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TOWARDS OVERCOMING THE LES CRISIS

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I. Abstract

While the development of accurate and fast methods for the logical sequence of fluid flow approximations: potential, full potential, Euler, RANS, LES, DNS) progressed rapidly during the 80's and 90's, the last 20 years have been a 'waiting mode' in order to get to LES. This should come as no surprise, as an accurate and statistically steady high Reynolds number LES run will require $O(10^9)$ points (or degrees of freedom) and $O(10^7)$ timesteps. This represents a factor of $O(10^1 - 10^2)$ in the number of points (something that could be absorbed by a larger number of processors), but, more importantly, a jump of $O(10^3 - 10^4)$ in the number of timesteps (or residuals, right-hand sides) required. It is this latter factor that was not taken into account by many a hopeful and optimistic researcher at the beginning of the century, and what is still the main reason why any LES run today lasts at least 3 weeks even if the number of cores available is arbitrarily high.

None of the 'false prophets of turbulence' that have claimed to be 'the solution' to this turbulence crisis (wavelets, chaos theory, cellular automata, proper orthogonal decompositions, higher order finite volume or element methods such as SEMs, DGMs and IGMs, sparse grids, proper generalized decompositions, artificial neural nets, and parallel in time methods) have been able to resolve it.

Simply put, in order to achieve the industrial goal of overnight ($4 \cdot 10^4$ secs) LES runs with $\mathrm{O}(10^7)$ advective timesteps, one needs to run at 250 timesteps/sec, or 0.004 sec/timestep. At present, we have not seen codes able to run faster than $O(0.020)$ sec/timestep when going beyong 10Kcores. On the other hand, this also implies that we may be close (a factor of 5-100 speedup still missing) to overcoming the turbulence crisis of the last 20 years.

The presentation will focus on current efforts to combine high order while being economical enough to achieve the required goal of overnight LES runs.