SPECIAL STUDY

D2 Interim Report: Development of a Supercomputing Strategy in Europe (SMART 2009/0055, Contract Number 2009/S99-142914)

Earl C. Joseph, Ph.D.
Steve Conway
Chris Ingle
Gabriella Cattaneo
Cyril Meunier
Nathaniel Martinez

Author(s)	IDC: Earl C. Joseph, Ph.D., Steve Conway, Chris Ingle, Gabriella Cattaneo, Cyril Meunier and Nathaniel Martinez
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Addressee officers	Bernhard FABIANEK Performance Computing Officer European Commission DG Information Society Unit F03 — office BU25 04/087 25 Avenue Beaulieu, B-1160 Bruxelles Tel: Email:
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Global Headquarters: 5 Speen Street Framingham, MA 01701 USA P.508.872.8200 F.508.935.4015 www.idc.com

IDC OPINION

This is the Interim Report (Deliverable D2) of the study, "Development of a Supercomputing Strategy in Europe" by IDC, the multinational market research and consulting company specialized in the ICT markets, on behalf of DG Information Society and Media of the European Commission.

This D2 Interim Report presents the main results of the supercomputer market and industry analysis and the overview of main the technology trends and requirements (WP1 and WP2 of the study workplan). With the terms supercomputers or HPC (High Performance Computers) in this study, we refer to all technical computing servers and clusters used to solve problems that are computationally intensive or data intensive, excluding desktop computers. The results presented in this report will feed into the next phase of the study, which is the development of the Strategic Agenda for Supercomputing in Europe, to be presented in the Final Report of the study.

We greatly thank the Technical Working Group contributors for their ideas, insights, and suggestions, which helped to crystallize the findings in this report. The Technical Working Groups are made up of members of this project's Technical and Strategy Committee, along with IDC representatives. External team members included: Hervé Mouren, TER@TEC and Christian Saguez, TER@TEC; Richard Blake, STFC Daresbury Laboratory; Arndt Bode and Herbert Huber, Leibniz-Rechenzentrum/LRZ Munich; and Friedel Hossfeld, Forschungszentrum Jülich.

Findings include:

- Europe is under-investing in HPC, while other nations grew their supercomputer investments dramatically even in 2009, the most difficult year of the global economic recession.

Europe is under investing in HPC, while other nation's investments grew their supercomputer investments dramatically

- HPC use is indispensable for advancing both science and industrial competitiveness.
- Supercomputing revenues (annual spending on systems priced above €375,000, or $500,000) increased by 25% worldwide in 2009, but decreased 9% in Europe.
- HPC research funding in Europe includes a diversity of EU, national and regional programs, and few countries have a coherent HPC development strategy.
- HPC stakeholders from research, industry and academia rank U.S. and Japanese HPC research programs ahead of Europe's research programs.
- There is strong support for expanding PRACE (Partnership For Advanced Computing in Europe) to respond to growing industry demand for HPC capacity.
- The transition to petascale and exascale computing creates opportunities for Europe's scientific and computing communities to return to the forefront of development for the next generation of research and HPC software technologies.

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EXECUTIVE SUMMARY

Supercomputing has become a key element for the competitiveness of knowledge-based economies. But in recent years, Europe has under-invested in High Performance Computing (HPC), both in annual spending on computing resources and in research investments, while other nations' investments grew even during the economic recession. European stakeholders from industry, research, and academia believe that Europe has a chance to jump back to the forefront of development for the next generation of HPC-based research, and for the applications and other software technologies required for the transition to petascale and exascale computing.

European stakeholders from industry, research and academia believe that Europe has a chance to jump back at the forefront of the development of the next generation of HPC

This section presents key findings on the HPC market in Europe, based on the research carried out by IDC on behalf of DG Information Society and Media of the European Commission. Again, the main goal of this project is to develop a supercomputing strategy for Europe, and this Interim Report presents the results of IDC's field research carried out in the period December to March, 2010. The Final Report due out in a few months will present the recommended strategy.

The research conducted for the Interim Report included a broad survey of the European HPC stakeholders (scientific and engineering end users, vendors, and others); in-depth interviews with supercomputing stakeholders from funding agencies and research centers in Europe, the U.S. and Japan; and case studies of four major HPC centers in Europe, to illustrate the situations of centers of this kind.

Although the main focus of this report is on the HPC market and industry in Europe, the supercomputing market is global in scope. To help put the European HPC market in perspective, this report also presents research findings and other information about HPC in other major world regions, particularly North America, Japan, and other areas of the Asia-Pacific region, including developments in China and India.

HPC Market Size

According to IDC's HPC tracking research, the worldwide market for HPC systems was worth about €6.45 billion in 2009. And although the recession pummeled lower-priced HPC systems, the market for high-end HPC systems grew substantially even during the difficult global recession year of 2009, when revenue for HPC systems priced above $500,000 (€375,000) increased by 25% and revenue for HPC systems priced above $3 million (€2.25 million) jumped an impressive 65%.

EU HPC system revenue in 2009 amounted to about €1.9 billion ($2.5 billion), or 29.4% of worldwide revenue, compared with 49.5% for North America, 10.5% for the Asia-Pacific region without Japan, and 9.5% for Japan. EU's share of the worldwide market slipped nearly 2% from the pre-recession 2007 high of 33.1%. During the same period (2007-2009), North America's market share grew nearly 2%, from 47.8% to 49.5%.

IDC forecasts that the worldwide market for HPC systems will expand at a healthy 6.3% compound annual growth rate to surpass €8.3 billion ($11 billion) in 2013.

The Broader HPC Ecosystem

The addition of the other categories, including storage, service, application software, and middleware, to system revenue pushed the aggregate value of the worldwide HPC market in 2009 to €12.9 billion, and to €17.3 billion as forecast for 2013. The revenue growth rate for the non-computer categories has been, and is projected to remain, higher than for the HPC systems. Storage in particular has been growing at a pace several percentage points higher than HPC systems, owing to the "data explosion" associated with running increasingly large, complex HPC problems and workloads.

Aggregate HPC revenue (spending) within the EU amounted to €3.3 billion in 2009. IDC forecasts that total HPC spending within the EU will more than double to surpass €4.5 billion by 2013. As with the worldwide forecast, the compute category is expected to experience the lowest growth rate among the revenue categories.

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"Supercomputers" Segment For Systems Priced at $500,000/€375,000 and Higher

In the "supercomputer" segment for HPC systems priced at $500,000/€375,000 and up, IBM was most often the EU market share leader in 2005-2009, with HP jumping ahead of IBM only in 2008 and otherwise remaining a close second. Together, IBM and HP captured 78% of the EU market in this price band in 2009. The third-place vendor, Bull, accounted for only about 5% of the market.

The Very High End Bracket For Systems Priced at $3 Million/€2.25 Million and Up

The topmost price band, for HPC systems sold for more than $3 million/€2.25 million, is especially relevant for HPC leadership initiatives. In 2009, the most recent historical year, IBM easily led all other vendors by capturing nearly half (46%) of EU revenue for HPC systems in this price band. HP finished second, with about half of IBM's market share (23%), followed by Cray (11%), Bull (9%), and SGI (6%). Only about 5% of the revenue in this highly competitive segment went to "others."

Over the last five years (2005 to 2009), the EU market for these high-end supercomputers grew at a rate of only about 2.7% a year, while the U.S. grew by 14% and the world as a whole grew by 13%. Clearly, the EU is not investing at the same level as many other nations in the critical over-$3 million supercomputer category.

HPC Server Market Suppliers

During the period 2005 to 2008, HP was consistently the leading supplier of HPC systems in the EU region, with IBM running second and Dell a more distant third. In 2009, IBM exceeded HP by a small amount. In 2009, the EU HPC market share for these three vendors totaled 77%, leaving less than one-quarter of the market for all others to share. The only EU-based vendor on the list, Bull, had 2009 EU HPC market share of only 1.8%. Note, however, that the "Other" category was really the third-place finisher, ahead of Dell with 11.6% market share. This shows that opportunities still exist for small HPC system vendors in the EU region, and that the barriers to market entry are not overly difficult to surmount. This market openness is related to the fact that a large majority of contemporary HPC systems are based on standard technologies, especially x86 processors from Intel and AMD.

The Broader HPC Ecosystem

- **HPC storage suppliers.** In 2009, the HPC storage market was worth €2.2 billion ($3.0 billion) worldwide and €530 million ($707 million) in the EU alone.

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- **HPC service market suppliers.** "Service" refers here to the contractual service and support of HPC systems, rather than to special after-market services provided by suppliers. In 2009, the HPC service market amounted to €1.2 billion ($1.6 billion) worldwide and €304 million ($405 million) in the EU. Most service continues to be provided by hardware system vendors.

- **HPC applications software suppliers.** Software applications, also known as "programs" or "codes," enable users to carry out specific tasks, such as word processing on personal computers or climate modeling on HPC systems. Government and academic users of large HPC systems typically employ application software that they have created themselves ("in-house codes") or that has been created by some other government or academic organization for common use ("community codes"). Industry is typically far more reliant on application software that is purchased from and maintained by commercial software firms called independent software vendors (ISVs) — although ISV software may also be used in government and academia.

- **HPC management software suppliers.** Software at work between user applications and the operating system has played an increasingly important and diverse role. From their intermediate position, these programs perform a wide variety of crucial linking, mediating, and control functions. This category, commonly called middleware, accounted for €825 million ($1.1 billion) worldwide and €223 million ($297 million) in the EU in 2009. Companies active in this market include Platform Computing and Altair Engineering.

HPC Case Studies

The report presents four case studies of leading European HPC users, including CINECA, the Italian national supercomputing center for science and research; HLRS (High Performance Computing Center Stuttgart, in Germany), one of the three nodes of the German supercomputing network, serving both research and industry; SARA Computing and Networking Services, a hybrid organization comprising the national supercomputing agency in the Netherlands and the SARA managed services business; and CERN, the European organization for nuclear research and the initiator of the LCG (LHC Computing Grid) project, based in Switzerland. These case studies highlight the increasing demand for supercomputing capacity, the need for European-level cooperation to respond to these needs, and the main benefits for research and industry from the use of HPC.

The report presents 4 case studies of leading European HPC users

Stakeholders' Opinions on HPC

A full 89% of those who responded to the survey said HPC is extremely important for scientific leadership, 11% felt it is important, and no one felt it isn't important. 66% responded that HPC is extremely important for industrial competitiveness, 34% felt it was important, and no one felt it wasn't important for this purpose.

89% of those who responded to the survey felt HPC was extremely important for scientific leadership, 11% felt it was important, and no one felt it wasn't important.

The top areas that the stakeholders said the EU should focus on in developing a stronger HPC leadership position were as follows:

- HPC applications and applications scaling

- The use of HPC to solve important scientific problems

- The use of HPC to solve important engineering problems

According to the HPC stakeholders, the areas of expertise most needed for an EU HPC strategy fall into these main categories:

- Expertise in parallel programming for highly parallel HPC systems (i.e., expertise in writing highly scalable application software)
- Expertise in creating advanced software algorithms
- The ability to port and optimize applications for new hardware architectures, including heterogeneous architectures that include newer processor types

Many respondents said the PRACE structure would be a good place to begin any EU HPC initiative.

Major HPC Issues That Impact the Development of HPC

Software hurdles will become a top priority for most users. This trend is driven heavily by multicore processors and hybrid systems, accompanied by weak application scaling and hardware utilization. The challenges are how to deliver strong performance to users on their applications, and how to make optimal use of new processor and system designs.

Software hurdles will become a top priority for most users.

The increase in the number of processors (CPUs) and nodes in the average HPC system is creating significant IT challenges, especially managing complexity, providing power and cooling, and ensuring efficient application scaling and hardware utilization. Storage and data management also continue to grow in importance for HPC datacenters, driven by the increasing "data explosion."

Economic And Scientific Returns From HPC

HPC-based computer simulation has become a fundamental driver of scientific discovery in many disciplines and is often referred to as the "third pillar" of scientific discovery, complementing traditional theory and experimentation). Supercomputers are a tool for researching scientific areas in ways that were previously impossible to pursue. HPC typically allows for dramatically faster time-to-solution and time-to-discovery. Scientific and industrial organizations often find it difficult to quantify their returns from using HPC, yet some things are clear:

- A growing number of Nobel laureates have relied heavily on HPC for their achievements.
- In academia, HPC use has spread from its established strongholds in the physical sciences to the social sciences and the humanities.
- In an IDC study described elsewhere in this report, 97% of the industrial firms that had adopted HPC said they could no longer compete or survive without it.
- HPC use has saved lives and property time and again by predicting severe storms.
- In the automotive and aerospace industries, HPC has dramatically reduced the time-to-market and increased the safety and reliability of new vehicle designs.
- Some large industrial firms have cited savings of $50 billion or more from HPC usage.

A growing number of Nobel laureates have relied heavily on HPC for their achievements.

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Investment Levels Required For HPC Leadership

As noted elsewhere in this report, a single leadership-class supercomputer can cost €75 million ($100 million) or more today, and a U.S. government agency has estimated the price for developing an exascale supercomputer at more than $1 billion (€750 million).

The HPC investments required for scientific and economic success include many areas in addition to the cost of the computers. The most critical resource is human expertise, including the scientists and researchers as well as the experts in using the supercomputers. There is a growing worldwide shortage of HPC talent, due to an aging HPC workforce and a scarcity of new graduates in various HPC fields.

The bad news is that Europe has been falling behind in making the required investments to acquire the largest computers. The good news is that HPC leadership has changed hands multiple times in recent decades, moving from one country and region to another. Not only the European HPC stakeholders, but also their counterparts in the U.S. and Japan believe that with a differentiated strategy, and sufficient investment and collective willpower, Europe can be a global leader in HPC.

Recommendations For Europe's HPC Direction

This report focuses on the historic and current market conditions in Europe, based on the collected input from a broad set of HPC stakeholders on a broad range of HPC topics. The recommended strategy for HPC in the EU will appear in the final report that is scheduled to be submitted to the European Commission by the end of July 2010. Both this interim report and the final report will be posted for public comment on the Web site IDC created especially for this project (www.hpcuserforum.com/EU).

1.0 ABSTRACT

1.1 Study Highlights

This section summarizes the study findings in short bullets, so that the reader can quickly review the main results of the research.

- 89% of those who responded to the survey felt HPC was extremely important for scientific leadership, 11% felt it was important, and no one felt it wasn't important.
- 66% felt that HPC was extremely important for industrial competitiveness, 34% felt it was important, and no one felt it wasn't important.
- 94% said "extremely," 6% said "important," and no one said "not important" when asked if it was important for your own country to have access to leading HPC systems.

94% said extremely, 6% said important, no one said "not important" when asked if it was important for your country to have access to leading HPC systems

- The top areas that the EU should focus on in developing a stronger HPC leadership position included:
  - HPC applications and applications scaling
  - The use of HPC to solve important scientific problems
  - The use of HPC to solve important engineering problems
- The survey respondents see the areas of expertise most needed from HPC user organizations as falling into these main categories:
  - Expertise in parallel programming for highly parallel HPC systems
  - Expertise in creating advanced software algorithms
  - The ability to port and optimize applications for new hardware architectures, including heterogeneous architectures that include newer processor types
- Survey respondents also provided their opinions on how the EU member states should collaborate toward the goal of conducting research at sustained petascale and exascale speeds. The main ideas run along these lines:
  - The member states should form multinational projects focused on specific scientific or technology issues.
  - The member states should promote the formation of regional collaborations in areas of the EU (e.g., Nordic countries, Mediterranean countries). The collaborations should focus on the scientific and industrial priorities of each area.
  - The member states should formalize ("institutionalize") their existing HPC partnerships.
  - Many respondents said the established PRACE structure would be a good place to begin any EU HPC initiative.

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- The survey respondents' ideas for the best funding models to pursue HPC goals in Europe included:

  - Provide an EU-wide framework (such as PRACE) to drive toward HPC goals.

  - Create sustained, multi-year funding.

  - Focus funding most heavily on a limited number of well-defined scientific and industrial problems, and use a cost-benefit analysis to identify these problem domains.

  - Focus more on software than hardware.

  - Base access heavily on grants awarded through peer-reviewed proposals.

1.2 HPC Technology Issues Impacting The Future of HPC

Factors Driving HPC Growth

HPC has grown quickly for a number of reasons:

- The price and price/peak performance of HPC clusters has redefined the cost of technical computing.

The price and price/peak performance of HPC clusters has redefined the cost of technical computing.

- At the same time, "live" science and "live" engineering costs have escalated. Plus, time-to-solution is months faster with simulations.

- Global competitiveness is driving R&D and better product designs.

- The performance of standard x86 microprocessors on technical applications is weak, driving buyers to purchase a much larger number of processors.

- New materials and approaches require rewriting the "books and tables," which takes years. This makes HPC simulations faster solutions.

Major HPC Trends

The major trends in HPC today are as follows:

- The "supercomputer" segment for HPC systems priced at $500,000 (€375,000) and up is a high-growth market. Even in the midst of the current recession, it grew 25% in 2009.

- HPC datacenters are facing major challenges in power, cooling, real estate, and system management. Storage and data management also continue to grow in importance, driven by the increasing "data explosion."

HPC datacenters are facing major challenges in power, cooling, real estate, and system management. Storage and data management also continue to grow in importance, driven by the increasing "data explosion."

- Software hurdles will become a top priority for most users. This trend is driven heavily by multicore processors and hybrid systems, accompanied by weak application scaling and hardware utilization. The challenges are how to deliver strong performance to users on their applications, and how to make optimal use of new processor and system designs.

- SSDs will gain momentum and could redefine storage. (An SSD, or solid-state drive, uses solid-state memory to store data.)

1.3 Economic And Scientific Returns From HPC

HPC-based computer simulation has become a fundamental driver of scientific discovery in many disciplines and is often referred to as the "third pillar" of scientific discovery, complementing traditional theory and experimentation. Supercomputers are a tool for researching scientific areas in ways that were previously impossible to pursue and allow for dramatically faster time-to-solution and time-to-discovery. Scientific and industrial organizations often find it difficult to quantify their returns from using HPC, yet some things are clear:

- A growing number of Nobel laureates have relied heavily on HPC for their achievements.
- In academia, HPC use has spread from its established strongholds in the physical sciences to the social sciences and the humanities.
- In an IDC study described elsewhere in this report, 97% of the industrial firms that had adopted HPC said they could no longer compete or survive without it.
- HPC use has saved lives and property time and again by predicting severe storms.
- In the automotive and aerospace industries, HPC has dramatically reduced the time-to-market and increased the safety and reliability of new vehicle designs. Some of these firms have cited savings of $50 billion or more from HPC usage.

Countries are investing in HPC because HPC can affect the balance of economic and political power, as described in *Massive HPC Systems Could Redefine Scientific Research and Shift the Balance of Power Among Nations* (IDC #219948, September, 2009).

Countries are investing in HPC because HPC can affect the balance of economic and political power

1.4 Investment Levels Required for HPC Leadership

The investments required for scientific and economic success include many areas in addition to the cost of the computers. The most critical area is human expertise, including the scientists and researchers as well as the experts in using the supercomputers. There is a growing worldwide shortage of HPC talent due to an aging workforce and a scarcity of new graduates in various HPC fields (see the soon to be published DOE HPC Talent study at: www.hpcuserforum.com).

Investment requirements are growing quickly for the largest HPC systems:

- In the 1980s and 1990s, €26 million ($35 million) was the price of the largest supercomputers.
- In the late 1990's, €75 million ($100 million) was the price of the largest supercomputers.

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- In 2000, the Earth Simulator and DARPA set a new level of €190-€225 million ($200-$300 million) for the top supercomputers.

- Now, the U.S. government expects to spend at least $1 billion (€750 million) for a single exascale system, including development R&D costs.

the Earth Simulator and DARPA set a level of $250 to $300 million for one supercomputer s (€150-€200 million)

The bad news is that Europe has been falling behind in making the required investments to acquire the largest computers. The good news is that HPC leadership has often changed by country.

1.5 Potential EU HPC Application Focus Areas

The HPC-enabled scientific and engineering areas most often proposed for leadership were as follows:

- Clean energy (including nuclear reactor design/operation, oil and gas exploration, smart electrical grids, clean water, fusion energy, and other alternative energy research)

- Climate modeling and severe weather forecasting

- Physics (e.g., the Large Hadron Collider)

- Aerodynamics and other automotive/aerospace methods

- Chemistry, pharmaceutical, and other bio-life sciences research

Clean energy (including nuclear reactor design/operation, oil and gas exploration, smart electrical grids, clean water, fusion energy, and other alternative energy research)

1.6 Initial Observations About The Potential EU HPC Direction

The recommended HPC strategy ideas and implementations will appear in the final report that is scheduled to be submitted to the European Commission by the end of July 2010. In this report, we highlight the suggestions made by HPC stakeholders regarding the future direction of HPC in Europe. Both this Interim report and the final report will be posted for public comment on the project Web site (www.hpcuserforum.com/EU).

1. HPC Use is Indispensable For Advancing Science and Industrial Competitiveness

HPC-based modeling and simulation has become firmly established as the third branch of scientific inquiry, complementing traditional theory and physical experimentation. All components of the research done by IDC for this study support the notion that science should be the primary beneficiary of an EU HPC strategy. Every one of the respondents in the broad survey of the HPC community in Europe agreed that HPC is "extremely important" (89%) or "important" (11%) for scientific leadership. As one HPC stakeholder said, "The number of researchers who have migrated from the two traditional methodologies to computer modeling has become so significant that scientific leadership cannot be achieved without a significant presence in HPC."

"The number of researchers who have migrated from the two traditional methodologies to computer modeling has become so significant that scientific leadership cannot be achieved without a significant presence in HPC."

2. It Would be Very Beneficial if Both Science and Industry Have Substantial Access to EU HPC Systems

In surveys and in the in-depth interviews conducted for this report with key HPC leaders in Europe, all but one of the interviewees stressed that not only science, but also European industry must have substantial access to EU-sponsored HPC systems. They argued that this is essential for European industrial competitiveness and economic advancement.

3. Europe is Under-Investing in HPC at a Time When Other Nations Are Ramping Up

Spending in the HPC "supercomputer" market segment for systems priced at $500,000 (€375,000) and up is an important general measure of HPC leadership. In 2005–2009, which includes the 2008 and 2009 recession years, North America's 5.5% growth rate outpaced the worldwide average, as did Japan's 10.7% on a much smaller base. EMEA's revenue figure remained essentially flat (0.5% CAGR) during this period, meaning that EMEA has barely participated in the recent resurgence of high-end system purchasing.

4. Europeans Rank U.S. and Japanese HPC Research Programs Ahead of Europe's

The survey respondents most often named U.S. and Japanese programs as the most successful in the world. In fact, non-European HPC research programs occupied the top six positions in the ranking, with the PRACE program in the seventh position.

5. There is Strong Support for Expanding PRACE

In the broad survey, the PRACE and DEISA programs were mentioned most often by far as the most successful HPC research programs in Europe. There was strong support for using the established PRACE organization and its tier 0, 1, 2 HPC center hierarchy as the jumping-off points for an EU HPC strategy. This might require expanding the mission of PRACE to support a strategy driven by specific scientific, engineering, and technology goals.

6. HPC Investment Should Focus on the Science and Engineering Areas Where Europe Can Excel

There was strong support for focusing most heavily on computational science and engineering areas where Europe already has the potential to be a global leader. Among the most frequently mentioned areas were clean energy, climate modeling, bio-sciences, materials science/nanotechnology, oil and gas exploration/production, and aeronautics and crash simulation.

7. Funding of HPC System Software and Applications Development is at Least as Important as Funding HPC Hardware Technologies and Integrated Systems

There was also a strong consensus among the survey and interview respondents that software development will be more important than hardware development for determining future leadership in the global HPC market, and that world-class developers in multiple important software domains exist within Europe today.

"Algorithm development will be key and is what will allow people to get more than 3% of the performance of an exascale computer. Europe has some real strengths here."

"Algorithm development will be key and is what will allow people to get more than 3% of the performance of an exascale computer. Europe has some real strengths here."

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8. The EU Should Consider Investing in Pre-Competitive HPC Technology Areas

Although there was a heavy consensus that Europe should maintain open procurements for competitive-stage HPC products and services, there was also a strong belief that the EU should promote the growth of the EU-based vendor community by providing it with funding support and advantages in procurements for the development of pre-competitive, enabling technologies.

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2.0 REPORT INTRODUCTION AND BACKGROUND

This is the Interim Report (Deliverable D2) of the study "Development of a Supercomputing Strategy in Europe" by IDC, the multinational market research and consulting company specialized in the ICT markets, on behalf of DG Information Society and Media of the European Commission. This Interim report presents the main results of the supercomputer market and industry analysis and the overview of main technology trends and requirements (WP1 and WP2 of the study workplan). The report presents the results of the field research carried out in the period December 2009-March 2010, through a broad survey targeted at HPC industry, research and academia stakeholders, in-depth interviews with supercomputing stakeholders from funding agencies and research centers in Europe, the U.S. and Japan.

The study team has opened a dedicated section in the HPC User Forum Web site to gather comments and promote interaction with the HPC stakeholder community (www.hpcuserforum.com/EU). This will be particularly useful for the next phase of the study, which is the development of the Strategic Agenda for Supercomputing in Europe, to be presented in the final report. This report will include the specific recommendations for building an HPC strategy in Europe.

2.1 Focus and Scope

This study is focused on the supercomputer or High Performance Computing (HPC) market, which refers to all technical computing servers and clusters used to solve problems that are computationally intensive or data intensive, excluding desktop computers. The supercomputer market is a global one, but the main focus of this report is on the European Union's market and industry, and their comparison with the other main world regions, particularly North America and Asia-Pacific, mainly Japan (but also the emerging activities in China and India).

In this report, the designation EU stands for the European Union and refers collectively to the 27 member states: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. EU figures in the tables represent the total of HPC spending by the member states themselves and by the European Commission.

The designation EU+ includes the EU member states plus Norway and Switzerland.

2.2 Report Layout

After the Executive Summary, Abstract, and this Introduction, the report is structured as follows:

- The next chapter presents the main data on the HPC market size and structure (chapter 3), followed by the European HPC market size and structure (chapter 4).
- The European user application sectors are presented in chapter 5.
- The European HPC suppliers are in chapter 6.

- The results of the survey of HPC stakeholders are in chapters 7 to 14:
  - Demographics are in chapter 7
  - The importance of HPC is covered in chapter 8
  - Key application and use areas are covered in chapter 9
  - EU HPC strengths, weaknesses, opportunities and threats as seen by the survey stakeholders are in chapter 10
  - Major HPC challenges are in chapter 11
  - Examples of successful HPC research programs are in chapter 12
  - HPC market structure, funding, collaborations, and business models are in chapter 13
  - Stakeholders' general suggestions about the future of HPC and what they would like the EU to think about are in chapter 14
- HPC contributions to science and the economy are addressed in chapter 15.
- Investments required to lead in HPC are covered in chapter 16.
- Broad technology issues impacting the future of HPC are in chapter 17.
- The findings from the in-depth interviews with HPC opinion leaders and funders are in chapter 18.
- The four HPC case studies are in chapter 19.
- Initial ideas from the Technical Working Groups are summarized in chapter 20.
- A list of the EU HPC programs appears in chapter 21.
- Chapter 22 contains the appendices:
  - Overviews of HPC EU programs
  - IDC HPC reports and studies (for additional insight)
  - HPC stakeholder organizations that were invited to participate in the study
  - The stakeholder survey questionnaire

2.3 Methodology Overview

This study was conducted under the SMART 2009/0055, Contract number 2009/S99-142914, for the project entitled, "The Development of a Supercomputing Strategy in Europe." This is the D 2 Interim Report, and it contains Work Products one and two, as described in the contract.

The chief goal of IDC's methodology for the Interim Report was to capture, within the limited timeframe available (approximately four months), the opinions of a reasonably large, representative sampling of the European HPC community, along with key individuals in the worldwide HPC community, with respect to the development of a European HPC strategy. In pursuit of this goal of openness and transparency, IDC employed the following methods:

- **Broad Survey of the European HPC Stakeholders.** In February 2010, IDC distributed an extensive, custom-designed questionnaire to 321 targeted HPC community members representing all EU and EU+ countries, 11 other European countries, as well a few key individuals in Canada, Japan, and the U.S. (in order to capture perspectives on European HPC from other regions of the world). The primary survey questionnaire is in the appendix of this report, along with the list of organizations that were invited to participate in the survey or otherwise contributed ideas, suggestions, and recommendations. To encourage candor, IDC assured survey respondents that their comments would remain anonymous.

- **In-Depth Interviews with HPC Leaders.** During February and March 2010, IDC also conducted in-depth interviews, in person or by phone, with national funding agencies of EU member states; representatives of European HPC programs (PRACE, DEISA, et al.); senior officials of HPC centers in Europe; other HPC industry experts in Europe, the U.S. and Japan; and senior officials of HPC vendors in Europe, the U.S., and Japan. These interviewees included some of the most well respected, highly knowledgeable individuals in the European and worldwide HPC communities. The interviews typically lasted an hour or longer each. To encourage candor, IDC assured interviewees that their comments would remain anonymous.

- **Four HPC European Case Studies.** IDC also interviewed and developed case studies on four leading European HPC centers, including CINECA, the Italian national supercomputing center for science and research; HLRS (High Performance Computing Center Stuttgart, in Germany); SARA Computing and Networking Services; and CERN, the European organization for nuclear research based in Switzerland. The case studies are meant to illustrate the situations and challenges faced by leading European HPC centers, of which there are many others.

- **The Technical and Strategy Committee (TSC).** Because of their close understanding of relevant research programs, HPC centers, vendors, and users within the HPC market in Europe, the five individuals in this group provided invaluable consultation to IDC in the formation of this report. In particular, the TSC members, in various combinations, constituted the Working Groups whose perspectives appear under that designation in this Interim Report. The TSC members are: Hervé Mouren and Christian Saguez, TER@TEC; Arndt Bode and Herbert Huber, Leibniz-Rechenzentrum/LRZ Munich; Friedel Hossfeld, Foreschungszentrum Jülich; and Richard Blake, Daresbury Laboratory.

- **Special EU HPC Web site.** To enable comments from anyone in the HPC community, IDC also designed and deployed a special Web site (www.hpcuserforum.com/EU) that will remain live through the duration of this project and beyond. IDC emailed the more than 3,300 individuals on its European and worldwide HPC community contact lists, inviting them to visit the Web site and post comments. The Interim Report, Final Report and other relevant documents will be posted on this public Web site for comment as well.

- **IDC HPC Research Studies, including 25 years of technical server shipment data.** Each year, IDC conducts 10-12 major HPC-related research studies, most of them worldwide in scope and including interviews with members of the HPC community in Europe. IDC brought recent studies to bear on behalf of this report. The most relevant studies are described in the "IDC Research Summary" portions of the Working Groups section of this report. In addition, IDC typically organizes two HPC conferences in Europe each year and two in the U.S., called HPC User Forum meetings (www.hpcuserforum.com). The results of these conferences, especially presentations by leaders from Europe's HPC community, also informed this report.

3.0 HPC MARKET SIZE AND STRUCTURE

3.1 Definition of Technical Computing (Also Referred to as HPC)

IDC uses the term *technical computing and high-performance computing (HPC)* to encompass the entire market for computer servers used by scientists, engineers, analysts, and other groups using computationally intensive modeling and simulation applications. Technical servers range from small servers costing less than $5,000 to the large-capability machines valued in hundreds of millions of dollars. In addition to scientific and engineering applications, technical computing includes related markets/applications areas including economic analysis, financial analysis, animation, server-based gaming, digital content creation and management, business intelligence modeling, and homeland security database applications. These areas are included in the technical computing market based on a combination of historical development, applications type, computational intensity, and associations with traditional technical markets.

Technical Computing Server System Configuration

Technical applications tend to have an insatiable appetite for computing power. They want to commandeer as much as they can of the available capacity and capability of the HPC systems they are run on, in pursuit of advances in science, engineering, and large-scale data modeling. Among the characteristic requirements of technical applications are high computational capacity, high memory-to-processor data throughput, and fast-streaming I/O. Examples of the vendors and brands for these systems include, but are not limited to, Dell, IBM, and HP. Although clusters based on standard technologies and system designs dominate the HPC market, there are also symmetric multi-processing systems (SMPs) such as the IBM p690, HP Superdome, and Sun Fire 2500; NUMA architectures such as the SGI Altix series; and vector computers such as the Cray X1 or the NEC SX-8.

Tracking Methodology

Each quarter, IDC analysts conduct interviews with major hardware original equipment manufacturers (OEMs) in the technical computing space to gather information on each vendor's quarterly sales. Specifically, IDC collects data on the number of HPC systems sold, system revenue, system average selling price (ASP), the competitive segment that a system falls into, architecture of the system, average number of processor package per system, average number of nodes for each system sold, system revenue distribution by geographical regions, and system revenue distribution by operating systems.

IDC records all of this information and merges it into a master database that contains over 50 data fields. Some of these fields contain actual data gathered from the OEMs as described previously, some are calculated based on the actual data, and some are only used for special data cuts. IDC refers to this data structure as the "HPC QView," where "Q" stands for quarterly. In addition to the HPC QView, IDC maintains other HPC technical computing data structures, for example:

- HPC end-user demand-side data structure
- HPC application/industry segmentation data structure

- HPC ISV database

IDC Technical Computing Server Revenue Accounting Rules

Initial System Shipment

Initial system shipment (ISS) characterizes the first sale of an HPC server system (previously referred to as a "new footprint"). It also includes major upgrades to existing systems. An ISS unit consists of processors, memory, embedded disk storage, cluster interconnect hardware/software, any bundled operating system, compiler, math/statistical library, parallel computing, database, and networking software that would typically be configured when it leaves the OEM's factory floor. Note that separately acquired software is not included. Often, the database software is purchased separately as is most ISV application software. IDC recognizes a shipment only when the complete system or cluster is installed and accepted. In addition, major upgrades that include processors are treated as an ISS in the quarter when the system is accepted. External user storage and all paid services are excluded from the ISS revenue value. If a system is paid for over a number of quarters, for example via service or R&D contracts, IDC determines a value for the whole system when it is finally accepted by the buyer.

IDC Technical Computing Market Segmentation Definitions

Based on input from HPC vendors and end users, IDC created four price band ("competitive") segments to reflect the trends in the HPC technical server market. These segments are based on average selling prices and are defined as follows:

- **Supercomputers:** Technical servers that sell for $500,000 (€375,000) or more
- **Divisional servers:** Technical servers that sell for $250,000–$499,999 (€187,500-€374,999)
- **Departmental servers:** Technical servers that sell for $100,000–$249,999 (€75,000-€187,499)
- **Workgroup servers:** Technical servers that sell for less than $100,000 (€75,000)

Market Growth Rate Metric

In Table 1, the last column shows the yearly growth rate as a CAGR (Compound Annual Growth Rate). This reflects the yearly rate required to go from the starting point to the end point. This metric ignores variation between the end points, as it only uses the end points in the calculation.

Note: "systems" include only the compute component and excludes storage, software, etc. In this and subsequent tables, the terms "system" and "server" are used synonymously.

3.2 The Worldwide HPC Market

HPC Technical Server Revenues and Units

As Table 1 shows, the worldwide market for HPC systems was worth about €6.48 billion in 2009, down from the pre-recession 2007 figure of about €7.6 billion. The

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HPC system market was less heavily affected by the worldwide economic downturn than most other IT markets. And although the recession pummeled lower-priced HPC systems, the market for high-end HPC systems grew substantially even during the difficult year of 2009, when revenue for HPC systems priced above $500,000 (€375,000) increased by 25% and revenue for HPC systems priced above $3 million (€2.25 million) jumped an impressive 65%.

TABLE 1

Worldwide HPC System Revenue (€000) and Units, 2005–2009

Data	2005	2006	2007	2008	2009	CAGR (05–09)
WW Revenues	6,906,156	7,540,933	7,557,317	7,328,887	6,477,836	-1.6%
WW Units	191,283	236,147	230,724	174,091	104,604	-14.0%

Source: IDC, 2010

Note: This includes server spending only

Worldwide HPC System Revenue, by Region

Table 2 splits worldwide HPC system revenue by global region, using IDC's standard regional divisions. Later on in this section of the report, we present a series of tables, specially customized for this study, that strip out the small Middle East and Africa components to show revenue figures for the EU27 member states ("EU") and for the EU27 states plus Norway and Switzerland ("EU+"). First, however, we present IDC standard tables that do not employ special assumptions and modeling.

As Table 2 indicates, Europe HPC system revenue in 2009 amounted to about €1.9 billion, or 29.4% of worldwide revenue, compared with 49.5% for North America, 10.5% for the Asia-Pacific region without Japan, and 9.5% for Japan. Note that Europe's share of the worldwide market slipped nearly 2% from the pre-recession, 2007 high of 33.1%. During the same period (2007–2009), North America's market share grew nearly 2%, from 47.8% to 49.5%.

TABLE 2

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

Data	2005	2006	2007	2008	2009	CAGR (05–09)
Total WW Revenue	6,906,156	7,540,933	7,557,317	7,328,887	6,477,836	-1.6%
North America Revenue	3,423,290	3,723,609	3,616,377	3,701,752	3,208,180	-1.6%
Europe Revenue	2,112,759	2,317,138	2,427,108	2,243,779	1,848,628	-3.3%
** Percent of WW	30.6%	30.7%	32.1%	30.6%	28.5%	
Asia/Pac Revenue	801,801	828,395	922,943	859,244	686,696	-3.8%
Japan Revenue	476,720	532,902	429,308	376,165	617,794	6.7%
Rest of World Revenue	26,243	67,224	86,514	78,551	59,348	22.6%

Source: IDC, 2010

Note: This includes server spending only

Worldwide HPC System Revenue Forecast through 2013

IDC forecasts (Table 3) that the worldwide market for HPC systems will resume growth in 2010 and expand at a healthy 6.3% compound annual growth rate to surpass €8.2 billion in 2013. The figures are actual for 2008 and 2009.

TABLE 3

Worldwide HPC System Revenue (€000) Forecast, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Revenue	7,328,887	6,477,836	6,929,660	7,381,485	7,833,310	8,285,134	6.3%
Units	174,091	104,604	118,609	126,266	133,637	141,133	7.8%

Source: IDC, 2010

Note: This includes server spending only

3.3 The Broader Worldwide HPC Ecosystem

The preceding tables showed revenue only for HPC systems themselves, that is, the sum total of the actual prices paid for the computers at the time of purchase. The following tables add to this the other HPC revenue categories: storage (separate from "scratch" disk storage included on the purchased computer), service (the value of contracts for computer service and support), application software, and middleware (separate from software included on the purchased computer).

Worldwide HPC Revenue Forecast For All Revenue Categories

As Table 4A indicates, the addition of the other categories boosts the value of the worldwide HPC market in 2009 to €12.9 billion, and to €17.3 billion as forecast for 2013. The revenue growth rate for the non-computer categories has been, and is projected to remain, higher than for the HPC systems. Storage in particular has been growing at a pace several percentage points higher than HPC systems, owing to the "data explosion" associated with running increasingly large, complex HPC problems and workloads. The "application software" designation refers to commercial software provided by independent software vendors (ISVs).

TABLE 4A

Worldwide HPC Revenue for Server, Storage, Service and Software Revenue (€000) Forecast, 2008–2013

	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	7,328,887	6,477,836	6,929,660	7,381,485	7,833,310	8,285,134	6.3%
Storage	2,528,466	2,267,243	2,460,029	2,731,149	2,976,658	3,231,202	9.3%
Service	1,392,488	1,166,010	1,264,663	1,365,575	1,468,746	1,615,601	8.5%
Application Software	2,491,821	2,228,376	2,411,522	2,583,520	2,819,991	3,048,929	8.2%
Middleware	879,466	796,774	866,208	944,830	1,018,330	1,093,638	8.2%
Total	14,621,129	12,936,238	13,932,082	15,006,559	16,117,035	17,274,505	7.5%

Source: IDC, 2010

Worldwide HPC Revenue Forecast: Market Share by Revenue Category

Table 4B depicts the percentage of overall HPC revenue belonging to each revenue category. Because the non-computer categories are growing faster than the HPC systems compute category, IDC predicts that their share of the whole "pie" will continue to increase between now and 2013.

TABLE 4B

Worldwide HPC Revenue Shares for Server, Storage, Service, and Software Forecast, 2008–2013

	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	50.1%	50.1%	49.7%	49.2%	48.6%	48.0%	-1.1%
Storage	17.3%	17.5%	17.7%	18.2%	18.5%	18.7%	1.6%
Service	9.5%	9.0%	9.1%	9.1%	9.1%	9.4%	0.9%
Application Software	17.0%	17.2%	17.3%	17.2%	17.5%	17.6%	0.6%
Middleware	6.0%	6.2%	6.2%	6.3%	6.3%	6.3%	0.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

3.4 The Worldwide Supercomputer HPC Market Segment

IDC defines the "supercomputer" category as including HPC systems sold for $500,000 (€375,000) or more each. Large, powerful HPC systems in this category are important for HPC leadership and for supporting advanced science and engineering work.

IDC defines the "supercomputer" category as including HPC systems sold for $500,000 (€375,000) or more each

As Table 5 illustrates, revenue in the "supercomputer" category jumped by about 25% in 2009. Even in the depths of the recession this segment began to advance, fueled by multiple single-system sales/upgrades in the €75 million range each, and by the increasingly irresistible urge for nations and regions to join the "petaflop club" and the race for global HPC leadership. In addition, some private enterprises, notably in the oil and gas industry, have deployed clusters that will soon approach or reach petascale size.

The resurgence of the "supercomputer" category during a recession that harmed other categories has dramatically shifted revenue share in the HPC market toward these larger higher priced systems.

TABLE 5

Worldwide HPC System Revenue (€000) and Units in Supercomputer Segment, 2005–2009

Data	2005	2006	2007	2008	2009	CAGR (05–09)
WW Revenue	2,160,829	1,925,165	2,011,793	2,014,596	2,527,058	3.0%
WW Units	2,137	1,868	1,841	1,863	2,100	-0.4%

Source: IDC, 2010

Note: This includes server spending only

Worldwide HPC Supercomputer System Revenue by Region, 2005–2009

The HPC "supercomputer" market segment for systems priced at $500,000 and up had compound annual growth of 4.0% in 2005–2009, which includes the recession years of 2008 and 2009 (see Table 6). North America's 5.5% growth rate outpaced the worldwide average, as did Japan's 10.7% on a much smaller base.

Europe's revenue figure remained essentially flat (0.5% CAGR) during this period, meaning that Europe has barely participated in the recent resurgence of high-end system purchasing. During the economically challenging 2007–2009 period, purchases of "supercomputer"-priced HPC systems increased 38.5% in North America, 284% in Japan (a figure heavily skewed by a few major upgrades), stayed flat in the rest of the Asia-Pacific region, but declined by 9% in the EMEA region that consists almost entirely of Europe. To sum up, Europe lost ground to other world regions, especially North America, during this period.

TABLE 6

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

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

Source: IDC, 2010

Note: This includes server spending only

Worldwide HPC Supercomputer System Revenue Forecast through 2013

Based on projections from recent history and known purchasing plans and patterns, IDC forecasts (Table 7) that the "supercomputer" segment of the HPC market will continue on a healthy growth path to reach about €3.3 billion by 2013, with unit shipments increasing at a more modest 4.8% CAGR.

TABLE 7

Worldwide HPC System Revenue (€000) and Units Forecast in Supercomputer Segment, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
System Revenue	2,014,596	2,527,058	2,718,264	2,909,471	3,100,677	3,291,884	6.8%
System Units	1,863	2,100	2,171	2,306	2,433	2,532	4.8%

Source: IDC, 2010

Note: This includes server spending only

Worldwide HPC Supercomputer Revenue Forecast, All Categories, Through 2013

Table 8A augments the HPC system ("compute") forecast shown in Table 7 with the remaining HPC revenue categories. IDC forecasts that the total amount for all revenue categories in the "supercomputer" segment will exhibit healthy growth (CAGR) of about 8.5% during the period 2009 to 2013.

In 2013, IDC expects investment in this segment to reach about €9.3 billion. This would elevate investment in the "supercomputer" segment to 54% of the total investment for all HPC segments, up from 52% in 2009. In the "supercomputer" price segment as in the overall HPC market, IDC expects the HPC system ("compute") category to exhibit less rapid growth than the other segments. Middleware, defined as the software between the operating system and the user applications, should experience especially robust growth. Also called HPC management software, middleware will be increasingly vital for reducing the complexity of HPC cluster and grid management, and for presenting an integrated and responsive HPC resource to users.

TABLE 8A

Worldwide HPC Revenue (€000) for Server, Storage, Service and Software Forecast in Supercomputer Segment 2008–2013

	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	2,014,596	2,527,058	2,718,264	2,909,471	3,100,677	3,291,884	6.8%
Storage	1,551,239	1,819,481	2,011,516	2,182,103	2,356,515	2,534,751	8.6%
Service	523,795	581,223	638,792	698,273	775,169	855,890	10.2%
Application Software	1,390,071	1,667,858	1,848,420	2,080,272	2,232,488	2,403,075	9.6%
Middleware	141,022	161,732	176,687	218,210	238,752	263,351	13.0%
Total	5,620,723	6,757,352	7,393,679	8,088,329	8,703,602	9,348,951	8.5%

Source: IDC, 2010

Worldwide HPC Supercomputer Forecast, Revenue Share by Category, Through 2013

Table 8B parses the share of "supercomputer" segment revenue belonging to each revenue category, for the historical years 2008 and 2009, and then forecast out through the year 2013. IDC predicts that the compute (HPC systems) category will retain the lion's share of revenue during the forecast period, with storage and application software following closely behind.

TABLE 8B

Worldwide HPC Revenue Share for Server, Storage, Service and Software Forecast in Supercomputer Segment 2008–2013

	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	35.8%	37.4%	36.8%	36.0%	35.6%	35.2%	-1.5%
Storage	27.6%	26.9%	27.2%	27.0%	27.1%	27.1%	0.2%
Service	9.3%	8.6%	8.6%	8.6%	8.9%	9.2%	1.6%
Application Software	24.7%	24.7%	25.0%	25.7%	25.7%	25.7%	1.0%
Middleware	2.5%	2.4%	2.4%	2.7%	2.7%	2.8%	4.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

Future Outlook

At this time IDC is forecasting a moderate rate of growth for the HPC market due to the uncertainties related to the overall global economic situation. If the global economy weakens or sees a second recessionary dip, the market will grow much more slowly. If the global economy starts to grow, the overall HPC market could grow substantially faster than currently predicted (as it did in 2002 to 2007). IDC expects that the highest end of the HPC market will see more stability and growth than the other sectors over the next 3 to 5 years due to the strong government commitments around the world.

3.5 The Over $3 Million/€2.25 Million Worldwide High-End HPC Market Segment

The top bracket IDC tracks in the "supercomputer" segment is for HPC systems sold for $3 million (€2.25 million) and up. This segment includes the largest, most powerful systems and is where HPC leadership initiatives reside.

The $3 million-plus segment exhibited strong growth (CAGR) of 11.5% in 2009–2013 and expanded by a whopping 65% during the difficult 2009 recession year to reach about €1.0 billion in value (see Table 9). Unit shipments jumped by a lesser, but still impressive 43% in 2009, indicating that average selling prices (ASPs) for HPC systems in this segment also increased.

Even in the depths of the recession, this segment began to advance, fueled by multiple single-system sales/upgrades in the €75 million range each, and by the increasing attraction for nations and regions to join the "petaflop club" and the race for global HPC leadership. In addition, some private enterprises, notably in the oil and gas industry, have deployed clusters that will soon approach or reach petascale.

The race for HPC leadership promises to turbo-charge the "supercomputers" segment for possibly a decade to come. Even though to IDC's knowledge only three real-world applications have been run at sustained trans-petaflop speeds to date, scores of additional codes have been identified with the potential to exploit significant fractions of petascale computers that are already installed, on order, or in the planning stages.

And although the Petascale Era is just dawning, governments in the U.S., Europe, and Asia-Pacific have launched initiatives aimed at developing and deploying exascale HPC systems in the latter half of this decade. The high-end beat goes on.

TABLE 9

Worldwide HPC Revenue (€000) and Units for $3M/€2.25M + Price Band, 2005–2009

Data	2005	2006	2007	2008	2009	CAGR (05–09)
Revenue	665,360	447,116	522,093	466,891	1,029,103	11.5%
Units	144	110	180	123	177	5.3%

Source: IDC, 2010

Note: This includes server spending only

Worldwide Revenue for HPC Systems in the $3M+ Price Band, 2005–2009

In 2005–2009, which includes the recession years of 2008 and 2009, worldwide revenue for the $3 million+ price band of HPC systems grew strongly at a CAGR of 13.1% (see Table 10). This expansion was driven primarily by dramatic 2009 spending increases in North America, where 2009 revenue skyrocketed 208% over 2008. Europe spending in this high-end leadership price bracket also shot up in 2009, increasing 183% over the prior year but still lower than Europe's 2007 pre-recession spending in this price bracket (the 2009 North American figure, by contrast, easily reached an all-time high). In 2009, for the first time during this period, Japan nearly outspent all of Europe in this price band.

TABLE 10

Worldwide HPC System Revenue (€000) by Region for $3M/€2.25M + Price Band, 2005–2009

Data	2005	2006	2007	2008	2009	CAGR (05–09)
Total WW Revenue	665,360	447,116	522,093	478,692	1,090,403	13.1%
North America Revenue	345,026	203,507	246,732	280,797	583,807	14.1%
Europe Revenue	230,332	180,165	277,532	140,431	256,681	2.7%
** Percent of WW	34.6%	40.3%	53.2%	29.3%	23.5%	
Asia/Pac Revenue	51,431	35,840	58,481	44,196	63,312	5.3%
Japan Revenue	92,628	69,887	20,210	46,227	246,846	27.8%

Note: There were a number of larger European deals by Cray, HP, and SGI in 2007.

Source: IDC, 2010

Note: This includes server spending only

Worldwide Revenue Forecast for HPC Systems in the $3M/€2.25M + Price Band Through 2013

IDC forecasts that the $3M+ HPC systems market will grow at a 6.8% CAGR to reach about €1.42 million in 2013, with unit shipments declining slightly and average selling prices continuing to grow (Table 11).

TABLE 11

Worldwide HPC System Revenue (€000) and Units Forecast for the $3M/€2.25M + Price Band, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
System Revenue	478,692	1,090,403	1,126,010	1,222,917	1,319,824	1,416,732	6.8%
System Units	123	177	147	164	172	154	-3.5%

Source: IDC, 2010

Note: This includes server spending only

Worldwide Revenue Forecast for the $3M/€2.25M + Price Band, All Categories, Through 2013

IDC predicts that total spending for all revenue categories associated with the purchase of HPC systems in the $3M+ price band will expand at a 10% CAGR through 2013 (Table 12). For reasons described earlier, we expect the HPC management software ("middleware") category to undergo the fastest growth (22%), as more highly parallel and heterogeneous high-end HPC systems, sometimes affiliated with newer environments such as grids and clouds, place greater management demands on the middle software layer.

