Aerodynamic Study of a Ballute using CFD

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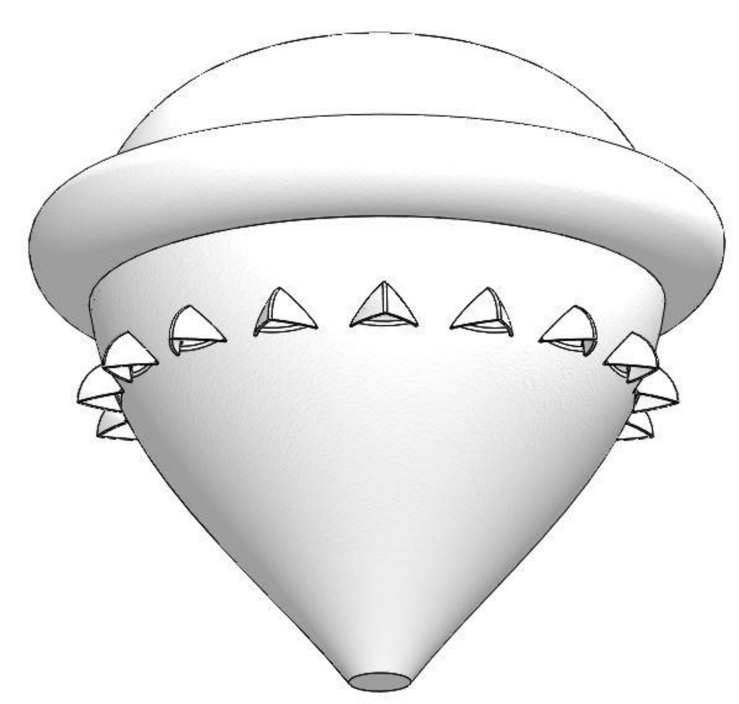
Introduction

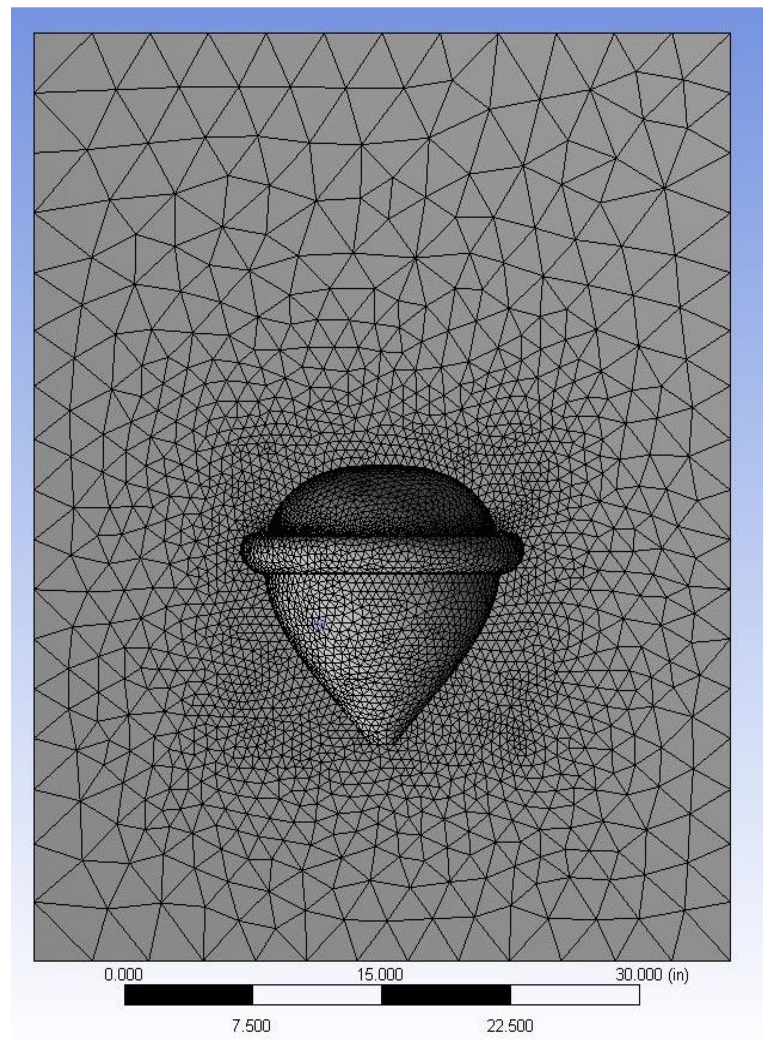
A ballute is a combination of the two words balloon and parachute (ball – ute). The ballute takes the large body size of the balloon and adds the drag inducing qualities of a parachute.

