new manufacturing jobs and return some lost manufacturing jobs to Europe. HPC has enabled European automakers to reduce the time for developing new vehicle platforms from an average 60 months to 24 months while greatly improving crashworthiness, environmental friendliness, and passenger comfort. IDC market tracking indicates that Europe spent about €450 million on the HPC ecosystem for manufacturing in 2013 and will spend about €638 million in this sector in 2018. A substantial, growing portion of this spending is by manufacturing SMEs, who, like larger manufacturing firms, employ HPC to accelerate innovation. Hence, HPC is important for the success of I4MS (ICT Innovation for Manufacturing SMEs) is the initiative promoted by the EC to support the European leadership in manufacturing through the adoption of ICT technologies.

- The oil and gas industry is responsible for 170,000 European jobs and €440 billion of Europe's GDP. An HPC performance advantage lets O&G companies engaged in exploration "see" farther and more clearly than their competitors, especially when miles-thick subsalt formations get in the way, as often happens in undersea exploration. The combination of superior hardware performance, strong software, and massive data storage, has paid dividends for O&G companies in the discovery and exploitation of promising new, difficult-to-locate fields.
  - Total recently upgraded to one of the world's most powerful supercomputers. Philippe Malzac, CIO of exploration and production for Total, said the new research made possible by the supercomputer will enable more efficient upstream oil and gas exploration, as well as the discovery of reserves under more challenging geological conditions. "Total is committed to leveraging technological innovation and high performance computing to provide the best response to growing global energy demand," he said.

- The health sector represents 10% of EU GDP and 8% of the EU workforce. The pharmaceutical industry alone contributes €800 billion to Europe's GDP. Biology is fast becoming a digital science, and HPC is increasingly important for advanced medical research, biomedicine, bioinformatics, epidemiology, and personalized medicine—including "Big Data" aspects. IDC market tracking indicates that Europe spent about €416 million on the HPC ecosystem for bio-life sciences in 2013 and

---

will spend about €510 million in this sector in 2018. The following examples illustrate the importance of HPC in the European/global health sector.

- Swiss pharmaceutical giant Novartis and Schrödinger, a global life sciences and materials science software company with offices in Munich and Mannheim, Germany, greatly accelerated the testing of drug candidates by using HPC. They tested 21 million drug candidate molecules on the Amazon public cloud, using a new technical computing (HPC) algorithm Schrödinger developed. The successful run cost only about €10,000. Schrödinger has completed even larger runs since this.  

- The Center for Pediatric Genomic Medicine at Children's Mercy Hospital, Kansas City, Missouri, has been using HPC to help save the lives of critically ill children. In 2010, the center's work was named one of *Time* magazine's top 10 medical breakthroughs. Roughly 4,100 genetic diseases affect humans, and these are the main causes of infant deaths. But identifying which genetic disease is affecting a critically ill child isn't easy. For one infant suffering from liver failure, the center used 25 hours of supercomputer time to analyze 120 billion nucleotide sequences and narrowed the cause of the illness down to two genetic variants. Thanks to this highly accurate diagnosis, the baby is alive and well today. For 48% of the cases the center works on, HPC-powered genetic diagnosis points the way toward a more effective treatment.

- Weather forecasting. From 1970 through 2012, severe weather cost 149,959 lives and €270 billion in economic damages in Europe. Severe weather forecasting on national and regional scales depends heavily on HPC, and Europe arguably leads the world in numerical weather forecasting. IDC market tracking indicates that Europe spent about €173 million on the HPC ecosystem for weather/climate in 2013 and will spend about €230 million in this sector in 2018.

  - The weather model from the European Center for Medium-Range Weather Forecasts (UK) proved substantially more accurate than U.S. models in predicting the path of Hurricane Sandy that devastated America's East Coast in 2012.

- IDC field research conducted for the present study confirmed that European HPC investments are producing excellent returns-on-investment (ROI) for science and industry. Each euro invested in HPC on average returned €867 in increased revenue/income. Total increased revenue for the 59 HPC-enabled, quantifiable projects was €133.1 billion, or about €230 million per project on average.

---


2.1. Examples of Using HPC to Help Society, Make Scientific Discoveries and for Economic Success

This section provides examples of how organizations have been using supercomputers to achieve breakthroughs of major scientific or economic importance. These achievements, many of which were accomplished through access to very powerful supercomputers and HPC experts at national laboratories, already have saved American companies, many millions of dollars and have the potential to save many billions of dollars.

Without these achievements and the supercomputer access they depend on, these companies and research organizations would be dramatically less competitive than they are today. They would almost surely be able to support fewer jobs and make smaller contributions to the nation’s economy, now and in the future. Examples of the impact of supercomputers in industry include:

- HPC has enabled automakers to reduce the time for designing new vehicle platforms from 60 months to 24 months or less, while greatly improving safety, passenger comfort and environmental friendliness. At Rolls-Royce, single components and sub-systems design/analysis/optimization through to whole engine modelling all rely heavily on HPC.

- Total recently tripled the power of its supercomputer to develop more complete visualizations of seismic landscapes and run simulations at 10 times the resolution of existing oil and gas reservoir models. This new capability will enable more efficient upstream oil and gas exploration, as well as the discovery of reserves under more challenging geological conditions.

- Swiss pharmaceutical giant Novartis and Schrödinger, a global life sciences and materials science software company with offices in Munich and Mannheim, Germany, hired Cycle Computing, a cloud computing services company, to test 21 million drug candidate molecules on the Amazon public cloud, using a new technical computing (HPC) algorithm Schrödinger developed.

- The Center for Pediatric Genomic Medicine at Children’s Mercy Hospital, Kansas City, Missouri, has been using HPC to help save the lives of critically ill children. In 2010, the center's work was named one of Time magazine’s top 10 medical breakthroughs.

- GE used a supercomputer to reveal a new aspect of turbine behavior that is already providing GE with a competitive advantage in fuel efficiency. Every 1% reduction in fuel consumption saves users of these products $2 billion/year.

- BMI utilized supercomputers and computational models to design components that could save 1.5 billion gallons of fuel and $5 billion in fuel costs per year.
BMI: An Example of Reducing Fuel Consumption of a Trucking Fleet

- Researchers from the Centers for Disease Control (CDC) created a far more detailed model of the hepatitis C virus, a major cause of liver disease. Annual health care costs associated with this virus are $9 billion in the U.S. alone.
- For the first time researchers developed a computer model that comprehensively simulates the human heart down to the cell level. This innovation has significant potential for saving health care costs by reducing heart disease and improving heart health. This research has strong potential for helping to reduce coronary heart disease, which costs the United States over $100 billion each year.

Using HPC to Improve Cancer Treatments

Source: Mary Bird Perkins Cancer Research Center, Louisiana State University, 2014

But that's just part of the story. Without supercomputers, detecting today's sophisticated cyber security breaches, insider threats and electronic fraud would be impractical. In short, high performance computing has become indispensable for both maintaining national security and economic competitiveness.

That's why other nations and global regions including China, US, Japan and Russia, are racing ahead and have created national programs that are investing large sums of money to develop exascale supercomputers. What this global race is really about is supremacy in supercomputing and in all the disciplines and markets that depend heavily on this game-changing technology.
3. THE HPC ECOSYSTEM IN EUROPE

3.1. Evolution of the European HPC Ecosystem

High performance computing (HPC) technology has been advanced and exploited by European users since the dawn of the supercomputer era in the 1960s. Even before then, European contributions to early computer technology development and usage were crucial for enabling the supercomputer era.

No single nation within Europe has the financial and related means to compete effectively in HPC against the United States or China—the world’s number one and number two national funders of HPC technology development and consumption today. Japan is another nation that is determined to remain a global scientific and industrial leader with the help of HPC. Only by banding together can European nations hope to realize the Action Plan’s goal to attain leadership in the supply (production) and use (consumption) of HPC.

But Europe is a collection of autonomous nations with their own histories and interests. This makes the HPC ecosystem in Europe inherently more challenging to organize and collaboratively advance than its single-nation counterparts in the U.S., China, and Japan. Until recently, organized HPC initiatives in Europe were largely confined to the national and regional levels, and pan-European HPC collaboration was far more limited.

As this report will demonstrate, EU-sponsored HPC programs, the Commission-led effort to create the first Europe-wide HPC strategy, the PRACE 25-nation partnership to establish a pan-European computing infrastructure for scientific and engineering research, and initiatives such as ETP4HPC, EESI and others, have recently been advancing the European HPC ecosystem to secure HPC leadership as a 21st-century prerequisite for scientific, industrial and economic leadership.

Today, the European HPC ecosystem is a vibrant mix of national, regional and pan-European initiatives, augmented by European participation in international HPC-supported scientific collaborations that extend far beyond Europe—notably the Intergovernmental Panel on Climate Change (IPCC), ITER, and the Square Kilometer Array (SKA) project. The Large Hadron Collider at CERN is a shining example of a European HPC-supported success—Europe has become the center of the global ecosystem for particle physics research. The HPC-supported Human Brain FET flagship initiative has the potential to establish Europe similarly as the hub of global brain research. HPC is already contributing to advanced research on graphene, the focus of another EU FET flagship initiative.

Among the most important recent structural developments promoting collaborative HPC progress have been the following:

- The successful formation of a European (complementing national) HPC consciousness
- The tiered structure for organizing HPC centers at the European (tier-0) and national levels (tier-1, tier-2)
- The single review process for access to PRACE tier-0 supercomputers

With a few notable exceptions, the European HPC ecosystem was slower to embrace industry than its counterparts in the U.S. and Japan. But today, industry can access the
PRACE HPC research infrastructure and the PRACE SHAPE program is reaching out to encourage use of the infrastructure by small and medium-sized enterprises (SMEs). The present study found, however, that industrial use of Europe's HPC ecosystem remains comparatively low and awareness of the opportunities available to industrial firms is not as widespread as it could be.

A global IDC study\(^{13}\) showed that the proportion of sites exploiting cloud computing to address parts of their HPC workloads rose from 13.8% in 2011 to 23.5% in 2013, with public and private cloud use about equally represented among the 2013 sites. Although European cloud use for HPC was not always separable—some clouds are multi-continental or worldwide—it was clear that the percentages in Europe closely matched global counterparts.

Another important new area for the European HPC ecosystem is high performance data analysis (HPDA)—using HPC for data-intensive simulation and advanced analytics. HPDA requirements are increasing in many scientific domains and are driving more commercial companies, including SMEs, to exploit HPC technology for the first time. In the same 2013 worldwide IDC study\(^{14}\), 67% of the HPC sites said they use HPC systems for HPDA, and that HPDA use consumes 30% of their HPC cycles on average. The same study found that 23.5% of the HPC sites were using cloud computing to address parts of their HPC workloads rose, with public and private cloud use about equally represented among the sites.

### 3.2. Europe and Global Competition for HPC Leadership

Europe's overall HPC capabilities have made impressive progress in recent years. Largely through the PRACE program, Europe has narrowed the former wide gap separating the most capable U.S. and Japanese supercomputers from their European counterparts. (Chinese supercomputers now also belong in the "most capable" list.) In November 2010, shortly after the founding of PRACE, only 9 of the world's 50 most powerful supercomputers were located in Europe (www.top500.org). Four years later, in November 2014, Europe hosted 19 of the top 50, including the PRACE tier-0 supercomputers. The aggregate peak performance of the Europe-based supercomputers rose more than ten-fold during this period, from 4.3 petaflops in November 2010 to 48.9 petaflops four years later. (During this same period, the aggregate peak performance of all top 50 supercomputers grew by a lesser 7.6 times, from 32.8PF to 249.7PF. Europe's share of these totals increased from 13.1% in November 2010 to 19.9% in November 2014.) Clearly, Europe's standing as a provider of high-end supercomputing resources to end-users advanced in both absolute and relative (worldwide) terms during this period.

\(^{13}\) *International Data Corporation Worldwide Study of HPC End-User Sites. 2013.*

\(^{14}\) *Ibid.,* 2013
High-end supercomputers at national centers in Europe, the U.S., and Japan (but not China) are regularly oversubscribed—the demand for computing cycles typically exceeds the supply by a factor of two to three. It is therefore safe to assume that the 10-fold increase in capacity among Europe's largest supercomputers is being almost fully utilized today (this is confirmed by utilization data reported by the centers hosting these supercomputers). Hence, the use of Europe's most powerful supercomputers has greatly increased in volume since 2010.

IDC survey results for this study confirm that the use of PRACE supercomputers has also been substantially democratized through the single peer-review process that makes access available on an equitable basis to scientists throughout Europe. Access to PRACE supercomputers by European industry is a newer phenomenon. It has improved recently but needs to improve more. PRACE needs stronger outreach to European industrial/commercial companies that might benefit from HPC. European HPC experts say that many European companies are not yet aware of the PRACE resources and how to access them.

**Coordinating Member State HPC Strategies.** A majority of European HPC stakeholders IDC interviewed for this study agreed that no single European Member State has the financial and related means to compete effectively with the U.S., China and Japan for HPC leadership. Yet for understandable reasons, Member States are concerned primarily with their national needs and do not closely coordinate or pool financing for their supercomputer procurements. Nor does the Commission in a position to impose coordinated procurements on the Member States. Hence, the status quo will make it exceedingly difficult for Europe to amass enough money to acquire pre-scale and exascale supercomputers in competitive timeframes. Today, the Commission's rules of participation state that it may contribute no more than 20% of funding to initiatives with the Member States and that at least three Member States must also
participate. If these rules remained unchanged, Member States would need to contribute a total of at least 80% of the funding for exascale systems that would benefit Europe as well as the hosting site(s) in Member States. As detailed in the financial section of this report, IDC recommends that the European Commission contribute a substantial portion (recommended: 50%) of the funding for these systems, in return for securing a substantial portion (recommended: 50%) of the computing cycles of these systems and expertise of the hosting centers for European initiatives. Actual percentages would need to be worked out with the Member States through PRACE and would need to consider the fact that the Member States will own the supercomputers.

IDC believes that moving forward, the EU must actively respond to the looming complexities of exascale technologies and the new and complex requirements they will impose on both designers and users of exascale systems. One way to address these issues should be through a comprehensive test bed program supported by a cooperative EU-wide public/private partnership. This test bed program would be tasked with exploring key concepts in exascale design, applications, and operational considerations including exascale co-design capabilities, exascale architectural simulators, and advanced architectural test beds to support agile system software R&D. A key element of this test bed program would be to serve as a proving ground for industry technology options, not only for potential exascale hardware and software suppliers, but also for industrial users to participate from the earliest development stages and to provide input on their requirements for using exascale systems in their R&D process. In addition, such a program should also include an element of direct funding for R&D projects within industry, placing the EU in a stronger position to influence the direction of exascale-relevant COTS hardware development while also setting a clear path forward the ISV software base.

Ultimately, as the HPC community strives to realize exascale systems within the next five to seven years, there indeed is opportunity for some shifting in the positioning of the major global players. From a pure hardware perspective, gone are the days where any single HPC maker could afford to develop custom hardware that was significantly faster or more efficient than what was available on the COT market and, consequently, also readily available to its competitors. As a result, the ability of any single HPC developer to differentiate their HPC system is becoming less of a hardware issue and more of an architectural one. Indeed, as the world moves towards exascale systems, HPC leadership will increasingly depend on the ability of a HPC developer - be it for a commercial product line or a one-off government system - to design and implement an HPC architecture that is closely suite to a specific workload. Perhaps more important, these new HPC increasingly will not be a single source, but a confederation of hardware and software suppliers such as the ARM or OpenPower community.

Simply put HPC leadership in the coming years will be less about who can assemble the fastest hardware, but more about who can design and then assemble from a host of HPC-constituent suppliers, targeted systems that meet the specific goals of critical and often diverse applications. Building such an HPC ecosystem will present significant challenges to some within the HPC ‘old guard’ that have little experience managing a more complex, diverse, and perhaps geographically extended HPC hardware and software supply chain. Indeed, one could argue that the both Japan and China owe much of their current HPC prowess to centralized planning schemes that targeted narrowly focused HPC
requirements, addressed specific usage models, and did little to boost overall domestic HPC capability writ large. For the US, government HPC development has been driven primarily by its national defense agenda and as some critics point out, these programs are increasingly moving away from the more general HPC requirements of the commercial sector from both a supply and demand perspective. In contrast, EU HPC leadership, building on its base of existing and planned EU-wide HPC development programs, is positioned to manage and coordinate a strong base of both indigenous and foreign technology across its commercial and government sectors to assemble exascale HPC capability that could, in some critical application sectors achieve world-class, if not global leadership, status.

3.2.1. Europe and the U.S.

The U.S. will likely continue to outspend all of Europe on HPC systems through the year 2020 (and 2022). The U.S. has historically purchased just under half of all of the HPC systems sold each year. The U.S. has large, established system vendors and strong capital markets. As a single nation, the U.S. has an easier time than Europe focusing its investments on a few very large supercomputers, rather than having to collect and distribute funding among a larger number of EU countries. The U.S. government has long-standing models for R&D collaborations with HPC vendors, many of which include supercomputer procurements. The recently completed Department of Energy "CORAL" procurement, for example, employed a single process to acquire next-generation supercomputers with strong R&I requirements for three DOE national laboratories. Government and government-related portions of the U.S. HPC market are effectively closed to non-U.S. system vendors by "Buy American" legislation and other preferential policies and practices. Products from European software vendors are not uncommon in these segments, however. The U.S. government is substantially under-investing in advanced software development, and its future leadership is vulnerable because of this. U.S. HPC system vendors have the lion's share of the European market today, but the Atos acquisition of Bull may create a stronger competitor for U.S. (and other non-European) HPC vendors over a longer period.

3.2.2. Europe and China

China is ramping up HPC spending faster than any other nation or region, although increases may slow down. Utilization of Chinese supercomputers is typically much lower than in Europe, the U.S., or Japan. China's growth in supercomputer capacity is outpacing the growth of China's HPC user base. More than 85% of China's supercomputers come from U.S. vendors today. European HPC system vendors have no strong presence in China. The U.S. government recently blocked Intel from exporting its processors to upgrade some of China's most powerful supercomputers, claiming that the computers were being used for nuclear weapons research, and this may accelerate China's initiatives to develop

indigenous processors.\textsuperscript{16} China’s HPC vendors—Lenovo, Inspur, Huawei, and Sugon (Dawning)—are gaining market experience. Lenovo’s 2014 acquisition of IBM’s x86 server business has suddenly made Lenovo one of the world’s top 4 HPC server system vendors. Lenovo should be able to retain the critical infrastructure accounts in China that IBM, as a non-Chinese vendor, was being transitioned out of by the Chinese government. Lenovo is taking assertive steps in Europe, such as by joining the EPT4HPC initiative and established a global HPC innovation center in Stuttgart. China has at least five initiatives under way to advance the development of indigenous processors for HPC systems, and some of China’s (and the world’s) most powerful supercomputers now incorporate Chinese processors. The slowing down of China’s domestic economy will likely curtail the growth of HPC spending.

3.2.3. Europe and Japan

Japan has twice fielded the world’s most powerful supercomputer, most recently (2011) the €400 million, Fujitsu-built K computer at RIKEN. Japanese supercomputer vendors had considerable success selling into European markets, but they largely retreated from Europe when x86-based HPC systems began heavily displacing Japan’s vector supercomputers. Today, the most powerful supercomputers from NEC and Fujitsu still rely on custom (non-x86) processors—including the K computer and the new NEC vector computers—but x86-based systems can also be bought from Japanese vendors. Non-Japanese HPC system vendors have had limited success penetrating Japan’s government market and have fared better in the Japanese private sector. Japan seems intent on competing for HPC performance leadership, but Japan’s periodic, heroic efforts to deploy the world’s number one supercomputer indicate that Japan may not be able to compete on a sustained basis with U.S. or Chinese funding levels. Japanese vendors Fujitsu and NEC may soon ramp up their efforts in Europe’s comparatively open HPC market.

3.2.4. Collaboration vs. Competition

Europe already collaborates with the U.S., China, and Japan in HPC and will continue to do so, even as Europe also pursues the goal of HPC leadership by the year 2020. The ETP4HPC initiative, for example, includes Intel, Lenovo and IBM, along with Europe-based organizations. Other non-European HPC vendors are also involved in European initiatives to develop technologies and capabilities for the coming era of exascale computing. In the Cray Exascale Initiative in Europe, for example, Cray is partnering with the Swiss National Supercomputing Center (CSCS), the University of Edinburgh, Allinea Software, and other European collaborators. As noted elsewhere in this report, Europe plays a key role in major international scientific collaborations involving HPC.

3.2.5. Europe and the Changing HPC Supplier Scene

Historically, Europe has arguably been the most open HPC market in the world and has generally allowed vendors not based in Europe to compete freely for public- and private-sector HPC procurements. This may be due in part to the fact that Europe has not had HPC system vendors with the size and resources of global IT firms such as IBM, Hewlett Packard (HP), Dell, NEC, or Fujitsu. As a result, firms not based in Europe—primarily U.S. vendors and secondarily Japanese vendors—have long dominated the European HPC systems market.

In recent years, IBM and HP have vied for revenue leadership in the global and European HPC markets. In some years, IBM took the lead and in other years HP moved slightly ahead of its main rival. The 2014 sale of IBM’s x86 server business to Chinese vendor Lenovo effectively cut IBM’s global HPC revenue approximately in half. Today, HP is the largest global HPC server vendor, while IBM (U.S.), Lenovo (China), and Dell (U.S.) compete for second place.

Since completing the acquisition of IBM’s x86-based server business, Lenovo (helped by about 6,500 former IBM employees) has been moving assertively into the European HPC market. The company has entered collaborations with a number of leading HPC sites in Europe (e.g., CINECA, Leibniz Rechenzentrum, and Barcelona Supercomputing Center) and has located its first global HPC innovation center in Stuttgart. In addition, Lenovo has joined Intel and IBM as the third non-European-based member of the ETP4HPC initiative.

Also noteworthy is the 2014 acquisition of Bull by France-based Atos SE. The larger resources of Atos position the company to expand HPC market share over time against non-Europe-based vendors in the European and worldwide HPC markets. (Atos recently unveiled plans for a next-generation supercomputer named SEQUANA, targeted at exascale performance that is designed to easily integrate with most current and future technologies and to be compatible with successive generations of both mainstream CPUs and GPUs.)

IDC believes that during the limited period from now through 2020, Lenovo will make strong progress in the European HPC systems market. At a minimum, Lenovo should retain a substantial portion of the x86-based market share formerly held by IBM—but Lenovo could gain additional European market share. Atos will record notable wins in the European market for HPC systems, but is unlikely to attain European market share on a par with those of the leading U.S. HPC systems vendors or Lenovo during this short period. In

18 Ibid.
addition, IDC believes that Japanese vendors NEC and Fujitsu may ramp up their presences in the European HPC systems market by 2020.

IDC expects major HPC system vendors throughout the world to offer supercomputers that include processors (CPUs) based on patented designs from UK-based ARM Holdings—some vendors already do this. Although ARM Holdings does not make the processors, the company's ownership of intellectual property rights brings a portion of HPC processor revenue to Europe and positions this European supplier to drive processor innovation on a substantial global scale, especially as an increasingly important alternative to today's leading processor suppliers: Intel, IBM and AMD.

3.2.6. Consumption versus Production

Tables 1 through 3 in this section of the report look at spending on HPC systems and related resources; that is, they look at the consumption (use) of these resources, no matter where in the world the resources are produced. A different picture emerges when spending (consumption) is tied to the market share of HPC vendors and their home countries. Tables 4 through 6 depict European spending on HPC systems by vendor and capture this important production (supply) perspective.

Note: “EU” represents the 28 Member States of the European Union. “EU+” represents the 28 Member States, plus Norway and Switzerland. Figures for the years up to and including 2013 are historical unless specified otherwise. Figures for 2014 and beyond are forecast numbers unless otherwise specified. Finally, the term “revenue” in the titles of the tables is synonymous with spending.

3.3. European Consumption of HPC Systems

3.3.1. All HPC Systems

The EU now has the largest GDP in the world (€13.2 trillion), having surpassed the GDP of the United States (€12.6 trillion). Yet as Table 1 illustrates, the U.S. has substantially outspent the EU (and EU+) region on HPC server systems and IDC forecasts that this pattern will continue. On the spending (consumption) side, the U.S. will continue to handily outspend the EU/EU+ and other global regions at least through 2018 (the end of IDC’s current forecast period). The EU/EU+ region has outspent and will continue to handily outspend China and every global region other than the U.S. through 2018. IDC has closely tracked HPC spending by global region for more than 25 years and does not foresee these spending patterns changing markedly by the year 2020.

- The EU/EU+ share of worldwide HPC server spending in 2013 was 25.7%/27.1% (similar to preceding years) and IDC forecasts that in 2018 these figures will grow slightly to 26.4%/27.6%.

---

20 International Monetary Fund statistics. 2014
• Comparable market share figures for North America (almost entirely representing the world's largest HPC spender, the U.S.) are 43.9% (2013) and 42.9% (2018).

• The figures for China are 9.8% (2013) and 8.4% (2018).

• **Hence, where the entire HPC server market is concerned (all price points), Europe has maintained, and is forecast to maintain, relatively constant share of slightly more than one-quarter of global spending.**
Table 1

ALL HPC Server Revenue by Region (Euros 000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>3,141,484</td>
<td>3,024,375</td>
<td>3,344,075</td>
<td>3,475,831</td>
<td>3,251,811</td>
<td>3,471,455</td>
<td>3,691,099</td>
<td>3,910,743</td>
<td>4,130,388</td>
<td>4,350,032</td>
<td>6.0%</td>
</tr>
<tr>
<td>EMEA</td>
<td>1,791,362</td>
<td>2,179,440</td>
<td>2,310,807</td>
<td>2,395,782</td>
<td>2,233,407</td>
<td>2,410,801</td>
<td>2,588,195</td>
<td>2,765,589</td>
<td>2,942,983</td>
<td>3,120,377</td>
<td>6.9%</td>
</tr>
<tr>
<td>** EU Only</td>
<td>1,526,503</td>
<td>1,867,046</td>
<td>1,979,021</td>
<td>2,049,407</td>
<td>1,904,746</td>
<td>2,049,684</td>
<td>2,204,614</td>
<td>2,363,781</td>
<td>2,512,684</td>
<td>2,670,860</td>
<td>7.0%</td>
</tr>
<tr>
<td>** EU+ Only</td>
<td>1,610,838</td>
<td>1,969,132</td>
<td>2,086,994</td>
<td>2,161,036</td>
<td>2,008,565</td>
<td>2,161,486</td>
<td>2,324,361</td>
<td>2,491,435</td>
<td>2,648,206</td>
<td>2,795,167</td>
<td>6.8%</td>
</tr>
<tr>
<td>Asia/Pacific w/o Japan</td>
<td>644,286</td>
<td>873,956</td>
<td>1,098,139</td>
<td>1,145,739</td>
<td>1,376,967</td>
<td>1,304,967</td>
<td>1,411,676</td>
<td>1,518,385</td>
<td>1,625,094</td>
<td>1,910,513</td>
<td>6.8%</td>
</tr>
<tr>
<td>Japan</td>
<td>588,231</td>
<td>412,820</td>
<td>563,871</td>
<td>898,107</td>
<td>477,577</td>
<td>508,895</td>
<td>540,214</td>
<td>571,532</td>
<td>602,851</td>
<td>634,169</td>
<td>5.8%</td>
</tr>
<tr>
<td>** China</td>
<td>254,171</td>
<td>359,689</td>
<td>437,180</td>
<td>472,757</td>
<td>726,517</td>
<td>573,025</td>
<td>623,716</td>
<td>677,986</td>
<td>705,291</td>
<td>853,336</td>
<td>3.3%</td>
</tr>
<tr>
<td>Rest-of-World</td>
<td>53,359</td>
<td>73,090</td>
<td>99,150</td>
<td>74,916</td>
<td>75,350</td>
<td>83,809</td>
<td>92,268</td>
<td>100,728</td>
<td>109,187</td>
<td>117,646</td>
<td>9.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,218,722</td>
<td>6,563,682</td>
<td>7,416,042</td>
<td>7,990,375</td>
<td>7,415,111</td>
<td>7,260,601</td>
<td>7,717,126</td>
<td>8,256,167</td>
<td>9,329,469</td>
<td>10,132,736</td>
<td>6.4%</td>
</tr>
<tr>
<td><strong>Share</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>50.5%</td>
<td>46.1%</td>
<td>45.1%</td>
<td>43.5%</td>
<td>43.9%</td>
<td>47.8%</td>
<td>47.8%</td>
<td>47.4%</td>
<td>44.3%</td>
<td>42.9%</td>
<td></td>
</tr>
<tr>
<td>EMEA</td>
<td>28.8%</td>
<td>33.2%</td>
<td>31.2%</td>
<td>30.0%</td>
<td>30.1%</td>
<td>33.2%</td>
<td>33.5%</td>
<td>33.5%</td>
<td>31.5%</td>
<td>30.8%</td>
<td></td>
</tr>
<tr>
<td>** EU Only</td>
<td>24.5%</td>
<td>28.4%</td>
<td>26.7%</td>
<td>25.6%</td>
<td>25.7%</td>
<td>28.2%</td>
<td>28.6%</td>
<td>28.6%</td>
<td>26.9%</td>
<td>26.4%</td>
<td></td>
</tr>
<tr>
<td>** EU+ Only</td>
<td>25.9%</td>
<td>30.0%</td>
<td>28.1%</td>
<td>27.0%</td>
<td>27.1%</td>
<td>29.8%</td>
<td>30.1%</td>
<td>30.2%</td>
<td>28.4%</td>
<td>27.6%</td>
<td></td>
</tr>
<tr>
<td>Asia/Pacific w/o Japan</td>
<td>10.4%</td>
<td>13.3%</td>
<td>14.8%</td>
<td>14.3%</td>
<td>18.6%</td>
<td>18.0%</td>
<td>18.3%</td>
<td>18.4%</td>
<td>17.4%</td>
<td>18.9%</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>9.5%</td>
<td>6.3%</td>
<td>7.6%</td>
<td>11.2%</td>
<td>6.4%</td>
<td>7.0%</td>
<td>7.0%</td>
<td>6.9%</td>
<td>6.5%</td>
<td>6.3%</td>
<td></td>
</tr>
</tbody>
</table>
Table 1

ALL HPC Server Revenue by Region (Euros 000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China</strong></td>
<td>4.1%</td>
<td>5.5%</td>
<td>5.9%</td>
<td>5.9%</td>
<td>9.8%</td>
<td>7.9%</td>
<td>8.1%</td>
<td>8.2%</td>
<td>7.6%</td>
<td>8.4%</td>
<td></td>
</tr>
<tr>
<td>Rest-of-World</td>
<td>0.9%</td>
<td>1.1%</td>
<td>1.3%</td>
<td>0.9%</td>
<td>1.0%</td>
<td>1.2%</td>
<td>1.2%</td>
<td>1.2%</td>
<td>1.2%</td>
<td>1.2%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

Source: IDC 2015
3.3.2. All Supercomputers (HPC Systems Sold for €360,000 or More)

The EU/EU+ market share evolution has been much stronger in the segment of the HPC server market that is more important for scientific and industrial computing leadership—supercomputers priced at over €360,000 (Table 2). In this strategic segment, the EU/EU+ share of the global market grew robustly from 21.8%/23.0% in 2009 to 27.1%/28.5% in 2013 and is forecast to expand to 30.6%/31.8% in 2018.

During the forecast period 2013-2018, IDC projects that North America's share of the supercomputer market will decline modestly from 41.6% to 38.1%, and China's share will drop from 17.7% to 13.6%. IDC does not expect China to maintain the explosive growth rate that its national economy and supercomputer spending experienced during the period 2009-2013, when China jumped from 3.5% to 17.7% of worldwide supercomputer market share.

At the very high end of the supercomputers segment, Europe has significantly narrowed the former wide gap separating the most capable U.S. and Japanese supercomputers from their European counterparts. In November 2010, shortly after the founding of PRACE, 9 of the world's 50 most powerful supercomputers were located in Europe (www.top500.org). Four years later, in November 2014, Europe hosted 19 of the top 50, including the PRACE tier-0 supercomputers. The aggregate peak performance of the Europe-based supercomputers rose more than ten-fold during this period, from 4.3 petaflops in November 2010 to 48.9 petaflops four years later. Clearly, Europe's standing as a provider of high-end supercomputing resources advanced in both absolute and relative (worldwide) terms during this period.