TABLE 12

Worldwide HPC Revenue (€000) for Server, Storage, Service and Software Forecast for the $3M/€2.25M + Price Band, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	478,692	1,090,403	1,126,010	1,222,917	1,319,824	1,416,732	6.8%
Storage	406,195	864,447	979,629	1,076,167	1,121,851	1,246,724	9.6%
Service	140,067	288,149	371,583	428,021	501,533	552,525	17.7%
Application Software	331,492	720,372	810,727	886,615	963,472	1,048,381	9.8%
Middleware	46,689	92,619	123,861	146,750	184,775	205,426	22.0%
Total	1,403,136	3,055,990	3,411,811	3,760,471	4,091,456	4,469,788	10.0%

Source: IDC, 2010

Worldwide HPC $3M/€2.25M + Price Band Forecast, Revenue Share by Category, through 2013

Table 13 shows the share of $3M+ HPC segment revenue belonging to each revenue category, for the historical years 2008 and 2009, and then forecast out through the year 2013. Here again, IDC predicts that the compute (HPC systems) category will retain the lion's share of revenue during the forecast period, with storage and application software following closely behind.

TABLE 13

Worldwide HPC Revenue Share for Server, Storage, Service and Software Forecast for $3M/€2.25M + Price Band, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	34.1%	35.7%	33.0%	32.5%	32.3%	31.7%	-2.9%
Storage	28.9%	28.3%	28.7%	28.6%	27.4%	27.9%	-0.4%
Service	10.0%	9.4%	10.9%	11.4%	12.3%	12.4%	7.0%
Application Software	23.6%	23.6%	23.8%	23.6%	23.5%	23.5%	-0.1%
Middleware	3.3%	3.0%	3.6%	3.9%	4.5%	4.6%	11.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

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4.0 THE EUROPEAN HPC MARKET

4.1 The EU and EU+ Countries

In the following series of tables, the designation EU stands for the European Union and refers to the 27 member states: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. EU figures in the tables include HPC spending by the member states themselves and by the European Commission.

The designation EU+ includes the EU member states, plus Norway and Switzerland.

The figures in these tables were derived primarily from IDC's revenue figures for Europe, by stripping out the small components belonging to the Middle East and Africa, and secondarily by cross-checking to make certain that large, visible HPC system purchases in the EU and EU+ regions were accounted for.

EU and EU+ Countries, HPC System Revenue, 2005–2009

Table 14 shows revenue for HPC systems at all price points in 2005–2009, first for the EU member states and then for the EU+ grouping. Not surprisingly, the figures for the EU+ grouping are only marginally higher than those for the EU member states. To put these figures in further perspective, the 2009 total for the EU+ category was about 5% higher than the EU figure and only about 8% lower than the 2009 Europe-wide (beyond just the EU member states) revenue total of €1.91billion.

TABLE 14

EU and EU+ Countries HPC System Revenue (€000), 2005–2009

Data	2005	2006	2007	2008	2009	CAGR (05–09)
EU Revenue	1,916,730	2,102,146	2,201,912	2,035,594	1,677,105	-3.3%
EU+ Revenue	2,014,744	2,209,642	2,314,510	2,139,687	1,762,867	-3.3%

Source: IDC, 2010

Note: This includes server spending only

EU and EU+ Countries, HPC System Revenue Forecast through 2013

As Table 15 illustrates, IDC forecasts that spending for HPC systems within the EU will increase at a healthy 7.6% CAGR to surpass €2.2 billion in 2013, and spending for the EU+ grouping will rise slightly faster to approach €2.38 billion. These growth rates are moderately higher than the 6.3% CAGR IDC forecasts for the worldwide HPC market during this period, but note that these figures include spending for HPC systems of all sizes, not just the high-end, leadership-class category in which the EU has been under-spending compared to North America and Japan.

TABLE 15

EU and EU+ Countries HPC System Revenue (€000) Forecast, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
EU Revenue	2,035,594	1,677,105	1,918,565	2,031,054	2,152,202	2,251,559	7.6%
EU+ Revenue	2,139,687	1,762,867	2,016,674	2,135,508	2,262,887	2,379,190	7.8%

Source: IDC, 2010

Note: This includes server spending only

4.2 The Broader European HPC Ecosystem

EU HPC Forecast, All Revenue Categories, Through 2013

When the other revenue categories are added to the HPC systems ("compute") category (see Table 16), IDC's forecast for total HPC spending within the EU more than doubles to surpass €4.6 billion by 2013. As with the worldwide forecast, the compute category is expected to experience the lowest growth rate among the revenue categories.

TABLE 16

EU Countries HPC System, Storage, Services and Software Revenue (€000) Forecast, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	2,035,594	1,677,105	1,918,565	2,031,054	2,152,202	2,251,559	7.6%
Storage	653,426	529,965	619,697	700,714	755,423	815,064	11.4%
Service	411,190	303,556	354,935	383,869	419,679	454,815	10.6%
Application Software	692,102	576,924	667,661	710,869	774,793	828,574	9.5%
Middleware	266,663	223,055	262,843	284,348	305,613	324,224	9.8%
Total	4,058,974	3,310,606	3,823,701	4,110,853	4,407,711	4,674,236	9.0%

Source: IDC, 2010

In Table 17, the percentages of spending belonging to each revenue category closely resemble those for the worldwide HPC market (Table 4B).

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TABLE 17

EU Countries HPC System, Storage, Services and Software Revenue Share Forecast, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	50.2%	50.7%	50.2%	49.4%	48.8%	48.2%	-1.3%
Storage	16.1%	16.0%	16.2%	17.0%	17.1%	17.4%	2.2%
Service	10.1%	9.2%	9.3%	9.3%	9.5%	9.7%	1.5%
Application Software	17.1%	17.4%	17.5%	17.3%	17.6%	17.7%	0.4%
Middleware	6.6%	6.7%	6.9%	6.9%	6.9%	6.9%	0.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

EU+ HPC Forecast, All Revenue Categories, Through 2013

As would be expected, the EU+ forecast figures that add Norway and Switzerland to the mix (Table 18) closely resemble and only modestly increase the EU figures shown in Table 16. Table 19 shows the percentages of overall revenue belonging to each revenue category for the historical years 2008 and 2009, and for the forecast period through 2013.

TABLE 18

EU+ Countries HPC System, Storage, Services and Software Revenue (€000) Forecast, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	2,139,687	1,762,867	2,016,674	2,135,508	2,262,887	2,367,353	7.6%
Storage	683,821	554,064	647,658	730,692	787,411	848,760	11.3%
Service	420,065	310,328	362,903	392,473	428,924	464,620	10.6%
Application Software	694,693	578,827	669,932	713,338	777,465	831,427	9.5%
Middleware	267,420	223,590	263,491	285,056	306,385	325,055	9.8%
Total	4,205,686	3,429,675	3,960,657	4,257,068	4,563,071	4,837,216	9.0%

Source: IDC, 2010

TABLE 19

EU+ Countries HPC System, Storage, Services and Software Revenue Share Forecast, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	50.9%	51.4%	50.9%	50.2%	49.6%	48.9%	-1.2%
Storage	16.3%	16.2%	16.4%	17.2%	17.3%	17.5%	2.1%
Service	10.0%	9.0%	9.2%	9.2%	9.4%	9.6%	1.5%
Application Software	16.5%	16.9%	16.9%	16.8%	17.0%	17.2%	0.5%
Middleware	6.4%	6.5%	6.7%	6.7%	6.7%	6.7%	0.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

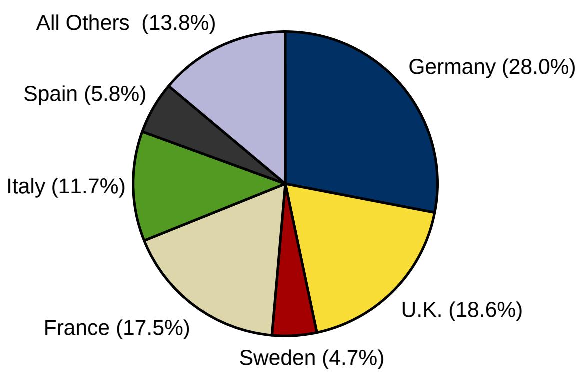
4.3 The EU Supercomputer HPC Market Segment

EU HPC Supercomputer System Revenue by Country

Figure 1 shows the 2009 share of HPC system revenue (i.e., spending) by country for the segment of "supercomputer" systems priced at $500,000 (€375,000) and up. Germany led all other EU countries by providing about 28% of the EU revenue for this segment, followed by the U.K. (19%), France (19%), Italy (12%), and Spain (6%).

FIGURE 1

EU Total Supercomputer Revenue Mix by Country, 2009



Source: IDC, 2010

EU HPC System Revenue in the Supercomputer Segment, 2005–2009

Spending in the EU for "supercomputer"-class HPC systems grew at a rate (CAGR) of less than one percent during the years 2005–2009 (Table 20), a small fraction of the growth rate in North America and worldwide for the same period.

TABLE 20

EU HPC System Revenue (€000) in Supercomputer Segment, 2005–2009

	2005	2006	2007	2008	2009	CAGR (05–09)
EU Revenue	595,308	564,959	670,635	574,209	608,318	0.5%

Source: IDC, 2010

Note: This includes server spending only

EU HPC System Revenue Forecast For the Supercomputer Segment Through 2013

As Table 21 shows, IDC predicts that EU spending on "supercomputer"-class HPC systems will increase at a healthy 10.7% CAGR to reach about €900 million in 2013. This assumes that the PRACE program will continue to be funded substantially and that the EU member states on average will invest in "supercomputer"-class system purchases at rates somewhat above recent historical patterns in order to keep pace with the worldwide market.

TABLE 21

EU HPC system Revenue (€000) Forecast in Supercomputer Segment, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
EU Revenue	574,209	608,318	692,451	760,303	824,842	912,839	10.7%

Source: IDC, 2010

Note: This includes server spending only

EU HPC Revenue Forecast, All Categories, through 2013

Table 22 lays out IDC's forecast for revenue (spending) in the EU for all HPC categories through to 2013. IDC expects total spending to increase at a strong 12.6% CAGR to reach about €2.5 billion in 2013, with the compute category again growing at a somewhat slower rate than the other categories.

TABLE 22

EU Countries HPC System, Storage, Services and Software Revenue (€000) Forecast in Supercomputer Segment, 2008–2013

	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	574,209	608,318	692,451	760,303	824,842	912,839	10.7%
Storage	384,720	371,074	432,782	510,924	536,147	604,300	13.0%
Service	161,353	136,263	175,190	198,439	221,058	251,031	16.5%
Application Software	431,805	421,564	508,951	574,029	627,705	697,409	13.4%
Middleware	47,085	45,624	54,011	61,585	68,462	76,679	13.9%
Total	1,599,173	1,582,843	1,863,385	2,105,279	2,278,214	2,542,258	12.6%

Source: IDC, 2010

In Table 23, the percentage share of overall HPC revenue in the EU is laid out by category for the historical years 2008 and 2009, as well as for the forecast period through to 2013. As in the worldwide forecast, the compute category commands the largest share of spending and the storage and applications software categories are next in prominence.

TABLE 23

EU Countries HPC System, Storage, Services and Software Revenue Share Forecast in Supercomputer Segment, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	35.9%	38.4%	37.2%	36.1%	36.2%	35.9%	-1.7%
Storage	24.1%	23.4%	23.2%	24.3%	23.5%	23.8%	0.3%
Service	10.1%	8.6%	9.4%	9.4%	9.7%	9.9%	3.5%
Application Software	27.0%	26.6%	27.3%	27.3%	27.6%	27.4%	0.7%
Middleware	2.9%	2.9%	2.9%	2.9%	3.0%	3.0%	1.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

4.4 The Over $3M/€2.25M + EU High-End HPC Market Segment

As noted earlier in the discussion of the worldwide HPC market, the uppermost bracket for systems priced at $3 million (€2.25 million) and above is the arena where HPC leadership is pursued and determined. This market segment therefore has special relevance for any EU HPC leadership strategy.

Table 24 shows that spending in this category in the EU remained essentially flat over the past five years (1.6% CAGR), though the figures bounced up and down considerably from year to year. This pattern is in sharp contrast to the substantial

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spending ramp-ups in North America and Japan during this period, especially in the economically difficult year of 2009 (see Table 10).

TABLE 24

EU HPC system Revenue (€000) in $3M/€2.25M + Segment, 2005–2009

Data	2005	2006	2007	2008	2009	CAGR (05–09)
EU Revenue	172,749	135,124	204,039	99,128	183,917	1.6%

Source: IDC, 2010

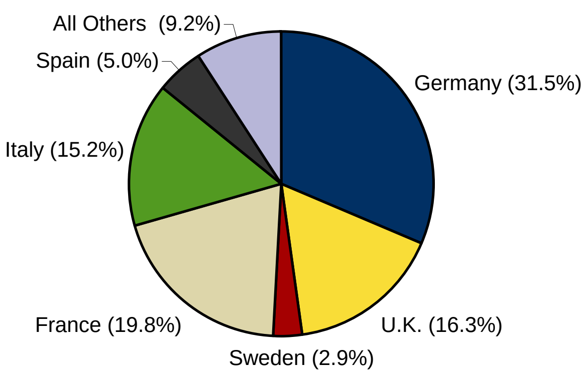
Note: This includes server spending only

2009 EU Revenue (Spending) For HPC Systems in the $3M+ Price Band, by Country

Figure 1 showed 2009 EU revenue (spending) for HPC systems in the $500,000 (€375,000) and up "supercomputer" segment by country. Figure 2 does the same thing for the uppermost $3 million+ (€2.25 million) price band of HPC systems. It once again shows the highest level of spending by Germany (32% of the EU total), followed by France (20%), the U.K. (16%), Italy (15%), Spain (5%), and Sweden (3%). 2009 spending by all other EU members states in this price band amounted to about 9%.

FIGURE 2

EU Total Over $3M/€2.25M + High-End Supercomputer Revenue Mix by Country, 2009



Source: IDC, 2010

EU HPC System Revenue Forecast For the $3M+ Price Band through 2013

IDC forecasts that spending in the EU for systems in the $3M+ segment will grow at a strong 13% CAGR through to 2013 (Table 25).

TABLE 25

EU HPC system Revenue (€000) Forecast in $3M/€2.25M + Segment, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
EU Revenue	99,128	183,917	203,042	232,501	262,566	299,894	13.0%

Source: IDC, 2010

Note: This includes server spending only

EU HPC Revenue Forecast, All Categories, For the $3M+ Price Band Through 2013

Table 26 shows IDC's forecast through 2013 for EU revenue (spending) in all categories associated with HPC systems in the $3 million (€2.25 million) price band. IDC projects that EU spending in this segment will increase during this period at a very strong CAGR of about 20%, with spending in all non-compute categories leading the way. Table 27 splits out the percentages of total spending for each category. As expected, revenue provided for HPC systems themselves is the largest beneficiary, with storage and application software next in importance.

TABLE 26

EU Countries HPC System, Storage, Services and Software Revenue (€000) Forecast in $3M/€2.25M + Segment, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	99,128	183,917	203,042	232,501	262,566	299,894	13.0%
Storage	70,318	92,970	147,003	169,958	193,248	222,221	24.3%
Services	25,690	32,182	51,370	59,520	67,742	78,272	24.9%
Application Software	71,444	94,427	149,033	172,516	198,500	229,119	24.8%
Middleware	7,782	10,330	16,040	18,600	21,268	24,591	24.2%
Total	274,361	413,826	566,488	653,095	743,324	854,097	19.9%

Source: IDC, 2010

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TABLE 27

EU Countries HPC System, Storage, Services and Software Revenue Share Forecast in $3M/€2.25M + Segment, 2008–2013

Data	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Compute	36.1%	44.4%	35.8%	35.6%	35.3%	35.1%	-5.7%
Storage	25.6%	22.5%	25.9%	26.0%	26.0%	26.0%	3.7%
Services	9.4%	7.8%	9.1%	9.1%	9.1%	9.2%	4.2%
Application Software	26.0%	22.8%	26.3%	26.4%	26.7%	26.8%	4.1%
Middleware	2.8%	2.5%	2.8%	2.8%	2.9%	2.9%	3.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: IDC, 2010

5.0 APPLICATION SECTORS IN THE EU HPC MARKET

5.1 Definition of Main HPC Application Areas

According to IDC research, the main HPC application areas are the following workload segments:

- **Biological sciences.** This workload centers on applications such as genomics, proteomics, 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.** This workload centers on 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.** This workload centers on applications such as mechanical computer-aided design (CAD); 2D, 2.5D, and 3D design and drafting; 3D wire frame; 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.** This workload centers on applications such as finite element modeling and analysis, mechanical computer-aided engineering (CAE), 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 category centers on 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, as well as servers used for large scale games. 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.

- **Economic and financial modeling.** This workload centers on applications such as econometric modeling, portfolio management, stock market and economic forecasting, and financial analysis. The segment includes both trader and computationally intensive nontrader 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.** 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 areas such as mining, natural resource management, geographic information systems (GIS), and mapping.

- **Government laboratories and research centers.** This workload centers on 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.** 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.

- **University and academic.** This workload centers on scientific research and engineering R&D efforts conducted at public or private institutes of higher education and includes systems sold for both research and educational 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.** This workload centers on 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."** This segment includes any technical computing workloads not otherwise specified by the above definitions.

5.2 EU HPC Application Sector Sizes

EU HPC System Revenue by Application Sector, 2005–2009

Table 28 splits out **HPC system revenue** according to the primary use (purchasing rationale) of the systems. Hence, revenue for an HPC system that was purchased primarily for CAE use falls into that category.

The table shows that in 2009, the most recent historical year, EU spending was greatest for systems in the following application sectors, in order of the amount spent:

1. University/academic (€278 million)

2. Bio-sciences (€266 million)

3. CAE (€252 million)

4. Government labs (€227 million)

5. Defense (€156 million)

The highest growth rate (CAGR) in 2005–2009 was for HPC systems dedicated to defense (4.3%). No other specified application sector experienced growth of more than 2.9%.

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TABLE 28

EU Countries HPC Revenue (€000) by Application, 2005–2009

Application	2005	2006	2007	2008	2009	CAGR (05–09)
Bio-Sciences	302,182	331,635	348,304	322,705	265,509	-3.2%
CAE	261,610	294,130	316,270	299,927	252,487	-0.9%
Chemical Engineering	43,681	51,332	57,368	56,064	48,493	2.6%
DCC & Distribution	97,497	102,734	102,900	89,934	69,348	-8.2%
Economics/Financial	42,898	50,917	56,969	55,636	48,018	2.9%
EDA	126,954	141,789	150,907	140,428	115,781	-2.3%
Geosciences and Geo-engineering	107,260	119,138	126,176	117,248	96,894	-2.5%
Mechanical Design and Drafting	38,718	41,583	42,306	37,792	29,774	-6.4%
Defense	131,623	155,652	175,132	174,738	155,639	4.3%
Government Lab	309,590	325,110	324,815	286,797	226,579	-7.5%
Software Engineering	4,472	4,474	4,240	3,520	2,563	-13.0%
Technical Management	22,192	22,058	20,479	16,417	11,285	-15.6%
University/Academic	339,481	365,139	375,398	341,381	278,036	-4.9%
Weather	87,922	93,970	96,225	87,239	70,561	-5.4%
Other	648	2,484	4,422	5,768	6,138	75.4%
Total Revenue	1,916,730	2,102,146	2,201,912	2,035,594	1,677,105	-3.3%

Source: IDC, 2010

Note: This includes server spending only

EU HPC System Revenue Forecast by Application Sector, Through 2013

As Table 29 illustrates, IDC forecasts that in 2013 the same five application sectors that led in 2009 will remain the leaders, with CAE exhibiting the highest growth rate among the five and pulling even with bio-sciences, as follows:

1. University/academic (€378 million)

2. Bio-sciences (€367 million)

3. CAE (€367 million)

4. Government labs (€322 million)

5. Defense (€212 million)

The five application sectors projected to experience the highest growth rates through 2013, though sometimes on much smaller bases, are CAE (9.8%), chemical engineering (9.7%), economics/financial (9.4%), government labs (9.2%), and electronic design automation, or EDA (8.7%).

TABLE 29

EU Countries HPC Revenue (€000) Forecast by Application, 2008–2013

Application	2008	2009	2010	2011	2012	2013	CAGR (09–13)
Bio-Sciences	322,705	265,509	308,889	329,031	350,809	367,004	8.4%
CAE	299,927	252,487	295,584	320,055	346,711	367,004	9.8%
Chemical Engineering	56,064	48,493	58,413	62,963	67,794	70,249	9.7%
DCC & Distribution	89,934	69,348	59,476	62,963	62,414	63,044	-2.4%
Economics/Financial	55,636	48,018	53,720	58,901	63,490	68,673	9.4%
EDA	140,428	115,781	133,794	143,061	153,102	161,747	8.7%
Geosciences and Geo-engineering	117,248	96,894	111,714	119,185	127,271	134,168	8.5%
Mechanical Design and Drafting	37,792	29,774	28,778	24,373	17,218	13,509	-17.9%
Defense	174,738	155,639	180,345	186,857	200,155	211,647	8.0%
Government Lab	286,797	226,579	262,843	282,317	303,461	321,973	9.2%
Software Engineering	3,520	2,563	2,546	2,286	1,989	1,628	-10.7%
Technical Management	16,417	11,285	10,584	8,743	6,655	4,233	-21.7%
University/Academic	341,381	278,036	316,563	337,155	359,418	378,262	8.0%
Weather	87,239	70,561	78,899	81,597	84,420	86,180	5.1%
Other	5,768	6,138	16,417	11,570	7,296	2,240	-22.3%
Total Revenue	2,035,594	1,677,105	1,918,565	2,031,054	2,152,202	2,251,559	7.6%

Source: IDC, 2010

Note: This includes server spending only

In Summary: Sectors Where the EU is Comparatively Strong

The survey and previous IDC HPC research confirm that there are a number of application segments where the EU is extremely strong – that is, where Europe has a sizeable market today that we project will show healthy growth (CAGR) through the year 2013. The strength is more than a recent event in that Europe has a long and strong history in all major fields of science, starting long before there were supercomputers. In addition, Europe has a large and talented pool of end users that understand scientific research and engineering. The sectors that Europe is best known for applying HPC include:

- Bio-sciences
- CAE
- Chemical engineering
- Government lab
- University/academic
- Weather/climate

The sectors where the EU is average:

- Economics/financial
- Geosciences and geo-engineering
- Mechanical design and drafting
- Defense
- Software engineering

The sectors where the EU is comparatively weak include:

- DCC and distribution
- EDA
- Technical management

6.0 HPC SUPPLIERS IN EUROPE

6.1 for All HPC Servers In The EU And EU+

Tables 30 and 31 show the revenue derived by HPC system vendors in the EU and EU+ regions in 2005–2009.

EU Revenue by HPC System Vendor, 2005–2009

HP was consistently the leading supplier of HPC systems in the EU region during this period, with IBM running second and Dell a more distant third (Table 30). In 2009, the EU HPC market share for these three vendors totaled 77%, leaving less than one-quarter of the market for all others to share. The only EU-based vendor on the list, Bull, had 2009 EU HPC market share of only 1.8%. Note, however, that the "Other" category was really the third-place finisher, ahead of Dell with 11.6% market share. This shows that opportunities still exist for small HPC system vendors in the EU, and that the barriers to market entry are not overly difficult to surmount.

TABLE 30

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

Manufacturer	2005	2006	2007	2008	2009
HP	772,738	896,036	1,000,074	936,087	634,720
IBM	592,399	613,414	624,307	535,405	516,048
Dell	201,438	285,881	272,623	289,942	202,414
Sun	201,954	171,513	114,344	96,477	77,342
Bull	21,718	7,968	15,653	31,952	32,602
NEC	31,027	23,348	12,038	18,510	30,533
SGI	42,210	26,284	51,937	28,519	26,126
Cray	21,184	43,633	50,885	13,907	22,901
Appro	0	0	0	24,135	2,054
Other	107,281	114,892	143,000	137,583	203,844
Grand Total	1,991,947	2,182,968	2,284,861	2,112,517	1,748,585

Source: IDC, 2010

Note: This includes server spending only

EU+ Revenue by HPC System Vendor, 2005–2009

The numbers and the order of market leaders remain about the same when Norway and Switzerland are added to the mix (Table 31). The addition of these two countries boosted the 2009 revenue total by about €59 million.

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TABLE 31

EU+ Countries HPC Revenue (€000) by Vendor, 2005–2009

Manufacturer	2005	2006	2007	2008	2009
HP	812,253	941,856	1,047,335	983,955	667,178
IBM	622,692	644,782	656,232	562,783	542,437
Dell	201,438	285,881	272,623	289,942	202,414
Sun	201,954	171,513	114,344	96,477	77,342
Bull	21,718	7,968	15,653	31,952	32,602
NEC	31,027	23,348	12,038	18,510	30,533
Cray	21,184	43,633	50,885	13,907	22,901
SGI	42,210	26,284	51,937	28,519	26,126
Appro	0	0	0	24,135	2,054
Other	107,281	114,892	143,000	137,583	203,844
Grand Total	2,061,755	2,260,156	2,364,046	2,187,763	1,807,431

Source: IDC, 2010

Note: This includes server spending only

6.2 for HPC Supercomputers in the EU and EU+

EU Revenue in the Supercomputer Segment by System Vendor, 2005–2009

Table 32 shows that in the "supercomputer" segment for HPC systems priced at $500,000 (€375,000) and up, IBM was most often the EU market share leader in 2005–2009, with HP jumping ahead of IBM only in 2008 and otherwise remaining a close second. Together, IBM and HP captured 78% of the EU market in this price band in 2009; and the third-place vendor, Bull, accounted for only about 5% of the market.

TABLE 32

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

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

Source: IDC, 2011

EU+ Revenue in the Supercomputer Segment by System Vendor, 2005–2009

Adding Norway and Switzerland to the picture to form the EU+ grouping (Table 33) does not change the leadership or market share positions to any noteworthy extent.

TABLE 33

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

Manufacturer	2005	2006	2007	2008	2009
IBM	333,991	292,815	291,148	223,756	300,706
HP	194,756	217,502	284,642	280,878	192,733
Bull	19,125	4,383	13,432	27,301	27,122
NEC	2,941	0	0	1,005	24,533
Dell	10,174	6,022	3,000	3,750	23,690
Cray	17,850	42,297	50,885	13,907	22,901
SGI	21,412	8,312	32,419	14,173	15,465
Sun	11,026	2,224	0	2,464	12,457
Appro	0	0	0	14,280	2,054
Other	0	6,201	13,924	8,320	4,925
Grand Total	611,275	579,757	689,450	589,834	626,587

Source: IDC, 2010

Note: This includes server spending only

6.3 Suppliers in the $3M+ Price Band

EU Revenue in the $3M+ Price Band by System Vendor, 2009

As noted earlier, the topmost price band, for HPC systems sold for more than $3 million (€2.25 million), is especially relevant for HPC leadership initiatives. Figure 3 shows that in 2009, the most recent historical year, IBM easily led all other vendors in by capturing nearly half (46%) of EU revenue for HPC systems in this price band. HP finished second with about half of IBM's market share (23%), followed by Cray (11%), Bull (9%), and SGI (6%). Only about 5% of the revenue went to "others."

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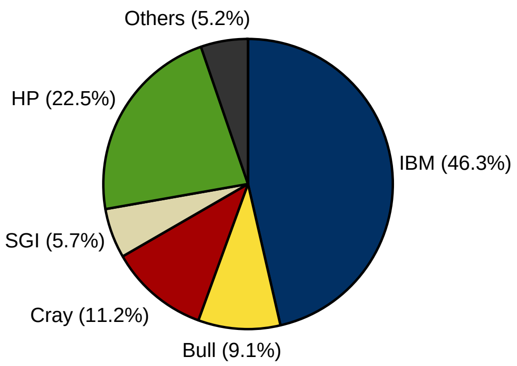
FIGURE 3

EU Countries 2009 HPC Revenue Share in $3M/€2.25M + Band



Source: IDC, 2010

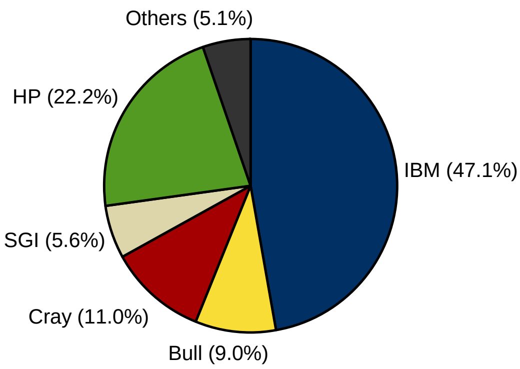
Note: This includes server spending only

EU+ Revenue In the $3M+ Price Band by System Vendor, 2009

For the EU+ grouping of countries (Figure 4), the order of leadership and market share numbers were very similar to those cited above for the EU region.

FIGURE 4

EU+ Countries 2009 HPC Revenue Share in $3M/€2.25M + Band



Source: IDC, 2010

Note: This includes server spending only

6.4 EU HPC Supplier Profiles In The Broader HPC Market

The following list of EU-based HPC suppliers, while not exhaustive, should provide a good feel for the depth and breadth of the EU HPC vendor community. These suppliers range from smaller firms serving a single European country or area, to companies with worldwide reputations in the HPC market, such as Allinea, Bull, NAG, and others.

Allinea Software (Warwick, UK) is a leading supplier of tools for multicore and high performance computing (HPC). Its Distributed Debugging Tool (DDT) and Optimization and Profiling Tool (OPT) are used by universities, government research institutes, and commercial organizations. With new product features aimed at novel computing architectures, and the announcement of new GPGPU features, Allinea aims to be a leader in the tool arena.

Alpha Data (Edinburgh, UK) provides solutions for floating point gate arrays for a range of industries including HPC.

ANS (Hamburg, Germany) is a reseller of storage solutions and specializes in data management (SAN, NAS), networking, clustered storage, storage virtualization, data backup (tape, VTL, HSM), and archiving. Customers include universities, public research companies, healthcare, military, maritime IT solutions, and industrial clients.

ATP (Rotterdam, Netherlands) has over 18 years of experience in the design, manufacturing, and support of high performance, high quality DRAM modules and NAND flash storage products. ATP focuses on mission-critical applications in industrial/automation, telecom, medical, and enterprise computing, where high levels

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of technical support, performance, and manufacturing quality are required. All products are fully RoHS compliant.

Boston Limited (St. Albans, U.K.), now in its 18th year of business, is a system integrator that provides power-optimized CPU/GPU clustered and storage solutions for the HPC and rendering markets, utilizing the latest products from Supermicro, Intel, AMD, nVIDIA, ATI, and other industry partners. Boston Limited builds, tests, and manufactures high performance GPU and CPU compute solutions to meet clients' exact needs.

Bull (les Clayes Sous Bois, France) is one of the leading European IT companies. Bull has a large team of HPC experts and designs and delivers integrated solutions, from departmental clusters to world-class supercomputers. Bull has a growing number of HPC customers at research centers, universities, and industrial companies.

Since 1985, the **CADFEM** (Grafing, Germany) has been a leader in ANSYS and competence in CAE in Germany, Austria, and Switzerland.

CAPS (Rennes, France) is a software company providing products and solutions for manycore application programming & deployment.

christmann informationstechnik + medien GmbH & Co. KG (Ilsede, Germany), started in 2005 with networks and today focuses on energy-saving IT infrastructure.

Cluster Resources (Cambridge, U.K.) is a leader in unified intelligent automation software for high performance computing (HPC) datacenters and cloud computing environments. With more than a decade of experience deploying adaptive operating environments powered by Moab in the world's most advanced datacenters, Cluster Resources delivers software and services that enable organizations to obtain a unified perspective of their resources and optimize service levels through intelligent policy-based governance.

ClusterVision (Amsterdam, Netherlands) is a specialist in the design, implementation, and support of small- and large-scale computer clusters. ClusterVision's team of experts has designed and built some of the largest and most complex computational, storage and database clusters in Europe. With a background in applied scientific research and practical experience with a wide range of HPC technologies, the team provides tailor-made solutions. ClusterVision has offices in most major European countries.

Consolidate IT (Almere, Netherlands) is a European operating distributor specializing in providing iSCSI storage and infrastructure solutions. The company's storage and infrastructure solutions are available in both 1 and 10 Gigabit Ethernet.

E4 Computer Engineering S.p.A. (Scandiano, Italy) specializes in the production of high-end, high performance systems for professional use as well as in academia and calculation centers. E4 has won the Intel award "Number 1 Channel Server in Southern European Union Region" for three consecutive years.

Emilio Billi Engineering's (Novara, Italy) mission is to develop high performance technologies to accelerate complex and intensive calculations. The company develops and designs complex hardware systems such as hardware accelerators using FPGA technologies; high performance, multidimensional, low latency interconnect subsystems for supercomputer systems; and FPGA cores.

Eurotech (Amaro, Italy) develops and produces HPC systems and miniaturized computers for pervasive computing applications (NanoPCs) in the defense, security, transport, aerospace, industrial, medical, and research sectors.

GNS Systems (Braunschweig, Germany) offers information technology services for product development and engineering, including the planning, implementation, and operation of complex systems and applications infrastructures.

Go Virtual (Askim, Sweden) provides HP HPC-systems, servers, and workstations as well as software from partners including Metacomp Technologies (CFD++ and CAA++), ThermoAnalytics (RadTherm, WinTherm), and Intelligent Light (FieldView).

Greeny's (Bergamo, Italy) has a strong focus on HPC and FPGA acceleration and design. It has energy-saving solutions in multiple application areas. Greeny has technical and commercial collaborations with companies including Intel and Xilinx.

Gridcore (Göteborg, Sweden) is a privately held company based in Göteborg, Sweden. Gridcore is a worldwide HPC solutions provider that has formed long-term partnerships with companies such as IBM, ANSYS, and Microsoft. Gridcore also owns and operates Gompute, an HPC-on-demand service that operates worldwide.

HMK Computer Technologies GmbH (Kronberg, Germany) was founded in 1995 by Dipl.-Ing. Helmut Mühl-Kühner in Kronberg near Frankfurt/Main. For more than 10 years, HMK has been working together with strategic partners in the area of file storage and data management.

Isilon Systems (Berkshire, U.K.) is a leader in scale-out NAS. Isilon's products are designed to enable enterprises and research organizations worldwide to manage large and rapidly growing amounts of file-based data.

Kerlabs (Rennes, France) is a spin-off of INRIA, created in 2006 to develop the Kerrighed.One operating system for clusters.

LSI (Bracknell, Berkshire, U.K.) is a leading provider of innovative storage, silicon, systems, and software technologies for some of the world's leading OEMs in the storage and networking markets.

MEGWARE Computer GmbH (Chemnitz-Roehrsdorf, Germany) distributes high-performance computing systems and IT-equipment to industry, banks, trade, universities, schools, and public facilities. The company's solutions are customized to the specific requirements of a broad range of customers.

Mercury Visualization Sciences Group (VSG), Mérignac, France, is a leading provider of high-performance 3D visualization toolkits and application software for demanding industrial and scientific applications. Mercury VSG customers are in the geosciences, materials science, oil and gas, manufacturing, and engineering industries.

NAG (Oxford, UK) is a worldwide leader in numerical software and high performance computing services. NAG serves leading HPC customers such as the HECToR program in the U.K.

Nallatech (Glasgow, U.K.), a subsidiary of Interconnect Systems, Inc., designs and manufactures FPGA products for high performance computing applications and rugged embedded computing platforms.

Nema Labs (Göteborg, Sweden) offers technology to migrate software to multicore platforms. The FASThread product line is designed to parallelize code automatically and reliably.

NICE (Cortanze, Italy), with its EnginFrame grid portal, aims to increase user productivity through highly customizable, intuitive access to grid-enabled applications and infrastructures.

Numascale's (Oslo, Norway) NumaConnect technology enables system-wide, cache-coherent shared memory. NumaConnect allows high volume manufactured server boards to be used as building blocks for systems.

The **ParTec Cluster Competence Center** (Munich, Germany) specializes in cluster operating software and support services designed to deliver ground-breaking performance for large scale supercomputing clusters. Parastation5 is the current release of ParTec's cluster operating and management software.

Promise Technology (Dortmund, Germany) develops and manufactures sophisticated RAID solutions, ranging from RAID controller cards to SAS/SATA RAID subsystems.

RZNet (Kerpen, Germany) is an IT reseller for complex storage solutions and specializes in data management (SAN, NAS, clustered storage, data backup) and archiving. Customers include universities, public research companies, medicine, pharmaceuticals, biotech, and other industrial clients.

science + computing ag (Tübingen, Germany), a subsidiary of the Bull Group, is a service and software company for technical/scientific design and simulation environments (CAD/CAE/CAT). s+c focuses on the operation of complex Unix, Linux and Windows environments.

STORDIS (Stuttgart, Germany) has an HPC product portfolio that includes InfiniBand and 10 GbE networking as well as native InfiniBand HPC storage systems. Storage offerings range from virtualization and SAN solutions to general purpose and rugged storage systems.

T-Platforms (Moscow, Russian Federation) provides a wide range of HPC services, including large-scale cluster solutions. T-Platforms has already completed over 100 integrated projects.

transtec (Tübingen, Germany) provides consultation and integration services for HPC projects, including computer systems, storage, backup, and desktop requirements.

VA Technologies (Luton, U.K.) is one of the U.K.'s leading suppliers of high performance servers, storage and workstations. The systems are tailor-designed and optimized for a wide range of applications.

Ylichron (S. Maria di Galeria, Italy) was founded in 2005 as a spinoff company of ENEA (the Italian Agency for the New Technologies, the Energy and the Environment). The company's main product is the HCE compiler.

7.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: SURVEY DEMOGRAPHICS

7.1 Survey Respondents: HPC Stakeholders

In conjunction with this study, IDC completed a broad survey of the HPC community, focusing primarily on individuals within the EU27 member states and other European nations, but also including HPC leaders in the U.S., Canada, and Japan in order to capture their perspectives on the topic of EU HPC leadership.

Within the EU27, EU+, and wider European groupings, IDC distributed the survey questionnaire to individuals in the following categories and others:

- HPC user organizations (government, university, and industry)
- EU and national HPC-related organizations (DEISA, ECCOMAS, ESFRI, HET International Science Panel, PRACE, and others)
- Funding agencies of EU member states
- HPC industry experts (e.g., directors of large HPC centers, technical experts, and other leading figures from European and non-European countries)
- HPC vendors from throughout the world (hardware, software, storage, and other)

In all, 321 survey questionnaires were sent to targeted HPC community members in all EU and EU+ countries, 11 other European countries, as well as Canada, Japan, and the U.S. We received 67 responses. Because surveying every individual in the European HPC community within the budget and timeframe of this study would have been unfeasible, the objective was to achieve a broad, representative sampling from this community, along with capturing the perspectives of key HPC leaders from other regions of the world.

A sizable number of individuals completed the entire survey, while others provided input via the Web site (http://www.hpcuserforum.com/EU/), and 17 completed in-depth interviews in person or by phone. An even larger number provided input in specific areas of importance to them and their organizations. The appendix contains a list of the organizations invited to participate in the study and the questionnaire used in the survey.

Mix of European and Non-European Respondents

As would be expected, the vast majority (86%) of those who completed the surveys were from European countries (see Figure 5).

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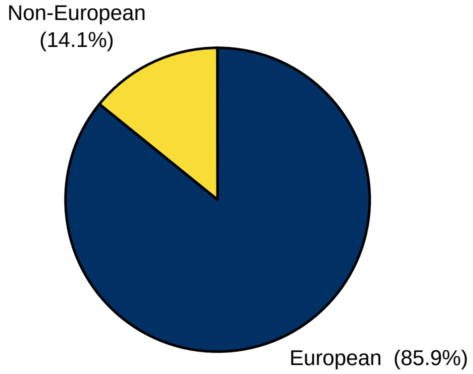
FIGURE 5

HPC Survey Mix



Source: IDC, 2010

Primary Roles of the Survey Respondents

Table 34 shows the primary roles of the survey respondents.

- Nearly half (48%) of the survey respondents belonged to HPC user organizations. In almost all cases, these individuals were senior officials with large or medium-size HPC datacenters, or representatives to important EU or national HPC user-centric organizations such as PRACE, DEISA, and others.

- The next-largest respondent category (30%) consisted of HPC vendors that provide hardware, software, storage, services, and other offerings in Europe. Some of these vendors are based in Europe, but many are headquartered in the U.S., Japan, or elsewhere. All of the non-European vendors sell into the European market and they often but not always have operations in Europe that employ people locally.

- HPC industry experts made up the third-largest respondent category (17%). This category includes a strong sampling of the most prominent individuals in the European and global HPC communities.

- The fourth category (9%) included officials with agencies of EU member states that have responsibility for overseeing and funding HPC initiatives.

TABLE 34

HPC Survey Mix: Primary Roles Of Respondents

	Respondents	Percentage of Sample
A user, datacenter manager, or part of an end-user organization	31	48.4%
A provider of HPC hardware, software, applications, networking, storage, grids, clouds or services	19	29.7%
A funding body that funds HPC activities	6	9.4%
An industry expert	11	17.2%
Total	67	

Note: Multiple responses were allowed, so the total can exceed 100%. There were 67 responses from 64 respondents.

Source: IDC, 2010

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8.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: IMPORTANCE OF HPC

8.1 Importance of HPC for Scientific Leadership

Every one of the survey respondents agreed that HPC is "extremely important" or "important" for scientific leadership (Figure 6). The following representative comments taken from Table 35 support these strongly pro-HPC opinions, although a few comments caution that HPC alone is not a panacea for scientific excellence.

> *"HPC is a major tool for most scientific activities."*

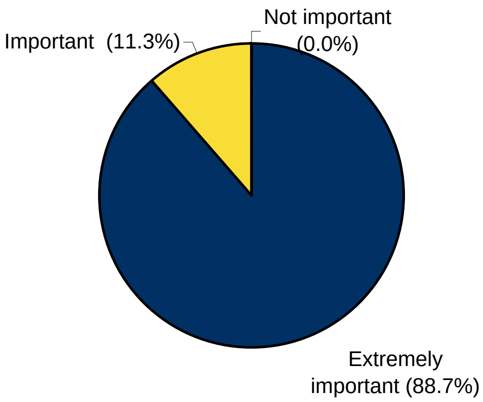
> *"The number of researchers who have migrated from the two traditional methodologies to computer modeling has become so significant that scientific leadership cannot be achieved without a significant presence in HPC."*

> *"[HPC-based] simulation is the third research method besides theory and experiment."*

> *"The focus should be put on educating the scientific elite who can navigate easily between theory and numerical models. Scientific excellence and leadership depend more on the excellence of the scientific elite and the efficiency and flexibility of the research funding frameworks than on the availability of HPC resources."*

FIGURE 6

How Important is HPC for Scientific Leadership?



Source: IDC, 2010

TABLE 35

How Important is HPC for Scientific Leadership?

Comments:	Comments:
In silico science (simulation-based research) is a very important direction, especially in biology/medicine	The number of researchers who have migrated from the two traditional methodologies to computer modeling has become so significant that scientific leadership cannot be achieved without a significant presence in HPC. Especially in: materials design, life sciences, and environmental sciences among others.
In theoretical chemistry and physics it is extremely important, also in genomics. It is merely "important" in some other domains.	More and more scientific results are achieved/supported through simulations; access to high-end HPC systems gives a competitive edge
High performance computations would push both fundamental and applied research beyond the borders of the current status if knowledgeable users take decisions how, when, and for what goals to implement the HPC.	Science policies should put more focus on theoretical frameworks and fundamental research. HPC is misused if it marginalizes theoretical backing and considerations about robust mathematical models.
HPC is a major tool for most scientific activities	Focus should be put on educating the scientific elite who can navigate easily between theory and numerical models. Scientific excellence and leadership depend more on the excellence of the scientific elite and the efficiency and flexibility of the research funding frameworks than on the availability of HPC resources.
In fast changing worlds when scientists have to deal with very complex tasks and phenomena, HPC can provide modern simulations which have enabled them with the ability to go beyond what can be done in the laboratory in areas where experiment is impossible or not practical.	However, some fields of science can't make progress beyond the state of the art without HPC (particle physics for example).
In addition, nowadays in the scientific world where they have got an access to immense volume of information HPC is not only an instrument for processing of all this data but very often the "last drop" for tuning the scientist's physical intuition into regimes that we have not had (experimental) access to before.	Simulation is the third research method besides theory and experiment.
It's important but it's just a tool, so would not say that's extremely important, more important are users and applications.	Simulation of complex systems leads to crucial new insights.
Low level availability of HPC resources means scientific stagnation.	Simulation with HPC is nowadays the third leg of science next to theory and experiments.
Modeling is gaining increased recognition as the third pillar of scientific inquiry alongside theory and experiment.	Without computational assistance, scientific endeavor would be much slower than it is today, as well as being much more labor and capital intensive.
HPC provides a mechanism for testing and evaluating multiple scenarios, reducing the need for physical experiments and accelerating discovery in every field of scientific research. Without HPC, European scientists would be lagging the rest of the world.	.

Source: IDC, 2010

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8.2 Importance of HPC for Industrial Competitiveness

Although the mix of survey respondents was heavily skewed toward science, every one of the respondents said that HPC is also "extremely important" (66%) or "important" (34%) for industrial competitiveness (Figure 7). These representative comments from Table 36 indicate that there is strong support for HPC use by industry, even among non-industrial respondents.

> *"Applied research utilizing HPC is extremely important for industrial competitiveness."*

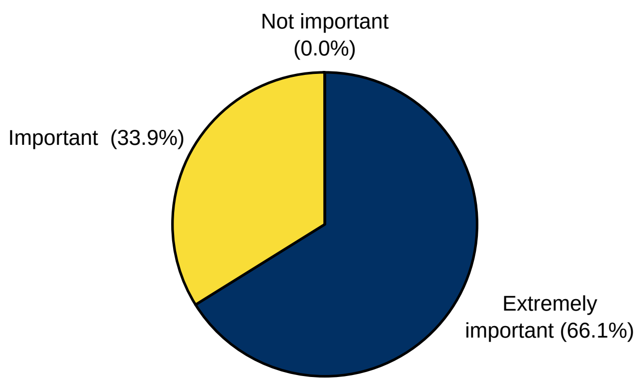
> *"Scientific HPC and industrial HPC span different utilization scales and usage models but meet at some points and both are important."*

> *"[HPC is] extremely important for industry sectors such as aerospace, oil and gas, energy, chemistry and life sciences."*

> *"Future drug development and personalized medicine will heavily rely on HPC and simulation-based research."*

FIGURE 7

How Important is HPC for Industrial Competitiveness?



Source: IDC, 2010

TABLE 36

How Important is HPC for Industrial Competitiveness?

Comments:	Comments:
Applied research utilizing HPC is extremely important for industrial competitiveness	In many areas (such as engineering, drug design) HPC is used routinely to improve and speed up the development cycle.
Especially because of the crucial role of HPC simulation in design optimization and process development (e.g. airplane, motorcars, crash tests, drug design, materials tailoring, logistics)	In some industries design-by-simulation may become a real alternative to design-by-fabrication (chip industry, pharmaceutical industry, automotive industry)
Extremely important for industry sectors such as aerospace, oil and gas, energy, chemistry and life sciences	Modern product design needs advanced methods of simulation and HPC researchers bring CSE culture into industry
For Industry HPC is getting more and more important, not only for design phase but for all phases of the product or service life	Scientific HPC and industrial HPC span different utilization scales and usage models but meet at some points and both are important
Future drug development and personalized medicine will heavily rely on HPC and simulation-based research	For companies like Shell having access to high-end HPC is extremely important and critical to their (absolute and relative) success in finding oil and the efficient exploration of wells.
HPC helps shrink time to discovery and time to invention	For companies, like AKZO or DSM (chemistry) the jury is still out if high-end computational chemistry can/does make a difference.
If we agree that HPC is extremely important for scientific leadership then we have to multiply this suggestion towards the role of HPC for industrial competitiveness.	HPC should be able to make a company more competitive, but many industries in EMEA are still hesitant to invest in these types of resources. HPC is most often so core to their business a low risk approach is taken rather than a bleeding edge approach.
It is well-accepted theory that to be competitive industry has to provide fast new products and services on the market, optimizing their efforts and costs for exploring new ideas, R&D as well as product and services validation.	The uptake of Capability HPC in industry remains anecdotal unfortunately. This limited success can be primarily attributed to the modest scalability of typical ISV applications (compared to best of breed academic or community research codes).
HPC can play several really important roles such as: (1) provision of the necessary e-Infrastructure as an accelerator or catalysis of all processes, leading to novel product, production and services innovation, sometimes disruptive technologies;	However that "general purpose" (or "capacity") HPC is well established in industry.
(2) Carry out simulations of sufficient fidelity of advanced complex systems in technology leading areas with high value-added such as: automotive industry, pharmaceutical, aerospace, biomedicine, the power industry and etc., saving a lot of money and time.	Time to market is a key to a better industrial competitiveness. Being able to simulate more and faster reduces the general production cost and improves the industrial actors' positioning on the market.

Source: IDC, 2010

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8.3 Importance of HPC for the Respondents' Organizations

Nearly all of the survey respondents (95%) declared that HPC is important for their organizations (see Figure 8 and Table 37), and the comments accompanying their responses make it clear that some or all of the respondents who disagreed come from organizations such as funding agencies that oversee HPC initiatives without needing to use HPC themselves. These representative comments help to tell the story:

"As a National HPC Center, our organization has a clear mission to provide an optimal environment for research groups based in our country to achieve high levels of international competitiveness. Our strategy encompasses an ensemble of measures and services catering for the needs of (and developing) grass root research, all the way to world-class computational research groups. It is for the latter in particular that access to leading edge hardware and expertise is crucial. While we do provide the expertise, the high costs associated with the acquisition and operation of a genuine capability computing infrastructure precludes us from offering this service locally. Access programs such as DEISA's Extreme Computing Initiative (DECI), the Partnership for Advanced Computing in Europe (PRACE), or the U.S. DOE's INCITE, to name a few, provide suitable mechanisms for access to these types of resources.:

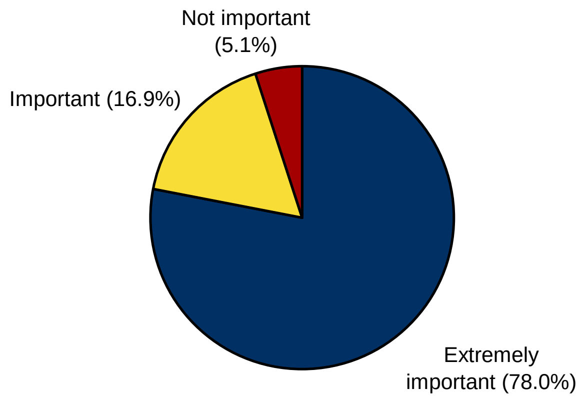
"As the largest research center in [country], our activity in energy research, material science, health and environment relies on HPC to a large extent."

"We use HPC for a wide range of activities, from science to development. HPC in itself is an important asset and tries to foster the usage of HPC in [country] and in Europe, while supporting as much as possible European HPC industry and service.