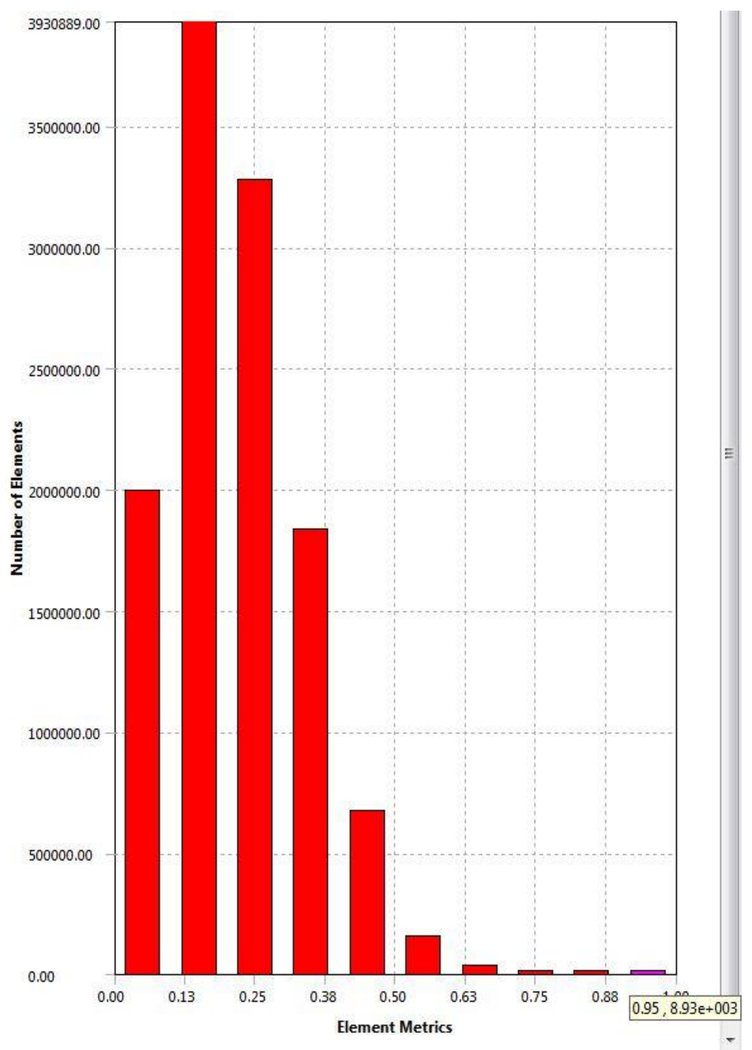
When the two are combined in the proper design, they can decelerate payloads drastically. The ballute has a large ring (called a burble fence) and a set of air scoops to allow for inflation. The ballute being studied has a diameter of 35 meters (approx. 115 feet). The diameter is comparable to two school buses parked bumper to bumper. The ballute is part of a larger system which is used for atmospheric re-entry. The total system is comprised of multiple deceleration and stabilization devices which are all unmanned.



Geometry and Meshing

Testing all of the different devices in a mock atmosphere re-entry happens rarely and is very costly. Computational Fluid Dynamics (CFD) is a cost effective tool enabling the study of various parameters and factors that impact the performance of the ballute. Multiple scaled geometries were simulated. Meshes were created for each geometry. Mesh specifications were monitored to assure geometric precision. One such specification monitored closely is orthogonal quality, plotted in this photo. Meshing is done to closely replicate the triangulated geometry of a model. This triangulation was achieved, accounting for very small details in the model's geometry. The more details and triangles, the finer the approximation of the fluid dynamic transport equations.





