Apr 16th, 1:20 PM - 1:40 PM

Using Computational Fluid Dynamics to Predict Drag on a Boat Hull

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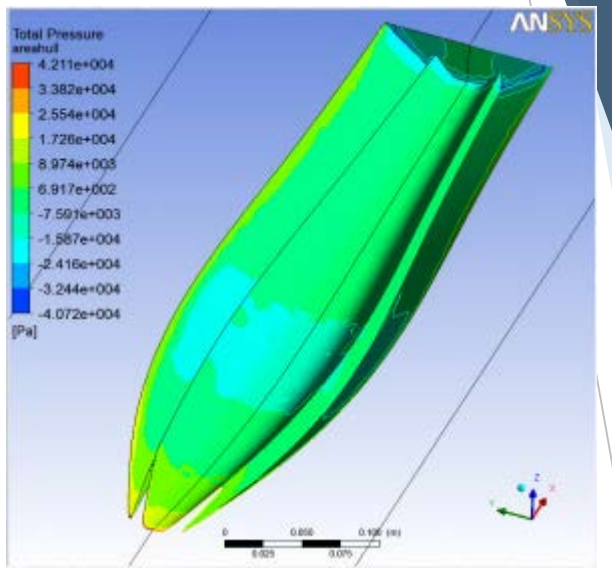
Motivation

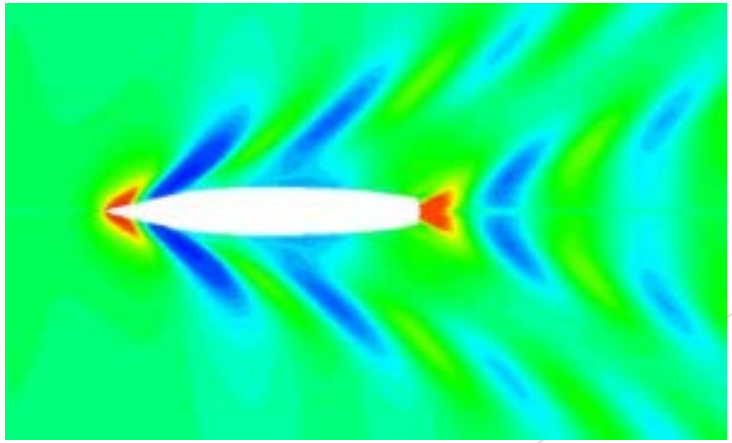
- Predict boat hull drag
  - Reduce need for physical boat
  - Calculate multiple variables
    - Drag vs. Boat Weight
    - Wave Patterns
    - Max Speed

Background Research

- Leap Australia – Marine Challenge
  - Dr. Ben Simpson[1]



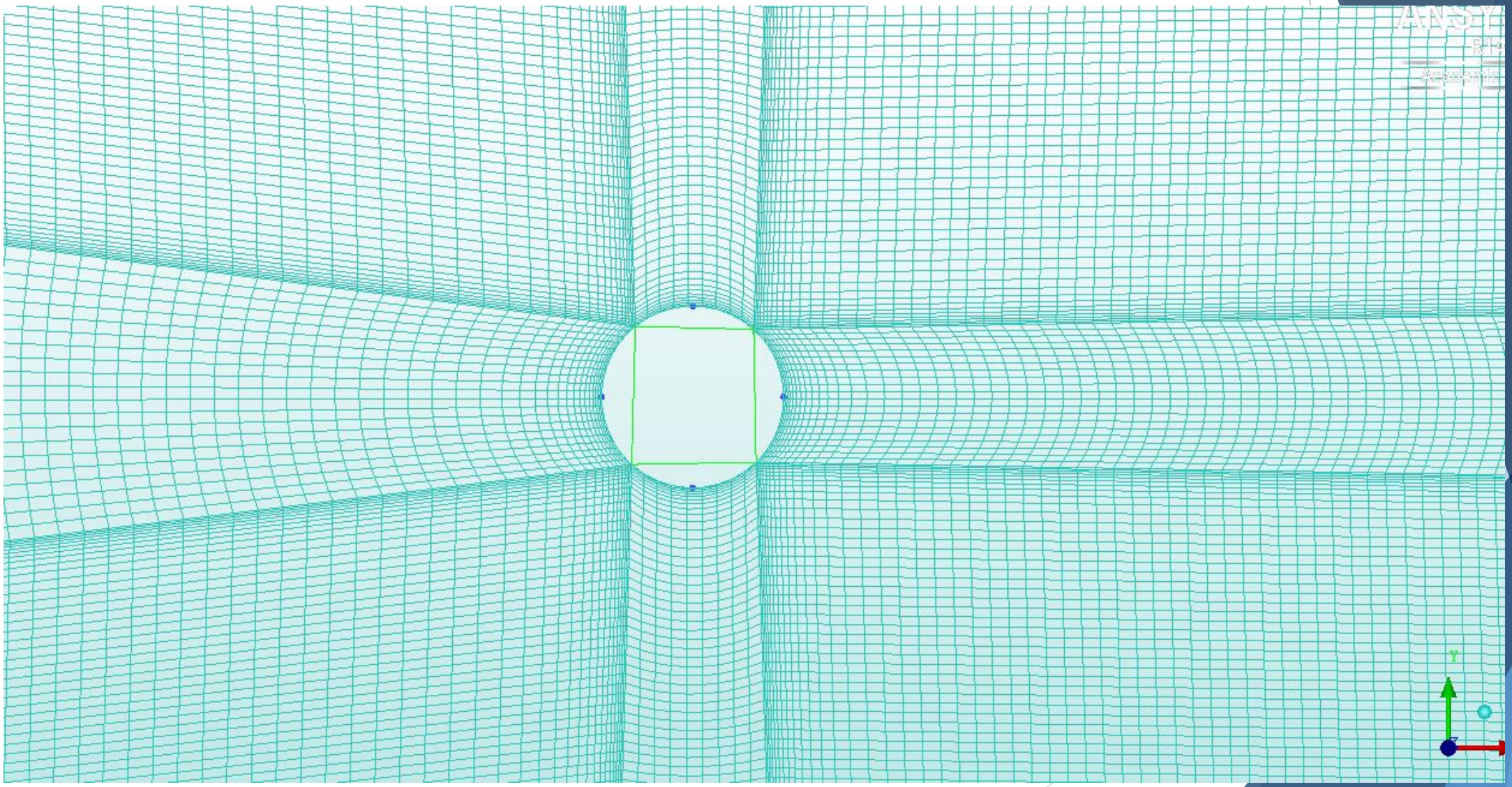
- Australian Department of Defense
  - D.A. Jones and D.B. Clarke[2]



