Fluid Transport Behind a Hemisphere

Allen Ma and (Faculty Advisor) Dr. Chris White
Department of Mechanical Engineering, University of New Hampshire, Durham, NH

University of New Hampshire

Introduction/Objective:

•Understanding and predicting heat transfer is critically important in many engineered and natural flow systems (e.g., engines, power plants, atmosphere, ocean, among many other systems).
•The above flow systems are inherently three-dimensional, yet the models used to predict the behaviors of these systems are based on two-dimensional flow systems.
•The project objective is to conduct a systematic investigation of fluid transport in simple three-dimensional flows.
•The project aim is to provide data that can be used to improve the engineering modeling of three-dimensional flow systems.

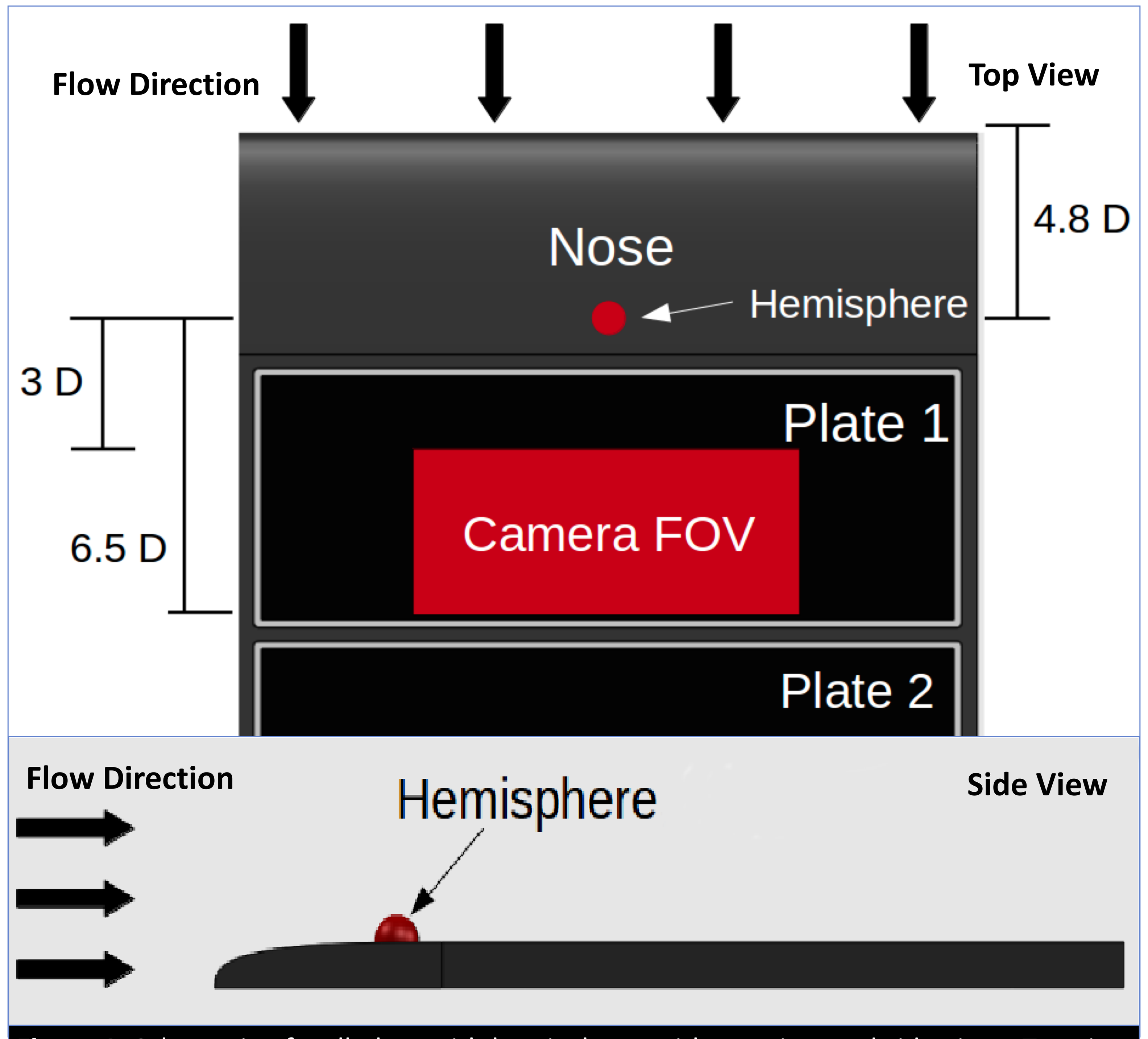

Figure 1: Schematic of wall plate with hemisphere, with top view and side view. Top view shows the relative position of the hemisphere in the spanwise and streamwise directions, and the infrared (IR) camera field of view (FOV). Beneath each plate are