Introduction to CFD at the University of Florida: Class Development and Outcomes

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Outline

The University of Florida Department of Mechanical and Aerospace Engineering recently created a new senior technical elective in the field of computational fluid dynamics (CFD).
Outline

- Class overview, description, process, and outline
- Integration of class with student groups
- Use of one commercial software package
- Example projects

We present the class philosophy for teaching undergraduate CFD and the outcomes of the newly developed course.

Major Class Objectives

- Computational Fluid Dynamics Process
  - Define the problem
  - Pre-process
  - Solver
  - Post-process
- Skepticism
  - How do I know I have a great prediction?
  - Develop healthy skepticism of results
- Use of one popular commercial CFD code
  - Star-CCM+
  - Many of the commercial codes work similar

Course Overview

Course Description - This course introduces students to the general theories, numerical algorithms, and processes of computational fluid dynamics. The main objectives are to understand the pre-process that includes the definition of the problem and grid generation, the solver, and the post-process that includes analysis of the results. The students will learn to interpret computational fluid dynamics results and develop skepticism that is balanced by verification and validation techniques. Throughout the course concepts will be illustrated through the use of one popular commercial computational fluid dynamics computer program. The students will have fundamental knowledge of boundary conditions, grid generation, solvers, turbulence modelling, visualization, numerical methods, and a variety of special topics at the termination of the course.

Course Outline

- Preliminaries ~ 1 week
- Introduction ~ 1 week
- Grid Generation ~ 1 week ~discretization, structured grids, unstructured grids, best practices
- Fluid Dynamics ~ 2 weeks ~governing equations, specialized equations
- Boundary Conditions ~ 2 weeks ~basics, CFD BC, and best practices
- Numerics ~ 2 weeks ~discretization, numerical methods, stability, residual, convergence, solvers
- Visualization ~ 2 Weeks ~plots, derived quantities
- Turbulence Modeling ~ 2 Weeks ~history, motivation, zero, one, two equation models, LES, DNS
- Special Topics ~ 1 Week ~aeroacoustics, aeroelasticity, multiphase, combustion
- Project Presentations ~ 1 Week
- Exam

Integration with Student Groups

- AIAA Rocket Team, FSAE, and other student groups adopted CFD and benefit from the class.
- Students have integrated these lessons within student groups across the University of Florida.
- The emphasis of the course is on skepticism, increasing integration with the curriculum, and student group activities.
- FSAE Team - Designed complete aerodynamics package in house including wings and undertray every year with validation including full-scale wind tunnel testing in UF's hurricane tunnel.
- AIAA Rocket Team - Simulations of rocket nozzle, cooling, combustion chamber

Figure 1: Team in action in Michigan.

Figure 2: Team wind-tunnel test.

Class Project Overview

- Students in the class undertake a course project to predict a fundamental flow-field and compare predictions with excellent measurements from the open literature.
- Students in groups or individual
- Project is assigned mid-semester
- A different journal article is given to each group that details an experiment and presents results
- Group must perform a CFD prediction corresponding to the experiment
- Compare CFD prediction with experimental results
- More interested in the process than prediction accuracy
- Group must give a ~10 min. presentation at end of semester

Class Project - Articles

- Articles are available to the students via the class website or they can choose their own
- Each group is responsible for reading and fully understanding the article that correspond to their project
- The articles discuss classic experiments within the field of fluid dynamics
- They are all experimentally based and present excellent measurements

