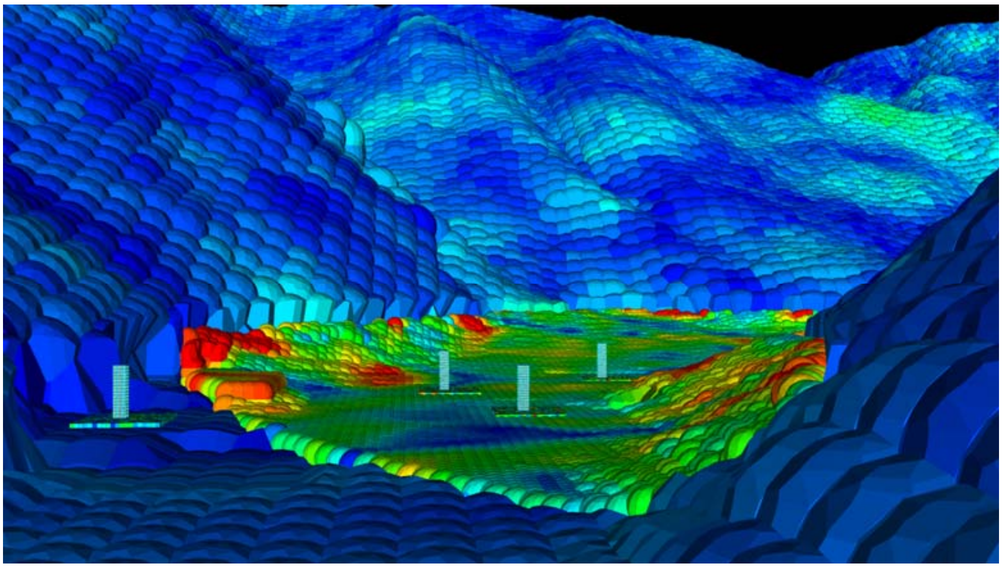
Modelling the effects of earthquakes, from the fault to the buildings

Estimation of the destructive power of large earthquakes (landslides, surface ruptures, damage to buildings and infrastructures, etc.) is very important in determining public safety policies and in the sizing of sensitive or dangerous facilities.
At any given location, these effects depend not only on the strength of the earthquake and its distance away, but also on the local geological environment and, most particularly, the nature of the relief and the presence or otherwise of sedimentary basins which are likely to amplify seismic movements very strongly.
One way to estimate these destructive effects is through computer simulation. In this field, the collection of expertise of CEA/DAM employees in mechanics, seismic risk, applied mathematics and computing, added to the power of the CEA supercomputers, has made it possible to carry out this type of numerical simulation on a scale, and with a degree of realism, which has not previously been attained.



The physical challenge

This involves simulating, in a single computation, the generation of a seismic wave by fault rupture followed by its propagation through a complex geological medium, including perturbations due to local side-effects, and finally forecasting the behaviour of buildings subject to this seismic activity. An innovative piece of software - Mka3D - developed at the CEA/DAM several years ago, is perfectly suited to meeting this objective.
For this type of numerical simulation, the physical medium is divided up into a very large number (several million) of discrete elements, each subject to the laws of mechanics. The calculation is performed step-by-step and at each time step a very large number of equations need to be solved. Use of supercomputers is therefore inevitable because the computer power required is colossal.
In the current example, which required the use of 500 processors over a period of 40 hours (i.e. a total of 20,000 hours of computation), a fault generated an earthquake with a magnitude of 5.5 on the Richter scale. The seismic waves then propagated through a three-dimensional medium, complicated both by its shape (topography) and its composition (the nature of the geological medium). In this case the volume studied was on the scale of a town (11 x 11 km^2 and 2 km thick).
The seismic waves arrive at the foot of the buildings which are also modelled in the same calculation so that the interaction of the ground with the structures can be directly investigated. One of the unique capabilities of the software is its capacity to manage very large changes of scale, between the dimensions of a building and the dimensions over which seismic waves propagate.
Above all, the numerical approach of the Mka3D code can consider complex physical problems in order, for example, to predict possible ruptures and to follow the collapse of a structure or the formation of a landslip area.

The outlook

Future developments, both in simulation software and in the amount of computing power available, will enable performance of computer simulations over larger timescales and distances, as well as introducing more realism into the consideration of physical phenomena (particularly fracturing).
This type of numerical tool will also make it possible to forecast the effects of other dangerous types of natural or man-made phenomena: rock falls, explosions, meteorite impacts, etc.

For further details, see: http://www-dase.cea.fr/