Europe has significantly narrowed the former wide gap separating the most capable U.S. and Japanese supercomputers from their European counterparts.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>1,250,474</td>
<td>1,178,378</td>
<td>1,339,559</td>
<td>1,433,670</td>
<td>1,199,782</td>
<td>1,260,777</td>
<td>1,307,584</td>
<td>1,366,900</td>
<td>1,486,452</td>
<td>1,553,372</td>
<td>5.3%</td>
</tr>
<tr>
<td>EMEA</td>
<td>617,619</td>
<td>829,768</td>
<td>970,913</td>
<td>1,184,846</td>
<td>877,914</td>
<td>753,003</td>
<td>1,082,769</td>
<td>1,108,914</td>
<td>1,329,622</td>
<td>1,408,842</td>
<td>9.9%</td>
</tr>
<tr>
<td>** EU Only**</td>
<td>529,397</td>
<td>715,011</td>
<td>836,020</td>
<td>1,019,504</td>
<td>781,926</td>
<td>658,374</td>
<td>927,722</td>
<td>953,375</td>
<td>1,141,890</td>
<td>1,245,707</td>
<td>9.8%</td>
</tr>
<tr>
<td>** EU Only**</td>
<td>557,786</td>
<td>752,947</td>
<td>880,277</td>
<td>1,073,382</td>
<td>821,754</td>
<td>692,455</td>
<td>976,608</td>
<td>1,003,315</td>
<td>1,201,628</td>
<td>1,295,224</td>
<td>9.5%</td>
</tr>
<tr>
<td>Asia/Pacific w/o Japan</td>
<td>217,544</td>
<td>348,751</td>
<td>516,215</td>
<td>481,114</td>
<td>582,204</td>
<td>541,001</td>
<td>582,565</td>
<td>597,327</td>
<td>698,470</td>
<td>821,144</td>
<td>7.1%</td>
</tr>
<tr>
<td>Japan</td>
<td>327,374</td>
<td>64,932</td>
<td>277,204</td>
<td>611,441</td>
<td>202,153</td>
<td>211,095</td>
<td>223,056</td>
<td>224,650</td>
<td>243,470</td>
<td>256,119</td>
<td>4.8%</td>
</tr>
<tr>
<td>** China**</td>
<td>85,821</td>
<td>143,534</td>
<td>215,926</td>
<td>248,047</td>
<td>510,911</td>
<td>365,784</td>
<td>418,843</td>
<td>473,764</td>
<td>508,093</td>
<td>554,025</td>
<td>1.6%</td>
</tr>
<tr>
<td>Rest-of-World</td>
<td>12,179</td>
<td>18,896</td>
<td>36,629</td>
<td>22,527</td>
<td>22,218</td>
<td>7,679</td>
<td>18,384</td>
<td>22,834</td>
<td>30,445</td>
<td>32,804</td>
<td>8.1%</td>
</tr>
<tr>
<td>Total</td>
<td>2,425,191</td>
<td>2,440,726</td>
<td>3,140,521</td>
<td>3,733,597</td>
<td>2,884,271</td>
<td>2,773,555</td>
<td>3,214,358</td>
<td>3,320,625</td>
<td>3,788,459</td>
<td>4,072,281</td>
<td>7.1%</td>
</tr>
<tr>
<td><strong>Share</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>51.6%</td>
<td>48.3%</td>
<td>42.7%</td>
<td>38.4%</td>
<td>41.6%</td>
<td>45.5%</td>
<td>40.7%</td>
<td>41.2%</td>
<td>39.2%</td>
<td>38.1%</td>
<td></td>
</tr>
<tr>
<td>EMEA</td>
<td>25.5%</td>
<td>34.0%</td>
<td>30.9%</td>
<td>31.7%</td>
<td>30.4%</td>
<td>27.1%</td>
<td>33.7%</td>
<td>33.4%</td>
<td>35.1%</td>
<td>34.6%</td>
<td></td>
</tr>
<tr>
<td>** EU Only**</td>
<td>21.8%</td>
<td>29.3%</td>
<td>26.6%</td>
<td>27.3%</td>
<td>27.1%</td>
<td>23.7%</td>
<td>28.9%</td>
<td>28.7%</td>
<td>30.1%</td>
<td>30.6%</td>
<td></td>
</tr>
<tr>
<td>** EU+ Only**</td>
<td>23.0%</td>
<td>30.8%</td>
<td>28.0%</td>
<td>28.7%</td>
<td>28.5%</td>
<td>25.0%</td>
<td>30.4%</td>
<td>30.2%</td>
<td>31.7%</td>
<td>31.8%</td>
<td></td>
</tr>
<tr>
<td>Asia/Pacific w/o Japan</td>
<td>9.0%</td>
<td>14.3%</td>
<td>16.4%</td>
<td>12.9%</td>
<td>20.2%</td>
<td>19.5%</td>
<td>18.1%</td>
<td>18.0%</td>
<td>18.4%</td>
<td>20.2%</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>13.5%</td>
<td>2.7%</td>
<td>8.8%</td>
<td>16.4%</td>
<td>7.0%</td>
<td>7.6%</td>
<td>6.9%</td>
<td>6.8%</td>
<td>6.4%</td>
<td>6.3%</td>
<td></td>
</tr>
</tbody>
</table>
Table 2

Supercomputer (Price Over 360,000 Euros) Revenue by Region (Euros 000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>3.5%</td>
<td>5.9%</td>
<td>6.9%</td>
<td>6.6%</td>
<td>17.7%</td>
<td>13.2%</td>
<td>13.0%</td>
<td>14.3%</td>
<td>13.4%</td>
<td>13.6%</td>
<td>13.6%</td>
</tr>
<tr>
<td>Rest-of-World</td>
<td>0.5%</td>
<td>0.8%</td>
<td>1.2%</td>
<td>0.6%</td>
<td>0.8%</td>
<td>0.3%</td>
<td>0.6%</td>
<td>0.7%</td>
<td>0.8%</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: IDC 2015
3.3.3. **High-End Supercomputers (HPC Systems Sold for €2.25 Million or More)**

Supercomputers sold for €2.25 million ($3.0 million) and up are the most important class for advanced scientific and engineering work. These supercomputers are a high-end subset of the overall Supercomputers category discussed in the prior section. Spending levels for these high-end supercomputers are therefore also an important measure of HPC leadership. Table 3 shows spending on large supercomputers by global region during the period 2009-2014 (all figures in this table are historical). When considering these findings, it is important to note that spending in this small but strategically important high-end market can vary greatly from year to year, because it is driven by a small number of large financial transactions that are subject to non-annual, cyclical renewals.

The table shows that during the period 2009-2014, worldwide spending on large supercomputers grew by 25.9% to reach €1.2 billion. Growth for specific regions often varied greatly from year to year, for the reason mentioned above. 2012 was an atypically strong year, owing especially to several major new installations in China and Japan, the largest of which (Japan's K supercomputer and China's Tianhe 2 system) alone added €400 million and €237 million in spending, respectively. Taking the year-to-year fluctuations into account, it is fair to conclude that North America (primarily the U.S.) did not greatly increase spending levels but remained the spending leader, while spending increased substantially in the EU/EU+ for large supercomputers from 2009 to 2012, but then declined. European overall spending on large supercomputers grew from 112 million euros in 2009, to 658 million in 2012, then down to 362 million euros in 2014 (table 3). Japanese spending on these leadership-class supercomputers has shown an historical pattern of funding "bursts" about once per decade (e.g., 2002, 2012) that have been aimed at recapturing global performance leadership on the Top500 list of the world’s most powerful supercomputers (www.top500.org).

**Table 3**

<table>
<thead>
<tr>
<th>Region (Euros 000)</th>
<th>Revenue</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td></td>
<td>555,055</td>
<td>467,761</td>
<td>492,697</td>
<td>1,028,771</td>
<td>721,084</td>
<td>498,196</td>
</tr>
<tr>
<td>EMEA</td>
<td></td>
<td>129,733</td>
<td>265,654</td>
<td>386,983</td>
<td>760,518</td>
<td>526,279</td>
<td>421,552</td>
</tr>
<tr>
<td>** EU Only</td>
<td></td>
<td>111,762</td>
<td>230,068</td>
<td>334,898</td>
<td>657,688</td>
<td>453,748</td>
<td>362,331</td>
</tr>
<tr>
<td>** EU+ Only</td>
<td></td>
<td>117,602</td>
<td>241,958</td>
<td>352,165</td>
<td>691,541</td>
<td>477,120</td>
<td>381,009</td>
</tr>
</tbody>
</table>
Table 3

Historic Large Supercomputer (Over 2.25M Euros) Revenue by Region (Euros 000)

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia/Pacific w/o</td>
<td>60,779</td>
<td>154,623</td>
<td>298,404</td>
<td>291,234</td>
<td>362,651</td>
<td>130,639</td>
</tr>
<tr>
<td>Japan</td>
<td>236,972</td>
<td>25,702</td>
<td>170,220</td>
<td>611,764</td>
<td>136,001</td>
<td>181,785</td>
</tr>
<tr>
<td>Rest-of-World</td>
<td>–</td>
<td>3,849</td>
<td>14,665</td>
<td>11,958</td>
<td>5,614</td>
<td>5,190</td>
</tr>
<tr>
<td>Total</td>
<td>982,539</td>
<td>917,589</td>
<td>1,362,969</td>
<td>2,704,247</td>
<td>1,751,629</td>
<td>1,237,362</td>
</tr>
</tbody>
</table>

Share

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>56.5%</td>
<td>51.0%</td>
<td>36.1%</td>
<td>38.0%</td>
<td>41.2%</td>
<td>40.3%</td>
</tr>
<tr>
<td>EMEA</td>
<td>13.2%</td>
<td>29.0%</td>
<td>28.4%</td>
<td>28.1%</td>
<td>30.0%</td>
<td>34.1%</td>
</tr>
<tr>
<td>** EU Only</td>
<td>11.4%</td>
<td>25.1%</td>
<td>24.6%</td>
<td>24.3%</td>
<td>25.9%</td>
<td>29.3%</td>
</tr>
<tr>
<td>** EU+ Only</td>
<td>12.0%</td>
<td>26.4%</td>
<td>25.8%</td>
<td>25.6%</td>
<td>27.2%</td>
<td>30.8%</td>
</tr>
<tr>
<td>Asia/Pacific w/o</td>
<td>6.2%</td>
<td>16.9%</td>
<td>21.9%</td>
<td>10.8%</td>
<td>20.7%</td>
<td>10.6%</td>
</tr>
<tr>
<td>Japan</td>
<td>24.1%</td>
<td>2.8%</td>
<td>12.5%</td>
<td>22.6%</td>
<td>7.8%</td>
<td>14.7%</td>
</tr>
<tr>
<td>Rest-of-World</td>
<td>0.0%</td>
<td>0.4%</td>
<td>1.1%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.4. European Production of HPC Systems

3.4.1. All Sizes of HPC Systems

Table 4 shows European (EU+) spending on all HPC server systems (all prices) by the vendors (i.e., producers) of the systems. The only Europe-based vendor large enough to escape the "Other" category was Atos (formerly Bull); all the rest of the named vendors were U.S.-based companies. Of these, Hewlett Packard (HP) and IBM were the clear leaders, and Dell was a strong third-place finisher.

From this production standpoint (and ignoring the relatively small "Other" category that includes very small vendors from the U.S., Europe, and Asia-Pacific), U.S. vendors represented 89.6% of all European (EU+) HPC server system revenue/spending in 2009 and 81.2% in 2014. The only sizeable Europe-based vendor, Atos (formerly Bull), accounted for 1.7% of spending in 2009 and 2.0% in 2014. In its largest revenue
year during this period, 2011, however, Atos/Bull captured 9.7% of European HPC server system revenue.

Table 4

<table>
<thead>
<tr>
<th>Vendor</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM</td>
<td>562,961</td>
<td>679,325</td>
<td>715,680</td>
<td>956,306</td>
<td>769,006</td>
<td>560,533</td>
</tr>
<tr>
<td>HP</td>
<td>692,422</td>
<td>838,452</td>
<td>858,954</td>
<td>887,033</td>
<td>891,242</td>
<td>939,427</td>
</tr>
<tr>
<td>Dell</td>
<td>194,317</td>
<td>257,885</td>
<td>256,562</td>
<td>240,615</td>
<td>236,090</td>
<td>241,235</td>
</tr>
<tr>
<td>Cray</td>
<td>21,985</td>
<td>31,526</td>
<td>16,807</td>
<td>38,210</td>
<td>47,168</td>
<td>168,890</td>
</tr>
<tr>
<td>SGI</td>
<td>28,635</td>
<td>61,036</td>
<td>48,608</td>
<td>15,986</td>
<td>18,951</td>
<td>49,187</td>
</tr>
<tr>
<td>Sun</td>
<td>74,249</td>
<td>37,765</td>
<td>15,805</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>NEC</td>
<td>29,311</td>
<td>7,700</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Appro</td>
<td>1,188</td>
<td>5,044</td>
<td>2,455</td>
<td>1,881</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Atos/Bull</td>
<td>31,298</td>
<td>75,460</td>
<td>223,164</td>
<td>38,814</td>
<td>50,105</td>
<td>49,405</td>
</tr>
<tr>
<td>Other</td>
<td>154,995</td>
<td>185,246</td>
<td>172,772</td>
<td>216,938</td>
<td>220,845</td>
<td>402,123</td>
</tr>
<tr>
<td>Total</td>
<td>1,791,362</td>
<td>2,179,440</td>
<td>2,310,807</td>
<td>2,395,782</td>
<td>2,233,407</td>
<td>2,410,801</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.4.2. Vendors of Supercomputers (HPC Systems Sold for €360,000 or More)

Vendors' European revenues for the more strategic supercomputer category (HPC systems sold for €360,000 or more) appear in Table 5. Market share for U.S. vendors declined slightly from 95.0% in 2009 to 93.2% in 2014. IBM and HP were the strong leaders in this segment. Atos/Bull market share grew slightly from 4.2% in 2009 to 4.5% in 2014, but had a peak of 18.6% market share in 2011.

Table 5

<table>
<thead>
<tr>
<th>Vendor</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM</td>
<td>300,706</td>
<td>422,338</td>
<td>461,878</td>
<td>748,854</td>
<td>482,588</td>
<td>261,779</td>
</tr>
</tbody>
</table>
Table 5

Historic European SUPERCOMPUTER (Price Over 360,000 Euros) Market Share by Vendor (Euros 000)

<table>
<thead>
<tr>
<th>Vendor</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>192,733</td>
<td>220,593</td>
<td>250,045</td>
<td>296,450</td>
<td>284,011</td>
<td>248,626</td>
</tr>
<tr>
<td>Dell</td>
<td>22,742</td>
<td>28,781</td>
<td>35,077</td>
<td>32,957</td>
<td>9,675</td>
<td>7,740</td>
</tr>
<tr>
<td>Cray</td>
<td>21,985</td>
<td>31,526</td>
<td>16,807</td>
<td>38,210</td>
<td>47,168</td>
<td>168,890</td>
</tr>
<tr>
<td>SGI</td>
<td>11,989</td>
<td>29,940</td>
<td>14,110</td>
<td>6,241</td>
<td>4,422</td>
<td>15,247</td>
</tr>
<tr>
<td>Sun</td>
<td>11,958</td>
<td>3,818</td>
<td>292</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>NEC</td>
<td>23,551</td>
<td>7,700</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Appro</td>
<td>1,188</td>
<td>4,353</td>
<td>2,455</td>
<td>1,471</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Atos/Bull</td>
<td>26,037</td>
<td>68,160</td>
<td>180,163</td>
<td>35,308</td>
<td>43,052</td>
<td>33,926</td>
</tr>
<tr>
<td>Other</td>
<td>4,728</td>
<td>12,557</td>
<td>10,086</td>
<td>25,354</td>
<td>6,997</td>
<td>16,794</td>
</tr>
<tr>
<td>Total</td>
<td>617,619</td>
<td>829,768</td>
<td>970,913</td>
<td>1,184,846</td>
<td>877,914</td>
<td>753,003</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.4.3. Vendors of High-End Supercomputers (HPC Systems Sold for €2.5 Million or More)

Table 6 contains the European revenue figures for vendors of the strategic category of high-end supercomputers (sold for €2.25 million or more) during the historical period 2009-2014. U.S. vendors captured 86.9% of European revenue in this category in 2009 and 96.7% in 2013 (the most recent year for which IDC had Atos/Bull revenue figures for this category).

In 2009, revenue for IBM alone accounted for 66.7% of European revenues (HP did not report any revenue in this category in Europe). In 2014, combined revenue for IBM and HP represented 58.9% of European revenue. Cray had an exceptionally strong 2014 in Europe and accounted for 39.2% of revenue in this high-end category. In 2011, Atos (formerly Bull) had an exceptional year and captured 20.3% of European high-end supercomputer revenue.
Table 6

European LARGE SUPERCOMPUTERS (Price Over 2.25M Euros) Market by Vendor

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM</td>
<td>86,426</td>
<td>158,779</td>
<td>221,658</td>
<td>517,377</td>
<td>304,310</td>
<td>118,668</td>
</tr>
<tr>
<td>HP</td>
<td>–</td>
<td>17,107</td>
<td>76,781</td>
<td>173,756</td>
<td>151,084</td>
<td>129,772</td>
</tr>
<tr>
<td>Dell</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>25,173</td>
<td>9,675</td>
<td>7,740</td>
</tr>
<tr>
<td>Cray</td>
<td>21,985</td>
<td>27,529</td>
<td>9,851</td>
<td>38,210</td>
<td>43,707</td>
<td>165,371</td>
</tr>
<tr>
<td>SGI</td>
<td>4,359</td>
<td>14,737</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Atos/Bull</td>
<td>11,131</td>
<td>47,502</td>
<td>78,694</td>
<td>6,001</td>
<td>17,503</td>
<td>–</td>
</tr>
<tr>
<td>Other</td>
<td>5,832</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>129,733</td>
<td>265,654</td>
<td>386,983</td>
<td>760,518</td>
<td>526,279</td>
<td>421,552</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.5. The Rest of the Ecosystem: Beyond the HPC Servers

IDC’s 2013 Worldwide HPC End-User Multi-Client Report confirmed that computer hardware easily remains the largest item in the HPC budget, consuming (including processors/accelerators) 39.5% of the average HPC budget. The preceding tables described Europe’s position regarding these hardware server systems. This section evaluates Europe’s capabilities in other important parts of the HPC ecosystem: processors and coprocessors/accelerators, interconnects, software, storage, and service.

Tables 7 (EU) and 8 (EU+) look at European revenues for the entire HPC ecosystem that includes server systems, storage, middleware, applications software, and service. Note that these are numbers for actual spending on computers and supporting equipment/software/services.

3.5.1. European HPC Ecosystem Revenues: EU Only

During the period 2009-2013, European spending for the HPC ecosystem grew 24.4%, from 3.07 in 2009 to reach €3.8 billion (Table 7), or 26.1% of the worldwide HPC ecosystem spending (€14.6 billion). Spending on HPC servers represented 49.8% of that total.
IDC forecasts that European HPC ecosystem spending will increase by 37.8% (6.6% CAGR) to reach about €5.2 billion in 2018, or 24.9% of worldwide HPC ecosystem spending (€21.3 billion).

IDC predicts that spending on HPC servers in 2018 will represent 50.8% of the increased ecosystem total.
Table 7  
European HPC Ecosystem Revenues: EU Only (Euros 000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Server</td>
<td>1,526,503</td>
<td>1,867,046</td>
<td>1,979,021</td>
<td>2,049,407</td>
<td>2,049,684</td>
<td>2,204,614</td>
<td>2,363,781</td>
<td>2,512,684</td>
<td>2,670,860</td>
<td>7.0%</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>534,276</td>
<td>681,654</td>
<td>704,080</td>
<td>876,459</td>
<td>715,226</td>
<td>778,428</td>
<td>837,402</td>
<td>851,396</td>
<td>870,198</td>
<td>1,037,956</td>
<td>7.7%</td>
</tr>
<tr>
<td>Middleware</td>
<td>187,760</td>
<td>226,063</td>
<td>220,351</td>
<td>270,750</td>
<td>218,083</td>
<td>234,283</td>
<td>248,770</td>
<td>249,654</td>
<td>253,982</td>
<td>293,176</td>
<td>6.1%</td>
</tr>
<tr>
<td>Applications</td>
<td>525,117</td>
<td>648,062</td>
<td>647,496</td>
<td>794,185</td>
<td>638,569</td>
<td>684,790</td>
<td>725,852</td>
<td>727,144</td>
<td>732,152</td>
<td>852,809</td>
<td>6.0%</td>
</tr>
<tr>
<td>Service</td>
<td>293,089</td>
<td>353,898</td>
<td>345,952</td>
<td>422,390</td>
<td>338,075</td>
<td>360,891</td>
<td>380,785</td>
<td>379,721</td>
<td>383,058</td>
<td>401,976</td>
<td>3.5%</td>
</tr>
<tr>
<td>Total Revenue</td>
<td>3,066,744</td>
<td>3,776,722</td>
<td>3,896,901</td>
<td>4,413,190</td>
<td>3,814,698</td>
<td>4,108,075</td>
<td>4,397,425</td>
<td>4,571,697</td>
<td>4,752,073</td>
<td>5,256,777</td>
<td>6.6%</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.5.2. European HPC Ecosystem Revenues: EU+ Only

As would be expected, the figures for the EU+ region (Table 8) differ only slightly from those for the EU region alone. Note that these are numbers for actual spending on computers and supporting equipment/software/services.

Table 8

European HPC Ecosystem Revenues: EU+ Only (Euros 000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Server</td>
<td>1,610,838</td>
<td>1,969,132</td>
<td>2,086,994</td>
<td>2,161,036</td>
<td>2,008,565</td>
<td>2,161,486</td>
<td>2,324,361</td>
<td>2,491,435</td>
<td>2,648,206</td>
<td>2,795,167</td>
<td>6.8%</td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>Storage</td>
<td>480,435</td>
<td>615,877</td>
<td>635,599</td>
<td>790,581</td>
<td>643,222</td>
<td>697,926</td>
<td>752,040</td>
<td>766,997</td>
<td>783,037</td>
<td>932,174</td>
<td>7.7%</td>
</tr>
<tr>
<td>Middleware</td>
<td>168,838</td>
<td>204,249</td>
<td>198,919</td>
<td>244,221</td>
<td>196,128</td>
<td>210,054</td>
<td>223,411</td>
<td>224,906</td>
<td>228,543</td>
<td>263,298</td>
<td>6.1%</td>
</tr>
<tr>
<td>Applications</td>
<td>472,198</td>
<td>585,526</td>
<td>584,519</td>
<td>716,368</td>
<td>574,283</td>
<td>613,972</td>
<td>651,861</td>
<td>655,062</td>
<td>658,817</td>
<td>765,896</td>
<td>5.9%</td>
</tr>
<tr>
<td>Service</td>
<td>263,553</td>
<td>319,748</td>
<td>312,304</td>
<td>381,003</td>
<td>304,040</td>
<td>323,569</td>
<td>341,969</td>
<td>342,080</td>
<td>344,690</td>
<td>361,009</td>
<td>3.5%</td>
</tr>
<tr>
<td>Total Revenue</td>
<td>2,995,862</td>
<td>3,694,531</td>
<td>3,818,334</td>
<td>4,293,210</td>
<td>3,726,239</td>
<td>4,007,007</td>
<td>4,293,642</td>
<td>4,480,479</td>
<td>4,663,293</td>
<td>5,117,543</td>
<td>6.6%</td>
</tr>
</tbody>
</table>

Source: IDC 2015
3.6. The Rest of the Ecosystem: Deeper Discussion

3.6.1. Processors and Coprocessors/Accelerators

The 2013 IDC study found that U.S.-based processor vendors heavily dominate the global HPC market. X86-based processors, primarily from Intel and secondarily from AMD, accounted for 90.3% of the 9.6 million processors installed in HPC systems during that year. When other U.S.-supplied processors are added (e.g., Intel Itanium, IBM Power, RISC), the U.S. advantage climbs to more than 98%. In the small but growing market for HPC coprocessors/accelerators, which represented 1.1% of all HPC processor parts shipped in 2011 and 3.4% in 2013, U.S.-based vendors Nvidia and Intel taken together represent nearly all of the volume in this formative global market.

There is considerable early momentum behind the development of HPC processors (CPUs) based on designs from UK-based ARM Holdings plc. By the year 2020, IDC expects all, or nearly all, large and mid-sized HPC hardware vendors to offer systems configured with ARM-based processors, not just in Europe but worldwide. Sales of ARM-based HPC systems should benefit from ARM's attractive energy efficiency and from ARM's position as an alternative to Intel's strong dominance in the global HPC processor market. On the other hand, sales of ARM processors likely will be constrained for a number of years until a large portfolio of HPC software applications have been ported to, and performance-optimized for, the ARM architecture.

Kalray is a French company that focuses on developing manycore processors positioned as alternatives to field-programmable gate arrays (FPGAs) and ASICs. Kalray does not have significant market share yet.

IDC expects major HPC system vendors throughout the world to offer supercomputers that include processors (CPUs) based on patented designs from UK-based ARM Holdings—some vendors already do this. Although ARM Holdings does not make the processors, the company's ownership of intellectual property rights brings a portion of HPC processor revenue to Europe and positions this European supplier to drive processor innovation on a substantial global scale, as an increasingly important alternative to today's leading suppliers: Intel, IBM and AMD.

A further important development was the 2013 creation of the OpenPOWER Foundation, a global organization that allows vendor-members to develop custom innovations based on IBM's Power processor architecture. OpenPOWER has developed strong research momentum, including in Europe, but it is too soon to predict what impact this initiative will have by 2020.

3.6.2. Interconnects

The 2013 IDC study found that non-European-based vendors heavily dominate the global market for HPC interconnects, the communication networks (also called fabrics or switches) that link processors, memory, and other components together within HPC systems. The study also confirmed, however, that the worldwide HPC interconnect market remains fragmented, with a total of 15 named vendors, seven of which were present at 10% or
more of the surveyed HPC sites. No vendor has presented a value proposition compelling enough to establish market dominance. This fragmentation creates opportunities for new vendors to succeed in this important part of the HPC market.

The leading interconnect communications standards today are Ethernet, which holds a 50% share of the global HPC market, and InfiniBand, which accounts for about 40% the market. The remaining 10% market share is split among proprietary interconnects from various HPC system vendors.

The InfiniBand standard is associated with the world’s most powerful supercomputers and is therefore more strategically important for HPC leadership than Ethernet. The leading vendor of InfiniBand interconnects today is Mellanox, an Israeli company that has established a second headquarters in the U.S. European vendor EXTOLL (Germany) sells an interconnect product designed to compete favorably with InfiniBand, and Atos (France) is developing an interconnect product to rival InfiniBand. U.S.-based mega-vendor Intel is widely expected to market its own high-performance, non-InfiniBand interconnect fabric in the next year or so.

3.6.3. Highly Parallel Software

The situation regarding highly parallel software in Europe has not changed markedly since IDC’s 2011 study on this topic for the Commission, entitled Financing a Software Infrastructure for Highly Parallelised Codes, that study noted, in summary (with necessary updating):

- 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. In addition, great strides have been made within initiatives such as CRNS, INRIA, Germany's Special Programme on Exascale Computing, and others, as well as within large industrial firms such as Daimler, EDF, Airbus, and quite a few others. Where extreme-scale software is concerned, however, Europe (like the rest of the world) has been overly focused on funding parallel hardware to the detriment of parallel software, and on "big science" in comparison with industry.

- Where funding has been made available for parallel software development, the funding typically has been for only a year or two, compared with at least 5-10 years of funding needed to develop robust, production-quality software that can remain useful for 10-20 or even 30 years and across multiple generations of HPC hardware systems.

- The vast majority (83%) of the most important parallel software applications in use at the surveyed European HPC sites were created in Europe. Intellectual property rights for a substantial majority of the sites' most important application codes (66%) were exclusively owned by European organizations. But many of these important codes are used only by one or a handful of HPC sites.

Consumption. The worldwide commercial market for HPC software was worth €4.4 billion in 2013. IDC believes that the European portion of global spending in this market closely
matched Europe's portion of global spending in the HPC server market (~27%) and was therefore worth roughly €1.2 billion in 2013. IDC forecasts that the worldwide HPC software market will expand to about €6.4 billion in 2018 and European spending in this market will be about €1.7 billion.

Production. Companies such as Allinea (UK), Bright Computing (Netherlands), Dassault Systèmes (France), Schrödinger (Germany), and others have demonstrated that European software vendors can achieve notable success in both the European and global HPC markets. IDC estimates that European independent software vendors (ISVs) today represent 15-20% of the global HPC market for ISV software, and 25-30% of the European market.

Centers of Excellence. The Centers of Excellence within the European HPC strategy are considered indispensable for helping to advance Europe's existing leadership areas in highly parallel software and for developing skills and expertise needed for the coming era of exascale computing. The centers will function as incubators for collaborations involving software developers from European HPC user sites and vendors.

3.6.4. Software ISVs

Europe has struggled to provide better support to the European ISV supply chain. The ISV supply chain in Europe is very strong, and could be much stronger.

As mentioned early, the EU should initiate an EU-wide exascale test bed program to provide strong support for exascale co-design capabilities. Such a test bed would allow both EU-based ISVs and EU Software Centers of Excellence to participate in the design of exascale systems, understand the critical software requirements that these new hardware platforms engender, identify and define technical specifications for various elements of an emerging exascale software stack, glean best case situations for collaborative efforts among various ISVs and CoEs, and develop a sense early on of leading-EU-based exascale architectural and algorithmic development efforts. This test bed should also extend similar co-design access to key industrial or other application users to ensure that co-design and related software development efforts are in synch with the exascale-related needs of key industrial players. Industrial participants should include a mix of long-standing HPC users, both large and small, as well as potential new HPC users.

3.6.5. Storage

Storage is quickly rising in importance because of the HPC "data explosion" related to problems being run at larger sizes, at finer resolutions, and with more iterations—as well as the growing importance of advanced data analytics in many HPC domains.

Consumption. In Europe and worldwide, storage will remain the fastest-growing segment of the HPC market at least through 2018. IDC forecasts that in the period 2013-2018, HPC storage will grow at a CAGR of 7.7%, compared with 6.8% for HPC server systems. Europe's share of worldwide spending on HPC storage will closely mirror Europe's portion of global spending on HPC server systems. IDC expects European HPC storage spending to increase from about €643 million in 2013 to about €932 million in 2018.
Production. Recent IDC global research confirms that the HPC storage market remains fragmented and U.S.-dominated. Eleven of the top 12 vendors are based in the U.S., and the only European vendor, Bull (now Atos), has market share of well under 10% in Europe today.

3.6.6. Service

The primary service category in HPC is technical support for HPC systems. This maintenance service is typically provided by the HPC system vendor or a subcontractor of the vendor. IDC forecasts that HPC service spending in Europe will grow at a modest 3.5% CAGR to reach about €361 million in 2018.

3.7. High Performance Data Analysis: Big Data Needing HPC

High-performance data analysis (HPDA) is the term IDC coined to describe the formative market for big data workloads that exploit HPC resources. The HPDA market represents the convergence of long-standing, data-intensive modeling and simulation (M&S) methods in the HPC industry/application segments IDC has tracked for more than 25 years, and newer high performance analytics methods that are increasingly employed in these segments as well as by commercial organizations that are adopting HPC for the first time. HPDA may employ either long-standing numerical M&S methods, newer methods such as large-scale graph analytics, semantic technologies, and knowledge discovery algorithms, or some combination of long-standing and newer methods.