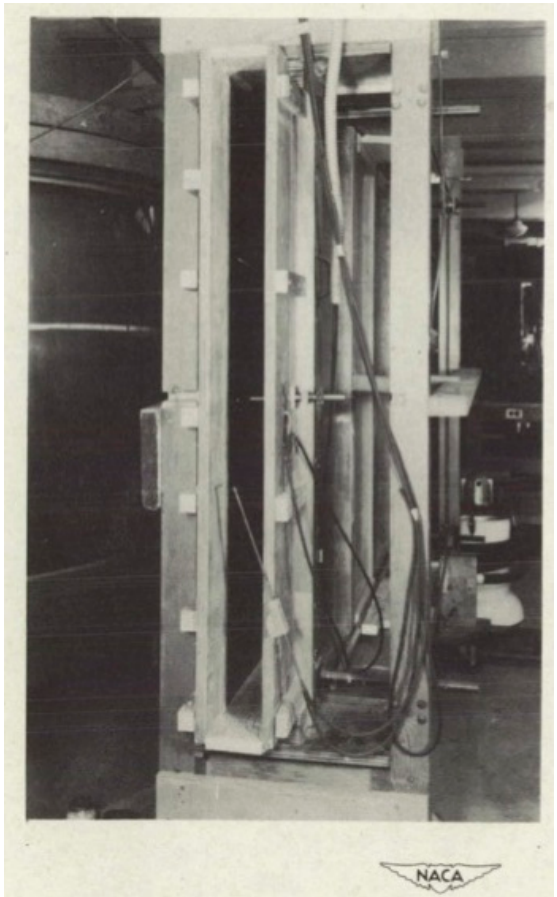
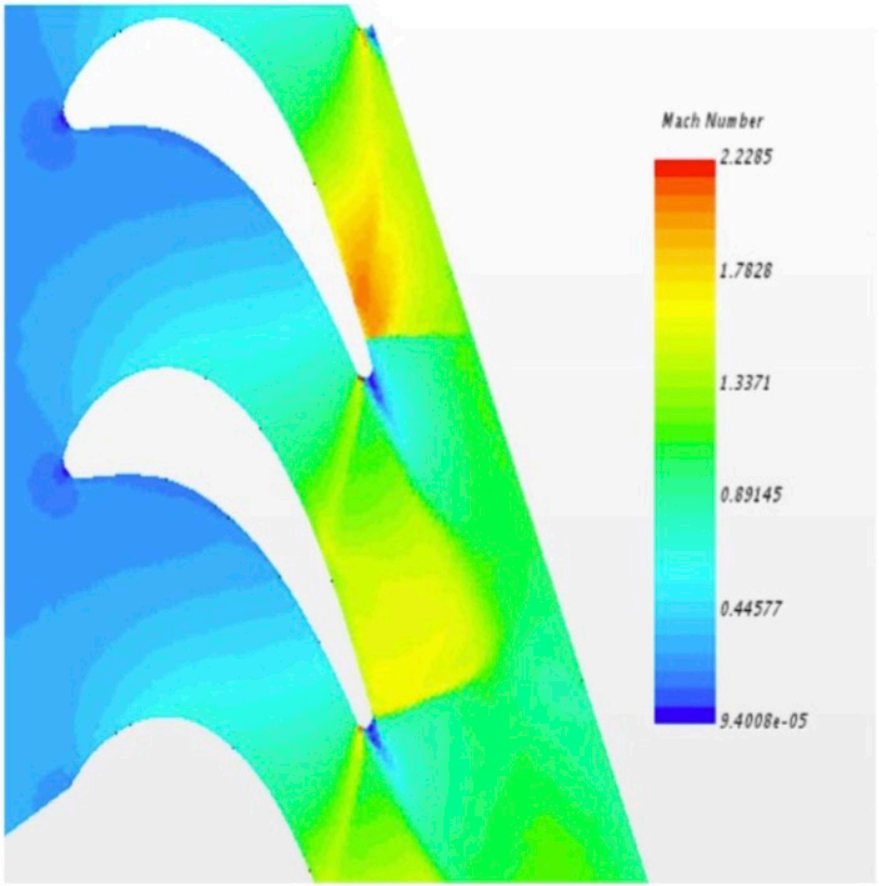


Figure 3: NACA report on measurements of channel flow.