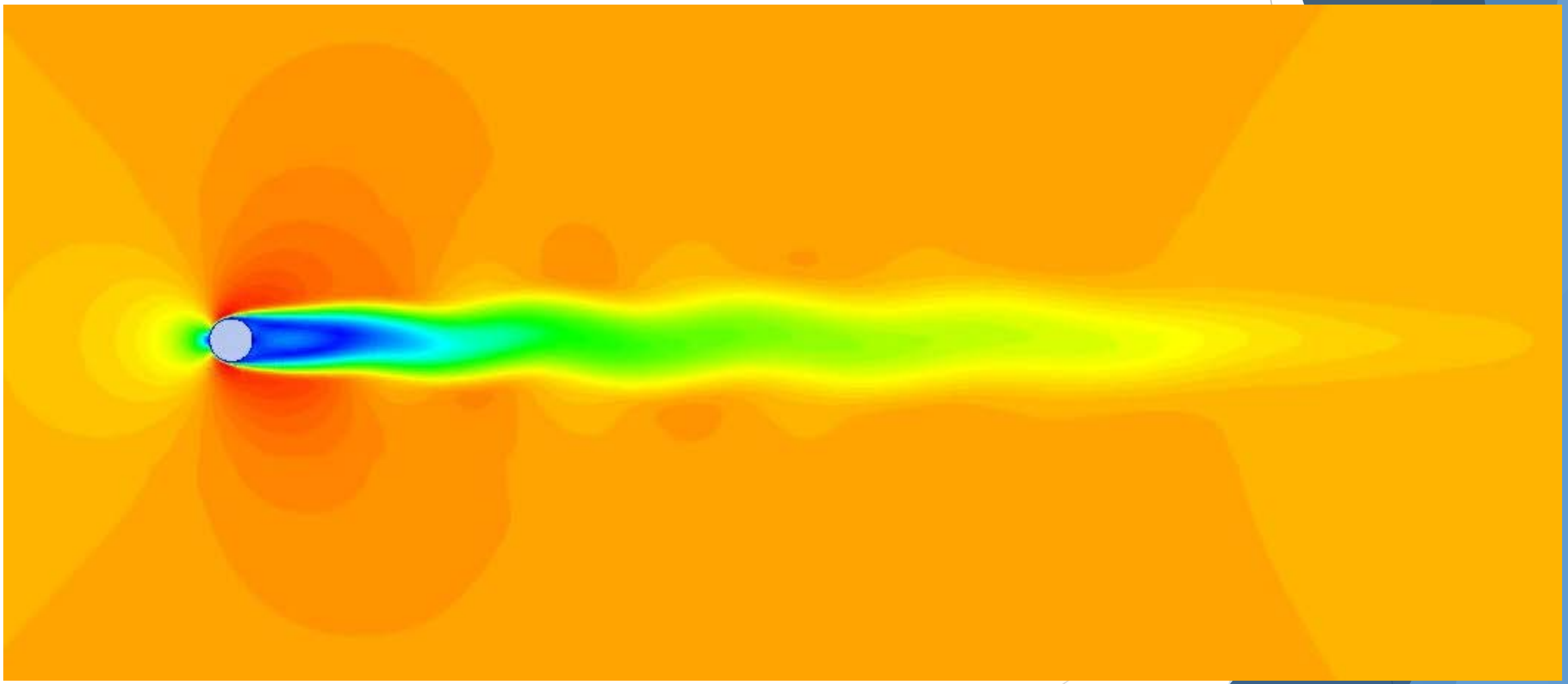
What is CFD?

- Stands for Computational Fluid Dynamics
- Model fluid flow around a fixed object

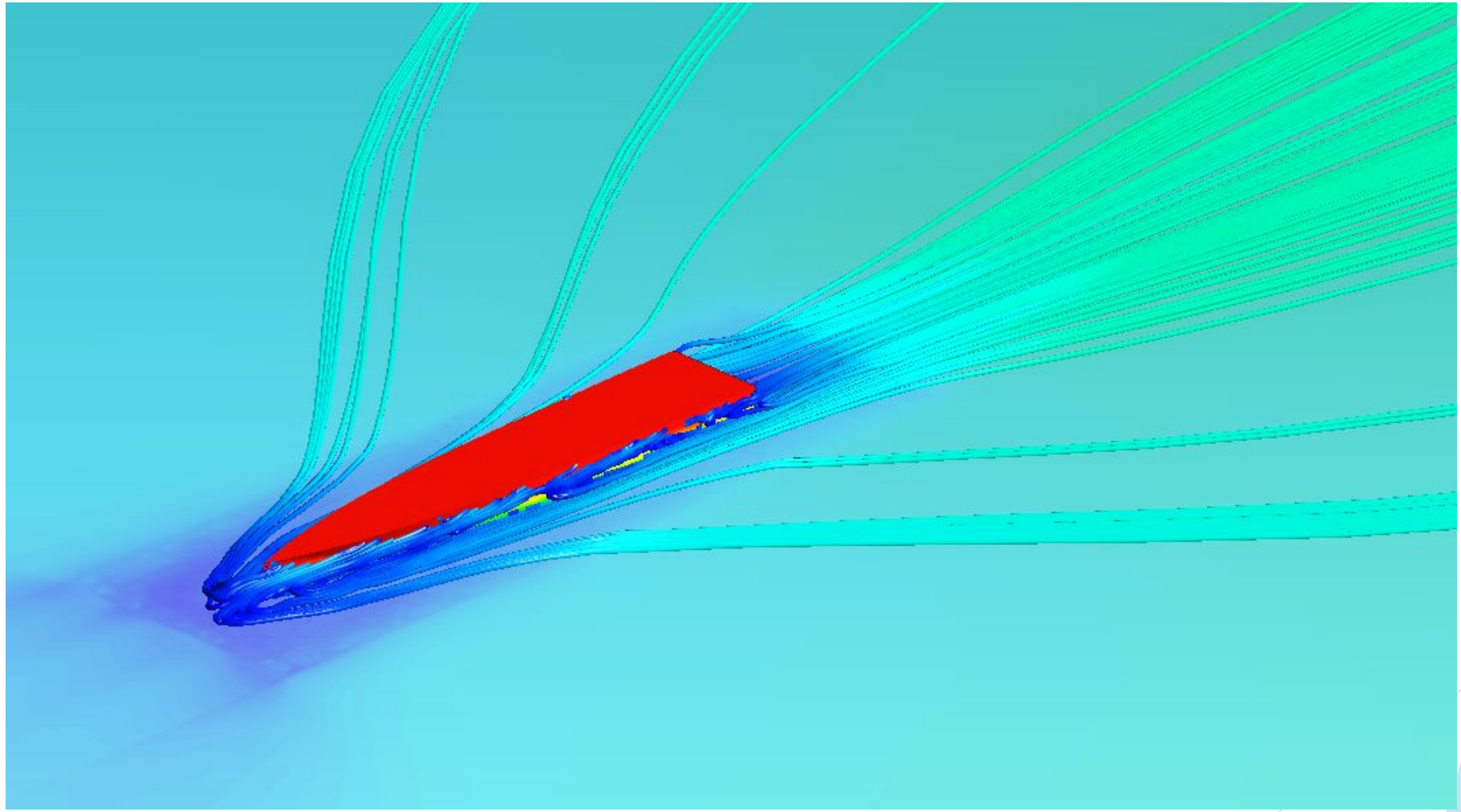
What is CFD?



What is CFD?



What is CFD?

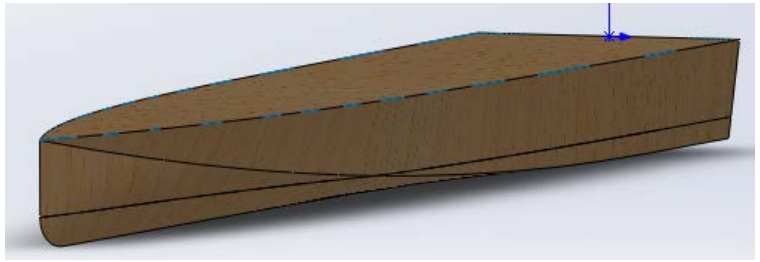


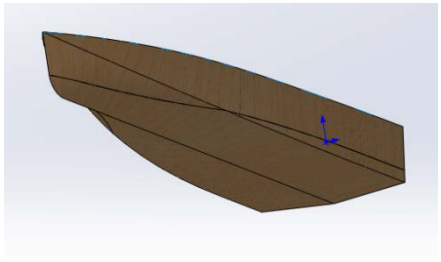
Methodology

- Create Mesh in Ansys ICEM
- Import Mesh into Ansys Fluent
- Run Simulation in Fluent
- Analyze Results

