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**EUROPE DESIGNS
THE SUPERCOMPUTERS
OF THE FUTURE**

Interview with Piero Vicini, coordinator of the European supercomputer project ExaNeSt for the Italian INFN

A billion billion calculations per second (that is a one followed by 18 zeros). Such is the computing power of the supercomputers of the future. Developing them is the ambitious goal of a European project now set to get underway. The project is called ExaNeSt, European Exascale System Interconnect and Storage. Among its various Italian partners are the INFN - with the CNAF (National Centre for Research and Development in Information Technology) and the Rome division at the Sapienza University of Rome - the Italian Institute for Astrophysics (INAF), eXact LAB and the Italian branch of ENGINSOFT.

Piero Vicini is the project coordinator for the INFN. We asked him to explain why we need increasingly high-performing supercomputers in the so-called era of Big Science.

Can you tell us what the ExaNeSt project is all about?

ExaNeSt is a research project funded by the European Commission as part of the Horizon 2020 framework programme. It will contribute to the development of large-scale parallel HPC (High Performance Computing) systems. Production should start within the next five to seven years. We expect these systems to reach one ExaFLOPS, where FLOPS stands for FLoating point OPerations per Second, and the prefix "Exa" indicates 10^{18} , the equivalent of a 1 followed by 18 zeros. Put simply, we are talking about a computing system capable of performing a billion billion arithmetic operations per second, that is, a million times more powerful than the latest generation PCs available today.

The acronym "NeSt" in the name of the project refers to the scope of application, namely Network and Storage: ExaNeSt will develop and prototype innovative technological solutions for the processor-to-processor interconnection network and distributed data storage architecture.

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What is the INFN's role in this project?

In the ExaNeSt project the INFN's supercomputer technology group in Rome (APE) and the CNAF in Bologna are working together within the framework of a heterogeneous and multidisciplinary international partnership to achieve some extremely innovative results. The partnership includes research institutes, universities and industries from seven European countries (Italy, Greece, Great Britain, France, the Netherlands, Germany and Spain) with many years of experience in the development and use of extreme-scale HPC systems.

The INFN will contribute to all stages of the design process, assuming leadership and management responsibilities for many activities: from the design and implementation of the interconnection network and distributed data storage system, to the optimisation of full-scale scientific applications using the hardware platform prototype.

How do supercomputers work and why is their use of such importance in the era of Big Science?

An HPC supercomputer can be defined as a very large group of calculation nodes composed of high-performing processors that can be coordinated and synchronised and work in parallel to solve a numerically complex computational problem. Hence, it is clear that the efficiency of the processor-to-processor communication network and the architecture of the distributed data storage system affect the overall performance of the supercomputer. That is why it is so important to have properly designed and efficient interconnection networks and data storage systems.

The constructive efforts to develop systems to this degree of complexity are necessary because with this level of computing power not only will we be able to solve some computational problems that persist in fundamental physics, but we will also be able to address some large-scale scientific applications with a huge social impact. These include, for example, the discovery of new drugs using "ab-initio" molecular simulations, more complex and accurate meteorology and climatology models that will improve our understanding of climate change and allow us to have more accurate medium and long-term weather forecasts, the simulation and study of the properties of new materials, the simulation of neural networks on a big enough scale to obtain results that can be compared with measurements obtained from in vivo experiments.

What are the applications of ExaNeSt in physics?

The list of applications is long and reflects the heterogeneous nature of the project's partners. In terms of developing the system, it will promote a virtuous cycle of interaction between those designing and building the machine and those who will have to use it efficiently in future. They include, for example, the INAF, which is contributing with numerical cosmology and astrophysical simulation codes, simulations of materials science and climatology by ExaCtLab, and computational fluid dynamics engineering codes (ENGINSOFT). The INFN will contribute with simulation codes for theoretical physics and a large-scale neural network simulation application.

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It is important to underline the importance of the project's Italian application partners, who bear witness to Italy's expertise in the production of numerical simulation codes, despite structural difficulties that have hampered research in this country in recent years.

In an initial phase of analysis and selection, a set of applications will be selected on the basis of computational needs and characteristics, and on their social impact. These will then be the starting point from which to develop the programmes in order to test the platform.

How is this linked to the Human Brain Project?

The main points in common are the synergies in terms of objectives and activities. The INFN is coordinating the WAVESCALES project, which is part of the Horizon 2020 flagship Human Brain Project (HBP). Its goal is to simulate a large-scale neural network, focusing in particular on the propagation of brain waves during deep sleep and anaesthesia, and in the waking state. This application is of great importance, both for its social implications and as regards the system architecture, as it introduces some very interesting aspects. The programmes we will develop in WAVESCALES will be the starting point for developing the code to simulate neural networks that will be used to test the ExaNeSt prototype.

Does the INFN have a tradition of working in this sector?

Since the 1980s, drawing on a brilliant idea of Nicola Cabibbo and Giorgio Parisi who, in turn, were encouraged and supported by a group of young physicists who were particularly interested in computational physics and informatics, the INFN has developed four generations of supercomputers dedicated to theoretical physics calculations. The first was APE (*Array Processor Experiments*), which was for many years the scientific/technological benchmark for the international community involved in the development of supercomputers for scientific computing. Other technological activities aimed at improving scientific calculation systems have been developed in recent years. These include interconnection networks for PC clusters accelerated by GPU (APEnet), and low latency systems for readout by detectors for HEP experiments (NaNet). Furthermore, the INFN's previous collaborations with industry and its focus on fostering the transfer of technology - with Finmeccanica/QSW in the mid-1990s and with Eurotech in the 2000s, to mention just a few - have been fundamental for assuming a key role in the ExaNeSt collaboration, in which industry plays an important part.

What results do you expect to achieve by the end of the first three years, and what are the prospects for the future?

The first three years of the European Commission's plan are just the first stage of a cycle that will last between five and eight years, during which Europe will seek to acquire a more important role in

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the global market of supercomputing technology. In this initial stage we will analyse the enabling hardware and software technologies. This should be followed by at least two more stages that will concentrate on the development of pre-competitive systems and their industrial production and placing on the market. This represents a challenge for the giants in the sector in existing markets such as America and Japan, as well as in emerging countries, especially China.

At the end of the project, the ExaNeSt system prototype should permit us to embark on the pre-competitive development stage and then start on production engineering. In this context, the INFN will once again have a role in the HPC systems of the future, in terms of ideas and the capabilities to implement innovative, non-conventional solutions. ■