Previous Student Efforts - Turbine Cascade



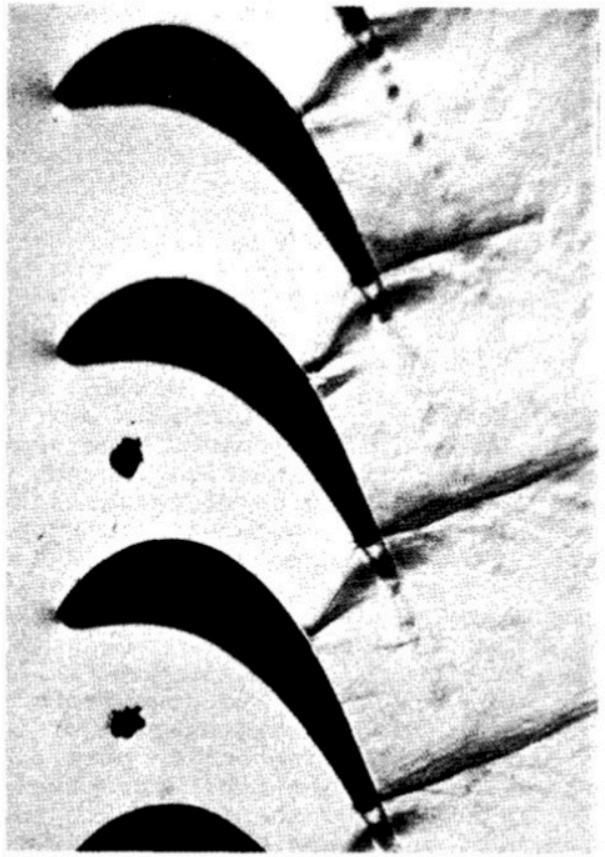


Fig. 8 Schlieren picture, $\beta_1 = 30^{o}$, $M_2 = 0.96$, $Re_2 = 7.8 \cdot 10^5$

Figure 4: RANS results of the 2D turbine cascade case. Experimental results from NASA.