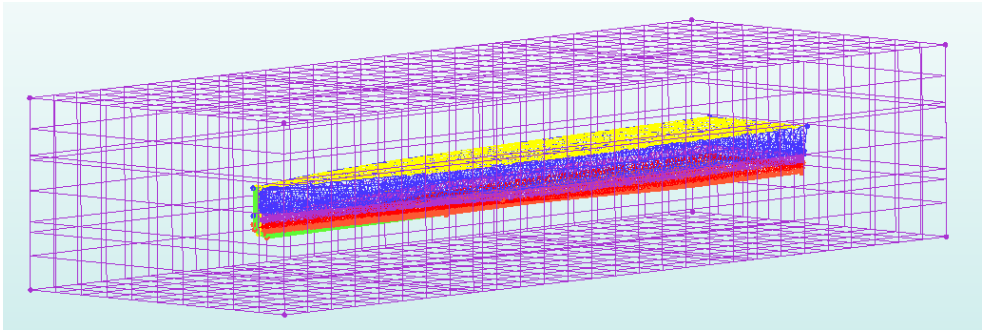
Create Mesh in Ansys ICEM

- Import Solidworks Model of Solar Boat



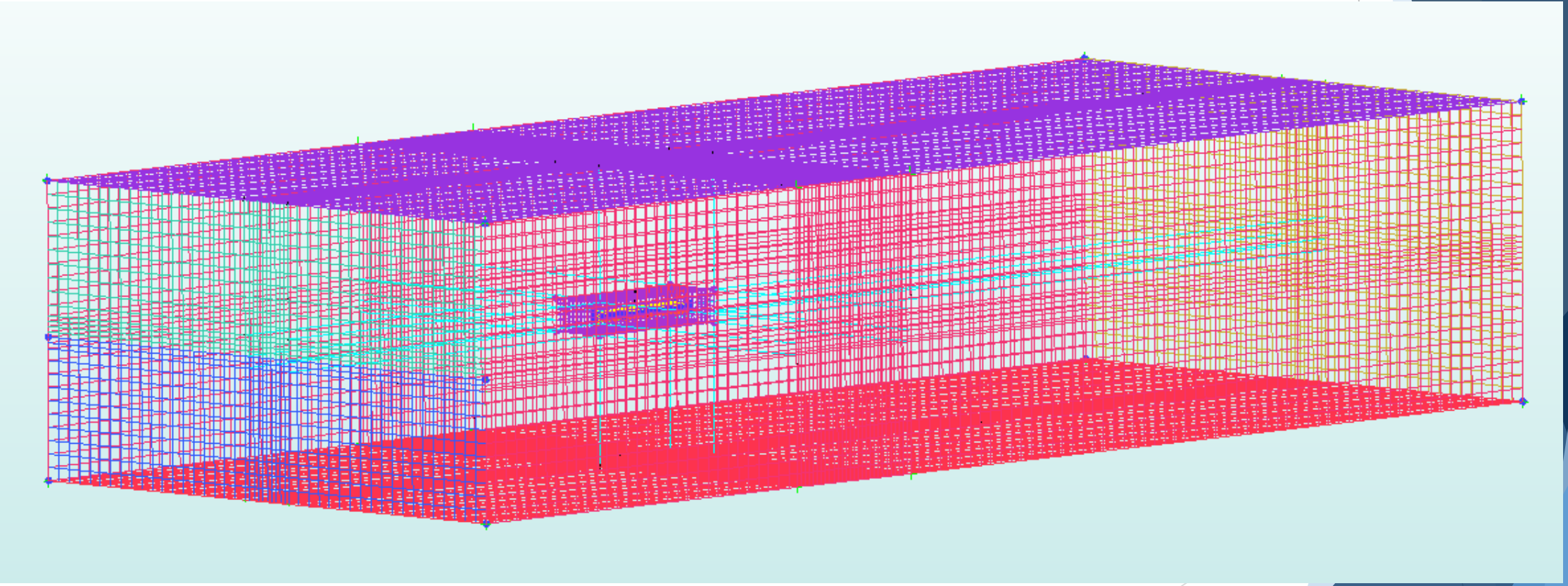


- Create Inner Box for Volume Fill



Create Mesh in Ansys ICEM

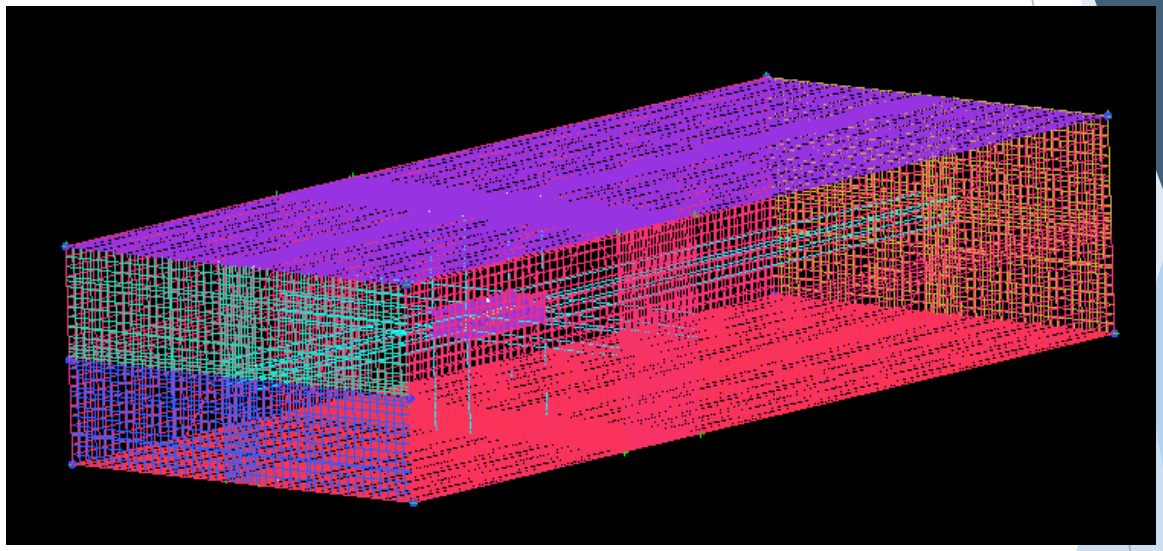
- Create remaining Flow Field



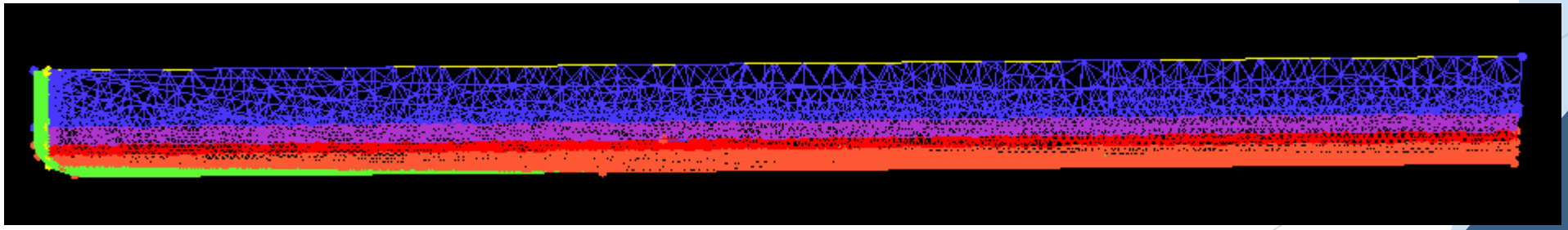
Mesh Summary

3D Solar Boat – Mesh In ICEM

- Cell Limit
  - Required careful cell placement
  - Sectioned the geometry
  - Varied volume mesh parameters
  - Reduced flow field cell count
- Mesh Results
  - 474k Cells (512k Limit)