multiple flexible heaters that are used to raise the temperature of the plate to a constant temperature. D represents the relative position in terms of hemisphere diameters.

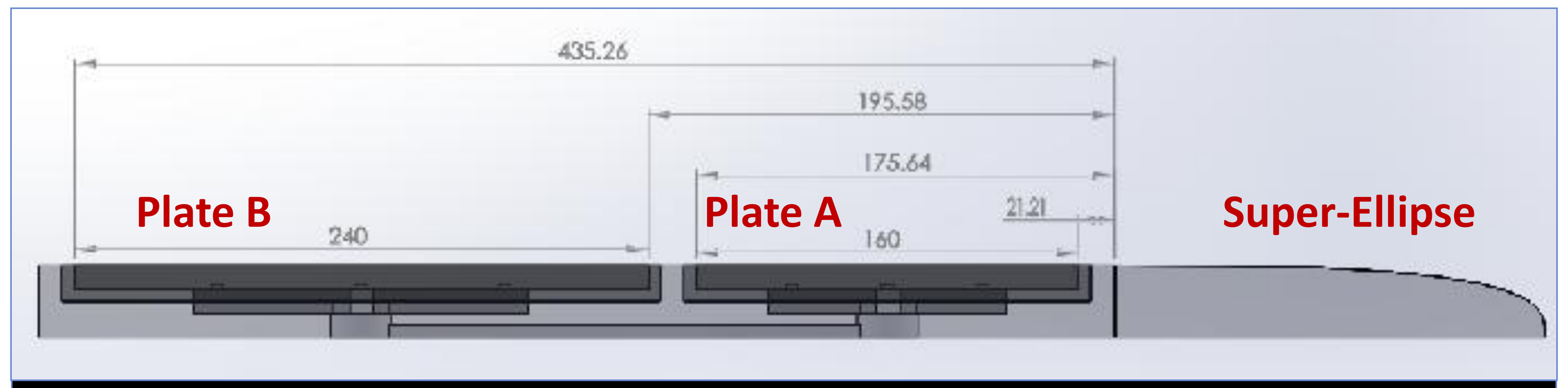

Figure 2: Design for the Wall Plate (*Side View*)

Results:

Velocity Data (see Figure 3):
Test 1: No Heat, No Hemi (red star)
Test 2: 48C, No Hemi (red circle)
Test 3: 48C, With Hemi (blue circle)
Test 4: No Heat, With Hemi (blue star)

The different tests show clearly different velocity profiles. The tests without heating reached free stream velocity more quickly, while the tests with the hemisphere had higher velocities closer to the wall.

Temperature Data (see Figure 4):
Only temperature data without the hemisphere has been acquired so far. The wall plate was set to a temperature of 48C.

In Figure 3, "Temperature" is the temperature of the fluid flow above the wall plate and behind the hemisphere. "Distance" is the height of the measurement with respect to the wall plate; it is in a logarithmic scale due to the rapid changes in the temperature profile versus height.

