CAMBRIDGE FLOW SOLUTIONS
Proprietary and customised CFD

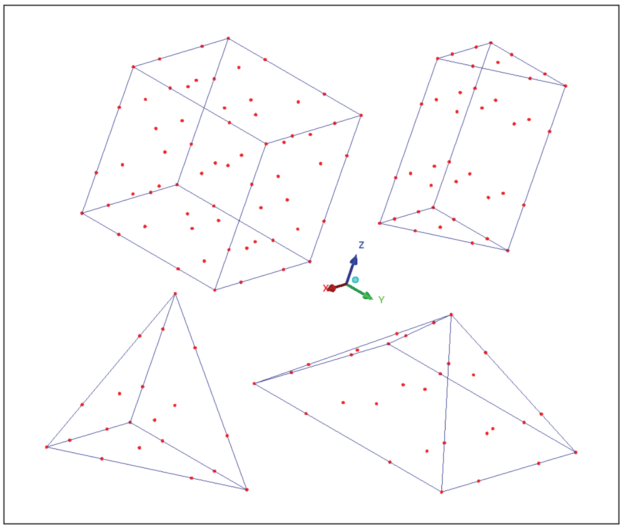
HOTnewt – Higher-order LES solver

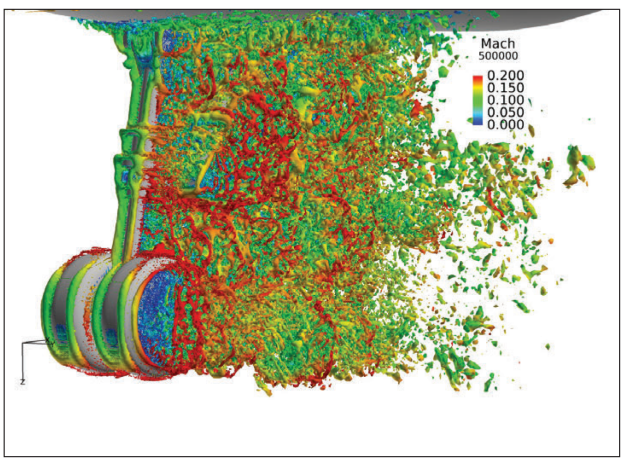
CFS is developing higher-order LES technology that delivers routine and affordable LES of complex, industrial applications on time-scales compatible with design cycles[1,2,3]. The result is HOTnewt, a higher order LES solver built on novel, highly-efficient algorithms that provide significant improvements in speed relative to uniform time-stepping LES, combined with modest memory requirements, allowing users to run on more widely accessible platforms.

1 Y.Lu, K. Liu & W.N. Dawes, "Large eddy simulations using high order flux reconstruction method on hybrid unstructured meshes", AIAA 2014-0424, AIAA SciTech 2014, National Harbor, MD
2 Y.Lu, K. Liu & W.N. Dawes, "Flow simulation system based on high order space-time extension of flux reconstruction method", AIAA 2015-0833, AIAA SciTech 2015, Kissimmee, FL
3 Y.Lu, K. Liu & W.N. Dawes, "Fast, high order large eddy simulations on many core computing systems for turbomachinery", GT2016-57468, ASME Turbo Expo 2016, June 2016, Seoul, Korea

Features

- **Novel STEFR Scheme:** Explicit approach using MPI & OpenMP, with time-accurate local time-stepping
- **High order flux reconstruction:** up to 4th order accurate
- **Wall-resolved or wall-modelled:** adaptive dynamic wall model
- **Differential form, quadrature-free, no mass matrix**
- **Space & time adaptive**





NASA PDCC-NLG Landing Gear - HOTnewt 3rd Order LES simulation
Contours of Mach number – Q=5x10^5

Benefits

HOTnewt delivers efficient higher-order LES simulation: efficient in **space**, in **time** and in **computing resource and effort**

- **Practical:** support for real-world applications via implementation on general hybrid unstructured (Boxer) meshes
- **Fast:** speed-up ratios of up to 100 relative to conventional LES algorithms
- **High Computing Efficiency:** low memory footprint – ideal for multi-core systems (like the Intel Phi or GPU's). Able to run on more affordable and widely accessible platforms

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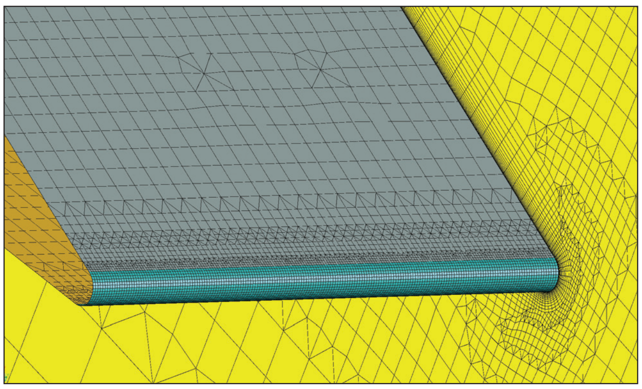
HOTnewt Higher-order LES Case Study – LESfoil

The HOTnewt higher-order LES solver was used to calculate the flow past a representative aerospace aerofoil (LESfoil test case4) at a Reynolds number of $Re=2.1x10^6$ and an incidence angle of $\alpha=13.3°$. A feature of this test case at these conditions is that the suction surface flow experiences a laminar separation, which transitions to turbulent and re-attaches, forming a separation bubble.