Previous Student Efforts - Off-Design Jet

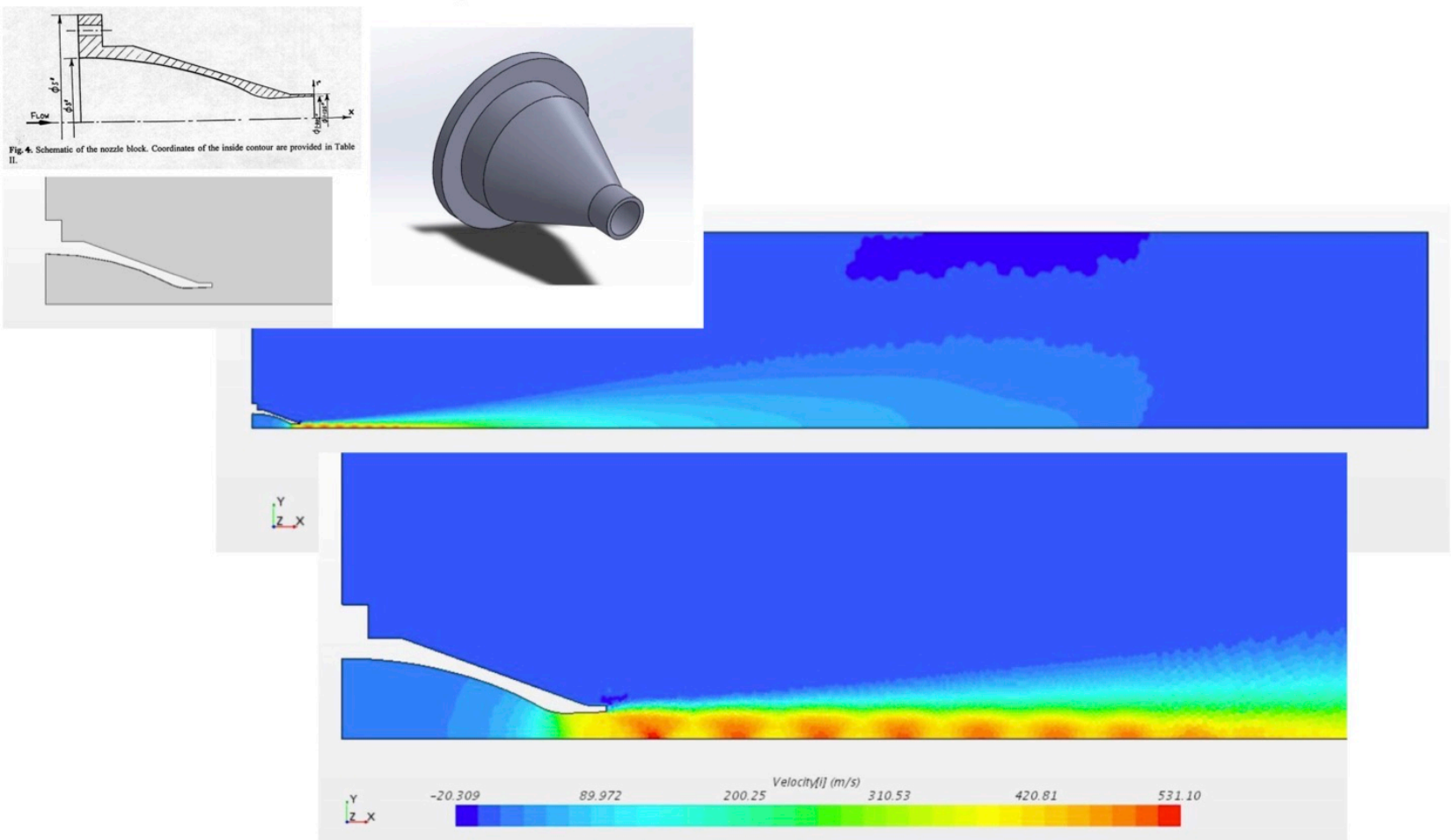


Figure 5: RANS results of an off-design supersonic jet showing contours of velocity. Results are compared with an experiment of NASA.