3.7.1. Convergence of the HPC and Commercial Analytics Markets

The convergence of HPC and big data analytics is being driven by HPC users and the growing contingent of commercial firms that are adopting HPC solutions to tackle data analytics jobs that are too complex or time critical for enterprise IT resources to handle efficiently and cost effectively. In addition:

- Within the HPC ranks, HPDA is already becoming mission critical in the government, academic, manufacturing, energy, weather/climate, life sciences, and digital content creation markets — not to mention high frequency trading as an important addition to existing HPC-driven financial services applications.
- IDC works with dozens of commercial firms that have moved up to HPC for the first time for advanced business analytics/business intelligence, fraud/errror/anomaly detection, real-time affinity marketing, and other applications. Even though the existing HPC solutions they use may not be explicitly designed to excel at data analytics, it is not unusual for these firms to save $10 million or more per year from upgrading to HPC sold for a fraction of that amount.

3.7.2. Factors Driving Industry/Commerce to Adopt HPC

The factors driving businesses to adopt HPC for big data analytics (i.e., HPDA) fall into the following main categories, all of them reflecting the growing recognition that "to out-compute is to out-compete":

50
• **Complexity.** HPC technology allows companies to aim more complex, intelligent questions at their data infrastructures. This ability can provide important advantages in today’s increasingly competitive markets, such as for customer acquisition and retention, supply chain management, and forecasting.

• **Time to value.** Businesses face ever-shortening innovation and production cycles. Solutions that are not available quickly enough are of little value, analogous to not getting the weather report for tomorrow until the day after tomorrow. That's why analytics (including Hadoop) is moving from batch processing toward low-latency, interactive capabilities. Interactive responsiveness is increasingly crucial. For financial services companies engaged in high frequency trading, for example, HPC technology enables proprietary algorithms to exploit market movements in fractions of a second, before the opportunities disappear.

• **Variability.** People generally assume that big data is "deep," meaning that it involves large amounts of data. They recognize less often that it may also be "wide," meaning that it can include many variables. Think of "deep" as corresponding to many spreadsheet rows and "wide" as referring to many columns (although a growing number of HPDA problems don't fit neatly into traditional row-and-column spreadsheets). A "deep" query might request a prioritized listing of the previous quarter's 500 top customers in Europe. A "wide" query might go on to analyze the buying preferences and behaviors of those customers in relation to dozens of criteria. An even "wider" analysis might employ graph analytics to identify any fraudulent behavior within the customer base.

• **Costs.** All too often today, businesses' data analytics require a series of multiple single-purpose clusters for functions such as ETL, stream processing, data mining, and interactive querying. Such an array of separate servers can be expensive in terms of initial costs, power and space, and ongoing operation and maintenance. Mainstream HPC clusters are designed from the start as multi-purpose platforms, and an HPC cluster configured for HPDA has the potential to shrink the analytics pipeline into a single, cost-effective cluster.

In summary, HPC analytics platforms can finally help realize users' largely unfulfilled dreams of the 1990s/2000s by quickly and efficiently turning torrents of heterogeneous data into actionable knowledge.

### 3.7.3. European HPDA Initiatives

Notable HPDA initiatives within Europe include (but are not limited to) the following:

- **EUDAT** [self-description] "offers common data services, supporting multiple research communities as well as individuals, through a geographically distributed, resilient network connecting general purpose data centers and community-specific data repositories. These shared services and storage resources are distributed across 15 European nations and data is stored alongside some of Europe’s most powerful supercomputers."

- The **Research Data Alliance**, to which EUDAT and others contribute, is a community focused on "building social, organizational and technical infrastructure to reduce barriers to data sharing and exchange [and to] accelerate the development of a
coordinated, global data infrastructure.” EUDAT drives a number of RDA working and interest groups, notably Data Foundation and Terminology PID Information Types, Data Type Registry, Practical Policy, Data Citation, Metadata, Big Data Analytics and Legal Interoperability.

- The **European Genome-phenome Archive** (EGA) is a repository of datasets from numerous genetic studies. Europe is also a partner in the International Cancer Genome Consortium.

IDC closely tracks the worldwide HPDA developments and believes that European initiatives such as those mentioned above are at the forefront of these formative developments. The following are notable examples of European HPDA leadership; interestingly, they correspond to industrial and scientific areas in which Europe can also lay claim as global leaders:

- The report from the first Climate Knowledge Discovery Workshop (April 2011, Hamburg, Germany)\(^\text{21}\) nicely sums up the potential for HPDA in that important domain:

  Current approaches to data volumes are primarily focused on traditional methods, best-suited for large-scale phenomena and coarse-resolution data sets. The data volumes from climate modeling will increase dramatically due to both increasing resolution and number of processes described. What is needed is a suite of new techniques [i.e., knowledge discovery algorithms] interpreting and linking phenomena on and between different time- and length scales as well as realms and processes. Such tools could provide unique insights into challenging features of the Earth system, including extreme events, nonlinear dynamics, and chaotic regimes.

### 3.7.4. The European and Worldwide HPDA Server Market

Table 22 displays the percentage of worldwide and European HPC server spending represented by high performance data analysis (HPDA) servers, that is, HPC servers purchased primarily to run data-intensive simulation or analytics workloads. The table includes forecast data for 2013–2018.

**IDC forecasts that worldwide revenue for HPDA servers will grow robustly (23.5% CAGR) during the period 2013–2018,** increasing from €672 million to about €1.9 billion in 2018. This is more than three times the IDC-forecasted growth rate of the worldwide HPC server market as a whole. Europe’s share of this HPC-related market is similar to Europe's share of the HPC server system market as a whole, about one-quarter of the global total.

Table 22

Worldwide High Performance Data Analysis Server Revenues (Euros Millions)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WW HPDA from Historic HPC</td>
<td>385</td>
<td>434</td>
<td>472</td>
<td>510</td>
<td>566</td>
<td>660</td>
<td>860</td>
<td>1,072</td>
<td>1,314</td>
<td>1,536</td>
<td>22.1%</td>
</tr>
<tr>
<td>WW HPDA From New Segments</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>92</td>
<td>107</td>
<td>129</td>
<td>178</td>
<td>236</td>
<td>313</td>
<td>395</td>
<td>29.9%</td>
</tr>
<tr>
<td>Total WW HPDA Server Revenues</td>
<td>385</td>
<td>434</td>
<td>472</td>
<td>602</td>
<td>672</td>
<td>789</td>
<td>1,037</td>
<td>1,308</td>
<td>1,627</td>
<td>1,930</td>
<td>23.5%</td>
</tr>
<tr>
<td>** EU Only HPDA Revenues</td>
<td>85</td>
<td>111</td>
<td>113</td>
<td>139</td>
<td>155</td>
<td>200</td>
<td>267</td>
<td>337</td>
<td>394</td>
<td>458</td>
<td>24.1%</td>
</tr>
<tr>
<td>** EU+ HPDA Revenues</td>
<td>90</td>
<td>117</td>
<td>119</td>
<td>147</td>
<td>164</td>
<td>211</td>
<td>281</td>
<td>355</td>
<td>416</td>
<td>479</td>
<td>23.9%</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.8. The European HPC Server Market by Industry/Application Area

3.8.1. European HPC Server Market by Industry/Application Area: EU Only

Table 9 lays out EU HPC server system spending by the industry/application segments that IDC has tracked for more than 25 years. For the five-year forecast period 2013-2018, IDC predicts that strongest growth will occur in computer-aided engineering (CAE), which is heavily used in the manufacturing sector. Other predicted fast-growth areas including weather/climate (7.6%), government labs/centers (7.6% CAGR), chemical engineering (7.2% CAGR), academia (7.0% CAGR) and geosciences (6.9% CAGR). Geosciences use today is primarily related to "upstream" oil and gas exploration and will secondarily for alternative energy research. We forecast that the largest segments for EU HPC spending in 2018 will be, sequentially, government labs/centers, academia, CAE, bio-sciences, and geosciences.
### Table 9

**European HPC Market by Industry/Application Area: EU Only (Euros 000)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Sciences</td>
<td>179,165</td>
<td>217,298</td>
<td>225,360</td>
<td>231,464</td>
<td>210,964</td>
<td>222,759</td>
<td>236,818</td>
<td>251,748</td>
<td>255,552</td>
<td>270,907</td>
<td>5.1%</td>
</tr>
<tr>
<td>CAE</td>
<td>188,777</td>
<td>234,923</td>
<td>251,484</td>
<td>265,137</td>
<td>248,876</td>
<td>271,633</td>
<td>296,405</td>
<td>321,078</td>
<td>343,328</td>
<td>363,957</td>
<td>7.9%</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>6,433</td>
<td>7,225</td>
<td>7,806</td>
<td>7,765</td>
<td>6,935</td>
<td>7,839</td>
<td>8,769</td>
<td>9,259</td>
<td>9,263</td>
<td>9,820</td>
<td>7.2%</td>
</tr>
<tr>
<td>DCC &amp; Distribution</td>
<td>7,431</td>
<td>6,980</td>
<td>7,289</td>
<td>7,430</td>
<td>6,848</td>
<td>7,234</td>
<td>7,524</td>
<td>8,235</td>
<td>8,983</td>
<td>9,523</td>
<td>6.8%</td>
</tr>
<tr>
<td>Economics/Financial</td>
<td>28,003</td>
<td>35,257</td>
<td>45,723</td>
<td>46,985</td>
<td>43,620</td>
<td>46,612</td>
<td>49,816</td>
<td>53,802</td>
<td>57,372</td>
<td>60,819</td>
<td>6.9%</td>
</tr>
<tr>
<td>EDA</td>
<td>49,899</td>
<td>59,833</td>
<td>63,016</td>
<td>64,544</td>
<td>61,027</td>
<td>66,336</td>
<td>71,743</td>
<td>76,478</td>
<td>80,993</td>
<td>85,860</td>
<td>7.1%</td>
</tr>
<tr>
<td>Geosciences</td>
<td>158,644</td>
<td>188,306</td>
<td>201,703</td>
<td>201,234</td>
<td>187,474</td>
<td>202,778</td>
<td>217,493</td>
<td>232,829</td>
<td>247,116</td>
<td>261,966</td>
<td>6.9%</td>
</tr>
<tr>
<td>Mechanical Design</td>
<td>2,787</td>
<td>3,263</td>
<td>2,914</td>
<td>2,521</td>
<td>2,567</td>
<td>2,725</td>
<td>2,421</td>
<td>2,336</td>
<td>2,146</td>
<td>2,275</td>
<td>-2.4%</td>
</tr>
<tr>
<td>Defense</td>
<td>153,966</td>
<td>185,537</td>
<td>192,906</td>
<td>196,688</td>
<td>182,116</td>
<td>193,388</td>
<td>204,310</td>
<td>215,439</td>
<td>235,807</td>
<td>249,975</td>
<td>6.5%</td>
</tr>
<tr>
<td>Government Lab</td>
<td>379,128</td>
<td>477,874</td>
<td>513,356</td>
<td>539,136</td>
<td>509,113</td>
<td>549,792</td>
<td>593,336</td>
<td>640,869</td>
<td>684,402</td>
<td>732,725</td>
<td>7.6%</td>
</tr>
<tr>
<td>University/Academic</td>
<td>287,796</td>
<td>348,133</td>
<td>372,468</td>
<td>386,959</td>
<td>358,983</td>
<td>388,059</td>
<td>417,530</td>
<td>449,137</td>
<td>475,503</td>
<td>504,074</td>
<td>7.0%</td>
</tr>
<tr>
<td>Weather</td>
<td>43,156</td>
<td>52,328</td>
<td>55,559</td>
<td>56,705</td>
<td>53,088</td>
<td>57,090</td>
<td>61,779</td>
<td>66,165</td>
<td>72,365</td>
<td>76,713</td>
<td>7.6%</td>
</tr>
<tr>
<td>Other</td>
<td>41,317</td>
<td>50,087</td>
<td>49,437</td>
<td>42,841</td>
<td>33,134</td>
<td>33,438</td>
<td>36,670</td>
<td>36,405</td>
<td>39,853</td>
<td>42,248</td>
<td>5.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,526,503</strong></td>
<td><strong>1,867,046</strong></td>
<td><strong>1,979,021</strong></td>
<td><strong>2,049,407</strong></td>
<td><strong>1,904,746</strong></td>
<td><strong>2,049,684</strong></td>
<td><strong>2,204,614</strong></td>
<td><strong>2,363,781</strong></td>
<td><strong>2,512,684</strong></td>
<td><strong>2,670,860</strong></td>
<td><strong>7.0%</strong></td>
</tr>
</tbody>
</table>

Source: IDC 2015
3.8.2. European HPC Server Market by Industry/Application Area: EU+ Only

The figures for the EU+ region are slightly larger than those for the EU region and follows the same patterns (see Table 10).
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Sciences</td>
<td>184,707</td>
<td>225,698</td>
<td>234,246</td>
<td>240,689</td>
<td>215,933</td>
<td>243,323</td>
<td>260,582</td>
<td>264,783</td>
<td>276,800</td>
<td></td>
<td>5.1%</td>
</tr>
<tr>
<td>CAE</td>
<td>194,617</td>
<td>244,005</td>
<td>261,401</td>
<td>275,704</td>
<td>254,738</td>
<td>280,537</td>
<td>304,547</td>
<td>332,344</td>
<td>355,729</td>
<td>371,874</td>
<td>7.9%</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>6,632</td>
<td>7,504</td>
<td>8,113</td>
<td>8,074</td>
<td>7,098</td>
<td>8,096</td>
<td>9,010</td>
<td>9,584</td>
<td>9,598</td>
<td>10,034</td>
<td>7.2%</td>
</tr>
<tr>
<td>DCC &amp; Distribution</td>
<td>7,661</td>
<td>7,250</td>
<td>7,576</td>
<td>7,726</td>
<td>7,009</td>
<td>7,471</td>
<td>7,731</td>
<td>8,524</td>
<td>9,308</td>
<td>9,730</td>
<td>6.8%</td>
</tr>
<tr>
<td>Economics/Financial</td>
<td>28,869</td>
<td>36,620</td>
<td>47,526</td>
<td>48,858</td>
<td>44,648</td>
<td>48,140</td>
<td>51,184</td>
<td>55,689</td>
<td>59,444</td>
<td>62,142</td>
<td>6.8%</td>
</tr>
<tr>
<td>EDA</td>
<td>51,443</td>
<td>62,146</td>
<td>65,501</td>
<td>67,117</td>
<td>62,465</td>
<td>68,510</td>
<td>73,714</td>
<td>79,161</td>
<td>83,919</td>
<td>87,727</td>
<td>7.0%</td>
</tr>
<tr>
<td>Geosciences</td>
<td>163,552</td>
<td>195,585</td>
<td>199,262</td>
<td>209,254</td>
<td>209,425</td>
<td>223,468</td>
<td>240,998</td>
<td>256,043</td>
<td>267,663</td>
<td></td>
<td>6.9%</td>
</tr>
<tr>
<td>Mechanical Design</td>
<td>2,873</td>
<td>3,389</td>
<td>3,029</td>
<td>2,621</td>
<td>2,627</td>
<td>2,815</td>
<td>2,488</td>
<td>2,418</td>
<td>2,224</td>
<td>2,325</td>
<td>-2.4%</td>
</tr>
<tr>
<td>Defense</td>
<td>158,729</td>
<td>192,709</td>
<td>200,513</td>
<td>204,527</td>
<td>186,406</td>
<td>199,727</td>
<td>209,923</td>
<td>222,999</td>
<td>244,324</td>
<td>255,413</td>
<td>6.5%</td>
</tr>
<tr>
<td>Government Lab</td>
<td>413,124</td>
<td>518,782</td>
<td>556,050</td>
<td>590,572</td>
<td>550,583</td>
<td>590,121</td>
<td>646,625</td>
<td>678,260</td>
<td>731,504</td>
<td>748,664</td>
<td>6.3%</td>
</tr>
<tr>
<td>University/Academic</td>
<td>311,544</td>
<td>369,069</td>
<td>394,640</td>
<td>402,381</td>
<td>396,916</td>
<td>423,087</td>
<td>451,194</td>
<td>494,706</td>
<td>515,059</td>
<td>581,248</td>
<td>7.9%</td>
</tr>
<tr>
<td>Weather</td>
<td>44,491</td>
<td>54,351</td>
<td>57,750</td>
<td>58,965</td>
<td>54,339</td>
<td>58,962</td>
<td>63,476</td>
<td>68,487</td>
<td>74,979</td>
<td>78,382</td>
<td>7.6%</td>
</tr>
<tr>
<td>Other</td>
<td>42,595</td>
<td>52,023</td>
<td>51,387</td>
<td>44,548</td>
<td>33,915</td>
<td>34,534</td>
<td>37,678</td>
<td>37,682</td>
<td>41,293</td>
<td>43,167</td>
<td>4.9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,610,838</td>
<td>1,969,132</td>
<td>2,086,994</td>
<td>2,161,036</td>
<td>2,008,565</td>
<td>2,161,486</td>
<td>2,324,361</td>
<td>2,491,435</td>
<td>2,648,206</td>
<td>2,795,167</td>
<td>6.8%</td>
</tr>
</tbody>
</table>

Source: IDC 2015
3.9. The ROI from HPC Investments in Europe

Note: Annex 6 contains the overall assessment of the ROI with HPC in Europe.

In summary, European HPC investments are producing excellent returns-on-investment (ROI) for science and industry. IDC captured detailed ROI information on 143 European HPC projects. For projects that generated financial returns, each euro invested in HPC on average returned €867 in increased revenue/income and €69 in profits.

3.10. HPC Stakeholders Assess Progress in Europe

As an important reality check, IDC augmented our heavily quantitative research with a broad opinion survey aimed at European HPC stakeholders. IDC emailed a brief questionnaire (Appendix A2) to a pre-qualified list of 832 stakeholders in the European HPC community (Appendix A3). The list of individuals invited to participate included government officials, managers of HPC centers of all sizes, scientists representing many disciplines and European countries, executives and product designers in industrial firms of many sizes, leaders and ordinary workers in HPC vendor/supplier companies, and other categories. The questionnaire also invited respondents to provide comments under guarantee of anonymity, and most of them did.

In addition, IDC conducted in-depth telephone interviews with more than 20 of Europe's leading HPC experts, along with interviewing a handful of non-European HPC experts who could help put European developments into perspective (Appendix A1).

All of the questions asked about European HPC progress during the past 2-3 years.

3.10.1. Europe’s Overall HPC Capabilities

As Table BS1 indicates:

- **Three-quarters (75.7%)** of the respondents believe that Europe's overall HPC capabilities have gotten "somewhat stronger" (56.8%) or "much stronger" (18.9%) in the past 2-3 years.
- One-quarter (24.3%) think overall capabilities have "stayed about the same."
- No one thinks that the overall capabilities have gotten weaker during this period.

<table>
<thead>
<tr>
<th>Europe’s Overall HPC Capabilities (Past 2-3 Years)</th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Much Stronger</td>
<td>18.9%</td>
</tr>
<tr>
<td>Somewhat Stronger</td>
<td>56.8%</td>
</tr>
</tbody>
</table>
Table BS1

Europe’s Overall HPC Capabilities (Past 2-3 Years)

<table>
<thead>
<tr>
<th></th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stayed about the Same</td>
<td>24.3%</td>
</tr>
<tr>
<td>Somewhat Weaker</td>
<td>0.0%</td>
</tr>
<tr>
<td>Much Weaker</td>
<td>0.0%</td>
</tr>
<tr>
<td>Not Sure/Don’t Know</td>
<td>0.0%</td>
</tr>
<tr>
<td>Totals</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.10.2. Access by Scientists to Supercomputers at PRACE Centers

- A majority of respondents (59.4%) believe it has become "somewhat easier" (48.6%) or "much easier" (10.8%) for scientists to access HPC resources at PRACE centers in the past 2-3 years (Table BS2).
- About one in five respondents (21.6%) say access by scientists has "stayed about the same."
- No one (0.0%) thinks that access by scientists has gotten harder.

Table BS2

Access by Scientists to Supercomputers at PRACE Centers (Past 2-3 Years)

<table>
<thead>
<tr>
<th></th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Much Easier</td>
<td>10.8%</td>
</tr>
<tr>
<td>Somewhat Easier</td>
<td>48.6%</td>
</tr>
<tr>
<td>Stayed about the Same</td>
<td>21.6%</td>
</tr>
<tr>
<td>Somewhat Harder</td>
<td>0.0%</td>
</tr>
<tr>
<td>Much Harder</td>
<td>0.0%</td>
</tr>
<tr>
<td>Not Sure/Don’t Know</td>
<td>18.9%</td>
</tr>
<tr>
<td>Totals</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: IDC 2015

3.10.3. Access by Industry to Supercomputers at PRACE Centers

- Respondents (Table BS3) were about evenly divided on whether access to PRACE centers by industry has gotten easier (31.4%) or "stayed about the same" (32.4%) in the past 2-3 years. 32.4% said that it has gotten easier.
Only one in 12 respondents (8.1%) believes industrial access to PRACE centers has become harder in the past 2-3 years.

**Table BS3**

<table>
<thead>
<tr>
<th>Access by Industry to Supercomputers at PRACE Centers (Past 2-3 Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of respondents</td>
</tr>
<tr>
<td>Much Easier</td>
</tr>
<tr>
<td>Somewhat Easier</td>
</tr>
<tr>
<td>Stayed about the Same</td>
</tr>
<tr>
<td>Somewhat Harder</td>
</tr>
<tr>
<td>Much Harder</td>
</tr>
<tr>
<td>Not Sure/Don't Know</td>
</tr>
<tr>
<td>Totals</td>
</tr>
</tbody>
</table>

Source: IDC 2015

### 3.10.4. Europe's Ability to Develop HPC Software

In prior IDC studies of HPC in Europe and in other components of the field research performed for this study, a substantial majority of European respondents consistently stated that developing software is a demonstrated strength of Europe's HPC community. We asked respondents to this broad survey to comment on what has happened with HPC software development in Europe during the past 2-3 years (see Table BS4).

- **A majority (54.0%) believe Europe's ability to develop HPC software has become "somewhat stronger (45.9%) or "much stronger" (8.1%).**
- One in three respondents (35.1%) think that this ability has "Stayed about the same."
- Only one in 12 respondents (8.1%) believe that Europe has gotten "somewhat weaker" in developing HPC software.

**Table BS4**

<table>
<thead>
<tr>
<th>Europe's Ability to Develop HPC Software (Past 2-3 Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of respondents</td>
</tr>
<tr>
<td>Much Stronger</td>
</tr>
<tr>
<td>Somewhat Stronger</td>
</tr>
<tr>
<td>Stayed about the Same</td>
</tr>
<tr>
<td>Somewhat Weaker</td>
</tr>
<tr>
<td>Much Weaker</td>
</tr>
</tbody>
</table>
### Table BS4

Europe's Ability to Develop HPC Software (Past 2-3 Years)

<table>
<thead>
<tr>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Sure/Don't Know</td>
</tr>
<tr>
<td>Totals</td>
</tr>
</tbody>
</table>

Source: IDC 2015

#### 3.10.5. Europe's Ability to Develop HPC Hardware

The verdict on progress in hardware development is mixed, but more negative than positive (Table BS5).

- **One-quarter of the respondents** (24.3%) think that Europe's ability to develop HPC hardware has gotten "somewhat stronger" (21.6%) or "much stronger" (2.7%).
- More than one-quarter of the group (29.7%) say it has "stayed about the same."
- **The largest contingent (43.2%) believes that Europe has become "much weaker"** (35.1%) or "somewhat weaker" (8.1%) in developing HPC hardware in the past 2-3 years.

### Table BS5

Europe's Ability to Develop HPC Hardware (Past 2-3 Years)

<table>
<thead>
<tr>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Much Stronger</td>
</tr>
<tr>
<td>Somewhat Stronger</td>
</tr>
<tr>
<td>Stayed about the Same</td>
</tr>
<tr>
<td>Somewhat Weaker</td>
</tr>
<tr>
<td>Much Weaker</td>
</tr>
<tr>
<td>Not Sure/Don't Know</td>
</tr>
<tr>
<td>Totals</td>
</tr>
</tbody>
</table>

Source: IDC 2015

#### 3.10.6. Europe's Position in the Worldwide HPC Market

- The largest group of respondents (40.5%) say that Europe's position in the worldwide HPC market—that is, Europe's standing in relation to non-
European nations and regions—has become "somewhat stronger" in the past 2-3 years (Table BS6).

- One in three (32.4%) thinks that Europe's position has "stayed about the same."
- One in four (24.3%) thinks that Europe has gotten "somewhat weaker" during this period.

### Table BS6

<table>
<thead>
<tr>
<th>Percentage</th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Much Stronger</td>
<td>0.0%</td>
</tr>
<tr>
<td>Somewhat Stronger</td>
<td>40.5%</td>
</tr>
<tr>
<td>Stayed about the Same</td>
<td>32.4%</td>
</tr>
<tr>
<td>Somewhat Weaker</td>
<td>24.3%</td>
</tr>
<tr>
<td>Much Weaker</td>
<td>0.0%</td>
</tr>
<tr>
<td>Not Sure/Don't Know</td>
<td>2.7%</td>
</tr>
<tr>
<td>Totals</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: IDC 2015

#### 3.10.7. Europe’s HPC Cloud Environment

IDC tracks and measures three major type of HPC clouds:

1. Public clouds: The running of technical applications on cloud resources owned by other organizations.
2. Private clouds. The running of technical applications on compute resources owed by the organization, using advanced interfaces that make it easier to use, and makes the actual compute resources invisible to the user.
3. Custom vertical clouds. These are clouds created to support a specific industry or application areas. Typically these make use of HPC optimized hardware and software, often running a very specific set of highly optimized applications.

IDC found that worldwide, the number of sites using cloud computing for some HPC workloads rose from 13.8% in 2011 to 23.5% in 2013. In general, public and private clouds were equally represented, and hybrid clouds are quickly gaining ground in HPC. Ultimately IDC believes that HPC cloud use could double in 2015 from a modest base, especially as advances in virtualization capabilities becoming more efficient and HPC-friendly.

IDC research indicates that currently, HPC usage within public clouds are still best suited for highly parallelized workloads, and accordingly, such workload use is seeing some of the fastest growth rates within the cloud especially from new or first time commercial HPC users. However, there will be a growing emphasis within the cloud service sector to target the HPC user base looking to solve more traditional modeling and simulations problems that are not as easily parallelized, and. as a result,
IDC expects to see even more cloud centers offering dedicated HPC hardware. Currently, the particulars for pricing models for these new HPC-centric cloud systems are in flux.

- The main cloud use scenarios for at least the next few years include jobs that can be easily split across processors, surge workloads, R&D projects, and SMB-based efforts that lack on-premise HPC systems.

Although the EU has an overall plan for general-purpose cloud computing, for example, as outlined in a recent Communication entitled *Unleashing the Potential of Cloud Computing in Europe*, the vision to bring HPC into the cloud is less clear. Regardless, IDC believes that moving forwards, EU HPC leadership should embrace cloud-based HPC as an integral element in any HPC-related program, both for so-called capacity computing and for capability computing (as public clouds evolve sufficiently to support more capability computing). Cloud computing, by its very nature, offers the ability for EU HPC leadership to acquire and provision flexible, on-demand HPC cycles to a wide range of potential scientific users from government, industry, and academia in a relatively low cost environment. Such capabilities will be especially important for potential new users that are not wholly committed to or technically capable of justifying an in-house HPC capability.

One significant recent development in Europe’s HPC in the cloud status is the recent acquisition of Bull, the EU’s leading HPC vendor by Atos, a French IT service company and one of the leading IT and cloud service providers in Europe. Indeed, Atos’ stated goal of the acquisition was to take advantage of Bull’s know-how in sectors such as cloud operations, security, and big data. Ultimately, the combined company will not just be a managed services and outsourcing giant, but it will leverage the deep infrastructure and system software skills of Bull to create a unified stack from the hardware out to application software to help companies design products and process massive amounts of data. Because of the additional revenue added though the Bull acquisition, Atos is now second only to Amazon in the European cloud operation market, surpassing Microsoft and IBM.
4. STATUS OF THE EUROPEAN HPC STRATEGY

This section evaluates progress in relation to the European HPC strategy, as outlined in the Action Plan within the Commission's 2012 communication. It is structured to provide both the IDC assessment for each area, and summary of the recommended areas that need improvement.

4.1. Overall Progress on the Four EU HPC Action Plan Objectives

<table>
<thead>
<tr>
<th>Action Plan Objectives</th>
<th>Strategy Actions</th>
<th>IDC Overall Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provide a world-class European HPC infrastructure</td>
<td>Governance at the EU Level</td>
<td>Great progress in installing and running very large systems, funded mainly by nations</td>
</tr>
<tr>
<td>2. Ensure independent access to HPC technologies, systems and services</td>
<td>Financial Envelope</td>
<td>Good progress in providing broad, independent access</td>
</tr>
<tr>
<td>3. Establish a pan-European HPC governance scheme</td>
<td>Funding Mechanisms</td>
<td>Industry and SME support has improved, but more is needed</td>
</tr>
<tr>
<td>4. Ensure the EU's position as a global actor</td>
<td>European Supply Capabilities</td>
<td>Governance is better</td>
</tr>
<tr>
<td></td>
<td>Industrial Use Of HPC</td>
<td>Greatly raised the awareness of the importance of HPC</td>
</tr>
<tr>
<td></td>
<td>A Level Playing Field</td>
<td>Great progress made in investing in two primary research areas (brain and graphene)</td>
</tr>
</tbody>
</table>

Assessment of Specific Action Plan Objectives:

1.) Provide a world-class European HPC infrastructure, benefitting a broad range of academic and industry users, and especially SMEs, including a workforce well trained in HPC.

- Strong progress has been made in purchasing, installing and putting into use large HPC systems across Europe. These were primarily funded by the Member States. Current rules of participation specify that the European Commission may contribute no more than 20% of funding, and only for initiatives in which at least three Member States participate. The European Commission supported PRACE (for activities such as the peer review system, training, seminars, and some prototyping procurements including a PCP). The Member States funded tier-0, tier-1 and tier-2 systems at a much greater level than expected.
  - Strong investment progress was made in two primary research areas that rely substantially on HPC, the Human Brain and graphene FET flagships.

---

2.) Ensure independent access to HPC technologies, systems and services for the EU

- Hardware technologies from Europe-based suppliers today have a very small share and presence in HPC across Europe. Some European software companies are highly successful in Europe and across the world, but their number is small.
- Good progress was made in providing Europe-wide access to HPC resources and services for scientists via PRACE and its single peer-review system. Access for industry has advanced, but more needs to be done.
- ETP4HPC has wisely defined "European supplier" as any supplier that performs R&D in Europe, no matter where in the world the supplier is based. This will allow European scientists and engineers, as well as Europe-based suppliers, to benefit from R&D collaborations that also involve suppliers not based in Europe. A large majority of the European HPC stakeholders IDC interviewed agreed that European scientists and engineers require access to best-in-class HPC technologies and systems, no matter where in the world they come from.
- Because ETP4HPC members are vendors and not buyers/users, ETP4HPC roadmaps reflect buyers' requirements only indirectly (mainly as represented by vendors) and could be more closely tied to buyers' requirements.

3.) 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

- The European Commission has done an admirable job of advancing the HPC strategy by coordinating with the efforts of multiple initiatives and parties, including the Member States through PRACE, European suppliers through ETP4HPC, and others.
- Pre-commercial procurement (PCP) and public procurement of innovative solutions (PPI) are underutilized in Europe's HPC market today. In contrast, PCP and PPI are key mechanisms used by the governments of the United States, China and Japan (Europe's main rivals for HPC leadership) to drive commercial competitive advantage and to advance suppliers of indigenous technologies. European HPC stakeholders strongly prefer PCI and similar mechanisms over PCP.
- ETP4HPC does not conduct HPC procurements. The Commission has contributed limited co-funding for HPC procurements within PRACE. Member States within PRACE conduct HPC procurements, but few of these have used PPI or related mechanisms. Hence, today there is no central procurement entity in Europe with the financial ability and motivation to exploit PPI or related mechanisms on behalf of Europe, as needed to compete successfully with the U.S., China and Japan.

4.) Ensure the EU's position as a global actor

- IDC said in our 2010 report to the Commission and still believes that advances in highly parallel software will be one of the most important determinants of future global HPC leadership.
- Europe has world-class strengths in highly parallel software. The de-emphasizing of funding for exascale software development by the U.S. government has created an opportunity for Europe to gain an important advantage. EESI's exceptional work has set the stage for this. The cPPP on HPC,
with the EC in partnership with ETP4HPC and €700 million in EC funding, provides a framework for making it happen, especially through the centers of excellence and continued EESI work.