"HPC is of limited importance to us, as we are a funding organization."

FIGURE 8

How Important is it for Your Company/Organization to Have Access to Leading HPC Systems?



Source: IDC, 2010

TABLE 37

How Important is it for Your Company/Organization to Have Access to Leading HPC Systems? (And other leading HPC resources [e.g. software, networking, storage, experts])?

	Responses	Percent of Respondents
Extremely important	46	78.0%
Important	10	16.9%
Not important	3	5.1%
Total	59	100.0%

Source: IDC, 2010

8.4 Importance of HPC for Respondent's Country

Nearly all of the respondents (94%) rated access to leading HPC systems as "extremely important" (94%) for their countries, and the remaining 6% considered it "important," as Figure 9 and Table 38 indicate. This represents a very strong block vote in favor of making time on large HPC systems widely available in Europe.

Representative Comments from Respondents

"As a small country, access to large-scale HPC systems is crucial as this represents a limiting factor for many computational scientists. World-class research is taking place

particularly in nanoelectronics, drug design, climate and sustainable energy, all requiring significant compute power."

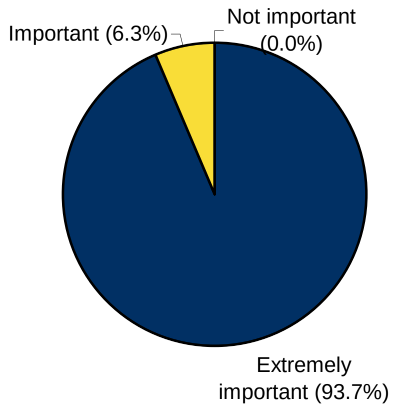
"HPC is crucial for [our country's] industries like chemical, nanotechnology, life sciences and media and entertainment."

"Scientific and industrial leadership is of utmost importance for [our country]. The federal government is highly aware of this and is making significant investments into national and European HPC infrastructures through funding."

"Under any respect a country cut out of HPC is doomed to be and remain marginal, possibly even to lose its position if he had one. On that respect the size of the country is a problem and, for us Europeans, the best idea would be to join forces."

FIGURE 9

How Important is it for Your Country to Have Access to Leading HPC Systems?



Source: IDC, 2010

TABLE 38

How Important is it for Your Country to Have Access to Leading HPC Systems? (And other leading HPC resources [e.g. software, networking, storage, experts])?

	Responses	Percent of Respondents
Extremely important	59	93.7%
Important	4	6.3%
Not important	0	0.0%
Total	63	100.0%

Source: IDC, 2010

8.5 Importance of HPC to the EU and Europe

Similarly, 97% of the survey respondents said that access to leading HPC systems is "extremely important" (84%) or "important" (13%) for the EU's ability to compete in the global market place (see Figure 10 and Table 39).

Representative Comments From Respondents

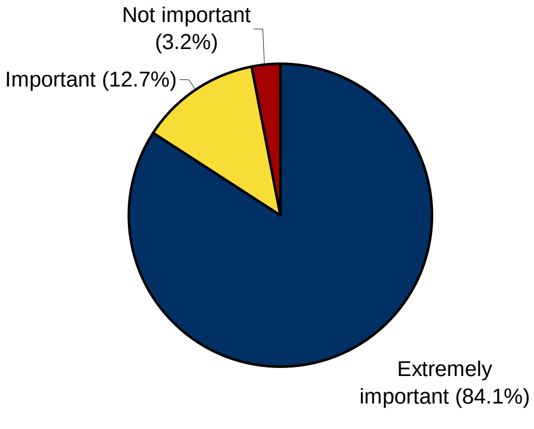
"Failure to compete at the highest level would allow the U.S. and Asia-Pacific regions to take the leadership in key areas such as materials design, drug design, etc…Europe must think as a region and economic area, rather than a federation of individual countries. Hopefully, initiatives such as DEISA and PRACE are significant."

"If we agree that access to high-end resources is necessary from a scientific and industrial competitiveness point of view, this will be critical in the EU's ability to compete with other regions in the world where this is already being done (like the national labs in the U.S.)."

"Seen from the EastMed corner of Europe, advanced computing is a key technology for modernizing societies in the entire region. HPC networking is a means to reduce traditional brain-drain (mainly to U.S.) by forming a local research area."

FIGURE 10

How Important is it for the EU as a Region in a Competitive Global Marketplace, to Provide EU Member States With Access to Leading HPC Systems?



Source: IDC, 2010

TABLE 39

How Important is it for the EU as a Region in a Competitive Global Marketplace, to Provide EU Member States With Access to Leading HPC Systems?

And other leading HPC resources (e.g. software, networking, storage, experts, etc.)?

Comments:	Comments:
Certainly. Failure to compete at the highest level would allow the U.S. and Asia-Pacific regions to take the leadership in key areas such as materials design, drug design, etc. It is important for Europe to be in a position of leadership, to protect the resulting IP and hopefully, provide an environment maximizing chances for successful commercialization when appropriate. Europe must think as a region and economic area, rather than a federation of individual countries. Hopefully initiatives such as DEISA and PRACE are significant steps in this direction, though much remains to be done.	If current political context persists, can't reach ambition totally just by becoming expert users of technology they get on the open market. Choice is theirs. Personal belief that in next five years there will be discontinuity as people come to grips with radical changes in technology they use for HPC (driven by power constraints, etc). EU is presented with an opportunity over the next few years as innovations in multiple dimensions will be necessary simultaneously in HPC. The question is who gets there first. It will be monumentally dislocating to the software installed base. It will be possible for the EU to take a major role in the evolution of these new technologies. Future might be centered on issues of memory and interconnect or on programming models and tooling much more so than on microprocessors which could be opportunity for investments in training and software and algorithms to create foundation for future HPC systems. To do so would require organizing in an interesting way.
Competitiveness is crucial for the EU as a region.	Modern sciences are more and more global; not having access to HPC will make scientists move.
The EU needs to create intellectual challenging environment which enables world-class scientific research and engineering by pioneering, operating and supporting leading-edge HPC technologies into the next decade. This is the only way towards the restoration and maintenance of European science and industry competitiveness. In addition, EU has to attract many young scientists and engineers who graduates every years to continue their work in Europe. Providing them with access to capability computers of leadership-class can boost their recognition and appreciation to deal with the complexity of phenomena.	The EU would (at least theoretically) be able to (support) purchasing true leading HPC resource infrastructure (basically hardware) that would be of an order of magnitude larger than is available in any of the member states. In my opinion (if we agree that access to high-end resources is necessary from a scientific and industrial competitiveness point of view) this will be critical in the EU's ability to compete with other regions in the world where this is already being done (like the National labs in the U.S.). For this to be successful beyond using these resources for science, a body of expertise, freely accessible to the industry, will need to be provided.
The EU should catalyze developing the competitive edge of member states by encouraging and supporting sustainable HPC development, but not direct member states on actions and technology decisions.	Scientific and industrial leadership is of utmost importance for Europe.
EU wide collaboration is important, especially re high performance networks. EU wide data repositories are also strategically important	Seen from the EastMed corner of Europe, advanced computing is a key technology for modernizing societies in the entire region. HPC networking is a means to reduce traditional brain-drain (mainly to the U.S.) by forming a local research area.
Europe has got to compete on other basis then quality or cost and this can only be done by stimulating discovery inventions	Research is worldwide and can't wait on other countries technology
The market of HPC is being globalized, HPC is becoming a commodity that can be bought anywhere. The notion of region is less relevant today. Global market forces should be the drivers for decreasing the cost and improving the quality of services in a world market for HPC.	.

Source: IDC, 2010

9.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: KEY APPLICATION AREAS

9.1 Scientific and Engineering Areas That Stakeholders Would Like the EU to Support

The survey respondents cited a large number of scientific and economic domains that should have access to leading HPC systems and related resources (see Table 40). Among the most frequently mentioned areas were the following:

- Clean energy
- Climate modeling
- Bio-sciences (healthcare, drug discovery, medical research, genomics/proteomics)
- Materials science/nanotechnology
- Oil and gas exploration/production
- Aeronautics and crash simulation

TABLE 40

What Scientific or Engineering Should the EU Support by Providing Access to Leading HPC Systems and Other HPC Resources?

E.g. software, networking, storage, experts, etc.?

Comments:	Comments:
1) Efficient and clean energy production (all kinds of energy) 2) healthcare (design of equipment such as imaging devices, improve diagnosis methods, drug design etc.) 3) materials and nanotechnologies (design of materials and devices).	Large scale simulations where experiments are not possible, too expensive or too time costly.
1) Oil and gas industries: solve the full 3D inverse waveform problem, derive and calibrate fine-scale reservoir simulation models and run them at the appropriate scales, 2) Structure calculation: design new composite compounds in order to a better knowledge on deformation, absorption, fatigue, wear … for seal, acoustic insulation.	Life sciences (genomics, proteomics, systems biology) and a combination of CFD and structures. Medical research, EU countries tend to lag in particular the U.S. in terms of access to very large systems and the consequent impact on developing cures for illness and disease.
3) Energy: achieve computations with smaller and smaller scales in larger and larger geometries for a better understanding of physical phenomena and energy efficiency. Some examples: Turbulent combustion in closed engines and opened furnaces, explosion prediction for security purposes, as well as to nuclear and fusion plants.	Material science, nanotechnology, energy (e.g. fusion), systems biology, astrophysics.

TABLE 40

What Scientific or Engineering Should the EU Support by Providing Access to Leading HPC Systems and Other HPC Resources?

E.g. software, networking, storage, experts, etc.?

Comments:	Comments:
4) Aeronautics: full multidisciplinary optimization, for CFD-based noise simulation and for real-time CFD-based in-flight simulation. This would lead to the complete design before starting industrial developments (the so-called digital aircraft) 5) Engineering (in general): multiscale CFD, multi fluids flows, multi physics modeling, flows with transfer and turbulence in complex and large geometries, complex systems modeling …	Materials modeling (OLED, Fuel Cells, nanomaterials), protein structure prediction and design.
1) Scientific software development framework; 2) advanced tools and middleware to allow "seamless" workflows across all the different infrastructures: grids and clouds, HPC, knowledge and data banks.	Medical application/drag design, automotive industry.
Air pollution, chemistry-climate interaction, earth system modeling.	Nanotechnology and quantum systems, brain and brain disease research, astrophysics and cosmology, airplane and car design optimization, new materials technology.
All areas of science and engineering need better EU HPC support.	Nanotechnology, drug design and climate modeling/NWP in particular. A number of other areas (e.g., sustainable energy) are equally important but do not currently require the same level of capability.
All scientific or engineering areas listed in the HET scientific case.	New energy sources and technologies including advanced NE.
All the areas described in the HET report.	Nuclear fusion, climatology, data mining, and medical simulation.
Bioinformatics, material sciences, fluid dynamics, structural analysis.	Particle physics, climate simulation, nuclear/energy industry, automotive/aeronautic industry, financial industry, etc.
Classic HPC applications are typically from physics or engineering. With today's HPC systems for the first time, meaningful biological problems can be addressed which is a game changer in that field.	Physics/chemistry/biology.
Climate modeling, fundamental research (physics/astro…)	Scientific software development, sophisticated systems of hardware power consumption control.
Climate research, life-science.	Climate, environmental, digital archeology, and basic science applications.
Climate, bio, material sciences.	Simulation of new materials, life science, climate changes, self organization of matter.
Condensed matter physics, Fusion, CFD, life sciences.	So-called blue collar computing (SMEs), financial services (real time financial modeling predicting recessions) and also human sciences.
Energy (e.g., wave/tidal power modeling), climate change, drug design/bioinformatics, health (self-diagnosis/monitoring), energy efficient computing (e.g. photonics)	Software, algorithms, computational science.
Energy (short term to long term like fusion), life science including support of ageing society.	Software, parallel programming, networking, experts.
Energy generation.	Support of computational science as a research field (chemistry, biology, physics and engineering).

TABLE 40

What Scientific or Engineering Should the EU Support by Providing Access to Leading HPC Systems and Other HPC Resources?

E.g. software, networking, storage, experts, etc.?

Comments:	Comments:
Engineering — design of future solutions to enable the next generation compute platforms, datacenter power consumptions, green computing.	The entire field of computational sciences and engineering (materials, biomaterials, geophysics, meteorology, aeronautics etc.) desperately need that!
Extensive user training and application development.	SKA because the Europeans are probably going to have a hyper-prominent position relative to participation, funding, etc. The technology that will underpin SKA will be massive computing.
Genomics, climate change, material sciences.	Tools at scale, new languages, libraries etc.
High-energy physics and plasma physics; astrophysics; material science; chemistry; automotive and aerospace industry; gas turbines and internal combustion engines; nanoelectronics; pharmacy.	Water management, climatology, social behavior, traffic and vehicle safety and behavior, medical insights (from bone to brain), pharmacology/genomics, materials science, catalysis.
Weather simulation, ocean models, nuclear fusion simulation, crash simulation, medical analysis (brain).	

Source: IDC, 2010

9.2 Areas the EU Should Focus on in Developing a Stronger Position

Table 41 shows the responses when IDC asked which general areas the EU should focus on to develop a stronger HPC leadership position. Because respondents were allowed to name more than one area, the rankings in the table are by number of responses for each choice.

The most popular choice for the EU's HPC strategy to focus on was HPC software applications and application scaling (mentioned by 71% of the 63 respondents to this question). Becoming stronger in "the use of HPC to solve important scientific problems" (62%) was the second most popular choice, followed by "the use of HPC to solve important engineering problems" (46%).

Focusing on the development of HPC systems themselves (33%) ranked fourth on the list, with less than half the support shown for advancing leadership in HPC applications and applications scaling. As one respondent said, "The EU should not focus on HPC technology; it should instead focus on funding science research, which can then acquire HPC as it needs." Based on their earlier input, this person's fellow respondents would add industrial research to the priorities.

TABLE 41

What General Areas do You Think the EU Should Focus on in Developing a Stronger HPC Leadership Position?

Area	Responses	Percentage of Sample
Core technologies: HPC applications and applications scaling	45	71.4%
The use of HPC to solve important scientific problems	39	61.9%
The use of HPC to solve important engineering problems	29	46.0%
Core technologies: HPC systems	21	33.3%
Core technologies: HPC middleware and system software	15	23.8%
Core technologies: HPC services	15	23.8%
Core technologies: HPC interconnects	11	17.5%
Core technologies: External HPC services, platforms, grids and/or clouds	10	15.9%
Core technologies: HPC storage (internal and external)	4	6.3%
An area not named above	2	3.2%
None, the current approaches are working fine.	0	0.0%

Note: Multiple responses were allowed. 63 people responded.

Source: IDC, 2010

9.3 Technical Areas Where the EU Should Focus its HPC Efforts

Table 42 depicts the results when respondents were asked not simply to name areas that the EU HPC strategy should focus on (see Table 41), but to rank their importance on a scale of 1 to 10, where 10 is most important and 1 is least important.

In the resulting rankings, the highest-rated priority for the EU HPC strategy was to ensure the availability of an adequate number of qualified personnel for HPC-related positions (7.8 average rating). The prominence of the staffing/training issue was not surprising. At conferences and in meetings with HPC officials around the world, one of the top issues IDC runs into is almost always the workforce shortage in HPC. This has been constraining the plans of government agencies and large HPC datacenters to an increasing extent in recent years. IDC recently completed a worldwide study on this issue for the U.S. Department of Energy, which gave IDC permission to share the key findings of the groundbreaking study elsewhere in this interim report to the European Commission.

The issues ranking second and third on the priority list both concern software: namely, new application software based on open source standards (6.3 rating) and parallel programming and debugging tools (6.2 rating). As noted in other sections of this report, there was strong consensus among the respondents and within the global HPC community that software development is more crucial for advancing HPC than hardware development.

Other important priorities for the respondents included addressing power and cooling costs (6.1 rating) and system scalability (5.9 rating). Note that focusing on the development of HPC hardware systems emerged as a low priority, coming in at number 10 with an average rating of only 4.2.

List of Other Suggestions

- Quantum Computing (3 responses)
- Visualization, data analysis making use of the wealth of data (simulated, experimental, observational) and connecting them (3 responses)
- Application scalability
- Build scientific multidisciplinary researches
- Create true EU HPC research centers support with EU budgets
- Develop and maintain scientific software
- Develop scientific algorithms
- FPGA-based HPC
- Green HPC technologies and products
- Integration with domain-scientists to allow meaningful simulation-based research
- None — the EU should not focus on providing HPC; it should focus on funding science research directly and allow the research to procure HPC as needed
- Optimization of standard x86 hardware for HPC applications
- Professional programmers with HPC skills plus an appropriate career path for them. Professional system administrators with skill sets appropriate to running very large systems in higher education institutions.
- Programming hybrid systems.
- Provision and development of HPC services.
- Technologies optimizing utilization of existing hardware.

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TABLE 42

Technical Areas That the EU Should Focus its HPC Efforts

Using a scale of 1 to 10 with: 10 = most important, 1 = least important

Area	Total Score	Average Rating
Personnel, talent, skill sets, and training, including access to external HPC services and experts.	468	7.8
New applications software — open source.	379	6.3
Parallel programming tools. Debugging tools.	371	6.2
Power and cooling costs.	368	6.1
System scalability.	354	5.9
Libraries.	307	5.1
Storage software/file systems.	293	4.9
System manageability.	284	4.7
Compilers and new programming languages.	268	4.5
HPC system hardware — complete systems.	254	4.2
Profiling tools.	251	4.2
Systems software, including operating systems.	247	4.1
New applications software — fee based.	242	4.0
Interconnect software.	239	4.0
System grid/monitoring/management software.	237	4.0
Job scheduling and queuing tools.	225	3.8
Interconnect hardware.	220	3.7
System hosting solutions (utilities, grids and clouds).	209	3.5
New memory technologies.	206	3.4
Processors — standard accelerators, e.g. GPGPUs.	199	3.3
Storage interconnects and backbone protocols.	191	3.2
New storage hardware, including SSDs.	187	3.1
Large external storage farms.	163	2.7
Processors — standard x86.	139	2.3
Processors — custom.	100	1.7

Note: Multiple responses were allowed. 60 people responded.

Source: IDC, 2010

9.4 HPC Historic Contribution to Leadership in the EU

For Scientific Leadership

HPC's contributions to scientific leadership in the EU are numerous and varied, according to the survey respondents (Table 43). They range from inspiring young people to pursue careers in science and engineering, to making specific contributions across a broad spectrum of scientific disciplines, including paving the way for personalized medicine, helping to predict climate change, improving energy efficiency and research on new energy sources, and enabling progress on research into the origins of the universe.

Representative Comments from Respondents

["HPC has had a] wide-ranging societal impact, from inspiring generations of kids to take up science and engineering as a career (with direct impact on our ability to develop the smart economy), to even contributing to philosophical debates on the origin of the Universe, creation, etc." [general comment]

"Paving the way to personalized medicine to tackle the challenges of today's drug development" [biology/medicine]

"Drug design" [biology/medicine]

"[Enabling] better design, lower RD costs" [automotive industry]

"[Enabling scientists to] understand global change and evaluate consequences of possible counter-measures" [climate modeling]

"[Enabling research on] clean and efficient energy, new sources of energy like fusion" [energy research]

[Giving Europe a] leading position in research, e.g., at CEA (ITER, but also in renewable energy issues like hydrogen cells)" [energy research]

"New materials" [material science]

TABLE 43

Assessment of the HPC Contribution to Leadership in the EU

For Scientific Leadership

Area	Description of the Benefit
Astrophysics	Better understanding of the universe
Astrophysics and theoretical particle physics	Wide-ranging societal impact, from inspiring generations of kids to take up science and engineering as a career (with direct impact on our ability to develop the smart economy), to even contributing to philosophical debates on the origin of the universe, creation, etc.
Automotive	Better design, lower RD costs
Basic physics	New knowledge
Bio technologies	Developing new drugs
Biology/medicine	Paving the way to personalized medicine to tackle the challenges of today's drug development
CFD	Knowledge creation
Chemistry	Improving heterogeneous catalysis
Chemistry	Knowledge creation
Chemistry	Knowledge creation
Climate	Predict future development
Climate modeling	Understand global change and evaluate consequences of possible countermeasures
Climate modeling	Policy guidance
Climate Research	Better understanding
Climatology	Predict climate change
Climatology, earth science	Characterization of the global warming
Computational physics	Non-linear science
Computational quantum physics	Lead application for HEC with impact on new compute technologies
Drug design	Fighting cancer
Energy	New solutions
Energy	Future energy solutions
Energy	Clean and efficient energy, new sources of energy like fusion
Energy	Technological innovation
Energy	Plasma physics and fusion
Energy fission/fusion/others	Leading position in research, e.g. at CEA (ITER, but also in renewable energy issues like hydrogen cells)
Engineering	Optimized procedures with improved energy, noise and CO_2 footprint balances
Engineering	Airbus
Future energy	Develop new energy solutions from fusion to renewable
Genetic research	Faster modeling
Green IT	Lower CO_2 emissions
Health	New treatments and new drugs
Inverse problems	Higher research performance
Life-science	Protein folding
Material modeling and molecular dynamics	Leadership in many highly relevant community codes

TABLE 43

Assessment of the HPC Contribution to Leadership in the EU

For Scientific Leadership

Area	Description of the Benefit
Material science	Existence of scalable application codes simulating new materials of technological interest
Material science	New materials
Materials science	New better materials, nanotech solutions
Medical imaging	Leading position (e.g. NEUROSPIN, SHFJ at CEA) with industrial (devices) and public health by-products
Nano technologies	New materials
Particle physics	European leadership in the field with CERN and LHC
Physics	Scientific research
Physics	Advancing scientific knowledge
QCD	A fundamental theory 'proven' by simulation (hadron mass calculation in 2008)
QCD	Solving long-standing problems related to essential aspects of the strong interaction
Quantum systems	Spintronics
Simulation of Electromagnetic systems	Design optimization
Soft, condensed matter etc.	World scientific leadership.
Solid state physics	New materials
Systems biology	Advances in agricultural research and food sciences, as well as contributions to the biotech industry

Source: IDC, 2010

For Economic Leadership and Other Leadership Areas

In the realm of economic and other areas of leadership (Tables 44 and 45), the respondents compiled an equally impressive list of HPC-enabled achievements, including these:

- Keeping Europe's aerospace and automotive industries globally competitive
- Saving lives and property through better prediction of severe storms
- Reducing the time and cost to design new drugs
- Strengthening the IT industry in Europe
- Designing new materials for energy applications, such as power cells and turbines
- Reducing risks in the insurance and larger financial industry

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TABLE 44

Assessment of the HPC Contribution to Leadership in the EU

For Economic Leadership

Area	Description of the Benefit
Aerodynamics and car design	Competitive industry (F1)
Aeronautics	Competitive industry (AEDS)
Aircraft engine	Competitiveness of French suppliers by providing better engine (longer lifetime, reduced fuel consumption, less noise)
Aircraft industry	More optimized shapes
Airplane design	Airbus successful on global market
Automotive and aerospace industry	Permit extensive engineering optimization of complex designs
Blue Collar Computing	Competitive SMEs
Car design	Crash test and optimization
Climate research	Impact prediction
Computational fluid dynamics	Faster cars/boats/planes, which also pollute less.
Drug design	Reduce time/cost of development
Economics/Finance	Faster calibration of option pricing models
Energy	Increase life time and safety of nuclear reactor
Energy	Improve efficiency/availability of nuclear plant, design new generation of nuclear plants
Energy	Create large market volume
Energy (energy has scientific AND economic sides)	Better nuclear power plants and nuclear fuel management cycle, solar and hydrogen cells, etc.
Engineering	Competitiveness
Engineering	Help the automotive aerospace/pharmaceutical industry to keep their position
Engineering	New products
Finance and insurance	Reducing risks
Financial modeling	Prevent economic disasters
IT industry	Strengthen the European industry
Life sciences	Understanding of processes, drug design, health improvements
Material engineering	Designing new materials for energy applications: power cells, turbines, etc
Material science	New materials
Materials sciences and nanotechnologies	Leading edge research with huge economic perspectives (materials, devices)
Medicine	Drug design, e.g., high-throughput screening, advancement of personalized medicine, etc.
More competitive	
Nanoscience	Design of new materials (e.g., integrated nanoscale devices, nanowires, carbon nanotubes, etc.)
Protein simulations	More productivity
QCD	Hadron mass calculation
Structural engineering	Effectively designing and testing new metallic structures in civil engineering, automotive and aeronautic industry, power plants

Source: IDC, 2010

TABLE 45

Assessment of the HPC Contribution to Leadership in the EU

In Other Areas

Area	Description of the Benefit
Airplane design	Airbus global competitiveness
The universe	Better understanding of solar and cosmic processes
Climate modeling	Provide necessary data for national strategy for adaptation to climate change
CSE education	Increased expertise
Energy research	Development and/or improved usage of energy sources
HPC R + D	HPC as an export article
Meteorology	Improved weather prediction/alerts
Oil and gas	Optimized prospection and extraction (TOTAL)
Plasma physics	Simulations of high density high temperature plasmas in future fusion reactors
Better life	Strong industrial network, many jobs
User training	Efficient use of people

Source: IDC, 2010

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10.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS

10.1 EU Strengths

In Tables 46A through 46C, the survey respondents provide their opinions on the EU's greatest strengths in and for HPC. The following representative comments summarize the most frequently cited strengths:

"A broad mixture of HPC installations used for a wide variety of different purposes."

"Diversity."

"Application domains like climate modeling, brain simulation, combustion engines, and nuclear fusion."

"Application software."

"Software development."

"No major [hardware system] vendors, so Europe is open to all technologies and open to focusing on apps and not systems."

"Cooperation between countries in PRACE — important for the future"

"Good university research"

TABLE 46A

What Are the EU's Greatest Strengths in HPC Today?

Strength #1	Strength #1
A broad mixture of HPC installations used for a wide variety of different purposes.	High speed network
A vivid and multi-approach software community	Its scientists
Access to the technology	Large application basis
An EU political will expressed by the Council of the EU in its Conclusions from December 2009	Leadership in different scientific fields
Application domains like climate modeling, brain simulation, combustion engines and nuclear fusion	Many well equipped and skilled computing centers at regional/national levels
Application software	National HPC centers in several countries (e.g. Germany, Finland, Spain, NL)
Available of HPC tier 0-systems	Networking and Grids (CERN etc)
Awareness of the need; some strong national efforts	No major vendors (Bull is more of a cluster vendor) so they are open to all technologies and open to focusing on apps and not systems.
Competence, people, networking	No national pride when buying systems

TABLE 46A

What Are the EU's Greatest Strengths in HPC Today?

Strength #1	Strength #1
Competences (software, academic research, Bull, CEA)	Nothing comes to mind
Computational science, middleware, and tools	Number and qualities of the scientific users, code developers
Consolidation of the resources through HPC-Europe	Number of first class centers for computing
Cooperation between countries in PRACE — important for the future	People
Cooperation between countries in PRACE is a very strong asset as such as it allows coordination of required future actions	PRACE and EGEE projects
Development of scalable scientific and some engineering application software.	PRACE project and desire to be real
Development tools and libraries; e.g., Scalasca, Tau, DDT, Vampire, HMPP, NAG	Presence of CERN
Different HPC systems distributed over the whole EU	Provides good access to state-of-the-art HPC hardware
Diversity	Quality of education
Experts in math models, numeric models, etc.	Scientific HPC applications
Finite element methods	Software development
Fostering diversity (PRACE)	Software developments/scientific software
Good areas of concentrated skills (e.g., Max Planck, U.K., Netherlands) and centers (e.g., Juelich, CNRS) though unorchestrated;	Software R&D
Doing parochial missions but never been harnessed to work collectively. If worked collectively the impact would be a lot more dramatic than it is today.	Software system for HPC center: grid system
Good university research	Solid basis of HPC expertise in European HPC centers, research and industry labs
Great teams of experts	Supra-national collaborations
GRID computing, with in particular GRID5000 platform	The start of a European HPC environment with PRACE
Hardware	World class HPC centers in France, Germany, and Great Britain
High expertise throughout the member states	.

Source: IDC, 2010

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TABLE 46B

What Are the EU's Greatest Strengths in HPC Today?

Strength #2	Strength #2
A few computing centers of international level, with rich scientific environments and a cross-fertilized vision of industry/research HPC usage.	Industrial application of HPC
A good EU-level interconnection network for academia (GEANT)	Innovative bioscience ecosystem
A strong economy, backing research in a proactive manner through different means.	Knowledge based society, with stakeholders having a positive attitude towards HPC
Access to the technology	Large industrial users
Algorithms	Large scale parallel application development for engineering fields
Application knowhow	Light side of hardware developments
Applications, both community-driven and ISVs applications, e.g., QuantumEspresso, VASP, Abaqus, DL-POLY, Abinit	More than 20 European Universities offering educational programs in CSE
At some locations expertise	realization of need for coordination to compete with the world's largest installation
Capacity of trusting in limited resources forcing to find smart solutions	Software development
Coordination on the European level through PRACE	Software skills
Distributed system management and interoperability concepts	Some HPC centers are on the same level as U.S. centers (JUGENE/Juelich still TOP No. 3)
Emerging industrial HPC applications	Strong research and industrial communities
Existence of some R&D of interconnect hardware	Systems integration (Bull) and interconnects, perhaps also embedded processors
Experts in scientific areas like weather, fluid dynamics, biology, etc.	Systems integrations
Good ISVs	The faster computer in an industrial company is in Europe (TOTAL SGI computer at PAU, France)
Good network of national computing centers	There are some excellent HPC centers with leading edge HPC systems and recourses distributed in some European countries
Having created one of the few operational international Grids (CERN) in the world	Variety of approaches
Idea of PRACE	Various scientific skills in universities
Important financial resources backed by a political determination	Weather forecasting

Source: IDC, 2010

TABLE 46C

What Are the EU's Greatest Strengths in HPC Today?

Strength #3	Strength #3
A wide variety of cutting edge researchers and research institutes.	HPC research and education
Algorithm development in applied math.	Leadership in embedded HPC applications
Well-established mechanisms for sharing of information and experience which provides an basis for fast dissemination of HPC outcomes in the public domain	Many skills and successful achievements in application software and middleware development
Communities; e.g., CECAM, CCPs (in the U.K.), Psi-k, Simu, Virgo, etc.	Networks and telecom
Computational scientists	PRACE and DEISA with GEANT provide efficient HPC structure
Development of some HPC custom processors	Software strength; lots of untapped potential in Central Europe in design and software skills
Diversity and excellence in software	Some good providers of HPC technologies and services
Excellent specialists in computer science	Strong collaborations with the U.S. (ORNL/Jülich for example)
Good education system for mathematics and engineering sciences	Strong scientific research involvement (e.g. DEISA)
Usually produce quality with limited budgets	.

Source: IDC, 2010

10.2 EU Weaknesses

Tables 47A through 47C lay out the EU's greatest HPC-related weaknesses, as seen by the survey respondents.

Interestingly, although in response to earlier questions the surveyed individuals as a group expressed strong consensus that the EU should not try to develop a European HPC hardware platform — an opinion expressed even more forcefully in the in-depth interviews with the leading lights of the HPC community — here, quite a few respondents were dismayed that, as they saw it, Europe lacks an indigenous hardware vendor with its own architecture (they generally do not see Bull as having its own hardware design). Other respondents, however, echo the opinion expressed elsewhere that not having a strong European hardware vendor keeps the European HPC market more open and competitive.

These representative comments encapsulate the respondents' views of EU HPC weaknesses:

"Leadership is not defined."

"[There is a] lack of a Unified European strategy."

"[There is] almost no coordination of efforts between countries."

"[There is] no common concept. Every country has its own HPC strategy."

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"[There is] fragmentation of investment with insufficient coordination across member states, leading to suboptimal ecosystem (lack of cohesion, inconsistent access policies and practices)."

"[There is a] focus on trying to build a systems capability when [Europe is] too far behind and doesn't have the infrastructure to support it."

"The lack of major European hardware vendors (with the exception of Bull) makes it more difficult for European HPC centers to form strong partnerships with vendors or get involved in the development of leading edge technology."

"[The] lack of a European HPC industry (e.g., processor, interconnect, storage, system development)."

"[The] lack of HPC training/courses at the university level. There are few graduates with HPC skills."

TABLE 47A

What Are the EU's Greatest Weaknesses in HPC Today?

Weaknesses #1	Weaknesses #1
Focus on trying to build a systems capability when they are too far behind and don't have the infrastructure to support it.	Lack of coordination
Activities are not optimized in common efforts	Lack of EU-level funding
Almost no coordination of efforts between countries	Lack of European HPC industry (e.g., processor, interconnect, storage, system development)
Bio- and materials applications	Lack of funding
Budgets	Lack of funding, coordination, and interconnections of the SCCs
Bureaucracy	Lack of hardware technology
Computer hardware development, especially in CPU	Lack of HPC on-demand offering. Considerable annual running cost of the infrastructure
Coordinated effort	Lack of HPC solution awareness in decision-makers
Difficulty to get access to HPC facilities	Lack of major European hardware vendors (with the exception of Bull) make it more difficult for European HPC centers to form strong partnerships with vendors or get involved in the development of leading edge technology.
European activities rely mainly on national funding, this is a risk for a sustainable joint strategy	Leadership not defined
Few connections between HPC centers and industry	Long bureaucratic funding cycles
Few large-scale, goal-oriented, integrated projects combining domain science with HPC	No common concept. Every country has its own HPC strategy
Fragmentation of country HPC initiatives as well as the lack of cohesion among the involved parties — science community, hardware and software providers, funding body, including government	No competitive European HPC industry
Fragmentation of the human potential and low level of involvement of SMEs	No effective funding programs for HPC research
Hardware	No real HPC hardware industry and no tradition

TABLE 47A

What Are the EU's Greatest Weaknesses in HPC Today?

Weaknesses #1	Weaknesses #1
Hardware design	No solid national and international funding scheme and no long-range budgets guaranteed
Hardware design and manufacturing	No vision
HPC capabilities fall behind U.S./Asia	Non-existent development of processor hardware
HPC hardware/systems vendors	Not a significant HPC hardware industry by comparison with U.S. or Japanese HPC industries
HPC not being strategic	Not enough direct help for its own (European) HPC industry. If funding is handed down, then it is done so to well defined "clubs" that have been set up specifically for this purpose.
Ignorance of technical aspects	Not enough support of HPC application development by stimulating consortia of mathematicians at universities and developers of leading simulation codes
Inconsistency in individual national priorities	Poor availability of Tier 0 HPC systems
There is no European HPC Research center with a Petascale computer	Slow progress in the integration of some small countries (mainly new members) in the utilization of transnational HPC centers
Lack in systems development	Sustainable policies
Lack of a global vision and strategy beyond national levels with an industrial (vendor) backbone	Too few industries among the major users
Lack of a unified European strategy	Too little support to make HPC illiterates understands the benefit of HPC.
Lack of coherent, long-term strategies and commitment to HEC funding	Too much bureaucracy
Uncoordinated	.

Source: IDC, 2010

TABLE 47B

What Are the EU's Greatest Weaknesses in HPC Today?

Weaknesses #2	Weaknesses #2
Absence of strong and leading European brand in the areas of HPC hardware, networking and storage	Lack of strategic support to EU computer industry in competitive setting
Academia funding does not create as efficient results as it could	Lack of support for EU HPC industry
Almost no hardware vendor	Lack of understanding (by decision makers) for the need of e-infrastructure
Complicated system of European grant application process	Marketing
Computer language development	Medium and long term view
Cost of computing time for industrial partners	National Defenses didn't invest in HPC as DARPA does in U.S.
EU funding often ends up with non European industrials. When compared to non-European countries where the top down funding ends up local.	National interests can prevent free knowledge transfer
Feeble development of compilers and development tools	No competitive hardware manufacturer for large systems
Fragmentation of funding for R&D and large projects in HPC (funding scattered among too many and too academic projects with insufficient long term vision)	No EU-wide HPC strategy
Fragmentation of investment with insufficient coordination across member states, leading to suboptimal ecosystem (lack of cohesion, inconsistent access policies and practices).	No priority
HPC not being of strategic importance yet in a military sense at the European level (like in the U.S.)	No true competition in HPC
HPC software vendors (ISV)	No common politics for access to advanced HPC resources
Ignorance of the HPC market	No cyber infrastructure in place yet
Insufficient support for open source, absence of a clear software strategy	OS development
Investment comparable to the U.S. one	Protectionism
Isolation of science and engineering from computer science	Still perceived as an "elite" infrastructure
Lack of a European software development strategy	System software
Lack of coherent data management policies	The legacy of the disastrous e-Science projects of the past
Lack of experts in computational sciences with expertise in parallelization and optimization techniques	There is no European HPC industry (Bull's awakening? JuRoPa in Juelich!)
Lack of funding	Too great a differentiation in technical levels of realization
Lack of funding for petascaling of important scientific applications	Too little explicit support for HPC education.
Lack of HPC training/courses at University level → few graduates with HPC skills	Too little support for smaller businesses to reap the benefits of (supra)national HPC installations.

Source: IDC, 2010

TABLE 47C

What Are the EU's Greatest Weaknesses in HPC Today?

Weaknesses #3	Weaknesses #3
Ignorance of existing structures	No significant funding
Almost no company making system or application software	No significant HPC hardware vendors in the EU
Difficulties in some places to understand that simulation is a scientific discipline in itself	No significant strategic reports comparable with U.S. NSF reports with political impact
EU has no long term project to support HPC	Poor usability of the European infrastructure. Absence of a systematic approach related to HPC "user research", interaction, design, etc.
EU HPC companies, if not directly financed by their local governments, are left in an uphill struggle with not enough backing. In many cases, when reaching a certain maturity, European HPC companies are bought by larger non-European companies.	Power, space, and cooling are harder issues than in other parts of the world
Feeble development of algorithms, new computer languages, and other aspects of computer science applied to HPC	Pretty low level of collaboration between RI/eRI and industry
Funding leadership and coordination for projects	Small capacity and therefore bad accessibility
HPC application support industry	Still insufficient coordination to invest in large cross-national HPC resources
Lack of a European hardware Industry	The fact that most expenditure in hardware goes over the European border to the U.S. or Japan
Lack of operational pre-competitive procurement procedure (compare to U.S. procedure)	Too little appreciation of the potential of CSE among European youth
Lack of overall European framework for monitoring and evaluation, taking steps to position HPC community needs and opportunities in order to attract future funding and lack of sound deliverables in different research areas based on the usage of HPC by science community or industry	Too much focus on equipment, not enough on expertise! This imbalance will become more noticeable as we are now confronted with the challenges of developing massively parallel applications and harnessing disruptive technology such as GPGPU.
Lack of vendors (or strong relations with), HPC industry	Waste of funding with poor results due to isolation of science and engineering from computer science
Little research on systems, hardware	.

Source: IDC, 2010

10.3 EU Opportunities

The respondents saw the biggest HPC-related EU opportunities as follows, as Tables 48A through 48C indicate:

- Ramp up HPC use in scientific and industrial areas where Europe already excels, such as the energy sector, bio-sciences, materials science, physics and chemistry, and climate and weather.

- Increase support for the development of advanced algorithms and scalable software, where there are already world-class capabilities in the EU.

- The HPC market will need to undergo a paradigm shift as it approaches exascale computing speed, and then Europe can lead the way, especially in the software area.
- Existing programs such as PRACE, EGEE, ESFRI, and HET provide a strong basis for pursuing EU leadership in HPC.

Representative Comments from Respondents

"[The EU has] international leadership in atmospheric modeling, climate modeling."

"Energy efficiency."

"Biosciences."

"Materials science and bioinformatics are sectors where great competencies are present in the EU."

"Innovation in HPC middleware and application software."

"Applications, but need to pick 2 or 3 major areas to focus on."

"Algorithms and parallel programming."

"Highly scalable application and system software."

"A new computing gap will be reach around 10 petaflops and HPC has then to be 're-invented.'"

"Start fresh towards exascale systems and software."

"Coordination of national activities and funding of the member states, as undertaken by PRACE, can create a critical mass and buying power that can have an impact on vendor roadmaps and stimulate a European HPC industry."

"Jump from nothing to a complete solution provided by PRACE and EGEE."

"The results of the work done by European experts: HET, e-IRG, ESFRI."

TABLE 48A

What Are the EU's Greatest Opportunities in HPC Today?

Opportunity #1	Opportunity #1
A new computing gap will reach around 10 petaflops and HPC will then have to be "reinvented"	Infrastructure: good quality and relatively cheap electricity, plus very good network infrastructure on which HPC activities can be connected
Active role in new areas, for example green IT, innovative computing (GPU etc.), software development	Innovation in HPC middleware and application software
Applications, but need to pick 2 or 3 major areas to focus on	International leadership in atmospheric modeling, climate modeling
Apply computer science expertise to HPC	Invest in the existing European HPC industry and help it strengthen over time
Be the leader in petascale	Investment in people skills
Biosciences	Jump from nothing to a complete solution provided by PRACE and EGEE
Build an integrated Tier 0 (EU level)/tier 1(national level)/tier 2 (regional level) HPC politics	Liaisons between research and industry through PRACE
Build European expertise	Materials science and bioinformatics are sectors where great competencies are present in EU and should be supported with adequate computational resources
Building and development of national (Tier 1) SCCs	Materials simulations (nano and bionano)
Chance to be leading edge	People and people's talent
Change of the technology	PRACE project
Considerable experience of users in HPC applications	Responding to new HPC innovation/disruption as vehicle to compete internationally and create competitive environment for science/companies to use
Coordination of national activities and funding of the member states, as undertaken by PRACE, can create a critical mass and buying power that can have an impact on vendor roadmaps and stimulate a European HPC industry	Save the savable
Create a supra-national environment in which researchers and those running operational simulations, can access local/national resources but have seamless access to high-end resources when that is necessary. This would very much be an HPC cloud ecosystem (for lack of a better word).	Should focus on middleware and applications exclusively
Create an exascale HPC center	Software design
Developing software for HPC	Start fresh towards exascale systems and software
Dynamic under PRACE	Strengthening of industry
Effectively and efficiently usage of well-educated and skilled manpower	Support integrative, large-scale projects for bringing different sciences to the future
ESFRI projects which involve HPC — in such a way that the large research infrastructures will 'push' the development of new generation HPCs	Talent, basic structures in place
EU-wide grids and provision of funding for science	Talented people attracted by the opportunities given in the EU
Europe can build on sound ground of HPC excellence to respond to grand challenges	Technical ruptures (systems, software)

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TABLE 48A

What Are the EU's Greatest Opportunities in HPC Today?

Opportunity #1	Opportunity #1
Excellent software developers (OS, tools, middleware)	The creation of a European ecosystem in HEC (PRACE) to extend HPC into all of Europe and beyond
Forming of a EU-wide HPC infrastructure through PRACE	The location in Europe of major scientific infrastructures which need HPC simulations is an opportunity for further scientific applications software development
Grand challenge applications	The results of the work done by European experts: HET, e-IRG, ESFRI
Greening by HPC	To overcome the problem of 14)
Harnessing disruptive technology (GPGPU computing) and addressing the challenges of massively parallel computing. Related opportunities include the development of next-generation programming languages (to replace the traditional Fortran+MPI combination).	Training/people/skills
Highly energy-efficient technologies	Tremendous reservoir of brains, world class experts/scientists and institutions capable of tackling the important scientific/engineering challenges involving HPC
In life science application development because there are big drug and medical equipment manufacturers	Well-educated students at universities

Source: IDC, 2010

TABLE 48B

What Are the EU's Greatest Opportunities in HPC Today?

Opportunity #2	Opportunity #2
A European approach can leverage and exploit the expertise in computational science and engineering in all members states, including the smaller/less resourceful ones	Making HPC (at the capability end) accessible and relevant to industry could have a significant economic impact. We believe that the nature of the relationship between ISVs and centers of excellence in HPC should be revisited to encourage effective partnerships. This will be key to achieving highly scalable applications of industrial relevance.
Algorithms and parallel programming)	Many skilled groups in software and HPC operations
Attract talented students from neighboring regions to CSE by appropriate fellowship programs for the CSE graduate schools	Possibility to connect HPC to cloud computing very efficiently
Compression of HPC industry — small set of vendors getting smaller by the day	Potential synergies with EGI (grids)
EC support getting better	PRACE
Economic growth through innovation	PRACE and DEISA have proved that strong cooperation and coordination of this excellence in Europe can establish competent HPC infrastructures
Energy efficiency	PRACE, the first European HPC infrastructure, is about to start
Established industries that already used HPC to grow and will profit immediately from the extended capabilities to grow faster	Promoting efficient collaboration between RI and e-infrastructure
Establishing EU platform of national SCCs	Software scaling tools
Expand on low latency interconnects	Start developing the weak sector using the force of the European scale
Great opportunity in urgently needed SW developments	Strong prerequisites for creating general purpose HPC systems
Grow university-based scientific research through funding, thus helping universities reach a cutting edge status.	Support research of new/optimized/more scalable solvers to allow significantly better use of high-end HPC systems.
Highly scalable application and system software	The existence of a considerable pool of HPC scientific applications is an opportunity to influence the design of future HPC systems
Industrial cooperation in HPC	We are in the transition phase from simple parallelism to heterogeneous computing. No single country will be able to solve it.
Life-sciences	.

Source: IDC, 2010

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TABLE 48C

What Are the EU's Greatest Opportunities in HPC Today?

Opportunity #3	Opportunity #3
Algorithmic research	Neuroinformatics
Applicability of HPC results to industry	Tight cooperation between HPC centers and industrial companies. A European HPC industry could be developed and stabilized in the market if long-term support is guaranteed
Data storage	Potential for software design
Develop European HPC industry and services outside Europe	Provision of HPC services and support not only to academia and industry, but also to governments and calls for increased national engagement with the objective of exploring new ways of implementing HPC-based applications and services
Energy research	Renewed, strong interest across the continent and economy wanting to focus on stronger, innovative, real-value products (after the speculation disasters — leading to massive job losses in under-competitive industrial areas)
Europe is a huge consumer of HPC, there is a thriving market within which new actors for utility HPC can emerge	Research cooperation in HPC
Finding ways to prove that investments in HPC will bring dramatic returns on investment to the EU over time, and also within industry.	Some 'local' technology providers and skills (micro-nanotechnologies) + an integrator/vendor (Bull) on which to build a real HPC industrial path forward
Infrastructures like GEANT	Start building strong liaisons between research and industry through PRACE
Investment in skills development	Success in building a coherent and complex ecosystem could have a major impact.
Federated states allow the opportunity for diversity and fosters a practical basis for flexible/cloud-based HPC exploration.	Support research and development of optimized message passing libraries for commodity high-end. In practice that means optimizing an MPI implementation.

Source: IDC, 2010

10.4 EU Threats

The respondents' opinions on the greatest threats to EU leadership in HPC are shown in Tables 49A through 49C. The threats generally fall into two categories:

- Internal threats within the EU
- External threats, especially from the U.S. and China

The following representative comments tell the story, including the persistent conflict of opinions between those who believe Europe should not try to build its own HPC hardware platform and those who consider this important.

Internal Threats Within the EU

"Limited political support [for HPC]."

"Lack of a European HPC roadmap."

"The extraordinary financial crisis in the national economies."

"Competition between member states to host the largest computers and the related administrative staff (local interests)."

"Different interests of the various countries."

"To only focus on buying or building computers."

"Wasting time trying to recreate things that already exist (i.e., supercomputing vendors)."

"Overprotection of European industry."

"Political machinery, protectionism, and increasing regulations in Europe."

"A high position in the TOP500 should not be the dominant motivating factor."

External Threats

"The speed of development in the U.S. still outperforms the EC."

"Very fast progress of simulation in some parts of the world like China."

"All the software and hardware systems are imported."

TABLE 49A

What Are the EU's Greatest Threats in HPC Today?

Threat #1	Threat #1
All the software and hardware systems are imported	Limited political support
Being leapfrogged by the U.S.	Loss of competitiveness in comparison to U.S. and China in materials and bio simulation
Brain drain	Loss of expertise
Bureaucracy	National inability to spend the money (will U.K. contribute?)
Competition between member states to host the largest computers and the related administrative staff (local interests)	Not a stimulating competition between the computational centers
Dependence on non-EU technologies	Overprotection of European industry
Different interests of the various countries	Political incompetence
Distribution of funding over member states	Political machinery, protectionism, and increasing regulations in Europe (e.g., have development facilities in Europe, manufacture there, collaboration with companies in Europe)
Economic crisis due to bad investments into bubble economies	Reduce overhead and administration
Emerging countries are building large HPC centers to support research	Reduction of funding due to the economic crisis
Emerging economies in the far east (Japan, China, India) have identified the strategic importance of HPC, are investing heavily and catching up rapidly	Spending money on HPC research projects that have no realistic chance of fostering a proper European HPC industry
Excessive dependence on non European technology and system integration know-how	Sprinkling of effort
Fragmented funding and low-impact science results through separation of HPC experts and domain experts	Stopping halfway due to lack of resources
Generic technologies dominating	Stopping halfway due to lack of resources

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TABLE 49A

What Are the EU's Greatest Threats in HPC Today?

Threat #1	Threat #1
Global competition for best brains	That HPC becomes a peak performance race without investing in necessary SW and application skills
Hard to say	That HPC will be supported in a similar was to the old e-Science initiative in the past
HPC clouds and the rapidly evolving technologies may make the existing supercomputing infrastructure obsolete faster than expected	The drive to get to national and/or supra-national HPC installations based on pure HPL size. Purchasing should be based on a well articulated strategy and continuous monitoring of results and effectiveness. A high position in the TOP500 should not be the dominant motivating factor.
It is very dangerous to get benefit from HPC development in the short term, 3 or 5 years, and to focus on easy problems.	The extraordinary financial crisis in the national economies
Knowledge turned into real products outside of the EU	The very large projects and national programs in the U.S.
Lack of EU governance for HPC investment and usage	Tier 0 not delivering the services needed for (or not accessible to) scientific leaders who need them
Lack of coordination of national efforts in developing software and hardware for HPC	To fall behind in applications
Lack of EU money for HPC infrastructure after 2015	To only focus on buying or building computers
Lack of funding could lead to obsolete unusable SCCs equipment	Too much nationalism
Lack of HPC skills	Uncoordinated national HPC activities
Lack of investment	Wasting time trying to recreate things that already exist (i.e., supercomputing vendors)
Lacking scale of funds to be globally competitive	Watch out for new players such as China, expected to have a major impact within the next few years (scale of development teams will be significantly larger than in Europe)
Leaving HPC development only in the hands of member states and their own national policies	Well organized per country but EU not so well organized, which delays decisions
Let non-EU HPC companies dominate the EU market, and thus dictate the terms	Wrongly focused investments

Source: IDC, 2010

TABLE 49B

What Are the EU's Greatest Threats in HPC Today?