Entire Mesh



Mesh of the Boat

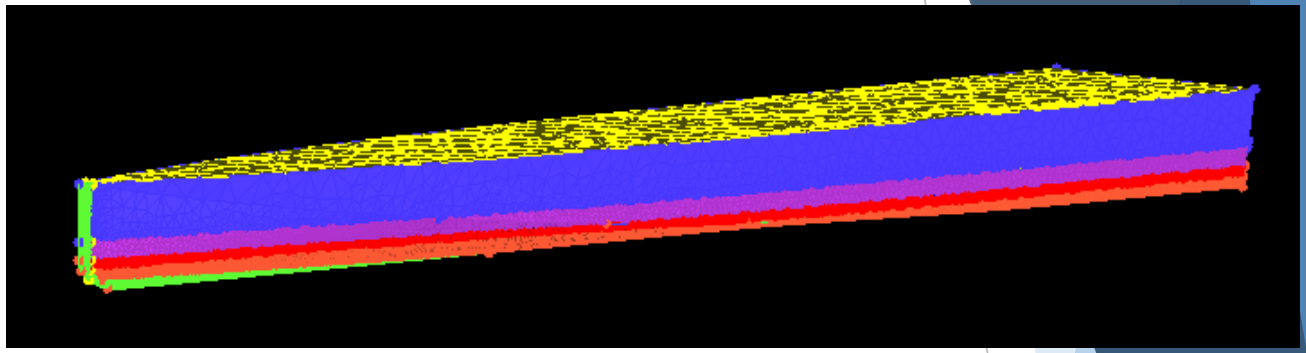
Import Mesh into Ansys Fluent

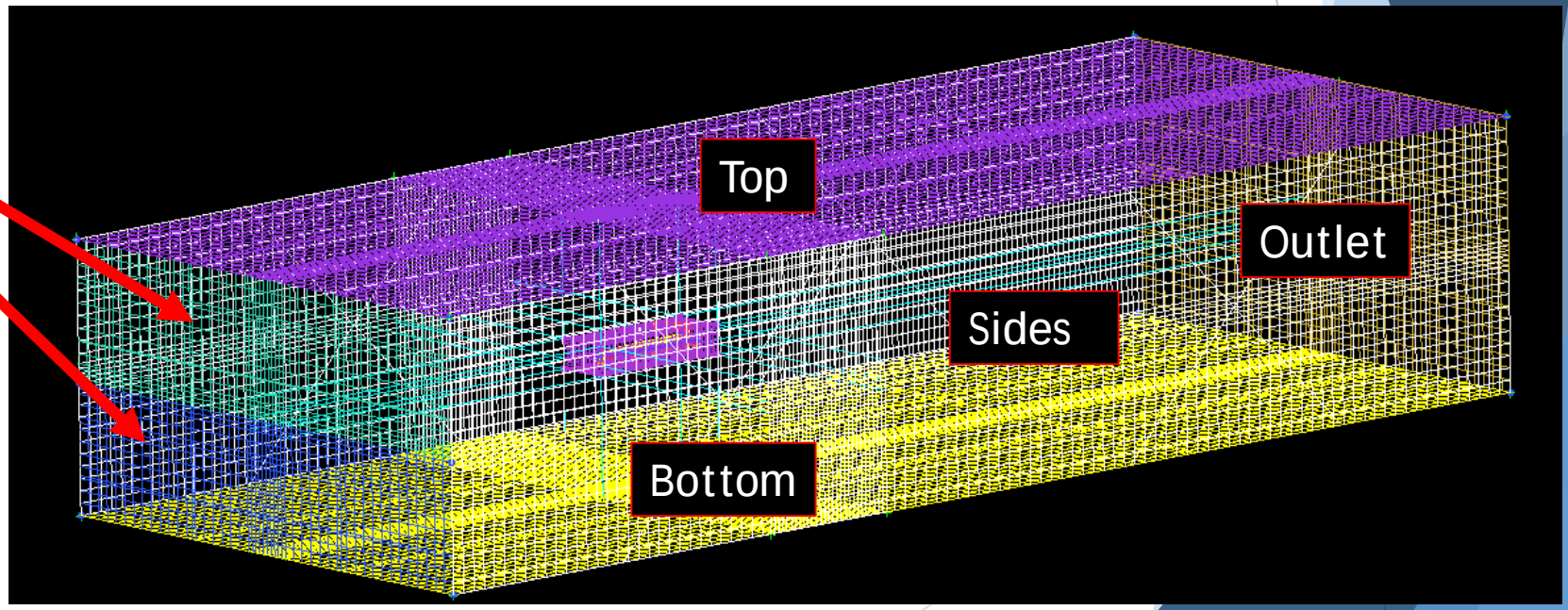
- Scale Mesh
- Setup Solution Parameters
  - Viscous Model: K-Epsilon
  - Body Weighted Pressure Formulation
  - Relaxation Factors below 0.5
  - Initialize Solution
    - Patch Water and Air Regions
  - Define Time Steps
    - 20 Iterations per Time Step