- IDC believes that no single Member State will have the financial resources needed to acquire an exascale supercomputer in the same time frame as the U.S. or China. A pooling of resources will be needed, but to IDC's knowledge there is no plan among the Member States to accomplish this; and, as stated before, the current rules of participation governing the Commission limit its contributions to 20% of initiatives engaged in with Member States. Hence, there is no clear path for acquiring exascale capabilities in a globally competitive time frame.

Assessment of the progress and success of the six Strategy Actions:

Based on the overarching objectives defined in the European HPC plan, specific policy-related strategy actions were created. For those six strategy actions, IDC offers the following further assessment and recommendations. N. B. For the sake of clarity, the content of this section will necessarily repeat some of the content of the preceding section.

1.) Governance at EU level: seeks adequacy, openness, and efficiency of the current organisations (e.g., PRACE and ETP4HPC) to structure the industrial and scientific stakeholders, to steer the high level objectives and policies on HPC, to pool available HPC resources across the Member States, and to efficiently implement the HPC strategy.

- The key organizations contributing to the implementation of the European HPC strategy—the European Commission, PRACE and EPT4HPC—have done an admirable job of advancing Europe's position in the few short years since the 2012 Communication. No single European Member State has the financial and related means to compete effectively with the U.S., China and Japan for HPC leadership. If Europe is to be an HPC leader, it will therefore be necessary for Member States to coordinate their HPC strategies more closely, including the pooling of funding, and for the EC and the Member States to coordinate even more closely. This tighter coordination will require some adjustments to existing governance rules and practices by all parties. Tensions already present within Europe's loosely coupled, collaborative HPC governance model will likely grow as the exascale computing era approaches, unless these issues are addressed. Governments of some Member States hosting PRACE tier-0 supercomputers are reluctant to continue funding 100% of the substantial, rising operating expenses associated with these computers. They would like some relief from the Commission and/or from other PRACE members. Access to more of the tier-0 supercomputers' cycles may need to be secured for European, as opposed to national, use.

2.) Financial envelope for HPC spans current investment levels for the acquisition of high-end HPC resources in Europe, and analysis of required levels to meet the Action Plan objectives (including investments for system acquisition, training, HPC software and applications, etc.).

- The growth in purchases of HPC computers over the last five years has been very good and is critical for advancing science and supporting industry. The European Commission's HPC investment levels have grown substantially, through a range of initiatives including the €700 million, multi-year investment to support the future-oriented cPPP on HPC with the EC in partnership with ETP4HPC. This increase is especially laudable because it occurred during a difficult economic period for Europe. As noted earlier, the Member States are
the only parties that conduct HPC procurements and have provided most of the financing for tier-0 systems (as well as tier-1 and tier-2 systems) that have moved Europe forward. The Commission has contributed to support PRACE, and plans to start helping to support some procurements for large supercomputers in 2016. A minority of tier-0 supercomputer cycles at Member State sites (typically 10-15%) are available for Europe-wide access.

• Because software will be the one of the main determinants of future HPC leadership, and a significant portion (25%) of cPPP financing is being targeted at software development. Collaboration with the academic community is increasing and is the main avenue for expanding education and training to the levels needed for European HPC leadership. More is needed in this area.

3.) The implementation of funding mechanisms, such as pre-commercial procurement in the public sector (the major buyer of high-end HPC) and pooling of research resources, to support HPC suppliers for developing a leadership-class HPC system about every 2 years.

• As noted earlier, PPI and related mechanisms are crucial for attaining and maintaining HPC leadership. Europe's rivals for HPC leadership—the U.S., China and Japan—regularly employ these mechanisms. These mechanisms are used today only occasionally in Europe. Positive examples include the supercomputer acquisitions that leverage R&D collaborations between CEA and Bull (Atos), the SuperMUC system at the Leibniz Rechenzentrum (LRZ), the "Hornet" supercomputer acquisition by HLRS, and the Human Brain Project sponsored by the European Commission.

• No clear strategy exists for pooling resources to finance the acquisition of pre-exascale supercomputers in 2020 and exascale supercomputers in 2022, in order to Europe to remain competitive with the U.S., China and Japan. No Member State is likely to be able to do this alone or with only minor additional funding from the Commission, and there is no indication that multiple Member States plan to pool resources to procure exascale systems.

4.) Development of European state-of-the-art supply capabilities needed for European independent access to key HPC technologies, systems, services and tools for Europe (including level of pre-commercial procurement and other R&D investments, support to European HPC suppliers, jobs in European HPC supply industry, etc.).

• ETP4HPC is an organization comprised of European suppliers and dedicated to advancing European HPC technologies and Europe's HPC supply chain. The European Commission is contributing €700 million on the cPPP on HPC in partnership with the ETP4HPC's. ETP4HPC has wisely defined "European supplier" as any supplier that performs R&D in Europe, no matter where in the world the supplier is headquartered. This definition allows European scientists and engineers, as well as Europe-based suppliers, to benefit from R&D collaborations that may also involve suppliers not based in Europe. A large majority of the European HPC stakeholders IDC interviewed agreed that European scientists and engineers require access to best-in-class HPC technologies and systems, no matter where in the world they come from. ETP4HPC's Commission-supported strategy is well conceived to support the goals of European scientific and engineering leadership.

• It is especially important that European suppliers (again using ETP4HPC's definition) not only participate in exascale technology innovation, but also gain experience and feedback in real-world HPC customer environments. For this
reason, ETP4HPC roadmaps for indigenous technology development need to be linked as closely as possible to the requirements that will drive supercomputer procurements.

- Just as there is no clear path today for financing European exascale supercomputer procurements in competitive timeframes, there is also no clear opportunity for ETP4HPC-developed technologies and designs to be supported in these procurements.

5.) **Industrial exploitation of HPC** including regional/national centers for the access of industry (including SMEs) to HPC (HPC Competence Centers), industrial HPC-based development and innovation, education and training in HPC, HPC trained workforce in Europe, and more.

- Europe already has some of the world's leading HPC centers for collaborations with industry, including SMEs. These include HLRS (Stuttgart), Teratec (Paris), SURFsara (Amsterdam), CINECA (Bologna), and LRZ (Munich), to name a few. Europe, like the rest of the world, also has many HPC centers that have recently added industrial outreach programs and are struggling with how to work with industry. Centers with strong industrial experience are well positioned to mentor less-experienced centers, and to assume leadership roles in any future HPC competence centers.

- Many of the European HPC stakeholders IDC interviewed for this study agreed that European programs supporting industrial access and collaboration, such as PRACE, SHAPE and Fortissimo, have been successful but need to do more. Only a small percentage of European SMEs that could be helped by HPC seem aware of these opportunities, for example. In addition, existing programs tend to award access on the same basis that is used for science—peer-review to determine the scientific merit of projects. Europe's economy would be better served if SMEs could also gain limited, initial access (“try it out”) to HPC resources, including expertise, based on the value HPC could bring to their businesses, even without the prospect of advancing the known science or engineering.

6.) **Ensuring a level-playing field**, in particular regarding inequalities in HPC market access and exploitation obligations regarding intellectual property rights of HPC results generated in Horizon 2020.

- Europe has long been the world’s most open HPC market. Government HPC markets in the U.S., Japan and China all present barriers to non-domestic HPC suppliers, although the private-sector markets in these countries are more open and both government and private-sector markets are generally open to non-domestic commercial software. A large majority of European HPC stakeholders IDC interviewed for this study agreed that European scientists and engineers should continue to have access to the world’s best supercomputer systems, no matter where in the world they come from. Specific market asymmetries should be addressed at a government (EC)-to-government level and not made part of Europe's HPC strategy.

- At the same time, it is important to support the development of European HPC technologies and suppliers. ETP4HPC, with substantial Commission funding support, is pursuing this strategy. ETP4HPC’s goal is to accelerate pre-commercial innovation by European suppliers. ETP4HPC does not conduct procurements or become involved at the acquisition stage. IDC believes that European suppliers will not be globally competitive if they are given preference in commercial-stage procurements. Pre-commercial procurements present important opportunities, however, for HPC public- and private-sector buyers to support the development of European technologies and their suppliers. Europe needs to make more use of PPI and related mechanisms for this reason.
4.2. Progress in Implementation

This section provides a more detailed assessment of progress in implementing the European HPC strategy, for readers who desire a deeper discussion.

4.2.1. Europe Has Made Impressive Progress in HPC

As noted earlier, Europe has significantly narrowed the former wide gap separating the most capable U.S. and Japanese supercomputers from their European counterparts. In November 2010, shortly after the founding of PRACE, 9 of the world’s 50 most powerful supercomputers were located in Europe (www.top500.org). Four years later, in November 2014, Europe hosted 19 of the top 50, including the PRACE tier-0 supercomputers. The aggregate peak performance of the Europe-based supercomputers rose more than ten-fold during this period, from 4.3 petaflops in November 2010 to 48.9 petaflops four years later. Clearly, Europe’s standing as a provider of high-end supercomputing resources advanced in both absolute and relative (worldwide) terms during this period.

High-end supercomputers at national centers in Europe and the U.S. are regularly oversubscribed—the demand for computing cycles typically exceeds the supply by a factor of two to three. European high-end supercomputers are no exception. It is therefore safe to assume that the 10-fold increase in capacity among Europe's largest supercomputers is almost fully utilized today (this is confirmed by utilization data reported by the centers hosting these supercomputers). Hence, the use of Europe’s most powerful supercomputers has greatly increased in volume since 2010. IDC survey results for this study confirm that the use of PRACE supercomputers has also been substantially democratized through the single peer-review process that makes access available on an equitable basis to scientists from throughout Europe. PRACE initiatives to provide European industry with access are newer and are showing initial success, but there is a need for greater outreach to industry.

4.2.2. European HPC Investments Are Producing Outstanding ROI

European HPC investments are already producing excellent returns-on-investment (ROI) for science and industry. IDC used the capture-and-measurement tools developed during our successful 2013 HPC ROI (return-on-investments) pilot study for the U.S. Department of Energy (DOE) to help assess the impact of recent HPC investments in scientific and industrial projects carried out within Europe. In all, IDC captured detailed ROI information on 143 European HPC projects, of which 84 produced innovations and 59 produced quantifiable financial returns. In most cases, the investments consisted mainly of HPC systems and software acquired for the project, but payments for time on installed HPC systems also contributed to investments in some cases. A project, as defined for this study, is a short-term initiative that has definite starting and ending points. The study evaluated information only from completed projects.

- Each euro invested in HPC on average returned €867 in increased revenue/income.

---

• Academic projects averaged €30 in cost savings per €1 invested in HPC, and industrial projects averaged €75 in bottom-line profits or costs savings per €1 of HPC investment.

• Total increased revenue for the 59 HPC-enabled, quantifiable projects was €133.1 billion, or about €230 million per project on average. Average increased profits/cost savings for the projects amounted to €69 billion.

These results for Europe are in line with IDC results obtained for the U.S. in the 2013 DOE pilot study. They indicate that ROI gains (multiples) related to HPC investments are exceptionally strong. Prior studies by IDC and others confirmed that HPC is a strategic, transformational technology that can accelerate scientific progress, industrial innovation, and economic competitiveness. The ROI findings help to quantify the financial and other gains associated with HPC-enabled projects. (Fuller results of the European ROI field research appear in Section 4.4 of this report.)

4.2.3. Europe Needs Major Financing for HPC Leadership in 2020-2022

The 2012 EC Communication on HPC recommended that “the Union, Member States and Industry should increase their investments in HPC to some EUR 1.2 billion per year.” All European spending on HPC server systems (not just public sector spending) will expand at a compound annual growth rate (CAGR) of about 6.9%, compared with 6.0% in the U.S. Despite this apparent European advantage, in 2018 IDC predicts that in absolute terms the U.S. (€4.3 billion) will still handily outspend Europe (€2.7 billion) on HPC servers. (For more details, see Table 1 in this report.) The public sector/government portion of European HPC spending has grown nicely. Europe as a whole was able to step up to very healthy public sector funding growth in 2010, 2011 and 2012 – well above the 2010 IDC recommended levels, but then Europe-wide funding declined heavily in 2013 and 2014. European sector/government investments in HPC have grown during the past five years but significant increases will be needed to attain and maintain leadership for Europe, meaning at minimum parity with best-in-class HPC resources in the U.S., Japan, and China. Significant investments will especially be needed for two pre-exascale systems in the period 2019-2020 and two exascale systems in 2022 (see Financial Envelope section of this report).

IDC Recommendation: European sector/government investments in HPC have grown during the past five years but significant increases will be needed to attain and maintain leadership for Europe, meaning at minimum parity with best-in-class HPC resources in the U.S., Japan, and China. Significant investments will especially be needed for two pre-exascale systems in the period 2019-2020 and two exascale systems in 2022 (see Financial Envelope section of this report for details).

4.3. Governance

Because the EU is an alliance of nations, rather than a single nation, organizing and governing the European HPC strategy is inherently more challenging than developing and organizing an HPC strategy in the U.S., Japan or China—Europe’s main contenders for HPC leadership. In the face of this challenge, Europe has developed a collaborative governance model for its HPC strategy. Rather than investing final authority in one
organization, the European model spreads authority for governing key elements of the HPC strategy among multiple collaborating organizations—a loose confederation consisting primarily of the European Commission, PRACE and ETP4HPC. Their factual division-of-labor is as follows:

- The European Commission has substantial influence in shaping and coordinating the implementation of Europe's HPC strategy, through active collaboration with the other main actors. Although responsible Commission officials have performed this task admirably, their work is made considerably more difficult because Europe is a collection of autonomous nations, rather than a single nation such as the U.S., China and Japan.

- PRACE, currently representing 25 Member State governments, has primary responsibility for making investments in leadership supercomputers and for providing European scientists and engineers with equitable access to these supercomputers and related HPC resources, especially HPC expertise. Individual Member States have primarily responsibility for funding and procuring the tier-0 supercomputers. The European Commission contributes a minority portion of the funding, to date mainly for training, seminars, and the like, in return for a minority portion of computing cycles (typically 10-15%) that are made available for EU-wide access.

- ETP4HPC has assumed primary responsibility for HPC technology development and the goal of expanding and strengthening Europe's HPC supply chain. ETP4HPC is an alliance of suppliers and collaboratively develops roadmaps for technologies and system designs. ETP4HPC does not conduct procurements. Under a contractual public-private partnership agreement signed in 2013, the European Commission committed to providing €700 million (€142 million in 2014-2015) and ETP4HPC will aim to elicit matching funds from the private sector.

On the positive side, this collaborative governance model has narrowed the former large gap between leading supercomputers within and outside of Europe. The existing model also deserves credit for the largely positive opinions the European HPC stakeholders we surveyed expressed concerning progress in implementing the European HPC strategy. (It is more difficult to move a strategy forward if stakeholders do not believe it is moving forward.) Last but not least, out of the current governance model has come arguably the world's best strategy for exascale and other highly parallel software—IDC believes that software advances will be one of the main determinants of future HPC leadership.

4.3.1. The European Commission

The European Commission serves as a needed central coordinator of the European HPC strategy. The Commission is also an important financial contributor to key elements of the strategy, especially through the cPPP agreement with ETP4HPC and minority funding of PRACE tier-0 supercomputers. Without the Commission's coordinating role, the three pillars of the European HPC strategy could not be effectively integrated to pursue the Action Plan's leadership goals.

The distributed-authority governance model creates healthy tension among the organizations involved in governance, but so far the model, with the Commission as chief coordinator, has made impressive progress against the Action Plan. In the view of IDC and most of the European HPC stakeholders we interviewed for this study, the European
Commission has done an admirable job of creating and shepherding the pan-European HPC strategy since 2012. In particular:

- The European HPC strategy, whose formation was led by the EC in collaboration with other parties, is widely accepted—although inevitably not all parties agree with every element of the strategy. Not surprisingly, national interests can still color perceptions.

- EC support for PRACE and ETP4HPC has helped those organizations and other EU-supported HPC initiatives to make important progress in their missions and on behalf of the European HPC strategy.

### 4.3.2. PRACE Governance

The PRACE governance structure, as described on the PRACE website, is as follows:

- The **Council** is the deliberative body of the Association and decides on all matters of the Association. It is composed of one representative from each Member. Depending on the nature of the decisions to be taken, different voting rules apply. As a general rule, decisions of a purely scientific nature are subject to majority vote, while decisions related to provisioning and usage of funding and resources require a qualified majority based on partner contributions. All other decisions require a double majority of members and contributions, apart from a small number of issues that imply changes of the contract of the Association which require unanimity. The working rules of the Board of Directors (BoD) can be found here.

- The **Board of the Council** is elected by the Council from among the delegates representing the Members. It consists of a Chairman, a Vice-Chairman and a Secretary. The current members of the Board of the Council are: Sanzio Bassini (Chair), Anwar Osseyran (Vice-Chair) and Sergio Bernardi (Secretary).

- The **Scientific Steering Committee (SSC)** is composed of European leading researchers that are responsible for advice and guidance on all matters of a scientific and technical nature which may influence the scientific work carried out by the use of the Association’s resources. The SSC has an odd number of members up to a maximum of twenty one, of which one is appointed Chairman. The members of the Scientific Steering Committee are appointed by the PRACE Council. SSC Members serve a two year term renewable twice consecutively. The working rules of the SSC can be found here. The current members of the SSC are:

- The **Access Committee (AC)** gives advice to the Board of Directors concerning the allocation of resources of the RI. The AC, proposed by the SSC, is composed of researchers experienced in areas of science, engineering and supercomputing. The AC is appointed by the Council and shall comprise an odd number of members with a minimum of five, from among which a Chairman and a Vice-Chairman is appointed. AC members serve a two year term renewable once. The working rules of the AC can be found here. The current members of the AC are: Frederic Bournaud, Peter A. Boyle, Javier Jimenez,

---

25 [http://www.prace-ri.eu/organisation/](http://www.prace-ri.eu/organisation/)
Peter Nielaba, Ursula Roethlisberger, Sophie Valcke, and Claudio Zannoni (Chair).

- The **Industrial Advisory Committee (IAC)** is composed of European industry representatives (both from multi-nationals and SMEs) representing 11 industrial sectors: Aeronautics/Aerospace, Automotive/Transport, Energy, Engineering/Manufacturing, Oil & Gas, Renewable Energy, Telecommunications/Electronics, ISV, HPC Vendors, Life Sciences, and Finances. They provide PRACE with advice on HPC usage for the benefit of European competitiveness and economic growth. The IAC reserves an observer seat for the Chair of ETP4HPC. A Chair and Vice-Chair are chosen by the committee, who, like all members, are appointed for 2 years renewable once.

- The **Board of Directors (BoD)** is the executive body of the Association and is generally responsible for managing and representing the Association. The BoD is composed of a minimum of two members elected by the Council. Each Director will serve for an initial term of three years, renewable for subsequent periods of two years. The current members of the BoD are: Sergi Girona (chair), Sergio Bernardi, Thomas Eickermann, Sylvie Joussaume, Alison Kennedy, and Stephane Requena.

The PRACE RI has two forms of members:

- **Members** – a government organization or legal entity representing a government. The PRACE RI accepts only one member per Member State of the European Union or of an associated country as described in article 217 of the European Union Treaty. Further, to be eligible as a PRACE RI member the legal entity must be responsible for the provisioning of HPC resources and associated services.

- **Hosting Members** are members who have committed to fund and deliver PRACE RI computing and data management resources at a level of at least 100 M€ over a period of five years. There are 4 Hosting Members: France, Germany, Italy and Spain.

PRACE governance has worked reasonably well. In particular:

- The tiered classification scheme for European HPC systems at PRACE host centers (tier-0 supercomputers), HPC systems at national centers (tier-1), and HPC systems serving areas/communities within Member States (tier-2) has been a surprisingly powerful force for organizing Europe's HPC community.

- The single peer-review system has enabled fair access to PRACE's leading supercomputer by scientists, and more recently industrial engineers, from throughout Europe.

PRACE's ability to support the ambitious goal of European HPC leadership, including pooling/sharing resources and funding and obtaining the best systems and services, depends heavily on PRACE's ability to secure adequate funding for these things. PRACE is a voluntary alliance of 25 Member States with substantially different economies and political perspectives. In the first iteration of the alliance, PRACE 1.0, only four of the nations stepped up to role of acting as hosting members, which required a €100 million financing commitment from each. Even nations with some of Europe's largest economies
were unable to make this political and financial commitment. That left the four hosting members with the responsibility of contributing the lion’s share of the PRACE budget, including large operating expenses, while scientists from non-contributing Member States were able to access the hosted supercomputers. The PRACE 2.0 financing scheme was still under discussion at the time of this writing, but it may require every PRACE member to contribute some amount based on a formula. This would ease the financial burden on the largest states but risks curtailing access for scientists and engineers from Member States that are unable or unwilling to make their assigned contributions.

4.3.3. ETP4HPC Governance

ETP4HPC is a Commission-recognized European technology platform (ETP) that is led by European technology providers—defined as organizations having at least some R&D based in Europe. This definition has enabled organizations with headquarters outside of Europe—such as Intel, IBM, Lenovo, Cray, Micron, Nvidia, Fujitsu and Huawei—to participate in ETP4HPC. In December 2013, ETP4HPC signed an agreement with the Commission to form a contractual public-private partnership (cPPP) to build a European HPC technology value chain, that is, to support the three pillars of the Action Plan of the European HPC strategy.

ETP4HPC is organized as a Dutch association and is managed by a steering committee representing the following constituencies:

- Research centers
- European SMEs
- European-controlled corporations
- International companies with R&D operations in Europe

IDC believes it is crucially important for the European HPC strategy to make greater use of the PPI and related mechanisms to enable more procurements of innovative, pre-commercial HPC technologies and systems—a practice that is commonplace in the U.S., Japan and China, Europe’s main contenders for HPC leadership.

4.3.4. The Use of PCP/PPI

PCP (Pre-Commercial Procurement) and PPI (Public Procurement of Innovation) are primary mechanisms the governments of the United States, Japan, and China have used to promote innovation in leadership supercomputing, i.e., innovation that provides advantages over competing nations and global regions. Major national procurements that have incorporated these mechanisms include the Tianhe-1a supercomputer (China), the K supercomputer (Japan), and the CORAL procurements (United States). With notable exceptions, such as the EC-sponsored PCI for the Human Brain FET flagship project, these procurements have resulted in contracts between a national government and a domestic supercomputer maker. Hence, the contracts have been aimed at benefiting both the government buyers and the domestic HPC industry.

---

26 ETP4HPC Background and Future. PowerPoint presentation by Malcolm Muggeridge. 2014
• The assumed benefit to the supplier may not be realized, however, if the government buyer's pre-commercial requirements are so specific ("one-off") that they do not adequately address the needs of the commercial market.\footnote{Survey of the ASC Program's Effectiveness in Stimulating HPC Innovation. IDC special study for the U.S. Department of Energy/National Nuclear Security Administration. 2008.}

The chief reason why PPI and related mechanisms have been under-utilized in Europe in general (not restricted to HPC) is conveyed in a European Commission statement cited earlier in this report:

This lack of the European procurers proactively acquainting themselves with emerging innovations and steering industrial developments to meet future public sector needs (PCP) also slows down the adoption rate of innovative solutions in the public sector in Europe (PPI).\footnote{"Policy-Related Frequently Asked Questions on PCP and PPI." http://cordis.europa.eu/fp7/ict/pcp/docs/faq-v9.pdf}

As for HPC, key reasons for the underuse of PPI and related mechanisms are the newness of supercomputer procurements that include EU-wide goals and, more important still, the paucity of Europe-based supercomputer vendors and other suppliers. In France, which has a domestic supercomputer maker, CEA and Bull (now Atos) have long collaborated under contracts containing PPI-like clauses. Until recently (Italy's Eurotech), no other European nation had an indigenous HPC system supplier to partner with.

4.4. Financial Funding for HPC

This section reviews the funding requirements and recommendations for a successful HPC strategy.

Mirroring the structure of the European HPC ecosystem, Europe's HPC financial funding is a mix of local, regional, national, multinational and pan-European funding sources. Furthermore, Europe's HPC financial envelope includes both private-sector spending and public sector/government spending associated with initiatives at the European level and within the Member States.

4.4.1. Europe's Overall HPC Financial Funding and Purchase Levels

IDC's close quarterly and annual tracking of all EU/EU+ spending on HPC servers, software, storage and service produces a fairly complete accounting of Europe's HPC financial envelope. Missing from this perspective are most personnel costs and operating expenses, but the IDC figures provide an accurate picture of total spending on the HPC resources that are most important for the present study.

Overall EU/EU+ spending on HPC servers, software, storage and service is detailed in Tables 1 through 10 of this report. Overall spending (EU+) amounted to €3.7 billion in 2013 and IDC forecasts it will grow to €5.1 billion in 2018 (Table 8).

4.4.2. European Public Sector/Government Spending on HPC

HPC spending by public sector/government sources is an important component of Europe's overall HPC financial envelope. Although it is only a fraction of all European HPC spending, public sector/government spending is highly strategic because it is typically aimed at benefiting entire HPC communities at the national or European level.
Precise figures for public sector/government spending are not always practical to obtain, because some of these expenditures—as in PRACE—are in-kind contributions of computing cycles or services. The value of in-kind contributions is accounted for, however, in the following tables and charts.

4.4.3. European Commission Financing for HPC

The EC, representing the 28 EU Member States, has contributed funding that has been substantially lower than the plan to advance the European HPC ecosystem and has committed to increase its contribution substantially during the period ending in 2020. EU financing for the European HPC strategy supports the following three pillars (along with training, education and skills development):

- Advancing computer science for the exascale era. This is a special Future and Emerging Technologies (FET) initiative.
- Providing industry and academia with access to the best supercomputing facilities and services. This happens via the PRACE HPC e-infrastructure.
- Achieving excellence in HPC applications. This will happen through centers of excellence in key domains for Europe

The following slide provides more information about the three pillars:

An integrated HPC approach

- HPC strategy combining three elements:

  (a) Computer Science: towards exascale HPC; A special FET initiative focusing on the next generations of exascale computing as a key horizontal enabler for advanced modelling, simulation and big-data applications [HPC in Future and Emerging Technologies (FET)]

  (b) providing access to the best supercomputing facilities and services for both industry and academia; PRACE - world-class HPC infrastructure for the best research [HPC in e-infrastructures]

  (c) achieving excellence in HPC applications; Centres of Excellence for scientific/industrial HPC applications in (new) domains that are most important for Europe [HPC in e-infrastructures]

  - complemented with training, education and skills development in HPC

(a) and (c) will be implemented in the context of the HPC Public-Private Partnership

Spending to date based on EC financing includes the following in FP7

- As noted under the PRACE entry below, the EC contributed €67 million toward the PRACE 1.0 Preparatory and Implementation Phase Projects, complemented by the consortium budget of over €43 million.
- The EC provided €49 million in support of the HPC FET (Mont-Blanc, DEEP and CRESTA), along with EESI and EESI2, plus the exascale objective of the EU’s ICT Call 10.
Horizon 2020: The cPPP Initiative

In Horizon 2020, the EC has substantially elevated planned financing levels for HPC-related initiatives during the period ending in the year 2020. The largest EC contribution and greatest spending is slated to occur under the Contractual Public-Private Partnership (cPPP) initiative that will run from 2014 to 2020. Under this umbrella initiative, the EC has committed €700 million to pursue the goals of the three pillars in conjunction with the European Technology Platform for HPC (EPT4HPC). Hence, ETP4HPC will have a management role in this important initiative that will include many coordinated elements and calls. The cPPP initiative also aims to attract R&D investment matching funds from the HPC community, hence total spending in the initiative could substantially exceed the €700 million figure. Like the ETP4HPC itself, the cPPP initiative will include non-European collaborators.

- Under the FET WP2014-15, the EC committed €93.4 million to support the development of core technologies and an additional €4 million for ecosystem development. Additional 85 m€ are budgeted in the FET WP2016-2017.
- The EC also committed €40 million for Centers of Excellence and 2 m€ for a Network of HPC competence centers for SMEs under the e-infrastructure programme in 2014-2015.

Horizon 2020: support to PRACE

- The fourth implementation phase of PRACE received 15 m€ in 2015, and 15 m€ more are budgeted in the Work Programme 2016-2017.
- Innovation. The EC has also committed €26 million in 2016-2017 to support a public call for innovation (PPI) related to PRACE supercomputers.

Other key financing commitments include the following.

- The FET flagship Human Brain Project. The EC plans to contribute €25 million in 2016-2017 for the HPC component of the project.

4.4.4. PRACE Financing for HPC

As its website states, "PRACE is an international not-for-profit association. It has 25 member countries whose representative organizations create a pan-European supercomputing infrastructure, providing access to computing and data management resources and services for large-scale scientific and engineering applications at the highest performance level." The SHAPE initiative within PRACE is aimed at helping more SMEs transition to using HPC. The Fortissimo project, coordinated by the University of Edinburg, includes 45 partners and aims to offer a commercial HPC cloud infrastructure, through a 'one-stop shop' where companies will be able to obtain the tools they need to bring their industrial projects to reality (applications, expertise, resources, etc.), on a 'pay-per-use' basis. Fortissimo has a budget of €16 million over three years, starting 01 July 2013.

The first PRACE initiative (PRACE 1.0) extends from 2010 to mid-2015, at which point PRACE 2.0 is scheduled to begin. For the PRACE 1.0 period, the four hosting members—Spain (BCS), Germany (GCS), France (GENCI) and Italy (CINECA) each pledged to contribute €100 million, for a total pledge of €400 million. Some of the commitment involves not cash investment in acquiring supercomputers, but in-kind contributions, such as supercomputing cycles, operating expenses and personnel time. As of this writing, three of the four hosting members have been given extensions until early 2016 to complete the full amounts of their PRACE 1.0 commitments. IDC estimates that total contributions to date from the hosting members are in the range of €250 million to €300 million.
The PRACE project partners receive EC funding under the PRACE Preparatory and Implementation Phase Projects (PRACE-1IP, 2010-2012, RI-261557, PRACE-2IP, 2011-2013, RI-283493, PRACE-3IP, 2012-2014, RI-312763) for a total of €67 million, complemented by the consortium budget of over €43 million. The EC funds covered activities such as the peer-review process for access to PRACE supercomputers, training, prototyping, application tuning and a helpdesk. The EC funds did not apply to supercomputer procurements or operating costs. As noted above, the EC has also committed €26 million in 2016-2017 to support a public call for innovation related to PRACE supercomputers.

PRACE 2.0. The financing scheme for PRACE 2.0 has not been settled yet. Based on discussions with directly involved individuals, however, IDC expects the scheme to differ markedly from the one on which PRACE 1.0 was based. Instead of placing the heaviest burden of contributions, including operating expenses, on the tier-0 sites hosting the supercomputers while providing peer-reviewed access to these supercomputers by researchers from throughout Europe, all Member States wanting access to the supercomputers for their researchers might need to contribute some amount to PRACE financing. Contributions might be based on a formula that takes into account each country's GDP and historic HPC usage level, among other factors.

If this new financing scheme were adopted (uncertain as of this writing), it would ease the financial burdens on the hosting countries—a burden some of them say will become unsustainable for exascale supercomputers—but could reduce access for Member States that are unable, for whatever reason, to make their assigned financing contributions. Because the projects—indeed, the careers—of computational scientists and engineers often depend heavily on continued access to leading supercomputers, there is a risk that halting access could trigger a "brain drain" in which researchers from poorer nations in Europe relocate to wealthier nations in order to preserve the supercomputer access they need. Should this happen, it would reintroduce the digital divide that PRACE 1.0 did so much to erase. IDC realizes that there should be consequences for a Member State's failure to contribute and urges PRACE officials to continue their efforts to find a solution for this issue.

IDC Recommendation: It is too soon to predict the amount of financing the PRACE 2.0 initiative will be able to collect using this or whatever other scheme is adopted. Given the momentum established by PRACE 1.0 and the PRACE 2.0 financing scheme, IDC believes it is likely that PRACE 2.0 funding will exceed the level of PRACE 1.0. But the anticipated costs for acquiring and operating pre-exascale and exascale supercomputers will require substantially higher funding levels that aggregate contributions from the Member States and currently planned EU contributions together may not be able to attain. IDC believes the Commission and the Member States should both contribute to help close the financing gap.