Threat #2	Threat #2
Concentration on the national scale	Lack of researchers/programmers/systems administrators with appropriate HPC skills
Conflicting interests between EU states	Lack of self confidence
Confusion with grid and cloud	Lack of new HPC tools and HPC application software
Delay in HPC implementation process of HPC programs and projects with fundamental importance for bureaucratic reasons	Large research programs have already existed for years in the U.S., Japan, and China
Dependency on hardware/systems from overseas vendors	Misguidance of young talent away from science and engineering (into investment banking)
Destruction of existing competitive centers	National focus and too much national competition
Economic downturn	Non-unified approach to solution of problems connected to HPC infrastructure
Emerging market development capabilities	Not being able to sustain the efforts of refreshing large infrastructures
Fragmentation of funding, inconsistent policies, joined up thinking sometimes lacking	Risk of excessive domination or monopolistic position of processor manufacturer
If Europe doesn't act, they could buy systems from IBM or Dell or SuperMicro, etc.	Suppliers are all American
Important investments in HPC in U.S., China, Russia, India, Japan	The considerable financial resources involved in HPC capacities building reduce the funding available for fundamental/theoretical research and lead to missing significant opportunities for scientific breakthroughs
Individualism of the countries, preventing financing of large European projects	The inefficient "tradition" of short-range support programs is not favorable to handling major challenges and building an HPC industry
Investment only in organizations that are set up specifically to obtain EU funding	The size or the performance number of HPC facilities is too easy an index of goals or milestones, which might create errors in the choice of an HPC system
Lack of coordination	The speed of development in the U.S. still outperforms the EC (to some extent but not only driven by military applications and requirements)
Lack of efficient user codes	Too heterogeneous working area (many nations, can we collaborate optimally)
Lack of European HPC roadmap	Too much emphasis on diversity. Over the years I have had many conversations where it was indicated by prospects that a "different" architecture would bring funding
Lack of funding from the EU to support pan-European HPC infrastructures as well as software and hardware (when appropriate) development	Very rapid progress of simulation in some parts of the world like China
Lack of interest in scientific careers versus finance	Without investment in software and applications the very large systems will continue to be just throughput machines

Source: IDC, 2010

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TABLE 49C

What Are the EU's Greatest Threats in HPC Today?

Threat #3	Threat #3
Bureaucracy replaces science	Lack of HPC experts and users of HPC
Bureaucratic process	Lack of long-term strategy, including sustainable funding
China's increasing HPC/cloud computing capabilities	Lack of pan-European strategy and deployment
Conservative and static education system	Lack of political will to overcome the global technological challenges we face
Deepening economic crisis and the uncertainty of the marketplace may force countries and industry to reduce their R&D efforts and to stop employing new staff in crucial science and engineering areas and continuing process of losing science and engineering talent to other countries and regions	National budget commitments
EU bureaucracy and national egotism	Not tracking "results" which might cause the EU to follow the "wrong" path towards computational excellence
Failure to develop ESF into a "European NSF" for key strategic large-scale-computing technologies	Promotion of mediocre instead of excellent activities
Getting misled by unjust claims by the grid/cloud community (which themselves very much deserve support, but not at the expense of the attention for HPC)	Slow adoption of new technologies
Inability to start a cynical analysis of European weaknesses	Squeeze between U.S. and China. China has decided it doesn't want to be dependent on the West. They view HPC as a viable element of their export business in the future (targeting third world countries).
The lack of long-range planning in the industry due to shareholder value pressures and the higher speed of HPC technological developments in the U.S., Japan, China, and even Russia.	.

Source: IDC, 2010

11.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: MAJOR CHALLENGES

11.1 Challenges the EU Needs to Overcome in Pursuit of HPC Leadership

Tables 50A through 50C address the main challenges the EU needs to overcome in pursuit of HPC leadership. The main challenges were as follows:

- Overcoming national egoism so that Europe can act as one entity
- Developing a European vision and strategy for HPC
- Deciding whether developing a European HPC hardware platform is important or not
- Ensuring stable, sustained funding to carry out the HPC strategy
- Training an adequate number of qualified people

Representative Comments from Respondents

"Act as one entity."

"Develop a truly European vision."

"[Overcome] national pride thinking."

"Both small and big European countries must come together under the sponsorship of the EU to develop the HPC competencies of their scientists, engineers and computer technicians."

"Overcome fragmentation [and ensure the] involvement of smaller, in particular new, member states."

"Coordination among the member states."

"Difficulties of building a European HPC ecosystem."

"The EU should fund research — not the technology of HPC."

"Ensuring the stability of funding."

"Development of a sustainable funding scheme for an HPC Infrastructure."

"Training people."

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TABLE 50A

Major Challenges That Need to be Overcome to Enable the EU to Become a Leading Provider and User of HPC

Challenge Area #1	Challenge Area #1
Access too complicated, or not efficient	Leverage existing technological and integration skills with a sustainable industrial focus
Act as one entity with multiple people	Local coordination
Algorithm development for huge scale parallelism and heterogeneity	Low number of skilled resources
Both small and big European countries must come together under the sponsorship of the EU to develop the HPC competencies of their scientists, engineers, and computer technicians	Motivation for domain and HPC experts to collaborate
Budgets	National pride
Challenge to bureaucracy to overcome the inefficient "tradition" of short-range budgets and programs	Overcome fragmentation, involvement of smaller, in particular new member states
Change the view of HPC as a leading power of scientific research and development	Overcome the "HPC is for scientists" syndrome
Close the gap between machine performance and the current average expertise of the user community to really profit from this performance. In the hardware community, one is already working towards exascale, while many users experience problems in using petascale (or even smaller parallel) computers efficiently	Overcoming the above-mentioned weaknesses and threats
Coordination among the member states	Produce good scale of investments
Coordination of national efforts	Provide an effective funding of HPC-based research on EU and national level
Create more coherent European patterns for HEC researchers' careers	Providing integration and interoperable solutions in order to tackle the problems of fragmentation and system diversity
Develop a common vision	Reaching real coordination at the EU level
Difficulties of building a European HPC ecosystem	Should not be a provider
Education	Software development, especially parallel programming
Ego and pride of stakeholders and overcoming nationalist feelings	Software development is not funded in the core sciences
Encourage development of expertise in systems (storage, operating systems, etc.)	Struggle with and answer fundamental question if they want to exploit the upcoming disruption; does it give us a chance to create a new industry in Europe? A new dimension of the economy?
Ensuring the stability of funding	Sufficient competence: education system to support new required skills such as multidisciplinary competencies, data scientists, grid, computational science, etc.
Establish seamless EU-wide HPC infrastructure tier 0 to tier 2	Sum of States (bad) vs. United States of Europe (good)
Finding a commercial model that encourages development	Tackle lack of cohesion in European ecosystem — will require more guided approach with key strategic investments, stronger leadership, and political courage to tackle "holy cows" such as access models based on the principle of "juste retour" for instance
Full PRACE deployment	The EU should fund research — not the technology of HPC
Getting an HPC-industry (or industry in essential parts for HPC-systems) off the ground	There is no HPC hardware industry in the EU and this needs to be acknowledged to concentrate on those areas where Europe can actually make a substantial contribution
Help EU HPC providers in a fair and equitable manner	To compete worldwide

TABLE 50A

Major Challenges That Need to be Overcome to Enable the EU to Become a Leading Provider and User of HPC

Challenge Area #1	Challenge Area #1
Inability to commercialize research findings	To support effective use of new supercomputer architectures
Involve the users in the decision making process related to capacity building/increase the usability of the system/identify clearly the use cases to be tackled	Train people
Lack of innovation in adoption of new technologies	Training
Launch long-term research project such as SciDAC in the U.S., evaluated by international experts	Working together
Legislation	Working together on a common objective and direction

Source: IDC, 2010

TABLE 50B

Major Challenges That Need to be Overcome to Enable the EU to Become a Leading Provider and User of HPC

Challenge Area #2	Challenge Area #2
Balancing HPC systems at Tier 0 level, along with fast interconnect, fast processors, and fast memory	Language and compiler development for large scale parallelism and heterogeneity
Bringing the research users and service providers closer together	Low investments in facilities and hardware
Channeling funding to areas where the EU does not have a competitive edge. Farming wrong areas	National egoism
Coordinate efforts beyond national levels	National interests can prevent free knowledge transfer
Cost of energy in Europe compared to the U.S.	No good understanding of the importance of HPC
Demonstrate that HPC can be helpful to solve actual problems	Possibility of launching ambitious R&D programs on the software side
Develop a truly European vision	Promote clearly identified HPC career in industrial companies
Development of a sustainable funding scheme for an HPC infrastructure	Provide suitable mechanisms to enable and support the (sustainable) involvement of national HPC centers' applications specialists with communities of users. In our opinion the most effective model to produce high-quality scalable application codes, and achieve high-impact scientific output.
Ensure that funding, whether in the HPC industry or in research programs, is done fairly, and followed closely	Recruiting and retaining the skilled research, development and support staff required
Establish EU HPC industry (vendors)	Resources
Find a non-military backbone strategy for long-term funding of provider industry (the alternative to the DOE approach) and find an efficient way to overcome the software crisis on many core systems	Services lacking quality and continuity
Guarantee long-range budget plans despite the threats of the financial crisis	Simplify usage of HPC for industry to innovate their production
Help in the emergence of European world-class private providers of HPC-clouds and cloud computing infrastructures	Splitting leadership in thinking versus hosting actual systems
HPC industry	Structural thinking
Human potential and interactions with the decision taking bodies	Students' education

TABLE 50B

Major Challenges That Need to be Overcome to Enable the EU to Become a Leading Provider and User of HPC

Challenge Area #2	Challenge Area #2
Invest in technical competence and less political inefficiency. Reform/simplify EU bureaucracy. Reduce bad political influence.	The reluctance of stakeholders to provide easily measurable results/ROI. High-end systems should be less "experimental" (it is high-end and so "by definition" esoteric?) but be purchased (including expert knowledge) based on measurable "output". Scientific fuzziness should be forbidden. "Targets" should be set beforehand and targets should include relevant goals for the "society" at large.
Lack of full HPC funding beyond the systems (and for very large systems)	There needs to be a defined HPC strategy which is then broadly adopted by the member states and its leading HPC institutions
University collaboration across the EU — sponsored funding?	.

Source: IDC, 2010

TABLE 50C

Major Challenges That Need to be Overcome to Enable the EU to Become a Leading Provider and User of HPC

Challenge Area #3	Challenge Area #3
"Religious wars" around technological solutions (today: Grid vs. HPC) have to be avoided at all costs	Get more directly involved in the promotion and adoption of best practice in member states. For instance, a number of perennial issues remain unresolved in a number of member states (e.g., debates on balance of investment between centralized versus distributed approach; balance of investment between staff and equipment, etc.)
Ability to use e-infrastructure in a shared way over multiple RIs	Increase awareness of potential industrial users for high-end HPC, provisioning of scalable industrial codes
Bring in non-EU countries in a stronger way	Less politics, more science
Convincing the European community (general public) of the importance of HPC as an essential part of modern fundamental and applied research through widespread awareness campaigns and the length and expense of the development cycle for new HPC systems and resources which can scatter public approval	Leverage/structure large software developments with an open-source model
Draw a clear line between funding HPC providers and HPC users (such as Universities and Companies requiring HPC to drive their research) so as to avoid corruption where possible.	Low funding available
Develop European HPC industry and services outside Europe	Modernize IT and CSE education programs to better include state-of-the-art many core parallel programming technology
Education of new scientists familiar with HPC and research areas using HPC	Provision of infrastructure and support personnel to allow researchers to concentrate on research. At a basic procurement level, disparate purchasing allows little room for any commonality of HPC. The HPC industry must be allowed to thrive commercially — in order for this to happen the industry must be allowed to profit directly from HPC.

TABLE 50C

Major Challenges That Need to be Overcome to Enable the EU to Become a Leading Provider and User of HPC

Challenge Area #3	Challenge Area #3
Energy use and sourcing alternative green energy assets (e.g. tidal/wave)	Simplify the existing funding frameworks and introduce more flexibility and agility in dealing with rapidly evolving technologies and rapidly changing industrial landscape. Ensure the sustainability of the existing infrastructure and ensure the sustainability/maintainability of the HPC-related software
Find an efficient way to overcome the software crisis on many core systems and modernize IT and CSE education programs to better include state-of-the-art many core parallel programming technology	Supported HPC European master and launch student HPC contest, as between high school teams in Japan
Fragmentation of HPC offerings	Work against disastrous possible tendencies of protectionism and exorbitant EC centralism
Funding	.

Source: IDC, 2010

12.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: SUCCESSFUL HPC PROGRAMS

This section reviews the HPC stakeholders' views of HPC programs around the world and in Europe. Section 20 provides profiles for many of the HPC programs in Europe.

12.1 Successful Worldwide HPC Programs

The survey respondents' candidates for the world's most successful HPC research programs are presented in Table 51. It is telling that even though the vast majority of the respondents were from Europe, U.S. and Japanese programs occupied the top six positions in the ranking.

The programs ranked as follows, based on the number of mentions (only programs receiving at least two mentions are listed):

1. U.S. Department of Energy — SciDAC (10)
2. U.S. Department of Energy — INCITE (9)
3. U.S. National Science Foundation (8)
4. Japan's RIKEN /Keisoku Project (7)
5. U.S. Department of Defense — DARPA (5)
6. U.S. Department of Defense — High Performance Computing Modernization Program (3)
7. PRACE (2)
8. IESP (2)
9. U.S. Department of Energy — ASC (2)

TABLE 51

Top HPC Research Programs Around the World Today, and What in Your Opinion Makes Them Successful?

#1 Programs	#1 Programs	#1 Programs
Academy of Finland CoE in Inverse Problems/ Versatile expertise. Availability of HPC	Elementary particles (CERN)	NSF HPC investments
ASCR (U.S.) http://www.er.doe.gov/ascr/ as a funding scheme that encourages synergies between hardware/software/application driven researchers	Forschungszentrum Jülich. Successful because of interdisciplinary research on solving the major challenges facing society.	NSF OCI
Astrophysics simulations	Global climate simulations	NSF programs, including infrastructures, research and education.
Biotechnologies (Extensive application of computers)	GRACE project (http://www.ari.uni-heidelberg.de/grace/)with Silk-Road project as follow-up (http://silkroad.bao.ac.cn/)as an international astrophysics driven accelerator based computer project with FPGA technology	NSF, focused approach
BlueWater project, Urbana-Champaign	Grid computing at Argonne National Lab	Oak Ridge National Laboratory. Successful because of its research in strengthening the U.S.' leadership in key areas of science.
CERN	HPC in astronomy (insight into cosmos)	ORAU and OAK RIDGE: public and private, ambition to train high school teachers in leadership class scientific center — open the new generation to the beauty of HPC
Climate research and modeling (supercomputing)	HPC in nano science (NIST) — new materials, medicine, life science are strongly dependent on this research	Parallel Programming initiative in the U.S.
DARPA	HPCS DARPA/U.S., links with vendors	Power consumption reduction
DARPA — vendor involvement	Human genome, human curiosity/health related/potential for healthcare	PRACE
DARPA HPC Program	Human genome, human curiosity/health related/potential for healthcare	PRACE: creation of a pan-European HPC infrastructure
DARPA HPCS (U.S.) — aims at developing programming models to increase productivity and ease of access to supercomputing	IBM's systems approach to building HPC machines (allowing a holistic view to the challenges of exascale)	PRACE: establishing efficient structure of European HPC ecosystem
DARPA HPCS = long-term structured support mixing vendors and labs, industrial vision	IESP since it is global collaboration on the main challenge of Petascale Computing: Software	Protein chains simulations
DEISA Partnership in Europe — started from a shared vision, now with a strong user base.	IESP: worldwide initiative for software development	Protein Data Bank — excellent collaboration at world level

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TABLE 51

Top HPC Research Programs Around the World Today, and What in Your Opinion Makes Them Successful?

#1 Programs	#1 Programs	#1 Programs
Development of Linux kernel and free tools	INCITE (DOE) a strong support for extreme use of computer by groups including industry	RIKEN- Japan
DFG Sonderforschungsbereich SFB/TR-55 (Germany) as it demonstrates (again) the science driven design of a novel HPC architecture through cooperation between particle physicists, industry and an HPC center http://www.scribd.com/doc/23397042/Novel-Architectures-QPACE-Quantum-Chromodynamics-Parallel-Computing-on-the-Cell-Broadband-Engine	INCITE (U.S./DoE) providing billions of supercomputing processors hours to cutting-edge research projects.	Riken/Japan
DFG Sonderforschungsbereich SFB/TR-55 (Germany) as it demonstrates (again) the science driven design of a novel HPC architecture through cooperation between particle physicists, industry and an HPC center http://www.scribd.com/doc/23397042/Novel-Architectures-QPACE-Quantum-Chromodynamics-Parallel-Computing-on-the-Cell-Broadband-Engine	INCITE supporting grand challenges in science and engineering	Rosetta protein structure prediction (Baker Lab)
DoD	INCITE: due to the amount of resources available and the vast worldwide usage from academia to industry	SCIDAC — focus on applications
DOD CHESSI to get DOD applications to scale	INCITE: national access programs (U.S.)	SciDAC (U.S./DoE) to develop the Scientific Computing Software and Hardware Infrastructure needed to use terascale computers.
DoD High Performance Modernization Program (HPCMP) supports HPC Center, Networking and Application Software (http://www.er.doe.gov/ascr/About/about.html)	Japan's efforts to combine domain scientists with HPC experts in a joint effort (i.e. not just to put FLOPS on the ground)	SciDac: computer scientists, applications developer and hardware experts are working together
DOE	Kei-Soku project, Japan links between vendor/academia/industry	SciDAC = integration of computer/computational science and China's 863 program: long term vision, vertical integration

TABLE 51

Top HPC Research Programs Around the World Today, and What in Your Opinion Makes Them Successful?

#1 Programs	#1 Programs	#1 Programs
DoE Advanced Scientific Research Program (ASCR and INCITE): discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex phenomena	Los Alamos National Laboratory (same as above)	SciDAC bringing together U.S. top researchers and most challenging scientific problems
DOE and U.S. military programs	Lustre; it is the adopted reference of file system	SCIDAC DOE/U.S., multi-disciplinarity
DOE INCITE (U.S.) — enables industry and academia to advance technology and increase competitiveness by promoting its access to large DOE supercomputers	Modeling and Reverse Engineering of Delayed Stochastic Models of Genetic Regulatory Networks/top talents working as a team. Availability of HPC	SCIDAC, U.S. (long term federal support, multidisciplinary project, led by major scientists)
DOE Leadership computing — partnership with 2 major vendors (Cray and IBM)	MPI programming language: it is a standard	SciDAC: leading in grand challenge simulations
DOE SciDAC	NASA	SCIDAC: code development (U.S.)
DOE's Research and Development Support — the U.S.	National Science Foundation — the U.S.	Supernova Simulation (ASC Flash Center)
DoX initiatives, reasonable funding	NCI in Australia	Teragrid — ease of access to researchers
Earth research/Climatology, sense of urgency	NexGen Project, Japan (long term support, from hardware to computational science)	TeraShake (Southern California Earthquake Center)
Earth research/Climatology, sense of urgency	Next Generation Japanese Supercomputer/Coherent hardware and software program	The U.S. National labs for their sustained innovation in conjunction with manufacturers
Earth Simulator during beginning of 2000	NNSA/ASC (ASCI at the beginning) strong funding, strategic vision, very good teams	U.S. DOE ASCI (Advanced Strategic Computing Initiative) — major catalyst for accelerated development
Earth system modeling (Japan, earth simulation) become international expertise + hardware	NNSA/ASC = coordination of big labs and mix of h/w and s/w projects	U.S. NSF Office of Cyberinfrastructure — coherent and far-reaching policymaking at continental scale
EGEE project	NSF — OCI Petapps (U.S.) — promotes the development of scientific applications to take advantage of petascale supercomputers to advance knowledge in crucial scientific areas	Water management, safety-related/sanitation third world/primary life conditions

Source: IDC, 2010

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12.2 Successful EU HPC Programs

Among European HPC research programs, the most successful (Table 52) ranked as follows (only programs receiving at least two mentions are listed):

1. PRACE (14)
2. DEISA (10)
3. CEA-DAM (4)
4. CERN (4)
5. HPC Europa (4)
6. Blue Brain –EPFL (2)
7. EGEE (2)
8. ESA (2)
9. Forschungszentrum Juelich (2)
10. GEANT (2)

TABLE 52

Top EU HPC Research Programs Around the World Today, and What in Your Opinion Makes Them Successful?

#1 EU Programs	#1 EU Programs
10 Sites mentioned: DEISA	EUROATOM (alternative energy sources)
14 sites mentioned: PRACE	European Theoretical Spectroscopy Facility — ability in involving research and industry
4 sites mentioned: CEA including the CEA/DAM TERA program	FP7 — full spectrum of research
4 sites mentioned: CERN	GAUSS alliance
4 sites mentioned: HPC Europa	GEANT connecting Europe
Academy of Finland CoE in Inverse problems/versatile expertise. Availability of HPC	GEANT for the high speed access to important datacenters and computer centers
Biotechnological processes for manufacturing pharmaceutical	Genomics, health related/potential for healthcare, "understood by public"
Blue Brain Project (Swiss) as a simulation-based research project combining biology and HPC	German Government HPC Program — for instance JULICH Research Center
Blue Brain Project reverse-engineering the brain through detailed simulations	Hartree (U.K.). Will sponsor innovative research, exploring the petascale multiphysics multiscale area
Cancer research, long term research effort, cooperation, modern technology support	I hope the VPH is successful.
CECAM — community hub	INRIA
COST = cooperation in science and technology	ITER aiming to produce commercial energy from nuclear fusion
Developing grid technologies for e-Science infrastructures and evaluating the Pros and Cons	Juelich Supercomputer Center, presence of a 72 rack IBM BlueGene/ P

TABLE 52

Top EU HPC Research Programs Around the World Today, and What in Your Opinion Makes Them Successful?

#1 EU Programs	#1 EU Programs
Development of new applications	LHC as most challenging international lab solving the most challenging fundamental problems
EGEE project	Mathematics (long tradition in several countries and good education)
EGEE/EGI: standard of grid computing all around EU	Nanotechnology, potential understood by public
e-Infrastructures	Program COSINUS ANR in France
Elementary particles (CERN)	Research programs owned by specific research organization (example EMBO)
EPSRC	Simulations on the amorphous and ordered states of Ge-Sb-Te (Jülich)
ERC	TER@TEC — France
ESA as research driven organization with broad European participation	The 7th Framework Program — capacity program on research infrastructure
ESFRI Roadmap	Virtual Physiological Human — well-focused objectives
EU Fusion project/IFERC	Worldwide LHC Computing Grid (WLCG): more a "data grid" than a "compute grid", certainly the best example of what grid concepts can really bring to science

Source: IDC, 2010

12.3 HPC Programs Respondents Would Like to See Added to the EU Agenda

The survey respondents next described the HPC research programs they would like the EU to undertake (Table 53).

- The most frequently mentioned program, by far, would focus on developing highly scalable applications and other software to effectively exploit petascale and exascale HPC systems. A suggestion was to house this program in an EU center for exascale computing.
- Another popular recommendation was for a program dedicated to using HPC for clean, alternative energy research, perhaps including the creation of more energy-efficient HPC systems.

TABLE 53

What New HPC Research Programs Would You Like to See Added to the EU Agenda?

New Programs	New Programs	New Programs
16 sites said: peta and exascale scaling (and system software, libraries, domain applications	Evaluate FPGA-based HPC	Need to fund the development of highly scalable applications, and their port to disruptive technology such as GPGPU, and next-generation high level programming languages.
9 sites said: application focused programs	Flood risk predictions	Over-critical research programs to solve the grand challenges of scalability
A/Exascale Applications European program, links with U.S. and Japan	Generally, there is no need for new programs at the EU level. Europe can think in direction of strengthening and diversifying the existing ones such as the Capacity Program on Research Infrastructure as well as adding HPC topics (services) in Competitiveness and Innovation Program	Parallel programming tools
A/Exascale Enabling Technologies European program, links with U.S. and Japan	Green ICT	Exaflop applications in engineering
A SCIDAC-like project developed by EU	HPC application software	PRACE with more contact with scientific
Advance energy leadership including NE and others	HPC cloud	Programs focused on providing tools for user that make use of HPC system more easy
Advanced and extended PRACE program to stabilize the HPC ecosystem	HPC for engineering	Programs similar to U.S. Petapps and HPCS , enabling the use of supercomputers by an increasing fraction of the scientific and industrial user communities
Air pollution + climate from global to region	HPC in human sciences	Programs to help the European HPC industry
Air pollution modeling	HPC research training	Projects for data management
Alternative energy research	HPC software tools	Research of non-parallel (distributed) computing in science
Basic research for technologies for the post-Moore's law area, such as quantum computing	HPC to assist in real-time large scale predictions	Research programs on hardware-software co-design on the HPC level
Cloud computing and possible remote control of some experimental facilities like synchrotrons	Industrial application software	Robotics
Computer Labs for interdisciplinary algorithmic research in capability computing to optimize core algorithms for key applications on many core architectures	Integrating activities	Seamless integration of tier 0 and tier 1 supercomputers

TABLE 53

What New HPC Research Programs Would You Like to See Added to the EU Agenda?

New Programs	New Programs	New Programs
Design and development of a 100 petaflop European computer for 2015, "industrial" i.e. not an exotic dedicated machine, involving also academia and with a software part (middleware and scaled applications)	Integrative programs for bringing domain experts and HPC experts together	Similar to SCIDAC or DOD CHESSI (sp?), focusing on getting applications to scale
Design and development of large supercomputers and associated storage system targeting energy efficient without compromise to programmability/performance	Large scale programs with longer duration for transforming classical sciences into simulation-based sciences	SME for R&D work in major science and engineering applications on many core architectures
Develop new computational highly scalable HPC software	Long-term program to develop, petascale and mature scientific applications and tools	SME for R&D work in major science and engineering applications on many core architectures
Development of new compilers	Major effort towards selected scientific/technical domains to improve dramatically the scalability of key applications	Software development (including HPC)
Effective workload management of large-scale and distributed systems (Computer Science).	Materials investigation (for developing lithium air batteries for example)	Strongly coordinated research program in simulation technology and methods and strongly coordinated research and development program in Quantum Computing as a major option of (high performance) computing after the end of Moore's Law
e-Sciences: calls aimed at using HPC to solve materials modeling challenges	More effective promotion and adoption of best practice at national level.	Support of Europe-wide community driven initiatives (a la CECAM), and support of effective and sustainable collaborations between those communities and National Center's' applications specialists.
Establish a European center for exascale computing	More topic driven collaborations on an EU scale. Similar to the U.K. CCPs http://www.ccp.ac.uk/	Tools software
Establishment of a data-infrastructure	Multinational, multidisciplinary HPC education programs	Training and education for computational science

Source: IDC, 2010

13.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: HPC MARKET STRUCTURE, COLLABORATION, FUNDING, AND BUSINESS MODELS

13.1 Should the EU Change the Market Structure

A sizeable majority of the respondents (72%) did not favor having the EU attempt to change the market structure or business models for HPC in Europe (Table 54), such as for instance might happen if the EU were to adopt a protectionist policy in competitive procurements or provide direct funding support for EU-based vendors' commercial (as opposed to pre-competitive) technology and product development.

The respondents did have specific suggestions for the EU, however, as the following comments illustrate.

Representative Comments from Respondents

"1) Provision of robust and persisting funding at EU level; 2) Synergies through mobilizing additional national or regional funding; 3) A bold attitude towards risk investment in science and engineering development beyond the boundaries of the bureaucratic precaution; 4) Promotion of the way towards stronger funding involvement of industry through public-private partnership models; 5) More aggressive approach when we talk about state aid support."

"Better characterize the HPC market structure."

"Encourage smarter ways to access the HPC resources: community members receive (grant based on their scientific excellence, or buy) 'access vouchers' to HPC systems and services to use on a set of different infrastructures; create a quality label for HPC and transnational clouds."

"Establish European vendors."

"Introduce some pre-competitive approaches (cf 23) + foster the development of open source services offer (OS, middleware, libraries, etc.)."

"Avoid PFI/PPP style approaches as they only focus on the short term and have proven to be counterproductive. But yes, changes will be required in order to address the cohesion of the ecosystem and incentivize stakeholders to address challenges highlighted earlier."

"Launch pre-competitive programs and fund R&D."

"Make it easier for new HPC companies to get started — provide funding."

"More focus on usability and scientific results."

"More investment in research."

"New access models."

"Stop building supercomputers directly under the supervision of the EU. Support European utility HPC vendors."

"Switch from short-term to long-term ROI model and involve SME's and industries."

"Try to establish at least two competing international manufacturers/vendors of European base."

TABLE 54

Should the EU Try to Change the HPC Market Structure or HPC Business Models?

	Respondents	Percentage of Sample
Yes	18	28.1%
No	17	26.6%
No opinion	29	45.3%
Total	64	100.0%

Source: IDC, 2010

13.2 Ways for Member States to Collaborate Toward Conducting Research at Exascale Speeds

By way of background, IDC research shows that although the petaflop era in computing is just dawning, government agencies in the U.S., Europe, and Asia are already eyeing the next major milestone — the thousand-fold leap to *exascale* computing speed (10^{18} operations/second). Several applications have already been run at sustained (actual) speeds in excess of one petaflop, and best estimates are that the first HPC systems with peak exascale performance will arrive in the 2017–2018 timeframe.

Problems have been identified that need this much horsepower, and at least one U.S. agency is putting the price tag for an exascale computer at more than $1 billion (€750 million). Aside from the challenge of designing applications to exploit massively parallel computers with more than a million processor cores, there is the issue of powering and cooling systems this big, which may consume as much electricity as a mid-sized city.

Table 55 displays the survey respondents' opinions on how the EU member states should collaborate toward the goal of conducting research at sustained petascale and exascale speeds. The main ideas run along these lines:

- The member states should form multinational projects focused on specific scientific or technology issues.
- The member states should promote the formation of regional collaborations in areas of the EU (e.g., Nordic countries, Mediterranean countries), focused on the scientific and industrial priorities of each area.
- The member states should formalize ("institutionalize") their existing HPC partnerships.

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- The EU should establish a new independent body dedicated to carrying out the HPC strategy — an EU HPC center — with sustained, multi-year commitment and funding.

- Don't neglect collaborations with non-European countries such as the U.S. and Japan.

- Many respondents said the PRACE structure would be a good place to begin any EU HPC initiative.

Representative Comments From Respondents

"Institutionalization of HPC partnership among EU member states — organizational, administrative and financial."

"Form multinational small/medium size projects focusing on specific science/technology issues."

"Networks of research groups working on similar scientific projects — here the problem is 'who will cover the costs if there is no single funding agency?'"

"Promotion of regional cooperation based on some indicators, for instance — Nordic countries; South-East region; Danube countries, Mediterranean region, etc."

"Establish a powerful EU-coordinated and supported network of expertise in major research centers and HPC centers based on solid long-range EU support programs and long-range national budget plans; the structure of PRACE would be an effective model."

"Establishment of an independent entity with a clear mandate, along the lines of ECMWF and EMBL in other areas. This entity is likely to emerge from the PRACE partnership in due course. Require annual subscription and multi-annual commitment."

"Creating a EU HPC center, following the CERN model."

"Joint European multidisciplinary projects/initiatives; Joint projects with U.S. and Japan."

TABLE 55

What Are the Best Ways For the EU Member States to Collaborate Toward the Goal of Conducting Research at Petascale/Exascale Supercomputing Speeds?

Responses	Responses
Institutionalization of HPC partnership among EU member states — organizational, administrative and financial	Flagship projects with clear goal and incentive to collaborate between domains
Efficient usage of EU community programs such as framework programs by gathering together computer scientists, applied mathematicians, and discipline scientists	Focus on training and education, promoting collaboration between researchers and software specialists in application development
Promotion of regional cooperation based on some indicators, for instance — Nordic countries; South-East region; Danube countries, Mediterranean region, etc.	Focus the alliances on a limited number of strong core organizations, build on multilateral relationships relying on a "natural" affinity
Cooperation in PRACE.	Form multinational small/medium size projects focusing on specific science/technology issues
Best usage of existing resources while sharing them with other countries	Foster collaboration between very good existing HPC research labs involving HPC centers and EU industry
Branch offices of transnational HPC centers (better and closer cooperation among member states)	Interoperable infrastructures
Building interdisciplinary teams and networks	Joint European multidisciplinary projects/initiatives; Joint projects with U.S. and Japan
Cooperation in PRACE	Make funds available and encourage the collaboration.
Cooperation in PRACE; PRACE must and will establish an independent user forum/committee; distinguish clearly between funding for system software, libraries and user applications and organize the interlinking of these efforts	Need to execute faster (re PRACE style programs). As often, current or near future products/capabilities are termed "future" and several year old generic established products are termed leading edge — holds back real advancement.
Create a true EU research center in HPC with multidisciplinary European teams, led by major active academic scientists, with a Top5 computer in situ. With supports to this center for European postdoc, researchers, master fellowships and long term visits for European scientists. EU has to really develop European research on post-petascale computing.	Networks of research groups working on similar scientific projects — here the problem is 'who will cover the costs if there is no single funding agency?'
Create EU-wide multidisciplinary working groups to improve performance and scalability of existing, widely used, applications.	Not needed, stay with somewhat (20X) slower machines.
Create more research institutions following the CERN model	Participate in PRACE and other EU funded projects and initiatives like PROSPECT
Create one or two (instead of many) centers of excellence	PRACE
Creating an EU HPC center, following the CERN model	PRACE is the best way to advance, with a strong scientific steering committee, possibly reinforced by a new ESF "Council for Simulation Sciences". This should be made the strategy of the decade, with adequate long-term funding.
Creation of networks of excellence, involving all stakeholders such as the major HPC centers, academic and industrial research centers, vendors and technology providers — leveraging already existing structures such as PRACE and STRATOS; Eventually creation of an ETP for that purpose	Promote the initiative within the academia and industrial HPC user

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TABLE 55

What Are the Best Ways For the EU Member States to Collaborate Toward the Goal of Conducting Research at Petascale/Exascale Supercomputing Speeds?

Responses	Responses
Dedicated organizations, Web site for communication, workshops etc.	Promotion in the media, public focus, stress technology leadership with examples, have a contest
DEISA/PRACE seems to be a suitable approach	Sharing expertise, sharing problem and solution
Encourage broad collaborations of computer scientists and applied scientists and bring supercomputing power close to people	Support projects exclusively focused on computational science (computational physics, chemistry, biology, medicine) without the explicit obligation to collaborate with industrial partners or to search for applications and solutions for societal problems. In this early stage there should be more support for computational science with a rather fundamental character.
Establish a powerful EU-coordinated and supported network of expertise in major research centers and HPC centers based on solid long-range EU support programs and long-range national budget plans; the structure of PRACE would be an effective model.	Support the different scientific communities in providing new scientific computational methods
Establish cross-country HPC centers and leverage cross-country synergies, expertise, and knowledge	There has to be EU funding specifically aimed at this collaboration
Establish market mechanisms to use HPC systems	They should very considerably improve each of their own national facilities in this area before even thinking of EU-wide collaboration
Establishing one EU body to support homogenous HPC. Currently, member states have local supercomputing centers, which do this on a local level. This creates nothing but overheads if looked at from the EU level.	Through scientific major challenges and through collaboration programs like PRACE (pyramid collaboration)
Establishment of an independent entity with a clear mandate, along the lines of ECMWF and EMBL in other areas. This entity is likely to emerge from the PRACE partnership in due course. Require annual subscription and multi-annual commitment.	To accept a strong European authority in this goal and to accept to collaborate (in other words to accept a reduction of national authority in these matters)
EU should consider forming a new company like Airbus that would operate without the constraints that Bull operates under. It would have to be dramatically subsidized for a while. Don't do it as a way of isolating Europe but as a vehicle to competing internationally.	To associate with large, relevant user communities, capable of leveraging long term funding
European exascale software project	To establish or join an existing common pan-European HPC project like PRACE
Find applications that are highly parallel	.

Source: IDC, 2010

13.3 Funding Models Best for Pursuing HPC Goals in Europe

Table 56 contains the survey respondents' ideas for the best funding models to pursue HPC goals in Europe. The chief ideas are the following:

- Provide an EU-wide framework (such as PRACE) to drive toward HPC goals.
- Create sustained, multi-year funding.

- Focus funding most heavily on a limited number of well-defined scientific and industrial problems, and use a cost-benefit analysis to identify these problem domains.
- Focus more on software than hardware.
- Base access heavily on grants awarded through peer-reviewed proposals.

TABLE 56

What Funding Model or Models Would Work Best for Pursuing HPC Goals in Europe?

Responses	Responses
Additional focused funding for specific critical/important projects	Funding multidisciplinary consortia from academia and industry
Annual national subscription with multi-annual (5-year cycle) commitment	Funding only for software
Association with industrial users	Funding R&D in areas they deem important — with system vendors, software vendors, applications vendors.
Avoid additional bureaucratic burdens by national authorities and EU authorities as well. Be careful with ideologically motivated models of public-private partnerships.	Funding related to exascale (system-) hardware and software through PRACE-STRATOS (long term cooperation between PRACE, research institutes, and vendors) under FP-x supervision.
Call for proposal for long term research and development, including computer scientists as experts.	Give incentive for collaboration between domain scientists and HPC experts
Careful involvement of industrial partners only if they contribute something useful	Grant funding of proposals
Collaborative projects based on well-defined research goals or industrial needs	Increase collaboration between academia and industry
Collaborative with good mix of computer scientists and applied scientists.	Large, constituted user communities should be the main actors (like particle physics did with their large instrumentations)
Combined national and EU funding for systems procurement and operation	Long-term support for large applications efforts to take advantage of supercomputing technologies
Combined national and EU research programs	National funding for research will remain a major actor
Condominium model	No funding for hardware
Cost benefit analysis should be applied on the national and as well as on the European model to compare investments costs with benefits to economic/scientific development/progress. If this is done, it should be decided if national and/or pan-European model of public funding should be applied to HPC. Concerning private financing of HPC the same model as for any other contract/collaborative research should be applied	OK as is — but needs higher funding levels
Create long-term programs	PRACE will ensure, through its peer review process, the effective participation of scientists from non-hosting countries in large-scale simulations. During the initial 5 years of PRACE operation, EU money should carry the costs from HPC projects for members from EU countries with upcoming HPC
Current models are not too bad, even though funding level of e-infrastructure projects is seldom adequate	Pre-competitive procurement procedure

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TABLE 56

What Funding Model or Models Would Work Best for Pursuing HPC Goals in Europe?

Responses	Responses
Cycles model with national and EU funding	Pre-competitive studies funded by businesses
Direct funding to groups that have proven HPC research competence	Project-based (Project duration: 3 to 5 years because programming and simulating is labor-intensive and research benefits from some continuity)
Encouraging institutional collaboration pan EU	Project-based funding
Establish one clearly strong organization that reflects European cooperation and represents Europe in contact with the other continents (PRACE) and prevent competition at that level. Establish an INCITE-type funding scheme for SMEs' use of HPC-resources	Projects have always to be evaluate by extra-European experts
Establishment of a European agency of international cooperation in HPC (agency should have funds which it could distribute to research teams and transnational HPC centers)	Provide funding for post-RTD, pre-competitive developments (maturing)
EU funding 50% and member states funding the rest	Provide funding for research infrastructures: for investment and operation
EU has to fund personnel exchange and collaboration for research and code development, but also increasingly has to fund computer cycles of high-end supercomputers in order to promote their usage without regard to nationality of the scientific or industry users	Provide the EU-wide HPC ecosystem (like PRACE) with consolidated long-range EU budget and sound research programs to tackle grand challenges in HPC and evolve the ecosystem
EU should contribute to PRACE HPC research at the financial level of one hosting country	Provide the HPC centers with consolidated long-range budgets for their own national planning
EU should create new company, on the Airbus model, that it dramatically subsidizes to innovate HPC technology.	Secondly, Europe must dedicate a relatively big funding support for both investment in long-term future for HPC science and engineering excellence and catching up applied research efforts such as in the U.S. and Japan
EU-level funding (e.g. transfer from structural funds for the benefit of research and research infrastructure)	Shared funding — EU + local funds for big centers, however under control (there are examples demonstrating that HPC centers have been abandoned by local governments once the external support is not there)
Firstly, we need a clear and long-lasting national funding support, engaging more than one national institution and deploying a few public-private partnership projects/models with visible outcomes for the whole society	Small and medium size proposals focusing on specific challenges
Flagship projects with clear goals and incentives to collaborate between domains	Small number of significant projects (2 or 3) with significant development funding. Vendors cannot/will not fund development because procurement bidding system means that the development costs can't be recovered through product sales.
Flexible access to EU grants	Split country/EU funding model (50:50)

TABLE 56

What Funding Model or Models Would Work Best for Pursuing HPC Goals in Europe?

Responses	Responses
Full EU funding for high-end with clearly articulated and measured "output". Lower level funding from member states to build the necessary eco system. "Matching" will strongly favor the larger economies and will make the process unnecessarily politically complicated.	Support applications and users
Fund a limited number of big projects	Support HPC PhD completed on industrial contexts
Fund prototypes	Support training and dissemination
Fund R&D	The PRACE hosting/non-hosting model seems initially to be workable. However, any model must have a suitable element of sustainability is built in.
Fund science and technology research directly — don't try to force HPC development artificially	Thirdly, it is important to be adopted and carried out regional funding schemes following EU community programs
Funding at application level in various disciplines preferably by enabling (from FPx-related funds) the ERC to run dedicated calls for application development for and Exascale codes, with PRACE as one of the external advisors.	Three-fold funding: technological bricks+prototypes+computing centers with an industrial driven governance
Funding by the EU is best	To go from the present subsidiary model to a bold centralization of the HPC funding process. Until now national policies have been rarely far-reaching (possibly with exceptions in U.K. and Germany)
Funding models, where EU doubles the money brought in by universities. Including total HPC infrastructure investment (HW + SW + Training + Administration. Not limited to HW only).	.

Source: IDC, 2010

13.4 Funding Models That Have Failed in HPC

Table 57 shows the opinions on which HPC funding models have failed (and presumably should not be repeated). The perceived failures fall into these categories:

- Funding models based on short-term goals
- Funding heavily focused on many small projects rather than a few large ones
- Funding procurements that include protectionist measures
- Funding models that impose overly burdensome bureaucratic requirements to gain access to HPC resources.
- Funding models that require organizations to pay to use HPC resources
- Funding models that require countries to "buy their way in"
- Funding models aimed at developing new HPC system architectures

Representative Comments from Respondents

"Funding the procurement of (high performance) computers with protectionist constraints."

"Any form of protectionism; European vendors have to be competitive worldwide."

"Scattering of funding on many small projects with no sustainable perspective or industrial target or broader coordination."

"Too short-term research agendas and strategies."

"The 'matching' model. Too much influence from the member state on type of infrastructure."

"Avoid additional bureaucratic burdens by national authorities and EU authorities as well."

"Airbus model (was flawed because it was late to the game)."

"Pay-per-cycle models — all fail."

"Charging for computer resources for/from research projects will be a failure."

"PRACE model was for countries/center to buy their way in. Today the U.K. has no money to invest in HPC but has talented people though no one is served by this situation."

"Public funding only for developing completely new architectures."

TABLE 57

What Funding Models Have Failed in HPC? Do You Know of Specific Examples That Should be Avoided?

Responses	Responses
Airbus model (was flawed because it was late to the game)	Latin America — almost no maintenance of the high speed Internet connections after the Americans left it to the local people
Any form of protectionism; European vendors have to be competitive worldwide	Many, almost all: I have seen panel committee in Europe looking at the creation of a cyber infrastructure; the attempt to "stimulate" the creation of a European HPC supercomputer center without taking the responsibility for it. CERN has been extremely successful. EU should try to realize a similar effort for HPC.
Attempt to create centralized top-down structures	Most STREPs/IPs in ICT produce almost no important scientific results with real impact and are a waste of money
Avoid additional bureaucratic burdens by national authorities and EU authorities as well. Be careful with ideologically motivated models of public-private partnerships.	Mostly, those relying on a single source of funding and motivated by short term issues
Avoid too much competition, but combine	One cannot rely exclusively or even on the major part on private/industry financing

TABLE 57

What Funding Models Have Failed in HPC? Do You Know of Specific Examples That Should be Avoided?

Responses	Responses
Badly located European HPC center without top 5 computer and well-know scientists in situ	Pay as you use would lead to sub-optimization and capital destruction
Big EU prestige projects with little payoff	Pay-per-cycle models — all fail
Buying capacity from abroad (skills development happens in target country)	PFI in the U.K.
Charging for computer resources for/from research projects will be a failure	PPP/PFI
COST projects	PRACE model was for countries/center to buy their way in. Today the U.K. has no money to invest in HPC but has talented people, though no one is served by this situation.
EU does not specifically cover HPC in latest framework programs and it can get funds only via scientific research programs	Pricing models: HPC is basic R&D, there is no "market"
Europe can only act strongly by combining all available forces. Competition only at the appropriate level, not as an adagium.	Public funding only for developing completely new architectures
Financing the creation of new HPC centers in economically-poor areas, especially without long-term sustainability plans, as made in recent years with Italy PON-financing plans	Public-private partnership
Finnish government funneling all university HPC money to CSC. CSC building an low-efficiency environment and a high-overhead organization, which supports only a limited number of applications and a limited number of users	Rather not say in open forum
FP7	Research funding in EU is lost opportunity for the creation of innovation
Fragmented funding	Research funding in EU is used as cheap workforce for EU companies
Funding for European hardware (DEISA, PRACE)	Scattering of funding on many small projects with no sustainable perspective nor industrial target nor broader coordination — may work fine for some topics and research but not for HPC
Funding models based on individual country efforts — very often separated into only government or private funding initiatives	Separation of HPC research from domain problems
Funding models that replicate other large-scale research instruments in Europe without taking into account shorter investment cycles of HPC systems	Single country funding (local only) for high-end
Funding models that take into account only the interests of the funding agencies which follow mainly indicators such as return on investment, profits, etc.	SUPRENUM was a national computer project built outside of the market, funded by the German government, and became a complete failure; user communities MUST be heard during procurement
Funding only resources	That every country of the EU has its own funding model
Funding projects with little practical relevance and sustainability	The "matching" model. Too much influence from the member state on type of infrastructure
Funding the procurement of (high performance) computers with protectionist constraints	The whole e-Science initiative of the last decade was an unmitigated disaster and waste of money

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TABLE 57

What Funding Models Have Failed in HPC? Do You Know of Specific Examples That Should be Avoided?

Responses	Responses
Funding very focused HPC application projects. These projects support one use case, but expanding the application to something else will double the cost. These applications do not support any reuse, which kills the business case	Too diverse
Government funding	Too much competition (see grid/e-Science calls) result: much uncoordinated effort, not aimed at European or worldwide use (re-)use of the output (middleware), too much waste of money
Grids: disseminate small amounts of money without real focus	Too short-term research agendas and strategies
I have not seen any added value of grid-based technology in HPC	Top-down approach
Joint government/industry funding	Trying to start up new vendors — almost 100% failure rate

Source: IDC, 2010

13.5 Organization's Current Funding Approaches for HPC

Table 58 lays out the funding sources for the respondents' organizations. With rare exceptions, the organizations are either primarily self-funded (50% of respondents) or receive partial funding support from their national government (65%). There is overlap between these two categories, of course.

A smaller number of the organizations are funded in part by public-private partnerships (10%) or by multiple countries (15%).

TABLE 58

What is Your Company/Organization's Current Funding Approach for HPC?

	Respondents	Percentage of Sample
Our internal funding is helped by government funding from within our country	34	65.4%
Our HPC is primarily funded by our own organization	26	50.0%
We receive multi-country funding, but it is less than 20% of our HPC costs	5	9.6%
We have public-private partnership(s) that help to fund our HPC	5	9.6%
We receive multi-country funding, and it is more than 20% of our HPC costs	3	5.8%

Note: Multiple responses were allowed. 52 sites responded to this question.

Source: IDC, 2010

13.6 Multinational HPC Collaborations for The EU To Consider

In Table 59, the surveyed HPC leaders discuss which multinational HPC collaborations they believe the EU should pursue. The main recommendations were as follows:

- Continue the successful PRACE and DEISA programs.
- Form a single entity to drive the EU HPC strategy. This could be done by joining PRACE and DEISA together, or by forming a new entity.
- Focus on exascale computing, especially software development for exascale.
- Form multinational collaborations in Europe, but also with the U.S., Japan, and China.

Representative Comments from Respondents

"[Continue] both PRACE and DEISA, but managed as a single European entity/infrastructure, and with a clear European focus. In my opinion, a strong independent organization (along the lines of EMBL or ECMWF in other areas) will be necessary to achieve the necessary impact. This will require national annual subscription with multi-annual commitment.

"Establish a centralized EU body to support homogenous HPC."

"The EU has to create an EU agency for HPC and science to lead the EU HPC collaboration."

"[Create] initiatives [to move] towards exascale computing, driven by key players already involved in PRACE and STRATOS."

"Exascale software initiative."

"Exascale software development should not be done alone and isolated."

"Partner with the U.S., Japan and China."

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TABLE 59

What Multinational HPC Collaborations Would Make the Most Sense for the EU to Take on?

Responses	Responses
5 sites mentioned DEISA	For large, transnational clouds and HPC centers: support structuring actions between large, constituted user communities, service providers, and solution vendors
9 sites mentioned PRACE	If multinational means intra-European, I believe EVERYTHING concerning HPC should become multinational. Almost everything remaining national in HPC has a high risk of becoming wasteful
Apart from having a consistent approach on the best way forward to exascale, anything based around data curation	Initiatives towards exascale computing, driven by key players as already involved in PRACE and STRATOS
Both PRACE and DEISA, but managed as a single European entity/infrastructure, and with a clear European focus. In my opinion a strong independent organization (along the lines of EMBL or ECMWF in other areas) will be necessary to achieve the necessary impact. This will require national annual subscription with multi-annual commitment.	Just seek to enable all EC+ countries to become partner in PRACE and Stimulate cooperation between Computational Research centers in Europe (ERAnet?)
Branch offices of transnational HPC centers (better and closer cooperation among member states)	Mostly on applications (scientific, technical), balanced collaboration on HPC technologies and architectures is usually difficult.
Climate research, HEP, ITER, genomics	Open to the scientific communities
Cooperation on new paradigms for HPC and efficient HPC SW development	Partner with U.S., Japan, and China
Create a key technology program to fund HPC –based research in physics/chemistry/biology/engineering	Possibly increased collaboration effort with emerging economies (i.e. India).
Enable scientists from developing countries having privileged relationships with Europe to access European HPC infrastructures. Direct collaborations with the U.S. most important supercomputing centers (on the model of the ORNL/Jülich collaboration)	Research in exascale computing. Establishment of tier 0 HPC infrastructure, R&D cooperation on tier 0, tier 2-levels
Enlarging PRACE funding to the regional centers to create a real HPC EU ecosystem and fostering stricter connections with similar U.S. initiatives.	Software development and integration efforts
Establishing an centralized EU body to support homogenous HPC. Currently, member states doing this on national level. Which is very low efficiency	The EU should identify the classical science fields that are strong in Europe but will unavoidably have to move to simulation-based research (e.g. personalized medicine), and try to make a push on that front. The EU should certainly incorporate international manufacturers in any program for this kind
EU has to create an EU agency for HPC and science to lead the EU HPC collaboration. Multinational collaboration would not be reactive and dynamic enough to face the challenges (to launch PRACE takes years, just to buy a first computer)	The DEISA model should be pursued in connecting supercomputer centers of medium and small countries. They should be encouraged to share resources and expertise in several HPC domains, which would have the side effect of enabling the use of larger HPC systems.
EU should do a survey of available expertise in systems/applications across all the member states and develop focused instruments that take advantage of the available strengths.	Typically with the U.S. and Japan, as long as some kind of parity and reciprocity is guaranteed (EU money for European investment and added value, purchase of technology and systems must be both ways)

TABLE 59

What Multinational HPC Collaborations Would Make the Most Sense for the EU to Take on?