Fluent Test Conditions

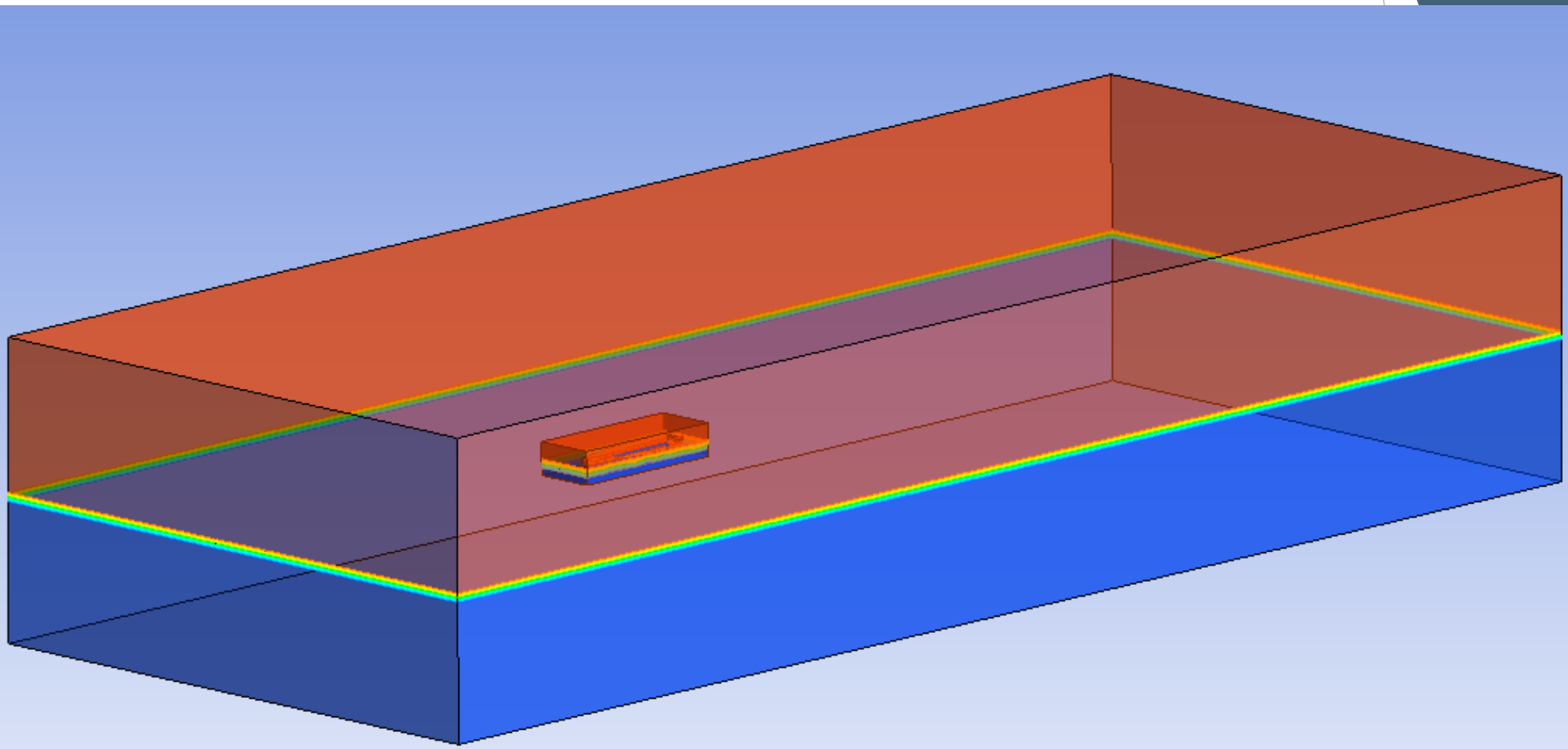
3D Solar Boat – In Fluent

- Boundary Conditions:
  - Wall
    - Boat
    - Bottom of Flow Field
  - Velocity-Inlet
    - Inlet_air
    - Inlet_water
  - Outflow
    - Flow Field Outlet
  - Symmetry
    - Flow Field Sides
    - Flow Field Top

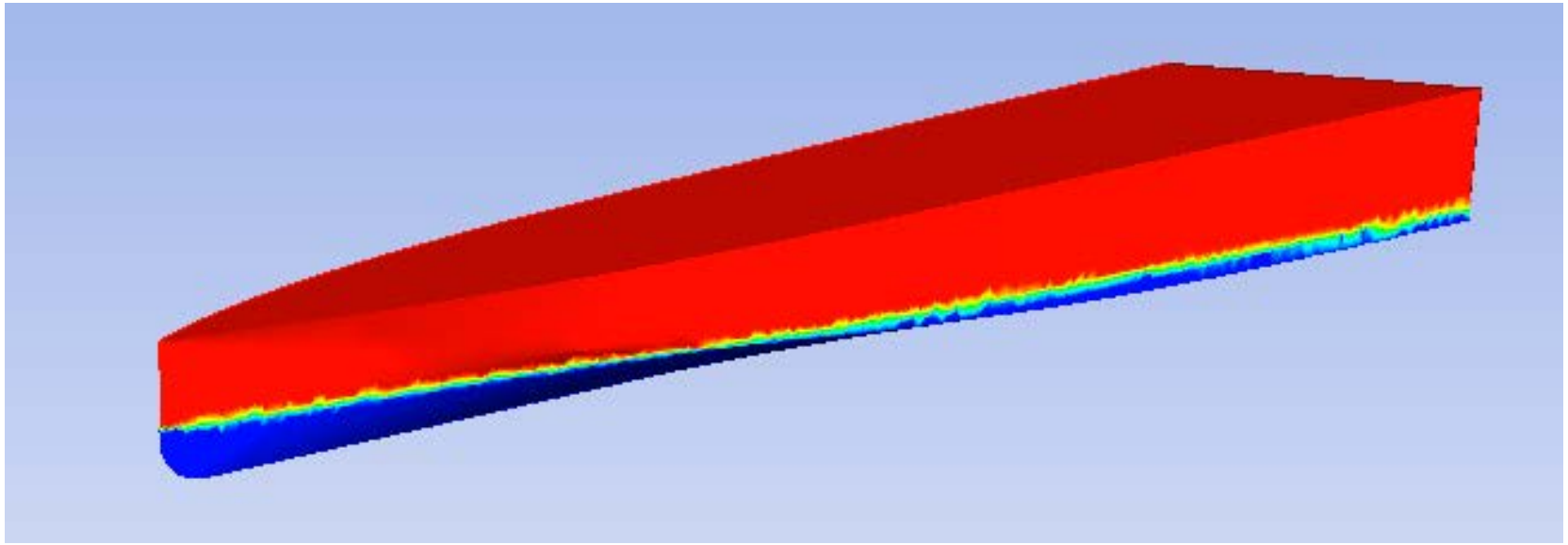




Simulation Before CFD



Simulation Before CFD



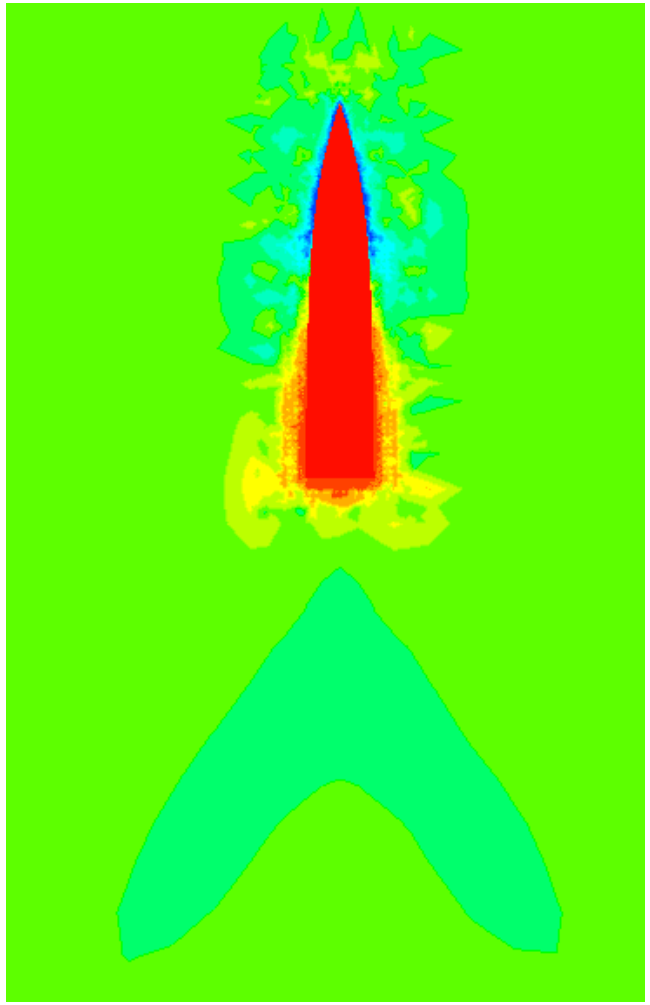
Close-up view of the Boat

Final Solution Parameters

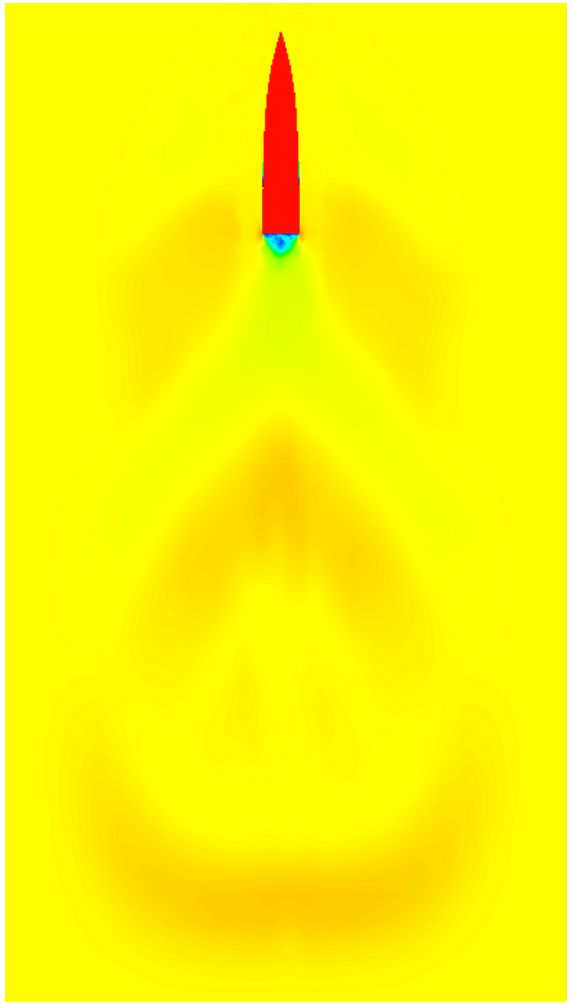
- Time Step Size: 0.001
  - 20 Iterations per time step
- Require 2000-5000 time steps to converge
  - 40k-100k iterations
  - 2-4 weeks on CU Computers