4.4.5. ETP4HPC Contributions for HPC

As noted earlier, ETP4HPC is a Commission-recognized European technology platform (ETP) that is led by European technology providers—defined as organizations having at least some R&D based in Europe. This definition has enabled suppliers with headquarters outside of Europe to participate in ETP4HPC and to qualify as European suppliers. In

---

29 "PRACE Research Infrastructure." http://www.prace-ri.eu/prace-in-a-few-words/

30 Based on IDC interviews with PRACE 1.0 hosting centers for the present study.

31 ETP4HPC Background and Future. Powerpoint presentation by Malcolm Muggeridge. 2014
December 2013, ETP4HPC signed an agreement with the Commission to form a contractual public-private partnership (cPPP) to build a European HPC technology value chain, that is, to support the three pillars of the Action Plan of the European HPC strategy. Financing comes from two sources:  

- Commission funds of €700 million over the period 2014-2020  
- Matching funds from industry, i.e., ETP4HPC full and associate member organizations

The cPPP structure allows member organizations to collaborate in developing novel technologies within ETP4HPC, following its strategic research agenda (SRA), or roadmap. But ETP4HPC is not involved in acquisitions of technologies or HPC systems. IDC recommends elsewhere in this report that PRACE should exploit the PPI and related mechanisms to procure—and thereby further stimulate the development of—pre-commercial technologies and innovative HPC systems.

### 4.4.6. Financing of HPC Initiatives within the Member States

Another important component of the overall European HPC financial picture—one that in most cases predates the formation of the European Union—is public sector/government financing of HPC initiatives within European nations. Central governments of Member State typically fund 50% or more of the total annual budgets of their national supercomputing centers, including computer upgrades, infrastructure, operating costs, and personnel. Central governments typically see this funding as an important investment in their countries’ economic futures. In most cases, other government funding sources (e.g., state and city governments) contribute additional money to the budget. (For country-specific details, see Annex 5: How European Countries Fund Their National Supercomputing Center.)

In addition, until now the full operating costs of PRACE tier-0 supercomputers have been financed by government sources within PRACE hosting members. The Commission has not contributed to these rising costs. Based on discussions for this study, IDC believes that Member State governments will be increasingly reluctant to bear the full burden of these operating costs, especially as pre-exascale and exascale systems escalate these costs.

### 4.4.7. European HPC Actual vs. Planned Spending

As the preceding country profiles should indicate, accurate, detailed information on actual European HPC spending at the national level is available in some cases but not in others. This situation makes it impractical to produce an accurate spending total for all HPC expenditures by the Member States.

The 2012 EC Communication called for aggregate HPC financing by the EU, Member States and industry to double to €1.2 billion per year by 2020, with roughly half of the added money to be reserved for supercomputer procurements, a quarter for education and training, and the remaining quarter for software development.

The Communication hoped that perhaps 10% of the public sector hardware budget would be used to “develop and maintain native EU supply capabilities that cover the whole technology spectrum from processor architectures to applications.” Innovation-driven initiatives could be eligible for EU co-funding if they supported the EU-level mission. The total EC expenditure on HPC during the seven years of Horizon2020 was expected to be around €600 million (this figure does not include anticipated contributions from the Member States and industry).
The rationale for the European early procurement is nicely captured in the 2012 document arguing for the UK’s participating in PRACE (Europe's HPC community prefers PPI and related mechanisms over PCP in particular, but the following statement applies in spirit).

The overall PCP model has been created in order to tackle a difference between how Europe and the USA benefit from their basic research expenditure. Although the EU and US have similar levels of spend on basic and applied R&D (2% of GDP in Europe versus 2.5% of GDP in the USA), the USA has, over the past 30 years, followed a public procurement policy that encourages early procurement by the public sector of new innovative products prior to their commercial release. This has led to a great difference between public procurement of R&D results by Europe and the USA (EUR 2.5 billion in Europe versus EUR 50 billion in the USA annually). This twenty times difference is felt by the EC to be a major contributing factor in Europe’s inability to build large innovative companies, particularly in the IT sector.32

### 4.4.8. HPC Spending by Nations Competing with Europe for HPC Leadership

- **United States.** The U.S. government historically has been the world’s biggest public sector spender on HPC. The Obama Administration’s budget request for fiscal year 2016 (begins October 1, 2015), not yet approved by Congress, makes progress toward exascale computing a high priority for the DOE Office of Science and asks for exascale funding to jump from €93 million to €195 million. The request for the DOE ASCR program that includes DOE supercomputer acquisitions is for €581 million, up 14.8% from the fiscal year 2015 amount.33 Funding of €475 million has already been reserved for the acquisition of pre-exascale supercomputers for three DOE national labs: Oak Ridge, Lawrence Livermore and Argonne. In addition, the government has allocated €93 million for the development of innovative HPC technologies under the FastForward2 program. HPC spending by the Department of Defense’s HPC Modernization Program has averaged €37 million per annum historically but rose to €64 million for fiscal year 2015.34 Funding for the National Science Foundation’s Computer and Information Science and Engineering (CISE) division, all of which arguably involves HPC, totaled €835 million in fiscal year 2014, is expected to total €862 million in fiscal year 2015, and is requested to increase to €894 million for fiscal year 2016.35 Based on these figures, IDC estimates that U.S. government spending on HPC will exceed €1.5 billion in fiscal year 2015 and will be more than €1.7 billion in fiscal year 2016. (These figures do not count HPC spending by the U.S. intelligence community.)

- **Japan.** Japan has twice (2001, 2011) deployed the world’s most powerful supercomputer, each time following a concentrated financing and R&I effort. For the Fujitsu-built K computer at RIKEN that captured that crown in 2011, Japan’s government provided a multi-year budget of €860 million, of which €400 million was for the computer itself. A major portion of Japanese government spending on


33 *FY2016 Budget Request to Congress for DOE’s Office of Science.* February 4, 2015


35 *National Science Foundation FY2016 Budget Request to Congress.* February 2015.
HPC is devoted to such multi-year projects to develop the next-generation national flagship supercomputer. MEXT (Ministry of Education, Culture, Sports, Science and Technology) is the lead government agency for Japan's HPC strategy. Under MEXT, the High Performance Computing Infrastructure (HPPI) consortium, founded in 2012, includes 38 organizations (among them Japan's 9 major HPC university centers) and has PRACE-like responsibility for ensuring scientific and engineering access to leading supercomputers, while also promoting the use of HPC and carrying out R&D for future HPC systems. Japan has a strong focus on exascale technologies. Under the CREST program, Japan invests about €15 million per year in system software development for exascale, for example.

- **China.** Especially via the Chinese Academy of Sciences (CAS) and its academic partner the National University of Defense Technology (NUDT), Chinese government investments in HPC have risen rapidly in recent years from a relatively small base—partly as an expression of national pride and partly to lessen dependence on non-Chinese (primarily U.S.) HPC vendors over time. CAS and others are supporting at least five initiatives related to domestic Chinese processors. Key government financing sources include:
  - CAS: hardware, system software, applications. €150 million per year
  - NSFC: applications. About €6 million per year
  - MOST: hardware, system software, apps. €4 million per year

The U.S. government's recent decision to ban Intel from exporting Xeon x86 and Xeon Phi processors to upgrade Tianhe-2 and several other leading supercomputers in China may accelerate China's efforts (and financing) to advance domestic processor development. Also of note, China has urged investment banks and other "critical infrastructure" sites to replace non-Chinese HPC systems (primarily IBM) with Chinese supercomputers. Lenovo's acquisition of IBM's x86 server business should enable Lenovo as a Chinese firm to move into these sites.

- **Overall competition for leadership.** Europe's HPC capabilities have made impressive progress. Europe's strategy should not be to outspend everyone else. Europe should focus on its competitive strengths (user expertise, software and certain hardware technologies such as ARM processors and interconnect technologies from Bull, Numascale and Extoll). Among the competitive weaknesses the experts pointed out are Europe's lack of multiple large HPC vendors and lack of strong venture capital markets. Through the ETP4HPC initiative and other existing programs, Europe should continue aggressively developing pre-competitive, enabling hardware and software technologies for HPC users. In IDC's view, software advances will be one of the most important determinants of future global HPC leadership.

---

36 *Updates of Chinese HPC Efforts.* Zhong Jin, CAS. 2013
5. ANALYSIS OF FINANCIAL PROGRESS

The objective here is to assess the progress of the “financial funding” included in the HPC's Communication, suggesting that the MS, the EU and the industry together add approximately 500 million of yearly R&D investments and HPC procurements in 2016, growing to an yearly increase of just over 600 million euros by 2020, in addition, investing in two pre-exascale systems in 2020 and another two in 2022. This includes the assessment of current investment levels for the acquisition of high-end HPC resources in Europe compared to the levels required to meet the Action Plan objectives. The investments considered will not be limited to R&D and system acquisitions, but will include all other components necessary for the successful deployment and use of HPC (investments in training, HPC software and applications, etc.)

In our 2010 study report for the Commission, IDC's analysis indicated that "in recent years Europe has under-invested in HPC and is falling behind other regions of the world. From 2007 to 2009, Europe lost 10% market share in the worldwide HPC supercomputer market space, a very significant decline. In order to catch up and keep pace with competing nations and regions, Europe needs to both increase its HPC investments and find ways to apply HPC in a more productive and innovative manner."

In the 2010 plan, IDC also recommended that Europe take on this strategic vision to help guide its HPC investments and plan:

Providing world-class HPC resources to make EU scientists, engineers, and analysts the most productive and innovative in the world in applying HPC to advance their research in the pursuit of scientific advancement and economic growth.

IDC's report went on to recommend investment levels needed for Europe to close the funding gap and exploit an opportunity to pursue global HPC leadership. The subsequent EU HPC strategy and Action Plan targeted a doubling of European annual HPC funding by 2020, from €600 million to €1.2 billion, to support the EU HPC leadership goals delineated in the Action Plan.

IDC estimates that the overall European-wide HPC R&D investments, supercomputer purchases, and related services in 2010 amounted to approximately €1.8 billion: €715 million in purchases of supercomputers, plus €90 million (in supporting investments, integration services and professional services); plus ~€850 million (storage, software and repair services purchased with the computers); plus ~€30 million (from the EC); and ~€90 million (R&D by vendors and users). Note that these are IDC estimates, as there is no European tracking of these numbers at this time.

An important objective of this study was therefore to evaluate whether the pace of financing is on track and whether it will be adequate for the European HPC strategy's high-level objective of "ensuring European leadership in the supply and use of HPC systems and services by 2020." IDC interprets this leadership objective as meaning that by 2020 Europe aims to have an HPC ecosystem that is on a par with the best in the world and that Europe aims to be number one in the world in targeted aspects of HPC.

5.1. 2010 Action Plan Funding Alternatives

Figure 5.A shows the four alternative recommended funding levels from the 2010 IDC strategic plan report (the full leadership funding level, the reach major goals level, the partial funding level, and the minimal funding level). In 2010, IDC recommended that Europe and the EU fund the broader HPC ecosystem at the Full Leadership funding level. This represented an approximate increase in HPC ecosystem spending of €300 million in 2012, growing quickly to €400 million and reaching close to €900 million by 2020. This funding was to come from multiple sources as laid out in the 2010 report. Note that in
2010 total European HPC investments and HPC purchases were approximately 1.8 billion euros.

*Figure 5.A: Funding Alternatives from the 2010 Action Plan*

**5.2. New Recommended Funding Level Compared to the 2010 Level**

Figure 5.B adds the new IDC recommended increase in the HPC ecosystem funding level for Europe and the EU (in comparison to the 2010 recommended levels). The new recommendation level is a bit lower than the previous recommendation in order to take into account the previous difficulties in obtaining the recommended full leadership level of funding (enough to move Europe ahead of its existing competitive level in the world). It also adds two large funding spikes in 2020 and again in 2022 to cover the costs of funding four exascale class systems (two pre-exascale systems in 2020 and two exascale systems in 2022).
5.3. The New Recommendation Compared to the Actual Growth in European Spending on Supercomputer Servers

Figure 5.C adds a comparison to the chart showing the ACTUAL increase in European spending for supercomputers from 2010 to 2014. Although these numbers are not apples-to-apples (one set is for the whole ecosystem, and other is just for purchases of supercomputers), it (the green line) shows that Europe as a whole was able to step up to very healthy funding growth in 2010, 2011 and 2012 -- well above the 2010 IDC recommended levels, but then Europe-wide funding declined heavily in 2013 and 2014. Taken as an average, the net funding increase over the last five-year period was extremely good for reaching a leadership level for Europe.
5.4. The New Recommended Funding Increase Levels Compared to the 2010 Plan

Figures 5.D and 5.E compare IDC’s new recommended funding levels to the levels recommended in our 2010 report to the Commission.

The tables show the yearly funding increase recommended starting in 2016.

The new recommendation levels show grow over time by approximately 5% a year (compared to the 10% yearly growth rate in the 2010 plan recommendations).

The first column shows the three pillars of the strategy: (a) developing the next generation of HPC technologies, applications and systems towards exascale; (b) providing access to the best supercomputing facilities and services for both industry including SMEs and academia (PRACE); (c) and achieving excellence in HPC application delivery and use.
<table>
<thead>
<tr>
<th>Pillar Area</th>
<th>Funding Areas</th>
<th>Exascale Leadership Level</th>
<th>IDC Recommended Level</th>
<th>Minimal HPC Funding Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 0 systems)</td>
<td>180 (2)</td>
<td>150 (1)</td>
<td>100</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 1 systems)</td>
<td>120</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Technology Development, Industry Access and Application Delivery/Use</td>
<td>HPC development testbeds (U/W)</td>
<td>45</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Technology Development, Industry Access and Application Delivery/Use</td>
<td>HPC development testbeds (people)</td>
<td>75</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Technology Development</td>
<td>Exascale software &amp; hardware development</td>
<td>130</td>
<td>120</td>
<td>75</td>
</tr>
<tr>
<td>Developing People/Skills</td>
<td>Scientific talent magnet program</td>
<td>50</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Application Delivery &amp; Use Excellence</td>
<td>Invest in specific application leadership programs</td>
<td>150</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Total yearly funding increase</td>
<td></td>
<td>750 (1)</td>
<td>500 (1)</td>
<td>250</td>
</tr>
</tbody>
</table>

Note: These figures include HPC funding paid by the EU, by Member States, and contributions by vendors.

(1) Note: In addition two Exascales class systems in 2020 at approximately 250 million euros each and two more in 2022, at a cost of approximately 350 million euros each.

Source: IDC 2015
Note: the categories used in the “Funding Areas” are the ones from the 2010 recommendations report. There have been some changes since 2010, including: a) the exascale investments now include both hardware and software; and b) the “Testbeds” are similar to the centers of excellence. The testbeds are focused primarily on supporting a broad set of users across Europe in learning about HPC, in developing better software, in testing new hardware/software/storage solutions, etc.

IDC investigated three potential funding levels (Figure 5.F):
**Minimal HPC funding level.** This level allows Europe to at best stay close to its current level, but most likely to fall behind somewhat within 3 to 4 years. It’s close to the previous 2010 primary funding recommended, but with a slower growth rate in increases to the funding level. At this level there still need to be major investments in software and applications, as recommended in 2010. Exascale system purchases are still critical, but at this level, they will happen about 1.5 years after the first exascale systems show up elsewhere in the world, and even then systems in Europe may be perhaps only half-exascale in size. The minimum level addresses the need to invest in better communication of the plan and resources, including an easy to use, comprehensive web site and someone to be the leader in this area as well as a key point of contact.

**IDC new recommended funding level.** This level is close to the original 2010 recommended level, with a lower growth rate (5% vs. the previous 10%) the growth rate in the funding levels as proposed in 2010. Europe clearly has not yet reached this level of funding, so major funding shifts are required, as well as making the case more strongly for funding HPC. At this level, Europe will likely start to gain ground relative to the rest of the world. At this level there still need to be major investments in software and applications, as recommended in 2010. Exascale system purchases are still critical, but at this level, they will happen about 1 year after the first exascale systems show up, and perhaps at only a half-exascale in size. Funding from other groups should also support adding major new application areas, ones that can put Europe into the leadership role in a very specific area (like the Human Brain project). This should include at least 1 new FET flagship area every 2 to 3 years. This requires making the case for other groups to help fund these initiatives. We also recommend that a key part of the evaluation process includes the likely economic impact of success in these leadership areas, including projected job creation. This level addresses the need to invest in better communication of the plan and resources, including an easy to use, comprehensive web site and someone to be the leader in this area as well as a key point of contact.
**Advanced leadership funding level.** This level of funding would allow Europe to become a clear leader in HPC. This would greatly increase the draw of top talent to Europe as well as the economic growth from HPC investments in jobs and GDP. The level for this funding is only moderately higher than option two - reaching over €1 billion/year in 4 years (excluding the exascale system investments), but adds multiple new leadership investments at around €1 billion each, launching a new one every 1 to 2 years. We also recommend that a key part of the evaluation process include the likely economic impact of success in these leadership areas, including projected job creation. At this level there still need to be major investments in software and applications, as recommended in 2010. Exascale system purchases are still critical, but at this level, around 1 year after the first exascale systems show up, and perhaps at an 1 exascale in size. This level addresses the need to invest in better communication of the plan and resources, including an easy to use, comprehensive web site and someone to be the leader in this area as well as a key point of contact.

5.5. **Potential Funding Sources for the New IDC Recommended Increase Level (Starting in 2016)**

The funds should come from a number of sources, including the EU, Member States, and vendors/users. Vendors hopefully will cover the cost of a sizeable portion of the test bed hardware and exascale software development. It would be useful if the EU could cover 20% of the tier-0 hardware system costs and software development costs, with the Member States contributing the other 80%. It would also be key for the EU to support 50% of the recommended early exascale systems, with the member states funding the other 50%. These exascale systems would be purchased by the member states, but would provide 50% of the compute cycles to users across Europe. This would require extended coordination and negotiations, beyond what PRACE does today. The Member States should cover the major portion of the staffing cost; the Tier-1 systems; and the small to medium-sized systems. Industrial funds could come from two sources: a) HPC suppliers providing hardware, software, and people, plus funds; and b) from industrial end users paying for time on the systems.

- **Note:** IDC recommends that the Commission should fund a sizeable portion (50%) of the four exascale class systems (two pre-exascale in 2020 and two exascale in 2022). In return for this investment, the Commission should negotiate to obtain 50% of the capacity of these systems for EU-wide usage. Another option is for the Member States to cover the major portion of these four systems, perhaps as high as 80%, but then the supercomputers will be mostly used by the nation paying the major portion of the bill, and no nation today can afford these investments.

A potential yearly funding distribution example is shown in Figure 5.G. The 2016 to 2020 cumulative funding distribution is shown in Figure 5.H, and the 7 year (2016 to 2022) cumulative funding levels are shown in Figure 5.I. The recommended yearly increase from all sources is €500 million a year, starting in 2016, then growing by 5% a year (with an extra €500 million in 2020 and €700 million more in 2022).

The cumulative recommended total funding increase for the EU is €1,107 million over the period 2016 to 2020. The cumulative total for the Member States is €1,880 million over the same period. The total 5 year cumulative increase in HPC investments is €3.263 billion.

Figure 5.I shows the cumulative recommended funding levels for 2016 to 2022. (IDC recommends that the end date of the current European HPC strategy be extended to from 2020 to 2022 in order to match the expect exascale supercomputer deployment time.
frames of the United States, China and Japan—Europe's main competitors for HPC leadership.

Figure 5.6: IDC Recommended Funding Increase by Year, by Funding Source

<table>
<thead>
<tr>
<th>Pillar Area</th>
<th>Amount to be Added Each Year</th>
<th>EU</th>
<th>Member States</th>
<th>HPC Suppliers and Industrial Users</th>
<th>Yearly Total (2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 0)</td>
<td>25</td>
<td>125</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 1)</td>
<td>0</td>
<td>90</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>* Pre-Exascale Systems 2020 (1)</td>
<td>250</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>* Exascale Systems 2022 (2)</td>
<td>350</td>
<td>350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry Access, Technology Development and Application Delivery/Use</td>
<td>HPC development testbeds (H/W)</td>
<td>15</td>
<td>15</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>Industry Access, Technology Development and Application Delivery/Use</td>
<td>HPC development testbeds (people)</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Technology Development / Centers of Excellence</td>
<td>Exascale software &amp; hardware development</td>
<td>55</td>
<td>35</td>
<td>20</td>
<td>110</td>
</tr>
<tr>
<td>Developing People/Skills</td>
<td>Scientific talent magnet program</td>
<td>10</td>
<td>15</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Application Delivery &amp; Use Excellence</td>
<td>Invest in specific application leadership programs</td>
<td>40</td>
<td>5</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>Total yearly funding increase</td>
<td>155</td>
<td>295</td>
<td>50</td>
<td>500</td>
</tr>
</tbody>
</table>

(1) Note: In addition two Exascale class systems in 2020 at approximately 250 million euros each and two more in 2022, at a cost of approximately 350 million euros each.

(3) Note: It is recommended that the 2016 yearly spend should increase ~5% year

Source: IDC 2015
### Figure 5.H: Cumulative Potential Funding Sources for the New IDC Recommended Increase Level (2016 to 2020) (Millions of euros)

#### Cumulative Total Amount From 2016 to 2020

<table>
<thead>
<tr>
<th>Pillar Area</th>
<th>Funding Area</th>
<th>EU</th>
<th>Member States</th>
<th>HPC Suppliers and Industrial Users</th>
<th>2016-2020 Cumulative Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 0)</td>
<td>138</td>
<td>691</td>
<td>-</td>
<td>829</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 1)</td>
<td>-</td>
<td>497</td>
<td>55</td>
<td>553</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>* Pre-Exascale Systems 2020 (1)</td>
<td>250</td>
<td>250</td>
<td>-</td>
<td>500</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>* Exascale Systems 2022 (2)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Industry Access, Technology Development and Application Delivery/Use</td>
<td>HPC development testbeds (H/W)</td>
<td>83</td>
<td>83</td>
<td>28</td>
<td>193</td>
</tr>
<tr>
<td>Industry Access, Technology Development and Application Delivery/Use</td>
<td>HPC development testbeds (people)</td>
<td>55</td>
<td>55</td>
<td>28</td>
<td>138</td>
</tr>
<tr>
<td>Technology Development / Centers of Excellence</td>
<td>Exascale software &amp; hardware development</td>
<td>304</td>
<td>193</td>
<td>111</td>
<td>608</td>
</tr>
<tr>
<td>Developing People/Skills</td>
<td>Scientific talent magnet program</td>
<td>55</td>
<td>83</td>
<td>28</td>
<td>166</td>
</tr>
<tr>
<td>Application Delivery &amp; Use Excellence</td>
<td>Invest in specific application leadership programs</td>
<td>221</td>
<td>28</td>
<td>28</td>
<td>276</td>
</tr>
<tr>
<td>Total</td>
<td>Total cumulative funding increase (to 2020)</td>
<td>1,107</td>
<td>1,880</td>
<td>276</td>
<td>3,263</td>
</tr>
</tbody>
</table>

(1) Note: Includes two Exascale class systems in 2020 at 250 million each

Source: IDC 2015
### Figure 5.I: Cumulative Potential Funding Sources for the New IDC Recommended Increase Level (2016 to 2022)

(Millions of euros)

<table>
<thead>
<tr>
<th>Cumulative Total Amount From 2016 to 2022</th>
<th>7 Year Cumulative Amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pillar Area</strong></td>
<td><strong>Funding Area</strong></td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 0)</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>HPC system funding increases (tier 1)</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>* Pre-Exascale Systems 2020 (1)</td>
</tr>
<tr>
<td>Access to HPC resources</td>
<td>* Exascale Systems 2022 (2)</td>
</tr>
<tr>
<td>Industry Access, Technology Development and Application Delivery/Use</td>
<td>HPC development testbeds (H/W)</td>
</tr>
<tr>
<td>Industry Access, Technology Development and Application Delivery/Use</td>
<td>HPC development testbeds (people)</td>
</tr>
<tr>
<td>Technology Development / Centers of Excellence</td>
<td>Exascale software &amp; hardware development</td>
</tr>
<tr>
<td>Developing People/Skills</td>
<td>Scientific talent magnet program</td>
</tr>
<tr>
<td>Application Delivery &amp; Use Excellence</td>
<td>Invest in specific application leadership programs</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total cumulative funding increase (to 2020)</strong></td>
</tr>
</tbody>
</table>

(1) Note: In addition two Exascale class systems in 2020 at approximately 250 million euros each and two more in 2022, at a cost of approximately 350 million euros each

Source: IDC 2015
The concept of co-design rests on the belief that the HPC needs of science and industry will best be served if new hardware and software are designed and developed in close coordination with each other, rather than separately (as has often happened).

Within the European HPC strategy, a focal area for co-design activities is the cPPP agreement between the Commission and ETP4HPC. The Commission is contributing €700 million to this initiative, with the aim of obtaining matching funds from industry. ETP4HPC’s comprehensive milestone plan places a significant emphasis on co-design activities.\footnote{ETP4HPC Strategic Research Agenda for Achieving HPC Leadership in Europe. June 2013.}

**IDC Recommendation:** The co-design objectives within the ETP4HPC milestone plan are well thought-out and should contribute substantially to the usefulness of future leadership supercomputer designs for Europe. It is important to keep in mind, however, that contemporary co-design strategies typically contain some important limitations. The European Commission, as a key funder of the cPPP, should strive to ensure that the ETP4HPC plan addresses these limitations to the extent possible.

- The most important limitation is the system’s breadth-of-applicability. Exactly which applications are the hardware and software being co-designed to excel at? It is one thing to demonstrate stratospheric performance on "embarrassingly parallel" codes such as quantum chromodynamics (QCD), and quite another to do this on communications-intensive applications such as fluid-structures interactions that are very important for the aerospace and automotive industries. IDC believes that the most effective strategies begin with a targeted list of application codes that are intended to exploit a significant fraction (say, 20% or more) of the entire supercomputer. The list should not end there; co-design should also reflect the system’s goals for less-scalable scientific and industrial applications. To the extent possible, co-design should closely mirror the full intended use of the supercomputer, i.e., its targeted breadth-of-applicability. For example, co-design may need to accommodate modestly scalable, communications-bound industrial applications by incorporating stronger communications capabilities on a modest portion of the computer.

- It is also vitally important for end-users of the co-designed hardware/software systems to be integrally involved in the design process. This is especially true for industrial end-users, who historically have taken a back seat to their scientific counterparts in the design of leadership supercomputer hardware and software. If applications used by industry are being advanced, industrial end-users and ISVs should be part of the planning process from the very start; the process should not be left entirely to academic software experts.

- Last but not least, just because something seems possible to do does not always make it worth doing. It is important for co-design initiatives to avoid innovating for the sake of innovation and instead closely adhere to the future requirements described by intended users of the supercomputing technologies and systems.

- Ultimately, the EU needs to ensure that all stakeholders in an exascale ecosystem can participate in such co-design activities that should start with mutually agreed-upon requirements for key applications, scientific missions, or even grand challenge projects that can then be mapped to the myriad hardware and software specifications they engender. Such an effort would also provide the opportunity to generate a long-term exascale technology road map that would allow any single entity to understand the overall vision of the EU HPC leadership program and where they fit in.
6.1. The Global Trend toward Indigenous HPC Technologies

Europe's interest in fostering the development of an indigenous HPC supply chain is part of a global trend. The growing recognition of HPC's ability to boost scientific, industrial and economic competitiveness has increasingly led to the conclusion that this transformational technology is too strategic to be outsourced to foreign sources. The trend scarcely applies to the U.S., which has long had large domestic HPC suppliers that dominate the global market. But in other major geographies, such as Europe, China and India, the push is on to develop strong indigenous HPC supply chains in order to decrease reliance on foreign sources, especially the U.S. Even Japan's leading supercomputers, aimed mainly at the Japanese market, employ indigenous RISC processors and other domestic technologies.

To put this in perspective:

- In 2013, about 110,000 HPC systems were sold around the world and more than 90% of these systems came from U.S. suppliers. In the same year, more than 90% of the processors and co-processors powering HPC systems also came from U.S. suppliers.
- China today has at least five indigenous processor development initiatives under way, most famously the evolving Loongson processor series developed under the auspices of the Chinese Academy of Sciences (CAS).
- Japan's most powerful HPC system, the K Computer, is based on custom SPARC processors from Fujitsu and NEC continues to develop custom vector processors.
- In April 2014, Russian company Ruselectronics announced that it is developing a petascale supercomputer and "all of its processors and components will be designed in Russia."
- India has also signaled its intent to continue supporting the development of Param and other domestic technologies.

6.2. ETP4HPC: Driving the Development of the European HPC Supply Chain

Just before the SC11 worldwide supercomputing conference, a number of Europe's leading HPC vendors and research centers announced that they planned to join forces to create a European Technology Platform to strengthen Europe's HPC technology development and supply chain. Today, the ETP4HPC industry-led forum has more than 50 members (including non-European vendors such as Intel, Lenovo, IBM, Cray, Fujitsu, Huawei and others), along with an extensive network of connections to leading HPC centers and organizations in Europe.

The strength of Europe's HPC supply chain differs by category:

- **HPC server systems/supercomputers.** Europe has had no HPC server vendors large enough to compete with America's HP, IBM, and Dell, or Japan's NEC and Fujitsu, or China's Lenovo (following the acquisition of IBM's x86-based HPC server business). As a result, U.S. vendors represented 89.6% of all European HPC server system revenue/spending in 2009 and 81.2% in 2014. The only sizeable Europe-based vendor, Atos (formerly Bull), accounted for only 1.7% of European HPC server spending in 2009 and 2.0% in 2014. The acquisition of Bull may position France-based Atos to compete more successfully against these non-European vendors in the European and worldwide HPC markets. Eurotech (Italy) is a small but innovative HPC system vendor.

- **HPC processors.** IDC research, including studies completed in 2015, indicates that x86-based processors, especially from Intel, and coprocessors/accelerators from Intel and Nvidia will continue to dominate the European and global HPC markets for at least the next five years (2020). Recent studies also indicate,
however, that processors based on designs from UK-based ARM Holdings will establish a modest but expanding presence in the market during the period 2015-2020. It is important to understand that ARM Holdings does not make processors but instead creates designs for processors. Processors based on designs licensed from ARM Holdings will be incorporated into the HPC systems of non-European as well as European vendors. Non-European vendors dominate the European market for HPC systems and IDC expects the same non-European systems vendors (Hewlett Packard, IBM, Lenovo, Dell, et al.) to be the main purveyors of ARM-based processors in the European HPC market through 2020. Over time, Atos' size should allow the company's Bull-branded products to gain market share against the large, non-European HPC system vendors. It is unlikely that Atos' HPC market share will grow fast enough to rival the market shares of the non-European HPC system vendors by 2020, however. OpenPower may provide an option, but it's too early to understand its potential.

- **HPC storage and interconnects.** Europe has no indigenous HPC storage developers of note except Xyratex (now part of Seagate), but has several important interconnect suppliers. Extoll (Germany) and Numascale (Norway) already market their innovative interconnect products and Atos (Bull) is developing a high-capability interconnect. These will compete in the European and global market with the current world leader Mellanox (Israel-U.S.) and interconnects from Intel, among others. IDC believes that European vendors Atos and EXTOLL are positioned to begin capturing interconnect market share over time, starting in the European HPC market. Through the year 2020, however, the main combatants in the battle for leadership in the European and worldwide high-capability interconnect markets will almost surely be incumbent Mellanox and Intel. Intel's weapons in this battle include the company's large size, global market reach, and the technologies and related expertise it acquired from Cray and QLogic. Because of the increasing importance of interconnects for HPC leadership, IDC believes it is important for Europe to support advancements in interconnect technology, including promising developments at suppliers such as EXTOLL and Atos. Because Intel is a member of the ETP4HPC initiative, other promising developments might involve collaboration between Europe-based Intel experts and other European experts.

