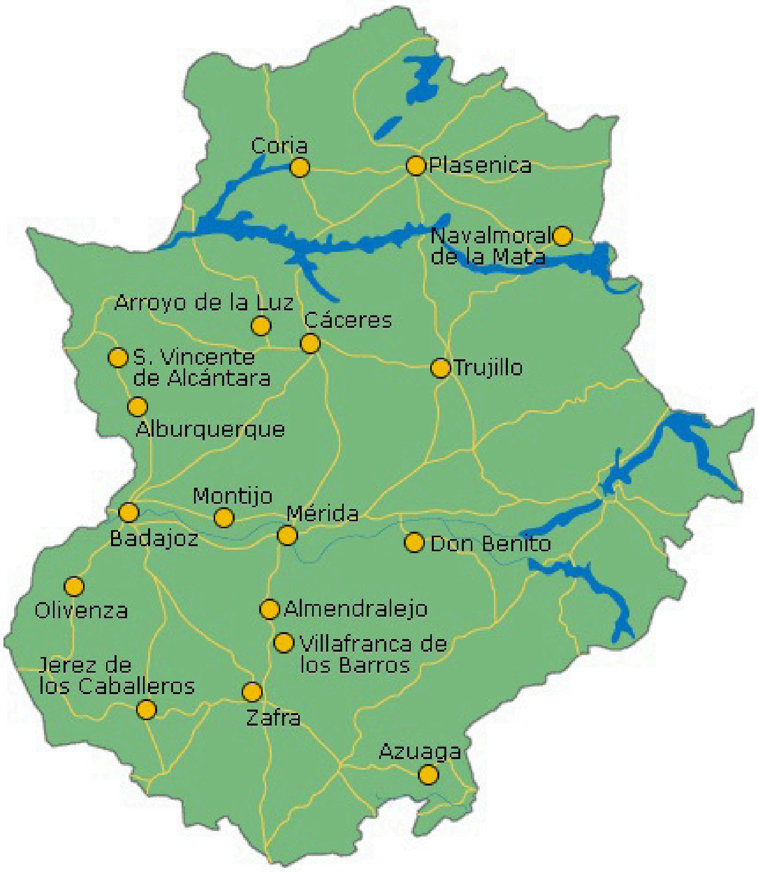
COMPUTAEX uses supercomputing to calculate a brighter economic future for Extremadura Region of Spain

Supercomputers are widely regarded as engines for running massive calculations within research, science and industry applications. For the Extremadura region of Spain, an Itanium-based supercomputer serves as an engine of economic growth.

Located in the southwest of Spain, Extremadura rests in the middle of the triangle formed by the cities of Madrid, Seville and Lisbon (the antique roman region that, 2,000 years ago, was named the Lusitania). It is the most economically depressed region of Spain, with an unemployment rate above 20%. That's why the regional government has been pursuing an Extremadura Regional Research and Technological Development Plan since 1998. Part of the strategy has been to improve infrastructure and access to resources for social projects, scientific research, and innovation.

To further this goal, COMPUTAEX, a nonprofit and public foundation formed by the Ministry of Economic Trade and Innovation of the Junta de Extremadura, was founded. The next step was to create the Extremadura Supercomputing, Technological Innovation and Research Center (CénitS) in 2009. The center is built around LUSITANIA, an extremely powerful, flexible supercomputer – an HP Integrity Superdome SX2000 using Intel® Itanium processors designed to process and manage large data volumes and the complexity of a large number of research projects. CénitS has been charged with boosting methodologies and tools for researchers and technologists within Extremadura and to serve as an accessible, highly competitive platform to nurture small and medium technology-based businesses.



Itanium platform meets many needs

Supercomputer simulations help researchers understand experimental or real-world effects such as climate changes and exposure to radiation. CénitS is helping researchers of Extremadura obtain simulation results very quickly, leading to innovative solutions to Spain's social, environmental, and scientific challenges. Since becoming fully operational in March 2009, the Itanium-based Superdome has already been applied to a spectrum of applications:

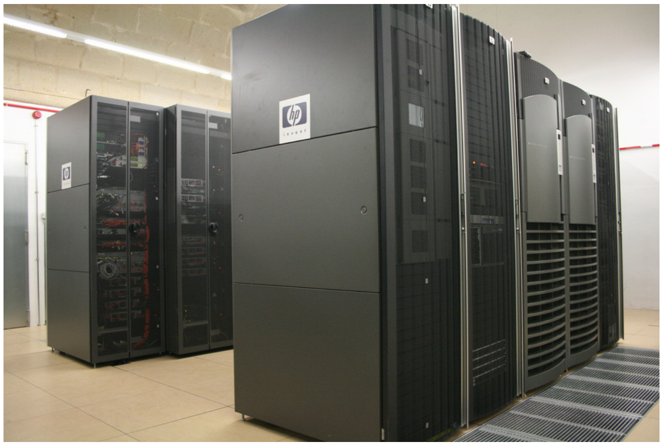
- Environmental impact forecasts for chemical, refinery, irrigation, and other industries.
- Biology and medical studies of cancer, genomes, disease prediction, and biodiversity.
- Earth sciences such as geological studies and fire predictions.
- Agriculture and farming to support studies ranging from livestock reproduction techniques to product simulations.
- Industrial designs of structures, bridges, aircrafts, and cars
- Climate prediction including global warming and local atmospheric effects.

One of the most important advantages of the shared-memory Itanium architecture is that it is easier to program than other parallel-programming platforms. Researchers have learned to exploit aspects of the Superdome such as workload balancing, data locality, memory footprint and rapid communications. They utilize large shared-memory nodes, and know how to maximize performance by combining OpenMP code with MPI for internode process communications and OpenMP for loop and thread parallelization. In some cases they use Hyper-Threading technology to further accelerate processing of applications using the MPI library or applications that contain threads or processes that frequently communicate with each other.

