European Parliament

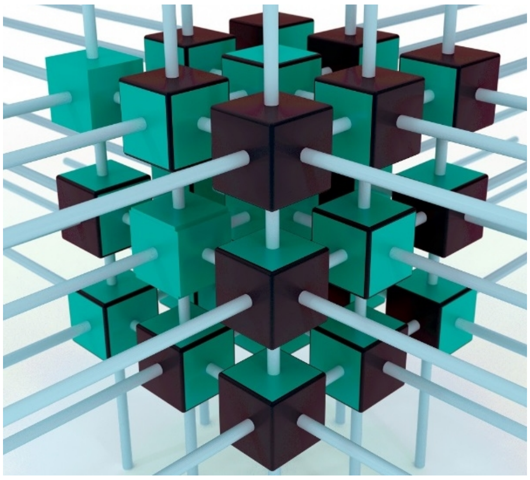
Developing supercomputers in Europe

SUMMARY

A number of companies, universities and start-ups are racing to develop the fastest supercomputer in global rankings. So far China, Switzerland and the USA occupy the top four places in this regard, while the EU does not feature in the top 10. To address the situation, the European Commission has launched, as part of its European cloud strategy, a target plan to acquire and develop European high-performance computers that would rank among the world's top three by 2022. This would allow European science and technology actors to regain competitive advantage.

Supercomputers are increasingly needed to exploit big data and facilitate scientific discoveries that need large computational efforts, such as materials science, artificial intelligence technologies, climate modeling and cryptography. As no single EU Member State has the capacity to develop this on its own, the Commission aims to launch an initiative on the scale of Airbus and, more recently, Galileo, to develop a European data-infrastructure ecosystem in high-performance computing. This has been set as a target in the European digital single market mid-term review, and it has also been established as a goal in the EuroHPC Declaration, which was signed during the first half of 2017 by nine Member States and more are expected.

In addition, the Commission has an ambitious €1 billion flagship initiative on quantum technology in place, which will also contribute to the development of quantum supercomputers in the longer term. Expected to surpass traditional supercomputers, the new ones could dramatically improve the technology used in communication, computing and sensing, as well as and in other areas.



In this briefing:

EPRS | European Parliamentary Research Service
Author: Mar Negreiro
Members' Research Service
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A global race to build supercomputers

Supercomputers operate a million times faster than regular (personal) computers. Traditionally, supercomputers have been used for complex, mathematically intensive problems, as they are capable of running scientific and engineering applications that handle very large databases and do a great amount of computation. That is why supercomputers are also referred to as 'high-performance' computers (HPC).

The results of these computational efforts are increasingly being applied in the simulation of space data, as well as in energy grids, material science, climate modelling, cryptography and the encryption of computer security codes, to mention a few. Thus, supercomputers are also increasingly important for advancing scientific discoveries and innovation in areas linked to artificial-intelligence technologies, such as driverless cars, robotics and medical diagnostics, where there are large amounts of real-time data and it is critical to take fast decisions.

All this would bring tangible impacts to our economies and societies. For instance, according to a report by a US Department of Energy research centre, supercomputing-led scientific advances could halve the unsubsidised cost of wind energy by 2030.

At present, supercomputers are part of a global race to develop the fastest supercomputer with exascale capacity.[1] This will require very large sums of investment and planning, and many countries have announced ambitious plans for building the next-generation HPC to deploy exascale state-of-the-art supercomputers. They have declared HPC a strategic priority and are funding programmes to develop national HPC ecosystems (hardware, software, applications, skills, services and interconnections).

China's *Sunway TaihuLight* supercomputer is currently leading the global race: singled out by a June 2017 global ranking as the world's most powerful, it has a processing power of 93 petaflops.[2] At its peak, it can perform 93 000 trillion calculations per second, way ahead of all other supercomputers ranked to date. The world's second-most powerful supercomputer, the *Tianhe-2*, is also Chinese, as are overall 167 of the 500 most powerful supercomputers participating in the above-mentioned ranking. Switzerland holds third place with its *Piz Daint* supercomputer, while the USA comes fourth with its *Titan*. Having slipped off the top three places, the USA is developing a number of supercomputers to help it regain the leadership it lost to China, earmarking an extra US$258 million for the purpose. However, that will take some catching up, given that China's Zhang Ting supercomputer, which is currently under development, is planned to be an exascale computer. Japan is also heavily investing in supercomputing technology and has said it will spend 19.5 billion yen (about €150 million) on a 130 petaflop computer, to make the country the new global hub for artificial intelligence research by April 2018.

What the EU is doing

The European cloud initiative

According to the European Commission, funding for high-performance computing in the EU and its Member States has declined heavily from 2013 onwards, as a result of which none of the world's 10 most powerful supercomputers are currently in the EU. Moreover, Europe depends ever more on other regions for critical technology, for the supply of key technological components for its supercomputing infrastructure, and for access to the most advanced computing facilities. Consequently, the Commission has set its own ambitious targets aimed at developing Europe's supercomputers and helping it regain its competitive advantage in the area.