- **HPC software.** IDC considers software the single most important category for future HPC leadership, because the ability to exploit future-generation (including exascale) supercomputers for science and industry will depend heavily on software capabilities. Important advances in hardware performance, packaging, and cooling will be needed for the coming era of exascale computing, but parallel software advances will be even more important for future HPC leadership. This is because the capabilities of the hardware systems have gotten far ahead of the ability of software to exploit them efficiently (or of interconnects to keep processors busy with data). Today, only about 1% of HPC application codes can exploit 10,000 or more processor cores. Yet, the largest HPC hardware systems today contain more than 1 million cores, and exascale supercomputers with tens or hundreds of millions of core will begin to arrive during the period 2020-2022. A number of EU-based companies, including Dassault Systemes, Bright Computing, Allinea and others, have had notable success in selling their software products into the European and worldwide HPC markets, including the U.S. The size and maturity of the U.S. HPC market, along with tax and market access considerations, often motivate European software firms to establish dual headquarters in Europe and the U.S.
IDC's 2011 study on highly parallel software in Europe found that the vast majority (83%) of the most important parallel software applications in use at the surveyed European HPC sites were created in Europe. Intellectual property rights for a substantial majority of the sites’ most important application codes (66%) were exclusively owned by European organizations. But many of these important codes are used only by one or a handful of HPC sites. Hence, there is a major opportunity for commercialization and further dissemination of parallel software codes already in use in Europe.

- The European Exascale Software Initiative (EESI, EESI-2) has secured participation from many of Europe's outstanding parallel software experts and is leading these experts to create what is arguably the world's most comprehensive, compelling vision for the development of exascale software. It is important that EESI, unlike the International Exascale Software Project (IESP), has focused on the software needs of industry as well as those of science. IDC believes that this dual focus will become increasingly important to justify the large investments needed to fund exascale initiatives around the world. Fundamental hardware and software technology advances made for exascale supercomputers will also benefit the smaller HPC systems that are used by the majority of HPC sites. EESI's weakness today is underfunding for the implementation of this important strategy. (Software funding under the FETHPC1 aspect of the Horizon2020 Work Program is important but limited.)

6.3. Creating a Parallel Software Clearinghouse

IDC's 2011 study for the Commission found that the vast majority (83%) of the most important parallel software applications in use at the surveyed European HPC sites were created in Europe, and intellectual property rights for a substantial majority of these application codes (66%) were exclusively owned by European organizations. But the study also found that most of these applications were being used only one or two sites.

6.4. Public-Private Partnerships within Member States (PPPs)

The most notable PPP within the European HPC strategy is the contractual Public-Private Partnership (cPPP), started in 2011, under which ETP4HPC is helping to advance European HPC technology and expand the European HPC supply chain. In the area of HPC, this is a one-off PPP that has grown to 64 organizations (including 34 companies, 20 of them SMEs). The EC has committed very substantial funding of €700 million to the cPPP on HPC under Horizon 2020.

The Member States are also part of the accelerating global trend in which government-funded HPC centers establish industrial collaborations. Some national supercomputing centers, such as Germany’s HLRS, France’s CEA-DAM/Teratec collaboration, Italy’s CINECA, the Netherlands’ SURFsara, and a few others have become masters in the art of collaborating with industry. But some other European national HPC centers are new to industrial collaboration and are struggling with the challenges of attracting and satisfying private-sector partners. These newer industrial collaborations with Member States could benefit from mentoring from the more experienced Member States PPPs.

6.5. Industrial Exploitation of HPC: PPP Case Studies

Thanks in part to its expanding use in industry and commerce, during the past two decades HPC has been one of the fastest-growing IT markets, expanding from €1.5 billion in 1990 to more than €15 billion in 2013. Industrial firms typically cannot justify acquiring leadership supercomputers, but industrial firms of all sizes can have computing problems that are just as challenging as major scientific computing problems. To advance European
economic competitiveness, it is therefore important to enable industry to access supercomputing resources that the companies lack, especially because the problems requiring these resources are typically mission critical. An excellent list of HPC success stories in industry, government and in partnerships can be found at: [https://hpcuserforum.com/downloads/HPCSuccessStories.pdf](https://hpcuserforum.com/downloads/HPCSuccessStories.pdf)

IDC’s 2010 Commission-sponsored study report, *Development of a Supercomputing Strategy in Europe*, emphasized the need for industry to be given increased access to HPC resources at PRACE tier-0 centers as well as at national and regional HPC centers in Europe. That goal became part of the Action Plan and since then (2012), considerable progress has happened:

- PRACE opened access to industrial users in January 2012 and has provided more than a dozen companies—half of them SMEs—with a total of 150 million CPU hours on tier-0 supercomputers. Twice-yearly calls offer qualifying companies free access to PRACE resources (including training) as long as the companies agree to publish the results in publicly media.

- This constitutes strong initial progress by PRACE, but European HPC experts and other stakeholders IDC surveyed for this study said that stronger outreach is needed to make European industry aware of these opportunities and of successes to date. Outreach is especially needed to raise awareness of SHAPE and Fortissimo among the large number of SMEs in Europe who might benefit from HPC access.

### 6.5.1. Industrial Partnership Case Studies

The case studies below summarize the activities of only a few of the European organizations that are involved in industrial partnerships involving HPC use. Other notable programs include (but are not limited to):

- Barcelona Supercomputing Center (Spain)
- CINECA (Italy)
- ETH, EPFL and CSCS (Switzerland)
- Edinburgh Parallel Computing Center (Scotland/UK)
- Imperial College London (UK)
- SURFsara (Netherlands)
- SHAPE (EU program aimed at SMEs)

### 6.5.2. Case Study: PRACE

(IDC notes from a talk at an IDC HPC User Forum by Stephane Requena, GENCI)

The plan is to establish a PRACE user forum and set up a PRACE training portal that includes best practices on efficiently using certain codes on certain machines. The next stage also includes finalizing the collection of industry needs and expectations. The third PRACE industrial seminar took place at SNIC/KH, Stockholm, Sweden in March 2011 and had an increased focus on SMEs. Target groups for the PRACE industrial offering include the following:

- Industrial users at the tera/petascale, using self-developed codes;
- Industrial users relying on ISV codes (not really interested in HPC);
- ISV vendors and tool vendors (validation/development of software at large scale);
Hardware vendors that aim for expertise for the assessment of planned products and co-development approaches;

Hardware customers, who will be offered a consultancy about new and emerging technologies and their applicability.

Elements of the PRACE offer:

- Differentiation strategy. Unique resources, high level of expertise, and help with porting/optimization
- Integration layer. Unification of access models and application procedures
- Co-development. Collaborations to shorten time to market in software, hardware, and so forth
- Training and consulting. Lower the barrier to exploiting available resources and help with the selection of the most appropriate system for the problem size
- Training of trainers

### 6.5.3. Case Study: Teratec

(IDC notes from a 2014 presentation at IDC’s HPC User Forum by Hervé Mouren, Director, Teratec)

This initiative is European, based in Paris, and led by industry. Industry needs HPC in many domains including energy, health care, services, the media, and others. HPC is becoming an engine for the economy.

Eight years ago, Teratec had six users from aerospace and energy, including EDF, Total, and CE). The six companies decided to start an initiative to launch HPC for themselves and their supply chains. Today, Teratec has 80 members. Teratec includes industrial users, technology providers, and research centers. One user is a cosmetics company that uses simulation because they are no longer allowed to do animal testing.

A few years ago, a decision was made to have a physical ecosystem for Teratec. Today, we have the Teratec campus 30 km south of Paris, next to CEA-DAM. CEA’s very large computing center is within CEA’s classified site. Teratec has a 60MW electrical supply. The Teratec campus includes a business incubator, research labs, and space for firms using HPC, and the European HPC Education Institute. The campus opened in June 2012. Our campus hosts many collaborations with industry.

We have three labs:

- The Exascale Computing Research Lab, led by Intel
- CEA and Bull share a lab focused on co-design
- The SystemX Technological Research Institute

2013-14 is a turning point when we launched the HPC European Technology Platform and are preparing the French national supercomputing plan and extending from French collaborations to European and international initiatives.

We host a large conference each year in the Paris area. This year the Teratec 2014 Forum will be a two-day conference with an exhibit area. Last year more than 1,000 people attended. The second day is working sessions. We focus not only on what’s happening today but on future plans.

CEA France launched 34 industrial sector-based initiatives, one of which is on supercomputers, which Teratec was asked to lead. Gerard Roucairol leads the supercomputer initiative. He is Teratec's chairman.
The goals are to help develop the next generation of supercomputers, including new architectures and software for health, agro, urban systems, materials, manufacturing, and multimedia. These are our six sector-specific initiatives in supercomputing. The initiatives include dissemination of the results and training.

### 6.5.4. Case Study: The UK’s Hartree Center

(IDC notes from a 2014 presentation at IDC’s HPC User Forum by Hartree Center Head of Business Development, STFC Hartree Center)

Douglas Hartree was an early scientific computing innovator. We're based at Daresbury in Cheshire, UK.

The 2011 Tildesley Report ultimately led to £160 million of investment through the UK Department of Business, Innovation and Skills (BIS) to enhance the economic impact of software and modeling. 25% of this investment was to set up the Hartree Center, and the rest was for universities and the Edinburgh Parallel Computing Center (EPCC). The UK and most of Europe does not compete globally on price but on innovative products and services, such as through ARM, BAE, Bentley, Glaxo SmithKline, UNilever, and JLR. The center makes services available to companies of all sizes, not for free. We believe visualization is the key. Physical prototyping is expensive and difficult, sometimes impossible to do (e.g., a heart attack).

The value of modeling and simulation is highlighted in the report *E-Infrastructure: One Year On*. For example, it costs £500,000 to do each physical crash test, vs. £12 for a virtual simulation of a car crash. Our customers define value as more sales/customers, better outcomes, and cheaper product design. We have a manufacturing partnership with Unilever R&D Labs.

Hartree Center projects include:

- Engineering /manufacturing: vehicle testing, consumer electronics design, consumer packaged goods design
- Environment
- Life science: genomics for better crop design
- Energy: advanced battery cell design, well head extraction
- Financial services

Hartree systems include:

- Blue Joule: 98,000 cores, 1.2PF
- Blue Wonder: 20,000 cores
- We have 9PB of disk storage and 15PB of tape
- 3 visualization walls
- Big data analytics cluster (288TB)
- Nvidia Tesla GPU cluster

Hartree employees: 48 employees in 2014, with 20 more coming

Hartree services:

- Collaborative R&D
- Software and algorithms
- Training and skills, including a high school summer course involving Jack Dongarra
We chose LLNL and they chose us to partner with. The agreement signed in August 2013 calls for the parties to share know-how and information related to competitive advantage. It includes an IBM commitment. The industrial partnerships we'll tackle together will be big and complex; otherwise there would be no reason not to handle them alone. We'll have industry days where we gather clients together for workshops, and we'll have joint projects in engineering, life sciences (drug development), and other fields.

### 6.5.5. Case Study: CEA Computing Center for Research and Technology (France)

(Based primarily on website information provided by CCRT)

Established in 2003, CCRT is a supercomputing center managed by CEA for academic and industrial partners. It was established to provide state-of-the-art HPC resources and services for large scientific computations while fostering synergy between research organizations, universities, and industry. Multi-year partnerships allow joint investments in high-end systems while developing sustainable exchanges and scientific collaboration between partners.

The Computing Center for Research and Technology (CCRT) partners invested in a new supercomputer that was installed at CEA’s Very Large Computing Center (TGCC) in Bruyères-le-Châtel in May 2012 (dedicated ½ Petaflops).

As of May 2015 industrial partners of CCRT are[^38], beside CEA divisions and their academic partners, and doing permanent, daily production on the “airain” machine:

- AREVA: energy
- CERFACS: multidisciplinary public-private HPC research center
- Airbus Defence & Space
- EDF: energy
- INERIS: industrial risk assessment
- L’Oréal: cosmetics
- Herakles/Safran: spacecraft engines
- Snecma: aircraft engines
- Techspace Aero: aerospace engine equipment
- Turbomeca: helicopter engines
- THALES
- Valeo: automotive equipment
- France Génomique: French genomic labs consortium (CCRT is their national IT hub for DNA sequencer data storage and processing).

The goals are to advance projects and research in various areas such as electric power plants’ lifespans, design and safety of nuclear power plants, aircraft and helicopter engines optimization, environmental risk assessment, protein study and genome decryption, climate change and other demanding domains.

6.6. SMEs: A Special Case

IDC studies during the past decade have consistently shown that HPC can accelerate mission-critical innovation and competitiveness for companies of all sizes and in a broad, expanding range of markets. Despite this proof, many SMEs that might be helped by HPC remain unaware or inadequately informed about the contemporary realities of HPC, especially system prices that now start at under $100,000 and possibilities for accessing supercomputers and HPC expertise at national HPC centers or from public cloud providers. In a sense, then, HPC adoption by the SMB community is akin to a car running with both the accelerator and brake pedals depressed.

In 2013, HPC systems sold for less than $250,000 each accounted for $5 billion in revenue, about half (49%) of the $10.3 billion in worldwide HPC server revenue. At an average price of only $40,400, the sub-$250,000 systems consumed 1.7 million processor parts, 52% of 3.3 million processors shipped last year, according to IDC research. SMEs are not the only firms that buy sub-$250,000 HPC systems — but that's where most SME buyers of HPC gear reside.

Purchasing systems is not the only option open to SMEs wanting to do HPC, of course. Public cloud computing can be an attractive alternative for SMEs that haven't invested in on-premise HPC resources for their cloud-friendly workloads. We know of SMBs that are doing very well by relying entirely on public clouds. Still other SMEs turn to large, national HPC datacenters for more powerful computing resources and expertise. A major advantage these centers typically offer is access not only to powerful HPC systems but also to HPC experts who can help SMEs run their problems on these supercomputers.

Among the world's premier national HPC datacenters, none has deeper experience with industrial firms of all sizes than the High Performance Computing Center Stuttgart (HLRS). HLRS Director Michael Resch explained that his center, situated in the heart of Germany's auto industry, is seeing increasing demand for HPC from SMBs. Especially in this region, among the world's premier national HPC datacenters, none has deeper experience with industrial firms of all sizes than the High Performance Computing Center Stuttgart (HLRS). This German national HPC center and PRACE hosting center, situated in the heart of Germany's auto industry, is seeing increasing demand for HPC from SMEs. Especially in this region, SMEs serve as technology solution providers for larger companies. Increasingly, these large clients require a validation of their technology through simulation. In certain fields, simulation can play a crucial role but is not well known inside tier 1 companies. Very small companies with very special knowledge in modelling and simulation make a living in these small market niches, but they need access to large-scale systems for the computational part of their portfolio.

6.6.1. SME Case Stories

As the real-world examples in the sections that follow illustrate, SMEs in a range of markets are using HPC resources to help drive innovation that can have a profound positive impact on our economies, our societies, and the quality of human life. Both of these SMEs use the HPC resources and expertise of the High Performance Computing Center Stuttgart (HLRS), which has a long history of working successfully with companies of all sizes.

6.6.2. Case Study: RECOM Services

RECOM Services, a 12-person SMB based in Stuttgart, Germany, started out doing combustion modelling for large-scale power plants and now does designs and process optimization for a wide range of industrial furnaces and boilers. This minute company could not justify buying an HPC system and instead performs simulations on supercomputers at the nearby High Performance Computing Center Stuttgart. This has enabled RECOM to grow revenue quickly, including recent moves into the U.S. and Asian markets.
### 6.6.3. Case Study: Sicos/M.A.R.K.13

Sicos subsidiary M.A.R.K. 13 is a 45-person German media company focused on designing movies. This business requires swift reaction time and extremely high quality. When approached to do work for the Australian-German animated movie based on the internationally known book "Maya the Bee," M.A.R.K. 13 entered into a collaboration with HLRS to guarantee high-quality, on-time production of 3D pictures for the 79-minute movie. Although the movie only required about 1% of HLRS resources, it could not have been done without high investment costs by such a small company. Using HLRS resources not only helped speed up the works but also substantially reduced the financial risk for the customer.

### 6.6.4. SME Recommendations, Ways to Get More SMEs Involved

- The PRACE Council's decision to make SHAPE (SME HPC Adoption Programme in Europe) a permanent service was prudent, but award eligibility today is limited to peer-reviewed proposals that include codes with the potential to scale high enough to exploit a reasonable fraction of a leading supercomputer.

- PRACE should consider creating a companion SHAPE initiative aimed at giving SMEs that might benefit from HPC an expert-guided, one-time opportunity to try it out without cost. The objective here would be to help make HPC use more pervasive among Europe's SMEs, in order to increase their competitiveness and ability to contribute to the European economy. This recommendation responds in part to the widespread perception among European HPC stakeholders surveyed for this study that greater outreach to SMEs in needed because relatively few seem to be aware of the value of HPC or the opportunities available to SMEs through PRACE.

- Accordingly, the projects the SMEs propose for HPC use would not need to be of special scientific or technical interest—they would only need to be important for advancing the SMEs' business prospects. Awards would be based primarily on this importance factor, along with the SMEs' commitment to the process. The initiative would be governed by the same groups that govern the SHAPE program and would be given access to compute cycles and expertise sufficient to accommodate, say, a dozen SMEs in the first year of the initiative's operation. The experiences would be monitored and reviewed to determine whether the initiative should be continued for a second year, with or without changes.

- Approval to extend or renew the awards would be based on PRACE's evaluation of progress during the initial award period and the potential for progress during the renewal period.

- PRACE (SHAPE) should provide award winners with access to PRACE computing resources optionally via GÉANT, the European communication network for research, education and public service. Some SMEs would find it difficult to perform their work on site at PRACE centers. But presumably in all cases the SMEs would need hands-on guidance from the tier-0 center staff.

---

6.7. HPC Education, Training and Skills

The use of HPC has contributed significantly and increasingly to scientific progress, industrial competitiveness, national security, and the quality of human life. But HPC advances are unattainable without an adequate number of properly trained personnel, including computational scientists, programmers, system administrators, technologists and all the others who help make up the HPC ecosystem. In HPC User Forum meetings and at other HPC conferences in the U.S. and elsewhere, IDC has repeatedly heard HPC leaders say their growth plans are increasingly limited by the shortage of qualified personnel.

The HPC personnel shortage is no accident. When government HPC funding declined sharply after the end of the Cold War, the HPC market entered a period of slowdown from which it did not start to recover until about the year 2002, when the fast rise of HPC clusters caused a five-year spurt of 20% annual revenue growth.

The period of HPC slowdown, occurring as it did alongside the explosive growth of Internet companies, helped to transform the image of HPC into that of a maturing and even a dying, "old technology" market. The number of university programs in computational science and related fields plummeted, as did HPC-related internship and postgraduate fellowship opportunities. Young people who might have chosen an HPC career a decade earlier all too often opted instead for employment with "new technology" Internet, PC or gaming companies. As a result, a high proportion of today's graying HPC workforce is within a decade of retirement age and educational institutions are not producing enough HPC-trained graduates to replace them.

The HPC community has only begun to address this labor shortage through new curricular and internship offerings, as well as through accelerated on-the-job training, but there is still a long way to go – especially in light of the challenges needed to harness the potential of petascale and exascale computers.

IDC's extensive 2010 worldwide study on this topic, sponsored by the U.S. Department of Energy, produced these main findings:

- There is a serious shortage of qualified candidates for HPC positions today. Nearly all (93%) of the surveyed HPC centers said it is "somewhat hard" or "very hard" to hire staff with the requisite skills. It is especially telling that the majority of the centers (56%) fell into the "very hard" category. This shortage spans the government, university, and industrial sectors and is global in scope.

- The job categories that the HPC center respondents consider hardest to find are scientists with HPC capabilities, parallel programmers, algorithm developers, and system administrator with high-end computing experience. The skills most badly needed today include a combined understanding of a scientific discipline and computational science and/or computer science; parallel programming and code optimization, especially for scaling to large processor/core counts; algorithm development; and understanding of parallel file systems.

- The candidate shortage affects the ability of HPC centers to staff up fully, but it has not yet seriously affected the quality of their support staff. Only 7% of the centers characterized their support staff size as "very adequate." When "somewhat adequate" responses are added to that figure, the total was still only a 41% minority of the centers. But the vast majority (93%) of the centers rated support staff quality as either "very adequate" (44%) or "somewhat adequate" (48%).

---

The best sources of job candidates are universities and other HPC data centers. The most fruitful source of qualified candidates for HPC positions are "university graduates in mathematics, engineering, or the physical sciences" (cited by 63% of the respondents). A smaller but substantial percentage of the respondents (48%) pointed to "university graduates in computer science." The most productive non-academic source of qualified HPC job candidates (mentioned by 48% of the respondents) were "employees of other HPC data centers," followed by "employees in related positions/areas at our own site" (41%) and employees of HPC software or hardware vendors" (37%). 22% of the respondents had found qualified candidates "through on-line posting and placement resources," such as monster.com and other websites.

Qualified job candidates from non-HPC centers are hard to find, but often work out well. The least productive hunting ground for qualified HPC positions was "employees at commercial or general IT data centers (non-HPC centers)." Despite this, the vast majority of respondents (89%) reported that they have hired people from non-HPC, commercial environments to work in their HPC centers. And the number of these hires that worked out well outnumb between the failures by a five-to-one ratio (20:4) – although this does not mean that the successes were immediate or complete.

The cost of transferring an employee from a non-HPC technical job is not especially burdensome, but it can take two years or more to become productive in the HPC environment. The HPC centers generally do not characterize the transfer cost as unreasonably large compared with the cost of getting any other new employee up to speed on the job. More important is how much relevant experience the person brings to the HPC position. Ease-of-transfer from non-HPC technical disciplines depends on which other discipline the individual is coming from and which HPC position the person is heading into. This can make a major difference in determining how long it takes until the person is performing to expectations in the HPC environment. The estimates vary from three months to two years, with many responses in the 6-12 month range.

Expanding the markets for HPC could make HPC a more attractive career path. But HPC architectures are becoming more narrow-purpose, making this even harder. Multiple HPC center respondents said that expanding the markets for HPC could help address the technology challenges by providing vendors with more incentive to innovate for HPC users. This could spark investment and make HPC a more vibrant, attractive market for young people to enter. But others point out that the recent evolution of HPC hardware architectures has been in the opposite direction, making them useful for fewer and fewer types of problems. More balanced architectures could increase the systems' breadth-of-applicability.

6.7.1. Recommendations on Training and Skills

**IDC Recommendation:** IDC recommends that the European Commission consider leading the following actions:

- To grow the HPC talent pool, undertake a communications campaign to update the image of HPC as a career choice. It is tragic that so many talented young people are struggling today to find jobs in their technical fields after completing university education, while thousands of well-paying HPC jobs go unfilled. More effort is
needed to acquaint students and faculty, with the exciting opportunities available in HPC, starting well before the students enter universities.

- Establish a task force to develop practical strategies for integrating HPC education and training more fully into the scientific and engineering curricula of European universities. The single biggest recommendation offered by HPC-knowledgeable people in academic and training organizations is for universities to expand coursework in computational science – as opposed to mere computer science – and to integrate computational science methods into the requirements for science degrees, certainly at the graduate level and preferably also at the undergraduate level. Because HPC-based modelling and simulation has firmly established itself as the third branch of scientific inquiry, alongside theory and experimentation, HPC should be as much a part of scientific education curricula as the two more established methods. But there is widespread recognition of the difficulty of adding new elements to already crowded science and engineering university curricula.

- The same task force should also develop recommendation for creating more HPC-related internships and post-doctoral opportunities, as well as guideline for HPC on-the-job training.

6.8. Ensuring a Level Playing Field

Europe historically has been the most open major HPC market in the world, perhaps in part because Europe has not had a large HPC system vendor of its own to promote. As noted earlier in this report, European HPC system vendors face asymmetries in major HPC markets outside of Europe:

- **United States.** Supercomputer acquisitions by U.S. federal agencies are restricted by the "Buy American" Act, although purchasing of software and components of non-U.S. origin is often allowed. U.S. government labs and defense sites together spent about €2.8 billion on HPC servers in 2013. Software and component technologies from ARM Holdings, Bright Computing, Dassault Systemes, and other European vendors are not uncommon at U.S. federal agencies.

- **Japan.** Japan's government market historically has tended to favor Japanese supercomputers, although non-Japanese supercomputers have had some successes in this market.

- **China.** China's fast-growing HPC market has been dominated historically by U.S. supercomputer vendors, because Chinese HPC vendors have not been able to compete effectively. More recently, the Chinese government directed investment banks and other "critical infrastructure" sites to cease acquiring non-Chinese HPC systems. Lenovo's purchase of IBM's x86-based HPC product line positions Lenovo to capture or retain these accounts.

It is important to keep in mind that Europe has had no HPC server vendors large enough to compete with America's HP, IBM, and Dell, or Japan's NEC and Fujitsu, or China's Lenovo (following the acquisition of IBM's x86-based HPC server business). As a result, U.S. vendors represented 89.6% of all European HPC server system revenue/spending in 2009 and 81.2% in 2014. The only sizeable Europe-based vendor, Atos (formerly Bull), accounted for only 1.7% of European HPC server spending in 2009 and 2.0% in 2014. The acquisition of Bull may position France-based Atos to compete more successfully against these non-European vendors in the European and worldwide HPC markets.

It is also important to remember that Europe today accounts for only about one-quarter of the worldwide market for HPC hardware systems and parallel software. This means that Europe-based HPC vendors generally cannot thrive and continually fund world-class
innovation unless they can match the investments of competitors who have fair and open access to the larger worldwide market.

- A number of Europe-based HPC software vendors, such as Allinea, Bright Computing, and Dassault Systemes, have been successful at this, but they are exceptions. A 2011 IDC study for the Commission found that the vast majority (83%) of the most important parallel software applications in use at the surveyed European HPC sites were created in Europe, and intellectual property rights for a substantial majority of these application codes (66%) were exclusively owned by European organizations. But the study also found that most of these applications were being used only one or two sites.

- Atos (Bull), the largest HPC system vendor within the EU, has had some successes outside of Europe but still relies on European sales for a large majority of its HPC revenues.

- Patented processor technologies from UK-based ARM Holdings are finding their way into system designs from HPC system vendors in the U.S., Europe, and Japan.
7. RECOMMENDATIONS AND CONCLUSIONS

IDC has concluded from this extensive study that Europe's HPC strategy has made impressive progress in the past few years, and that the governance and financing structures have been working relatively well so far. This section presents IDC's recommendations refining the HPC strategy, either because of the lessons learned to date or because developments outside of Europe have altered the competitive landscape for HPC leadership (e.g., the worldwide postponement of practical exascale computing until 2022 or later). The recommendations summarized here are discussed more fully in earlier sections of the report. For each recommendation, we have suggested which party is best positioned to take the lead or carry it out in full.

7.1. Overall Recommendations

In Summary: Recommendations

<table>
<thead>
<tr>
<th>Action Plan Objectives</th>
<th>Strategy Actions</th>
<th>IDC Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provide a world-class European HPC infrastructure</td>
<td>• Governance at the EU Level</td>
<td>#1 Expand Funding for HPC</td>
</tr>
<tr>
<td>2. Ensure independent access to HPC technologies, systems and services</td>
<td>• Financial Envelope</td>
<td>#2 Improve Communication of the Strategy</td>
</tr>
<tr>
<td>3. Establish a pan-European HPC governance scheme</td>
<td>• Funding Mechanisms</td>
<td>#3 Develop the HPC Ecosystem</td>
</tr>
<tr>
<td>4. Ensure the EU's position as a global actor</td>
<td>• European Supply Capabilities</td>
<td>#4 Improve Support for Industry</td>
</tr>
</tbody>
</table>

Recommendations on the Strategic Actions

Based on the progress to-date of the EU’s Strategy Actions, IDC makes the following targeted recommendations:

1.) Expand Funding for HPC (Financial Envelope & Funding Mechanism, and Needed for Making Europe World Class in HPC). PRACE members and the EC should agree to provide significant funding support to acquire two pre-exascale supercomputers in 2019-2020 and two additional exascale supercomputers in 2022. One path should stress European pre-commercial technology. The total 5 year cumulative increase in HPC investments (for all parties) from 2016 to 2020 is €3.263 billion. No Member State alone can afford to purchase systems of this size in the same timeframe as the U.S., Japan, or China and there is small likelihood of that multiple Member States would pool finances for this purpose without strong financial participation by the Commission. If European HPC leadership is truly an important shared goal, then IDC recommends that the Member States find a way to pool resources to cover a substantial portion of the needed funds (IDC recommends 50%), and the European Commission should find a way to revise or create an exception to the current rules of participation’s 20% contribution limit in order to contribute a substantial portion.
(IDC recommends 50%). In reality, the Members States and the European Commission will determine pooling contributions through discussions.

- **Extend the Planning Time Horizon.** The European Commission should extend the end date of the Action Plan from 2020 to 2022, to match the expected exascale time frames of the U.S., China and Japan and make it easier to amass the funding levels recommended in this study.

- **Improve Governance** To acquire exascale supercomputers in globally competitive time frames the Member States need to ensure that their governance structures (e.g., through PRACE) will facilitate coordination of their HPC policies—and the Commission may need to adjust its governance to pool resources with the Member States and contribute 50% of the acquisition costs of the pre-exascale and exascale supercomputers. ETP4HPC (technology developers) and Member States in PRACE (buyers) need to coordinate closely on requirements, especially for the exascale system that stresses European HPC technology. The Commission needs to determine what fraction of the exascale computers is needed for European (as opposed to national) initiatives and seek to secure this capacity, presumably in return for the recommended larger EC contribution toward the financing of these exascale supercomputers. PRACE should work to ensure continued fair access to leading supercomputers for scientists and engineers from all Member States.

- **Make More Use of PPI and Pooling resources (European Supply Capabilities).** As mentioned, to amass the funding needed for the pre-exascale and exascale supercomputers, the Member States (through PRACE) will need to pool resources with each other and with the European Commission. Member States through PRACE should increase the use of PPI and related mechanisms to support and accelerate the development of pre-competitive, innovative European HPC technologies and systems (including for exascale) and to increase the financial stability of innovative, sometimes small suppliers. To advance European technologies and suppliers, the Commission, PRACE and ETP4HPC need to agree on the strategy for employing PPI or related mechanisms on one of the two paths to exascale that IDC recommends.

2.) **Improve Understanding and Communication of the Strategy** (*Supply Ecosystem and Needed for Making Europe World Class in HPC*). The European Commission should create a single website portal enabling access to comprehensive information on the European HPC strategy. There needs to include a single person in charge and direct contact information for answering questions. This is key for getting more users, ISVs and SMEs involved.

3.) **Develop the HPC Ecosystem** (*European Supply Capabilities and Governance*). ETP4HPC should continue to support collaborations involving European suppliers and (often much larger) non-European suppliers. This will accelerate the learning curve of some European suppliers who are less experienced. European suppliers will benefit from competing on equal terms with suppliers not based in Europe.

- **Software is critical.** Software will be one of the main determinants of future HPC leadership and Europe is very strong in parallel software development. ETP4HPC or another organization in Europe (e.g. one of the centers of excellence) should create a clearinghouse (online storefront) to help disseminate, and in some cases commercialize, innovative European HPC software that is now in limited use, as well as for any future developments.
Ensure a Level Playing Field (Level Playing Field). Several IDC recommendations will contribute to ensuring a level playing field, including greater use of PPI and related mechanisms and an exascale path that stresses the inclusion of technologies from European vendors (defined as also including non-European-based suppliers doing R&D in Europe). Additional market, trade, and standards-related asymmetries for free and fair trade should be addressed on a government-to-government basis.

4.) Improve Support of Industry and SMEs (Industrial Use of HPC). PRACE should consider promoting SME and industry adoption of HPC with a SHAPE initiative that lets SMEs and other industrial firms that are new to HPC try it out without cost, and without needing to show scientific merit. ETP4HPC should ensure that software advances meant to benefit industry have strong, continuous input from industry representatives.

Help Newer Industrial Collaborations within Member States to Succeed (European Industrial Access to HPC). Europe already has some of the world's leading HPC centers for collaborations with industry, including SMEs. These include HLRS (Stuttgart), Teratec (Paris), SURFsara (Amsterdam), CINECA (Bologna), LRZ (Munich), Hartree Centre (Daresbury), and a few others. But many other HPC centres in Europe have recently added industrial collaboration programs and are struggling with how to work with industry. Centers with strong industrial experience are well positioned to mentor less-experienced centers, and to assume leadership roles in any future HPC competence centers. It would waste time and money to start competency centers focused on industrial collaboration without exploiting the existing competency of the HPC centers mentioned above and others like them.

