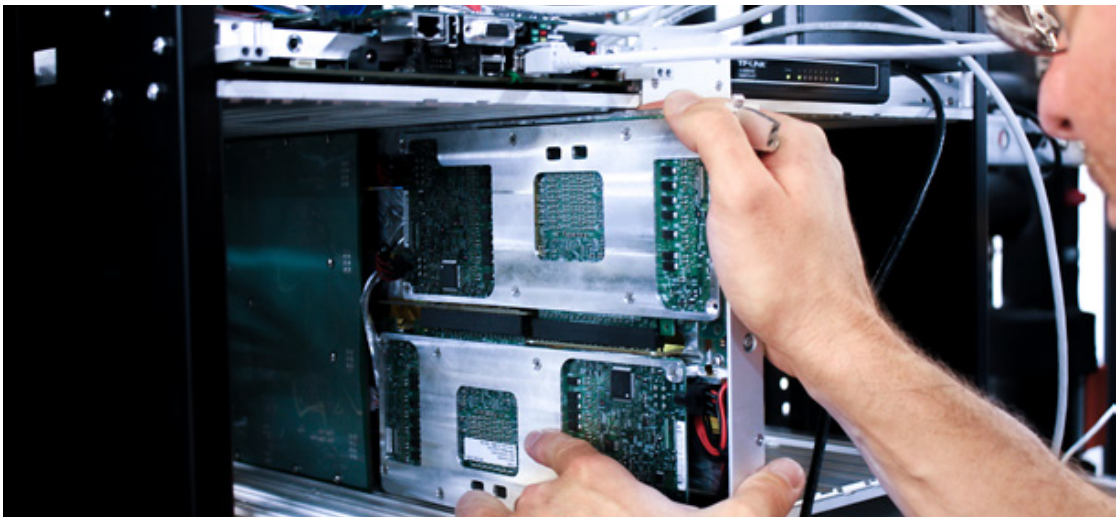
DEEP IMPACT



With its key achievements and the large body of expertise created, the DEEP project is poised to have a significant and lasting impact along four vectors. Besides opening up new avenues for the architecture of efficient HPC systems, it has materially increased Europe's indigenous capabilities in HPC system design and production, and has produced a complete system software stack together with a programming environment for heterogeneous platforms. Six relevant applications in critical fields of the European Research Arena have been remodelled and adapted, and what is more, best-known methods have been established that will enable many more codes to reap the benefits of the DEEP software and hardware architecture.

Novel approach to heterogeneous cluster computing

The DEEP system has proven that the Cluster-Booster architecture concept of dynamically associating different kinds of computing resources to best match workload needs can be implemented with state-of-the-art multi-core and many-core technology, and that such a system can indeed provide a superior combination of scalability and efficiency. It has thereby opened up a new avenue towards affordable, highly efficient and adaptable extreme scale systems (up to Exascale-class), merging the hitherto separate lines of massively parallel and commodity Cluster systems. The sibling project DEEP-ER is already carrying the flag further by integrating novel memory and storage concepts and providing scalable I/O and resiliency capabilities.

Leading-edge European system development

With its unprecedented integration of sensors, the DEEP system delivers a wealth of voltage, current and temperature data for all system components at high frequency, and uses this data for good measure to optimize operating parameters and safeguard operation. This example will influence future HPC system design and create opportunities for advanced analysis of monitoring data and data-driven system management.

> *"The companies, research institutes and universities behind DEEP can all be proud of having created a unique system, which is both most generally applicable and scalable beyond imagination. The DEEP Cluster-Booster concept will become part of the future of supercomputing.*
> **Thomas Lippert,**
> Head of Jülich Supercomputing Centre

Eurotech is one of the world-wide pioneers of direct liquid cooling for HPC. The DEEP project is the proof that hot water cooling can be safely operated, is compatible with modern system technology and can indeed provide free cooling year-round. These results will most importantly shape the expectations of HPC customers, who now know that they can eliminate a significant part of operating costs, and in turn materially increase the take-up of hot water, direct liquid cooling by future HPC systems.