Responses	Responses
Exascale software development should not be done alone and isolated	University wide collaborations, encouraging national initiatives such as the U.K.'s National Grid Service
Exascale software initiative	With Japan, because of its strong tradition of science-industry cooperation
Exchange experts	With the U.S.
First at all, it is extremely important for the EU to pursue concrete collaborations with related initiatives overseas, for example in the U.S., Japan, South-Korea, and China. It has to address projects with global scope and partnerships, such as the International Exascale Software Project (IESP). In addition, the EU's interest is to encourage globally distributed usage and collaboration in accessing extreme computing resources.	.

Source: IDC, 2010

13.7 Areas in Which Respondents Would be Interested in Participating

Table 60 contains a diverse range of HPC-related activities in which the survey respondents said they would be interested in participating. Not surprisingly in view of responses to previous questions, scalable software development was mentioned more frequently than any other single area.

TABLE 60

Which Areas Would You or Your Organization be Interested in Participating in?

Responses	Responses
All HPC related technologies, hardware, software tools and applications	Large scale data curation and manipulation, secure cloud, shared datacenters and DR, energy efficient computing.
Any collaboration which would allow us to train/motivate people to have a better use of development tools at scale	Mainly application software and middleware development but also some algorithmic development connected to parallel numerical methods
Application of HPC to industry and development of HPC software tools	My team is interested in participating in post-petascale programming, including algorithmic, power-aware HPC, linear algebra, applications, and languages. I would like to help with the creation of a large EU HPC research center.
Application tuning in collaboration with code developers	Nanoscience, economics, medical science, social science, security, governance
Atmospheric research	On behalf of the Netherlands: all areas
Calls similar to e-infrastructures or e-science	Parallel software development
Code development — application scalability	Partner with U.S., Japan and China.

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TABLE 60

Which Areas Would You or Your Organization be Interested in Participating in?

Responses	Responses
Co-design and assess HPC systems (computing center vision)	PRACE (as a Tier 0 center); exascale software initiative (applications and tools); advanced user support structures such as simulation labs; energy efficient systems; quantum computing
Computational applications	PRACE for software
Development of European and non-European cooperation programs	Running climate simulations with well balanced resources: CPU, storage, network access, post-treatment resources
Development of highly scalable software; 2. Software design, porting and/or optimization on GPGPU clusters; 3. Climate modeling and advanced NWP; 4. Bioinformatics.	Scientific applications (extreme scalability targeting 100,000's processors)
Development of next generation systems, peta/exascale programs, building "cloud HPC"	Simulation-based research in biology and medicine; scientific visualization; hardware-software co-development
Do systems research in operating systems/storage	Software development, data, computing on many levels, building the whole HPC ecosystem, green HPC… (CSC is one of the major European centers — we are interested in and also currently involved in many areas)
Exascale computing, software scalability, computational sciences, exascale data visualization, green IT	Software initiatives to prepare for future challenges (new languages, new programming techniques)
High-performance computing for science and engineering: operations (user support, system administration and maintenance) and sustainable development (hardware and software upgrades, fund raising and awareness and dissemination campaigns)	Solutions or services at the interface between HPC and clouds
HPC and cloud systems deployment and management software solutions best practice definition	Technology vendor and expert/ consultant in designing EU HPC investments to support material and energy efficiency
HPC education and training in the EastMed neighborhood region; participation in PRACE	Tier 0 HPC center; present and future PRACE collaboration; petascale and exascale programming and analysis tools; energy-efficient systems; simulation technology and simulation lab structures; quantum computing
HPC research in physics	Virtually any area as we are 100% dedicated to HPC and interested in most all areas
HPC usability, HPC-HTC interface, HPC-Cloud, HPC open source toolkits, HPC-enabled virtual research environments	We are interested in collaborating in every area
If the EU set up an Airbus-like firm to exploit the coming disruption, we [IBM] would help them and this would be a useful counterweight to Intel	We are very keen to begin a dialogue with the EU

Source: IDC, 2010

13.8 What Private-Public Partnerships Should the EU Explore in HPC

In Table 61, the respondents comment on HPC-related public-private partnerships that they believe the EU should explore. The following representative comments provide highlights of the respondents' thinking:

"Emphasis should be on getting 'better' engineering work done without expecting immediate financial backing from industry."

"[Pursue partnerships] in almost all sectors like aviation industry, automotive, life sciences, nanotechnology."

"Co-financing grants for SME to use HPC center facilities."

"[Partnerships through] PRACE-STRATOS (long term relationship between industry and research institutes/universities)."

"Partnerships with HPC hardware vendors such as IBM, NEC, Intel."

"Continue with JuRoPa-like R&D projects, as cooperation between HPC centers and industry."

"Help in the emergence of vendors providing HPC clouds."

TABLE 61

What Private-Public Partnerships Should the EU Explore in HPC?

Responses	Responses
"Partnerships" are too often used to get a foot in the door. Emphasis should be on getting "better" engineering work done without expecting immediate financial backing from the industry. Results should be available to the community at large. I have been interpreting "private" in this context as "industry".	It has been notoriously hard to involve companies, focus on those which have an inherent interest
Cloud with the Tier 1s.	Partnerships with HPC hardware vendors such as IBM, NEC, Intel
Co-financing grants for SME to use HPC centers' facilities	Partnerships with key European industries that have walked away from HPC (automotive for example), providing free access to large HPC facilities through an INCITE-like program
Collaboration agreement to help develop/improve new technology and address wide markets	Partnerships with some industry sectors as users (aviation, utility companies, automotive, etc.) as well as vendors, big hardware/software vendors as well as software SMEs
Continue with JuRoPa like R&D projects, as cooperation between HPC centers and industry	Perhaps real injection of effort into assisting commercial apps development (rather than just university based research programs) to accelerate to market, EU based codes to be deployed on large scale multicore for example or to run in an HPC cloud environment efficiently.
Development of exascale applications	Please avoid this model, as it favors short-term profit and compliance with KPIs above any other considerations.

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TABLE 61

What Private-Public Partnerships Should the EU Explore in HPC?

Responses	Responses
EU has to have partnership only with private companies would truly invest on research on HPC. Private-public partnership has to be evaluated by really independent experts.	PRACE-STRATOS (long term relationship between industry and research institutes/universities
EU level: A form of PPP such as joint technology initiatives in those technology areas where the EU has competitive advantages	Pre competitive procurement procedure co-funding with industrial end users.
Focus on: 1. execution of HPC projects; 2. HPC modernization of existing hardware, software and applications; 3. definition of strategic priorities, carrying out research HPC projects and promotion of the relationship: research — product.	Projects involving vendors/academia and not forgetting HPC centers that have great expertise and the end-use knowledge.
Focused and targeted academic/industry projects	Regional level: creation of regional associations including government, industries and research representatives from more than three countries
Help in the emergence of vendors providing HPC-Clouds. Use its critical mass to negotiate contracts/prices on behalf of the European research institutions with HPC/HPC-Clouds/Clouds vendors. Work with the software vendors in redefining their pricing models towards a pay-per-use model	Technology and integration partnerships
HPC vendor + academia + computing center, funding prototypes	Technology research
If the "real" PPP model is questioned, then it is usually applied to build public infrastructure for private money to get this investment cost back through fees from users. It is difficult to imagine such a model for scientific community as the users paying fees to private investor for using supercomputer.	There is very little room for European partnership and the existing partnerships with non-European companies cannot be avoided but should be more "controlled", so to speak.
In almost all sectors like aviation industry, automotive, life sciences, nanotechnology	Through PRACE-STRATOS, under FPx supervision if so wanted, set up long term relationships between industry and public research institutes/universities (1:1:1-funding) and An INCITE type program for SME's
Industry (users and IT) and academia	We would be very keen to start a dialogue with EU representatives, thus sharing information we currently have on the European market, sharing ideas on the EU HPC market growth, etc.
Integration of hard and software	.

Source: IDC, 2010

14.0 FINDINGS FROM THE SURVEY OF HPC STAKEHOLDERS: STAKEHOLDERS SUGGESTIONS ABOUT THE FUTURE OF HPC

14.1 Preferred Approaches for EU HPC Leadership

Table 62 ranks the respondents' preferred approaches (i.e., objectives) for pursuing EU HPC leadership. The ranking of approaches, based on the percentage of respondents mentioning each approach, was as follows:

1. Making world-class HPC resources more widely available to the EU scientific and engineering communities
2. Advancing scientific leadership by using HPC to solve some of the world's most challenging problems
3. Making HPC more readily available for the first time to small and medium-size businesses (including industrial supply chains, small educational sites, etc.)
4. Having many very large supercomputers, e.g., being at or near the top of the Top500 list of the world's most powerful supercomputers (www.top500.org)
5. Building an EU-based HPC vendor community with world-class capabilities in important areas (hardware, software, storage, networking, etc.)

Here again, building an EU-based HPC vendor community was the least popular rationale for an EU HPC strategy. Designing an EU HPC strategy to excel on the semi-annual "Top500" list was only slightly more popular than this.

TABLE 62

What Are the Most Important Approaches for EU HPC Leadership?

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

Note: Multiple responses were allowed. 61 sites responded.

Additional Comments:

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

Source: IDC, 2010

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14.2 Critical Areas of HPC Expertise That Are MOST Needed to Help Make the EU Stronger

The next two tables present the respondents' views on which areas of expertise are most critical for making the EU stronger in HPC. Table 63A covers what's needed from HPC user organizations, and Table 63B describes requirements for HPC vendors/suppliers.

Critical Expertise Requirements From HPC User Organizations

As Table 60A indicates, the survey respondents see the areas of expertise most needed from HPC user organizations as falling into these main categories. The focus here is strongly on software.

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

TABLE 63A

What Are the Critical Areas of HPC Expertise That Are MOST Needed to Help Make the EU Stronger?

From HPC User Organizations

Critical Areas	Critical Areas
Ability to identify benefits of HPC for innovation of scientific research programs and industrial production	Parallel code development application scalability
Access to resources and services	Parallelization and optimization experts
Access to system	Policy-making to build coherent HPC ecosystem
Address scalability	Professional scientific programmers with expertise in numerical analysis, parallelism, computer architectures. 2. Research staff that have similar but perhaps not as detailed knowledge
Air pollution and climate	Professional user training for efficient use of HPC systems
Applications	Programmability (most of the applications cannot be converted into parallel codes because of an obvious lack of expertise among the programmers
Awareness of available solutions and buying skills and ability to buy the most efficient solution for the application. Training on understanding different models	Programming and software engineering skills (think applications through frameworks and projects)
Capability computing, large scale parallelism	Programming and software engineering, numerical methods for scalability, visualization/data analysis
Cooperation of scientists informatics and mathematics in the field of computational code development	Programming and software tools

TABLE 63A

What Are the Critical Areas of HPC Expertise That Are MOST Needed to Help Make the EU Stronger?

From HPC User Organizations

Critical Areas	Critical Areas
Educated people, access to high-end HPC systems	Research staff who have similar but perhaps not as detailed knowledge
Efficient, Best practice approach to deployment and delivery of HPC infrastructure and services	Scalability of applications; advanced numerical methods; new programming paradigms
Facilitate access and understanding of HPC research.	Scalability of petascale applications and in future exascale applications; efficient highly parallel application development; advanced mathematical methods for computer simulation technology
Facilitate access to HPC resources	Scaling applications
General education in computer science	Software development
How to master efficient multicore (64+)-massively parallel (*10.000+)coding	Software scalability
HPC code developing, including scaling and porting to new hardware architectures. New algorithms and parallel computing paradigms research	State of the art HPC systems and resources in support of simulation science in natural sciences and engineering; Integration and provision of interoperability of different HPC systems and resources.
Hybrid architecture programming	System knowledge — optimizations, future technology trends
Increase efficiency of simulations by R&D on best implementations on many core systems, including accelerators	The creation of a strong cyber infrastructure
Integration skills with domain scientists,	Thorough knowledge of architectures to be able to optimally use HPC systems (optimization/parallelization/architectural design) and knowledge on how to use HPC applications on high-end systems in the applied sciences (notably engineering). Access to knowledgeable staff to help the organization make full and speedy use of the facilities.
Inter-/multidisciplinary collaborations	To get well educated students
Lack of HPC experts for optimizing scientific applications	Training + employment of young scientists/engineers without enforcing mobility
Massively parallel programming and debugging; real life codes which take benefit of the exa/petascale systems; the possibility to choose the best architecture for their applications (voucher concept)	Training to help them adopting new technologies while seeing the benefit, get the right skilled people able to use the technology
More contact between users and Centers like PRACE or DEISA	Usability and interaction design to make the infrastructure accessible to larger number of research professionals. Open source software development and governance.

Source: IDC, 2010

Critical Expertise Requirements from HPC Vendors

Table 63B describes the expertise areas the survey respondents viewed as most important for HPC vendors/suppliers. The main requirements emerged as follows:

- Designing HPC hardware and software that more closely fits the users' applications and workloads

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- Learning how to collaborate well with government agencies and universities on R&D projects, and to help these users employ HPC products more effectively
- Understanding the specific needs of HPC users in Europe
- Developing more energy-efficient power and cooling solutions

TABLE 63B

What Are the Critical Areas of HPC Expertise That Are MOST Needed to Help Make the EU Stronger?

From HPC Vendors/Suppliers

Critical Areas	Critical Areas
A lot of skills do actually exist among vendors and suppliers, what is missing is rather more 'connectivity' and alliances around joint projects with academia and government labs/agencies	Improve user support
Ability to address the HPC needs in the EU	Increase efficiency of simulations by R&D on best implementations on many core systems, including accelerators
Access to state of the art technology	Initiatives to increment the qualification of the operators in the field
Analysis their workload for planning their next purchase (when and what to buy); power and cooling innovative solutions	Interconnects; system integration; middleware, tools and libraries; application packages
Be able to provide products that are using this technology and propose the right pricing model, scalable, affordable	Investment in SW development and joint programs with user communities
Better use of HPC customers' feedback and its consideration in further HPC tools development	Keeping pace with the international developments in HPC technology — and not relying on EU protectionism but on their own technological and methodological competitiveness
Close collaboration influencing the development of new computer architectures (processor, interconnects, storage) as well as software development (system — middleware, parallel file systems — and applications)	Knowledge and support on the effective use of high-end systems. This would include a design optimized with the target user community in mind (operational excellence) and the ability to exploit a system with the user community in mind (workload management).
Competence for integrating/combining services	Lack of pre competitive procurement procedure
Competitiveness	Large collaborative projects
Cooperation of scientists informatics and mathematics in the field of computational code development	Need to address limited scalability of typical ISVs applications by putting in place measures to facilitate and/or incite collaborations between ISVs and applications specialists in national HPC centers
Critical areas	Provision of far more input (feedback) by users in design and performance of next-generation of leading-edge computers, software and applications
Don't over-sell capabilities available in a given timeframe	Relationship with academic and research developers. Hire PhDs in HPC projects
Efficient software tools optimized for hardware	Seek cooperation with HPC centers and advanced user communities for joint R&D projects to better meet realistic needs of applications
Efficient/customizable integration	Suppliers of HPC products and services: Closer collaboration, more help.

TABLE 63B

What Are the Critical Areas of HPC Expertise That Are MOST Needed to Help Make the EU Stronger?

From HPC Vendors/Suppliers

Critical Areas	Critical Areas
Focusing on the integration aspect of processors, interconnect and software	The architecture of the parallel machines
Help in the emergence of a utility HPC market in Europe by indirectly funding European HPC vendors through research projects needing HPC resources. Expertise in building and managing HPC-clouds.	To develop software tools
How to competitively build Europe-based low-latency-interconnected low-energy consuming systems	Understand how to apply and develop new algorithms. If you become masters of algorithms and the software that implements them, you become masters of the applications.
Hybrid architectures and multidisciplinary support	Understanding of the real needs of HPC users/applications, available funding

Source: IDC, 2010

14.3 What the EU Should Do to Help Develop and Obtain Critical HPC Skills

Table 64 contains the respondents' opinions on what the EU should do to help develop and obtain the critical skills described in the two preceding tables. The main recommendations for the EU are the following:

- Make HPC leadership a higher priority in the EU
- Ensure that HPC leadership becomes a long-term commitment with sustained funding
- Focus the EU HPC strategy on solving important problems rather than acquiring hardware systems
- Focus on algorithm and software development
- Strengthen HPC education and access in European colleges and universities
- Reduce VAT on HPC products

Representative Comments from Respondents

"Having HPC as a long term agenda item for the EU will encourage more people to look at HPC as a career path, rather than as a short-term tenancy, this will in turn help to broaden the appeal and usage of HPC throughout academia and industry and elevate HPC to a major area of endeavor rather than as a small subset of IT."

"Develop funding schemes that are not only directed to R&D but also to develop mature solutions; Long-term success depends on long-term strategies: funding and support schemes for such long-term strategies need to be developed."

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"Focus on algorithm development and software engineering with a strategy that maps to where computing will be in the 2018/2020 timeframe. Should be problem-centric rather than hardware-acquisition-centric."

"Strengthen HPC education in European colleges and universities."

"Deploy HPC certification programs offered through professional training institutes to the industry users."

"Find some method to fund HPC vocational training as a matter of urgency."

"Facilitate the HPC access for students that are involved in scientific projects."

"VAT reductions on HPC products."

TABLE 64

What Should the EU Do to Help Develop and Obtain These Critical Skills and Experts?

Actions Needed	Actions Needed
Small instruments to support local university funding for local HPC investments. Current funding instruments supporting centralized HPC infrastructure development, which supports only a limited number of applications and limited number of HPC system designs.	Having HPC as a long term agenda item for the EU will encourage more people to look at HPC as a career path, rather than as a short-term tenancy, this will in turn help to broaden the appeal and usage of HPC throughout academia and industry and elevate HPC to a major area of endeavor rather than as a small subset of IT.
Strengthening HPC education in the European colleges and universities.	I have the impression that important decisions are made by physicists and chemists who lack the necessary expertise in complex software design
Deploying HPC certification programs offered through professional training institutes to the industry users.	In U.K. universities and colleges there is no real funding stream for training/teaching people to have the required numerical and programming skills to support domain researchers at even the terascale never mind the peta/exascale. Finding some method to fund HPC vocational training is a matter of urgency.
Maintaining Web portals and Web-based materials for HPC self-education.	Invest more at the EU level and at the national level — 5x more.
Facilitating HPC access for students who are involved in scientific projects	Invest more in education, foster more innovation, more risk taking; availability of reasonable funding for hardware and software; closer working relationship of vendors and users
A huge effort is needed to help develop necessary SW and this is where the EU could make a difference and get into a leading role	Larger investment in people (scientists, engineers) that can efficiently use the very large computers by making project calls with a sufficiently large budget for hiring scientists and engineers (less focus on mobility, traveling, training, education, conferences)
Build an ecosystem with seed money	More addressed and transparent funding of HPC infrastructures. Support of HPC experts' education at university level. VAT reductions on HPC products.
Calls enforcing cooperation between industry, application science and HPC provision	More research programs, well financed

TABLE 64

What Should the EU Do to Help Develop and Obtain These Critical Skills and Experts?

Actions Needed	Actions Needed
Create a European agency for software that gathers leading experts and tackles the long-term challenge of HPC software sustainability. Fund the building of HPC-clouds in the different member states. Involve the CERN experts more in the elaboration of strategies related to capacities.	Need to develop a meaningful and sustainable model for expert staff in national HPC centers and increase their numbers. The lack of career path tends to pose problems either in terms of staff retention, and/or sustainability. Creative partnerships between HPC centers and the academic institutions it supports could provide such a mechanism.
Create a key technology program to fund HPC-based research in physics/chemistry/biology/engineering	Nothing: HPC is the formula 1 of simulation. Any bureaucratic act can only destroy what has been successfully built over the last 20 years
Create and fund large collaborative projects led by industrial users and techno providers	Promote close collaboration between countries and user communities. Develop pan-European programs for application software development in crucial scientific areas developing areas and computer science research in HPC specific domains. Promote collaboration with European industries to increase their usage of HPC.
Develop funding schemes that are not only directed at R&D but also at developing mature solutions; long-term success depends on long-term strategies: funding and support schemes for such long-term strategies need to be developed.	Propose a topic on "Knowledge-based decisions in HPC procurements"
Encourage and support interdisciplinary groups (application scientists, computer scientists and applied mathematicians) á la ASCR in a long-term program, with strong participation of the key user communities.	Simulation should be more widely taught. Collaboration between academic organization and industry
Enhance access to HPC systems, and support development of new algorithms and computational methods for different scientific communities	Sketch a long-term perspective rather than a project based short term injection; The perspective should include funding but by no means be limited to that. Develop social and political interest in solving the major global issues through modeling and HPC. Use European (scientific and political) independence as one of the key arguments.
Entertain long-range planning rather than short-range support programs and establish and foster EU-wide educational program and exchange of knowledge and expertise; support the EU-wide access to Leadership HPC systems in major centers through an efficient granting scheme for HPC capability and travelling as well.	Start a program that concentrates on software development on not only on buying HPC systems
Financing joint research projects between academia and vendors, suppliers of HPC products and services	Stimulate Computational Sciences at universities and collaboration between academia and businesses. Stimulate international collaborations. Provide the HPC resources and support at no charge
Focus from HW to skills development, strengthening the strong European areas (examples: software, networks, green ICT…), enable balanced resourcing (HPC and data intensive computing for example in a balance)	Support a long term project led by scientists who really know HPC; i.e., including several computer scientists and numerical analysis experts. In the U.S. and Japan, computer scientists lead several important projects and write important reports. In Europe, it is more computational scientists who have led HPC policies for a decade.
Focus on algorithm development and software engineering with a strategy that maps to where computing will be in the 2018/2020 timeframe. Should be problem-centric rather than hardware-acquisition-centric.	Support integrative teams of domain experts and HPC experts and encourage institutions to put HPC on the curricula of today's computer science departments.

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TABLE 64

What Should the EU Do to Help Develop and Obtain These Critical Skills and Experts?

Actions Needed	Actions Needed
Focus on the apps and the science/engineering and provide huge amounts of resources in that area.	Support projects of collaborative nature between industry and academia.
Foster alliances of government labs, academia, HPC vendors and suppliers in general around sustainable projects including prototypes of supercomputers (pre-competitive/pre-commercial-like approaches) with European companies.	Support sustainable personal infrastructure at HPC centers and user communities.
Fund science and research directly	Training through research programs similar to RTN (research and training networks) in the FP6, however focused on HPC applications, scientific predictions, insights in new areas
Give European opportunities much beyond what is done at the national scale; Invest in producing strong contacts between the national communities of "experts" so as to facilitate common standards, common languages and useful competition…	User training should be treated as very, very important. Building HPC system is easy, efficient use of it is not easy at all. Same applies to applications — there are many free applications that need professional tuning or sometimes redesign for efficient use.
Give more funding and promote the initiative	.

Source: IDC, 2010

14.4 What Respondents Would Like to See the EU Do to Make Europe Stronger In HPC

Recommended EU actions to make Europe stronger in HPC appear in Table 65. The main recommendations fall into these categories:

- Make HPC a higher priority on the EU's research agenda
- Create a central EU HPC organization, possibly by expanding the mission of PRACE and also borrowing from the CERN model.
- Drive toward EU leadership in petascale and exascale computing.
- Increase HPC funding and direct more of it toward software development and skills training
- Include support for industrial initiatives and promote public-private partnerships

Representative Comments from Respondents

"HPC should become a much higher priority on EU's research agenda."

"An increase in funding."

"Invest in software development."

"Support large projects with a solid industrial basis and perspective, around prototypes involving industry and academia and computing centers."

"A well funded program in HPC skills training."

"Creating an EU HPC center, following the CERN model."

"Continue to support the establishment of a European infrastructure (PRACE)."

"Fund exascale research and application development."

"Start a European exascale project."

TABLE 65

What Would You Like to See the EU Do to Make Europe Stronger in HPC?

Responses	Responses
A well funded program in HPC skills training.	Help European HPC vendors/suppliers
An increase in funding	Help the constitution of transnational communities of users
Apply innovative provisioning models, as cloud computing, to HPC environments. Cloud computing can enhance the different types of high performance computing infrastructures in science and engineering.	HPC should become much higher priority on EU's research agenda
Being first in applying HPC solutions which close the gap between theoretical and actual application performance is of major importance.	Improve the impact of HPC through bringing domain scientists and HPC experts together, this is best done by allowing "moon-shot" projects to overcome the fragmentation
Better define and support tier 0 – tier 1 HPC systems structure and access	Invest in software development
Better support of transnational HPC centers (see questions 25, 27)	Invest more at the community level
Calls integrating HPC provision with specific modeling challenges	Investing in its stronger points (application development in material science, for example) and become stronger on the weaker points, especially on the computer science part of HPC
Centralize coordination and work through PRACE	Investment in the user community (more support for scientists and engineers that are keen to use the full power of the large supercomputers)
Centralize coordination (PRACE legal entity) and work largely through PRACE; create an attractive environment for (potential) HPC vendors/manufacturers to run (part of their) creative business in/from Europe	Involve the HPC users in the decision making process. Promote utility HPC vendors. A global assessment should be made of the European infrastructure impact (HT/HP)C. Metrics for impact/success should be clearly defined.
Collaboration and coordination.	Large projects involving the most advanced countries and organizations (like PRACE) and support the EU HPC industry with prototypes, collaborations, and possibly pre-commercial procurements
Continue to support networks	Long-term investments in an HPC infrastructure as provided by PRACE; invest in application scaling and sustainable software development; support the creation of a data infrastructure
Continue to support the establishment of a European infrastructure (PRACE). Funding of exascale research and application development	More open requirements definition and procurement process/decisions re major HPC installations
Create a human mobility program to support greater movement of expert staff between national HPC centers across Europe.	Promote and facilitate effective partnerships between ISVs and National center of expertise to allow the effective exploitation of HPC in industry

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TABLE 65

What Would You Like to See the EU Do to Make Europe Stronger in HPC?

Responses	Responses
Create a true EU research center in post-petascale computing with multidisciplinary European teams, led by major active academic scientists, with a Top5 computer in situ; with long-term supports on strategic science domain. Basic researchers on computer science for petascale and exascale computing have to be supported.	Provide suitable programs or initiatives to address an extensive authoritative report on the European HPC ecosystem — with best practice highlighted and recommendations to stakeholders.
Create one or two centers with the most advanced HPC equipment	Put money into research
Create peta/exascale programs, invest in open source applications	Solve the funding issue with the U.K.
Creating a EU HPC center, following the CERN model	Start articulating expected "output" in a scientific, measurable and unambiguous way. Monitor progress. Do not fund first and "hope" that science and engineering will use. Step away from the hardware view and start working from the performance/scalability of existing applications that have a strong operational component.
Define and promote a unified strategy at the European level both from a technological and an application point of view.	Substantial funding to PRACE (50% or more) and stimulate collaboration with business and industry
Dissemination of HPC importance for modern scientific research and development and support of application of HPC to production and current research programs.	Adequately support initiatives to address the challenges of massively parallel architectures and disruptive technology (GPGPU) — porting, optimization and new codes as required
Educating people and organizations on HPC solutions to understand that in HPC "one size does not fit all". Looking at the big picture when designing funding. Making funding easier to apply.	Support for creating community-focused simulation labs
Enable PRACE through STRATOS to seriously engage into long term private-public partnerships with HW and SW vendors/manufacturers	Support hardware purchase and support scientific research
Establish long-range HPC R&D support programs on consolidated budgets for the major HPC players; Establish strong cooperative HPC networks by establishing good and effective coordination structures between the EU and the national authorities without new bureaucratic burdens.	Support large projects with a solid industrial basis and perspective, around prototypes involving industry and academia and computing centers, and foster the structuring of an open source offer for system software, middleware and application software.
Europe needs an independent access to key leading-edge HPC systems and resources	Support of research infrastructures; support of new ideas that would bring the HPC achievements closer to the public
Focus on balanced resourcing (computing, data, software, networks, people) focus on training and education	Support software both for science and industry
Focus time and efforts around applications and tools.	The STREPs/IPs should be more long term and less dependent on industry
Fund European Petascale systems and petascaling of applications; Start European Exascale project	To create an HPC CERN and to stop making so many conflicting initiatives.
Gathering of all EU countries to take part in community HPC strategic planning process	Well coordinated, focused and appropriately funded cross-country HPC program
Give open access to HPC facilities for small user and disseminate the initiative within the academic community	.

Source: IDC, 2010

14.5 Where Should the EU Focus its Investments and Support

The survey respondents (Table 66) said the EU should focus its HPC investments in the following areas:

Scientific and Industrial Domains

- Nuclear energy (including fusion)
- Other energy areas

HPC Technology Domains

- First and foremost, software development, including algorithms, scalable applications, and system software
- Parallel programming to efficiently exploit highly scalable HPC systems
- Programming and software to exploit accelerators and other newer processor technologies
- Energy-efficient power and cooling of HPC systems and datacenters
- Advanced interconnects

TABLE 66

In Which HPC Technology Areas Should the EU Focus its Investments and Support?

Responses	Responses
Algorithms and software for scaling on many core architectures	Nuclear
Application development and HPC tools development, Embedded HPC systems	Nuclear fusion
Applications and SW tools	Parallel computing, power saving
Applications and tools.	Parallel programming on large multicore systems
Architectures for integration of cloud technologies and services with HPC infrastructures and standardization of interactions between HPC platforms and cloud infrastructures	Reduce electrical power required to operate HPC facilities
Development of desktop supercomputing and software development	Research data storage and transmission from silo to end user
Energy areas	Scalability of applications and tools; interconnects; Energy efficiency
Energy efficiency in all its aspects; environmental savings	Scalability techniques and programming and analysis tools towards petascale and exascale systems; accelerators (GPGPUs; but also: capabilities of quantum computing) energy-efficient highly parallel computer systems (like QPACE) Interconnect software for massively parallel computer systems

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TABLE 66

In Which HPC Technology Areas Should the EU Focus its Investments and Support?

Responses	Responses
Energy saving technologies for HPC, to minimize the energy consumption of the future computers	Scalability, programming models and tools, application with strong focus on engineering
Engineering beyond silicon; solar cells; biochips	Software (message passing algorithms, solvers and workload management).
EU should major in scalable algorithms and make everything else secondary. However, they would need to guarantee what the target platform downstream would be	Software and applications
HPC systems, interconnect, middleware and system software	Software and optimization of scientific applications
HPC systems, interconnects, storage and applications scaling	Software development (system software, libraries), computer parallel languages both for general purpose CPUs and accelerators (FPGAs, GPGPUs, etc.) and interconnect future technologies
HPC usability, open source HPC toolkits, HPC-clouds, FPGA-based HPC/FPGA-clouds	Software systems because there is a lot of opportunity for improvement/leadership
Hybrid HPC systems and exascale software	Software, integration work, data, innovative computing (new methods and tools such as GPUs),green HPC
Impact of virtualization on the performance of memory, CPU and I/O intensive, and latency sensitive applications, and virtualization support for specialized communication transports and challenges of porting HPC applications to the cloud	Software: new paradigms and languages for parallel computing
Infrastructure deployment and management solutions (the final piece of the "commoditization" puzzle?)	System architecture and integration energy efficiency
Integration of hardware especially interconnects and software, and software development	Systems and software
Intermediate software: between middleware and the applications; or between OS and the applications; innovative, environmental friendly and sustainable solutions for hosting very large infrastructures	Technologies optimizing utilization of existing hardware — Also links to green values. Technologies improving application scalability.
Keep usability of HPC for domain scientists in focus, i.e. scientific visualization provide systems insight through advanced hardware-software co-design	The areas in which it has leadership since losing those will put Europe in an even worse condition
Multicore and accelerator based.	Very low latency interconnects, low-power technology (could be materials science), and at processor level Europe is stronger in embedded computing.
New applications software; systems software, including operating systems; parallel programming tools debugging tools; Interconnect software; storage software/file systems	.

Source: IDC, 2010

14.6 Actions That Are Needed at the National Level to Improve the EU Leadership Position in HPC

The respondents supplied a range of recommendations for what should be done by their countries at the national level to help advance EU leadership in HPC (see Table 67). Their recommendations for the most part fell into the following categories, as the following representative comments serve to illustrate:

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

Representative Comments from Respondents

"To create courses and workshops that focus on HPC (including parallel programming), and petascale-enabled science and engineering. To finance the installation of more supercomputers in the country. To provide allocations of computing time on large supercomputers, not only to academic research teams but also to industry including SMEs."

"Coherent HPC policy with one national system in NL and various regional and campus systems with open community and collaboration with industry and SMEs in precompetitive stage."

"Funding and support of HPC activities, including the setup of a national HPC facility"

"Provide funding of research in the physical sciences with primary emphasis on HPC, not as a vehicle for funding projects that have little or no affinity to HPC."

"Aggressive funding of medium sized systems."

"At the national level: promote EU study/ research/suppliers."

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TABLE 67

What Actions Are Needed at the National Level to Improve the EU Leadership Position in HPC?

At the national level

Comments:	Comments:
Clear definition of HPC as a priority topic in the national strategic documents — it can be in the national reform program, national development program or strategy for science and innovation development	Long term funding for Tier 1 centers
Inserting the HPC development into national operational programs, including e-infrastructure modernization; human resource development (training and education); industry competitiveness based on adoption and usage of HPC systems and services;	Make our country an attractive place for top HPC talents to locate their innovation. Taxation, centers of excellence
Provision of increasing and sustainable public funding for HPC projects in different areas: fundamental research, life science; manufacturing; government, etc.	More funding for HPC in universities
Accept higher level for FP8 budget, have funding organizations team up better with the framework programs	More help and guidance for leading European HPC companies such as ClusterVision.
Adequate support of scientific infrastructure and training	More support for fundamental research topics and engineering applications that can be studied by HPC, less focus on global challenges like energy, climate issues and so on. Better balance between investment in HPC hardware/software and in the user community (hiring people who can program and run applications on the high-end computers)
Aggressive funding of medium sized systems.	More software initiatives, strengthening and facilitating computational sciences
At the national level: coordinate efforts of research labs in HPC, and improve training in HPC and improve links between public research (universities) and industry	Much time and energy is still being wasted revisiting the perennial issue of centralized versus distributed resources, as well as the distribution of funding between equipment and staff. We would greatly welcome an authoritative report on this topic, advising governments and funding agencies on best practice, clearly highlighting, the importance and cost-effectiveness of each component of the ecosystem, how they interact and depend on each other, as well as to how to "integrate" them (not through middleware) through coherent policy making.
At the national level, foster multidisciplinary actions, academy/industry cross-actions	We feel that the use of the so-called "condominium model" should be encouraged more widely
At the national level: promote EU study/research/ suppliers	Need for significant national efforts for a strategic domain
Awareness of users should be increased by providing valuable services rather than semi-professional ones	Political commitment to prioritize HPC in research infrastructure policy
Clear, focused business plans for procurement/deployment of large scale HPC or cloud installations (using public money) that are monitored for efficiency and success criteria	Promote the value, teach the fundamentals, develop the interest of HPC during undergrad studies; promote mathematics and computational sciences towards youngsters
Cloud computing	Provide environments for computer scientists and domain scientists to work together in integrated teams

TABLE 67

What Actions Are Needed at the National Level to Improve the EU Leadership Position in HPC?

At the national level

Comments:	Comments:
Coherent HPC policy with one national system in NL and various regional and campus systems with open community and collaboration with industry and SMEs in precompetitive stage.	Provide funding of research in the physical sciences with primary emphasis on HPC, not as a vehicle for funding projects that have little or no affinity to HPC
Coordinate national efforts/agencies (cross-ministries) to support the development and acquisition of HPC resources — having academia and vendors work together	Provide HPC access and support to define new scalable applications training to enhance access to scaling HPC applications
Coordinate with other EU countries	Providing adequate funding to national and regional HPC centers in the framework of multi-year planning
Coordination of HPC activities	Software development targeted proposals
Don't know if countries in Europe have the wherewithal to do this separately.	Software development, training of new talent, promote the initiative with the academia
Education for software experts	Strengthen the educational programs at universities in relation with mathematical modeling and with the use of clouds and HPC in science and engineering
Establish solid Tier 1 and Tier 2 HPC infrastructures in every EU nation. Support development of scalable application codes in science and industry. Create human resources in HPC through interdisciplinary HPC master/PhD programs.	Stronger support for simulation on HOC systems
Focusing on specific area of scientific or engineering, fundamental applied math fields where each nation has its strength	Support experimental systems research
Funding, PR/marketing	Support of multidisciplinary collaborative efforts
Funding and support of HPC activities, including the setup of a national HPC facility	Sustainable personal infrastructure
Funding for people and equipment, education	Sustained investment in HPC capacity and services, coordination on the national and regional/local level and with the European activities. Fund R&D in HPC-relevant hard- and software technology; set up or extend university level education and training.
Further development of discipline specific centers of excellence	The critical problems are the HPC education and team management. Masters on HPC have to be developed in EU countries. Management of large multidisciplinary teams would be also one of the most complex problems at the national level. Actions need to be launched to build teams where computer scientists work with computational scientists; it is a really difficult but critical goal.
Higher level for FP8 budget — more eye for funding agencies and FP7/8	To create courses and workshops that focus on HPC (including parallel programming), and petascale-enabled science and engineering. To finance the installation of more supercomputers in the country. To provide allocations of computing time on large supercomputers, not only to academic research teams but also to industry including SMEs.
Implementation of national roadmaps (defined in many countries but funding not yet allocated), synergy and better collaboration/trust between research and e-infrastructure providers	To establish national super computer centers (SCC)

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TABLE 67

What Actions Are Needed at the National Level to Improve the EU Leadership Position in HPC?

At the national level

Comments:	Comments:
Increased and guaranteed long-range budget for HPC; better understanding of HPC and intellectual support by the informatics societies; better integration of HPC technology, methods and algorithms in university curricula	To follow or to develop HPC at national level in coherency with PRACE initiative. To promote HPC in universities and industry especially for SME.
International cooperation esp. in EU	Training and educating people to use HPC systems
Invest in the hardware and users infrastructure at the level reasonable for the size of the country. Integrate this effort with the European initiatives	Training and education for the scientific community and making knowledge available to the industry actively and at an affordable price
Joined up thinking between the academic research sponsors (in the U.K. the Research Councils), the appropriate government organizations and industry. More recognition of the Branscomb pyramid HPC ecosystem model; i.e. the need to develop skills at local level to allow proper exploitation of national and international resources.	Work coordination, providing a complete, easy to use environment
Keep sustainable budget at high level	.

Source: IDC, 2010

Actions That Are Needed at the EU Level to Improve the EU Leadership Position in HPC

In Table 68, the respondents offer their recommendations on what's needed at the EU level to advance European leadership in HPC. The comments generally fall into the following categories:

- Make HPC a higher priority for EU attention and funding
- Ensure broad access to large, tier 0 HPC systems by users in all member states (as elsewhere in the survey and the in-depth interviews, there was general strong support for the PRACE program, but also criticism that PRACE has been too limited to supplying access to HPC systems)
- Provide substantial EU funding and not just coordination.
- Actively promote the benefits of HPC for science and industry

Representative Comments From Respondents

"More substantial funding; HPC needs to be on the EU's agenda."

"Political commitment to prioritize HPC in research infrastructure policy."

"Sustained and increased funding in HPC capability and capacity (PRACE); foster international cooperation on future technologies (Exascale); maintain leadership in network infrastructure (GEANT)."

"The PRACE program was ill conceived and has not focused on advancing the economy, but was more focused on building big systems instead of focusing on 2–5 problems that are really important to Europe and orchestrate activity around solving those problems."

"Clean energy is clearly one of the EU's potential strengths. Also to look at the consequences of aging populations and the implications to future healthcare. Automotive is also strong in Europe."

"More active (and above all, visible) support for academic-industrial collaborations."

TABLE 68

What Actions Are Needed at the EU Level to Improve the EU Leadership Position in HPC?

At the EU level

Comments:	Comments:
Provision of pan-European HPC services at the highest level (Tier 0 level), following the integrated approach towards the diverse HPC systems and resources, allowing lower cost for customers, sustained application performance and effective and reliable management.	More substantial funding; HPC needs to be on the EU's agenda
Community funding support for better coordination of the HPC national initiatives/programs	More support for fundamental research topics and engineering applications that can be studied by HPC, less focus on global challenges like energy, climate issues and so on. Better balance between investment in HPC hardware/software and in the user community (hiring people who can program and run applications on the high-end computers)
Preparation of long-term HPC vision and plan for development followed by annual reports and every 2–3-year study for HPC development in EC and comparative analysis with other regions	Nothing
3 to 5 supernodes with open access and international collaboration. Stimulation of HPC technologies and education in computational sciences.	Political commitment to prioritize HPC in research infrastructure policy
A major push for integrated, goal-oriented science projects in simulation-based research	Promote HPC as a powerful lever for R&D in many new domains like urbanism: safety; life science; select and fund communities that focus on making the best use (efficient, innovative, sustainable) of the national/community infrastructure; support and encourage actions for the long term exploitation of the infrastructure; encourage public/private partnerships.
As with national, plus building more collaborative relationships with other equivalent large-scale organizations (e.g., exploring cofunding new programming languages with the NSF)	Provide funding of research in the physical sciences with primary emphasis on HPC, not as a vehicle for funding projects that have little or no affinity to HPC
At the EU level: Emergence of a unified strategy for HPC computing	Providing HPC facilities that a single country cannot have, software development that single nation cannot do. Developing large scale software system that is not in specific fields but can cover large fields, such as OS, programming language, HPC infra-type software system.
At the EU level: solve the organic transparency of the funding allocation	Provision of central funds to ensure leadership in times of recession

TABLE 68

What Actions Are Needed at the EU Level to Improve the EU Leadership Position in HPC?

At the EU level

Comments:	Comments:
Building of broadly accessible (for all EU member countries) HPC computing facilities	Push on HPC tier 0 systems and new applications development in different fields of computational sciences
Cloud computing	Real funding and not just coordination
Collaborate but the mechanism is critical. Form new company (like Airbus); degree of Balkanization to reinvigorate the software side	Software development targeted proposals
The PRACE program was ill conceived and has not focused on advancing the economy but more focused on building big systems instead of focusing on 2–5 problems that are really important to Europe and orchestrate activity around solving those problems.	Software development, promote initiative, give access to all the EU countries to state-of-the-art HPC facilities
Clean energy is clearly one of EU's potential strengths. Also need to look at the consequences of aging populations and implications of healthcare. Automotive is also strong in Europe. Disruption coming, opportunity exists to get in the game and compete at all levels of the HPC arena.	Substantial funding for world class HPC resources; launch of EU Exascale project
Coordinate at an international level.	Support an EU HPC center with state-of-the-art equipment and specialist staff to enable researchers to harness the power of the HPC facility without themselves having to become HPC experts. Let the researchers do the research.
Coordinating national and regional HPC centers in a pyramid scheme facilitating access for researchers.	Preferably installation in a country that does not have strong political views on high-end HPC facilities in its own country (Poland might be a choice) and preferably fully funded by the EU. As at the national level, industry support (through knowledge and expertise) will be critical and should be actively supported.
Coordination of national HPC efforts, creating an organization that provide pan-European HPC services taking advantage of all EU country competencies in several areas (software and some hardware development).	Definitely not a (part) industry funded facility. This would immediately be favoring the more established industries and would leave little room for entrepreneurial initiatives. More active (and above all: visible) support for academic — industrial collaborations.
Development of centers of excellence prepared to SHARE their skills/knowledge across the EU. Ensure at the high end that wheels are not being reinvented.	Support experimental systems research
Establish petascale centers, provide access to users for research/development, set plans for exascale	Support of multidisciplinary collaborative efforts
Establish solid Tier 0 HPC infrastructure: 4–6 systems to be produced in time interleaving and covering different architectures. Support use of the systems by international consortia.	Support systems development
EU has to create a European dynamic, not only national ones. For example, instead of the PRACE project, a true EU HPC center where researchers from all EU countries may work together with Petascale computers would have been really more interesting that several "national" centers.	Support systems development, applications development and numerical libraries; engage in stronger directed funding, based on (broadly supported) policy rather than competition.

TABLE 68

What Actions Are Needed at the EU Level to Improve the EU Leadership Position in HPC?

At the EU level

Comments:	Comments:
Foster a long-term vision of HPC development involving HPC industry (vendor level), focusing funding on a small number of strong projects.	Sustainable personal infrastructure
Funding for HPC scales, hardware on a permanent level.	Sustained and increased funding in HPC capability and capacity (PRACE); foster international cooperation on future technologies (exascale); maintain leadership in network infrastructure (GEANT)
Funding for people and equipment, deployment	The EC should take a more "hands on" approach to the above, not so much in terms of funding, but in terms of policy making, providing the necessary guidance, incentives and seed funding to enable and accelerate the development and effective operation of a coherent continental scale HPC ecosystem.
Guarantee the world level of leadership where it is already present and, with intelligence and patience (stupid to invest a lot when the results are forcefully meager), develop competences where we are not yet in a leadership position (e.g. in the production of hardware)	In particular, we consider that concepts such as "juste retour" are a significant obstacle to the creation of such an environment and should be de-prioritized from any EC-supported initiative.
Help in the emergence of European industrial providers of utility HPC. Encourage the development of HPC-Cloud offerings by those providers. Fund research and development about the use of FPGAs for HPC. Fund feasibility studies about FPGA clouds (federated FPGA-based infrastructure provisioned and managed through web services on a pay-per-use basis)	The repeated use of the so-called Branscomb pyramid, and its application to the European ecosystem is deeply flawed and lead to suboptimal operational models. More attention should be dedicated to HPC in industry.
Increased and guaranteed long-range budgets and programs for HPC; continuing support of HPC infrastructures like PRACE and broadband networks like GEANT; stronger coordination of innovative research in Quantum Computing as an important option (high performance) computing after end of Moore's Law	Initiatives such as PlanetHPC are very welcome, but more needs to be done in terms of providing incentives to ISVs to engage effectively with leading software development teams and National Centers' applications experts to make codes of industrial relevance more scalable.
Increasing the HPC research activities in the framework programs, especially in the ICT WP ; strengthening the support of the PRACE infrastructure.	There is no significant HPC hardware vendor in the EU . All EU HPC HW investments support American and Asian business. To support European interests and green values in the HPC ecosystem, EU should focus HPC efforts on middleware technology development to enhance HPC HW utilization and allow avoiding "unnecessary" HPC HW investments.
Keep sustainable budget at high level	To establish a hierarchical cooperation of the national SCCs across EU. The EU should provide adequate funding for running such a cooperation to be able to compete with U.S. and Asian SCCs
Less bureaucracy	To recognize the PRACE initiative has the umbrella to host and coordinate HPC projects. To initiate R&D on exascale computing in order to optimize scientific applications. To fund the next computers in the PRACE infrastructure
Long term funding for tier 0 centers and fellowship program for non-EU students in CSE	Training and educating people for usage of HPC systems

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TABLE 68

What Actions Are Needed at the EU Level to Improve the EU Leadership Position in HPC?

At the EU level

Comments:	Comments:
Maintenance of the HPC-Europe at the operational level with more flexibility in using the distributed centers	Very large scale regional centers
More funding to science research	Well defined and fair funding programs.
Work coordination, providing a complete, easy to use environment	.

Source: IDC, 2010

14.7 Consequences if the EU Does Not Take Additional Steps to Develop Leading HPC Capabilities

Next, the survey respondents described the consequences if the EU does not take additional steps to develop leading HPC capabilities (Tables 69, 70, and 71). The respondents almost universally portray the consequences as dire for both Europe and the EU member states, especially the smaller ones. The main consequences they foresee are these:

- Europe could become inferior to the U.S. and Asia in science
- Europe and the EU member states could lose industrial competitiveness and jobs
- Europe and the EU member states could experience a brain drain to the U.S. and Asia, along with great difficulty in attracting talented scientists and engineers
- Europe and the member states could become increasingly reliant on the U.S. and Asia for scientific, industrial, and technological advances
- The smaller, less affluent EU member states could lose the ability to access and benefit from large HPC systems. This could widen the digital divide in Europe, to the detriment of the smaller countries
- Europe's existing strengths in hardware, software and other HPC-related technologies could diminish or disappear from lack of use

Representative Comments From Respondents

"[Europe could] become third rate in science and lose economic standing in the world."

"[Europe could experience a] brain drain to non-EU countries."

"Loss of scientific competitiveness, which has very severe consequences to Europe's economic recovery and attractiveness at global level-competition for talent."

"Loss of European industry competitiveness."

"EU futures will rely on research done in the U.S. and Asia."

"Since sustainable HPC-leadership required large resources, only the larger/wealthier member states will be able to fund significant HPC resources on the long run. Without European investments, the smaller/less resourceful member states will further fall behind."

"Expected consequences are a digital divide in Europe, and a brain drain especially in smaller countries."

"Leaving each country to compete individually in the areas of science and engineering, leading to fragmentation, inefficiency and poor deliverables."

"Major difference between the members states in having access to large supercomputers."

"The HPC scientific and technological areas will no longer attract bright young scientists and engineers; this process will lead to the decay of the high level of expertise in the key EU member states which will again take decades to get re-established after the economic recovery."

"A waste of skills in software/applications and in micro/nanotechnology that do exist in the EU but would not properly be leveraged and used for HPC development, and a lack of independence on key technologies in the area of defense and security."

