Rapid Hypersonic Simulations using *US3D* and *Pointwise*

C. Tang*

* Aerothermal Engineer, NASA Ames Research Center, Moffett Field, CA

Abstract: The present paper outlines a new automated workflow that uses the flow solver, *US3D*, and the commercially available grid generator, *Pointwise*. The workflow, which uses unstructured volume grids, is applied to a 3D Orion capsule at an altitude of 47.6 km/s, angle-of-attack of 18°, and Mach number of 20. Results from the new process are compared with those from *DPLR* using a structured volume grid. The pressure and heat flux values between the two flow solvers are in good agreement.

Keywords: Unstructured Flow Solver, Anisotropic Hybrid Mesh, Shock-Fitting.

1 Introduction

It is often desirable to run high-fidelity CFD simulations for aerothermal analysis of spacecraft designs, but grid generation/adaption is typically a bottleneck in the workflow of obtaining quick numerical solutions. Unstructured grid generation offers a robust, rapid, and highly automated method of generating viscous meshes for complex geometries. For hypersonic simulations, the mesh also needs to be shock-fitted to accurately resolve the bow shock in the flowfield. Since the flow solver and grid generator are coupled in the grid adaption process, it is important that this coupling is robust and highly automated. A new workflow is highlighted using the *US3D* unstructured flow solver and the commercially available *Pointwise* software. The goal of the new workflow is to enable aerothermal engineers to produce accurate hypersonic solutions on any complex geometry in a couple of days.

2 Numerical Results

To test the new workflow, a 3D Orion capsule simulation was computed at an altitude of 47.6 km, α = 18°, and M_∞ = 20.

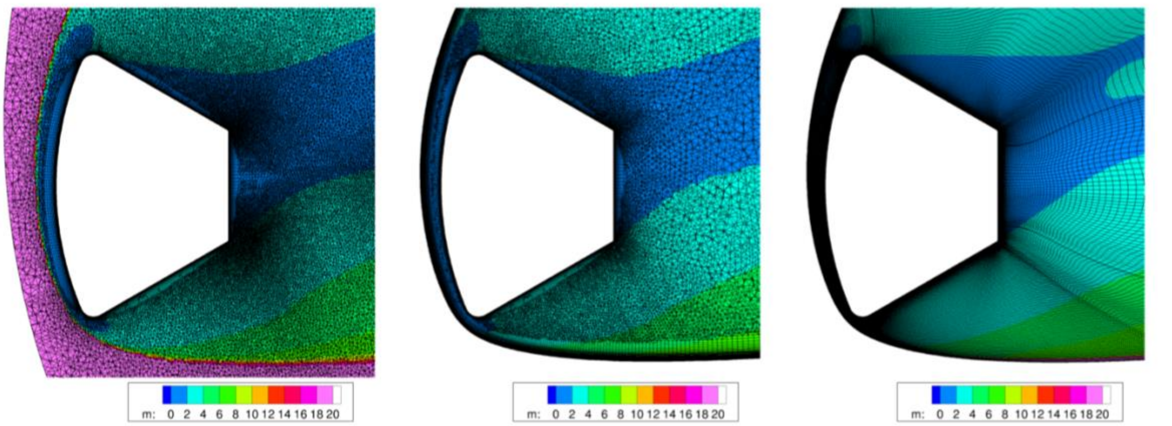

Figure 1: Centerline Mach contours on initial US3D grid (left), US3D grid after two adaptions (middle), and DPLR grid after 4 grid alignments (right)

Shown in the left plot of Fig. 1 is the initial grid generated using an anisotropic, hybrid mesh generation process (called T-Rex) in *Pointwise*. The generation of the initial grid is quite automated, and it took approximately 0.5 hour of wall-clock time on a laptop. *US3D* simulation on the initial mesh shows poor heat flux estimates on the centerline of the heatshield (see Fig. 2). A Mach isosurface (90% of M_∞) was extracted from the volume solution using *Tecplot*. The isosurface was imported as a database entity in *Pointwise*, and it was used to define the outer boundary in creating a new mesh. Prismatic cells were extruded from the surface of the capsule and around the bow shock. The T-Rex solver was utilized again to generate a new grid. This process of extracting the Mach isosurface; importing it into *Pointwise* to define the outer boundary; extruding prismatic grids from the body surface and bow shock; and running the T-Rex solver to generate a new grid can be repeated multiple times to improve the resolution and location of the bow shock. Shown in Fig. 2 is a comparison of the heat flux (normalized by the stagnation heating rate) and pressure (normalized by the stagnation pressure) on the centerline of the Orion capsule. Also shown is a *DPLR* solution that was shock-aligned a number of 4 times on a structured volume grid. Both the *US3D* and *DPLR* solutions share a common surface grid. Illustrated in Fig. 3 is a comparison of the heat flux contours on the heatshield between the final *US3D* and *DPLR* solutions. Overall, the agreement between the two solvers is excellent.

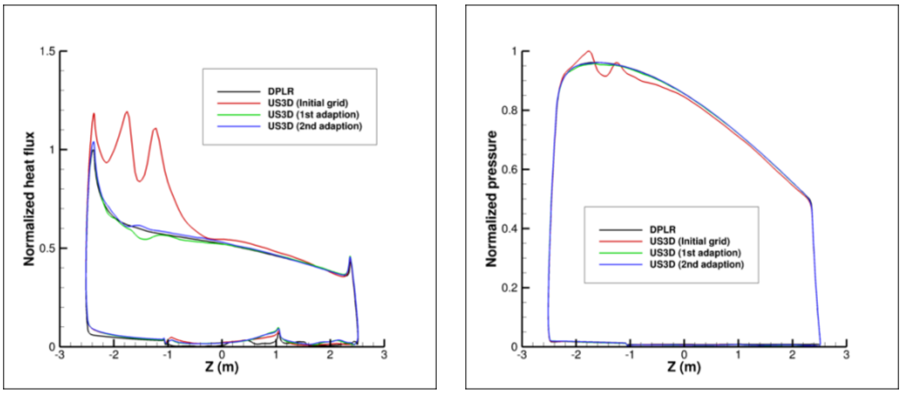

Figure 2: Comparison of normalized heat flux and pressure on centerline of Orion capsule

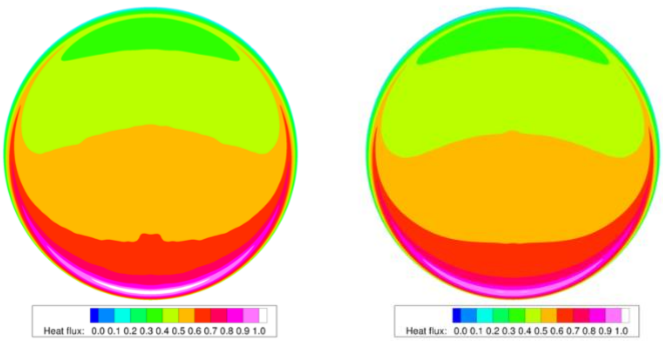

Figure 3: Comparison of heat flux contours on Orion heatshield: *US3D* (left) vs. *DPLR* (right)

References

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