Equally remarkable is the achievement of University of Heidelberg and their spin-off EXTOLL GmbH. They have brought a completely new and highly competitive interconnect into the HPC landscape: the direct-switched EXTOLL network has shown excellent scalability in the DEEP Booster system, and the performance improvement brought by the new ASIC-based TOURMALET implementation is a clear demonstration of the capability of this European technology.

The Munich-based HPC software house ParTec has contributed key expertise to design and build critical parts of the system software stack. The proven ParaStation product was the basis to master the major software challenge of DEEP's Cluster-Booster concept: the seamless co-operation of two physically autonomous parallel systems, bridging dissimilar networks efficiently, without requiring substantial CPU involvement on the Booster Interface nodes while being transparent for the application. ParaStation ensures the future adaptation of the Cluster-Booster concept to a much wider range of heterogeneous platforms.

> *"DEEP is a tangible proof that cooperation between leading European research organisations and European technology providers can produce world-class innovation in HPC. Separating a dedicated highly scalable "Booster" from the general purpose "Cluster" infrastructure in a supercomputer is a game changing approach on the path to Exascale architectures. Real-life highly scalable scientific and engineering applications have shown significant performance on the system and we expect even stronger results moving forward.*
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> **Fabio Gallo,**
> Vice President and General Manager,
> HPC Business Unit at Eurotech

Collaborating in DEEP, the three European HPC companies, Eurotech, EXTOLL and ParTec have gathered a large body of invaluable expertise in designing, integrating and manufacturing the system together with Intel. The DEEP system is testament that these European technology companies are able to create innovative HPC solutions which deliver highest density and leading efficiency while fully mastering system complexity. DEEP's success will boost the market position of the three companies and will provide them with new opportunities.

Managing such a large-scale supercomputer project and driving the co-design between applications experts, system software developers and hardware architects is in truth no small task. JSC (for the project as a whole), LRZ (for the critical energy efficiency area) and BSC (for the programming model co-design) have amply demonstrated their capability to rise to the challenge. This will set them up as prime partners for the next round of system-centric co-design projects in Europe – in particular considering the impact discussed here.

Software innovation towards Exascale

The DEEP system software and programming model were carefully architected to be based on existing standards and product-quality solutions. Extensions were made where necessary to make the unique DEEP features available or enhance the ease of programming. Supported by the application proof points, the resulting software stack will certainly and substantially influence the direction of Exascale software architecture, with ParTec as a European HPC software house in a key role. Today, it provides a solid base for increasing the circle of applications optimized for heterogeneous architectures in general, and in particular for the DEEP-ER project.

Furthermore, the innovative monitoring and control hardware and software infrastructure prototyped in DEEP has created substantial progress in the field, showing how high-frequency sensor data can be collected and processed in a scalable way, and how it can effectively interact with the firmware of the system components to ensure safe and efficient operation.

Last but not least, proven performance analysis and modelling tools from JSC and BSC were extended in the project to fully support the programming models; they were also used to predict the performance of scaled-up systems, establishing a precedent for full system performance projection in the scaling dimension without the need to first create analytical application models. This could prove an extremely valuable innovation, given the need to carefully analyse architectural choices before building expensive Exascale prototypes.

Proof of concept: DEEP applications

Six relevant, real-world applications in important scientific and engineering fields of the European Research Arena have been thoroughly analysed, modernized and adapted to the DEEP architecture. This enables users to make scientific discoveries faster, and engineers to come up with better solutions. Since the DEEP software interfaces are based on standards and backed by a commercial company, they will be adapted to future heterogeneous platforms, enabling the six applications to take advantage of such new systems. In addition, the DEEP-enabled codes continue to run on conventional architectures, sometimes showing surprising performance and efficiency improvements compared to their old formulation.

Even more importantly, the experience gathered in the application analysis and adaptation was distilled into "best-known methods", resulting in a playbook for tackling a wide range of additional applications and preparing them for DEEP-class systems. It is our hope that this will have a profound beneficial effect on the entire application ecosystem.