Fluent Results

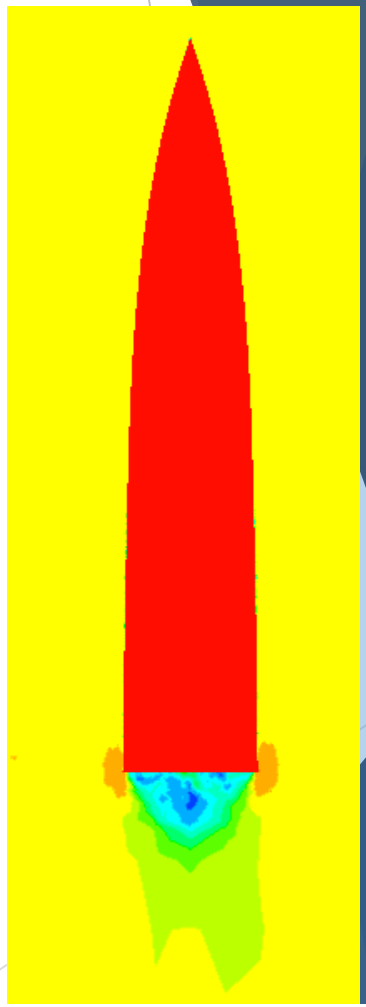
- Obtained initial converged result:



Top-View of the Wave Patterns of the Boat

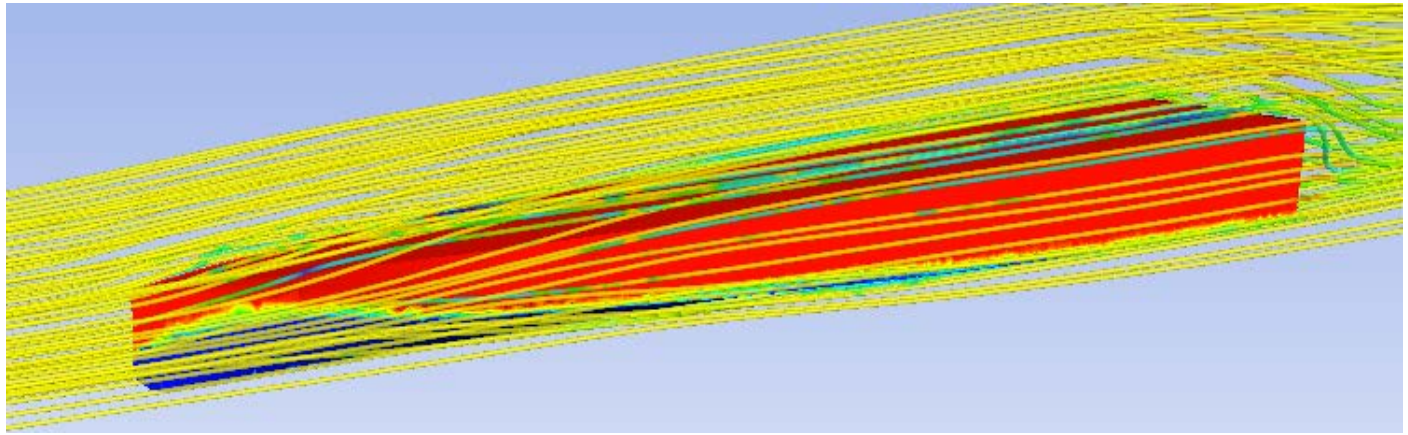


Top-View Showing the Wake Behind the Boat

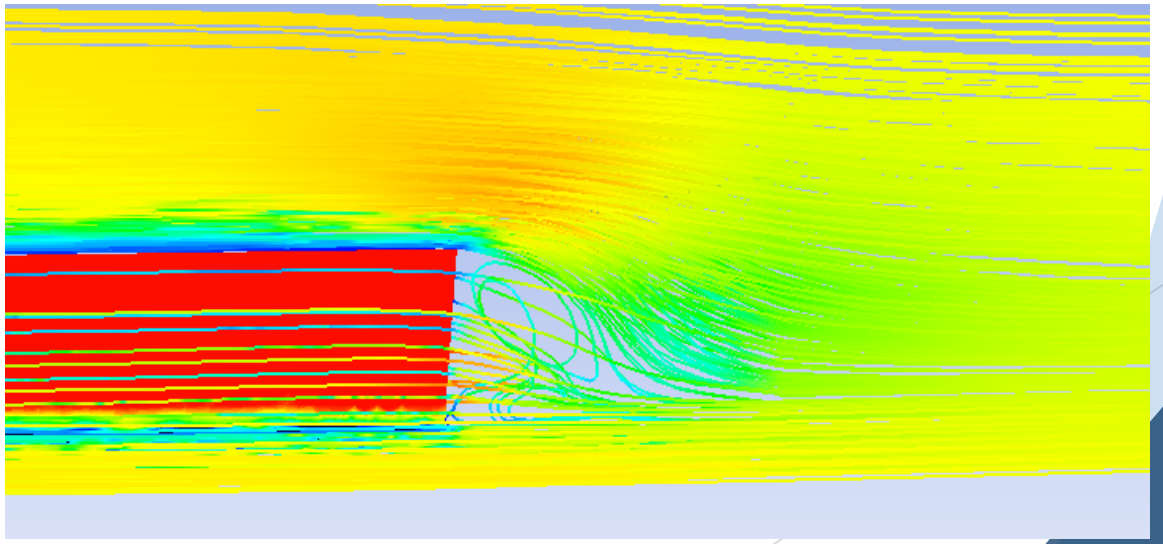


Top-View Showing the Velocity of the Boat

Simulation Post CFD



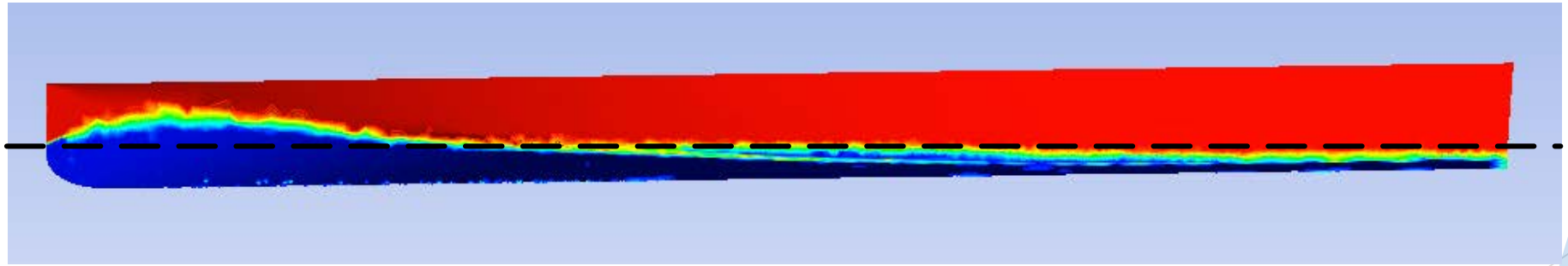
Velocity Streamlines of Boat



Turbulence at the Back

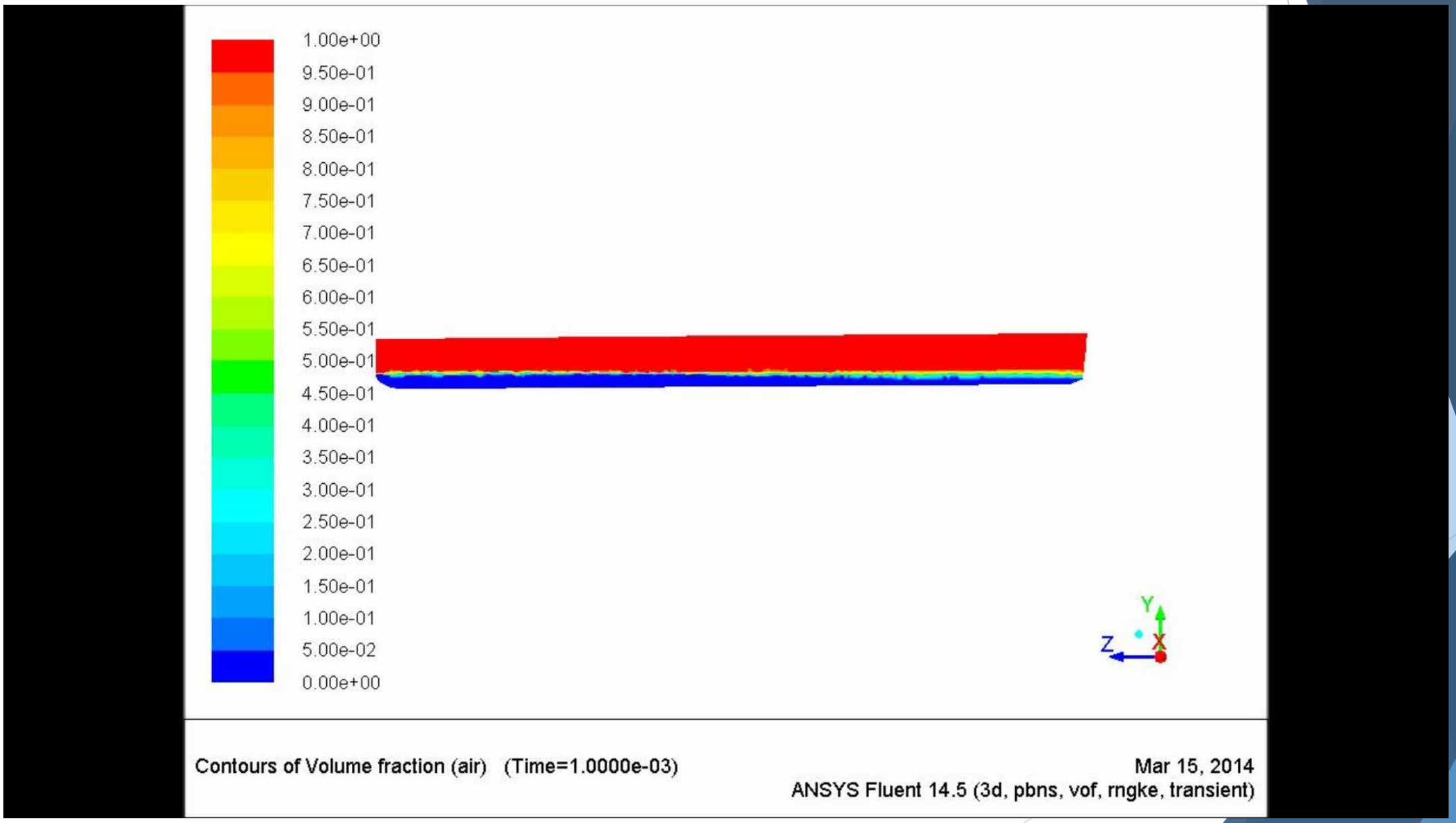
Simulation Post CFD

Picture of the Solar Boat at Competition



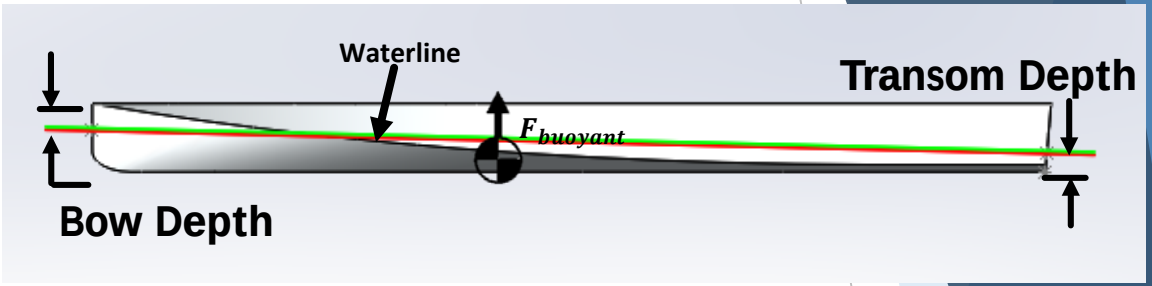
Side view of the Boat in Fluent

Wave Formulation



Drag vs. Boat Weight

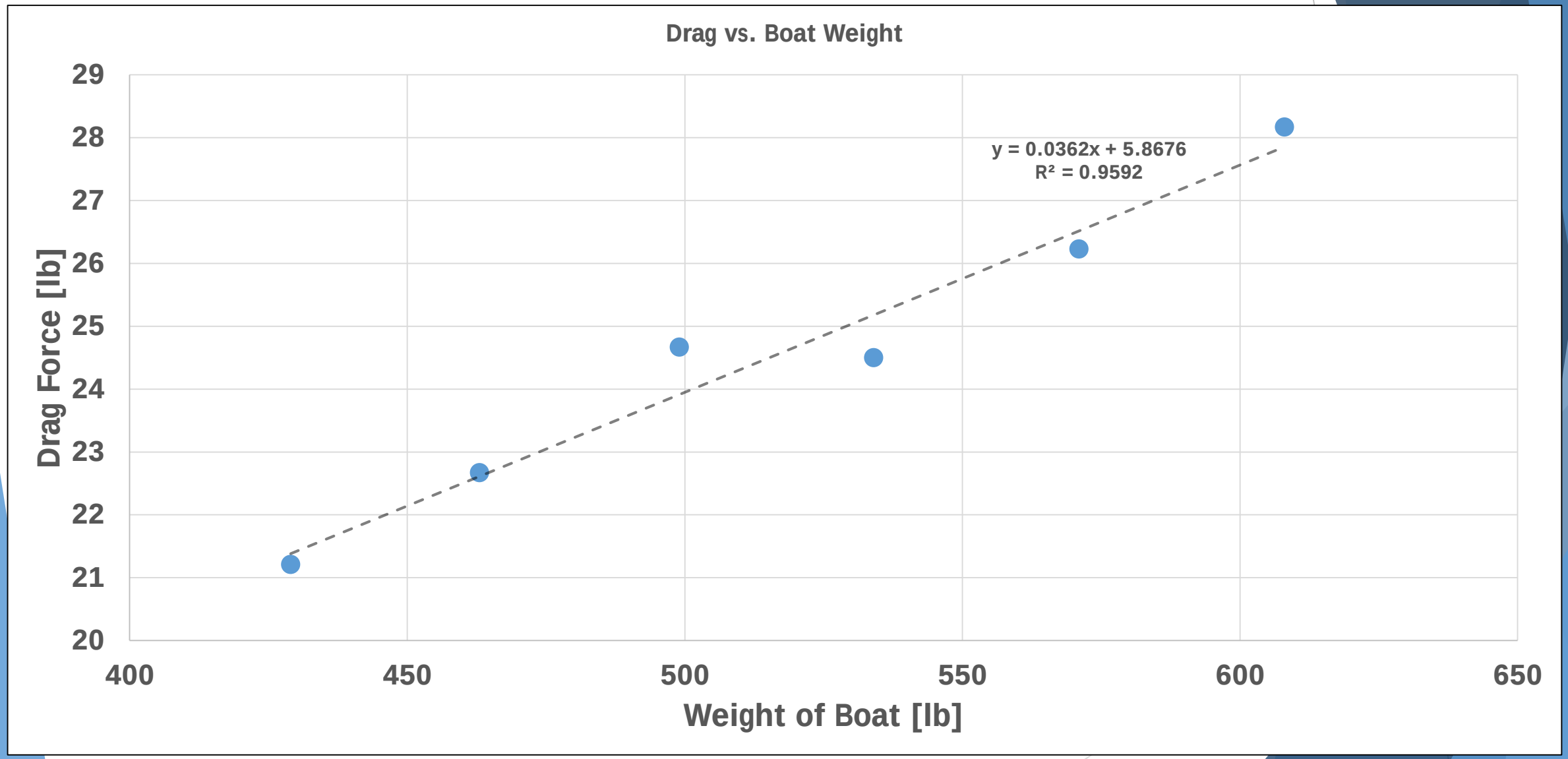
- Varied the Boat's Angle
  - Boat weight from 429-608 lb.