TABLE 69

Potential Consequences if the EU Does Not Take Any Additional Steps to Develop Leading HPC Capabilities

Consequence #1

Comments:	Comments:
An increasing amount of EU money will continue flowing outside the union	Loss of leadership respective to U.S.
Become third rate in science and lose economic standing in the world	Loss of scientific competence
Brain drain	Loss of scientific competitiveness, which has very severe consequences for Europe's economic recovery and attractiveness at global level-competition for talent
Brain drain to non EU countries	Loss of the European industry competitiveness and/or leadership (mid-term)
Collapse of HPC sector in Europe due to lack of competitive systems in comparison with U.S., India, China, etc.	National centers will be more successful
Competition between member states	No real consequence
Decadence on the world market and on the role of Europe in the world	Not able to maintain leadership in different research fields
Due to the dramatic financial crisis, the member states will have less budgets available to support leadership HPC systems on their own initiatives as they did so far, at least in Germany, Great Britain and France; therefore, additional significant steps of the EU are crucial.	Pay expensive fees to overseas companies

TABLE 69

Potential Consequences if the EU Does Not Take Any Additional Steps to Develop Leading HPC Capabilities

Consequence #1

Comments:	Comments:
Emigration of best researchers outside Europe	Poor competitiveness in scientific research and in industry
EU futures will rely on research done in the U.S./Asia	Reduced competitiveness
EU likely falls further behind	Research becomes dependant on non-European resources
EU will dramatically fall back, loss of leadership	Research will move to where the facilities are
EU will lose economic competitiveness with respect to U.S.	Researchers would work more with U.S. and Japanese teams than other EU teams, as is the case now,
EU will lose economic competitiveness with respect to U.S.	Risk of diluting the efforts at the national level
Existing SCCs could become obsolete and thus not be able to satisfy requirements of scientific research related to HPC	Since sustainable HPC-leadership requires major resources, only the larger/wealthier member states will be able to fund significant HPC resources in the long run. Without European investment, the smaller/less resourceful member states will further fall behind.
Fall behind in intellectual/scientific/engineering HPC development with respect to U.S. and Japan	The advantage of U.S. will grow even faster
Falling behind in the economy and science	A centralized effort led by the EU may not be always be required to back member states' capabilities. Europe should fund the researchers who need HPC rather than the generic capability itself. What is problematic is the insufficient determination of the use cases beforehand, the lack of clear "metrics for success," as well as the minor role of users in the decision making process.
Generic U.S. corp.-led solutions (often designed without HPC in mind) will dominate (inefficiently)	The EU will not stay competitive in the technical world
Get irrecoverably behind the United States, Japan, and other merging countries as far as HPC is concerned	The inability to do breakthrough science (when modeling is an integral part of that science)
If there is no EU coordination of national efforts, money will be wasted in duplicating similar systems and services	The risk is that China goes to radical scaling and reliability and software scaling. Thus China leverages the coming disruption to their advantage with a giant step forward without a software base to bring forward.
In many scientific and engineering fields, one of the key technologies that can lead the world in the 21st century is prediction, which HPC can provide. In this sense, competitiveness in many fields would decrease consequently.	The system/project sizes needed to approach personalized medicine are beyond the scope of an individual country, but of utmost importance for societies in Europe. The foundation in classical, lab-based sciences in Europe is a unique advantage for forming teams of domain experts and HPC experts.
Industry sectors will lose their leading market position in the world	They will not have applications that can take advantage of the next generation of supercomputers
Lack of competiveness in science and industry for very large scale simulations requiring petaflops systems like in U.S. or in Japan	This will in time be damaging to Europe's competitive edge in terms of scientific research.
Leaving each country to compete individually in the areas of science and engineering, leading to fragmentation, inefficiency and poor deliverables;	To lose scientific leadership and staying behind worldwide, not able to catch up
Losing competitiveness	Unacceptable dependence on "other continents" regarding measures to be taken to solve the global environmental and social issues

TABLE 69

Potential Consequences if the EU Does Not Take Any Additional Steps to Develop Leading HPC Capabilities

Consequence #1

Comments:	Comments:
Loss of competitiveness	U.S. and Far east will take the lead, to detriment of EU industrial development
Loss of competitiveness (weak HPC applications in science and engineering)	Waste of computational skills already accumulated in many organizations
Loss of competitiveness of industry and services	Will be a follower instead of a major player
Loss of economy of scale in developing HPC services	Will lag U.S., Japan and China in science and technology.
World-class scientists and engineers undertaking their research in smaller countries, or in countries choosing not to invest significantly in HPC will not achieve the same levels of productivity or the same impact as they would have if they had been given access to suitable levels and types of resources.	.

Source: IDC, 2010

TABLE 70

Potential Consequences if the EU Does Not Take Any Additional Steps to Develop Leading HPC Capabilities

Consequence #2

Comments:	Comments:
A domino effect will mean that will negatively impact the EU's industry offering over the long term.	Limited successful use would be made of "emerging" technologies (GPUs, HPC in cloud services, development, deployment and management software solutions)
Brain drain (Europe -> U.S.)	Loss of economic competitiveness
Cutting sparsely distributed communities away from resources and data potentially important for them	Loss of scientific leadership where we lead and never catch up where we should
Depend on foreign companies/countries	Loss of talented people
Depend strategically on overseas organizations in economic development	Lost positions in forefront research
Difficulty keeping the best scientists in Europe	Negative impact on industrial innovation
Drastic reduction of knowledge	R&D decrease in pharma and engineering
EU researchers will need to rely on compute resources in the U.S./Asia	Reduced innovation capacity
EU will suffer continued brain-drain in science and engineering, in particular from small EU countries	Science will fall behind the rest of the world
Europe will definitely lose its competitiveness in crucial scientific research and technology areas and, as a consequence, competitiveness of her industry.	Scientific communities will use HPC in the U.S. and Asia
European industry will look to other regions for R&D facilities.	Scientific research and innovation in EU will lose its competitive edge
European science and technologies will not have access to enough fast computers to develop innovations and the EU economy and welfare would not be competitive.	Supplier community will de-emphasize EU so it will be harder to rebuild capability.

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TABLE 70

Potential Consequences if the EU Does Not Take Any Additional Steps to Develop Leading HPC Capabilities

Consequence #2

Comments:	Comments:
Excessive dependency on non European technology and system integration	Technological backwardness and worsening of life conditions
Expected consequences are digital divide in Europe, brain drain especially in smaller countries.	The long term consequence would be that the European economy and research will be dependent on HPC resources provided mostly by American/Japanese companies. The markets of HPC and cloud computing are going to be very important and not having European actors involved means missing tremendous opportunities for economic growth.
Falling economic size, jobs losses, etc.	The choice presented to Europe in the future will become substantially narrower than it is today. Is Europe comfortable with that? When it becomes too narrow prices start to rise and the rate and pace of innovation starts to decline.
Fragmentation of resources	The inability for the industry to compete with innovative products. This has little to do with the complexity of the product being developed but mainly with innovative use of (computational) technology. The "Pringle" model is a nice example (on a smaller scale)
If the EU does not help researchers towards access to HPC resources in other countries, all EU research will be weaker	There is a genuine risk that the above may lead to a brain drain in certain fields, and place Europe at a disadvantage compared to the U.S. or the Asia Pacific region.
Lack of coordination and interconnection of existing SCCs	This will result in the best researchers moving outside Europe to get resources
Lag of scientific progress	…Medical field and drug discovery [will be affected]
Major difference between the member states in having access to large supercomputers	Will not play an important role in the field
Less European money is wasted	Withdrawing from the field of scientific and technology exploration and discoveries based on computational simulation and modeling to other regions and countries

Source: IDC, 2010

TABLE 71

Potential Consequences if the EU Does Not Take Any Additional Steps to Develop Leading HPC Capabilities

Consequence #3

Comments:	Comments:
Access to centers is less bureaucratic	Loss of employment opportunities
Brain drain to U.S., Japan, China and even India	Loss of leadership in many areas
Business (e.g. economics/ finance sector) will lose its competitiveness against American and Asian players	Member states will continue to grow HPC locally
Decline of HPC industry in Europe	Negative social impact
Deep falling behind the U.S. and Asian SCCs and worldwide research activities utilizing HPC	Not able to address leading edge science
Erosion of European industrial base.	Only projects on a smaller scale will be realized
EU nations would not be able to have strong simulation capabilities and would not be able to be credible at international conferences such as on climate. Strategic domains, such as European security and defense, will lack power for future developments.	SMEs, which form the core fabric of new job creation in Europe, will be cut from this source of innovation
Europe's economic welfare in danger	Staying far behind in the area of state of the art technology, products and services with strong impact on economic and social welfare
Lack of consolidation of the efforts of the different countries — most of the EU member states would not cooperate very extensively without EU support	Therefore, the HPC scientific and technological areas will no longer attract bright young scientists and engineers; this process will lead to the decay of the high level of expertise in the key EU member states which will again take decades to get re-established after the economic recovery. However, the EU should NOT act "on behalf of the member states" but in strong cooperation and coordination, since it was the key member states that promoted HPC in the past decades and provide the ground for education and expertise of the brains in HPC.
Less potential for scientific innovation in Europe	Unemployment
Lose leadership in science and engineering	Waste of skills in software/applications and in micro/nanotechnology that do exist in EU but would not properly be leveraged and used for HPC development and Lack of independence on key technologies in the area of defense and security
Losing political impact in the world scene	Will not have access to the newest technology

Source: IDC, 2010

14.8 What the EU Should do Related to HPC Cloud Computing

Regarding the emerging phenomenon of cloud computing, many (18) respondents advised the EU not to focus on it at all ("don't do it just because the media loves it"), either on the grounds that it will do little for HPC users or because they believe the commercial IT market will advance cloud computing capabilities without the need for EU investment (see Table 72).

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Other respondents, however, recommended that the EU fund pilot programs to test the value of cloud computing for HPC, or else that the EU should plunge directly into funding cloud computing projects.

TABLE 72

In Your View, What Should the EU do Related to HPC Cloud Computing?

Responses	Responses
18 sites said: Do Nothing at all related to clouds	Give free access to current existing cloud computing cluster
Assess the technology and its impact on scientific and general usage and then act according to the findings	HPC cloud is possibly more a concern for local/national scales of structuring and offer. HPC cloud is still some kind of an oxymoron (security issues, performance issues for capability computing not covered by cloud). Cloud in general encourages energy efficiency, good quality network infrastructures and services, which is good also for HPC.
Build supercomputers that can provide access to engineers/scientists	Investigate possibilities and support pilot installations. Probably the biggest (perceived) challenges today in using Cloud for HPC are the overhead in case virtualization will be used and the challenges of "gang scheduling" for parallel applications. Once this challenge has been answered any large (and hence costly) installation can be used beyond traditional HPC for a better ROI and efficient use.
Cloud computing is a trend, but its impact on HPC is not so clear. A possible impact could be a convergence of IT infrastructures and HPC.	It should not be a priority
Cloud computing should not be taken as a priority in EU's HPC activities. The major role should be placed on high-speed interconnected supercomputers.	Launch a small program
Continue doing what they are doing.	Make a strategic positioning to support this new model
Coordinate development of cloud software management solutions appropriate to HPC	More education and fast implementation of the available products
Cloud is driven by the commercial market, the challenges are not primarily technological; cloud computing will most likely be successful without EC activity	No cloud can offer real (high-end) HPC (in the sense of very low-latency connected computing cores across whole systems) without investing in such equipment first. But as clouds are about making money (fast) with existing farms of clusters, there seems no short time business case from there.
Create a quality label for public, transnational clouds and fund the (small) organization delivering the accreditation	Nothing separated by a unified vision of the entire problem. This policy "coup par coup" does not pay.
Define services and use cases.	Nothing. I believe cloud computing will have no impact on HPC. It is just another marketing idea.
Develop research and development on cloud computing, as a part of a global HPC ecosystem. The trap is to separate supercomputer HPC and GRID and cloud computing.	Promote it as the best economic model for HPC. Develop expertise in building HPC-clouds. Stop investing in non-cloud HPC infrastructures. Examine the opportunity of a moratorium for the European grid initiative and the related projects (EMI, etc.).
Encourage collaboration to provide — but note that most cloud is not compute parallel and is this not a universal panacea	Provide access to a well equipped, organized and managed HPC cloud infrastructure incl. HW+SW
Encourage real systems design and implementation rather than high-level white-board sketches that never really work and are of no use to the community	Provide funding to small companies developing HPC systems (do not do what has been done in the HPCN program, 15 or 20 years ago)

TABLE 72

In Your View, What Should the EU do Related to HPC Cloud Computing?

Responses	Responses
Facilitate the development of public, private and scientific clouds and stimulate business development	Security of data in transit and on host cloud systems is the big issue here, so some easier form of authentication/authorization would help (and let's get rid of the dependence on unwieldy grid certificates). Other than that, I think that the HPC cloud will evolve naturally based on storage and DR/BC principles. The tier 1 vendors will drive this along too.
Figure out what they need and do just that; don't just fund it because the media loves it.	Studying very carefully
First, to define internally what EU understands by cloud computing. Second, to understand what applications benefit from cloud computing. Cloud is a great tool for some applications, but it is not a "silver bullet" (i.e., a universal solution).	To support and to fund if it is really a new offer different from grids
Follow up and pilot (note: cloud is not too far from what we currently do when running a datacenter so we should focus on content, but not just fancy terminology)	Too early to intervene in my opinion, the technology is not mature enough.
Furthermore access mechanisms for cloud computing should be looked into for easy physical and accounting access by SMEs and other industrial parties to the PRACE infrastructure. Finally, as cloud computing is a purely commercial activity there seems no need whatsoever to spend public money on organizing that.	Underemphasize, unlikely to result into top-level science results

Source: IDC, 2010

14.9 What Should the EU Avoid Doing in HPC

It goes almost without saying that for strategy formation it can be just as important to know what to avoid as what to pursue. Table 73 displays the respondents' opinions on what the EU should avoid doing in HPC. The most important guidance from the respondents was as follows:

- Avoid funding a large number of small projects instead of a limited number of larger projects
- Avoid aiming for leadership in areas where other regions of the world clearly lead today
- Avoid trying to compete with the U.S. and Japan by building HPC systems
- Avoid protectionism in procurements

Representative Comments From Respondents

"Funding a large number of small projects."

"Go on scattering funding and encouraging many small overlapping initiatives."

"Bureaucracy and non-concentration on a few large projects."

"Hardware design."

"Develop the hardware for HPC systems."

"Developing EU sourced hardware systems."

"Trying to compete with the U.S. and Japan in building large supercomputers."

"Trying to compete in areas where other regions of the world have clear leadership (hardware manufacturing)."

"Protectionism."

"Protectionism; short-term programs."

"Wasting money on grid-computing/software, cloud computing/software."

TABLE 73

In Your View, What Should the EU Avoid Doing in HPC?

Responses	Responses
Allow HPC application people undertake systems design problem because they lack the expertise to push them successfully	Funding a large number of small projects and losing the focus on large/tightly coupled systems(don't go back to the stupid idea of doing general purpose HPC on grids)
Avoid doing nothing/status quo	Go on scattering funding and encouraging many small overlapping initiatives
Avoid not collaborating.	Hardware design
Avoid to fund hardware components (processors, memories)	Intermix regional planning and HPC support; adapt bureaucratic solutions
Build systems	Investing in proprietary systems, EU should help make standard technologies HPC technologies, which will enable more EU countries to leverage from HPC and build HPC systems — as well as small/mid businesses
Bureaucracy and non-concentration on a few large projects	One big center instead of a collection of distributed supercomputer centers
Compete for the sake of the Top 500 list only	Promote cloud or grid
Competing in areas with very few possibilities for success, for example trying to build a conventional supercomputer system in Europe (requires new innovation)	Protectionism and EC centralism
Concentrating on top-level centers, forgetting the lowest end of the HPC ecosystem	Protectionism; short-term programs; rapidly change direction
Define a strategy to merge HPC systems and large-scale datacenters by using/extending technologies	Provision of resources alone leads to "more-of-the-same" science, but does not open HPC to novel areas.
Delegate stimulation to the member states	Put together non-mature computational groups with experienced — this approach slows down development; avoid distributing messages that the HPC is a panacea for the unresolved problems listed in various areas of science and technology
Depends on national funding	Setting up a small HPC group of privileged people at EU level which would rather work in an isolated way than in close collaboration with end user community and HPC providers

TABLE 73

In Your View, What Should the EU Avoid Doing in HPC?

Responses	Responses
Develop the hardware for HPC systems	Simply following the U.S. (not saying that is always the case or that U.S. developed solutions typically have any problems but just deploying like-for-like based on what our cousins from across the pond do does not really advance HPC).
Developing EU-sourced hardware systems.	Sponsor hardware development
Development of secret military projects	Stopping or reducing the undergoing HPC funding programs due to government changes
Dilute the focus and attention by calling everything HPC; concentrate at the high end. Dilute the focus and attention to engage in competition at the wrong level; and Copying what the U.S. and Asia will surely do better.	Support HPC specific HW excluding embedded systems
Disintegrating financing and only hidden support of HPC in framework programs	Support medium scale activities; only support pure research projects
Don't try to compete with U.S. and the Far East on technology (CPUs, interconnects, SSDs etc). This will be a wasted investment.	The confused plethora of initiatives it is taking without any overall direction
EU funding mechanisms are launched in uncoordinated and unsustainable manner for developing of unrealistic or over-ambitious European HPC ecosystems in a very short timeframe	To support only national-based project and to separate computer scientists and computational scientist.
EU should avoid any further massive investment in hardware and should progressively leave the provisioning of federated computing infrastructures (HPC+HTC) to the private sector.	Trying to compete in areas where other regions of the world have clear leadership (hardware manufacturing)
The EU should avoid governing the HPC industry too much. The EU should also avoid taking the role of a technology decision maker. Organizations should have the freedom of selecting the best solution for their use	Trying to compete with the U.S. and Japan in building large supercomputers.
Financing only a few of the biggest European SCCs. Disproportionate focus on cloud and grid computing in EU	Trying to force HPC growth or usage
Financing without assessment studies. A clear picture of which are and where the competences and user groups are located is of fundamental importance	Trying to invent an HPC hardware industry; this has failed many times in the past
Focusing too much effort on technical areas where the EU is not an advanced power and which are lengthy and expensive can appear to be an inhibiting factor for overall HPC development	Trying to make new HPC companies….the ecosystem can't handle more companies, it needs the current players to become financially stronger.
Frequent policy changes	Waste money on grid-computing/software, cloud computing/software, bureaucratic entities that purport to support HPC research activities.

Source: IDC, 2010

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15.0 HPC CONTRIBUTIONS TO SCIENCE AND THE ECONOMY

15.1 Contributions: Scientific Leadership and Economic Gains

HPC and computer simulation has become a fundamental driver of scientific discovery in many disciplines, and is often referred to as the third pillar of scientific discovery (along with theory and experimentation). Supercomputers are a tool for researching scientific areas in ways that were previously impossible to accomplish and allows for dramatically faster time-to-solution and time-to-discovery.

The link between HPC and economic return is similar to linking R&D investments to economic successes. At a macroeconomic level, it can be shown that companies and countries that invest the most in R&D and in HPC clearly lead in both science and economic success. At the same time, success depends not only on the computers — it requires top researchers, scientists, engineers and analysts, as well as strong leadership and a clear mission.

Countries are investing in HPC because HPC can affect the balance of economic and political power as described in: *"Massive HPC Systems Could Redefine Scientific Research and Shift the Balance of Power Among Nations" (IDC #219948, September, 2009)*.

HPC-driven innovation has become a prerequisite for:

- Scientific leadership
- Industrial leadership
- Economic advancement
- National/regional security

16.0 INVESTMENTS REQUIRED FOR HPC LEADERSHIP

16.1 People, Experts, and Training

The investments required for scientific and economic success include many areas in addition to the cost of the computers. The most critical area is first the experts, including the scientists and researchers as well as the experts in using the supercomputers. There is a growing worldwide shortage of HPC talent due to a combination of an aging workforce with fewer new graduates in various HPC fields (see the soon to be published DOE HPC Talent study at: www.hpcuserforum.com).

16.2 System Level Investments

Investment requirements are growing quickly for the largest HPC systems:

- In the 1970's and early 1980's — $25 million was the price of the largest supercomputers

- In the 1980's and 1990's — $35 million was the price of the largest supercomputers
- In the late 1990's — $100 million was the price of the largest supercomputer
- In 2000 the Earth Simulator and DARPA set a level of $250 million to $300 million
- Now some are looking at $1 billion for a single system (including development R&D costs)

The bad news is that Europe has been falling behind in making the required investments to acquire the largest computers. A number of countries are now building multiple very large systems in the $75 million plus range.

The good news is that HPC leadership has often changed by country:

- 1970's to late 1980's: U.S. leads in HPC
- Late 1980's to mid-1990's: U.S. and Japan frequently trade leadership
- Late 1990's: U.S. (DOE ASCI) systems take the lead
- Early 2000: Japan (Earth Simulator) sets a new level
- 2002: U.S. (DOE ASCI) regains the lead
- 2010 — U.S. remains in the lead
- 2020 — Who will lead? Will leadership be hardware-driven? Software-driven?

16.3 Supercomputer Investments and GDP

Tables 74A and 74B compare supercomputer investments to gross domestic product (GDP) size by country. Clearly, the countries that are investing the most in supercomputers also tend to have the largest economies. The EU may want to commission an additional study to create a detailed economic model of the relationship between HPC and scientific and economic success by sector.

Table 74A lists countries in order of their GDP amounts, with the U.S., Japan, and China topping the list, followed by five EU member states. Note China's low ratio of HPC investment compared to GPD.

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TABLE 74A

GDP and Supercomputer Spending by Country ($M), Sorted by GDP

	GDP (1)	Average Supercomputer Sales Over Last Five Years (2)	Supercomputers as a Percentage of GDP
U.S.	14,270,000	1,276,067	0.0089%
Japan	5,049,000	278,385	0.0055%
China	4,758,000	67,836	0.0014%
Germany	3,235,000	203,245	0.0063%
France	2,635,000	142,209	0.0054%
U.K.	2,198,000	129,384	0.0059%
Italy	2,090,000	76,751	0.0037%
Spain	1,466,000	37,690	0.0026%
Russia	1,255,000	30,371	0.0024%
India	1,243,000	19,627	0.0016%
Australia	920,000	55,411	0.0060%
Korea	800,300	66,541	0.0083%
Netherlands	789,700	19,603	0.0025%
Switzerland	484,100	24,144	0.0050%
Sweden	397,700	21,314	0.0054%
Norway	369,000	12,897	0.0035%
Hong Kong	208,800	15,491	0.0074%
Singapore	163,100	16,324	0.0100%

Note (1) Source: CIA The World Factbook, 2009, Note (2) five year average yearly spending.

Source: IDC, 2010

Table 74B sorts the top countries by the ratio of their supercomputing spending as compared to their yearly GDP. Three of the top four HPC-investing countries are in Asia: Singapore, Korea, and Hong Kong. The other top four nation is the U.S.

In Europe, the strongest investors in HPC by this measurement are Germany, the U.K., France, Sweden, and Switzerland. Japan is only at number eight on this list, another indicator that Japan's commitment to pursuing HPC leadership has weakened in recent years.

TABLE 74B

GDP and Supercomputer Spending by Country, Sorted by Percent Spent on Supercomputers

	GDP (1)	Average Supercomputer Sales Over Last Five Years (2)	Supercomputers as a Percentage of GDP
Singapore	163,100	16,324	0.0100%
U.S.	14,270,000	1,276,067	0.0089%
Korea	800,300	66,541	0.0083%
Hong Kong	208,800	15,491	0.0074%
Germany	3,235,000	203,245	0.0063%
Australia	920,000	55,411	0.0060%
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Switzerland	484,100	24,144	0.0050%
Italy	2,090,000	76,751	0.0037%
Norway	369,000	12,897	0.0035%
Spain	1,466,000	37,690	0.0026%
Netherlands	789,700	19,603	0.0025%
Russia	1,255,000	30,371	0.0024%
India	1,243,000	19,627	0.0016%
China	4,758,000	67,836	0.0014%

Note (1) Source: CIA The World Factbook, 2009, Note (2) five year average yearly spending.

Source: IDC, 2010

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17.0 HPC TECHNOLOGY ISSUES IMPACTING THE FUTURE OF HPC

17.1 HPC Growth Drivers and Barriers

HPC covers all servers that are used for computational or data intensive tasks, IDC defines HPC as: "High Performance Computing (HPC) refers to all technical computing servers and clusters used to solve problems that are computationally intensive or data intensive. The term also refers to the market for these systems and the activities in this market. It includes technical servers but excludes desktop computers used for technical computing".

Technical computing has grown quickly for a number of reasons:

- Price and price/peak performance of clusters has redefined the cost of technical computing (>6x better than RISC, >70x better than vectors)
- At the same time, "live" science and "live" engineering costs have escalated — plus time-to-solution is months faster with simulations
- Global competitiveness is driving R&D and better product designs
- x86 performance on technical applications is weak, driving buyers to purchase a much larger number of processors
- New materials and approaches require rewriting the "books and tables", which takes years, making HPC simulations a faster solution

The major trends in HPC today include:

- The supercomputer segment is in a high-growth mode, even with the current recession — it grew 25% in 2009
- Major challenges for datacenters:
    - Power, cooling, real estate, system management
    - Storage and data management continue to grow in importance
- Software hurdles will rise to the top for most users
    - Driven heavily by multicore processors and hybrid systems
    - Weak application scaling and hardware utilization:
        - How to deliver strong performance to users on their applications
        - How to make optimal use of new processor and system designs

17.2 HPC User Pain Points: Potential Areas for EU Leadership

Clusters are still hard to use and manage:

- System management and growing cluster complexity
- Power, cooling, and floor space are major issues
- Third-party software costs
- Weak interconnect performance at all levels
- Applications and programming — Hard to scale beyond a node
- RAS is a growing issue
- Storage and data management are becoming new bottlenecks
- Lack of support for heterogeneous environment and accelerators

Software is becoming the #1 roadblock

- Better management software is needed
  - HPC clusters are hard to set up and operate
  - New users and researchers — require "ease-of-everything"
- Parallel software is lacking for most users
  - Many applications will need a major redesign
  - Multicore will cause many issues to "hit-the-wall"

Challenges affecting HPC datacenters:

- The increase in CPUs and nodes is creating significant IT challenges:
  - Managing complexity in all aspects, ordering, setup, expansion, etc.
    - How to best manage a complex cluster
    - How to install/set up a new cluster without having to buy a large number of separate pieces
  - Power/cooling and space
  - Application scaling and hardware utilization:
    - How to deliver strong performance to users on their applications

18.0 ADDITIONAL EU OPINION LEADERS INPUTS ABOUT THE EU HPC STRATEGY

As part of the research for this project, IDC conducted in-depth interviews, by telephone or in person, with HPC leaders in the following categories:

- National funding agencies of EU member states
- Representatives of European HPC programs (PRACE, DEISA, et al.)
- Senior officials of HPC centers in Europe
- Other HPC industry experts in Europe, the U.S., and Japan
- Senior officials of HPC vendors in Europe, the U.S., and Japan

These interviewees included some of the most well-respected, highly knowledgeable individuals in the European and worldwide HPC communities. The interviews typically lasted an hour or longer each. To encourage candor, IDC assured interviewees that their comments would remain anonymous.

At a high level, there was a strong convergence of opinions, both within and across the categories. Not surprisingly, however, opinions sometimes diverged at a more detailed level. The following summary presents the areas of major consensus among the HPC leaders, with representative quotes inserted to convey the "flavor" of the responses and important divergent viewpoints also cited.

18.1 An Expanded EU Strategy Would Be Beneficial To More Fully Pursue HPC Leadership

The interviewees all agreed (including leaders from the U.S. and Japan) that Europe can become an HPC leader by 2020 if Europe follows the right strategy. There was strong consensus that an HPC strategy is needed at the European level, so that Europe can compete effectively with other regions of the world and because no single European country can afford to pursue HPC leadership alone.

"The most important reason to have an EU HPC initiative is that no single country can compete with the U.S. or Japan." [EU member state funding agency]

"The most important reason to have an EU HPC initiative is that no single country can compete with the U.S. or Japan."

"The EC invests a lot of money in structural funds… I want to see much of this funding transferred to research, such as using HPC as a research tool." [EU member state funding agency]

"I'm very much for European cooperation [in HPC], and for setting targets in specific areas." [EU member state funding agency]

"The EC invests a lot of money in structural funds that are not always used well. I want to see much of this funding transferred to research, such as using HPC as a research tool." [EU member state funding agency]

"Europe should increase funding for HPC. It's important to concentrate funding on HPC and not to mix in other initiatives. The EU and the European countries together will invest something like what the U.S. will invest in HPC between now and 2020, although maybe not quite as much." [EU member state funding agency]

18.2 It Would Be Good to Have the Chief Objective of the Strategy Be "To Advance Science and Engineering"

It would be good to have the chief objective of the strategy be "To advance science and engineering"

The HPC leaders considered it self-evident that the objective of European HPC leadership should not be to provide powerful HPC systems for their own sake (e.g., to rank high on the semi-annual list of "The World's Top500 Supercomputing Sites), but as tools to help advance European science and engineering.

With that in mind, there was strong consensus that it is crucially important to continue to make HPC systems available through PRACE, using the existing tier 0-1-2 model, but the EU HPC leadership initiative also needs to extend well beyond the PRACE pan-European HPC service mission.

"Leadership is really about leading in science and engineering, not in HPC. HPC is just a tool, a means to an end." [DEISA official]

"We must continue funding large HPC systems as is happening with PRACE. This is fundamental. And the EU must compete in science as a unity versus the rest of the world." [Large European HPC datacenter]

"[Although] the PRACE strategy doesn't match our national strategy in all ways, it's important to have a central EU position for the development of tier 0 supernodes at the petascale level. Tier 1 and 2 should continue to be funded at the national level, [with] Tier 1 at the national and tier 2 for large universities." [EU large HPC datacenter]

18.3 Europe Should Think About Pursuing HPC Leadership in Areas Where Europe Can Excel

HPC leadership should be explicitly driven by important societal goals, and in an ideal world these goals would be chosen beforehand, so that Europe's HPC strategy could be shaped accordingly. Because waiting to achieve consensus on HPC-enabled societal goals seems impractical, a smart alternative is to pursue HPC leadership in computational science and engineering areas where Europe already has the potential to be a global leader.

The HPC-enabled scientific and engineering areas most often proposed for leadership were as follows:

- Clean energy (including nuclear reactor design/operation, oil and gas exploration, smart electrical grids, clean water, fusion energy, and other alternative energy research)
- Climate modeling and severe weather forecasting
- Physics (e.g., the Large Hadron Collider)
- Aerodynamics and other automotive/aerospace methods

- Chemistry, pharmaceutical, and other bio-life sciences research
- Algorithm and application software development. HPC experts in Europe and around the world stressed the importance of algorithm and applications software development for future HPC leadership and agreed that Europe is in a strong position to excel in this area.

Alongside the recommendation to stress science and engineering disciplines where Europe has the potential to be a world leader, the HPC leaders also emphasized the importance of making adequate HPC resources available to all other areas of science and engineering.

"I'm very much for European cooperation [in HPC], and for setting targets in specific areas." [EU member state funding agency]

"There are global challenges that need HPC that the EU can have a leadership position in. These include climate change and energy research." [EU member state funding agency]

"Europe has world-class researchers in climate change and clean energy, including fresh, clean water." [EU member state funding agency]

"Europe could be the world's best at sustainable energy: fusion, reactor design, windmill farm modeling, and other areas." [EU large HPC datacenter]

"Clean energy is clearly one of Europe's potential strengths. They also need to look at aging populations and healthcare. Automotive is also strong in Europe." [U.S. HPC vendor]

"Europe is strong in automotive and aerospace software. We organized a conference on this. Also in nuclear fusion, with ITER. Climate and water management are important for Europe, and also precision agriculture" [EU large HPC datacenter]

"Europe leads in aerodynamics/CFD, nuclear reactor design/operation, nuclear fusion/ITER, and perhaps HPC for R&D." [PRACE official]

"The three key challenges (application areas) that will command a lot of political attention in my opinion are climate, energy, and healthcare — meaning things ranging from sequencing to advances in medical research (e.g., Blue Brain), medical drugs and treatments and devices. These will require increasing compute power." [HPC vendor]

"Europe should focus on a few things like clean energy but Europe is heterogeneous and it should be done in agreement with the U.S. and Asia. Biomedical and bioinformatics is another. It would be good to have spearheads like these but funding for other research must also continue because we don't know what the next success story will be." [EU large HPC datacenter]

"I don't know if the countries in Europe have the wherewithal to do this separately. The PRACE program has been ill conceived and has not focused on advancing the economy but more focused on just building big systems instead of focusing on 2–3 problems that are really important to Europe." [HPC vendor]

"PRACE II should be problem-centric rather than hardware-acquisition-centric. The hardware should be tied to a problem domain for each hosting center, not exclusively but heavily, where the center becomes the hub for this as CERN is for high-energy physics. Brain science at EPFL, lattice physics at Juelich, health in the U.K., and these centers work collaboratively with other institutes in Europe." [HPC vendor]

18.4 Most Felt That Europe Should Not Try to Develop its Own HPC Hardware Platform

The near-unanimous consensus among the HPC leaders was that trying to attain HPC hardware system technology leadership or parity by 2020 would be nearly impossible and would divert funds and effort away from more important, realizable leadership goals. A few people argued that HPC hardware systems are a strategic technology that Europe should not depend on other regions for, but even these people acknowledged that the other regions are too far ahead for Europe to overtake by 2020. Initiatives to develop next-generation HPC architectures have been under way for years in the U.S. (DARPA HPCS program) and Japan (*Keisoku* program). They argued that it would make little sense now for Europe to start a program to compete with these initiatives, whose advances Europe could benefit from in the long run in any case, if Europe chooses to do so. In the meantime, contemporary HPC hardware systems are readily available from vendors based in the U.S., Asia, and Europe (Bull, EuroTech).

In sum, the EC should continue to invest with the member states in buying large HPC systems through the PRACE program but should not attempt to fund the development of a novel, world-class EU HPC hardware architecture for delivery by 2020.

"The European HPC market is too small to support an EU-based hardware vendor with its own technology." [DEISA official]

"There is no sense for the EU to compete by trying to fund the development of an EU-based hardware platform. The real opportunities are in software and more advanced hardware such as accelerators." [EU member state funding agency]

"It makes no sense for Europe to try to develop a new hardware system." [EU large HPC datacenter]

"Europe should not spend money on developing its own hardware architecture. Software investment is much more important. We should have minor investment in hardware, maybe memory technology or similar." [PRACE official]

"There is no way for Europe to lead in building supercomputers. It should be around the applications side. I think Europe could surpass the U.S. with a concerted effort to scale applications on exascale systems." [HPC vendor]

"I do not believe the EU has a chance to close the gap in HPC hardware production, but there is certainly an opportunity for Europe in the specialized software area. Europe should focus on the software opportunity and develop the necessary dedicated software." [EU member state funding agency]

"Is it important for Europe to be an HPC leader? It's more important to be able to lead in exploiting HPC resources, such as in software and science. It's not so important to be a leader in EU-based HPC technology itself. We should not try to compete in hardware technology." [EU large HPC datacenter]

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18.5 Europe Should Consider Pursuing Leadership in Other HPC Technologies

Many of the HPC leaders said it is important for the EU to invest in software development (algorithms, applications, system software, middleware) and in hardware technologies in which the EU already has some real strengths, such as interconnects and memory technologies. There was a strong consensus that software will be more important than hardware for future HPC leadership.

"Software is the big issue, much bigger than hardware. Software optimization makes a much bigger difference in turnaround time and better software can enable you to get by with half the hardware you'd need otherwise. The programming method for petascale and heterogeneous systems will be crucial. Algorithm development is extremely important and here in Europe can excel and make many breakthroughs." [EU large datacenter]

"Software and applications are more important to invest in than hardware." [EU member state funding agency]

"Europe could succeed and be a major player in the evolution of [HPC] technologies. Memory and interconnects might be much more important the microprocessors. Europe's also well positioned in some areas of software." [HPC vendor]

"Algorithm development will be key and is what will allow people to get more than 3% of the performance of an exascale computer. Europe has some real strengths here." [HPC vendor]

"Scalable algorithms are much needed. In linear algebra, all the well-known libraries like LAPACK, etc. are used by the worldwide HPC community but not all of these can scale up. We need new methods. We're entering an era with explosive volumes of data and to exploit this we need a new generation of models with new algorithms and methods." [EU large HPC datacenter]

"The fundamental way to get an economic contribution is to become masters of algorithms and the software that implements them. We're seeing different European institutions and universities turning toward this challenge. New algorithms are badly needed. Many of today's algorithms date from NSF investments in the 1960s. If you are master of the algorithms, you are positioned to be master of the applications. I would invest a ton of money in this if I were the EU, but only with where computing in 2020 will be in mind." [HPC vendor]

"The PRACE model was for countries and centers to buy their way in. Today the U.K. has no money to invest in HPC but has talented people — no one is served by this situation. The EU should major in scalable algorithms and make everything else secondary. But they would need a guarantee about what the target platform down the stream would be." [HPC vendor]

"Today, EC funds are only aimed at providing HPC cycles and connectivity. Europe is not doing much to encourage HPC R&D in Europe. Collaboration between technology and application development will be key for usable exaflop systems. The big projects like PRACE are mainly aimed at creating large HPC centers and providing users with compute power. This is important but it won't lead to leadership in HPC in 2010." [HPC vendor]

"Europe is strong in interconnects, memory and specialized low-consumption processors that come out of the electronics industry for embedded applications for set-top boxes, mobile phones, etc. We won't reach exaflops with commodity technology." [HPC vendor]

18.6 It is Healthy for the EU to Continue to Conduct Open Procurements for HPC Systems

The HPC leaders argued strongly for open competitive procurements that do not favor EU-based vendors. Because the primary goal of an EU HPC strategy should be to advance science and engineering rather than to be an HPC technology leader, they argued, European scientists and engineers must continue to have access to the best HPC resources, no matter where in the world they come from.

Several people stressed that one of Europe's great strengths is not having a dominant HPC hardware system vendor. This has enabled Europe to remain the world's most competitive, affordable HPC market, compared to the less-open U.S. and Asian markets. To preserve this advantage for HPC buyers in Europe, most people said that the EC should not show favoritism toward EU-based HPC vendors in procurements.

"It's counter-productive to do protectionism that favors EU HPC vendors. EU scientists and engineers should have access to the best HPC technologies and resources, no matter where in the world they come from." [EU large HPC datacenter]

"If the EU's motivation is competing for the big prize, which is clean energy, then any protectionism on their part will delay this. I think the clean energy space is the big problem the world faces, scientifically and economically." [U.S. large HPC datacenter]

"The EU should not favor EU-based vendors in procurements. EU's big advantage for many years now in HPC procurements is not having a dominant EU-based HPC vendor. This has allowed Europe to have fair, open competitions and to get lower prices and stronger competition from HPC vendors." [EU large HPC datacenter]

"Europe is the most competitive major HPC market in the world today. It's open to systems from anywhere in the world." [DEISA official]

"Complete protectionism is wrong. Today it's impossible to have a procurement in Europe that's not completely open. Two years ago we did pre-competitive procurements in Europe favoring EU vendors. Competitive procurements should not be completely open. We need to have something attractive for EU vendors. And for pre-competitive procurements, U.S. vendors should be able to compete too if they want to create employment in Europe." [EU member state funding agency]

"The EU is trending toward increased protectionism. We couldn't sell our product for three months because Europe was using their standards to control market access." [HPC vendor]

"Protectionism is not a good thing. If everyone is open, then everyone wins. If everyone is not open, then things need to be reconsidered. If some markets are not open such as North America right now and other markets are open, it is unfair. The European market is open and Asian markets are more open than North America. Europeans have given up the idea that HPC technology can be developed in Europe

and they are concerned that attempts to change this may lead to protectionism. When the situation is not symmetrical, what do you do?" [HPC vendor]

"I think it's not good to be protectionist in the field of technology and the EU should enable EU scientists to have access to the best HPC technology no matter where in the world it comes from." [EU medium-size HPC datacenter]

"EU scientists and engineers should have access to the best HPC technologies no matter where they are sourced." [EU member state funding agency]

18.7 The EU Should Consider Providing Funding for Selected EU-based HPC Technologies

Although the HPC leaders strongly favored maintaining open procurements for competitive-stage HPC technologies and products, many interviewees considered it important for the European Commission to foster the growth of the EU-based HPC vendor community. They said the European Commission should do this by providing funding support for the development of enabling technologies (such as perhaps the software, interconnect, and memory technologies mentioned earlier). They reiterated that new developments in software and other enabling technologies would likely be more important for future HPC leadership than hardware system development.

"It's important to distinguish between pre-competitive work and production industrial work. The involvement of companies and universities in pre-competitive work I consider very important." [EU large HPC datacenter]

"It's okay to help EU HPC vendors develop pre-competitive technologies by giving them access to HPC funding and resources." [EU large HPC datacenter]

"Public-private partnerships like HWW/Stuttgart are very good as long as they're limited to the pre-competitive stage. Our country has too much focus on theoretical research and lacks a link with the practical side." [EU large HPC datacenter]

"The EU should strongly support advanced, pre-competitive technology in Europe and also in the field of green computing technology for cooling and energy efficiency." [EU large HPC datacenter]

18.8 It is Good to Have Most Access on EU-Sponsored HPC Systems go to Peer-Reviewed Science Proposals

The HPC leaders agreed that the number one priority of EU-sponsored HPC systems should be to support science in Europe, and that the majority of time on the systems should be awarded on the basis of peer-reviewed proposals.

There was little support for the idea of reserving substantial blocks of time on the HPC systems for scientists from the member states that had contributed the most money to fund the HPC systems. Even representatives of the EU member states with the biggest economies and greatest histories of HPC purchasing and usage expressed little support for this idea (nor did the interviewed funding agencies of member states). As the director of a large HPC datacenter in one of the most prominent EU member states stated: "If Sardinia has the best scientific proposal, then

Sardinia should get the biggest block of time. This is the only way to promote scientific collaboration and integrate Europe's science community."

There was general, though not unanimous, support for the idea that centers hosting EU-sponsored HPC systems should be able to reserve minority blocks of time on the systems to allocate according to their own priorities.

There was strong consensus among the interviewees that the European Commission itself should not make decisions about access and time allocations on the HPC system, but should continue to assemble funding, administer the programs, and enforce compliance with rules when needed.

"The EC's role in HPC should be bringing the countries and the funding together. They should help the countries to collaborate and leverage their efforts. They should point out opportunities but not dictate what the member states should do. The EC could facilitate by acting like a referee to say who is 'offside', etc." [EU member state funding agency]

"Procurement decisions get increasingly politicized as they move from HPC centers to national and EU levels. The EC's role should be to define the goals and allocate funding to achieve these goals, but leave the allocation closer to the people using the HPC system time. The EU should not try to be a direct authority over the centers or they will make bad moves and waste a lot of money." [HPC vendor]

"Peer review based on scientific excellence is most important method for rewarding time on EU HPC systems, but the hosting centers should get some portion of the time to use for themselves." [EU member state funding agency]

"Two-thirds or so of the machine time should go to projects subject to peer review and one-third for the hosting center, because the hosting center can more easily support innovative work. Usually a peer review proposal that proposes something new is not funded because the reviewers come from traditional fields and viewpoints. Traditional physics or chemistry people won't understand proposals that contain truly new ideas." [EU large HPC datacenter]

"Access should be on the basis of the merit of the scientific project, as determined through a peer review process. Otherwise we won't integrate Europe. We need a unified pool of HPC resources that is accessed this way." [Large HPC datacenter in Europe]

"Scientific excellence should be the driver for access to the systems, but I don't concur that time should be left for the hosting center to allocate for their own purposes. They should have to justify the remaining time based on common EU goals because the funding comes from a common EU pool." [EU member state funding agency]

"Some people say access for science should be entirely based on peer review but this is not practical today because some countries contribute more funding and have more expectations. There's a long way to go for all peer review." [EU large HPC datacenter]

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18.9 It Would be Helpful for Industry to be Given Substantial Access to EU-Sponsored HPC Systems

All but one of the interviewees stressed that European industry must have substantial access to EU-sponsored HPC systems. They argued that this is essential for European industrial competitiveness and economic advancement. Some industrial problems are as challenging as scientific problems, and without access to large HPC systems, industry will have nowhere to go to solve these important problems.

Multiple interviewees pointed to the U.S. Department of Energy's INCITE program as a useful model for awarding time to industry. INCITE subjects industry proposals to a peer-review process and awards large blocks of time (typically multiple millions of core-hours per year) to proposals judged to have strong potential for scientific or methodological breakthroughs.

"It is absolutely crucial that industry have access to EU HPC systems. Big industrial problems can be as challenging as big scientific problems, and without access to big HPC systems industry has no way to solve these problems. If the EC excludes industry, then it is a waste of money to have HPC systems in Europe. These investments are only of value if we can use them to solve problems that are important for the European people and economy. We need a way to commercialize basic science. You start with basic science, then applied science, then industrially relevant problems. Any center receiving money from the EC should have a clear plan for making work done on these systems useful to industry and there should be an annual review of this by each center that receives EU funding." [EU large HPC datacenter]

"Industry has to solve big problems with important socio-economic impacts and if they can't use big HPC systems for this, they have nowhere else to go." [DEISA official]

"They'd be crazy not to open up these large HPC systems to industry. I believe big industrial problems can be tougher to solve because they're more dependent on third-party ISV applications they don't control unless they invest in building them themselves, whereas science controls its own codes. If the EU invested in ISV codes they could jump way ahead: because of the stagnation in the automotive space, this has high potential for European leadership. Pharmaceuticals, too." [HPC vendor]

"Industry should have access to EU HPC systems." [EU member state funding agency]

"Industrial competitiveness is critical and HPC resources should be open to industry." [Large EU27 HPC datacenter]

"I firmly believe in importance of giving HPC access to industry. Also, it helps politically to argue for funding for industrial competitiveness. In Europe, many countries have given up on competing with Southeast Asia. This needs continual investment." [Large EU27 HPC datacenter]

"Europe needs to give access to industry for industrial competitiveness. The best model for PRACE is the INCITE program, where industry access is awarded based on peer review, but we should also have a way for industrial users to pay for access. INCITE is reserved for R&D, and paid access would be open to non-R&D industrial use. PRACE is discussing this." [PRACE official]

"If the EU is providing HPC resources to everyone in Europe, industry should have access too. In our country, industry has a way to pay for access." [EU member state funding agency]

19.0 EUROPEAN HPC CASE STUDIES

19.1 CINECA — HPC Research Benefits

This profile looks at how HPC enhances scientific research and the investments in HPC that are needed to further research goals.

CINECA Organizational Profile

CINECA is the national supercomputing center for Italy and is a non-profit consortium made up of 37 Italian universities as well as the National Institute of Oceanography and Experimental Geophysics, the National Research Council, and the Ministry of Education, Universities and Research.

CINECA has over 350 employees who provide:

- HPC support to Italian academic research, particularly to enable their applications for HPC.
- Consultancy for application optimization and application development services for Italian industry as well as technical services for hosting a cluster for the Italian oil and gas industry.
- Training in all fields of HPC, from basic courses in parallel programming and optimization of codes to more advanced courses. For example, CINECA runs a summer school on parallel computing.

Representation for Italy in European HPC Initiatives

CINECA primarily focuses on supercomputing systems, rather than clusters and grids, and hosts a number of these systems, including:

- CINECA SP6. An IBM system P 575 cluster with 5,376 cores delivering 101 TFlops of computational power with 21 TB of RAM and 1.2 PB of disk space. This is used for large computational projects requiring significant amounts of memory and, as it ages, will be increasingly used for smaller jobs for academia and research.
- To assist the move to massively parallel architectures, CINECA has an IBM BlueGene system with 4,096 cores delivering 14 TFlops of peak performance. This is used to develop applications and programming models to take advantage of this and successor systems.

Funding for CINECA comes from national investments from the Italian education ministry and European projects including PRACE and DEISA. Paid consultancy for industry complements national and European funding.

Giovanni Erbacci from CINECA's Supercomputing, Applications and Innovation Department, gave an overview of how CINECA contributes to scientific research and leadership in Italy.

Scientific Leadership With HPC

Theory and experiment are the traditional pillars of scientific enquiry. HPC is adding a third pillar of computational science. The benefits of computational science are, initially, that it speeds up work that could be done through experiment. As Erbacci puts it: "Computational activity can speed up a process or produce a new product and have less restriction on the time to market for a new product. For CINECA, this is mainly seen in the field of computational physics, where time is very important. Using HPC in conjunction with traditional experiments gives us a way of enhancing what we could do less effectively with theory and experiment."

"Computational activity can speed up a process or produce a new product and have less restriction on the time to market for a new product."

CINECA has a strong research community in condensed matter physics, which uses a huge amount of HPC resources. There are sizable research communities in astrophysics and computational chemistry which also require significant HPC resources to achieve their research objectives.

As well as speeding up their research through HPC, these groups are carrying out research which can only be done with HPC. Erbacci cites the example of turbulence research in fluid dynamics, which is very hard to do without HPC.

Erbacci believes that HPC will bring together research domains by increasing the volume and enhancing the quality of scientific data. The way researchers produce and acquire data is changing, especially with the enormous quantity of data gathered via sensors used to gather data from physical or biological sources. This has the potential to create much more accurate models of these phenomena than has been possible in the past and share these models across different research communities.

Parallelizing enables much faster analysis of the data and much more frequent changes to the parameters of the simulation, as Erbacci observes: "A simulation that takes one day with 1,000 processors running in parallel takes over three years running sequentially. Reducing the cost and time of analysis means that it is relatively easy to have statistical sampling of models which is costly and difficult without extensive HPC use."

HPC Resources Needed for Scientific Leadership

A range of HPC resources is needed to address different types of scientific problems. CINECA is focused on supercomputing, but grid resources are available from other Italian research centers for computations that are suited to less tightly coupled systems than supercomputers.

Erbacci believes that a common European approach is needed to take advantage of all kinds of computing resources and solve complex problems. He observes that "a shared file system, middleware, and programming model is needed for Europe to match the scale of the United States and the investments in HPC made by emerging markets. Perhaps 10 years ago it was not so clear in Europe that HPC infrastructure was needed for scientific research, and Europe did not develop the national centers that have been so successful in the U.S."

As demand for HPC increases, Erbacci believes that Europe needs to address this with a European ecosystem and not a series of smaller national centers. In CINECA, a 20 TFlop system was sufficient until a few years ago, now the 100 TFlop system will soon be 100% utilized. In two or three years, petaflop scale systems will be needed to satisfy Italian research needs and even then CINECA will not be able to satisfy the increasing demand from Italian researchers. Hence a Europe-wide collaborative network of petaflop institutions supported by a wider network of institutions serving regional needs is the only way that Europe can achieve the scale of HPC systems needed to maintain global competitiveness in research.

The design of traditional HPC systems is costly in materials, programming time and, especially, in energy consumption. Erbacci suggests that the move to exascale systems is needed to address both the demand from scientists and the constraints of existing HPC systems. These systems will force a change to the programming paradigm for HPC to improve the efficiency of HPC system resource use.

Where Next for HPC and Science?

CINECA is investing in parallel programming, and Erbacci believes that this is the biggest change that is needed for HPC to improve scientific leadership; there needs to be a "renaissance" in computing, in which parallel programming replaces serial programming, not just in HPC but across computing.

As many-core systems become widely used in off-the-shelf personal computers, as well as in HPC, three things will come together:

- University courses need to teach parallelism as the standard programming model.
- Software libraries will need to be rewritten for parallel code.
- There will be a flourishing of HPC, with it becoming much more widely distributed, so that commercial code and commercial requirements and solutions become HPC-like.

These developments will enable HPC to better address scientific needs across a range of fields: energy, new materials, biological systems, human physical systems, and, critically, they will enable multidisciplinary teams to come together to solve scientific problems.

19.2 HLRS — Promoting Access to HPC Services

HLRS Organizational Profile

The High Performance Computing Center Stuttgart (HLRS as an acronym in German) is one of three national HPC centers in Germany (the other national centers are the Jülich Supercomputing Center [JSC] and the Leibniz-Rechenzentrum [LRZ]). The three centers are part of the Gauss Center for Supercomputing; an alliance established by these centers and German federal and state authorities to promote access to HPC in Germany and to users from other European countries.