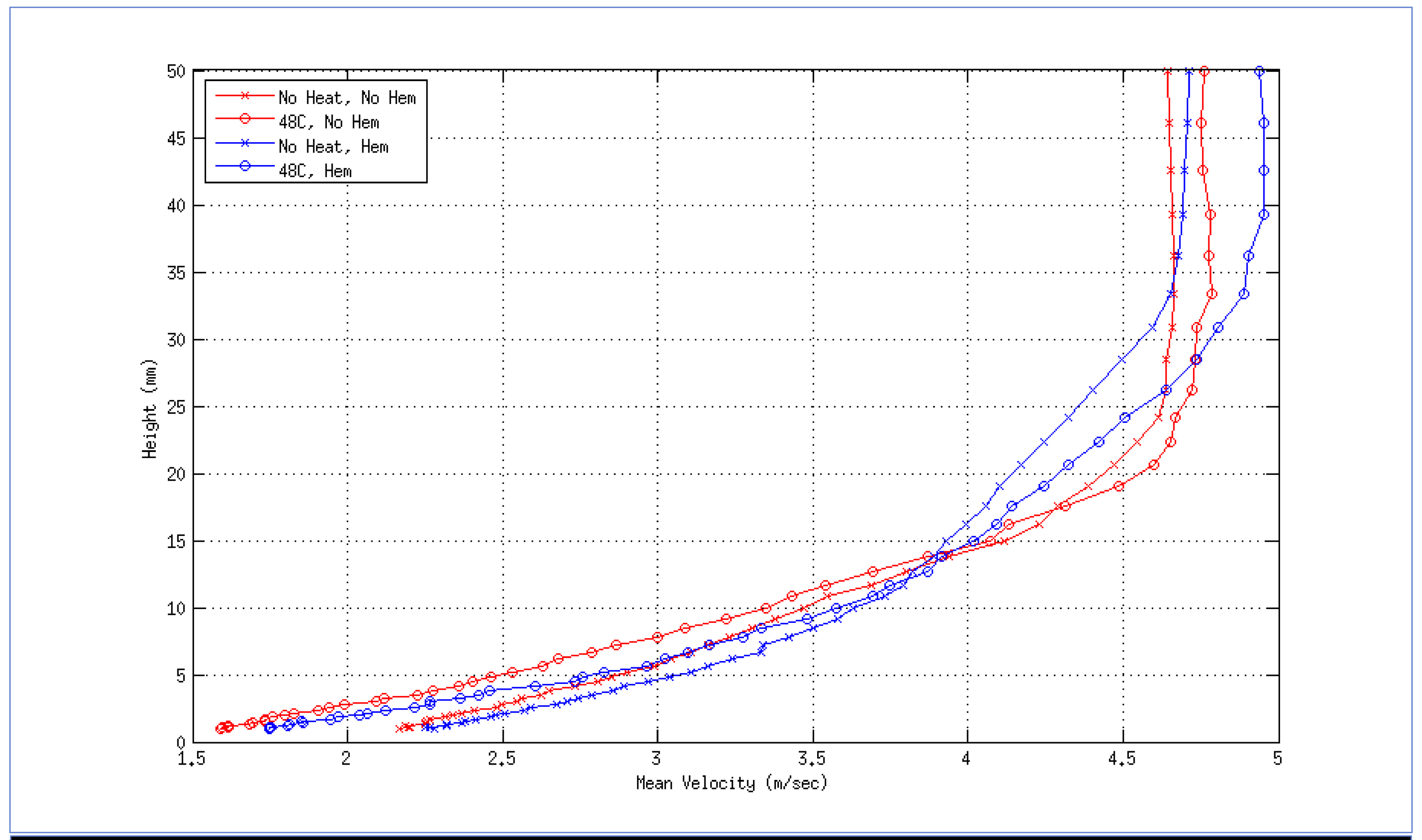

Figure 3: Velocity profiles with and without the hemisphere, and with and without heating. Red – no hemisphere; blue – with hemisphere. Star – no heating; circle – with heating.