5.) Improve Skills and Grow Talent (To Ensure Europe as a Global Actor and Needed for Making Europe World Class in HPC). The European Commission should undertake a communications campaign to update the image of HPC as a career choice. The Commission should also establish a task force to develop practical strategies for integrating HPC and related computational science education and training more fully into the scientific and engineering curricula of European universities.

In order for the EU to aggressively pursue world-class scientific innovation and boost industrial and economic competitiveness, particularity in the area of job creation, it must successfully realize the numerous opportunities offered by its current and planned HPC strategy. Should the EU fail to exploit this opportunity for whatever reason -- political, economic or technical -- it could substantially increase the risk of Europe lagging behind the U.S., China and Japan in critical technical areas, with a major impact on overall EU industrial, scientific, and military capabilities.

How the IDC Recommendations Address the Primary Objectives:

To implement the strategy, greater coordination among the Member States, and between the European Commission and the Member States, will be key. A majority of European HPC stakeholders IDC interviewed for this study agreed that no single European Member State has the financial and related means to compete effectively with the U.S., China and Japan for HPC leadership. Yet for understandable reasons, Member States are concerned primarily with their national needs and do not closely coordinate or pool financing for their supercomputer procurements. Nor does the Commission pool resources with the Member States to a large extent. Hence, the status quo will make it exceedingly difficult for Europe to amass enough money to acquire pre-scale and exascale supercomputers in competitive timeframes. As detailed in the financial section of this report, IDC recommends that the
European Commission contribute a substantial portion (recommended: 50%) of the funding for these systems, in return for securing a substantial portion (recommended: 50%) of the computing cycles of these systems and expertise of the hosting centers for European initiatives. Actual percentages would need to be negotiated with the PRACE hosting members and would need to consider the fact that the Member States will own the supercomputers.

1) Provide a world-class European HPC infrastructure, benefitting a broad range of academic and industry users, and especially SMEs, including a workforce well trained in HPC
   - IDC recommends that funding needs to be increased from the level recommended in the 2010 IDC report (as shown in section 5, Table 5.G), with a number of adjustments including having the EU fund at least 20% of the tier-0 systems, and in addition provide funding for 50% (instead of only 20%) of the 4 exascale class systems (two pre-exascale in 2020 and two exascale in 2022).
     - The EC should explore new approaches that will allow it to help fund, but not purchase, very large supercomputers. This concerns supercomputers that are more costly than a single Member State can afford. Perhaps CERN, where it’s a clear European-wide initiative, would be a good model.
   - IDC recommends that the EC needs to greatly expand its communication of the resources, services and activities available to the broader European HPC community and general public, and to also improve key elements of its HPC-related ecosystem, governance capabilities, educational options, and efforts to ensure a playing field to better address objective #1.

2) Ensure independent access to HPC technologies, systems and services for the EU
   - IDC recommends that the EU expands its support of industrial and SME user organizations through expanded outreach programs, especially to SMEs, and by creating an initiative for HPC sites experienced in industrial collaborations to mentor sites with less experience in attracting and satisfying industry partners.
   - IDC recommends that PRACE, in collaboration with ETP4HPC, make greater use of PPI and related mechanisms to support European suppliers of HPC technologies and designs. IDC recommends that ETP4HPC, PRACE, and the Commission coordinate closely to ensure that the ETP4HPC roadmap reflects the technology- and system-level innovations that PRACE members and other important HPC buyers would like to see developed for procurement.
   - IDC recommends that the European Commission and PRACE collaborate to ensure that access to tier-0 supercomputers remains available to scientists and engineers from all Member States under PRACE 2.0.

3) 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.
   - At present, there is no central procurement entity capable of managing pooled money from the Member States, along with EC contributions, in order to finance the acquisition of exascale supercomputers in a globally competitive time frame.
   - To acquire exascale supercomputers in globally competitive time frames the Member States need to ensure that their governance structures (e.g., through PRACE) will facilitate coordination of Member States’ HPC policies and pooling of financial resources—and the Commission may need to adjust its rules in order to coordinate more closely with the Member States (through PRACE), again including pooling of financial resources. ETP4HPC (technology developers) and Member States in PRACE (buyers) need to adjust governance to coordinate more closely on exascale requirements, including industrial requirements.
- Ultimately, the Member States (through PRACE), the European suppliers (through ETP4HPC) and the Commission need to find a governance scheme to make timely exascale financing happen, because of its importance for European HPC leadership. The success of these parties in agreeing on such a governance scheme (which may simply revise their respective existing schemes) will be an important indication of how serious they are about pursuing HPC leadership for Europe, in IDC’s opinion.

4) Ensure the EU's position as a global actor
- IDC in our 2010 report to the Commission stressed that advances in highly parallel software will be one of the most important determinants of future global HPC leadership. Accordingly, IDC recommends that the Commission and ETP4HPC ensure that software development receive in fact the proportion of funding intended for software development under the HPC strategy. Software is an area of special strength for Europe and should be pursued heavily.
- IDC recommends that more needs to be done in funding new and innovative work in software companies, in software research, and in new exascale and pre-exascale class areas such as the ARM software ecosystem. IDC also recommends that the EU funds the previous IDC recommendations on how to improve parallel software across Europe.41
- IDC recommends that the EU (a combination of EC funding and national funding) supports four exascale class systems (two in 2020 and two more in 2022) in order to keep pace with the U.S., Japan and China.

Additional Recommendations
In addition to the targeted recommendations outlined above that respond directly to key features of the European HPC plan, IDC offers this additional guidance that is beyond the direct scope of the current plan, but that nonetheless should be factored into any EU HPC policy strategy as it moves forward.

• High Performance Data Analysis (HPDA). This is the market for Big Data workloads that are complex or time-critical enough to require HPC resources. HPDA includes data-intensive modeling and simulation, and also advanced analytics. Many established HPC sites are adding analytics methods and more commercial companies are adopting HPC for advanced analytics. IDC recommends the following:
  o No dramatic shift in the European HPC strategy is needed for HPDA, because most HPDA, today and in the near term, will be data-intensive modeling and simulation (M&S) that HPC sites have been running for decades, but there are many opportunities to expand in this key area. The organic growth of floating point-based M&S Big Data and newer integer-based analytics methods (e.g., Hadoop, Spark, graph analytics) will not alter HPC’s fundamental von Neumann architecture but will increasingly shift configurations from today’s extreme compute-centrism to more balanced, data-friendly implementations (e.g., better interconnects and deeper storage hierarchies that include SSD, burst buffers, NVRAM).

Because of the growing importance of HPDA, one of the centers-of-excellence should be devoted to this topic, and especially to accelerating the transition from today’s static searches to the emerging era of higher-value, dynamic pattern discovery and cognitive computing in HPC. This transition will be relevant for nearly all HPC-supported scientific and engineering domains, such as life sciences (outcomes-based medicine), manufacturing (self-driving vehicles), climate research (climate knowledge discovery), and others.

European initiatives with industrial outreach goals, such as PRACE, SHAPE and Fortissimo, should ensure that they are also open to commercial (as opposed to industrial) firms that are adopting HPC for integer-based advanced analytics use cases, especially fraud/anomaly detection, affinity marketing, advanced business intelligence, and management of large IT infrastructures (e.g., IoT).

**Cloud Computing.** In IDC’s worldwide studies of high performance computing (HPC) end-user sites, the proportion of sites employing cloud computing—public or private—has steadily grown from 13.8% in 2011, to 23.5% in 2013, to 34.1% in 2015. IDC has the following recommendations for the European HPC strategy:

- As with HPDA, IDC believes that no major change to Europe’s HPC strategy is needed to accommodate the growing importance and technical evolution of public and private cloud computing, but that there are many emerging opportunities in this area. Most HPC sites already track cloud computing and, as noted above, a growing number of them are using clouds for some portion of their workloads. The challenge is less about educating users about cloud computing and more about the ability of clouds to handle more types of HPC jobs over time.

- The Commission has sponsored studies on cloud computing, including the HPC component, and should repeat these studies every 2-3 years to gauge progress. HPC public cloud computing has been mainly limited to workloads that are not latency-sensitive or IO-bound, but some cloud vendors now support applications as challenging as structural analysis and fluid-structures interactions. Data security/data loss in public clouds remain important concerns for HPC users and should be evaluated in these studies. A useful resource is UberCloud (www.theubercloud.com), an organization born in Europe that performs experiments to test the capabilities and limitations of public clouds. The annual ISC Cloud conference (Frankfurt) is another useful resource.

**Co-Design.** The EU should initiate an EU-wide exascale test bed program to provide strong support for exascale co-design capabilities. The test bed program would be a natural extension of ETP4HPC’s role. It would require ETP4HPC to collaborate closely with PRACE tier-0 supercomputer hosting members to test hardware and software technologies at large scale.

- Such a test bed would allow both EU-based ISVs and EU Software Centers of Excellence to participate in the design of exascale systems, understand the critical software requirements that these new hardware platforms engender, identify and define technical specifications for various elements of an emerging exascale software stack, glean best case situations for collaborative efforts among various ISVs and CoEs, and develop a sense
early on of leading-EU-based exascale architectural and algorithmic development efforts.

- This test bed should also extend similar co-design access to key industrial or other application users to ensure that co-design and related software development efforts are in sync with the exascale-related needs of key industrial players. Industrial participants should include a mix of long-standing HPC users, both large and small, as well as potential new HPC users (such as commercial firms moving up to HPC for advanced analytics that enterprise IT systems cannot handle effectively).

- **Centers-of-Excellence.** These fall under the cPPP on HPC. IDC recommends the following:
  
  - The centers should focus heavily on software—not just applications but also the whole HPC software stack (EESI has done an excellent job of laying the groundwork for this). Software will be one of the main determinants of future HPC leadership. It is very important, therefore, that software development receive in fact the full portion of cPPP funding that it is planned to receive.
  
  - The centers should focus not only on the software needs of the highly scalable scientific applications that will be first to exploit a large fraction of exascale supercomputers. At a minimum, one center should focus on the software requirements of industry, including advancing the capabilities of industrial applications that are only modestly scalable. It is important that intended industrial users be involved from the start in this process of identifying and improving the applications.
  
  - As noted earlier, IDC recommends that one center be devoted to HPDA.

### 7.2. In Conclusion

Seizing the opportunity targeted by the European HPC strategy is needed to pursue scientific innovation and boost industrial and economic competitiveness along with job creation. Conversely, failure to exploit this opportunity would substantially increase the risk of Europe lagging the U.S., China, Japan and other competing geographies in all of these critical areas.

By continuing its investments in HPC and following this proposed plan, Europe will have the ability to reach the original vision of: **Providing world-class HPC resources to make EU scientists, engineers, and analysts the most productive and innovative in the world in applying HPC to advance their research in the pursuit of scientific advancement and economic growth.**
8. ANNEX

Annex #1: Organizations Targeted for In-Depth Interviews

Table A1

<table>
<thead>
<tr>
<th>Organization</th>
<th>Organization</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Computer Center in Gdansk</td>
<td>Dassault Systemes Simulia Corp.</td>
<td>Imperial College London</td>
</tr>
<tr>
<td>Airbus Operation GmbH</td>
<td>DEISA</td>
<td>Intel</td>
</tr>
<tr>
<td>Allinea</td>
<td>Deutsches Klimarechenzentrum (DKRZ)</td>
<td>Lawrence Berkeley Lab - NERSC</td>
</tr>
<tr>
<td>Allinea</td>
<td>DLR (German Aerospace Center)</td>
<td>Leibniz Supercomputing Center</td>
</tr>
<tr>
<td>ANR</td>
<td>ECMWF</td>
<td>Louisiana State University</td>
</tr>
<tr>
<td>Asetek</td>
<td>Electric de France (EDF)</td>
<td>MPI für Meteorologie</td>
</tr>
<tr>
<td>Atomic Weapons Establishment (AWE)</td>
<td>EPCC</td>
<td>NEC</td>
</tr>
<tr>
<td>Barcelona Supercomputing Center</td>
<td>ETP4HPC (chair) + Bull</td>
<td>Netherlands Organization for Scientific Research</td>
</tr>
<tr>
<td>BBWorld</td>
<td>Eurotech</td>
<td>OCF</td>
</tr>
<tr>
<td>Bull (4)</td>
<td>EXTOLL</td>
<td>Oracle</td>
</tr>
<tr>
<td>Calit2</td>
<td>Forschungszentrum Juelich (2)</td>
<td>Riken</td>
</tr>
<tr>
<td>CEA</td>
<td>GENCI (3)</td>
<td>Rolls-Royce Deutschland</td>
</tr>
<tr>
<td>CERFACS</td>
<td>Hartree Center</td>
<td>SARA</td>
</tr>
<tr>
<td>CERN</td>
<td>HLRN</td>
<td>Tokyo Institute of Technology</td>
</tr>
<tr>
<td>CINECA</td>
<td>HLRS (Stuttgart)</td>
<td>University of Edinburgh - EPCC</td>
</tr>
<tr>
<td>Cray</td>
<td>HPC Information Service - Enter the Grid</td>
<td>University of Tennessee</td>
</tr>
<tr>
<td>CSC-Finland</td>
<td>IBM</td>
<td>University of Tsukuba</td>
</tr>
<tr>
<td>CSCS (2)</td>
<td>Iceotope</td>
<td>US Department of Energy</td>
</tr>
<tr>
<td>CSCS</td>
<td>ICM - University of Warsaw</td>
<td></td>
</tr>
</tbody>
</table>

Source: IDC 2015
Annex #2: Email Invitation Sent to Targeted Key Individuals

Dear [Name]:

The European Commission has selected IDC to perform a study on HPC progress in Europe in recent years (especially since the first Europe-wide HPC plan was adopted). You are one of the key people in the European HPC community, and so I would like to request an hour (or less) of your time for a phone interview on this topic.

Assuming you are willing to be interviewed, your remarks will have an important influence on the study findings but IDC will keep your remarks entirely confidential - nothing you say will be attributed to you or your organization.

You will be contacted soon by Joni Larson, who will work with you or your staff to arrange an interview time with me or my IDC colleague, Bob Sorensen. We hope very much that you are willing and available to contribute to this important study.

With best regards,

Steve Conway
IDC Research Vice President, HPC/HPDA and
Steering Committee Member, HPC User Forum
sconway@idc.com, +1 612-381-6939
## Annex #3: Organizations Invited to Participate in the Study

### Table A2

<table>
<thead>
<tr>
<th>Organization</th>
<th>Organization</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deutsches Klimarechenzentrum (DKRZ)</td>
<td>George Mason University</td>
<td>Ruhr-Universität Bochum</td>
</tr>
<tr>
<td>T-Systems Solutions for Research GmbH</td>
<td>Georgia Institute of Technology</td>
<td>RWTH Aachen University</td>
</tr>
<tr>
<td>Chinese Academy of Sciences</td>
<td>GIGABYTE Technology</td>
<td>Rybinsk State Aviation Technical University</td>
</tr>
<tr>
<td>Forschungszentrum Jülich GmbH</td>
<td>Glushkov Institute of Cybernetics NAS Ukraine</td>
<td>Sandia National Laboratories</td>
</tr>
<tr>
<td>JR Marketing Services</td>
<td>GRAU DATA</td>
<td>ScaleMP</td>
</tr>
<tr>
<td>Nikkei Computer</td>
<td>Greek Research and Technology Network</td>
<td>scapos AG</td>
</tr>
<tr>
<td>Tsinghua University</td>
<td>Helmholtz-Zentrum für Umweltforschung GmbH - UFZ</td>
<td>SCCAS</td>
</tr>
<tr>
<td>3DNews/ServerNews</td>
<td>Hewlett-Packard</td>
<td>Schäfer Ausstattungs-Systeme</td>
</tr>
<tr>
<td>451 Research</td>
<td>Customer Insight</td>
<td>High Performance Computing Center Stuttgart</td>
</tr>
<tr>
<td>A*CRC</td>
<td>HLRN</td>
<td>science + computing ag</td>
</tr>
<tr>
<td>A*STAR Computational Resource Center</td>
<td>Höchstleistungsrechenzentrum Stuttgart (HLRS)</td>
<td>Scientific Computing Magazine</td>
</tr>
<tr>
<td>Aalto University</td>
<td>HPCS - University of Cambridge</td>
<td>Scientific Computing World</td>
</tr>
<tr>
<td>Academia Sinica</td>
<td>HPCWire Editorial/Tabor Comm.</td>
<td>SGI</td>
</tr>
<tr>
<td>Academic Computer Center in Gdansk</td>
<td>HPCwire Japan</td>
<td>Shanghai Jiao Tong University</td>
</tr>
<tr>
<td>Acal BFI UK Ltd</td>
<td>HRZ TU-Darmstadt</td>
<td>Shanghai Supercomputer Center</td>
</tr>
<tr>
<td>Adapteva</td>
<td>IBM</td>
<td>Shell</td>
</tr>
<tr>
<td>Advania Data Centers</td>
<td>Iceotope</td>
<td>SICOS BW GmbH</td>
</tr>
<tr>
<td>AGCO/Fendt</td>
<td>ICM, University of Warsaw</td>
<td>Singularis Lab</td>
</tr>
<tr>
<td>Airbus Operation GmbH</td>
<td>IDC</td>
<td>SJTU</td>
</tr>
<tr>
<td>Alpha System AS</td>
<td>IDC</td>
<td>SKODA AUTO a.s.</td>
</tr>
<tr>
<td>Altair</td>
<td>IDC</td>
<td>SoftIron Ltd</td>
</tr>
</tbody>
</table>
### Table A2

**Organizations Invited to Take the Broad Survey on HPC Progress in Europe**

<table>
<thead>
<tr>
<th>Organization</th>
<th>Organization</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altera Corporation</td>
<td>Imperial College London</td>
<td>South Ural State University</td>
</tr>
<tr>
<td>AMK Bonn</td>
<td>Indiana University</td>
<td>Spectra Logic</td>
</tr>
<tr>
<td>ANSYS Germany GmbH</td>
<td>insideHPC, LLC</td>
<td>Springer-Verlag GmbH</td>
</tr>
<tr>
<td>Applied Micro Circuits Corporation</td>
<td>Institute of Computing Technology, CAS</td>
<td>STFC – Hartree Center</td>
</tr>
<tr>
<td>Argonne National Laboratory</td>
<td>Institute of Cybernetics NAS of Ukraine</td>
<td>Storus LTD</td>
</tr>
<tr>
<td>ARM Ltd</td>
<td>Institute of Physics AS CR</td>
<td>Sumitomo Bakelite Co. Ltd.</td>
</tr>
<tr>
<td>Asetek</td>
<td>Institute of Systems, Info Technologies &amp; Nanotech (ISIT)</td>
<td>SUPERCOMPUTERS Magazine</td>
</tr>
<tr>
<td>ASRock Rack</td>
<td>Intel</td>
<td>Supercmico</td>
</tr>
<tr>
<td>Autodesk</td>
<td>InterSect360 Research</td>
<td>Supersmith</td>
</tr>
<tr>
<td>Avangardco IPl</td>
<td>Irish Center for High End Computing (ICHEC)</td>
<td>SUSE</td>
</tr>
<tr>
<td>Bauman Moscow State Technical University</td>
<td>IT Center, RWTH Aachen University</td>
<td>Tateno Dennou, inc.</td>
</tr>
<tr>
<td>Bayer Business Services GmbH</td>
<td>iVEC</td>
<td>Technical University of Valencia</td>
</tr>
<tr>
<td>Bayer CropScience AG</td>
<td>JAMSTEC</td>
<td>Technisch Universität München</td>
</tr>
<tr>
<td>Beihang University</td>
<td>JARA-HPC</td>
<td>Technische Universität Chemnitz</td>
</tr>
<tr>
<td>Bentley University</td>
<td>Johann Wolfgang Goethe University</td>
<td>Technische Universität Darmstadt</td>
</tr>
<tr>
<td>Boeing</td>
<td>Johannes Gutenberg-Universität Mainz</td>
<td>Texas A&amp;M University</td>
</tr>
<tr>
<td>Bonn-Rhein-Sieg University</td>
<td>Jülich Supercomputing Center</td>
<td>Texas Advanced Computing Center</td>
</tr>
<tr>
<td>Bright Computing</td>
<td>Kalray</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>Broadcom</td>
<td>KAUST</td>
<td>The Federal State Unitary Enterprise &quot;Research Institute &quot;Kvant&quot;</td>
</tr>
<tr>
<td>Bull</td>
<td>KCA Ltd</td>
<td>The Institute of Cancer Research</td>
</tr>
<tr>
<td>ByteScale</td>
<td>King Abdullah University of Science &amp; Technology (KAUST)</td>
<td>The Institute of Statistical Mathematics</td>
</tr>
<tr>
<td>CADFEM</td>
<td>KISTI</td>
<td>The Ohio State University</td>
</tr>
<tr>
<td>Cardiff University</td>
<td>KIT / SCC</td>
<td>The Register</td>
</tr>
<tr>
<td>Carnegie Mellon University</td>
<td>KTH Royal Institute of Technology</td>
<td>The UberCloud</td>
</tr>
</tbody>
</table>
Table A2

Organizations Invited to Take the Broad Survey on HPC Progress in Europe

<table>
<thead>
<tr>
<th>Organization</th>
<th>Organization</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td>Kyoto University</td>
<td>The University of Colorado</td>
</tr>
<tr>
<td>Center for Development of Advanced Computing</td>
<td>Kyushu University</td>
<td>The University of Edinburgh</td>
</tr>
<tr>
<td>Center for Nuclear Study, University of Tokyo</td>
<td>Lawrence Berkeley National Laboratory</td>
<td>The University of Tokyo</td>
</tr>
<tr>
<td>CERN</td>
<td>Lawrence Livermore National Laboratory</td>
<td>Tohoku University</td>
</tr>
<tr>
<td>Cherokee Information Services Inc</td>
<td>Leibniz Supercomputing Center</td>
<td>Tokyo Institute of Technology</td>
</tr>
<tr>
<td>Children's Mercy Hospital</td>
<td>Linvision HPC B.V.</td>
<td>Tokyo University of Agriculture and Technology</td>
</tr>
<tr>
<td>CHPC (CSIR)</td>
<td>Magma</td>
<td>Toshiba Electronics Europe GmbH</td>
</tr>
<tr>
<td>CINECA</td>
<td>MAGNA STEYR AG &amp; Co KG</td>
<td>T-Platforms</td>
</tr>
<tr>
<td>CJSC I-Teco</td>
<td>MAN Diesel &amp; Turbo</td>
<td>transtec</td>
</tr>
<tr>
<td>Clemson University</td>
<td>MARIN</td>
<td>Tsinghua University</td>
</tr>
<tr>
<td>ClusterVision</td>
<td>Maxeler Technologies</td>
<td>T-Systems SfR GmbH</td>
</tr>
<tr>
<td>Computing Center (RZG) of the Max-Planck-Society</td>
<td>Memorysolution GmbH</td>
<td>TU Chemnitz</td>
</tr>
<tr>
<td>CoolIT Systems Inc</td>
<td>Mentor Graphics</td>
<td>TU Dortmund</td>
</tr>
<tr>
<td>CoolIT Systems Inc</td>
<td>Météo France</td>
<td>TU Dresden</td>
</tr>
<tr>
<td>CPU24/7</td>
<td>Micron Technology Inc.</td>
<td>TU-Clausthal</td>
</tr>
<tr>
<td>Cray</td>
<td>MOD</td>
<td>UCL (University College London)</td>
</tr>
<tr>
<td>CSC - IT Center for Science</td>
<td>Modular Reality</td>
<td>Ulsan National Institute of Science and Technology</td>
</tr>
<tr>
<td>CSCS and hpc-ch</td>
<td>Mokhurane Technologies</td>
<td>UNICORE Forum e.V.</td>
</tr>
<tr>
<td>CST AG</td>
<td>Moscow State University</td>
<td>UNIST</td>
</tr>
<tr>
<td>CU Boulder</td>
<td>MPI für Meteorologie</td>
<td>Universidad Nacional Autonoma de Mexico</td>
</tr>
<tr>
<td>Czech Technical University in Prague</td>
<td>National Center for High-performance Computing (NCHC)</td>
<td>Università della Svizzera Italiana</td>
</tr>
<tr>
<td>DALCO AG Switzerland</td>
<td>National Center for Supercomputing Applications</td>
<td>Universität Hamburg</td>
</tr>
</tbody>
</table>
Table A2

<table>
<thead>
<tr>
<th>Organization</th>
<th>Organization</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalmine spa</td>
<td>National Institute of Science &amp; Technology Policy (NISTEP)</td>
<td>University Kiel</td>
</tr>
<tr>
<td>Danish Defence Center for Operational Oceanography</td>
<td>National Renewable Energy Laboratory</td>
<td>University of Birmingham</td>
</tr>
<tr>
<td>Danish Defence Center for Operational Oceanography</td>
<td>National Supercomputer Center (Sweden)</td>
<td>University of Bristol</td>
</tr>
<tr>
<td>DataDirect Networks</td>
<td>National University of Defense Technology (NUDT)</td>
<td>University of Chinese Academy of Sciences</td>
</tr>
<tr>
<td>Defence Center for Operational Oceanography</td>
<td>NCSA - University of Illinois</td>
<td>University of Colorado Boulder</td>
</tr>
<tr>
<td>Delft University of Technology</td>
<td>NetApp GmbH</td>
<td>University of Hamburg</td>
</tr>
<tr>
<td>Dell</td>
<td>NICE srl</td>
<td>University of Kansas</td>
</tr>
<tr>
<td>Deutsches Klimarechenzentrum (DKRZ)</td>
<td>Nordic HPC</td>
<td>University of Macedonia</td>
</tr>
<tr>
<td>Discerning Analytics, LLC</td>
<td>Northeastern University</td>
<td>University of Mainz</td>
</tr>
<tr>
<td>DLR (German Aerospace Center)</td>
<td>NSC, Linköpings universitet</td>
<td>University of Manchester</td>
</tr>
<tr>
<td>DNV GL</td>
<td>Nuance Communications</td>
<td>University of Mannheim</td>
</tr>
<tr>
<td>D-Wave Systems</td>
<td>NUDT</td>
<td>University of Muenster</td>
</tr>
<tr>
<td>E4 Computer Engineering</td>
<td>Numascale</td>
<td>University of Nizhni Novgorod</td>
</tr>
<tr>
<td>Eclipse Holdings</td>
<td>Numerical Algorithms Group (NAG)</td>
<td>University of Tokyo</td>
</tr>
<tr>
<td>EMC</td>
<td>OCF plc</td>
<td>University of Tsukuba</td>
</tr>
<tr>
<td>EMCL</td>
<td>Osaka Prefecture University</td>
<td>University of Utah/SCI Institute</td>
</tr>
<tr>
<td>Endress+Hauser Flowtec AG</td>
<td>OstrichSoft</td>
<td>University of Vienna</td>
</tr>
<tr>
<td>ENEA UTICT-HPC</td>
<td>Panasas</td>
<td>University of Warwick</td>
</tr>
<tr>
<td>Energy Efficient HPC Working Group</td>
<td>PARATERA</td>
<td>Universität Rostock</td>
</tr>
<tr>
<td>EPCC University of Edinburgh</td>
<td>PC Week/RE</td>
<td>UPC</td>
</tr>
<tr>
<td>EPFL-Blue Brain Project</td>
<td>PDC / KTH</td>
<td>Uppsala Universitet</td>
</tr>
<tr>
<td>ETP4HPC</td>
<td>Performance Jones L.L.C.</td>
<td>USC / Information Sciences Institute</td>
</tr>
</tbody>
</table>
Table A2

Organizations Invited to Take the Broad Survey on HPC Progress in Europe

<table>
<thead>
<tr>
<th>Organization</th>
<th>Organization</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETRI</td>
<td>Poznan Supercomputing and Networking Center</td>
<td>Verne Global</td>
</tr>
<tr>
<td>European Exascale Projects</td>
<td>Poznan Supercomputing and Networking Center</td>
<td>Vienna University of Technology</td>
</tr>
<tr>
<td>EXTOLL</td>
<td>PRACE</td>
<td>Volkswagen AG</td>
</tr>
<tr>
<td>EXTOLL</td>
<td>Qatar Foundation &amp; Imperial College London</td>
<td>VSB-Technical University of Ostrava</td>
</tr>
<tr>
<td>Finisar</td>
<td>Reetone Parallel Processing Company</td>
<td>Wayne State University</td>
</tr>
<tr>
<td>Fraunhofer Institute for Industrial Mathematics ITWM</td>
<td>Regionales Rechenzentrum der Universität Hamburg</td>
<td>Weizmann Institute of Science</td>
</tr>
<tr>
<td>Friedrich-Alexander-Universität Erlangen-Nürnberg</td>
<td>Rice University</td>
<td>Wellcome Trust Sanger Institute</td>
</tr>
<tr>
<td>FSUE &quot;RDI &quot;Kvant&quot;</td>
<td>Riken</td>
<td>Wroclaw University of Technology, WCSS</td>
</tr>
<tr>
<td>Fujitsu Limited</td>
<td>Rittal GmbH &amp; Co. KG</td>
<td>Xel Electronics Ltd</td>
</tr>
<tr>
<td>Gabriel Consulting Group</td>
<td>Robert Bosch GmbH</td>
<td>Xyratex</td>
</tr>
<tr>
<td>Gartner Inc.</td>
<td>Rogue Wave Software</td>
<td>YarcData</td>
</tr>
<tr>
<td>Gauss Center for Supercomputing e. V.</td>
<td>Rolls-Royce PLC</td>
<td>Yeditepe University</td>
</tr>
<tr>
<td>Ryft Systems, Inc.</td>
<td>RSC</td>
<td></td>
</tr>
</tbody>
</table>

Source: IDC 2015
Annex #4: The Broad Survey Questionnaire

INTRODUCTION. The European Commission has engaged market research firm IDC (www.idc.com) to conduct a study on recent high performance computing (HPC) progress in Europe. You are on a list of individuals whose opinion is important for this study. Please take a few minutes to answer the 6 survey questions. Hit "reply" to return your answers to IDC by Friday, February 13, 2015. Thank you for your help.

IN THE PAST 2-3 YEARS:

Q1: Europe's overall capabilities in HPC have: (Choose ONLY ONE)
   __ a. Grown much stronger
   __ b. Grown somewhat stronger
   __ c. Stayed about the same
   __ d. Grown somewhat weaker
   __ e. Grown much weaker
   __ f. Not sure/don't know

Q2: Access by scientists to supercomputers at PRACE centers has: (Choose ONLY ONE)
   __ a. Grown much easier
   __ b. Grown somewhat easier
   __ c. Stayed about the same
   __ d. Grown somewhat harder
   __ e. Grown much harder
   __ f. Not sure/don't know

Q3: Access by industry to supercomputers at PRACE centers has: (Choose ONLY ONE)
   __ a. Grown much easier
   __ b. Grown somewhat easier
   __ c. Stayed about the same
   __ d. Grown somewhat harder
   __ e. Grown much harder
   __ f. Not sure/don't know

Q4: Europe's ability to develop HPC software has become: (Choose ONLY ONE)
   __ a. Much stronger
   __ b. Somewhat stronger
   __ c. Stayed about the same
   __ d. Somewhat weaker
   __ e. Much weaker
   __ f. Not sure/don't know

Q5: Europe's ability to develop HPC hardware has become: (Choose ONLY ONE)
   __ a. Much stronger
   __ b. Somewhat stronger
   __ c. Stayed about the same
   __ d. Somewhat weaker
   __ e. Much weaker
   __ f. Not sure/don't know

Q6: Europe's position in the worldwide HPC market has become: (Choose ONLY ONE)
   __ a. Much stronger
   __ b. Somewhat stronger
   __ c. Stayed about the same
__d. Somewhat weaker
__e. Much weaker
__f. Not sure/don't know

Comments:

Please hit "reply" to send your answers to IDC. Thank you!
Annex #5: Desk Research Performed for This Study (Partial List)


Desk Research Performed for This Study: How European Countries Fund National Supercomputing Centers:
This section briefly reviews the organization type (government, private), funding sources and budgets of some of the most prominent national supercomputing centers in Europe, as well as national centers in some smaller countries. The predominant funding model is one in which the central government finances 50% or more of the national supercomputing center's entire budget, including the acquisition and upgrading of tier-1 national supercomputing resources as well as operating costs. Given the important role supercomputing plays, central governments typically view this funding as a necessary investment in the economic future of their country.

