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## Some HPC challenges for multi-physics extended CFD computations

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### Abstract

As the numerical simulations become more and more used for prediction and analysis of complex non stationary flows and as the computer architectures steadily evolve towards massively parallel, there is a real need to adapt computational codes to make them ready for intensive use in a HPC cluster environment. In the same time there is a strong tendency in the CFD community to enlarge the scope of computations by associating and possibly by directly coupling different physics in a unique computation. Such multi-physics computations open the way to needed sizing, analysis and optimization of complex systems. Common examples are fluid/solid interactions (conjugate heat transfer, aeroelasticity, aeromechanics), aeroacoustics, two-phase flows, combustion.

This reality puts severe demands especially for multi-physics codes that are at stakes to provide HPC performances while addressing several physics that are discretized on the same computational domain. In such situation, not only each particular physical system must be rendered computationally efficient but the numerous exchanges between the implied physical systems must be also optimized to avoid ruining the overall efficiency of the computation.

The CEDRE code developed at ONERA as the reference code for energetics and propulsion is particularly concerned by these challenges. The present version CEDRE 5.1 is already daily used on clusters with thousands cores with a very good scalability, as illustrated by figure 1 below.

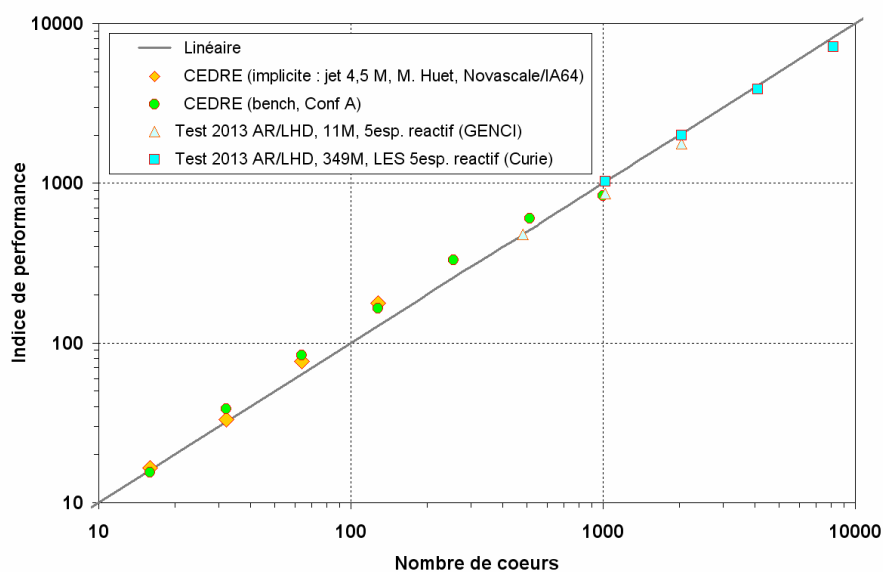


Figure 1: scalability of CEDRE

As CEDRE is formed of several solvers, each solver being dedicated to a particular physics, the HPC constraints must be addressed by each solver and by its exchange procedures.

CEDRE is composed of the following main solvers:

CHARME : Navier Stokes, multi species, turbulent, reactive, real gas  
SPIREE : dispersed phases (Eulerian)  
SPARTE : dispersed phases (Lagrangian)  
ACACIA : thermal problems in solids  
ASTRE : radiation (Monte-Carlo method)  
REA : radiation (discrete ordinate method)  
FILM : liquid films

These solvers, depending on the physical system they are solving, rely on different numerical approaches. As a consequence, dedicated HPC strategies must be developed for different solvers.

Other challenges exist at the CEDRE level, such as the parallel input/output (I/O) procedures and the pre- and post-treatments for massively parallel unsteady computations. As I/O is one of the main sources of bottleneck, a particular development effort has been made on this topic. The goal is not only performance, but also the ability to change the number of cores from a calculation to another. Concerning the preprocessing for large meshes, an alternative to sequential tools, used to partition a mesh and perform load balancing, is now proposed through the use of external parallel libraries such as PT-Scotch and ParMetis.

Finally, concerning external coupling capabilities, for reasons committed to sustainability, ONERA has decided to develop its own coupling library CWIPI (Coupling With Interpolation Parallel Interface). This library is essential to perform extended multi-physics computations, which require coupling with other codes and other physics (for example solid mechanics).

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