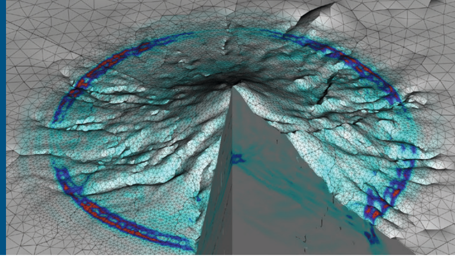
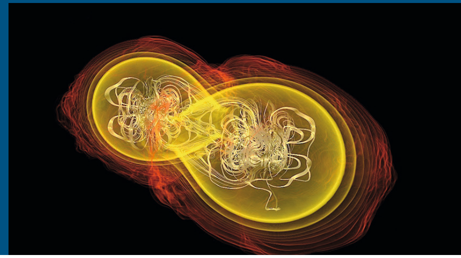
Simulated propagation of seismic waves in the strato-volcano Mount Merapi





Merger of two magne-tized neutron stars

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Project Profile

Funding programme:
The EU funds the European ExaHyPE consortium within the framework of Horizon 2020. ExaHyPE is part of the FETHPC – Future and Emerging Technologies High Performance Computing – programme.

Project: ExaHyPE (An Exascale Hyperbolic PDE Engine)

Project number: 671698

Project duration: 2015 – 2019

Total budget: EUR 2.8 million

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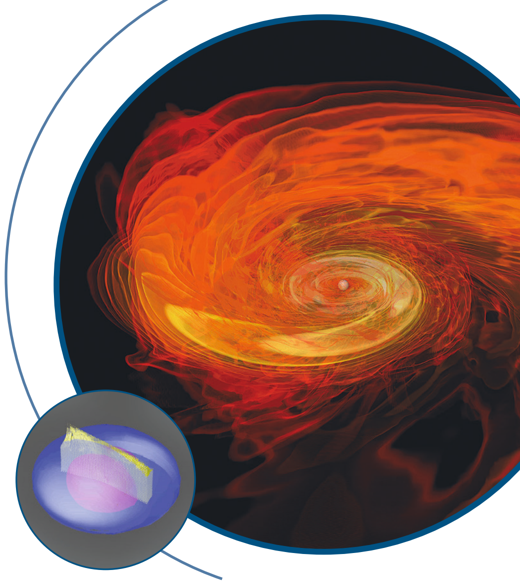
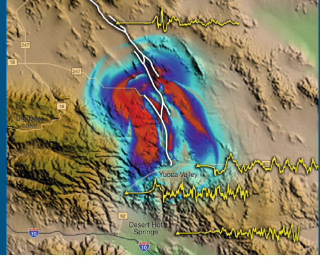
ExaHyPE

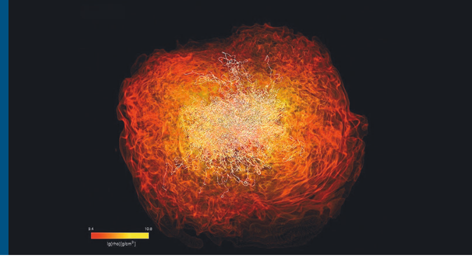
An Exascale Hyperbolic PDE Engine



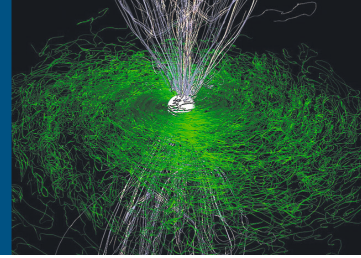
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 671698



Ground shaking obtained from a petascale simulation of the 1992 Landers Earthquake



Hypermassive neutron star produced by the merger of two magnetized neutron stars



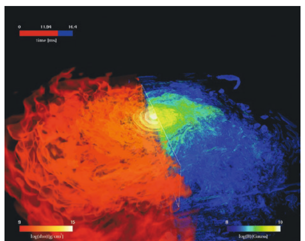
Magnetic field lines after the hypermassive star collapses to a black hole

Exascale High Performance Computing

Computer-based simulations drive scientific progress. In addition to theory and experiments, simulations have long since been crucial for acquiring knowledge and insight. Supercomputers continue to allow the computation of increasingly complex and precise models. However, programming such supercomputers is a key challenge.

The ExaHyPE project seeks to address the software aspect of supercomputer development. The project integrates well into Europe's strategy for developing a supercomputer that is capable of performing a billion billion (10^{18}) computer operations per second (1 ExaFlop/s) by 2020. In order to leverage this incredible processing power for correspondingly comprehensive simulations, the entire supercomputing infrastructure – including system software and simulation applications – must be prepared for such exascale systems.

ExaHyPE focuses on the development of new mathematical and algorithmic approaches to exascale systems – initially for simulations in geophysics and astrophysics. During this four-year project, researchers from seven institutions in Germany, Italy, United Kingdom, and Russia will develop novel software for performing simulations on exascale supercomputers. In October of 2015, the European Union began support of the ExaHyPE project with EUR 2.8 million.



Density (red) and magnetic field strength (blue) of a hypermassive neutron star produced by the merger of two magnetized neutron stars

Objectives of ExaHyPE – New Algorithms

Energy efficiency of supercomputing hardware

Today, a supercomputer capable of performing 1 ExaFlop/s could be built, but its energy requirements would be prohibitive. ExaHyPE's new simulation software will be designed for energy efficiency and the requirements of future energy-efficient hardware.

Scalable algorithms – dynamically adaptive

ExaHyPE will develop new mathematical algorithms that can take full advantage of the smallest possible amount of memory. Therefore, the resolution of a simulation – the number of used data points – will be dynamically increased wherever the simulation needs. In this way, the necessary computer operations can be kept to a minimum while simultaneously achieving the greatest possible accuracy.

Fast computer operations in spite of slow memory

In ten years, supercomputers will be able to operate 1000 times faster than today. However, in the same period, memory access speed may only increase by 50 times. It is necessary to completely rewrite simulation programmes in order to ensure that future supercomputers can cope with this discrepancy. The algorithms that will be used in ExaHyPE will be inherently memory-efficient and reduce the communication during parallel processing.

Extreme parallelism even with unreliable hardware

By 2020, supercomputers will hold hundreds of millions processor cores. To maximize efficiency, we must develop new programmes to run on such computers. ExaHyPE will examine the dynamic distribution of computer operations to millions of processor cores – even if some of these fail while performing calculations.

Benefit for Research and Society

Simulation of risk scenarios

Earthquakes cannot be predicted. However, we might be able to assess the risk of aftershocks following a large earthquake by using simulations. Regional earthquake simulations are one of the two application scenarios envisioned for ExaHyPE. Such simulations promise to provide a fundamentally better understanding of what takes place during large-scale earthquakes and the aftershocks, and will help to quantify seismic hazards more accurately.

Fundamental scientific findings

ExaHyPE will simulate systems of orbiting neutron stars that are merging. Not only are such systems suspected of being the greatest source of gravitational waves in the universe, but they could also be the cause of "gamma ray explosions" – the most powerful known catastrophic scenarios of the universe. Exascale simulations of such processes will allow us to study these long-standing mysteries of astrophysics and gain new insights.

Free software for flexible scenarios

Although these two simulation scenarios may be quite different, they are framed by very similar mathematical equations (hyperbolic differential equations), which represent conservation equations for mass, momentum, and energy. ExaHyPE is developing flexible software for such models, which will be free for use by science and industry as open-source software.