As part of its Digital single market strategy, on 16 April 2016 the Commission published a package of measures for digitising European industry, including a communication on the European cloud initiative. Despite the potential economic benefits, demand for cloud services remains low in Europe, with only one in five companies using them. According to the Commission's communication, the EU is falling behind other regions, as it is failing to invest in its HPC ecosystem and to reap the benefits of intellectual property in this field. On the supply side, EU industry provides about 5 % of HPC resources worldwide, while it consumes one third of them. A Commission study sampling 143 European HPC projects has concluded that in the 59 projects generating quantifiable financial returns, each euro invested on average returned €867 in increased revenue/income and €69 in profits.

The European cloud initiative includes three actions: first, creating a European open science cloud to offer EU researchers a virtual environment that would allow them to store, share and reuse their data across disciplines and borders; second, deploying a European data infrastructure including the development of supercomputers and an HPC ecosystem to process the large amounts of data stored; and third, supporting awareness-raising activities to increase the cloud's usage, not only by scientists, but also by the public sector and businesses at large.

Developing a European HPC ecosystem

As part of the second action, the European cloud initiative calls on the Member States to support the development of a high-performance computing ecosystem, based on European technology. This includes, for instance, producing low-power chips with better energy efficiency and drafting an ambitious European exascale high-performance computing strategy. According to the Commission, this project would be on the scale of Airbus in the 1970s to 1990s for the production of competitive aircraft, and of Galileo in the 2000s for the development of a European autonomous satellite navigation system for geolocalisation. The goal is to have and develop exascale supercomputers based on European technology among the global top three positions by 2022.

To achieve this, the European cloud initiative plans to build on existing EU research infrastructure, such as the GÉANT network (which already connects 50 million researchers), the Partnership for advanced computing in Europe PRACE (which already provides researchers with access to eight supercomputers) and the European technology platform for high performance computing (ETP4HPC).

In its communication on the Mid-term review of the Digital single market strategy, the Commission announced its intention to propose, by end-2017, a legal instrument[3] for a procurement framework for an integrated exascale supercomputing and data infrastructure in Europe, in the EuroHPC initiative. The Commission has recently launched a consultation that expects to collect further stakeholder ideas in order to define the EuroHPC, such as the instrument to implement it, its governance structure and budget, so as to put HPC in place by 2019. According to the Commission, the estimated budget for the EuroHPC instrument in the 2019-2020 financial period is €480 million, which will be sourced from the EU budget (through the key EU funding instruments Connecting Europe Facility and the EU Horizon 2020[4] programme for research and innovation, in their respective work programmes for 2019-2020), supported by another €500 million raised by the Member States and matched by equivalent industry funds. Support for the development of an integrated world-class HPC and data infrastructure in Europe was boosted this year with the EuroHPC Declaration, signed thus far by ten EU Member States (Belgium, Bulgaria, Germany, France, Italy, Luxembourg, the Netherlands, Portugal, Slovenia and Spain) to advance work in this area, and more are expected to join it this year.

The EU quantum technology flagship

Finally, the Commission has included into the European cloud initiative a longer-term €1 billion flagship on quantum technologies, which will also consider the development of supercomputers based on quantum technology.5 This significant budget builds upon funding worth more than €300 million that had already been invested in quantum research in the framework of European research programmes over the past 20 years.

A quantum manifesto signed in 2016 by more than 3 000 representatives from academia, industry and government and funding institutions called for the Member States and the Commission to launch an ambitious, long-term, flagship-scale initiative combining education, science, engineering and entrepreneurship across Europe.

Recently, a first call for proposals for the flagship's preparatory phase has been launched, and the Commission plans to launch an operational phase within Horizon 2020 as of 2018. The new ambitious flagship is expected to facilitate the exploration of quantum information and the development of new applications with the potential to dramatically improve technology for communication, computing and sensing.

Preparing for a quantum computing revolution

Quantum technologies, a growing branch of physics and engineering, is an umbrella term for all technologies using quantum phenomena to achieve new goals. Created in Europe in the first decades of the 20th century,[6] quantum physics brought about a revolution, which resulted in ground-breaking technologies such as the transistor and the laser.

While traditional computers encode information in binary bits (with the value of 1 or 0) quantum computers are based on quantum bits or 'qubits' (units of quantum information). Qubits operate according to two key principles of quantum physics: superposition and entanglement. Superposition means that each qubit can represent both a 1 and a 0 at the same time. Entanglement means that qubits in a superposition can be correlated with each other; that is, the state of one (whether it is a 1 or a 0) can depend on the state of another. Since a quantum computer can contain multiple states simultaneously, it has the potential to be millions of times more powerful than today's most powerful supercomputers.

It is expected that the engineering of quantum phenomena could lead to new classes of devices and computing capabilities, permitting novel approaches to solving problems that cannot be addressed using existing technology and existing traditional supercomputers.

According to many, a second revolution is currently taking place with regard to the application of quantum technology, including quantum computing; the industrial and societal impacts of this revolution are likely to be radically transformative, as novelties, ranging from ultra-sensitive sensors for biomedical imaging, to secure communication networks, to new paradigms for computation and computers, gradually come to fruition. Some experts even warn that they are capable of engendering new global threats, for instance by making it possible to destroy modern cryptography, which is a fundamental building block of cybersecurity and digital data protection.