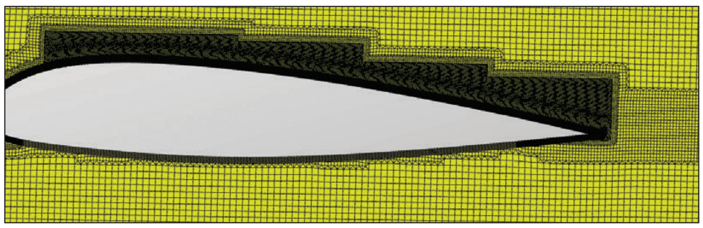
The mesh contained 1.77M cells with a total of 15.2M degrees of freedom. One flow passing period corresponded to 57hours on 512 Intel Sandy Bridge cores, requiring under 200GB of memory. HOTnewt's novel STEFR scheme delivered a speed-up factor of 14.7 relative to standard uniform time-stepping LES.

The solver was run in wall-resolved (Y+=1.3) mixed 2nd and 3rd order mode, with the 3rd order elements concentrated on the suction side. This adaption capability provides a very efficient way of targeting the resolution, allowing the solver in its standard form to capture accurately the suction-side boundary layer transition and subsequent re-attachment with no additional treatment.

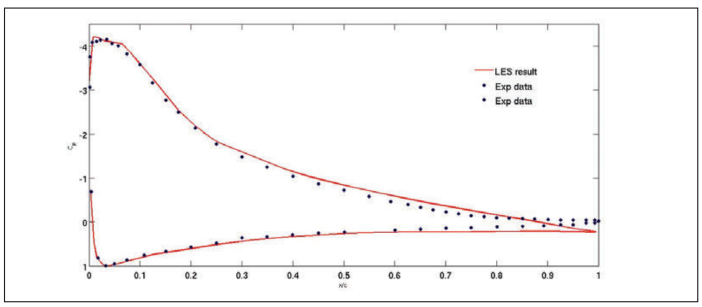
1 Christopher P. Mellen, Jochen Fröhlich and Wolfgang Rodi. "Lessons from LESFOIL Project on Large-Eddy Simulation of Flow Around an Airfoil", AIAA Journal, Vol. 41, No. 4 (2003), pp. 573-581.



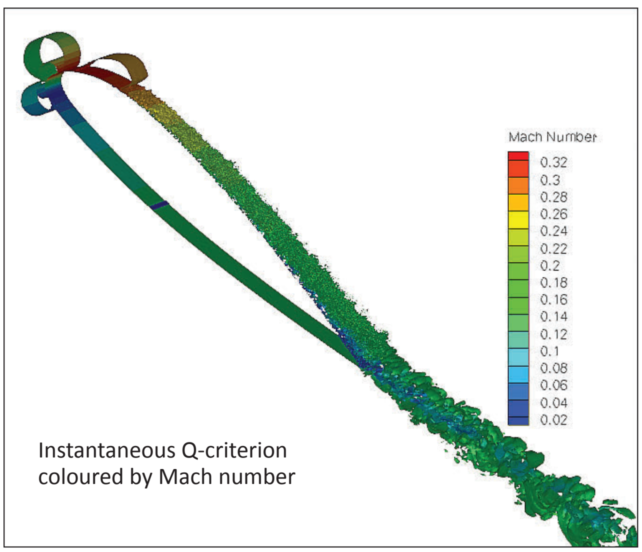
Detail of the mesh around the trailing edge



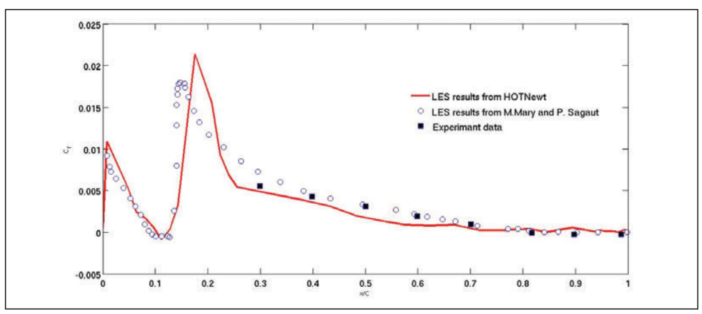
Mesh section around the LESfoil, showing the refined regions on the suction surface where 3rd order elements were used



Comparison of average Cp around the aerofoil with Experiment



Instantaneous Q-criterion coloured by Mach number



Plot of mean skin-friction coefficient on the suction surface.
Wall-resolved local 3rd order HOTnewt predicts transition.