Germany

- **National Supercomputing Center:** Germany’s Gauss Center for Supercomputing (GCS) is an alliance of the country’s three national HPC centers: HLRS (Stuttgart), LRZ (Munich) and FZJ (Jülich).
- **Funding Sources and Management:** GCS is jointly funded and managed by the German Ministry of Education and Science (Bundesministerium für Bildung und Forschung, BMBF) and the corresponding ministries of the three national states of Bavaria, Baden-Württemberg and North Rhine-Westphalia. The states provide half of the funding for their respective centers and the German federal government provides the other half. Furthermore, the federal government has started a Special Programme on Exascale Computing (SPPEXA [www.sppexa.de](http://www.sppexa.de)) for the development of software. This complements a special program by the Federal Ministry of Science which has since 2010 started three calls for projects on scalable software with a special focus on industrial applications (details at [https://www.gauss-allianz.de/en/projects](https://www.gauss-allianz.de/en/projects)).
- **Budget:** For the period 2007-2017, the federal government and the three state governments together have provided €400 million in funding for GCS. GCS also represents Germany in the PRACE alliance and has benefited from EC financing for PRACE.
- **Other:** The BMBF is separately investing €100 million over the next five years for the D-Grid infrastructure to support scientific collaboration. Germany was one of four European nations that committed to contribute €100 million in resources to the PRACE 1.0 budget. GCS represents Germany in the PRACE alliance and provides three of the current six Tier-0 systems of PRACE.

France

- **National Supercomputing Center:** France has two sites that function as national supercomputing centers: CEA, a secure site that addresses national nuclear security needs, and CINES, The National Computer Center of Higher Education. Another important actor is Agence Nationale de la Recherche (ANR). In the end, however, GENCI (Grand Equipement National de Calcul Intensif) has the central role in HPC in France. Plan Investissement d’avenir is investing €50 million for HPC and is managed by CEA. Also noteworthy is Teratec, an association which unites over eighty technological and industrial companies, laboratories and research centers, universities and engineering schools who want to combine their resources in simulation and high-performance computing.
- **Funding Sources and Management:** GENCI is a civil company (société civile) and is 49% owned by the State, represented by the Ministère en charge de l’Enseignement supérieur et de la recherche, 20% by the CEA, 20% by CNRS, 10% by participating universities, and 1% by INRIA. GENCI is invested with a central coordinating function by these organizations.
- **Budget:** ANR provides €25 million in HPC financing per year.
- **Other:** France was one of four European nations that committed to contribute €100 million in resources to the PRACE 1.0 budget. The Curie supercomputer, owned by GENCI and operated by CEA, is the first French Tier0 system open to scientists through the French participation in
the PRACE research infrastructure. Launched in October 2011 for a three year period, with a budget of €14.5 million euros, the purpose of the Mont-Blanc project, coordinated by BSC (Spain) and including GENCI together with the CEA, is to evaluate the potential of low energy components, such as the technologies used in our mobile phones, for the next generation of supercomputers.

**United Kingdom**

- **National Supercomputing Center**: The UK has no permanent national supercomputing center. Instead, major centers compete periodically for the contract for provide the HPC national academic service across the UK. At present, the Edinburgh Parallel Computing Center has that role. Also of note, the Science and Technology Facilities Council’s Daresbury campus manages the Hartree Center, which has a major role in supporting the HPC needs of industry (as well as academia) in the UK.

- **Funding Sources and Management**: The UK Research Councils coordinate HPC academic research activities.

- **Budget**: The Engineering and Physical Science Research Council manages the budget for national capability, described as "support for excellent, long-term disciplinary and multidisciplinary research in engineering and the physical sciences." The allocation for this HPC-related budget item has been substantial and covers not just investments in supercomputers but also grants for research performed using supercomputers. The largest HPC-specific initiative within this budget is ARCHER, the UK’s national academic supercomputing service. The UK government allocated £113 million (€157 million) for this program in 2014. The Hartree Center was founded in 2012 with £52 million in funding from the UK’s Science and Technology Facilities Council (STFC) to "develop, deploy and demonstrate HPC solutions," typically in partnership with industry.

- **Other**: The UK is a PRACE member but has not been a contributing/hosting member within the PRACE 1.0 period.

**Netherlands**

- **National Supercomputing Center**: SURFsara is the national supercomputing and e-science support center in the Netherlands. SURFsara’s customers include all Dutch universities, a number of large research, educational and government institutions, and the business community. SURFsara has been a partner in large European e-Infrastructure projects including PRACE 1IP, PRACE 2IP, PRACE 3IP, EESI2, EGI.InSPIRE and EUDAT, and partner in HPC-EUROPA2. The 1.6PF Cartesius supercomputer managed by SURFsara is the country’s most powerful.

- **Funding Sources and Management**: Cartesius was funded by SURF, with contributions from the Dutch Organization for Scientific Research (NWO), the Ministry of Education, Culture and Science and the Ministry of Economic Affairs. SURF is the organization in the Netherlands which supports higher education and research in the area of e-infrastructures.

- **Budget**: About €7 million (€3-4 million operating funds plus an average €3 million/year for acquiring supercomputing resources).

**Spain**

- **National Supercomputing Center**: BSC-CNS (Barcelona Supercomputing Center - Centro Nacional de Supercomputación) is the national supercomputing facility in Spain and hosts
the MareNostrum supercomputer. The mission of BSC-CNS is to investigate, develop and manage information technology in order to facilitate scientific progress.

- **Funding Sources and Management:** In 2004, the Ministry of Education and Science, Generalitat de Catalunya (Catalan Government) and Technical University of Catalonia founded the National Supercomputing Center in Barcelona. In 2004, the Ministry of Education and Science, Generalitat de Catalunya (Catalan Government) and Technical University of Catalonia founded the National Supercomputing Center in Barcelona.

- **Budget:** BCS had an initial operational budget of €5.5 million/year to cover the period 2005-2011. The income of the BSC-CNS in 2009 was €20.1 million of which €6.6 M corresponded to the ordinary budget coming from the patrons of the BSC-CNS, the Spanish and Catalan Governments; and €8.1 million from competitive projects. Of particular note, €3.9 million of funding was derived from projects with private companies. In 2009, the BSC-CNS participated in 23 competitively funded EU projects, 37 collaborative projects with industry and 14 national projects.

- **Other:** In 2012, BCS upgraded MareNostrum at a cost of €22.7 million. The Spanish Supercomputing Network links MareNostrum to more than a dozen smaller HPC sites in Spain. BCS is a PRACE tier-0 host member.

**Italy**

- **National Supercomputing Center:** CINECA is Italy's national supercomputing center and the country's PRACE host site. CINECA's Fermi supercomputer is one of the world's most powerful.

- **Funding Sources and Management:** CINECA is a non-profit consortium made up of 70 Italian universities, four Italian Research Institutions and the Italian Ministry of Education. 70% of CINECA's budget is funded by the Italian Ministry of Education University and Research, for services to science and industry. The remaining 30% of the budget comes for providing other services. A framework agreement governs how CINECA and other Italian HPC centers collaborate with industry (PPPs). CINECA is led by a Board of Directors composed of the rectors of the member universities or their delegates, by a representative of CNR (National Research Council) and one of the Ministry of Education, University and Research (MIUR). The Board of Directors is represented by the Chairman, while the General Manager is responsible for the development, organisation and management of the Consortium's activities.

- **Budget:** As a PRACE hosting member, Italy made a commitment to spend €100 million during the course of PRACE 1.0. IDC estimates that Italy's annual monetary budget for HPC is about €20 million.

- **Other:** CINECA also acted as the procuring entity for the PRACE 3IP PCP (pre-commercial procurement) submission of March 9, 2015, representing partners CSC (Finland), GENCI (France), FZJ (Germany) and the University of Edinburgh. The goal of this PCP is clear enough from its title, "Whole System Design for Energy Efficient HPC." If this initiative is accepted by the EU, the budget could total €9.0 million over the proposed 26-month duration. CINECA is led by a Board of Directors composed of the rectors of the member universities or their delegates, by a representative of CNR (National Research Council) and one of the Ministry of Education, University and Research (MIUR). The Board of Directors is represented by the Chairman, while the General Manager is responsible for the development, organisation and management of the Consortium's activities.
Finland

- **National Supercomputing Center**: CSC, the Finnish IT Center for Science, is Finland's national supercomputing center and supports both science and industry. CSC supports a European-wide customer base of thousands of researchers in disciplines such as biosciences, linguistics, chemistry and mathematical modelling.

- **Funding Sources and Management**: CSC is a non-profit limited company whose shares are fully owned by the Finnish state. CSC is directly governed by the Finnish Ministry of Education. The Finnish Funding Agency for Technology and Innovation (Tekes) provides about half of the HPC funding for Finnish universities, research institutes, and industry. Finland's innovative MASI (modeling and simulation) program, 2005-2010, was aimed at boosting the global competitiveness of Finnish firms through the use of HPC. Financing for MASI totaled €100 million over five years, with Tekes providing €53 million of that amount.

- **Budget**: €31 million

Denmark

- **National Supercomputing Center**: Danish Center for Scientific Computing (DCSC).

- **Funding Sources and Management**: DCSC is under the Danish Ministry of Education with government funding allocated for data processing capacity within the area of scientific computing for research assignments.

- **Budget**: €3 million (estimated)

Norway

- **National Supercomputing Center**: Norway has no single national supercomputing center. NOTUR, the Norwegian Metacenter for Computational Science, oversees time allocation for Norway's four supercomputer centers. They are located at the Norwegian University of Science and Technology (NTNU) in Trondheim, the University of Bergen, the University of Tromsoe, and the University of Oslo.

- **Funding Sources and Management**: The Research Council of Norway (Norges forskningsråd), like its Finnish counterpart, provides about half the funding for Norwegian HPC initiatives of national interest. A major thrust is the eVITA program aimed at developing innovative tools to support HPC use in science and industry.

- **Budget**: The eVITA annual budget is about €17 million. The Norwegian Intelligence Service's (NIS) annual budget was quadrupled in 2014 to more than €90 million, from which NIS plans to use a substantial but unspecified amount to acquire a powerful new supercomputer ("STEEL WINTER") for cryptoanalysis.

Sweden

- **National Supercomputing Center**: Like Norway, Sweden has no single national supercomputing center.
• **Funding Sources and Management:** The Swedish National Infrastructure for Computing (SNIC) is a distributed infrastructure that is funded in part by the Swedish Research Council (Vetenskapsrådet) and in part by the participating universities: Chalmers University of Technology, KTH Royal Institute of Technology, Linköping University, Lund University, Umeå University and Uppsala University. SNIC is part of the Swedish Science Council, whose task is to coordinate and develop high-end computing capacity for Swedish research. Prominent among the universities aligned with SNIC is the KTH Royal Institute of Technology in Stockholm.

• **Budget:** In October 2014, KTH installed a 2PF supercomputer, the largest to that date in the Nordic countries. The budget for acquiring the computer and four years of operations (with spending over four years) is about €18 million and comes primarily from SNIC. The SNIC annual budget is €4.8 million (45 MSEK).

• **Other:** The EU FET flagship graphene project is centered at Sweden's Chalmers Institute of Technology and will exploit HPC technology.

**Greece**

• **National Supercomputing Center:** Greece has no designated national supercomputing center, but in 2014 the state-owned company Greek Research and Technology Network (GRNET S.A.) teamed with Cosmos Business Systems to acquire a national supercomputer. IDC estimates the market value of the 180TF, Xeon-based supercomputer at about €6 million.

• **Funding Sources and Management:** The GRNET S.A. state-owned company operates under the auspices of the Greek Ministry of Education - General Secretariat for Research and Technology. Its mission is to provide high-quality infrastructure and services to the academic, research and educational community of Greece, and to disseminate ICT to the general public, including HPC. In 2014, GRNET signed a contract for Greece's first national supercomputer. The national supercomputer was developed under the “PRACE-GR - Developing National Supercomputing Infrastructure and Related Services for the Greek Research and Academic Community” project, which is co-funded by the Operational Program “Attica” and the European Regional Development Fund (ERDF).

• **Budget:** IDC estimates GR-NET's budget at €2-3 million per year.

**Switzerland**

• **National Supercomputing Center:** The Swiss National Supercomputing Center (Italian: Centro Svizzero di Calcolo Scientifico; CSCS) acts in this capacity.

• **Funding Sources and Management:** CSCS is an autonomous unit of the Swiss Federal Institute of Technology in Zurich (ETH Zurich) and closely collaborates with the local University of Lugano (USI). In addition to the computers of the National User Lab, CSCS operates dedicated compute resources for strategic research projects and tasks of national interest. Since 2000, the calculations for the numerical weather prediction of the Swiss meteorological survey MeteoSwiss take place at the Swiss National Supercomputing Center.

• **Budget:** €23.2 million
Annex #6: The ROI from HPC Investments

Measuring the Value of HPC in Europe: Returns on Investments (ROI)

In November 2012, the U.S. Department of Energy’s Office of Science and National Nuclear Security Agency awarded IDC an 8-month grant to create economic models that could be used to track HPC ROI and to help predict, in the aggregate, the returns from investments in HPC. Under this pilot study, which is now complete, IDC tested the economic models by populating them with a limited number (208) of real-world examples. By directly capturing and quantifying ROI achievements, the pilot study fortified the argument that investments in HPC are strongly associated with strong returns. The pilot study also shed light on differences in returns that might be expected from HPC-related investments in basic and applied research, as well as differences by major sector (government, academia, industry) and by scientific and engineering domain.

In 2014, IDC conducted a European specific ROI study for EESI-2. In this study IDC captured detailed ROI information on 143 European HPC projects, of which 84 projects produced innovations and the other 59 projects produced quantifiable financial returns. The 84 reported innovations did not need to be major breakthroughs; smaller, incremental advances qualified, as long as the associated HPC investments were quantified.

For the DOE study and the EESI-2 study, IDC defined a project as a self-contained, completed initiative with a fixed starting date and goal (or set of goals). The ROI findings are based on correlation with HPC use, not HPC-driven causality. Factors other than HPC investments presumably also helped bring about the positive outcomes. It is important to note, however, that the representatives of each of the 143 evaluated projects attributed the positive outcomes primarily to the HPC investments.

The use cases of the 143 projects varied greatly, but typified the kinds of HPC work that have been performed historically within the scientific and industrial domains in question. In scientific domains, the use cases involved clarifying or extending the known science. The industrial use cases nearly always involved upstream research and development, whether to speed the development of better products (e.g., automotive) and processes (e.g., transportation), or to provide deeper insight into "big data" (e.g., financial services, energy exploration, retail).

Although the number of organizations willing to provide IDC with ROI information exceeded our expectations by a factor of more than two (and by more than that in the normally reticent financial services industry), the scope and time frame of the current study made it impractical to ensure that every market segment using HPC in Europe was strongly and proportionately represented.

The ROI Capture-and-Measurement Tools

The successful 2013 pilot study created and tested two correlation-based macroeconomic models and a new innovation index:

- Model 1 captures and measures financial ROI—revenues, profits/cost savings, and job creation—that are closely associated with investments in HPC.
- Model 2 captures and measures non-financial ROI closely linked to HPC investments, that is, based and applied innovations in the public and private sectors.
The new innovation index asks respondents to rank the importance of their innovations on a 1-10 scale that also considers how many organizations use the innovation and its impact on the larger societies. (IDC refined the index four times before concluding that it was appropriate for the requirements of the pilot study.) The self-grading exercise is followed where needed by assessments from domain experts, which on the whole have not differed markedly from the results of the self-grading.

The units this method considers for ROI assessment are HPC investments related to individual projects completed within an organization, rather than the bulk HPC investments of government programs or the annual HPC budgets of organizations. Hence, an organization that completes three HPC-enabled projects might provide three separate ROI examples.

**Findings: ROI Associated with HPC Investments in Europe**

IDC used the capture-and-measurement tools developed during the successful DOE ROI pilot study to help assess the impact of recent HPC investments in scientific and industrial projects carried out within Europe. The pilot study and its findings are contained in IDC’s report for DOE, entitled *Creating Economic Models Showing the Relationship between HPC and the Resulting Financial ROI and Innovation—and How They Can Impact a Nation’s Competitiveness and Innovation*.42

**Revenue/Sales per Euro Invested in HPC**

As Table 11 shows, each euro invested in HPC on average returned an impressive €\1 in increased income. For the academic projects, the ROI was a more modest, but still substantial €30 in additional income (i.e., funding for research grants and other sources) per €1 invested. For industrial projects, the average ROI in revenues generated was a whopping €974 per €1 invested. These ROI figures are higher, but in line with those obtained for U.S. HPC projects in IDC’s 2013 HPC ROI pilot study for the U.S. Department of Energy (DOE).

Even if the average ROI gains were to decline somewhat if a larger sample were taken, it is easy to see from the European (and U.S.) findings why HPC is increasingly recognized as a transformational, game-changing technology by more and more governments around the world.

**Table 11**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Count</th>
<th>Average Revenue ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>Industry</td>
<td>52</td>
<td>974</td>
</tr>
<tr>
<td>Overall Total</td>
<td>59</td>
<td>867</td>
</tr>
</tbody>
</table>

42 For full findings on the 2013 DOE study, go to https://hpcuserforum.com/roi/
Revenue/Sales per Euro Invested in HPC, by Market Sector

Table 12 breaks down the Table 11 findings by market sector. The most modest revenue ROI gains occurred in the evaluated telecommunications projects—but these still averaged €10 in increased top-line revenue/sales per €1 invested in HPC. The largest average ROI gains per €1 invested in HPC were reported by financial services firms (€1590), transportation firms (€1180), and oil/gas companies (€312),

The major differences in the sizes of average financial returns by industry sector are related, not surprisingly, to the role HPC plays in each sector.

- In the financial services industry, even a slight competitive advantage provided by HPC to back-office "quants" can result in large, nearly immediate ROI.
- Similarly, an HPC advantage in upstream exploration can enable oil and gas companies to find and extract energy sources more efficiently, with large, fairly quick financial returns.
- In manufacturing, by contrast, HPC plays a vital but less stellar role. HPC-related ROI is correspondingly less dramatic.

Table 12

<table>
<thead>
<tr>
<th>Industry</th>
<th>Count</th>
<th>Average Revenue ROI (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>26</td>
<td>1,590</td>
</tr>
<tr>
<td>Insurance</td>
<td>1</td>
<td>71</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>O&amp;G</td>
<td>7</td>
<td>312</td>
</tr>
<tr>
<td>Research</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>Retail</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Telecomm</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Transportation</td>
<td>6</td>
<td>1,180</td>
</tr>
<tr>
<td>Environmental Safety</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>Overall Total</td>
<td>59</td>
<td>867</td>
</tr>
</tbody>
</table>

Source: IDC 2014
**Profit/Cost Savings per Euro Invested in HPC**

Table 13 displays ROI in the form of bottom-line gains, that is, cost savings or corporate profits related to HPC investments made for projects. Here again, the academic ROI was impressive—averaging €29 per €1 invested in HPC—even though not as large the €75 average ROI figure for the industrial projects.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Count</th>
<th>Average Profit ROI (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>Industry</td>
<td>52</td>
<td>75</td>
</tr>
<tr>
<td>Overall Total</td>
<td></td>
<td>69</td>
</tr>
</tbody>
</table>

Source: IDC 2014

**Profit/Cost Savings per Euro Invested in HPC, by Market Sector**

Table 14 presents profit/costs savings by market sector. The largest ROI gains in that respect were reported by oil/gas companies (€268 per €1 invested in HPC) and financial services firms (€67 per €1 invested in HPC). The smallest gains, though still substantial, occurred in the telecommunications companies (€10 per €1 invested in HPC) and the insurance firms (€7 per €1 invested in HPC).

<table>
<thead>
<tr>
<th>Industry</th>
<th>Count</th>
<th>Average Profit ROI (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>26</td>
<td>67</td>
</tr>
<tr>
<td>Insurance</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>O&amp;G</td>
<td>7</td>
<td>268</td>
</tr>
<tr>
<td>Research</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>Retail</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Telecomm</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Transportation</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Environmental Safety</td>
<td>1</td>
<td>30</td>
</tr>
</tbody>
</table>
Table 14

**EU ROI: Profit/Cost Savings per Euro Invested in HPC, by Market Sector**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Count</th>
<th>Average Profit ROI (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Total</td>
<td>59</td>
<td>69</td>
</tr>
</tbody>
</table>

Source: IDC 2014

**HPC Investment by Type of Return, Financial**

Table 17 shows the number of financial ROI projects in each beneficial outcome category (using the same categories DOE asked IDC to employ in our 2013 HPC ROI study). Most of the projects fell into the "new approach" and "better product" categories.

Table 17

**EU ROI: Types Of Financial ROI Projects**

<table>
<thead>
<tr>
<th>Primary Financial ROI Area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Approach</td>
<td>28</td>
</tr>
<tr>
<td>Better Products</td>
<td>22</td>
</tr>
<tr>
<td>Discovered Something New</td>
<td>4</td>
</tr>
<tr>
<td>Cost Saving</td>
<td>2</td>
</tr>
<tr>
<td>Helped Society</td>
<td>2</td>
</tr>
<tr>
<td>Helped Research Program</td>
<td>1</td>
</tr>
<tr>
<td>Grand Total</td>
<td>59</td>
</tr>
</tbody>
</table>

Source: IDC 2015

**HPC Investment by Type of Return, Innovations**

As Table 18 indicates, HPC investments required for the 84 evaluated projects that produced innovations were even more modest, on average, than HPC investments for the projects with quantifiable financial ROI. In total, €106 million was invested in HPC resources in the 84 projects that produced innovations, for an average investment of €1.3 million per innovation.
Table 18

EU ROI: HPC Investment by Type of Innovation

<table>
<thead>
<tr>
<th>Primary Innovation Area</th>
<th>Count</th>
<th>Average Invested (€ Million)</th>
<th>Total HPC Investment (€ Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Approach</td>
<td>43</td>
<td>0.5</td>
<td>21.7</td>
</tr>
<tr>
<td>Better Products</td>
<td>18</td>
<td>2.9</td>
<td>51.5</td>
</tr>
<tr>
<td>Discovered Something New</td>
<td>9</td>
<td>0.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Helped Society</td>
<td>8</td>
<td>2.1</td>
<td>17.0</td>
</tr>
<tr>
<td>Cost Saving</td>
<td>5</td>
<td>1.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Helped Research Program</td>
<td>1</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>84</strong></td>
<td><strong>1.3</strong></td>
<td><strong>106.1</strong></td>
</tr>
</tbody>
</table>

Source: IDC 2015

Basic vs. Applied Innovations

As Table 21 shows, both basic and applied innovations occurred in every sector: academia, government, and industry. Not surprisingly, most of the basic innovations happened in academia and most of the applied innovations were made in industry.

Table 21

EU ROI: Basic vs. Applied Innovations

<table>
<thead>
<tr>
<th>Sector</th>
<th># Basic</th>
<th># Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic</td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td>Government</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Industry</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>50</strong></td>
<td><strong>34</strong></td>
</tr>
</tbody>
</table>

Source: IDC 2014
Annex #7: HPC Application Workloads

IDC uses this term to refer to a set of related scientific, engineering or analytical applications, along with any associated infrastructure or support applications (e.g., visualization, data management). Each application workload is characteristic of a one or more market segments. Hence, the set of application workloads for biological sciences differs in important respects from the set used in chemical engineering and other segments.

- **Biological sciences (BioSci).** This workload centers around applications such as genomics, proteomics, pharmacogenomics, pharmaceutical research, bioinformatics, drug discovery, bioanalytic portals, ASP-type service providers, and agricultural research. Computational techniques include database searching and management, molecular modeling, and computational chemistry. These workloads appear in commercial, academic, and institutional research environments. Systems that are specifically targeted for these workloads should be included; systems purchased for more general scientific and R&D environments should be counted in the university and academic, national laboratory and research center, or national defense segments.

- **Chemical engineering (Chem Eng).** This workload centers around applications such as molecular modeling, computational chemistry, process design, and chemical analysis. It includes all chemistry applications that are not directly related to biosciences research and development. These workloads appear in commercial, academic, and institutional research environments.

- **Computer-aided design and drafting (CAD).** This workload centers around applications such as mechanical CAD; 2D, 2.5D, and 3D design and drafting; 3D wireframe; and civil engineering design. Design and drafting applications require graphics capability but are less compute intensive than design engineering and analysis applications. CAD tasks are typically done by designers and drafters. Users are found primarily in discrete manufacturing industries such as automotive, aerospace, heavy machinery, and consumer goods.

- **Computer-aided engineering and mechanical design and analysis (CAE).** This workload centers around applications such as finite element modeling and analysis, mechanical computer-aided engineering, civil engineering, structural analysis, computation fluid dynamics (CFD), crash, NVH, and solid modeling. Like CAD applications, these CAE tasks are used to design automobiles, aircraft, running shoes, ski equipment, sail boards, beer bottles, and other everyday items. Workloads include those tasks generally accomplished by engineers, not drafters.

- **Digital content creation and distribution (DCC&D).** This workload centers around applications such as 2D and 3D animation, film and video editing and production, and multimedia authoring for both CD and Web pages that utilize sophisticated graphics content. This category also includes servers used for image rendering, content management, and distribution of finished products for areas such as film, TV, commercial animation, advertising, product styling, and industrial design. These workloads are developed in large part in concert with scientific visualization research and technologies. In addition, the creation of special effects and animation for motion pictures requires significant amounts of computational capacity. Thus this category is included in technical computing based on a combination of historical affinity and computationally intensive applications.

- **Economic and financial modeling (Econ Fin).** This workload centers around applications such as econometric modeling, portfolio management, stock market and economic forecasting, and financial analysis. The segment includes both trader and computationally intensive non-trader tasks. In this case, we placed this workload in technical computing because of the numerically intensive applications of most applications and their association with economic modeling and simulation-based research.
- Electronic design and analysis (EDA). This workload covers all electrical/electronic tasks, including schematic capture, logic synthesis, circuit simulation, PCB routing, and system modeling.
- Geosciences and geoengineering (GeoSci). This workload includes earth resources-related applications such as seismic analysis, oil services, and reservoir modeling. These applications are used in both institutional research and commercial enterprises. Geoscience can also include such areas as mining, natural resource management, geographic information systems (GIS), and mapping.
- Government laboratories and research centers (Govt Lab). This workload centers around government-funded research and development institutions. These organizations are generally funded at a national or multinational level and may combine both purely scientific research with research in areas of national priority (e.g., cancer research) and/or research for defense-related programs. These users are less bound by strict economic constraints than those performing applications in product development environments. These centers don't normally offer degree programs for students.
- National defense (Defense). This workload centers around applications such as surveillance and signal processing; encryption; command, control, communications, and intelligence (C3I); geospatial image management and analysis; defense research; weapons design; and other national security applications. In addition, we believe that national security organizations are fielding applications that work to identify and track potential security threats through database-oriented pattern-matching applications. Although these applications may not always be numerically intensive, they will be developed and used by organizations that are firmly rooted in technical computing markets. In addition, we believe that these applications will be run in conjunction with traditional security applications such as cryptography and image analysis.
- Software engineering (Software). This workload centers around the development and testing of technical applications and middleware targeted (at least initially) at HPC users. The segment includes technical computers used by third-party software developers. These applications are typically performed by low-end and midrange systems, particularly low-cost technical workstations, and in some cases even PCs.
- Technical management (Tech Mgmt). This workload centers around the support of tasks such as tracking, documenting, and controlling the product life-cycle chain and the scientific research process. Tasks include product data management, maintenance records management and analysis, revision control, configuration management, network management, and project management.
- University and academic (Academic). This workload centers around scientific research and engineering R&D efforts conducted at public or private institutes of higher educations and includes systems sold for both research and educations activities. Privately funded and/or nonprofit research institutes that have a strong academic mission (i.e., work to extend the bounds of public knowledge) are also included in this segment. Applications are typically compute or data intensive and often require high-performance graphics. These users are less bound by strict economic constraints than those performing applications in product development environments. This segment includes NSF sites that are located at universities.
- Weather forecasting and climate modeling (Weather). This workload centers around applications such as atmospheric modeling, meteorology, weather forecasting, and climate modeling. This segment includes systems dedicated to these tasks primarily in the government and defense segments.
- "Other" (Other). This segment includes any technical computing workloads not otherwise specified by the above definitions. Falling into this category are advanced business intelligence/business analytics workloads from the growing number of commercial companies that have been adopting HPC for the first time in order to perform computing tasks that exceed the capabilities of enterprise server technologies.
Newest ARM Development Targeted for the Enterprise Data Center Apr 2015 Doc #lcUS25533715 Robert Sorensen

Total S.A. Retakes the Lead in Energy Sector Supercomputer Race Mar 2015 Doc #lcUS25528815 Steve Conway

The HPC Arms Race Escalates in the Energy Sector Mar 2015 Doc #lcUS25511215 Steve Conway


Los Alamos National Laboratory: Seven Decades of Computing Leadership Jan 2015 Doc #253567 Steve Conway, Earl C. Joseph, Ph.D., Robert Sorensen

IBM’s HPC Efforts: Navigating a Renewed Emphasis on POWER Technology within the OpenPOWER World Dec 2014 Doc #253005 Flash Robert Sorensen, Steve Conway, Earl C. Joseph, Ph.D.

Japan’s NEC Delivers Scalar Supercomputer to Germany’s University of Ulm Dec 2014 Doc #lcUS25339214 Robert Sorensen

NEC’s HPC Vision: Bringing Vector Supercomputing to a Broader Data-Intensive User Base Dec 2014 Doc # 25288 Robert Sorensen, Steve Conway, Earl C. Joseph, Ph.D.

PayPal Says More Fortune 2000 Firms Could Benefit from HPC for Big Data Analytics Dec 2014 Doc # 252836 Steve Conway

Bull Launches an Exascale Program for 2020, But the Vision Extends to Big Data and Beyond Dec 2014Doc # 252771Robert Sorensen, Steve Conway, Earl C. Joseph, Ph.D.


HPC Fabric Wars Are Heating Up November 24, 2014 Doc# lcUS25269814 Steve Conway

DOE Goes All in on IBM-NVIDIA for 300 Petaflops System November 15, 2014 Doc# lcUS25250414 Earl C. Joseph, Ph.D., Robert Sorensen


• Lenovo Completes Acquisition of IBM’s x86 Server Business Sep 2014 Doc #lcUS25176214 IDC Link Jed Scaramella, Matthew Eastwood, Raymond Boggs, Rob Brothers, Steve Conway
• USPS Touts Benefits of HPC for Big Data Sep 2014 Doc #lcUS25123014 IDC Link Steve Conway
• Perspectives on High-Performance Data Analysis: The Life Sciences May 2014 Doc #248348 Update Steve Conway, Chirag Dekate, Ph.D., and Earl C. Joseph, Ph.D.
• Micron Demonstrates Technologies to Address Emerging Challenges in Big Data Applications Dec 2013 Doc # 244843 Technology Assessment Chirag Dekate, Ph.D., Steve Conway, Earl C. Joseph, Ph.D.
• China Eyes 10,000-Fold Data Reduction for Internet of Things Oct 2013 Doc #lcUS24392513 Steve Conway
• Perspectives on Quantum Computing: HPC User Forum, September 2013, Boston, Massachusetts Oct 2013 Doc # 243777 Steve Conway, Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D.
• High-Performance Data Analysis in the Life Sciences: HPC User Forum, September 2013, Boston, Massachusetts Oct 2013 Doc # 243774 Steve Conway, Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D.
• Chinese Research in Processor Designs for High-Performance Computing and Other Uses Oct 2013 Doc # 243502 Chirag Dekate, Ph.D., Steve Conway, Earl C. Joseph, Ph.D.
European Commission

Luxembourg, Publications Office of the European Union
2015, 137 pages

doi:10.2759/034719