The quantum supremacy

Leading companies, such as Google, Microsoft and IBM, and research labs in Europe, Asia and the USA are investing heavily in quantum technologies. Moreover, they are racing each other to reach 'quantum supremacy', the point at which quantum computers become more powerful than traditional supercomputers. It is expected that quantum computing will soon achieve this historic milestone; Google claims it will do so by the end of 2017.

Some of the largest quantum simulations[7] have been done in the USA, Switzerland and China, which also lead the global race in traditional supercomputers. Chinese scientists reached an impressive quantum achievement in June 2017, after they succeeded in building the first quantum satellite network, which showcased the longest distance entanglement ever attained (1 200 km), and the first between the Earth and space.

Quantum computing for specific tasks will be more widely available over the next three to five years, as companies are increasingly investing in such projects. We are more than a decade away from computers that would be fully based on quantum technology, given among other things their current limited potential to scale up, create qubits and reduce error rates, when compared to traditional computers, which have been improved over decades. Yet, according to Google, early adopters will reap the rewards, as short-term returns on investment will be possible even with the small devices that will emerge within the next five years.

Currently, Europe is leading when it comes to research publications on quantum technologies, but not when it comes to investment in intellectual property in the domain. According to a recent expert report using Mckinsey data, over 50 % of academic papers in the field come from European scholars. In the 2013-2015 period, 2 455 EU authors published quantum physics papers, compared to 1 913 Chinese and 1 564 North American ones. However, China and the USA have the lead when it comes to patenting new quantum-based technology.

To improve this situation, some Member States are funding programmes that facilitate the transfer of academic research results into industrial products or applications by way of common projects carried out between academia and industry. Examples of such programmes are the UK's national quantum technologies programme QT Hubs, the Netherlands' advanced quantum research centre QuTech, Germany's quantum technologies initiative QUTEGA, and Denmark's quantum innovation centre QuBiz.

More developments are expected to take place in the EU as a result of the flagship on quantum technologies, which will also consider the development of supercomputers based on quantum technology. However, Brexit could create some problems for the flagship, as the UK has been leading in EU quantum research and patenting.

The European Parliament's position

In its resolution of 19 January 2016, Towards a digital single market act, the Parliament requested the Commission to establish a European open-science cloud by the end of 2016, 'which should seamlessly integrate existing networks, data and high-performance computing systems and e-infrastructure services across scientific fields within a framework of shared policies, standards and investments'. On 16 February 2017, the Parliament adopted a resolution on the European cloud initiative, which supports the Commission's initiative, yet asks for clarification on the next steps and on the €4.7 billion financing gap.[8] The total funding to be allocated to the European cloud initiative for all three of the above-mentioned actions and the quantum flagship is €6.7 billion over five years: According to the Commission €2 billion are expected to come from Horizon 2020 and the rest from other sources yet to be identified. The Parliament recalled that the EU is lagging behind in developing HPC as a result of its under-investment into an HPC ecosystem. Parliament welcomed the European cloud initiative as part of the implementation of the Digital single market strategy. It also called upon the Commission to tackle existing technical and legal barriers, such as lock-in effects that create dependency on others, or issues related to interoperability and standards; data protection and privacy; data location restrictions and copyright. Finally, it welcomed the Commission's €1 billion flagship-scale initiative in quantum technology, while stressing the need to accelerate its development and bring commercial products to public and private users, asking for a transparent and open stakeholder consultation.

Main references

The Impact of Quantum Technologies on the EU's Future Policies, Joint Research Centre, European Commission, 2017.

Intermediate Report from the Quantum Flagship High Level expert group, European Commission, 2017.

High Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy, analyst firm IDC, 2014.

Gutierrez D. D., Inside big data, deep learning and artificial intelligence, InsideBigData, Nvidia Corporation, 2017.

Mohseni M., Read P., Neven H., *et al*, Commercialise early quantum technologies in five years, Nature, Vol. 543, 9 March 2017.

Endnotes

[1] Capable of at least 1 quintillion (a billion billion) calculations per second.

[2] Supercomputers are measured according to how many floating point arithmetic calculations per second (FLOPS) they can do.

[3] The Commission is currently preparing an impact assessment to support the preparation of this initiative, based upon existing and future data collections and an analysis of the feedback received by stakeholders.

[4] More broadly the draft work programme for 2018 - 2020 of Horizon 2020 dedicates over €450 million in funding available to HPC

[5] The quantum flagship will be managed as part of the Commission co-funded Future and Emerging Technologies (FET) programme, which also includes ambitious projects such as the Graphene flagship and the Human Brain Project.

[6] Among others by physicists Bohr, Planck, Einstein, Heisenberg, Schrödinger, Pauli, Dirac, Curie, De Broglie and others.

[7] To find out whether quantum computers will work properly, scientists must simulate them on a classical computer.

[8] This includes €3.5 billion for data infrastructure, €1 billion for the Quantum Technologies flagship and €0.2 billion for actions on widening access and building trust.

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