HLRS has a particular interest in promoting access to supercomputing for industry and academia, with formal collaborations with T-Systems, Porsche, and other supercomputing institutions in Germany.

HLRS has a number of cluster, grid, and vector systems including:

- Cluster — 8.5 TFlops, 112 dual socket quad core AMD Cray XT5M machine with 16 GB memory per node and 5.4 TB storage

- Cluster — 62 TFlops 700 processor dual socket quad core Intel Nehalem NEC cluster with 12 GB memory per node and 60 TB storage
- Vector — NEC SX-9 192 CPU machine delivering 19.2 TFlops
- Vector — NEC-SX8 80 CPU machine delivering 1.2 TFlops
- Grid — 46 TFlops Grid utilizing IBM Cell, Intel Xeon, and Nvidia Quadro processors

Dr. Michael Resch, director of HLRS, provided insight into how supercomputing can benefit industry and academia and how policymakers could improve access to supercomputing.

Structure of the HLRS Center

HLRS provides HPC services for academic and applied research. HPC services provided to industry are organized through two organizations: hkz-bw and hww GmbH. T-Systems, T-Systems SfR GmbH, and Porsche AG provide co-funding and expertise for these collaborations. The Automotive Simulation Center Stuttgart (ASCS) is the organization through which HLRS provides HPC services to the wider automotive industry. The center has a focus on engineering and material science and a strong focus on physics.

HPC services at HLRS are organized into infrastructure provision and applications and visualization. Infrastructure includes training for users on developing parallel applications and optimizing code, managing HPC systems, and project management for jobs undertaken at the center.

Applications and visualization are split into five areas: applications, models and tools, intelligent service infrastructures, scalable computing and coupled systems, and service management and business processes and visualization.

These research areas include tools for parallel programming, scaling HPC jobs, particularly simulations over different HPC architectures, such as grid and cloud, and improving visualization of scientific data.

HLRS has approximately 90 staff, of whom 75 are scientists.

Economic Benefits of HPC

The economic benefits of HPC are easy to quantify in industry. Dr. Resch cites three examples: cost differentials between physical models and simulation; improving competitiveness in material design; and iterative simulations allowing researchers to develop products that otherwise would be impossible to develop or involve prohibitively lengthy design cycles.

Regarding the first of these, Dr. Resch observes: "A single physical crash simulation [in automotive design] has costs of €200,000 but the cost of running this on a supercomputer is around €500. In the automotive sector, simulation has replaced physical models and physical models are now only created for regulatory purposes."

A single physical crash simulation [in automotive design] has costs of €200,000 but the cost of running this on a supercomputer is around €500.

Reducing time cost and speeding up time to market are one element of the benefit of HPC seen by HLRS. HPC also improves the competitiveness of industry in developing new materials. It is physically impossible to test the behavior of materials over a long period without keeping them for that period; during this period, competitors will have started using them. Simulation allows researchers to test the properties of new materials over a long period without waiting to use them.

Iterative design using simulations allows researchers to develop products which otherwise would be impossible to create. Dr. Resch cites an example from aircraft design: "At HLRS we have been working for over 4 years on the optimum shape for aircraft wings. This work has helped reduce fuel consumption of airplanes by 15%, approximately €150 million of cost reduction every year for the industry. This simply could not be done without HPC. No organization could carry the cost of doing 1,000s of physical experiments each year."

Structuring Public and Private Collaboration for HPC

To gain these benefits, the structure of public and private collaboration for HPC is critical. Clearly, there are many ways of structuring this collaboration. Dr. Resch draws a distinction between a project-based model and the model used by HLRS, which is to develop permanent collaborations between research and industry: hww is an example of this.

The benefit of the permanent model is that the connection with industry is longstanding and hence both industry and academia can pursue research projects that deliver benefits over a longer timescale than is possible when the project has a shorter life. As Dr. Resch says: "[in choosing which projects to pursue] we don't say that this is an industrial project, we say that this is a useful project."

No matter which approach is chosen, collaboration between academia and industry brings a change in approach to HPC. Dr. Resch observes: "Closeness to industry is a clear advantage, it gives a better understanding of requirements and we produce research which we know is important. It produces a cultural change in that staff works in a way more familiar from industry than academia. However, this model creates challenges, particularly around security. The security needs of industrial users are very different to academia and hence this complicates how we manage and use systems."

The biggest challenge for HPC centers looking to collaborate with industry is the lack of generally understood principles for this type of collaboration in funding agencies and other government bodies. Dr. Resch's experience is that:

> "Public bodies understand research and they understand industry, they are less familiar with structures that combine both. Rightly, they are very concerned with cost and calculating cost. However, this is not the terms of the collaboration that we are trying to develop. The aim of our public-private collaborations is for them to be permanent and beneficial to both sides, hence we don't always have a fixed part which is 'private' and one that is 'public'.
>
> There is also an issue of familiarity with HPC. For example, depreciation cannot be greater than a three-year period, as a supercomputer is no longer a supercomputer after three years.
>
> That being said, public-private collaborations bring private investment into research, so overall are cost advantageous for academia."

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Improving Access to HPC

Access to HPC services is a critical challenge for Europe over the next ten years. If European industry and the European economy are to reap some of the benefits seen by HLRS in manufacturing and design, then there will need to be wider participation by European industry in HPC. From the standpoint of HLRS, there are two problems with access to HPC resources:

Access to HPC services is a critical challenge for Europe over the next ten years.

- Firstly, there are problems within countries, even in countries with significant investment in HPC.
- Secondly, there are problems with access for industry and scientists from countries which have not historically had investment in HPC resources.

For the first, Dr. Resch believes that coordinated action is needed between European bodies, national governments, industry, and academia: "We see demand for our HPC resources from smaller organizations and the problem is access to the systems. For example, there is not enough network bandwidth to utilize our systems. There is investment at the European level such that it is fairly easy, for example, to transfer data between Paris and Frankfurt, but not Toulouse and Paris. Unless this is addressed, smaller organizations and regions that do not have HPC centers on their doorstep will never develop a competitive economy using HPC."

The structure of HPC across Europe is going to be critical to ensuring participation in HPC from accession countries. Dr. Resch notes that there is a danger of a Europe of "two velocities" where two-thirds of the European Union states have a body of well-trained scientists and developing industry but no access to supercomputing resources. To change this, Dr. Resch believes that: "You need to build up infrastructure. However you can't create a successful HPC center from nothing. HPC requires a lot of expertise and you build up this expertise over many years. An artificial center would just be a waste of money. A more effective approach is to look at what is available and the needs of scientists from countries without resources then invest in training and access to an expanded set of centers and not create artificial centers."

Future of HPC — Where Should European Organizations Invest?

HPC coexists with the wider ICT industry. Research at the cutting edge of HPC drives the development of technologies that are used throughout the commercial ICT industry, and the scale of the commercial ICT market makes technologies to be used in HPC affordable. The maturity of the ICT industry creates a challenge for HPC in that there is insufficient growth potential to encourage companies to develop technologies to challenge current leaders; hence, HPC systems will increasingly be larger versions of what we have now and not radically different.

For Dr. Resch, this vision of the ICT and HPC industries prompts the direction of investment for European HPC in that "We have to move our investment into software; there is no future or need for a European 'hardware industry. Everyone will be using the same CPU and similar systems, but if our software is much better than alternatives then we will have HPC that is competitive with the rest of the world and industry which can take advantage of that competitiveness."

19.3 SARA — Assessing the Value of HPC to the European Economy

SARA Organizational Profile

SARA Computing and Networking Services is a hybrid organization comprised of the national supercomputing agency in the Netherlands and the SARA co-location and managed services business. SARA is funded through a mix of government grant investment and private sector use of SARA's services.

Dr. Anwar Osseyran, SARA's managing director, gave a view of the services offered by SARA and how supercomputing can assist growth in the European economy.

SARA's mission is to offer HPC services to universities and research institutions and industrial users. It has a particular focus on HPC networks, application support and e-science.

SARA maintains two main HPC systems:

- The Huygens supercomputer is a 3,328 core, 15.25 TB memory, 700 TB disk IBM pSeries 575 machine
- The National Compute Cluster, Lisa, is a 536 node system that can be configured in five compute node configurations and has 19 TFlop/sec peak performance

In addition, SARA has an experimental GPU machine and contributes to the Dutch e-science grid, BiG Grid.

Supercomputing in the Economy

As Dr. Osseyran observes: "HPC is not an end in itself. It is a tool to support industry and research. Researchers are interested in their own research and not in being experts on IT. The role of supercomputing centers is to provide the full range of support researchers need, not just the HPC system."

There are at least two key ways in which supercomputing is contributing to the Dutch economy. Firstly, it is allowing researchers to carry out research that, for practical or ethical reasons is simply impossible without supercomputing. Dr. Osseyran cites simulations of brain operations, which have the promise of producing more effective and lower cost procedures than current approaches, and simulations of methods of building dikes to prevent collapse, as examples of areas where supercomputing is creating an economic and social benefit.

It is allowing researchers to carry out research that, for practical or ethical reasons is simply impossible without supercomputing

Secondly, supercomputing is contributing to the analysis of large datasets collected through commercial operations. For example, data from sensors installed in industrial applications or data collected from customer information is being analyzed to improve the supply chain and customer service.

Some HPC projects can achieve both a research goal and have commercial spin off benefits. For example, the ESTEC telescope sensors provide data on ground level environmental conditions which, when properly analyzed, can be used for agricultural purposes.

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Challenges for HPC in Enhancing Economic Value

Supercomputing investments need to provide the physical facilities: the datacenter, power and cooling and management expertise but the future is in software, and particularly in providing services to assist researchers in optimizing their algorithms for the next generation of supercomputers. As Dr. Osseyran puts it: "Researchers need help with parallelizing their applications. This is one of the three greatest challenges for petascale and exascale: how do you write codes that can take advantage of these systems?"

Researchers need help with parallelizing their applications. This is one of the three greatest challenges for petascale and exascale

To this end, SARA has over 20 staff advising researchers on how to write and modify their applications so that they can take advantage of the capacity offered by SARA. This is a critical area where further investment in HPC specialists can reap economic rewards as researchers become more productive.

The second challenge for SARA is the reliability of petascale systems. With hundreds of thousands of processors, hardware failure is to be expected, but current configurations and software do not always cope with failure without downtime. Writing software that can cope with failure is going to be critical to taking advantage of future generations of technology.

Finally, managing the volume of data created by HPC is already a considerable challenge and requires much more work to stop it preventing growth in HPC use. While there is a lot of focus on the growth in storage and memory SARA, is also focusing on lifecycle management of data to increase the effectiveness of what is being stored.

Expanding the Value From HPC

Leadership in HPC is critical for the competitiveness of European industry. As Dr. Osseyran observes: "We are in a race where exascale will make inventions much faster and reduce the time to get insight into complex problems. For example, there will be faster patenting of bioinformatic innovations; there will be reduced cycles of product development in every industry domain."

For Europe to be competitive in this race Dr. Osseyran believes that three developments are needed:

Firstly, there needs to be a coherent strategy to enable SMBs to have access to HPC resources and training, Dr Osseyran observes that: "SMBs are often aware of the competitive advantage that HPC can offer them, but they do not have the time and money to invest in HPC and, even if they have the skills, they face challenges accessing appropriate resources." SMBs clearly don't have the scale to build these systems themselves but they would take advantage of these resources if they were available.

For SMBs, larger organizations and academia funding models need to price in all aspects of the system to enable a valid decision on whether to fund supercomputing investments with public money or whether companies and research institutions should fund smaller sites specific to their needs. In particular, the investment decision needs to include the cost of power, floor space, and management.

There are opportunities to improve the competitiveness of European industry through better coordination of industry projects at the pre-competitive stage. Start-ups may have a collective interest in funding common platforms for their products, on which they can then build differentiated products. However this needs a funding, tax, and legal framework which encourages this common development.

Finally, across industry there is a need to increase the number of public and private collaborations. As Dr. Osseyran explains: "The period of return on HPC is often too long for private business on its own. Government and industry need to collaborate to get the value from HPC."

19.4 CERN — Assessing the Value of HPC to the European Economy

CERN Organizational Profile

Founded in 1954, CERN (Conseil Européen pour la Recherche Nucléaire), is the European Organization for Nuclear Research, one of the most important centers for scientific research in the world. The main activities of CERN revolve around fundamental physics, as its stated mission is "Seeking and finding answers to questions about the universe". Funded and administrated by a joint council of 20 European member states, CERN has invested in the most complex and demanding scientific instruments to test and study the particles that lay at the base of matter, from atoms down.

The most ambitious and recent of CERN's research projects is the Large Hadron Collider (LHC), an ultra-high vacuum, giant particle accelerator with a 27km circumference that will allow scientists to answer questions on unexplored subjects such as dark matter, the origin of mass, and the physics phenomena linked to the Big Bang.

Dr. Iain Bird, LHC Computing Grid Project Leader, explained to IDC the function and scope of the supercomputing infrastructure developed over the past few years to support the LHC research project, whose build-out has created the roots for a range of activities spanning well beyond fundamental physics.

The Computing Grid

The WLCG (Worldwide LHC Computing Grid) project was initiated in 2002, and from 2004 saw the build out of hardware system designed to support LHC activities that effectively started at the end of 2009. As Dr. Iain Bird describes it: "The WLCG does not represent an example of high performance computing, nor is it a traditional supercomputing facility *strictu sensu*. Rather than relying on dense, tightly integrated high performing hardware, the WLCG is based on the concept of grid computing, in which resources are distributed between the internal CERN facility and more than 100 scientific datacenters scattered around the world. Given the astounding, ever-increasing amount of computing tasks that current and future research projects require, this was from the beginning the only way to go."

This also means that units of measurement differ from standard supercomputing centers. Dr Bird estimates that the overall WLCG system can reach up to a performance of circa 2. Yet performance is somewhat secondary to the scale of the infrastructure. In WLCG, 1 petabyte (1 PB = 1,000 TB = 1,000,000 GB) of data is moved around every week, and since the start of the LHC research this year, it is expected that approximately 15 PB of data every year will be collected for the next twenty years. Half a million "jobs" are performed on an average every day — a "job" being a batched computing task requiring between 8 and 12 hours to be completed

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by a CPU core. Overall data rate distributed from CERN amounts to 2 GB per second.

The WLCG is arguably one of the largest grid projects ever realized, and it is in its majority based on standard x86 computing resources (from servers to desktops). As of 2010, it entails three main layers of computing resources, each of which makes up approximately one-third of the total. However, every layer has a different grade of responsibility and carries out different activities:

Tier 0 — The CERN internal computing and storage resources, accounting for approximately 40,000 computing cores. It stores a complete version of the whole dataset and also works as the main center for the assignment and coordination of computing jobs throughout the whole system.

Tier 1 — Eleven regional supercomputer centers, distributing data from Tier 0 to Tier 2. A second copy of the whole LHC dataset is stored among them.

Tier 2 — 130 datacenters, located around the world and belonging to national labs or universities, sharing their resources with the WLCG. Their main role is to analyze and compute data locally.

The "fabric" allowing the distribution of parallelized job batches across the three layers is an open-source middleware software including components that have been developed by a number of projects and organizations

Use of the WLCG and its Role in Europe With the EGEE

The main function of the WLCG infrastructure is to support the LHC experiments, each of which is estimated to require computing capacity in the range of 1 million "jobs" per day. Before the LHC project ramped up, the WLCG resources were used by a number of other research projects in physics and other sciences.

It is important to note that the build-out of WLCG allowed CERN and a number of European actors, both in the public and private sectors, to start off the EGEE (Enabling Grids for E-SciencE) consortium in 2004. The EGEE project, which is now coming to an end, aimed to expand European efforts on grid computing using the WLCG experience and infrastructure as a foundation, in order to extend the use of distributed computing resources beyond pure scientific research to include public and private projects in the fields of geosciences, pharmaceutical, computational chemistry, healthcare, and multimedia. The EGEE has already been successfully involved in allowing private companies to make use of the infrastructure to conduct research projects in the aforementioned fields. Case studies include Total U.K. and Philips Research.

In parallel, the WLGC collaboration and the EGEE project have propelled the foundation of a European Grid Initiative (EGI), which will supersede the EGEE infrastructure and will link it to the national grid computing initiatives to build a generic e-infrastructure for all European research communities. The final objective of the EGI, founded in February 2010, is to take over from CERN and coordinate the grid initiatives in Europe beyond the initial efforts on physics, eventually including crucial research in natural sciences (e.g., climate prediction).

Challenges and Future Outlook

From a funding perspective, the WLGC is supported by a combination of central CERN budget and local funding agencies for the Tier 1 and 2 resources. The budget is allocated on a three-year plan, and takes into account an estimated 30% to 50% yearly growth of data and computing resources. All three tiers are expected to expand, but with the core of the network now set up, the largest part of the growth will come from Tier 2 sites.

"Organizational challenges were the biggest hurdle at the beginning, with a distributed staff that in most cases is not dedicated to the WLCG project, but rather supervises local datacenters. The strong collaboration effort has helped us overcome this, but now technical challenges stand before us, especially in the scaling-out of the resources," said Dr Bird. Server virtualization is now being studied for its efficiency benefits, and the network represents another area of investment, in particular to increase use of non-local data. However, the real issues WLCG will face over the coming years are the following:

- Data explosion and management — As data from the LHC experiments starts to flow in, storage will continue to be a main point of investment, together with robust tools for data management.

- The multicore dilemma — So far, most "jobs" are written to run on a single CPU core, and the computational process cannot easily exploit the power of a multicore processor. CERN is investing in adapting its code to be able to parallelize jobs on many cores at the same time. According to Dr. Bird, the scale-out will be able to cope with increasing demand only if this challenge is won.

Economic Impact and Legacy of WLGC

The European Investment Bank (EIB), the financial arm of the European Union, lent €300 million to CERN to help finance the construction of the Hadron Collider. As a side result, Europe found itself as the birthplace of the most ambitious grid computing project ever initiated. This proves how the relationship between new computing practices and groundbreaking scientific research is reciprocal. Without the former, the latter would be impossible, and without increasing demands from the latter, the former would not have been developed.

Even more interesting is the fact that practical, business-related activities (such as the business forum within EGEE) have found ways to grow starting from the pure research, in a similar way to how scientists at CERN ignited the World Wide Web revolution as a way to share information.

"The development of a collaborative grid computing infrastructure of the size of EGI is a European experience with no equal in the world. The staff involved in the grid projects, internally as well as in all the networking sites, went through a discovery process of techniques that simply weren't there before, adding significantly to the IT development of the region," argues Dr. Bird.

The development of a collaborative grid computing infrastructure of the size of LCG and EGI is an European experience with no equal in the world.

Such success could and should be matched by parallel investments in the standard supercomputing/HPC area, where the geographical division in countries, as well as antagonizing business players, are slowing down and possibly fragmenting the European efforts. Governments should do more to overcome the breaks and consolidate investments under a European umbrella.

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20.0 INITIAL RESULTS OF TECHNICAL WORKING GROUPS

In this report we summarize the initial results of the Technical Working Groups with a focus on the history and current situation of HPC in Europe. In the final reports, the recommendations and suggested implementation approaches from the Technical Working Groups will be covered.

We greatly thank the Technical Working Group contributors for their ideas, insights, and suggestions that helped to crystallize the findings in this report. The Technical Working Groups are made up of members of this project's Technical and Strategy Committee, along with IDC representatives. External team members included: Hervé Mouren, TER@TEC and Christian Saguez, TER@TEC, Richard Blake, STFC Daresbury Laboratory, Arndt Bode and Herbert Huber, Leibniz-Rechenzentrum/LRZ Munich, and Friedel Hossfeld, Forschungszentrum Jülich.

IDC's role was to first provide initial HPC market research findings and then collect and consolidate everyone's views and opinions into the summary sections.

20.1 Implementation Issues Working Group

Funding Considerations

A stated goal of the European Commission is to advance Europe's HPC capabilities, by 2020, to a position of parity or greater-than-parity with the best in the world. Among other things, this will require a substantial, well-directed funding effort. This section summarizes the HPC funding patterns of countries outside of Europe that may also be contending for HPC leadership during this decade.

United States. Today, at the dawn of the petascale computing era (10^{15} operations per second), the U.S. is the world leader in high performance computing by almost any measure — including the twice-annual list of the world's 500 fastest supercomputers (www.top500.org), where in November 2009 the U.S. held 55% of the spots on the list, Europe 31% (up from 29% six months earlier), and China, Japan, and India together just 8%. The current U.S. primacy is no accident, but the result of a deliberate, multi-year effort to regain global HPC leadership after Japan seized it for several years (2002–2004) with its surprisingly powerful "Earth Simulator" climate-modeling supercomputer that required five years of development and about €245 million ($350 million) in funding.

In response to this perceived threat to national security, scientific, and industrial competitiveness, the U.S. Government sharply increased funding for HPC systems development and purchases, especially through the Department of Energy's Advanced Simulation and Computing (ASC) program and the Defense Advanced Research Projects Agency (DARPA) High Productivity Computing Systems (HPCS) program. Since 2002, the U.S. Government has summoned the political will to invest well over $1 billion (€700 million) in aggregate HPC funding to recapture worldwide leadership. The U.S. is actively considering the need to spend at least that amount again to fund the development of a single exascale computer (10^{18} operations per second) for delivery in the second half of this decade.

Japan. In recent years, Japan has slipped from contention for worldwide HPC leadership and had none of the top 10 entries on the aforementioned November 2009 ranking of the world's "Top500" supercomputers. But Japan remains a technical powerhouse for HPC development and the country's *Keisoku* project, organized to produce a 10-petaflop HPC system in 2011–2012, had U.S. officials worried for a time. In 2009, the Japanese Government rejected a budget-cutting panel's proposal that would have slashed funding for supercomputing projects, including *Keisoku*, to almost nothing. Instead of accepting the drastic recommendation of the Government Revitalization Unit's budget-cutting panel, the government reduced the supercomputing budget by only about 15%, from the original €206 million ($295 million) request to about €175 million ($251 million). In the context of Japan's troubled economy, that represents a strong vote of confidence in the importance of high performance computing and a repudiation of a high-ranking panel member's public comments questioning HPC's ability to make Japan more competitive.

Russia. Interestingly, the debate in the Japanese Government began soon after Russian President Medvedev declared that without investment in HPC, "in five years our products will not be competitive or of interest to potential buyers." Vladimir Putin subsequently allocated €26 million ($37 million) for supercomputer procurements. Following that, Russia has begun spending a larger amount than that for HPC systems, including a new system with 414 teraflops of peak computing power deployed in April 2010 at Moscow State University.

"In five years our products will not be competitive or of interest to potential buyers." Medvedev

People's Republic of China. At the HPC China conference (November 29–October 1, 2009), IDC learned that China is strongly committed to HPC investment and pursuing HPC leadership. In 2009, China became only the third nation in the world — after the U.S. and Germany — to deploy an HPC system with a peak speed exceeding one petaflop. The supercomputer, nicknamed "Tianhe," was described as "a 100% self-made Chinese system." China has indicated strong interest in funding the development of domestic HPC component technologies, right down to the microprocessors, as opposed to purchasing these technologies from abroad.

India. Through our experience holding 2007 HPC User Forum conferences in India, in conjunction with the Indian Institute of Technology (New Delhi) and the Indian Institute of Science (Bangalore), along with intensive market tracking, IDC has a good sense of government funding patterns in that country. In sum, India to date has opted to fund multiple small to midrange HPC centers in various parts of the country, rather than concentrating funding on one or more large centers. This approach may reflect political realities as much as budgetary constraints. In any case, as a consequence of this policy the largest supercomputer in India today is not government funded but a commercial system at Tata's Computational Research Laboratories (CRL) site in Pune, India.

What to Fund

The lion's share of HPC funding throughout the world continues to be aimed at hardware development and hardware procurement, despite the widely acknowledged fact that HPC hardware capabilities are racing farther and farther ahead of software's (especially software applications') ability to exploit hardware capabilities fully. It is crucially important for the EU to make world-class HPC hardware systems available to Europe's scientific community, but it does not necessarily follow from this that the EU should fund the *development* of these systems in part or whole — as has happened with mixed success in the U.S. (e.g., DARPA HPCS) and Japan (e.g., *Keisoku*). The commoditization of HPC hardware systems means that large, standards-based clusters are now readily available on the world market. In the new petascale-exascale era, the EU can consider avoiding major expenditures on novel hardware development in order to concentrate funding on hardware system purchases and on advancing EU capabilities in HPC software applications and algorithms and other areas (e.g., energy efficiency) where global leadership is sorely needed and where the EU is in a strong position to provide this leadership.

Procurement: Open Procurement Versus Protectionism

For HPC procurements, the EU needs to strike an appropriate balance between supporting the growth of the EU-based HPC vendor community and protectionism that could harm European science and economic competitiveness.

The end-goal of any national or regional HPC program should not be leadership in HPC itself (although that may also happen), but enabling the advancement of science and engineering — with attendant benefits for economic competitiveness. HPC-based modeling and simulation is firmly established as the third branch of the scientific method, complementing traditional theory and experimentation. Hence, Europe's scientific and engineering communities should have access to the best HPC resources available, no matter where in the world they come from. This argues for open procurements that do not favor EU-based vendors. But the EU as a region cannot attain meaningful HPC leadership without actively promoting the development of best-in-class EU-based HPC vendors.

The historical HPC superpowers, the U.S. and Japan, have both faced this dilemma and have not always achieved a good balance between open procurement and protectionism. For many years, a bilateral trade agreement was in place to avert protectionism by either government in public sector HPC purchasing. As is well known, a trade dispute in the 1990s effectively prevented U.S. government agencies from purchasing Japanese-made supercomputers until 2001. Members of the U.S. climate modeling community felt especially deprived by this lack of open access to Japanese vector supercomputers and documented their frustration in a formal report. Separate from this, the Japanese government followed the practice of supporting all three Japanese supercomputer-makers (Fujitsu, Hitachi, and NEC). This lack of an open, merit-based domestic procurement process led to difficulties in 2009 when two of the three vendors dropped out of Japan's *Keisoku* project that aims to develop the next-generation national HPC system. There are also examples within EU countries of HPC procurements that were won by non-domestic vendors, and then awarded to domestic vendors following formal protests. Again, the usual victims of HPC protectionism, wherever it happens, are scientific and economic advancement.

An effective way to promote the development of the EU-based HPC vendor community and "ecosystem," without incurring the harms of protectionism, is to fund the development of pre-competitive, enabling technologies by EU-based vendors — while keeping procurements for competitive-stage products and technologies open to bidders from anywhere in the world.

Access to EU HPC Resources

Although it is important to reserve a minority of time (perhaps 10%–30%) on EU HPC systems for the centers that host the systems — as a motivator and to help them attract the best users and staff — the majority of time on the systems should be awarded based on the best scientific proposals, as judged by peer review, following a strategy directed towards leadership in a selected number of areas. This access formula will help to ensure that Europe's most promising scientific projects receive appropriate allocations of time on these powerful and costly resources, no matter which country or countries they come from. It will also help to ensure that Europe's scientific community is properly motivated to collaborate and become more integrated across national boundaries. Reserving a minority of system time for the hosting centers may also provide better opportunities for highly innovative proposals that might not qualify under the more formal, tradition-bound peer review process.

In the PRACE research infrastructure, peer-reviewed access to the systems will be supported, but as long as funding for the procurements is principally by the hosting member nations, free access will be restricted, even though the principle of *juste retour* among the nations is not applied up front but only following the closure of yearly access use accounts. Greater European funding can overcome this dilemma.

20.2 Industry Access Working Group

Although the majority of time on EU HPC systems should be allocated to science, a strong case can be made for reserving a minority portion of the available time to help advance European industry and European economic competitiveness.

How Industry Uses HPC

Industry is in the midst of a new, 21st century industrial revolution driven by the application of computer technology to industrial and business problems. HPC plays a key role in designing and improving many industrial products — including automobiles, airplanes, pharmaceutical drugs, microprocessors, computers, implantable medical devices, golf clubs, and household appliances — as well as industrial-business processes (e.g., finding and extracting oil and gas, manufacturing consumer products, modeling complex financial scenarios and investment instruments, planning store inventories for large retail chains, creating animated films, and forecasting the weather).

HPC users typically pursue these activities with *virtual prototyping and large-scale data modeling* (i.e., using computers to create digital models of products or processes and then evaluating and improving the design of the products or processes by manipulating these computer models). Given their broad and expanding range of high-value economic activities, HPC users are increasingly crucial for industrial and business innovation, productivity, and competitiveness.

Research Studies on Industrial Use of Government-Funded HPC Centers

A series of IDC research studies conducted over a four-year period on behalf of the Washington, DC-based Council on Competitiveness and its government-university sponsors firmly established the link between HPC and economic competitiveness. Most, but not all, of these studies were global in scope and included Europe. The studies are downloadable without charge at the Council's Web site: www.compete.org).

In the baseline *Council on Competitiveness Study of U.S. Industrial Users* (July 2004), 97% of the U.S. businesses that had adopted HPC said they could no longer exist or compete effectively without the use of high performance computing. Subsequent studies in this series expanded the scope of inquiry to the worldwide

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market place and produced similarly strong endorsements from industry of the crucial importance of HPC access and usage.

The July 2008 IDC-Council on Competiveness study, *Advance: Benchmarking Industrial Use of High Performance Computing for Innovation,* examined the use of HPC for innovation in four economically important industries whose leading firms have known histories of HPC usage: the aerospace, automotive, bio-life sciences and energy sectors. The study also explored the extent to which these tier 1 firms' supply chains embraced HPC, and then compared the leading U.S. firms with select, "best-in-class" international competitors. The international firms in this study were all based in Europe. Among the salient findings were these:

- Leading U.S. and international industrial firms agreed that HPC can dramatically boost their innovation. One hundred percent of the surveyed international best-in-class firms and U.S. tier 1 auto and aerospace firms, along with a strong majority of U.S. tier 1 energy firms (75%), agreed that HPC can play a role in dramatically increasing their innovation.

- International best-in-class firms apply HPC beyond traditional R&D functions more frequently than do U.S. tier 1 firms. Despite the U.S. energy industry's aggressive use of HPC, the international best-in-class industrial firms have pushed HPC usage much deeper into their organizations on average than the surveyed U.S. tier 1 firms — more frequently extending its use from traditional upstream applications in R&D and design engineering into high-value downstream uses, such as manufacturing, production, and large-scale data management. The international firms closely associate their HPC usage, whether upstream or downstream, with improved innovation of their products and industrial processes. Every one (100%) of the international best-in-class firms viewed HPC as a strategic asset that directly benefits its profits, competitiveness, and productivity, while only the auto tier 1 firms were unanimous in indicating this same assessment.

- International best-in-class firms are driving HPC through their supply chains more aggressively than U.S. Tier 1 Firms. One hundred percent of the best-in-class non-U.S. firms in the aerospace, auto, and bio-life sciences industries indicated that they require their suppliers to use HPC. This approach is far more aggressive than in the United States, where only 50% of the tier 1 aerospace and auto firms and none of the tier 1 bio-life sciences firms do the same. (The picture in the energy sector is identical for international best-in-class and U.S. tier 1 firms: neither requires suppliers to use HPC.)

The U.S. Department of Energy Incite Program

The U.S. Department of Energy-initiated INCITE program (Innovative and Novel Computational Impact on Theory and Experiment) began as a way for advanced scientific projects to gain access to large blocks of time on HPC systems at Department of Energy national laboratories, through a peer-reviewed proposal process. The majority of computer time in the program is still awarded to science, but in 2005 the program was extended to enable industry to compete for time awards, also through a peer review process that looked for projects with the potential to achieve pre-competitive R&D breakthroughs. Among the 2010 industrial award winners were Boeing (CFD), 6 million hours; General Motors (material science), 14 million hours; and General Atomics (fusion energy), 20 million hours.

Europe's PRACE Program

PRACE (Partnership for Advanced Computing in Europe) is a pan-European cooperation comprising 20 countries with the objective of establishing an infrastructure for high-end HPC computing activities. The ultimate goal of the PRACE project is to build a world-class high-performance computing capability and drive wider adoption of supercomputer technology in scientific research and industry segments across Europe to stay ahead of the competition in the world market. The budget for the initial two-year phase (January 2008 to December 2009) is €20 million (about $29 million), funded partially by the EU's seventh Framework Program. This funding is augmented by contributions from six "hosting members" (France, Italy, Germany, the U.K., the Netherlands, and Spain). These members have contracted to deliver HPC cycles worth €100 million in five years from each member, or a total of €600 million between 2010 and 2015. Additional funds for the implementation phase of the infrastructure, which will run from 2010 to 2013, are expected in the near future. PRACE held its second industry meeting in Toulouse, France, on September 7–8, 2009. PRACE plans to provide industry users with free access to hardware resources and support services.

Summary

Empirical research studies have firmly established the link between HPC use and industrial competitiveness. There are multiple examples in the United States, Europe and elsewhere (notably Japan), of government-sponsored programs that provide industrial and business firms of varying size with access to large HPC systems at government-funded HPC centers — and there is growing evidence that programs of this kind are successfully meeting their objectives in helping to make industry more efficient and competitive. The programs may address pre-competitive R&D work, competitive product development, or in some cases both. For programs that aim to support competitive product development, it is important for industrial partners to have a large say in specifying the calendar starting and ending points of the engagement, the amount of computer time needed, and other requirements related to the time-sensitive product development cycle.

20.3 SMB Access Working Group

In Europe and elsewhere, small and medium-sized businesses (SMBs) far outnumber large businesses and play a greater role in local, national, and regional job creation. IDC and other research studies in recent years have shown that SMBs that have adopted HPC typically find it just as indispensable for their ability to compete and survive as do large, tier 1 industrial HPC users. In addition, this empirical research largely dispels the notion that SMBs use HPC only to perform "capacity" or "throughput" computing that is aimed at completing a larger number of familiar tasks in an allotted time period. SMBs often employ HPC for both "capacity" computing and "capability computing," that is, doing new things that the users were unable to do before. Hence, providing SMBs with access to HPC resources is likely not only to increase industrial productivity, but also to accelerate industrial innovation — both of which would boost the competitiveness of European industry.

Two further IDC studies for the Council on Competitiveness shed new light on the government-provided HPC experiences of a broader range of industrial organizations, primarily SMBs. The participating companies' ("industrial partners") experiences were overwhelmingly positive, so much so that the government agencies involved — the National Science Foundation (NSF) and the Department of Energy's National Nuclear

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Security Administration (NNSA) — were strongly encouraged by the industrial partners to expand industrial access to an extent they might not have had the capacity to provide (NSF) or that was inconsistent with their government mission (NNSA).

The *Council on Competitiveness Study of Industrial Partnerships with the National Science Foundation* (June 2006) evaluated the experiences of industrial HPC user organizations engaged in partnerships with the NSF centers at the National Center for Supercomputing Applications, the Pittsburgh Supercomputing Center, the San Diego Supercomputer Center, and the Texas Advanced Computing Center. Of the 40 participating businesses, 95% said they would like to partner with the same NSF center in the future (78% had plans in place to do so.) Virtually all (93%) said the NSF center partnerships advanced their research and development efforts; 88% said the collaboration had "solved a specific problem"; and the vast majority (80%) concluded that the partnerships with the NSF centers had met their objectives. That percentage might have been even higher, since 13% of the projects were still in progress when this study was conducted. For most of the NSF center business partners, HPC is indispensable. More than three-quarters of the sites (77%) stated that they could not operate as businesses without access to HPC resources, and 80% said they could not compete effectively or bring products to market fast enough without HPC. The most frequently cited benefits of HPC were time savings and better science.

The *Council on Competitiveness Study of Industrial Partnerships with the Department of Energy NNSA* (June 2006) included 12 industrial partners. The great majority of the respondents (83%) reported that their collaborations with NNSA centers had met their objectives, and none claimed their objectives had not been met. Six of the 12 sites were able to assign an actual dollar value to the partnership results, ranging from $200,000 to $1 million. All of the respondents agreed that the partnerships advanced their firms' research and development efforts. An impressive one-third (33%) of the sites reported that their partnerships had "achieved a breakthrough or discovered something totally new." All 12 sites responded "yes" when asked about their willingness to partner with the centers in the future. Three of the firms stated outright that they could not operate as businesses without HPC, while many of the others said essentially the same thing in other ways. The benefits of HPC for the companies extend far beyond time and cost savings in the product development process. For many of the firms, HPC provides valuable new insights, breakthroughs in thinking that can result in superior products with important competitive advantages.

A Partially Invisible Segment

The largest HPC systems and the large organizations that operate them are made highly visible through publications such as the semi-annual list of "The World's Top 500 Supercomputing Sites" (www.top500.org). It is far more difficult to identify the many thousands of SMBs that employ HPC in Europe and around the world. For several years IDC has been pursuing this goal, often at the urging of large HPC systems vendors which see SMBs as a barely tapped, high potential market for their products and services.

SMB HPC users typically require "ease-of-everything" — from purchasing and installation to operation and upgrading. SMB end users typically lack ready access to HPC-knowledgeable IT personnel and do not have the time or experience to perform HPC system integration on their own. Since 2007, a growing number of HPC vendors, including IBM, Hewlett Packard, Dell, Cray, SGI, Bull, Appro and others, have launched new HPC systems with starting prices well below $100,000 (about €70,000) and with ease-of-everything attributes. Revenue for these HPC workgroup products aimed at the SMB market totaled about $1.7 billion (€1.2 thousand million) in 2009 and IDC projects it will reach $2.2 billion (€1.5 thousand million) in 2014.

SMB Desktop Users and the Migration to HPC

Another series of IDC studies conducted for the Council on Competitiveness and the University of Southern California's Information Sciences Institute (USC-ISI) sought to illuminate the situations of SMBs that employ desktop computers for modeling and simulation, but have not yet made the transition to running their problems on HPC systems.

The goal of the *Council on Competitiveness and USC-ISI Study of Desktop Technical Computing End users and HPC* (February 2008) was to identify the potential for using HPC to boost the productivity of these companies as a way of helping to increase the productivity of the U.S. industrial base as a whole. Fifty-seven percent of the 77 surveyed companies, who represented a broad spectrum of industries, said that they have problems they can't solve on their desktop computers. A high proportion (53%) of the companies was forced to scale down their advanced problems to fit their desktop computers, resulting in a loss of insight, innovation, and competitive gain. Others chose to ignore their advanced problems, with more dire consequences. A third strategy, pursued by more than half the firms, was to increase the amount of slower, more expensive physical prototyping. Previous studies showed that these alternatives render companies more vulnerable to competitors that have greater determination to employ HPC servers for their proven benefits. The chief barriers to HPC adoption among these companies were the lack of relevant application software, lack of sufficient talent, and cost constraints.

A companion study, the *Council on Competitiveness and USC-ISI In-Depth Study of Technical Computer End Users*, more deeply probed SMB end users in a single job field, welding (materials joining) and closely corroborated the findings of the broader study.

20.4 HPC Software Requirements Working Group

The Origins and Growth of HPC Software

Following its initial growth spurt in the late 1970s and 1980s, the market for HPC systems has expanded over time by adapting to the requirements of successive waves of new users — in large part through advances in software. Each new wave of users has expected HPC system vendors to do more for them, by providing software to make these systems easier to deploy and use.

In 1976, the CRAY-1 supercomputer was delivered to its first customer, Los Alamos National Laboratory (LANL), as a blazingly fast hardware platform with no operating system. Not to worry: LANL and others in the first wave of HPC users, primarily government and university researchers, typically had enough in-house technical savvy and personnel to write software themselves when the need was critical.

The second wave of adoption carried HPC into industry, initially the automotive and aerospace sectors, starting in the late 1970's. These users required HPC vendors to provide not only an operating system and other system software, but to port the key third-party ISV applications needed to run the users' industry-specific problems —

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and to run the applications with the reliability expected in production computing environments.

HPC Software in the Era of Clusters

The third important wave of HPC market growth began with the birth of the cluster in the late 1990s and took off in earnest in 2002. Since that year, clusters have almost single-handedly driven the rapid growth in the HPC market and are now the dominant species of technical servers. But especially since the advent of clusters, HPC hardware has increasingly outdistanced software development, such that today it is not uncommon for software to be capable of exploiting only a small fraction — often not even 5% to 10% — of a contemporary hardware system's theoretical ("peak") processing power. The peak speeds of the largest HPC hardware systems have jumped about one thousand-fold per decade during the past two decades, primarily by greatly increasing the number of processing elements. The largest HPC systems today include more than 200,000 processor cores, and systems with more than one million cores are just a few years away. Yet, relatively few HPC software applications ("codes") today are able to exploit more than 128 cores.

HPC systems have become more difficult for HPC software to exploit efficiently not only because of their skyrocketing parallelism and theoretical peak speeds, but also because with few exceptions they employ standard x86 microprocessors from Intel and AMD that were designed for broader computer markets — especially personal computers — rather than to meet the specific demands of HPC users. Adding to the software challenges is the growing trend toward heterogeneous processing in HPC systems, that is, the use of more than one type of processor.

Because x86-based HPC hardware systems are firmly entrenched and widely available from multiple vendors based in the U.S., Japan, and Europe (Bull, EuroTech), future HPC leadership will likely depend far more heavily on advances in software than on initiatives to develop novel hardware systems. Fortunately, Europe has considerable strengths in HPC software, particularly for certain scientific and industrial domains.

Programming Languages

Fortran, C, and C++ are the still-important legacy programming languages for HPC, but the rise of clusters to market dominance in recent years has made the Message-Passing Interface (MPI) standard the preferred protocol for programming high performance computers. MPI can be very labor-intensive and is not particularly efficient even for today's large HPC systems, not to mention the million-core systems that are on the near horizon. More efficient alternatives have been available for some time, notably Co-Array Fortran (CAF) and Unified Parallel C (UPC), and other so-called PGAS (Partitioned Global Address Space) languages are under development by Cray, IBM, and Oracle-Sun, but research has repeatedly shown that few HPC users are ready to leap to a new, more efficient programming language that would require new learning and the rewriting of applications.

Applications Software

Software applications, also known as "programs" or "codes", enable users to carry out specific tasks, such as word processing on personal computers or climate modeling on HPC systems. Government and academic users of large HPC systems typically employ application software that they have created themselves ("in-house codes") or that has been created by some other government or academic organization for common use ("community codes"). Industry is typically far more reliant on application software that is purchased from and maintained by commercial software firms called independent software vendors (ISVs) — although ISV software may also be used in government and academia.

IDC studies show that open source application software does not yet play a major role at most government, academic or industrial HPC sites, nor is it expected to do so in the foreseeable future. Only about 3% of HPC applications are "open source" codes. In addition, most open source software is middleware and not application software.

Studies of HPC Applications Software

In 2005 and 2006, IDC conducted two related, pioneering studies on HPC applications software. Although these studies were commissioned by two U.S. entities, the Defense Advanced Research Projects Agency (DARPA) and the Council on Competitiveness, their scope was global. The first study looked at HPC applications software from the standpoint of end users, while the second study explored the same phenomenon from the perspective of the independent software vendor (ISV) community.

The *Study of ISVs Serving the HPC Market: The Need For Better Application Software* (July 2005) showed that a serious gap exists between the needs of HPC users and the capabilities of ISV applications. High-end HPC users want to exploit the problem-solving power of contemporary HPC computer servers with hundreds, thousands or (soon) tens of thousands of processors for competitive advantage, yet few ISV applications today "scale" beyond 100 processors and many of the most-used ones scale to only a few processors in practice.

It is important to understand that the ISV organizations are not at fault here. The business model for HPC-specific application software has all but evaporated. As for-profit companies in most cases, ISVs focus their software development primarily on the much larger and more lucrative technical computing markets for desktop systems (workstations, PCs, Macs) and smaller servers. IDC market research shows that the HPC portion of the technical server market often represents less than 5% of their overall revenues, and in some cases this figure is less than 1%. Even if they could afford this investment, the motivation for major rewrites is generally inadequate because the HPC market is too small to reward this investment. For business reasons, the needs of HPC users are often an important but secondary concern.

The *Study of ISVs Serving the HPC Market: Part B — End User Perspectives* (February 2006) surveyed a select group of well-known U.S. businesses that are highly experienced HPC users. IDC asked them about their requirements for HPC-specific application software and related resources. The HPC end users IDC interviewed for Part B represented a wide range of industries, from defense contractors to an entertainment company and a consumer products supplier. Most of the firms (83%) said they have unsolvable problems that are 5–100 times larger than the problems they can solve today. Also, it is important to note that when industrial HPC end users talk about solving larger problems, they typically don't mean simply doing more of the same thing. In most cases, they mean solving problems with greater resolution that can lead to new insights and superior new products.

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Industry Needs Access to Petascale Supercomputers

Three-quarters of the industrial firms (73%) said they could make use of a petascale computer to run today's crucial problems faster or to tackle next-generation problems of great competitive importance. This is an interesting finding, given that industrial users usually acquire substantially smaller versions of HPC systems than do leading government and academic users. But commercial computer purchases are more heavily dictated by budgets, and the fact that industrial firms have more modest HPC budgets than leading government users does not mean the companies have smaller ambitions for applying HPC. For example, the majority of the industrial end users said they would (83%) or might (91%) use a petascale computer to run heterogeneous problems. A heterogeneous problem, also called a multiphysics or multidisciplinary problem, is one that involves multiple scientific disciplines — for example, studying the complex interaction between the structure of an automobile and the fluid dynamics of air flow around it.

One of the major findings of Part A of this study was that there is a lack of readiness for petascale systems among the ISV suppliers. Fewer than half (46%) of the ISV applications scale even to hundreds of processors today, and 40% of the applications have no immediate plans to scale to this level.

Parallel File Systems

The main role of a parallel file system is to handle multiple concurrent requests to transfer data to and from users of an HPC system. At HPC User Forum meetings in recent years, HPC users in the government, academic, and industrial sectors have generally agreed that none of today's parallel file systems is exceptionally good at meeting their requirements yet. Significant developments are needed to enhance the metadata performance of parallel file systems, and to extend the scalability of existing solutions to hundreds of thousands of clients while permitting simpler management, improved performance, and better error detection and self-healing capabilities.

Multiple storage vendors are waiting for the final version of NFS v4.1, which will standardize the parallel I/O operations in NFS (pNFS). As soon as the standard is finally released, it might initiate strong competition for established parallel file systems such as GPFS and Lustre.

HPC Management Software

From its origins more than 25 years ago in pioneering programs such as transaction processing (TP) monitor software, which among other things ensures the integrity of transactions passing between clients and applications, software at work between user applications and the operating system has played an increasingly important and diverse role. From their intermediate position, these programs perform a wide variety of crucial linking, mediating, and control functions.

By virtue of this intermediate position, it has become customary to refer casually to all software components that are not clearly part of the application or the operating system as middleware. However, the common term *middleware* does little to call out the many distinct and important roles now played by the software components working between HPC applications and the operating system. For this reason, IDC and a growing number of others in the worldwide HPC community now use the term *HPC management software* to refer to this software layer that has been adapted to address the specific requirements and growing complexity of parallel HPC environments.

Over time, HPC management software has become more integrated and "multi-talented." It has been forced to evolve in response to the evolution of computing environments; and in recent years, the proliferation of HPC clusters and grids has pushed leading-edge HPC management software products to new competency levels. Contemporary HPC management software products have the ability, when needed, to harness computing resources scattered across the globe on behalf of users and their applications. This ability will be increasingly evident with the emergence of cloud computing environments, such as the global private cloud now being developed by CERN in conjunction with HPC management software company Platform Computing, or NASA's climate modeling private cloud environment in the U.S., or the private cloud HPC site (used by Boeing and others) at Tata's Computational Research Laboratories in Pune, India.

Pre-Integrated, Pre-Tested HPC Software Stacks

As noted earlier, clusters are now the dominant species of HPC systems — including large-scale clusters at various government and university sites around the world — but users consistently report that clusters remain difficult to specify, purchase, install, deploy, and manage. A growing number of HPC vendors now offer HPC systems designed to meet the "ease-of-everything" requirements of entry-level and midrange HPC users, and IDC believes that over time, "ease-of-everything" systems will spread beyond the entry level to the HPC midrange and beyond. Today, these systems are intended for sites that do not have staff capable of performance HPC system integration. At the other end of the HPC market, at the very high end, staff with these skills exist, but the ballooning complexity of large-scale HPC systems (rampant parallelism and component counts, for example) is challenging their ability to deploy and manage these megasystems on behalf of their users. HPC systems that arrive with pre-integrated, pre-tested software stacks, such as those certified under the Intel Cluster Ready program and its equivalents from other vendors, may have a strong future at HPC sites large and small.

20.5 HPC Staffing and Training Working Group

HPC leadership, however defined, is unattainable without an adequate number of properly trained personnel, including computational researchers, 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 Europe, North America and elsewhere during the past decade, IDC has repeatedly heard HPC leaders say they expect their growth plans to be limited by a shortage of available, qualified personnel.

Moreover, especially in Europe, there is a tendency to support the procurement of HPC systems by national programs, but these programs neglect the necessity to have enough qualified personal to run, maintain, and enhance the systems but also for user support, porting of applications, and development of new applications and techniques.

The HPC personnel shortage that affects Europe and North America to a great extent, and the Asia-Pacific region to a lesser extent, is no accident. The United States is the world's largest HPC market and historically has been the largest university educator of the global HPC workforce. When HPC funding from the U.S. Government and closely allied nations 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

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until about the year 2001, when the fast rise of HPC clusters caused a five-year spurt of average 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 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 a "new technology" Internet or gaming company. 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.

Fortunately, HPC centers in Europe and elsewhere have begun to address the labor shortage in collaboration with academia 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.

20.6 HPC Visibility/Awareness Working Group

For more than 30 years, the use of HPC has contributed enormously to scientific and industrial advances, national and regional security, and the quality of human life. HPC-based modeling and simulation has become firmly established as the third branch of scientific inquiry, complementing traditional theory and experimentation. Yet few people outside of the HPC community are aware of HPC's varied contributions or its impact on their daily lives.

How many people know, for example, that HPC plays an integral part in designing the vehicles they drive and the airplanes they fly in, locating and extracting the fuel that powers these vehicles and heats and cools their homes, and producing the weather forecasts they rely on to plan for daily activities and severe storms that can devastate lives and property?

HPC use has become more pervasive than even some members of the worldwide HPC community may realize, as these further examples illustrate:

- Healthcare. In the early 1990s, a hospital in Germany began routinely using HPC to predict which expectant mothers would require surgery for Caesarian births, with the goal of avoiding traditional, riskier last-minute decisions during childbirth. A Washington, DC hospital routinely employs HPC to "read" digital mammograms with better-than-human accuracy to spot early signs of breast cancer (microcalcifications). Hospitals in Europe and the U.S. began using HPC in surgical training, especially to convey the "feel" of various procedures as experienced by veteran surgeons (haptics). Researchers at EPFL in Switzerland, in the U.K. and elsewhere are en route to creating functional computer models of the human brain to aid in neurological studies.

- Consumer products. Procter & Gamble uses HPC heavily to design its consumer products, including Pringle's potato chips, Pampers diapers/nappies, Ivory soap, and a host of others. Panasonic and other Japanese companies have long relied on HPC to help design rice cookers, microwave ovens, and electronic products. Sporting equipment makers employ HPC today to design everything from golf clubs to mountain climbing gear and Formula One race cars.

