Executive Summary

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Analyze the Future
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ABSTRACT

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

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

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

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

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

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

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

Overall, the main actors—the European Commission, PRACE and ETP4HPC, have done an admirable job of coordinating with each other to advance the European HPC strategy, but more needs to be done. To amass the €1 billion-plus in funding needed to acquire pre-exascale and exascale supercomputers in globally competitive time frames, the Member States will need to find a way to pool resources and the EC will need to find a way to contribute a significant portion of the funding (IDC recommendation: 50%). As IDC stressed in our 2010 report to the Commission, adequate investments in software will be one of the most important determinants of future HPC leadership. In addition, the Commission may need to contribute to the escalating operating expenses associated with PRACE tier-0 supercomputers.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

   - In carrying out this study, IDC found that even some of the most prominent members of Europe's HPC community did not adequately understand the impact of governance models on the European HPC strategy—or how all the pieces of the strategy fit together. Stronger communications outreach is needed to convey this understanding.
2) **Financial envelope for HPC** spans current investment levels for the acquisition of high-end HPC resources in Europe, and analysis of required levels to meet the Action Plan objectives (including investments for system acquisition, training, HPC software and applications, etc.).

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

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

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

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

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

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

- Europe already has some of the world’s leading HPC centers for collaborations with industry, including SMEs. Many of the European HPC stakeholders IDC interviewed for this study agreed that European programs supporting industrial access and collaboration, such as PRACE, SHAPE and Fortissimo, have been successful but need to do more. Only a small percentage of European SMEs that could be helped by HPC seem aware of these opportunities, for example. The EC hasn’t done an optimal job of communicating the HPC strategy, resources, plans and contact persons to the broader HPC community, and in particular to industry.
6) Ensuring a level playing field, in particular regarding inequalities in HPC market access and exploitation obligations regarding intellectual property rights of HPC results generated in Horizon 2020.

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

Overall Recommendations

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

In Summary: Recommendations

Recommendations on the Strategic Actions

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

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

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

3) **Develop the HPC Ecosystem** *(European Supply Capabilities and Governance).* ETP4HPC should continue to support collaborations involving European suppliers and (often much larger) non-European suppliers. This will accelerate the learning curve of some European suppliers who are less experienced. European suppliers will benefit from competing on equal terms with suppliers not based in Europe. Software will be one of the main determinants of future HPC leadership and Europe is very strong in parallel software development. ETP4HPC or another organization in Europe should create a clearinghouse (online storefront) to help disseminate, and in some cases commercialize, innovative European HPC software that is now in limited use.

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

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

**Additional Recommendations**

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

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

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

- **Centers-of-Excellence.** These fall under the cPPP on HPC. The centers should focus heavily on software—not just applications but also the whole HPC software stack (EESI has done an excellent job of laying the groundwork for this). At a minimum, one center should focus on the software requirements of industry, and one center be devoted to HPDA.

**Acronyms Commonly Used in This Report**

The following acronyms appear frequently in this report:

- **cPPP** Contractual Public Private Partnership
- **EESI** European Exascale Software Initiative
- **ETP4HPC** European Technology Platform for High Performance Computing
- **EU** European Union (of 28 Member States)
- **EU+** European Union (28 Member States) plus Norway and Switzerland
- **HPC** High Performance Computing
- **PCP** Pre-Commercial Procurement
- **PPI** Public Procurement of Innovative solutions
- **PPP** Public-Private Partnership
- **PRACE** Partnership for Advanced Computing in Europe
- **SHAPE** SME HPC Adoption Programme in Europe
- **SME** Small and Medium-size Enterprise(s)