Boat Model from Joel Ingram[3]

3in Transom Weight Study				
Bow Depth [in]	**Drag [lbf]**	**Lift [lbf]**	**Flow Time [sec]**	**Weight* [lb]**
7.0	28.17	477.0	1.750	608
6.5	26.23	455.4	1.359	571
6.0	24.5	421.3	2.762	534
5.5	24.67	420.3	3.191	499
5.0	22.67	375.1	2.493	463
4.5	21.21	359.4	4.965	429

Fluent Weight Vs. Drag

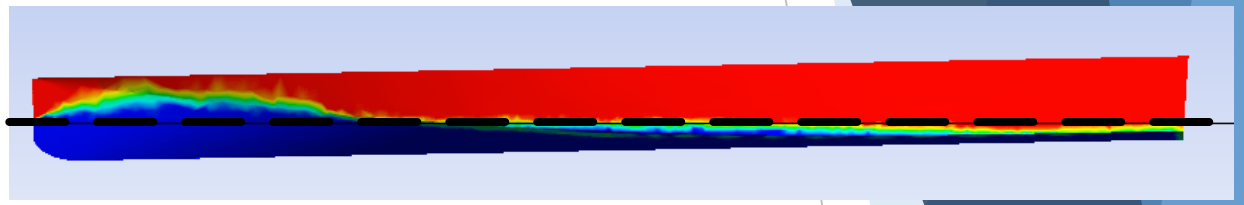


Fluent Weight Vs. Drag Study

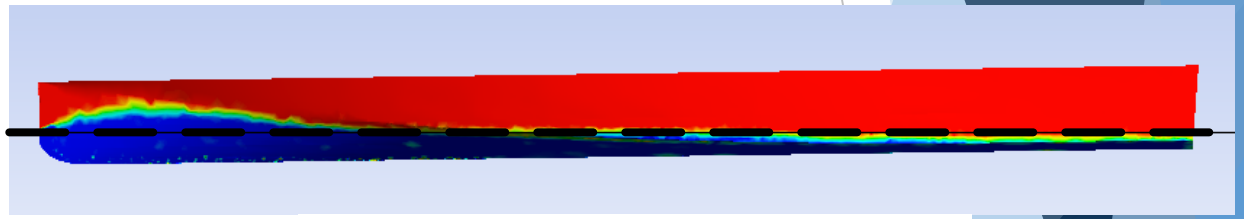
Governing Equation:	Inputs
Drag = 0.0362(Weight) + 5.8676	Outputs
Enter Desired Weight 1 [lb]:	500
Enter Desired Weight 2 [lb]:	550
Estimated Drag Force 1 [lbf]:	23.97
Estimated Drag Force 2 [lbf]:	25.78
Weight Difference:	50
Drag Difference:	1.81
Drag / (1 lb of Weight)	0.0362

Table showing how boat weight effects drag

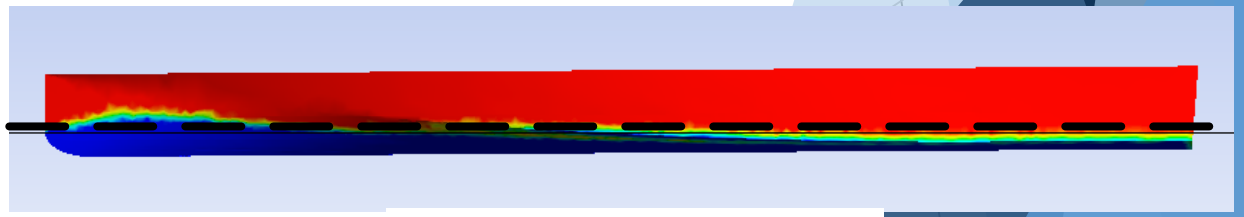
CFD Post Results



7.0 inch Bow Depth



5.5 inch Bow Depth



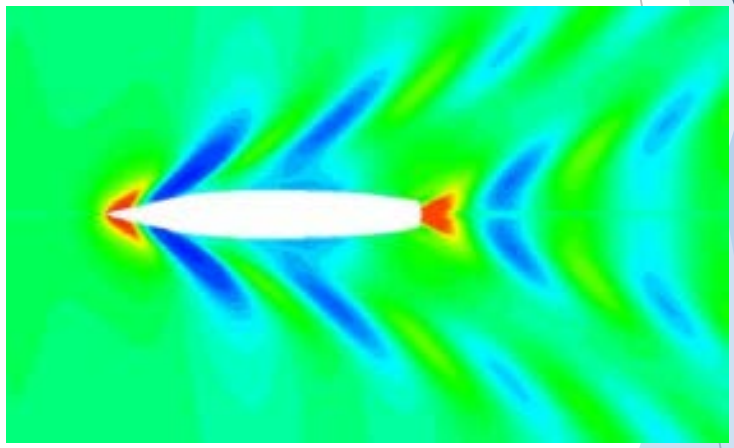
4.5 inch Bow Depth

Conclusions

- Predict Drag Force
  - 24.67 lb.
- Determine Boat Weight vs. Drag
  - 50 lb Boat Weight = 1.8 lb Drag Force
- Fluent Capabilities
  - Dual Phase Flow
  - Possible to do all this with Academic License

Further Study

- Wave Study
  - Trying to match Australian Department of Defense pictures
  - Use Ohio Supercomputer Center
    - Uses a much larger mesh ~4-7 million cells
- More Complex Boat Shapes
  - Add motors and other boat accessories
    - Driver Drag?
    - Drag with and without a boat deck



Special Thanks

- This work was supported in part by an allocation of computing time from the Ohio Supercomputer Center
- My Advisors:
  - Dr. George Qin
  - Dr. Timothy Dewhurst
- Cedarville University
  - Computers
- Additional Help
  - Dr. Harwood Hegna
  - Joel Ingram

Bibliography

1. http://www.marinechallenge.qld.edu.au/docs/Marine-challenge-CFD.pdf
2. http://www.dtic.mil/dtic/tr/fulltext/u2/a532509.pdf

Questions?