- Humanities. Scientists at Reading University in southern England have been using a supercomputer called "ThamesBlue" to model the evolution of words in English and the wider family of Indo-European languages over the last 30,000 years. University of Virginia researchers are using supercomputers to construct digital 3-D models of historic architecture, ancient art and artifacts. Other academics are putting HPC into service in sociology, archeology, and other disciplines.

With some notable exceptions, HPC vendors and others in the HPC community have not been good at telling the HPC story to people outside of the worldwide HPC community, including government funders. The EC can help to remedy this situation in Europe by acting as the catalyst for assembling and communicating the HPC success story to broader European constituencies, including the general public. A substantial communications campaign of this kind is necessary, in our opinion, to build support for HPC that is commensurate with HPC's historical and potential contributions to European science, industry, and quality of life.

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21.0 OVERVIEWS OF EU HPC PROGRAMS

21.1 Overview of Programs

In this section, we give an overview of types of programs in HPC and analyze the common features and differences in Europe. In the survey of HPC stakeholders section we cover the European view of the success of these HPC programs.

The following types of program are included in this section:

- Programs supporting the development of new or the adaption of existing application codes and algorithms for parallel architectures
- Programs supporting special topics in computer systems and networking architecture, system's software, tools and programming languages and HPC applications
- Programs aimed at building new HPC infrastructures including substantial research activities that are tight to designing and developing these infrastructures or additional ones (like PRACE at EU level or HECToR in the U.K.). We tried to only take into account the pure "research in HPC" activities for our estimations
- Educational support for graduate/PhD schools in computational sciences

The following types of program are excluded from the scope:

- Programs consisting only of procurement and maintenance/running cost support for HPC infrastructures (supercomputers, grids, networks)
- Research programs that only use HPC resources, infrastructures, or applications to carry research in any scientific or industrial field
- Programs or projects contributing to define HPC research roadmaps such as the European Science Foundation Lincei Initiative or the European Exascale Software Initiative (EESI) within the framework of the International Exascale Software Project (IESP)

In terms of geographical scope, the HPC research programs listed in this section can be split according to their regional applicability:

- "EU wide" programs (e.g., within the FP 7 Capacities Program or ITEA 2 Programs)
- National research programs (e.g., German HPC software initiative)
- Regional research programs (e.g., programs emerging from competitiveness clusters like Paris Region System@tic in France)
- International programs with the main research being carried out in Europe (e.g.: in CERN in Switzerland ITER in France) have not been taken into account here

EU Program Overview

The largest HPC or HPC-related projects are funded under the FP7 Specific Program "Capacities" aimed at optimizing the use and development of research infrastructures and running until the end of 2013.

PRACE, and more focused EuFORia and IS-INES projects, are infrastructure projects that include some research activities to design and build these future research infrastructures. This part of their activities has been included in the above-defined scope. Two HPC specific ongoing programs also concentrate an important amount of funding: Deisa 2 (€10.2 million funding over 4 years) and HPC-Europa 2 (€9.5 million funding over 4 years). They play an important role in providing access to current and future Tier 0 and Tier 1 HPC infrastructures across Europe. However, one can hardly consider them as "research in HPC".

Almost all EC funded "Research in HPC" projects are small or medium-scale focused research actions called STREps that target a specific research objective in a sharply focused approach. IDC could not identify any HPC specific so-called "large scale integrating project" (IP) including a coherent integrated set of activities tackling multiple issues and aimed at specific deliverables.

21.2 EU HPC Programs by Country

Table 75 lists the main programs and funding bodies as well as a sample of typical projects. STTICO

Overview

In most Western European countries, HPC national programmes' main component is support for procurement and running of Tier-0, Tier-1 and Tier-2 HPC-systems either as explicit funding programs or hidden in the budgets of universities or research organizations. What varies more from one country to another is the existence of an additional strategic effort towards research in HPC and the extent of this effort.

Germany, France, UK, Finland, Norway, and Switzerland have launched comprehensive and visible national HPC strategies, including substantial financial support for research in HPC.

Germany

Germany's position in HPC was strengthened with the creation of the Gauss Centre for Supercomputing (GCS) that resulted from an alliance between the three national tier-0 centers: Forschung Zentrum Jülich (FZJ), the Leibniz-Rechenzentrum (LRZ) in Garching, and the Höchstleistungsrechenzentrum Stuttgart (HLRS), under the July 2006 agreement between the Federal Ministry for Education and Research (BMBF) and the Regional Ministries for Research of Bavaria, Baden-Württemberg and Nordrhein-Westfalen. Approximately 50% of government investment in HPC in Germany comes from the German states (Länder), which fund half of the three tier-0 centers. The computational science projects of the John von Neumann Institute for Computing (NIC) and the research activities of KONWIHR Bavarian Competence center for high performance computing bring together mathematicians, informatics and application domains with emphasis on the interdisciplinary development of new application codes.

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At the national level, a massive BMBF investment in the DGrid project (100 m€ over 5 years) resulted in a core grid infrastructure for German scientists. Recently, strong emphasis has been dedicated to HPC software research projects within the German HPC Software Initiative under the “IKT 2020 Förderprogramm.” The innovation policy of the German Federal Government is focused on technology developments aimed at scientific and technological leadership, and the integration of novel services. HPC is clearly seen as needed for these goals. The Call for “HPC Software for Scalable Parallel Computers” in January 2010 is intended to close the gap between HPC hardware performance and application software scalability on extremely parallel systems, the major barrier to progress in computational science and engineering in simulation-based HPC applications. Since the complexity of extremely parallel systems and applications requires interdisciplinary cooperation among experts in the application fields, mathematical methodology and computer science, the invitation of the new BMBF to submit HPC software proposals requires the projects to act as active nodes on an HPC software network to cooperate within the existing Gauss Alliance of local and regional computer centres and the national supercomputing centres. In particular, effective cooperations of the HPC community and users of commercial applications are expected.

France

France has long invested in HPC and simulation in defense in particular. A new impetus was provided in 2005 with the creation of a strategic committee for HPC (the CSCI — le Comité Stratégique du Calcul Intensif), the creation of GENCI (Grand Equipement National de Calcul Intensif), which is entrusted with funding and ownership of major computer equipment for the French computer centers for civilian research and the launch by ANR (Agence Nationale de la Recherche) of the call for projects, "Calcul Intensif and simulation", now called Program Cosinus. According to The French ANR (Agence Nationale de la Recherche) total ANR funding for research in HPC is €25 million a year.

ANR published a book in January 2010 to raise awareness of HPC research in France — "Le calcul intensif: technologie clé pour le future". This work reported that 37 out of 123 projects were categorized as belonging to HPC-related "competitiveness clusters". Three competitiveness clusters: System@tic with nine projects, Materalia (innovative materials for intelligent products of the future, Lorraine and Champagne-Ardennes region), with five projects, and Aerospace Valley (Toulouse Region with four projects) concentrated 50% of funding in terms of number of projects in 2009.

Competitiveness clusters (in particular System@tic) and large research labs (CEA, INRIA, CNRS) are where most research in HPC is carried out in France. Competitiveness clusters are mainly funded by the French Government via the FUI (Fond unique interministériel), but also by local government and the European Union through FEDER (European Regional Development Fund). Created at the initiative of CEA-DAM Ile de France, TER@TEC association, a member of the System@tic Paris Region Competitiveness cluster, has brought together more than 60 companies and research labs and built a high performance digital simulation competence center that has initiated or taken part in major HPC research projects within System@tic, such as POPS, Open HPC, or CDSL.

U.K.

The coordination of high performance computing (HPC) activities for academic research in the U.K. is the joint responsibility of the U.K. Research Councils. Acting on behalf of the Office of Science and Technology (OST), the Engineering and Physical Sciences Research Council (EPSRC) implements and runs the U.K. research councils.

In 2007, a Strategic Framework for High End Computing (HEC) was produced by the High End Computing Strategic Framework Working Group at the request of the High End Computing Strategy Committee. The roadmap includes the strategic direction of HPC developments in the U.K., access arrangements to HPC services, planning the procurement and location of HPC services, and promoting their widespread use. In terms of HPC research, it was decided that new initiatives and funding should be established to grow the discipline of CS&E within the U.K. as "an advanced and complex HEC e-Infrastructure is ineffective without the people with the expertise to utilize it." The HEC strategy also called for partnerships between U.K. organizations, including the Research Councils, industry and the Meteorological Office in order to produce economies of scale and to promote new opportunities for research and the technology transfer. The HET strategy also encourages interdisciplinary coordination activities between HPC consortia that participate to U.K. Collaborative Computational Projects. These Collaborative computational projects (CCPs) are projects that bring together the major U.K. groups in a given field of computational research to tackle large-scale scientific software development projects, maintenance, distribution, training, and user support.

The HEC strategy resulted in the High End Computing (HEC) program that is coordinated by the EPSRC coordinated. The two main centers supported are EPCC — Edinburgh Parallel Computing Center that manages both U.K. national HPC facilities (HECToR and HPCx) and CLRC- Daresbury Laboratory. A flagship initiative, the Hartree Center is a flagship initiative. It is currently being implemented as a new kind of computational sciences institute for the U.K. It will bring together academic, government, and industry communities to focus on multidisciplinary, multiscale, efficient and effective computation focused amongst others on the themes of energy, climate, health and security.

Finland

A leading country in computing and simulation, Finland has long developed a strategy to foster both science and industry competitiveness with HPC. Its unique large national center, CSC, provides both scientists and industry with HPC resources and runs grid projects with Finnish universities that host much smaller centers. These universities collaborate in a widely recognized efficient way with industry in a wide array of scientific disciplines including HPC. The main public funding organization for research and development in Finland, Tekes (Finnish Funding Agency for Technology and Innovation) funds industrial projects as well as projects in research organizations, and especially promotes innovative, risk-intensive projects in scientific areas defined at national level. Tekes allocates about half the financing granted to companies, universities and research institutes through the programs. Flagship program in Finland is the five-year program MASI program. The aim of MASI, which was launched in 2005, is to develop new modeling and simulation methods, to enhance the utilization of these technologies in industrial and service sectors, and to create a competitive edge for Finnish companies on global markets. The program is expected to catalyze new businesses based on modeling and simulation expertise. The approach of the program is multidisciplinary. The total cost of MASI program research projects amounts to €26.3 million over five years, with the share of Tekes amounting to €20.9 million. Other HPC or HPC-related projects are also funded by the Academy of Finland.

Norway

Norway has long been strategic on supercomputing with the Research Council of Norway (NFR) defining and implementing HPC policy. Launched in 2000, the Notur project provides the national infrastructure for computational science in the country to researchers at Norwegian universities and colleges, and operational forecasting and research at the country's Meteorological Institute. Half of Notur project funding came from NFR and the other half from a consortium of public and provided partners including major universities and industry. The NFR funded program eVITA provides funding to research projects aimed at developing new theories, new models, methods, algorithms, techniques, and tools for applying high-volume computing and data resources to problems in science, technology, and medicine. 60% of the programs' research component is dedicated to large-scale interdisciplinary projects that get an annual budget of €0.5 million to €0.7 million per year.

Switzerland

Top HPC research has long been performed in Switzerland by ETH Zurich and EPFL (Lausanne). In May 2009, the Bundesrat launched the HPCN strategic plan for HPC, and its use, positioning HPC high in the research and competitiveness agenda in Switzerland. HPCN is to be implemented over three years at a cost of €120 million. The third pillar of this strategy is research and education to enable scientists to efficiently use the future research infrastructure to be implemented within the framework of the strategy. This will result in the creation of an HP2CSwiss Platform for High Performance and High Productivity Computing, which will be run by ETH Zurich, l'Università della Svizzera italiana (USI) and EPFL. Part of this effort will be dedicated to research in HPC software.

Italy and Spain

Italy and Spain have not launched any comparable national HPC planning strategies . However, they have funded and now host some of the largest HPC centers in Europe, including Cineca in Italy and Spain's Barcelona Supercomputing Center (BSC). Research in HPC is substantial in both countries. BSC cooperates with worldwide leading HPC technology vendors and performs leading research in several HPC Research domains. In Italy, research is disseminated in a larger number of research labs and institutes such as ICAR (Istituto di Calcolo e Reti ad Alte Prestazioni) and Cineca. These universities and centers are also active participants in EU-funded projects.

Sweden, The Netherlands and Denmark

In another group, countries such as Sweden, the Netherlands, and Denmark have defined and implemented HPC strategies based on research infrastructures and grids to support their scientific communities. They have provided medium- or long-term funding for the installation, running costs, and future upgrades or replacements of their infrastructures. Although these countries carry out research efforts in HPC within universities' computational science departments, supercomputing centers, or public-private clusters, a high proportion of this research in HPC is carried out within EU-funded projects.

Belgium, Austria and Poland

In Belgium, research is undertaken more at the regional level, such as at Wallonia's Cenaero Center of Excellence in Aeronautical research (with funding from the EU FEDER program) and Flandria's Ghent University. Two other countries should be mentioned for their substantial "research in HPC" activities within their universities and internationally: Austria and Poland.

Greece, Cyprus and Turkey

Greece has been a long-time HPC participant through institutions such as the University of Athens, the National Technical University of Athens, and the Computer Technology Institute of the University of Patras, et al., as well as through participation in EU collaborations. The Cyprus Institute plays a major role in supporting HPC initiatives and international collaborations, which also boasts a talented, experienced HPC research community. Turkey inaugurated its National Center for High Performance Computing in 2004 as a resource for both scientific and industrial research.

TABLE 75

European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
EC funded				
FP7 Capacities Program				
PRACE (includes research activities to design and build a permanent supercomputing infrastructure)	Building a world-class pan-European high performance computing (HPC) service	Size: €20M (EU: €10M) for 2 year preparatory phase ending in Dec 2009, and €20M (EC: €10M) for the implementation phase starting in July 2010	6 Principle partners: France (GENCI), Germany(GCS), Italy (CINECA), NL (NCF), Spain (BSC), U.K. (EPSRC). 14 other countries (general partners) including Turkey and Serbia	/www.prace-project.eu/about-prace/
IS-INES (InfraStructure for the European Network for the Earth System Modeling	Climate	Size: €10.7M (EC: €7.6M) March 2009–February 2013	Deutsches Klimarechenzentrum GMBH, Meteo France, Sveriges Meteorologisk a och hydrologiska Institut, Centro Euro-Mediterraneo Per I Cambiamenti Climatici, MET Office, CNRS, CERFACS, Max Planck Gesellschaft, Universities (Manchester, Linkopings…)	https://is.enes.org/ http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=0123c23a5a2d:b5d2:66daf260&RCN=91270
Euforia (EU Fusion fOR Iter Applications)	Nuclear	Size: €4.7M Jan 2008–Dec 2010		http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=10049250&pid=58&

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European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
				q=A5A085D4C2188273E6137C3663A23A95&type
FP 7 Cooperation Energy and ICT				
Hyperdno (HPC Technologies for Smart Electricity Distribution Network Operation)	Electricity smart grids	Size: €6.5M (EC: €4.4M) Feb 2010–Jan 2013		http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11157224&pid=26&q=A5A085D4C2188273E6137C3663A23A95&type
FP7 Future and Emerging Technologies (FET) Proactive initiatives				

TABLE 75

European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
FP7 Objective ICT-2009.3.6 Computing Systems	Systems	EC Funding: €12.5M Per year		
ICT-eMuCo (Embedded multicore processing for mobile communication systems)		Size: €4.6M (EC: €2.9M) from Feb 2008 to Jan 2010		http://www.emuco.eu/
FP7 TeraComp Program	Systems	EC Funding: €15M (Start: Jan–Feb 2010)		http://cordis.europa.eu/fp7/ict/fet-proactive/teracomp_en.html
FP7 TeraComp Program — Teraflux Project	Systems	Size: €7.5M (EC: €5.7M)	Universita degli Studi di Siena, Microsoft Israel, BSC, Thales, INRIA, Universität Augsburg, University of Manchester…	http://cordis.europa.eu/fetch?CALLER=PROJ_ICT&ACTION=D&CAT=PROJ&RCN=93541
FP7 Perada Program (Pervasive Adoption)	Pervasive information and communication systems			http://www.perada.eu/
Symbrion (Symbotic evolutionary robot organisms) project	Artificial Intelligence	EC funding: €6.8M	Universität Stuttgart, Institute of Parallel and Distributed Systems	
Other EC funded projects				
Towards EXaflop applications (TEXT)	HPC programming model, tools, and applications	€3.5M for two years (mid 2010–mid 2012)	BSC, HLRS, FZ Jülich, EPCC, FORTH, Univ. Manchester, Univ. de Pau, Univ. Jaume de Castillion, IBM Zurich,	
VC Compat	Crash tests	Size: €5.8M (EC: €3M over 12 years		http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=10093019&pid=75&q=A5A085D4C2188273E6137C3663A23A95&type=sim
Other European Initiatives (not EC funded)				
EUREKA				http://www.eurekanetwork.org/
ITEA 2 Program				www.itea2.org/

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European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
ITEA 2 Program/ParMa project	HPC multicore programming	€12.6M for 3 years (Jun 2007–May 2010	Germany, France, Spain, U.K.: FZ Jülich, TU Dresden, HLRS, GNS, RECOM, Magma, GWT, Allinea, Bull, Uni. Versailles, CEA-LIST, Dassault, CAPS, INT, Indra, UAB, Robotiker	http://www.parma-itea2.org/
ITEA 2 Program/HiPiP project	High Performance Image Processing		The Netherlands, France: Clusters System@tic (France) and Point One (NL)/Philips Healthcare, FEI Technosolution, Bull, CEA, DOSIsoft, IMSTAR	http://hipip.eu/
CATRENE Program				http://www.medeaplus.org/index.php
CATRENE Tsar project	HPC Architectures			http://www.catrene.org/web/medeaplus/appli_phase2.php
Open European Network for High Performance Computing on Complex Environments				http://w3.cost.esf.org/index.php?id=110&action_number=IC0805
NATIONAL				
Germany				
German HPC Software Initiative under IKT 2020	HPC	Funding: BMBF 1st HPC Software Call (9 January 2010) and 2nd (date still open) Size: €40M		http://www.bmbf.de/_search/searchresult.php?URL=http%3A%2F%2Fwww.bmbf.de%2Ffoerderungen%2F14191.php&QUERY=hpc+und+software
D-Grid Integration Project Phase 1 and 2 (2005-2010)	Grid	Funding: BMBF €11.5M Total D-Grid Project Size: €100M over 5 years (Sept 1, 2005–Dec 31, 2010)	21 partners: Supercomputing Centers (Leibniz-Rechenzentrum, Jülich), Universities (such as Universität Hannover), several applied Research labs (Fraunhofer)	www.d-grid.de
SILC (Scalable infrastructure for the automatic performance analysis of parallel codes)	HPC programming tools	Funding: BMBF Size: €1.5M 01/2009–12/2011	FZ Jülich, RWTH Aachen, TU Dresden, TU Munich, GNS mbH	http://www.vi-hps.org/projects/silc/

TABLE 75

European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
eeClust — Energy efficient Cluster Computing	HPC Systems	Funding: BMBF ~€1.2M	FZ Jülich, DKRZ, TU Dresden, ParTec	http://www.eeclust.de/
Highly Scalable Eigenvalue Solvers for Petaflop Applications (ELPA)		BMBF 2008–2012	Rechenzentrum Garching Bergische Universität Wuppertal, Lehrstuhl für Angewandte Informatik, Fritz-Haber-Institut, Berlin, Max-Planck-Institut für Mathematik in den Naturwissenschaften, Leipzig, IBM Deutschland	http://www5.in.tum.de/wiki/index.php/Running_Research_and_Development_Projects#Highly_Scalable_Eigenvalue_Solvers_for_Petaflop_Applications_.28ELPA.29
ScaFaCoS — Scalable Fast Coulomb Solver	HPC tools	Funding: BMBF	FZ Jülich, University of Bonn, University of Chemnitz, University of Stuttgart, University of Wuppertal, Fraunhofer Institute SCAI St. Augustin , Max-Planck Institute for Polymerscience Mainz, BASF, IBM, Cognis	http://www.fz-juelich.de/jsc/scafacos/
France				
ANR funded Program COSINUS	Conception and Simulation	10–15 projects/year, ? €7–15M /year		http://www.agence-nationale-recherche.fr/AAPProjetsClos?NodId=18&lngAAPId=272
Collaviz	HPC tools	Size: €4M ANR (€2M) Jan 09–Dec 11	17 ANR funded French partners (Teratec, EDF, Faurecia, INSA Rennes, Digiteo Scilab, Oxalya) + 10 foreign associates partners (Cardiff University, Colorado School of Mines, Web3D Consortium	www.collaviz.org
OMD2	Automotive	Size: €7.3M ANR (€2.8M) July 09–June 12	Renault, SMEs, Public Research labs (INRIA, ENS Cachan)	Omd2.wikispaces.com
LN3M	Tools	ANR (€8.2M) Jan 2006 (45 months)	CEA; CNRS, Université Lyon 1,Ecole Nationale des Ponts et Chaussées	

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European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
ANR funded Program ARPEGE (Systèmes embarqués et grandes infrastructures)				
USS-Simgrid	HPC Architectures	Size: €3M ANR (€839K) Jan 09–Dec 11 Research instit. universities	INRIA (Grenoble, Saclay, Bordeaux), CNRS, Université Nancy, Université Reims	.uss-simgrid.gforge.inria.fr/
ANR funded Program "RNTL"				
OMD	HPC tools	Size: €3M ANR (€1.2M) Jun 06–Dec 09	Astrium ST, Dassault Aviation, Renault, Scilab, Ecole Centrale Paris, ENS Cachan, INSA Rouen, INRIA, Onera, UTC Compiègne…	.leriche@emse.fr
ANR funded programs "Vulnérabilité Milieux Climat"				
MEDUP	Climate	Size: €4.8M ANR (€834K)	GAME/CNRM, CIRED research labs	www.cnrm.meteo.fr/medup
Other ARN funded programs: "Matériaux Fonctionnels et Procédés innovants", "Calcul Intensif et Grilles de Calcul", "Biologie Systémique"				
CEA/DAM program Tera	Nuclear			http://www-lmj.cea.fr/fr/programme_simulation/tera.htm
Finland				
MASI Program	Modeling and Simulation	TEKES (Finnish Funding Agency for Technology and Innovation) 2008: Total Size: €26.3M, of which Tekes: €20.9M.		www.tekes.fi/en/document/42726/masi_yearbook_pdf
Finnish CoE in Inverse Problems Program	HPC	Academy of Finland	University of Helsinki, Helsinki University of Technology, University of Kuopio, Lappeenranta University of Technology, University of Oulu	http://www.aka.fi/en-gb/A/Science-in-society/Centers-of-Excellence-/Centers-of-Excellence-in-Research-in-2006-2011/Finnish-CoE-in-Inverse-Problems/

TABLE 75

European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
Ketju Program — Suswood	Forestry	Academy of Finland	University of Helsinki, Helsinki University of Technology, University of Kuopio, Lappeenranta University of Technology, University of Oulu	http://www.aka.fi/Tiedostot/Tiedostot/KETJU/vuosiraportit%202008/SUSWOOD2008annualreport_final.pdf
U.K.				
ESPRC (Engineering and Physical Sciences Research Council) funded programs				http://gow.epsrc.ac.uk/ViewPSP.aspx?PSPId=269
Hector				http://www.hector.ac.uk/about-us/
The Hartree Center				http://www.cse.scitech.ac.uk/events/Hartree_Summary/
http://www.cse.scitech.ac.uk/arc/index.shtml				
Spain				
BSC Research activities	HPC			http://www.bsc.es/plantillaE.php?cat_id=2
Italy				
Cineca Research activities	Heath Care HPC applications		Italian Medicines Agency (AIFA), Superior Health Council, National Institute of Health — ISS, Research Institutions (Universities, non-profit Organizations.), Health Associations, Drug Companies, Local Care Units, European Organizations (SIOPEL), International Organizations (NABTT, JHU U.S.).	http://www.cineca.it/en/area/services_healthcaredep.htm
The Netherlands				
Lofar	Astronomy			http://www.lofar.org/astronomy/surveys-ksp/surveys-project-description/surveys-ksp-project-description

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European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
Norway				
eVita Program Research component		Research Council of Norway (NFR)		http://www.forskningsradet.no/servlet/Satellite?c=Page&cid=1226485583597&pagename=evita%2FHovedsidemal
The Power of Scale-Space Methods and Gaussian Markov Random Fields Applied in Climatology and Medicine		01.01.2007–31.12.2011		http://www.forskningsradet.no/servlet/Satellite?c=Page&cid=1226485583597&pagename=evita%2FHovedsidemal
Structure Preserving Algorithms for Differential Equations — Applications, Computing, Education		01.01.2007–31.12.2011		http://www.forskningsradet.no/servlet/Satellite?c=Page&cid=1226485583597&pagename=evita%2FHovedsidemal
Switzerland				
HP2C (Swiss Platform for High Performance and High Productivity Computing),	System and Application Software	HPCN Strategy Federal Government funding: €3.4M per year (2010–2012) of which probably 50% for research in HPC	ETH, Zurich, Università, della Svizzera italiana (USI) l'EPF de Lausanne	http://www.ethrat.ch/content/ethr_fact%20_sheet_HPCN_f.pdf
REGIONAL				
CEN Aero (Belgium)	Aeronautics	FEDER (EU): 50% , Wallonia Region: 50%		http://www.cenaero.be/Page_Generale.asp?DocID=15327&langue=EN
Competitive Clusters (France) such as System@tic), Materalia, Aerospace Valley	HPC			
System@tic/Teratec CSDL project	HPC tools			http://www.teratec.eu/activites/projetsR_D_systematic.html
System@tic Opus project (France)	HPC tools	Size: 2.2M ANR (€942K) April 08–Mar 11 System@tic Paris Region Cluster	EDF, CEA, Dassault Aviation, EADS, Softie, Ecole Centrale Paris, INRIA, Supple, Paris 7, Grenoble 1	Alberto.pasanisi@edf.fr
KONWIHR (Germany)	HPC			http://www.konwihr.uni-erlangen.de/about-konwihr.shtml

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European HPC Programs

Programs/Projects	Focus	Funding Sources/Estimated Size	Participating Bodies	Web site
ISAR (Germany)	Integrated system and application analysis for massive parallel computers	BMBF Oct. 2008 to Sept. 2011	University of Munich, Leibniz Compute Center (LRZ), Compute Center Garching (Max-Planck), ParTec Competitiveness Cluster	http://www.parastation.com/ccc2.php?lang=en&page=Projects#p_isar

Source: IDC, 2010

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22.0 INITIAL OBSERVATIONS ABOUT THE POTENTIAL EU HPC DIRECTION

The recommended HPC strategy ideas and implementations will appear in the Final Report that is scheduled to be submitted to the European Commission by the end of July 2010. In this report, we highlight the suggestions made by HPC stakeholders regarding the future direction of HPC in Europe. Both this Interim Report and the Final Report will be posted for public comment on the project Web site (www.hpcuserforum.com/EU).

22.1 HPC Use is Indispensable for Advancing Science and Industrial Competitiveness

HPC-based modeling and simulation has become firmly established as the third branch of scientific inquiry, complementing traditional theory and physical experimentation. All components of the research done by IDC for this study support the notion that science should be the primary beneficiary of an EU HPC strategy. Every one of the respondents in the broad survey of the HPC community in Europe agreed that HPC is "extremely important" (89%) or "important" (11%) for scientific leadership

But HPC has also proved important for industry. Recent IDC studies revealed that 97% of tier 1 industrial firms that have adopted HPC consider it indispensable for their ability to compete and survive. Separate studies showed that SMBs that adopt HPC typically report similar benefits. And in the broad survey of the European HPC community IDC conducted for this report, every one of the respondents said that HPC is "extremely important" (66%) or "important" (34%) for industrial competitiveness — this despite the fact that the mix of survey respondents was heavily skewed toward science.

Survey Comments

"HPC is a major tool for most scientific activities."

"The number of researchers who have migrated from the two traditional methodologies to computer modeling has become so significant that scientific leadership cannot be achieved without a significant presence in HPC."

"Applied research utilizing HPC is extremely important for industrial competitiveness."

"[HPC is] extremely important for industry sectors such as aerospace, oil and gas, energy, chemistry and life sciences."

"Future drug development and personalized medicine will heavily rely on HPC and simulation-based research."

22.2 Both Science and Industry Should Have Substantial Access to EU HPC Systems

In surveys and in the in-depth interviews conducted for this report with key HPC leaders in Europe, all but one of the interviewees stressed that not only science, but European industry must also have substantial access to EU-sponsored HPC systems. They argued that this is essential for European industrial competitiveness and economic advancement. Some industrial problems are as challenging as scientific problems, and without access to large HPC systems, industry will have nowhere to go to solve these important problems.

Survey Comments

"Leadership is really about leading in science and engineering, not in HPC. HPC is just a tool, a means to an end."

"It is absolutely crucial that industry have access to EU HPC systems. Big industrial problems can be as challenging as big scientific problems, and without access to big HPC systems industry has no way to solve these problems. If the EC excludes industry, then it is a waste of money to have HPC systems in Europe."

"These investments are only of value if we can use them to solve problems that are important for the European people and economy. We need a way to commercialize basic science. You start with basic science, then applied science, then industrially relevant problems. Any center receiving money from the EC should have a clear plan for making work done on these systems useful to industry and there should be an annual review of this by each center that receives EU funding."

22.3 Europe is Under-Investing in HPC at a Time When Other Nations Are Ramping Up

Spending in the HPC "supercomputer" market segment for systems priced at $500,000 and up is an important general measure of HPC leadership. In 2005–2009, which includes the 2008 and 2009 recession years, North America's 5.5% growth rate outpaced the worldwide average, as did Japan's 10.7% on a much smaller base. EMEA's revenue figure remained essentially flat (0.5% CAGR) during this period, meaning that EMEA has barely participated in the recent resurgence of high-end system purchasing.

During the economically challenging 2007 to 2009 period, purchases of "supercomputer"-priced HPC systems increased 38.5% in North America, 284% in Japan (a figure heavily skewed by a few major upgrades), stayed flat in the rest of the Asia-Pacific region, but declined by 9% in the EMEA region, which consists almost entirely of Europe. In sum, EMEA lost ground to other world regions, especially North America, during this period.

The top bracket IDC tracks in the "supercomputer" segment is for HPC systems sold for $3 million (€2.25 million) and up. This segment includes the largest, most powerful systems and is where HPC leadership initiatives reside. The $3 million-plus segment exhibited strong growth (CAGR) of 11.5% during the period 2009–2013 and expanded by a whopping 65% during the difficult 2009 recession year to reach about $1.4 billion (€1.0 billion) in value.

During the 2005 to 2009 period, the expansion of this segment was driven primarily by dramatic 2009 spending increases in North America, where 2009 revenue skyrocketed 208% over 2008 (after four very slow growth years). EMEA spending in this high-end leadership price bracket also shot up in 2009, increasing 183% over the prior year, but still lower than EMEA's 2007 pre-recession spending in this price bracket (the 2009 North American figure, by contrast, easily reached an all-time high). In 2009, for the first time during this five-year period, Japan handily outspent all of EMEA in this price band.

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22.4 Europeans Rank U.S. and Japanese HPC Research Programs Ahead of Europe's

In the broad survey of the European HPC community, the vast majority of the respondents were from Europe (a few individuals in North America and Japan were also invited to complete surveys for purposes of comparison). Yet, the survey respondents most often named U.S. and Japanese programs as the most successful in the world. In fact, non-European HPC research programs occupied the top six positions in the ranking, with the PRACE program in the seventh position.

Most Successful HPC Research Programs Worldwide

- U.S. Department of Energy — SciDAC
- U.S. Department of Energy — INCITE
- U.S. National Science Foundation
- Japan's RIKEN /Keisoku Project
- U.S. Department of Defense — DARPA
- U.S. Department of Defense — High Performance Computing Modernization Program
- PRACE

Most Successful HPC Research Programs in Europe

- PRACE
- DEISA
- CEA-DAM
- CERN
- HPC Europa

22.5 There is Strong Support for Expanding PRACE

In the broad survey, the PRACE and DEISA programs were mentioned most often, by far, as the most successful HPC research programs in Europe. And throughout the survey and the in-depth interviews, there was strong support for the existing PRACE model and for employing this model as the basis for a more comprehensive EU HPC entity. The chief criticism of PRACE was that its existing mission is too limited to service-oriented HPC resource distribution. A more comprehensive mission for HPC in Europe, some respondents argued, would be driven by a small set of scientific, engineering, and technology objectives.

Support for PRACE was hardly universal, however. The main criticism leveled at PRACE is that the focus of the program is too limited to making time on HPC systems available, rather than pursuing a scientific and engineering leadership strategy.

22.6 HPC Investment Should Focus on Science and Engineering Areas Where Europe Can Excel

Both in the broad survey of the European HPC community and in the in-depth interviews with key HPC leaders, there was strong consensus that HPC leadership should be explicitly driven by a limited number of important societal goals, rather than spreading time and funding over a large number of less-important priorities (this is not to say that the smaller priorities should not get some attention as well). Hence, there was support for focusing most heavily on computational science and engineering areas where Europe already has the potential to be a global leader. Among the most frequently mentioned areas were clean energy, climate modeling, bio-sciences, materials science/nanotechnology, oil and gas exploration/production, and aeronautics and crash simulation.

The HPC-enabled scientific and engineering areas most often proposed for leadership were as follows:

- Clean energy (including nuclear reactor design/operation, oil and gas exploration, smart electrical grids, clean water, fusion energy, and other alternative energy research)
- Climate modeling and severe weather forecasting
- Physics (e.g., the Large Hadron Collider)
- Aerodynamics and other automotive/aerospace methods
- Chemistry, pharmaceutical and other bio-life sciences research
- Algorithm and application software development. HPC experts in Europe and around the world stressed the importance of algorithm and applications software development for future HPC leadership and agreed that Europe is in a strong position to excel in this area.

"There are global challenges that need HPC that the EU can have a leadership position in. These include climate change and energy research."

22.7 Funding of HPC System Software and Applications Development is at least as important as funding HPC hardware technologies and integrated systems

There was also strong consensus among the survey and interview respondents that software development will be more important than hardware development for determining future leadership in the global HPC market, and that world-class developers in multiple important software domains exist within Europe today.

Although some people argued that Europe in the future should not be dependent on any other region for HPC hardware and should therefore develop its own HPC system, a clear majority of survey and interview respondents said that it would be unnecessary, infeasible, and a considerable diversion for Europe to try to compete with the U.S. and Japan by developing a European HPC system by 2020.

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"Algorithm development will be key and is what will allow people to get more than 3% of the performance of an exascale computer. Europe has some real strengths here."

22.8 The EU Should Invest in Pre-Competitive HPC Technology Areas

Although there was major consensus that Europe should maintain open procurements for competitive-stage HPC products and services, there was also a strong belief that the EU should promote the growth of the EU-based vendor community by providing them with funding support and advantages in procurements for the development of pre-competitive, enabling technologies.

Survey Comments

"It's important to distinguish between pre-competitive work and production industrial work. The involvement of companies and universities in pre-competitive work I consider very important."

"Public-private partnerships like HWW/Stuttgart are very good as long as they're limited to the pre-competitive stage. Our country has too much focus on theoretical research and lacks a link with the practical side."

"The EU should strongly support advanced, pre-competitive technology in Europe and also in the field of green computing technology for cooling and energy efficiency."

23.0 APPENDIX

23.1 Learn More: Related IDC Research

Additional research from IDC in the technical computing hardware program includes the following documents:

- *The Shanghai Supercomputer Center: China on the Move (IDC #222287, March 2010)*
- *GPGPUs Are Set to Make Headway in HPC Market (IDC #lcUS22216710, February 2010)*
- *IDC Leads Consortium Awarded Contract to Help Develop Supercomputing Strategy for the European Union (IDC #prUK22194910, February 2010)*
- *An Overview of 2009 China TOP100 Release (IDC #221675, January 2010)*
- *October 2009 HPC User Forum Meeting Notes: Lausanne, Switzerland (IDC #221355, December 2009)*
- *October 2009 HPC User Forum Meeting Notes: Stuttgart, Germany (IDC #220795, December 2009)*
- *September 2009 HPC User Forum Meeting Notes: Government HPC Trends (IDC #220790, November 2009)*
- *Massive HPC Systems Could Redefine Scientific Research and Shift the Balance of Power Among Nations (IDC #219948, September, 2009)*
- *The Second PRACE Industry Seminar (IDC #220029, September, 2009)*
- *China HPC Directions and Trends Looking at Evolution of the China Top 100 List (IDC #219952, September, 2009)*
- *The Race for the Fastest Computer Is Still On — Fujitsu's Petascale Project Plans* (IDC #lcUS21929009, July 2009)
- *Back-End Compiler Technology: HPC User Forum, April 2009, Roanoke, Virginia* (IDC #219119, June 2009)
- *I/O and Storage: HPC User Forum, April 2009, Roanoke, Virginia* (IDC #219121, June 2009)
- *HPC and Industrial Product Design: HPC User Forum, April 2009*, *Roanoke, Virginia* (IDC #219120, June 2009)
- *Petascale Computing: HPC User Forum, April 2009*, *Roanoke, Virginia* (IDC #219117, June 2009)
- *Alternative Processor Technology: HPC User Forum, April 2009*, *Roanoke, Virginia* (IDC #219118, June 2009)

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- *HPC and New Energy Solutions: HPC User Forum, April 2009*, *Roanoke, Virginia* (IDC #219122, June 2009)
- *Petascale Supercomputer Sales Continue to Grow: Cray Announces Largest Revenue Year Ever, with 52% Growth* (IDC #lcUS21683709, February 2009)
- IBM Sells First Petascale Supercomputer in Europe (IDC #lcUS21683809, February 2009)

23.2 Sites Invited to Participate in the Research

TABLE 76

Organizations Invited to Participate in the Research

Organization	Organization	Organization
Academy of Sciences	EPSRC	Panasas (Germany)
Acceleware	ESFRI	ParTec Cluster Competence Center
Airbus	ESI Group	Penguin Computing
Allinea	ETH-Zurich	Planning Bureau of the Republic of Cyprus
Altair Engineering srl	Eurotech	Platform Computing
AMD	Federal Ministry of Education and Research (BMBF)	Porsche
ANSYS U.K.	Flemish Supercomputer Center	PRACE — Cyprus Research and Educational Foundation
Appro	FNRS	PRACE — Faculda de Ciencias e Tecnologia de Universidade de Coimbra
Argonne National Laboratory	Forschungszentrum Juelich	PRACE — Greek Research and Technology Network
Atomic Weapons Establishment (AWE)	fturkey	PRACE — Institut Za Fiziku
Austrian Ministry of Science and Research	Fujitsu EMEA plc	PRACE — Instytut Chemii Bioorganicznej PAN W. Poznaniu
Barcelona Supercomputing Center	Fundaçao para a Ciência e Tecnologia	PRACE — National Univ of Ireland, Galway
BBWorld	Gdansk University of Technology	PRACE — Nat'l Center for Supercomputing Applications
BP	GENCI	PRACE — Swedish Nat'l Institute for Computing
Bull	Hellenic Ministry of Development	PRACE — Technical Univ of Istanbul
Bull SAS	HET International Scientific Panel	PRACE — Technicka Univerzita Ostrava
Calit2	Hewlett Packard	PRACE — UNINETT Sigma AS
Carnegie Mellon University	Hewlett Packard (Germany)	QLogic GmBH (Germany)
CASPUR	HLRN	Research Council of Europe
CCLRC/Daresbury Laboratory	HLRS (Stuttgart)	Riken
CD-Adapco (U.K.)	HPC Information Service — Enter the Grid	Russian Academy of Sciences — JSCC
CEA	HPC Project	SARA
CECAM — from EPFL	HWW (Stuttgart)	SCAPOS
CECAM — from Universita di Modena e Reggio Emilia	IBM	SGI
CERFACS	IBM (Germany)	SpectaLogic Europe
CERN	ICM — University of Warsaw	Streamline Computing
CILEA	IDRIS	Sun Microsystems (Sun/Oracle)
CINECA	Imperial College London	Swedish Research Council

TABLE 76

Organizations Invited to Participate in the Research

Organization	Organization	Organization
Cloud Era Ltd.	Institute of Graphics and Parallel Processing	Techila
ClusterVision	Institute of Meteorology and Water Management	Technical University of Madrid
Concurrent Thinking	Instituto Superior Tecnico	Technische Universitaet Wien
Cray	Intel	Technishe Universiteit Eindhoven
Cray (Europe)	Italian Ministry of University and Research	Teratec
Cray Research, Hewlett Packard	KAUST	Tokyo Institute of Technology
CSC	Lawrence Berkeley Lab — NERSC	T-Platforms
CSC-Finland	Leibniz Rechenzentrum	TUBITAK
CSCS	Louisiana State University	U.S. Department of Defense
CSIC	Max-Planck-Gesellschaft	United Kingdom Meteorological Office
Cyprus Institute	Mellanox	Universita degle Studi di Torino
Danish Center for Scientific Computing	Microsoft	Universita di Bologna
Daresbury Science and Innovation Campus	Microsoft (Europe)	University of Bergen
Dassault Systemes Simulia Corp.	Ministry of Education, Division for Higher Education and Science	University of Bristol
DEISA	Ministry of Education, Research Council	University of Edinburgh -EPCC
Dell (Europe)	Ministry of Science and Higher Education	University of Erlangen
Direct Data Networks (Europe)	Moscow State University	University of Genoa
DKRZ	NAG	University of Groningen
Dresden University of Technology	National Institute for Applied Sciences	University of Madrid
ECCOMAS — Dassault Aviation	National Institute of Nuclear Physics	University of Manchester
ECCOMAS — Laboratoire Jacques-Louis Lyons	National Oceanography Center	University of Mannheim
ECCOMAS — Nat'l Technical Univ of Athens	National Technical U. of Athens	University of Roma — "La Sapieza"
ECCOMAS — Univ of Jyväskylä	NEC	University of San Sebastian
ECCOMAS — Univ of Stuttgart	Netherlands National Science Foundation	University of Southampton
ECMWF	Netherlands Organization for Scientific Research	University of Sussex
Electricite de France (EDF)	Nicolaus Copernicus University	University of Tennessee
EMC	Nvidia	University of Tsukuba
EML Research	Oak Ridge National Laboratory	U.S. Department of Energy
EPCC	ONERA	Voltaire
EPFL	ORAP	Wroclaw Center for Networking & Supercomputing

Source: IDC, 2010

23.3 HPC Survey Questionnaire

Introduction

Special EU HPC Study: The Development of a Supercomputing Strategy for Europe

As an important member of the European HPC community, we wish to invite you to be part of the group developing a common vision for the future of HPC in Europe. The European Commission has contracted IDC to support the development of a supercomputing strategy for Europe and we would like you to join us in developing this strategy.

We are looking for your ideas, insights and thoughts, starting with the completion of the attached survey. You will have access to a web page where you will be able to add your additional ideas, feedback and comments throughout the process. This web site will also contain the results of the research of the study and various background reports. The Web site will be up and running in a few weeks at: **http://www.hpcuserforum.com/EU**

If you agree to be part of this team your name can be listed in the report as a contributor (or if you prefer you can choose to remain anonymous). In either case your opinions and ideas will be highly valued by us and the Commission.

We look forward to your answer at your earliest convenience; if possible it would be great if you could complete it within the two weeks. Please do not hesitate to contact us for any further information.

Best regards,

Earl Joseph II   Steve Conway   Chris Ingle

ejoseph@idc.com   *sconway@idc.com*   *cingle@idc.com*

Note: This study is being conducted on behalf of the DG Information Society and Media of the European Commission (SMART 2009/0055, Contract number 2009/S99-142914).

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Additional information about IDC and the reports we produce can be found at: www.idc.com and www.hpcuserforum.com.

Survey Questions

By HPC, IDC means the technical compute resources (hardware, software, storage, networking and services) applied to computationally intensive or data intensive problems as used in government, academia, and many industries including: automotive, aerospace, finance, oil/gas, life sciences, electronics, transportation, and others.

This study is focused on the higher-end of the HPC market, often referred to as "Supercomputers" and sometimes to referred to as "Capability" computers or called "Petascale-class" and "Exascale-class" computers. In these questions, we use the term HPC to refer to the higher-end of the HPC market.

Your Name: ______________________________

Your Company/Organization: ____

Your E-mail: ________________________

Your Phone Number: _____________________

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1) What is your primary role in the HPC sector?

___ A user, datacenter manage, or part of an end-user organization

___ A provider of HPC hardware, software, applications, networking, storage, grids, clouds or services

___ A funding body that funds HPC activities

___ An industry expert

___ Other, please explain: ______________________________

2) How important is HPC for **scientific leadership**?

___ Extremely important

___ Important

___ Not important

Comments: ____

3) How important is HPC for industrial competitiveness?

___ Extremely important

___ Important

___ Not important

Comments: ____

4) How important is it **for your company/organization** to have access to leading HPC systems and other leading HPC resources (e.g. software, networking, storage, experts, etc.)?

___Extremely important

___Important

___Not important

Comments: ____

5) How important is it **for your country** to have access to leading HPC systems and other leading HPC resources (e.g. software, networking, storage, experts, etc.)?

___ Extremely important

___ Important

___ Not important

Comments: ____

6) How important is it for the **EU as a region** in a competitive global marketplace, to provide EU member states with access to leading HPC systems and other HPC resources (e.g. software, networking, storage, experts, etc.)?

___ Extremely important

___ Important

___ Not important

Comments: ____

7) Can you think of **specific scientific or engineering areas** that the EU should support by providing access to leading HPC systems and other HPC resources (e.g. software, networking, storage, experts, etc.)?

___ Yes

___ No

Please describe them: ________________, ___________________

8) What general areas do you think the EU should focus on in developing a stronger HPC leadership position (please pick your top 3, with 1 being most important)?

___ Core technologies: **HPC systems**

___ Core technologies: **HPC interconnects**

___ Core technologies: HPC middleware and system software

___ Core technologies: HPC applications and applications scaling

___ Core technologies: HPC storage (internal and external)

___ Core technologies: **HPC services**

___ Core technologies: External HPC services, platforms, grids and/or clouds

___ The use of HPC to solve important **scientific problems**

___ The use of HPC to solve important **engineering problems**

___ An area not named above, Please specify: ______________________

___ None. The current approaches are working fine.

9) Please rate the following **specific technical areas** that you feel the EU should focus its HPC efforts, using a scale of 1 to 10 with: 10 = most important, 1 = least important:

___ HPC system hardware — complete systems

___ Power and cooling costs

___ System scalability

___ System manageability

___ Processors — standard x86

___ Processors — standard accelerators, e.g. GPGPUs

___ Processors — custom

___ New memory technologies

___ Interconnect hardware

___ Interconnect software

___ New storage hardware, including SSDs

___ Storage software/file systems

___ Storage interconnects and backbone protocols

___ Large external storage farms

___ Systems software, including operating systems

___ Compilers and new programming languages

___ Profiling tools

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___ Parallel programming tools Debugging tools

___ Job scheduling and queuing tools

___ Libraries

___ System grid/monitoring/management software

___ New applications software — open source

___ New applications software — fee based

___ Personnel, talent, skill sets and training, including access to external HPC services and experts

___ System hosting solutions (utilities, grids and clouds)

___ Other, Please describe: ___________________________________

___ Other, Please describe: ___________________________________

10) What actions are needed at the national and EU level to improve the EU leadership position in HPC?

At the national level:

At the EU level:

11) In your view, what are the potential consequences if the **EU does not** take any additional steps to develop leading HPC capabilities on behalf of the member states??

12) Are you able to provide an assessment of the HPC contribution to scientific or economic leadership within the EU?

___ Yes, in this scientific area:_______________, creating this benefit:__________

___ Yes, in this scientific area:_______________, creating this benefit:__________

___ Yes, in this economic area:________________, creating this benefit:_________

___ Yes, in this economic area:________________, creating this benefit:_________

___ Yes, in this area:_________________________, creating this benefit:_________

___ Yes, in this area:_________________________, creating this benefit:_________

EU SWOT Analysis Questions

13) What are the EU's greatest **strengths** in HPC today?

14) What Are the EU's Greatest Weaknesses in HPC Today?

15) What are the EU's greatest **opportunities** in HPC today?

16) What are the greatest **threats** to EU's leadership today?

17) What are the **major challenges** that need to be overcome to enable the EU to become a leading provider and user of HPC?

Successful HPC Research Programs

18) What are the Top 3 research programs **around the world today**, and what in your opinion makes them successful?

19) What are the Top 3 research programs **in the EU today**, and what in your opinion makes them successful?

20) What **new HPC research programs** would you like to see **added** to the EU agenda?

HPC Leadership Questions

21) Which of the following are the most important for EU HPC leadership? (Please check all that apply):

___ Having many very large supercomputers, e.g., being at or near the top of the Top500 list of the world's most powerful supercomputers (www.top500.org)

___ Making world-class HPC resources more widely available to the EU scientific and engineering communities

___ Making HPC more readily available for the first time to small and medium-size businesses (including industrial supply chains, small educational sites, etc.)

___ Advancing scientific leadership by using HPC to solve some of the world's most challenging problems

___ Building an EU-based HPC vendor community with world-class capabilities in important areas (hardware, software, storage, networking, etc.)

___ Another measure of EU HPC leadership, Please explain:

22) In your view — What are the critical areas of HPC expertise that are MOST needed to help make the EU stronger?

For USER organizations:

For vendors, suppliers of HPC products and services:

23) In your view — What should the EU do to help develop, and obtain these critical skills and experts?

HPC Market Structure and Business Models

24) Should the EU try to change the HPC market structure or HPC business models?

___ Yes

___ No

___ No opinion

Please explain the changes that are needed: _________________________

25) In your view, what are the best ways for the EU member states to **cooperate/collaborate** toward the goal of conducting research at petascale/exascale supercomputing speeds?

26) In your view, what **funding model or models would work best** for pursuing HPC goals in Europe?

27) In your view — What funding models **have failed in HPC**? Do you know of specific examples that should be avoided?

28) What is your company/organization's current funding approach for HPC?

___ Our HPC is primarily funded by our own organization

___ Our internal funding is helped by government funding from within our country

___ We receive multi-country funding, but it is less than 20% of our HPC costs

___ We receive multi-country funding, and it is more than 20% of our HPC costs

___ We have public-private partnership(s) that help to fund our HPC

___ Other, please explain: _________________________________

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Summary Questions On What You Would Like To See The EU Do Next

29) Overall, what would you like to see the EU do **to make Europe stronger in HPC**?

30) Which **HPC technology areas** should the EU focus its investments and support?

31) In your view, what should the EU do related to **HPC cloud computing**?

32) In your view, what should the EU **avoid doing in HPC**?

33) What **private-public partnerships** should the EU explore in HPC?

34) What **multinational HPC collaborations** would make the most sense for the EU to take on?

35) Which areas would you or your organization be interested in participating in?

36) Please feel free offer additional comments on any aspect of the survey here:

37) Would you like to be listed as a contributor in the report?

___ Yes. I would like to be listed in the report as a contributor.

___ No. Please don't list my name in the report.

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