

Viewpoint

The end of computing's steam age

Cloud technology offers a promising solution for the computing needs of particle physics.



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The CERN data centre is the heart of the Worldwide LHC Computing Grid, but the future of scientific computing could be on a dedicated Science Cloud.

By Eckhard Elsen

Steam once powered the world. If you wanted to build a factory, or a scientific laboratory, you needed a steam engine and a supply of coal. Today, for most of us, power comes out of the wall in the form of electricity.

The modern-day analogue is computing: if you want to run a large laboratory such as CERN, you need a dedicated computer centre. The time, however, is ripe for change.

For LHC physicists, this change has already happened. We call it the Worldwide LHC Computing Grid (WLCG), which is maintained by the global particle-physics community. As physicists move towards the High Luminosity LHC (HL-LHC), however, we need a new solution for our increasingly demanding computing and data-storage needs. That solution could look very much like the Cloud, which is the general term for distributed computing and data storage in broader society.

There are clear differences between the Cloud and the Grid. When developing the WLCG, CERN was able to factor in technology that was years in the future by banking on Moore's law, which states that processing capacity doubles roughly every 18 months. After more than 50 years, however, Moore's law is coming up against a hard technology limit. Cloud technology, by contrast, shows no sign of slowing down: more bandwidth simply means more fibre or colour-multiplexing on the same fibre.

Cloud computing is already at an advanced stage. While CERN was building the WLCG, the Googles and Amazons of the world were building huge data warehouses to host commercial Clouds. Although we could turn to them to satisfy our computing

needs, it is doubtful that such firms could guarantee the preservation of our data for the decades that it would be needed. We therefore need a dedicated "Science Cloud" instead.

CERN has already started to think about the parameters for such a facility. Zenodo, for example, is a future-proof and non-proprietary data repository that has been adopted by other big-data communities. The virtual nature of the technology allows various scientific disciplines to coexist on a given infrastructure, making it very attractive to providers. The next step requires co-operation with governments to develop computing and data warehouses for a Science Cloud.

CERN and the broader particle-physics community have much to bring to this effort. Just as CERN played a pioneering role in developing Grid computing to meet the needs of the LHC, we can contribute to the development of the Science Cloud to meet the demands of the HL-LHC. Not only will this machine produce a luminosity five times greater than the LHC, but data are increasingly coming straight from the sensors in the LHC detectors to our computer centre with minimal processing and reduction along the way. Add to that CERN's open-access ethos, which began in open-access publishing and is now moving towards "open data", and you have a powerful combination of know-how relevant to designing future computing and data facilities. Particle physics can therefore help develop Cloud computing for the benefit of science as a whole.

In the future, scientific computing will be accessed much as electrical power is today: we will tap into resources simply by plugging in, without worrying about where our computing cycles and data storage are physically located. Rather than relying on our own large computer centre, there will be a Science Cloud composed of computing and data centres serving the scientific endeavour as a whole, guaranteeing data preservation for as long as it is needed. Its location should be determined primarily by its efficiency of operation.

CERN has been in the vanguard of scientific computing for decades, from the computerised control system of the Super Proton Synchrotron in the 1970s, to CERNET, TCP/IP, the World Wide Web and the WLCG. It is in that vanguard that we need to remain, to deliver the best science possible. Working with governments and other data-intensive fields of science, it's time for particle physics to play its part in developing a world in which the computing socket sits right next to the power socket. It's time to move beyond computing's golden age of steam.



Eckhard Elsen became CERN director for research and computing in

January 2016. His research has led him to positions at Hamburg University, SLAC National Accelerator Laboratory and Heidelberg University, where he first made contact with CERN as a member of the OPAL collaboration. (Image credit: M Brice.)

Positioning Loads Accurately to the Micrometer: Hexapod at PETRA III

Since 2010, PETRA III (Fig. 1) is the most brilliant storage-ring-based X-ray light source in the world and it provides international scientists with excellent experimentation facilities. In particular, this benefits researchers investigating very small samples or those requiring tightly collimated and very short-wavelength X-rays for their experiments. The high-energy radiation of up to and above 100,000 electron volts with high light intensity offers versatile capabilities, for example in the broad field of materials research for the inspection of welded seams, or for the examination of fatigue symptoms in workpieces. In some cases, this involves accurately positioning really heavy loads down to the micrometer. At the heart of the P07 beamline, which delivers the high-energy X-ray radiation required for materials research, is therefore a heavy-duty Hexapod. Thanks to its accuracy, it facilitates in-situ measurements of material properties under realistic process conditions.



