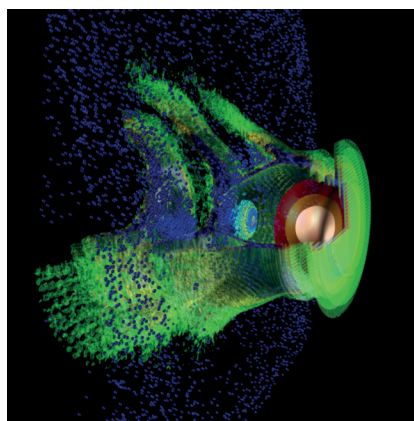


# High-Performance Plasma Physics

The Instituto Superior Técnico of the University of Lisbon advances student and researcher High-Performance Computing capabilities, powered by Intel® technology



TÉCNICO LISBOA

“The Intel® technology-powered HPC cluster enables us to conduct more detailed research internally, meaning we’re better prepared for the critical large-scale simulations, and that our students can get more experience of working on HPC projects.”

*Ricardo Fonseca,  
Principal Investigator at IST,  
ULisboa and Associate Professor  
at ISCTE-IUL*

The Instituto Superior Técnico (IST) of the University of Lisbon (ULisboa) has implemented a high-performance computing (HPC) platform based on servers powered by the Intel® Xeon® processor E5-2680 v2 product family, and connected using the Intel® True Scale Fabric Switch 12000 series. Internal tests have shown the new platform can offer previously unachievable levels of performance, enabling faster and more detailed research and strengthening the university's position among the international HPC community.

## Challenges

- **Complex calculations.** Plasma physicists running the OSIRIS\* particle-in-cell simulation code require strong computing power to support their research, usually resorting to the largest supercomputers in the world.
- **In-house preparation.** Limited internal resources meant IST scientists were heavily reliant on external HPC platforms, which did not promote advanced training and hindered research.
- **Students first.** IST wanted to give its students access to more HPC resources to enable them to gain the experience of running more complicated research projects using the top machines in the world.

## Solutions

- **European Research Council (ERC) investment.** The ERC provided funding to invest in a new HPC cluster for the Institute for Plasmas and Nuclear Fusion's Group of Lasers and Plasmas.
- **New cluster.** HP ProLiant\* SL230 servers were installed, powered by the Intel Xeon processor E5-2680 v2 product family for strong performance.
- **Scalable connectivity.** Intel True Scale Solution for InfiniBand\* Architecture ensures high performance and easy scalability for future growth.

## Impact

- **Available to all.** Students in the group now have regular access to HPC resources. Use of the cluster will also be offered to other IST departments and research groups.
- **Efficient research.** Able to conduct more tests internally, IST physicists can get more value from their large simulations by being better prepared for the top machines.
- **Industrial applications.** Discoveries in plasma physics can be used in the development and optimization of advanced concepts and novel accelerators, potentially impacting research into novel light sources, diagnostics for nanomaterials, possible cancer treatments or sustainable energy sources.

## Delving into Plasma

The laser and plasma physics team at the IST of ULisboa spends its time investigating the behavior of electrons and ions in the plasma state—matter hotter than a gas. Although this state of matter is not particularly widespread in everyday life, plasma is the most common state of visible matter in the universe, thanks to the large volumes of it created in large-scale and extreme events such as supernovae. On earth, plasma is used in a variety of industries—such as semiconductors, energy and utilities or medicine—that impact our lives.

Understanding the exact nature and behavior of plasma under different conditions requires highly detailed simulations and calculations.

The IST physicists carry out tailored particle-in-cell simulations using a code called OSIRIS, which IST has been involved in developing since shortly after it was first created by UCLA in 1999. These simulations focus on individual particles, meaning they can quickly become very complex as the number of particles assessed can go into the millions or even billions. Therefore, the computing resources that run the OSIRIS simulation code had to be very powerful.

The university had a computing cluster for a number of years, which executed some of the preparatory calculations needed before running a simulation. However, the platform was relatively small and did not offer the performance or capacity needed to carry out all the



## Portuguese research institution drives deeper in-house research with the Intel® Xeon® processor E5-2680 v2 product family

work needed at this stage, or to do the large-scale simulations themselves. For this reason, IST has always needed to book slots on external HPC platforms in Europe and the U.S. to carry out its research.

Ricardo Fonseca, principal investigator at the Group for Lasers and Plasmas of IST and associate professor at ISCTE-IUL, explains the challenges associated with this approach. "We had to wait in a queue for up to a month for our turn to use the external HPC resources," he says. "Not only did this delay our research, but it also meant that our students weren't able to get much experience using the HPC platform or carrying out the more complex simulations. With limited access to the platform, we had to have our more senior researchers running those simulations to ensure we got the best results possible."

Wanting to avoid the need to use external resources as much as possible, the Group for Lasers and Plasmas embarked upon a search for its own high-performance computing solution.

### Investing in the Future

IST received an Advanced Grant from the European Research Council (ERC) (ERC-2010-AdG 267841 ACCELERATES) to fund the purchase of its new HPC cluster. "As a public university, using public funds, we wanted to make sure we'd done our due diligence when it came to

selecting a solution," says Fonseca. He and his colleagues used the OSIRIS code to run a benchmark for a variety of solutions, evaluating each one for computing performance, energy efficiency, scalability, and connectivity.

"In the end, we chose a cluster made up of 96 nodes of HP ProLiant SL230 servers, with each node powered by two Intel Xeon processors E5-2680 v2 product family," explains Fonseca. "We felt that of all the solutions we'd seen, this one offered the strongest combination of value, performance, and scalability."

An important element of the scalability of the solution was the inclusion of the Intel True Scale Fabric Switch 12000 series. Equipped with an advanced set of InfiniBand features, the switches' strong connectivity and predictable low latency enable easy scalability, which IST feels will support the growth of its cluster over time.

The new platform was soon in place and available to the 15 members of the Group for Lasers and Plasmas, including undergraduates as well as senior researchers. It will also be offered to other departments with a need for HPC computing power, such as the Mechanical, Civil Engineering, and Chemistry teams. Eventually, as the platform grows, IST hopes to offer capacity to external users as well.

### Real-World Applications

As an educational institution, IST's primary concern is always for its students and ensuring they receive the best possible training and educational opportunities. The ability to give students more time to use OSIRIS, build their experience of running complex calculations, and prepare simulations in an HPC environment is, therefore, one of the greatest benefits of having its own cluster.

The team is also now able to do much more internally than it could before. "We've got the resources we need to conduct more in-depth preparatory work before we go to the large-scale simulations," explains Fonseca. "This means

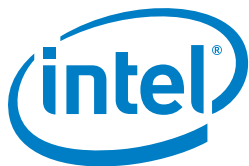
### Lessons Learned

It can be tricky balancing academic ambition, responsibility to students, and budget constraints. Like any publicly funded institution, IST needed to ensure that these three priorities were considered while implementing a solution that would deliver results worthy of the investment made by the ERC. It did this by installing an HPC solution scalable enough to meet its immediate and future needs, and with the performance to both support deeper research and enable greater use by the student community.

that when we do need to use external platforms for big simulations, we can be more accurate and focused, helping us get the results we need the first time and eliminating the need to go back for further testing. Needless to say, this saves us a lot of time, and cost as well."

As a result of these improvements, the plasma physics team can now accelerate and deepen everyone's understanding of this complex and critical field. Applications of their research include the development of cancer treatments, the development of cheaper and more sustainable energy through nuclear fusion with lasers, and building our understanding of the history and nature of our solar system.

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