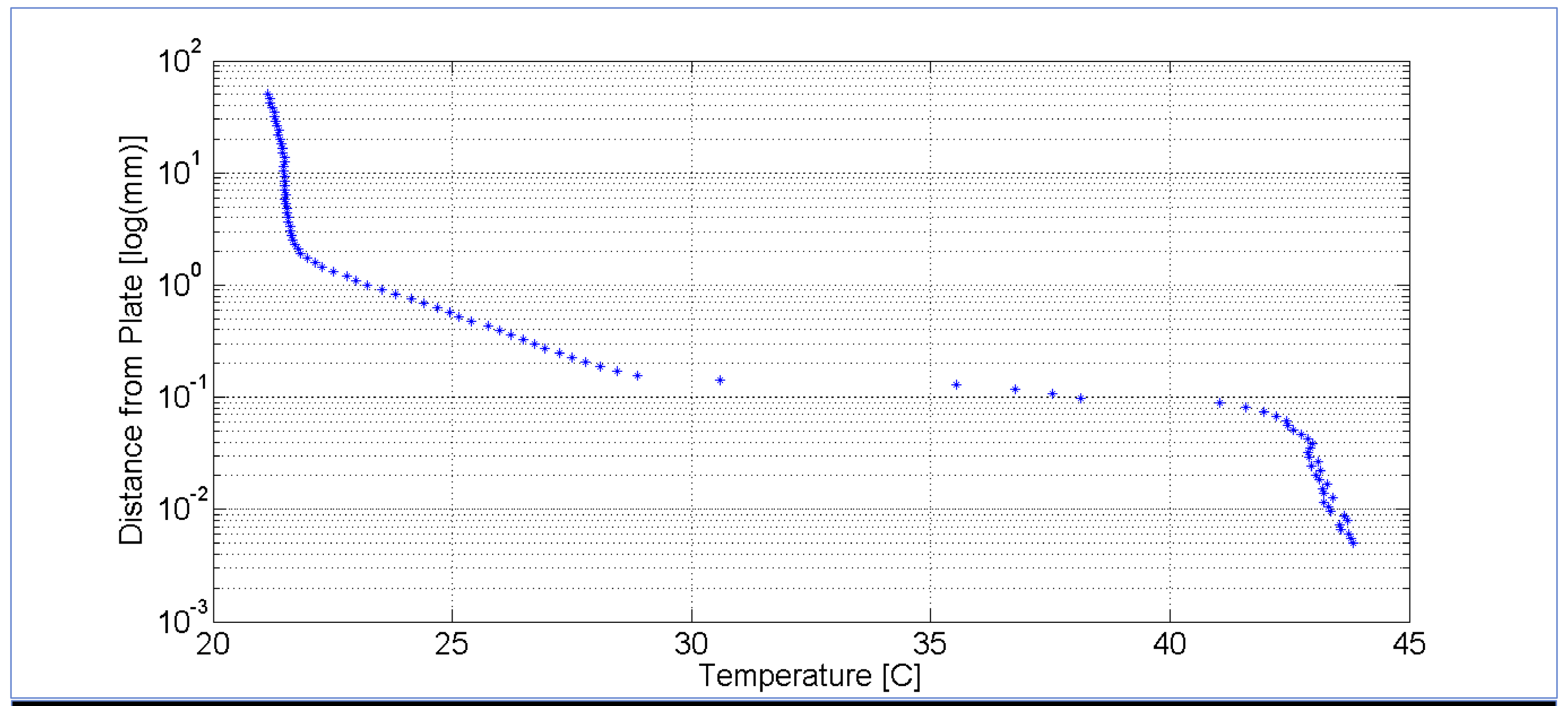

Figure 4: Temperature profile without the hemisphere. The distance from the plate is set to a logarithmic scale to better demonstrate the profile.

Discussion/Conclusions:

•From the velocity profiles in Figure 3, it can be seen that the velocity field does change when subjected to a hemisphere or a heated wall plate. This is expected, and is supported by much literature.
•It can be seen from Figure 5 that the hemisphere modifies the thermal transport between the flow and the wall. From this and from Figure 4, it can be inferred that the temperature profile with the hemisphere would be different than without the hemisphere. Measuring and quantifying these effects constitute on-going and near-term research.