Previous Student Efforts - Airfoil at Separation

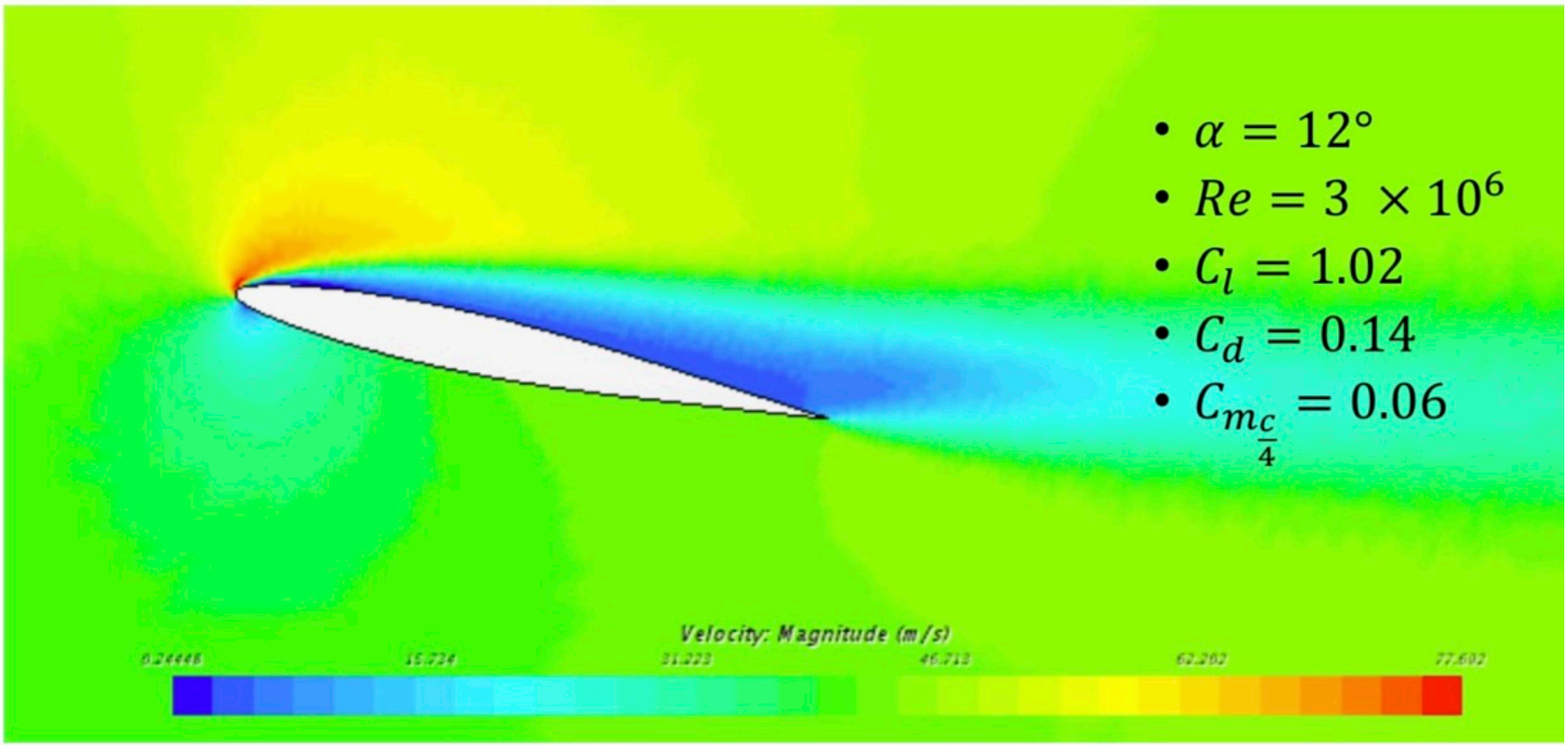


Figure 6: RANS simulation of an airfoil at separation. Students compare c_p, c_l, and c_D against experimental data from NASA.