Materials and Methods

Software
- ANSYS® v14.5
  - Geometry generation
  - Mesh generation
  - Post processing (CFD-Post)
- Fluent® v14.5
  - Fluid Dynamic Simulation
- Microsoft Excel® 2013
  - Flow Data Analysis

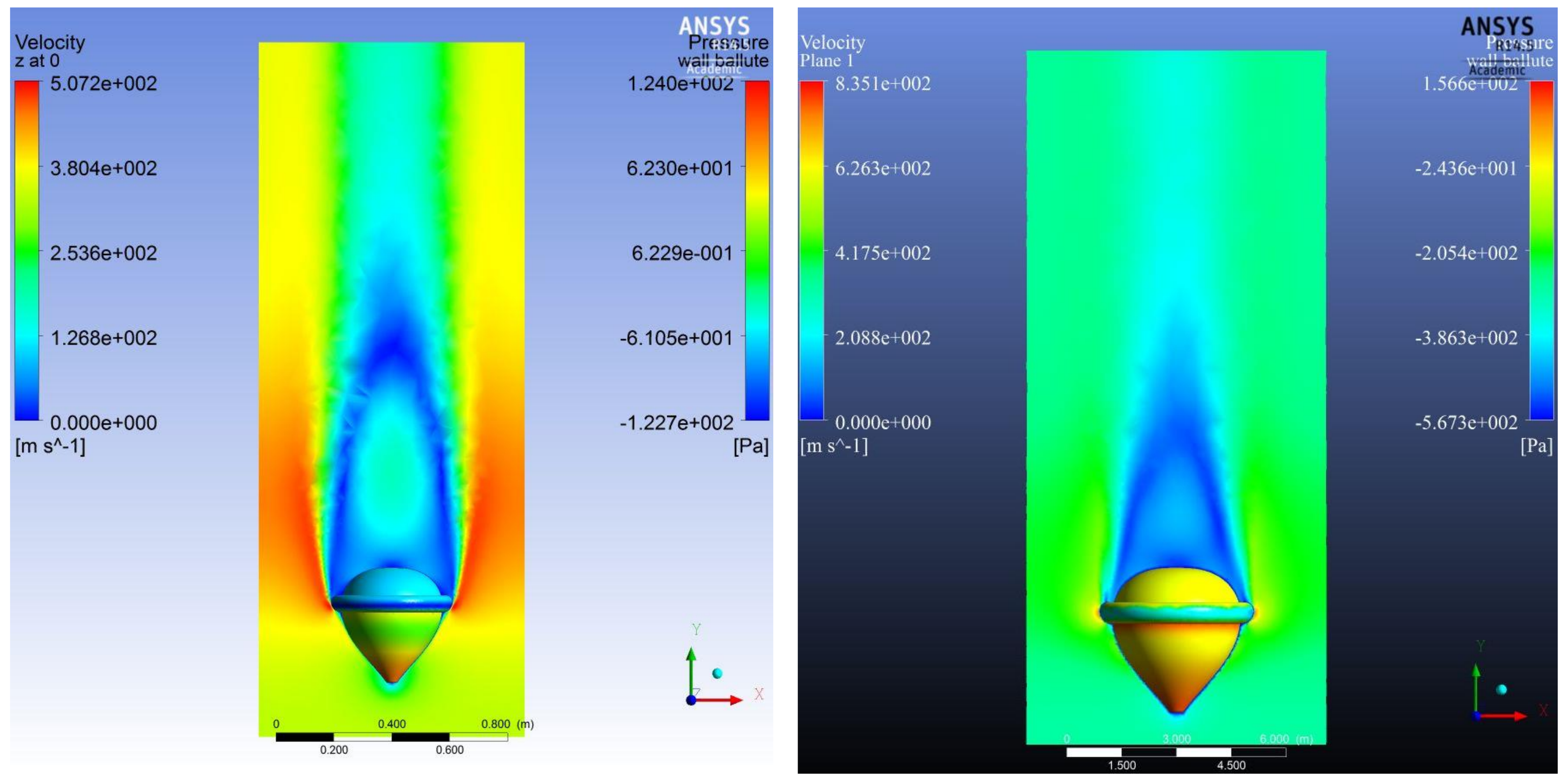
Testing Conditions
- Atmospheric replication of edge of stratosphere

Scales
- 1:10
- 1:100

The ballute was modeled in its most simple form, neglecting the air scoops. The ballute was also scaled down by an order of 10 and 100 from the actual experimental design. The flow speed was reduced by orders of Mach number. This was done to reduce the computational memory size, the computing power, and time needed to carry out each simulation.