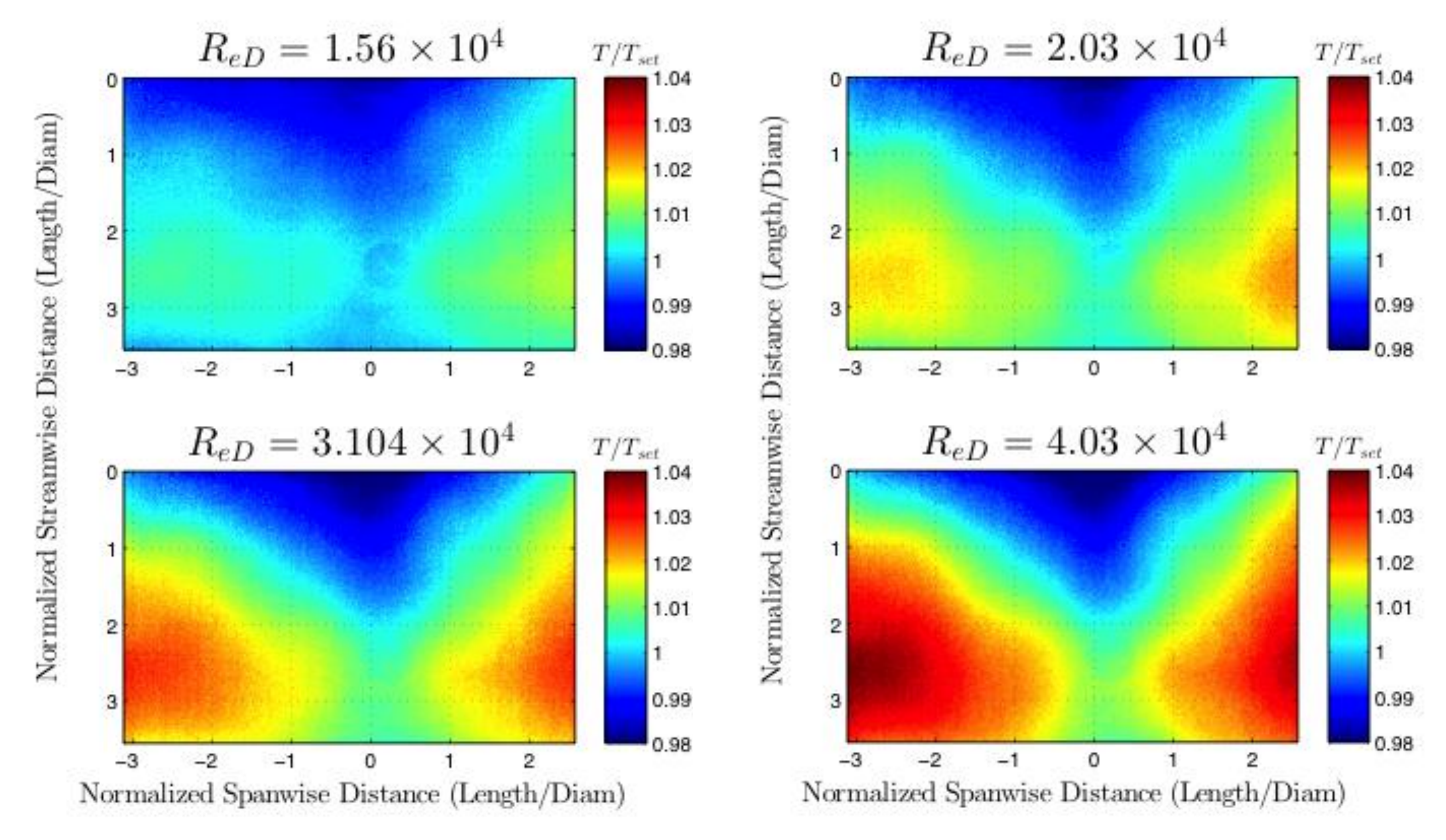

Figure 5: IR camera output of Plate A during heating at various Reynolds numbers. At all Reynolds numbers (Re_D), temperature variations can be seen in both the spanwise and the streamwise directions. These variations are more pronounced at higher Reynolds numbers.

Reynolds number is the ratio of the inertial forces of a flow to the viscous forces. It can be used to describe flow patterns and behavior, such as laminar or turbulent flow. Turbulent flow usually has a Reynolds number of approximately Re ~ 10^5.

Future Plans:

•Measure the temperature profile of fluid flow behind the hemisphere.
•Obtain velocity and temperature measurements of the fluid flow for hemispheres of various sizes.
•Analyze these data sets to validate and improve engineering computational fluid dynamics models.

Acknowledgements:

Dr. Chris White (Faculty Advisor)
Drummond Biles (Graduate Student)
Reza Ebadi (Graduate Student)