Previous Student Efforts - Backward Facing Step

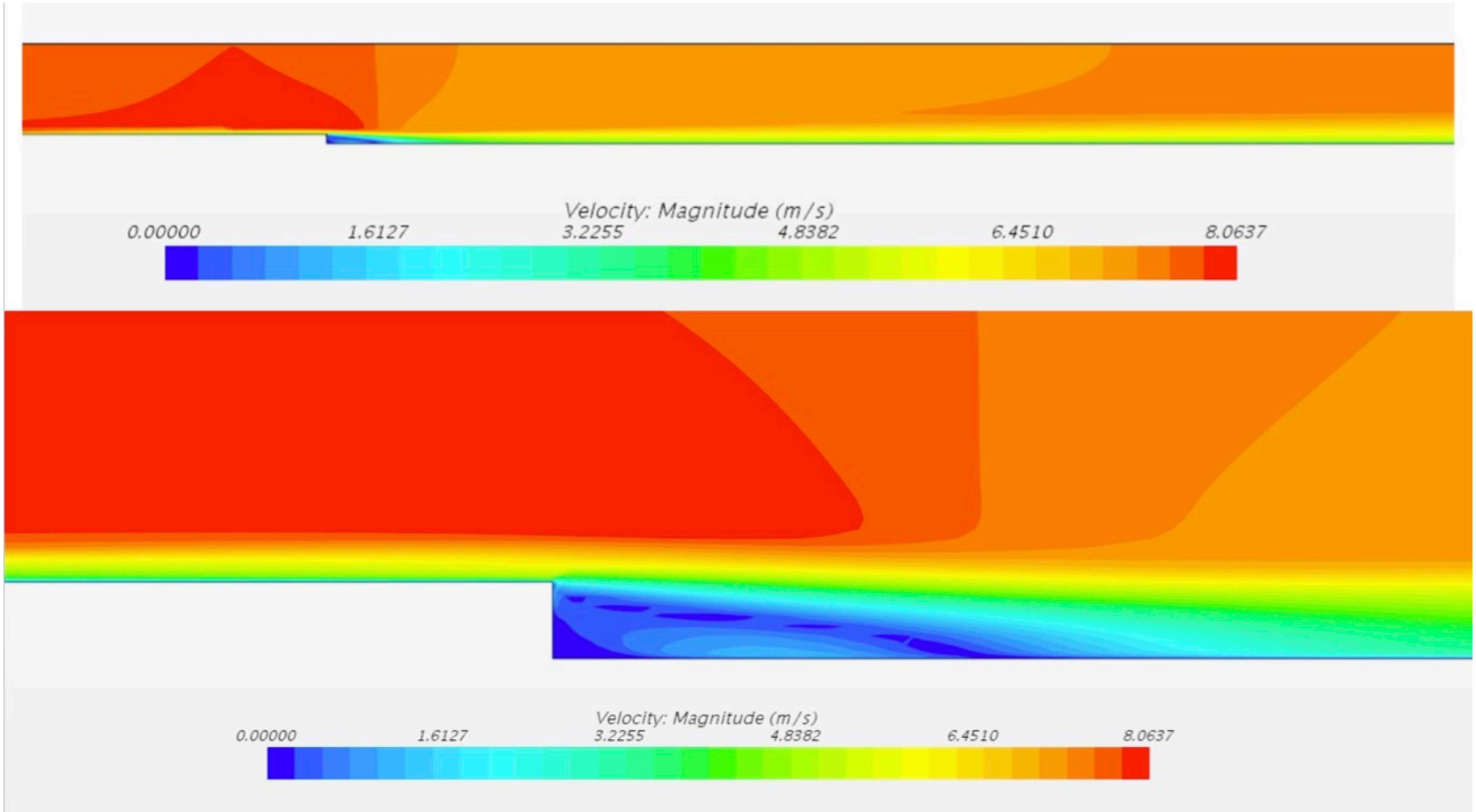


Figure 7: RANS simulation showing contour plots of u. Students compare measured values behind the step with experimental data from NASA.

Source Material and Acknowledgement

A number of important texts were used to develop the course including a number of important journal articles.

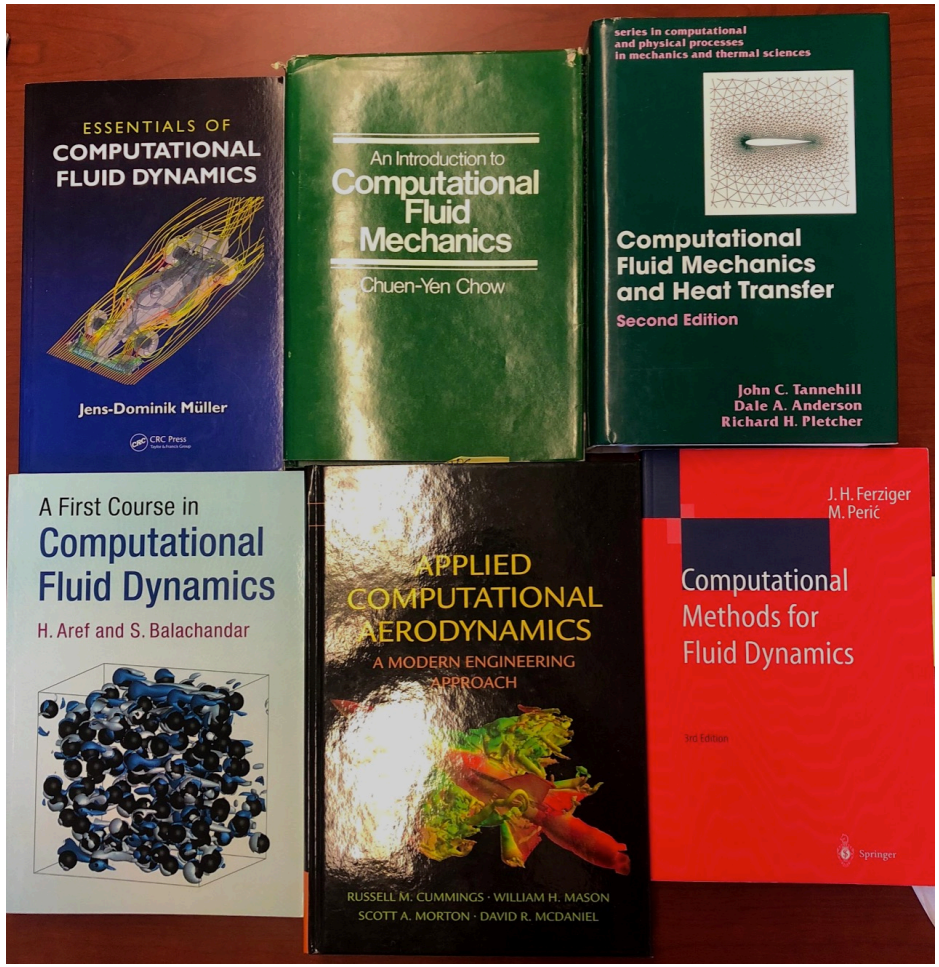


Figure 8: Selection of source material and the class is heavily based on this material.

Summary and Concluding Remarks

- Developed a new senior elective class in CFD at Florida Mechanical and Aerospace Engineering
- Class focuses on the CFD process, skepticism, a project, and use of one popular CFD solver
- Class is popular with student groups, those who are curious about CFD, and represents a tech. elective for students who love fluid dynamics
- In the future we will include a small CFD programming project

Thank You