Results

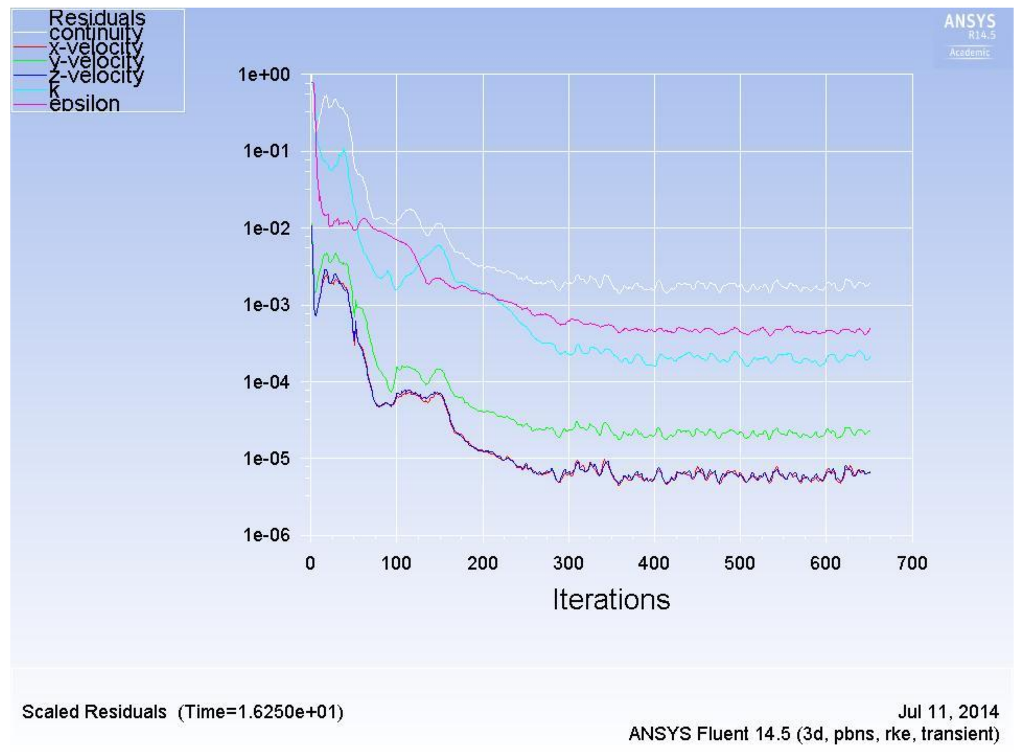
A study of the ballute with no air scoops was conducted on a small scale model and a larger scale model to discern major discrepancies in a comparison between the two models. The study concluded that there is a discernable difference between scaling a model.



1:100 Scale, Re = 1.13e+4 | 1:10 Scale, Re = 1.13 e+5

The images above were taken when the simulation had reached 30 seconds of flow time. It shows that the scalable geometry creates non-scalable flow patterns above the Ballute.

This graph (on right) is a transport equation result plot of a ballute with a radius of 1.75 meters (1:10 Scale) in air flowing at Mach 2.5 (1,900 mph). The continuity line (white) needs to fall under 10^{-6} (1e-06) for convergence and validation of any data readings such as forces, temperatures, and vortex formation.



Conclusions

My research has not concluded, as most of my simulations have not been validated. The simulations calculate transport equations which are monitored by the difference in the values from one answer to the next answer, called residuals. The residuals must have a difference no greater than 10^{-6}, which is the standard result precision for CFD. Most of the simulations I have run haven't had a difference in the residuals this small. This has prevented any drag and lift values from being considered an accurate calculation to be compared with experimental data to justify the methods used in CFD. In the future valid data will be compared to published literature data for an experimental ballute.

Image credit to NASA

Image credit to Armadillo Aerospace

References

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