Fig 1: PETRA III offers scientists from around the world superlative experimentation facilities. In particular, this benefits researchers investigating very small samples or those requiring tightly collimated and very short-wavelength X-rays for their experiments, e.g. in the field of materials research (image: DESY/Reimo Schaaß)

Hexapods are parallel kinematic positioning systems (Fig. 2), available in many versions with travel ranges of up to a few hundred millimeters. With precision below a micrometer, they can position loads weighing from a few kilograms to a few hundred kilograms, or even several tons. Their advantages compared with serial, i.e. stacked systems, are that they have much better path accuracy, repeatability and flatness. In addition, the moved mass is lower, enabling better dynamic performance, which is the same for all motion axes. Depending on the geometry of the Hexapod, rotations from a few degrees up to 60° and translations of a few millimeters to several centimeters are possible.

Short-Wave X-Ray Radiation for Materials Research

The PETRA III short-wave X-ray radiation penetrates very deeply into the material and thus is also capable of passing through material of greater thickness. This enables welded seams to be inspected and fatigue symptoms in workpieces to be measured as an aid to quantifying the anticipated durability and service

lives, or to analyze new metal alloys. Here effects can be proven down to the level of domain or crystal structures.



Fig 2: Basic design: In parallel-kinematic systems, all actuators act directly on the same platform. (image: PI)

The opportunities that proceed from this in respect of materials research are leveraged by Helmholtz-Zentrum Geesthacht (HZG) at the High Energy Materials Science Beamline (HEMS), P07, for example when conducting in-situ measurements of the material properties that occur during reshaping processes such as welding, pressing, rolling or stamping. The application of a mechanical load causes tensile and elongation stresses to occur inside the material. The investigation involving X-ray radiation then indicates the chronological sequence of effects occurring within a material at a crystalline level in micrometer-sized domain areas.

Powerful Positioning System for the Experimentation Chamber

At the heart of the described experimentation chamber is a Hexapod, developed by Physik Instrumente (PI). Dr. Norbert Schell, the scientist in charge of the HEMS Beamline, illustrates the context: "For an increasingly large range of in-situ investigations of 'real' processes, that is processes that actually occur in industry (but of course not only there) – associated with the cutting of workpieces, the coating of surfaces for the hardening or improvement of tribological properties, reshaping, welding, heat treatment as well as combinations of these techniques – it is our ultra-rigid Hexapod with its tremendous load-bearing capability and micrometer precision positioning that makes it possible for the first time for us to conduct scientifically rigorous examinations of the structural changes that occur at an atomic level. This is highly interesting, and is also important in helping us to understand the processes that are occurring and that, ultimately, enable customized materials to be optimized."

The parallel-kinematic custom model, the M-850K (Fig. 3), delivers micrometer-precision positioning for loads of up to one ton in every orientation. It stands $\pm 20^\circ$ approx. 700 mm high and has a diameter of 800 mm (top platform with large aperture) and 900 mm (bottom). The lower platform is installed on

a 360° rotation table and the cabling was designed to be dragchain compatible. With its high load capacity of up to one ton, the Hexapod can carry the entire measurement setup including the equipment where mechanical forces are applied. The Hexapod positions even these large masses over distances of 400 mm to a precision of ± 1 micron, and performs rotational motions of $\pm 20^\circ$ with a resolution to 0.5 μ rad. Inside the experimental hutch, this enables complete engine blocks, turbine components, sinter furnaces and cryogenic chambers as well as welding fixtures or other machining units to be aligned precisely for the planned investigations and to be moved accordingly during the analysis.



Fig 3: Hexapod in the experimentation station EH3 on the P07 beam guidance unit on PETRA III: With its high load capacity, it can carry the entire measuring setup including the structure where mechanical forces are applied – in this figure a chamber for the laser-welding of titanium aluminides. (image: PI / HZG)

PI (Physik Instrumente) in Brief

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range. With four company sites in Germany and ten sales and service offices abroad, the privately managed company operates globally. Over 700 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field of innovative precision positioning technology. All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors.

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