Projects highlight Itanium speed and flexibility

With the access to and knowledge of the Itanium platform, CénitS researchers have completed numerous projects with wide-ranging social and economic impact, including these:

The Whole-Atmosphere Community Climate Model (WACCM). In order to predict the behavior of the Earth's climate well into the future, numerical models are needed to simulate climate evolution with the assumption of various human development scenarios. The WACCM is a comprehensive numerical climate model spanning the range of altitude from the Earth's surface to the thermosphere (140 Km). The model unifies certain aspects of the upper atmospheric modeling of High Altitude Observatory (HAO), the middle atmosphere modeling of the NESL's Atmospheric Chemistry Division (ACD), and the tropospheric modeling of Climate



"The ability of the Itanium processor to efficiently handle hundreds of parallel processes along with huge amounts of RAM is providing solid performance to all research projects for Extremadura. Some leading-edge problems requiring more than 256 processes and almost 2 TB of RAM have been solved thanks to our Itanium-based solution."

– Prof. Dr. José-Luis González-Sánchez, General Manager, COMPUTAEX/CénitS

and Global Dynamics Division (CGD) at the National Center for Atmospheric Research (NCAR), using the NCAR Community Earth System Model (CESM) as a common numerical framework. The model is used for many important scientific calculations, including:

- Ozone depletion during the last 20, 30 and 50 years and forecasts into the future
- Atmospheric variability induced by the 11-year solar cycle
- Physical and chemical processes in the vicinity of the tropopause (the atmospheric boundary between the troposphere and the stratosphere), in particular changes associated with increasing CO2 concentrations

Because WACCM unifies several disparate models, most communications tasks are non-local programs and massive memory resources are transferred among nodes. The flexible, scalable parallel processing of the Itanium architecture, which is able to handle multiple TBs of principal memory, easily handles the hundreds of simultaneous processes that may be present in any one WACCM simulation run.

Benefits of Itanium

The flexible, scalable parallel processing of the Itanium architecture easily handles the hundreds of simultaneous processes that CénitS calculations may require. It also demonstrates nearly 100% availability. So CénitS researchers can run lengthy scientific simulations confident of fast, accurate and successful results.

MLFMA-FFT parallel algorithm. Understanding electromagnetics is very important to heavy industry. To address large-scale problems in electromagnetics, researchers at CénitS have developed an innovative algorithm that combines the advantage of two methods: the high scalability behavior of the fast multipole method Fast Fourier Transform (FMM-FFT) for the distributed computation; and the algorithm efficiency of the multilevel FFM called the MLFMA for shared-memory computers. This technique applies the power of the Itanium-based Superdome for solving extremely large problems with practical or industrial interest. In computational electromagnetics, for example, rigorous integral-equation based solvers such as the FMM and its variations consume very large amounts of RAM. In this project, a total of 1.6TB of RAM was required, involving more than 800GB of RAM per computing node. Though this capability, the Superdome has completed the analysis of the largest problem ever solved in computational electromagnetics to date, with more than 620 million unknowns. The project also modeled the electromagnetic behavior of a car at 79 GHz, providing results with direct applications in the future radar sensor design for the automotive industry.

Neutronic dose calculations. Radiation treatment is becoming more and more effective for cancer patients to fight their disease. The neutronic dose calculations project is helping doctors to apply adequate radiation therapy to patients while minimizing risk due to the out-of field dose delivered. In this CénitS project, digital devices are placed in the irradiation room to assess the neutronic contribution equivalent to the doses received by different organs of the patient during treatment. Then researchers use Monte Carlo simulations to correctly establish dosimetric responses of different detectors and give coherence to the measurements. Itanium processors contain several features that accelerate this type of calculation, such as control and data speculation, automatic register rotation for software pipelined loops, predication and explicit data/instruction prefetch instructions. These features allow the hardware to exploit instruction-level parallelism and help improve memory latency, making them very effective for running Monte Carlo simulations.

System Configuration

Two HP Integrity Superdome SX2000 supernodes with 64 dual-core (128 cores each) Intel Itanium2 Montvale processors running at 1.6GHz with 18 MB cache, 1TB memory each (upgradeable to 2TB); a cache-coherent memory system (ccNUMA) using a directory-based memory controller. Development occurs on an HP Integrity rx2660 with two Intel Itanium-2 dual-core Montvale processors, 16GB DDR-2 memory and six 146GB SAS disks. Two EVA 8100 storage units with 265,6TB total storage. Fiberchannel network with active-active multipathing (8 ports x 4 controllers), four NAS servers executing HP StorageWorks PolyServe and an HP StorageWorks EML 245e with 245 LTO-4 Ultrium 1840 tapes.

SUSE Linux Enterprise (v.10) with Platform LSF workload management, HP StorageWorks PolyServe NFS and compilers, libraries and binaries from Intel, HP and others.

Reliable, Scalable Resource

Scalability and parallel processing alone aren't sufficient for solving problems with very long run times. CénitS has been successful across such a wide range of study because the Itanium-based Superdome exhibits very high reliability, accessibility and serviceability (RAS). For example, random memory errors are corrected with built-in error correcting memory. Other features that avoid hardware and software errors result in availability close to 100%. The Superdome gives the CénitS researchers the confidence to run extremely complex scientific simulations without the fear of losing hours of research studies and simulations, while enjoying the security of fast and accurate results.

These results, in turn, lead to confidence in reviving the economy and aspirations of the citizens of Extremadura.

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