Meccanica dei Fluidi

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Meccanica dei Fluidi

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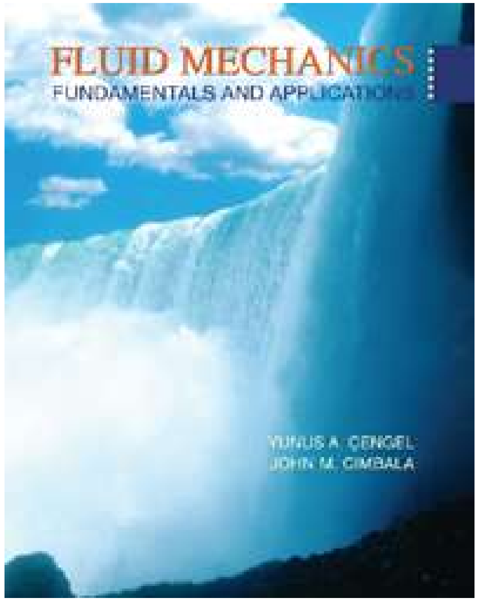
Dipartimento di Ingegneria Civile,
Chimica e Ambientale (DICCA)

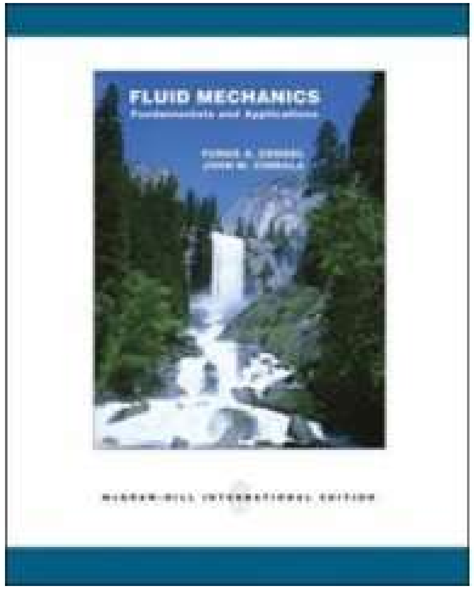
Secondo Semestre 2024/2025

Textbook

- **Fluid Mechanics. Fundamentals and Applications**, McGraw-Hill, 2006
  Yunus A. Çengal (Univ. Nevada, Reno) and
  John M. Cimbala (Penn State)
  Includes DVD with movies created at PSU
  by Prof. Gary Settles

- A version in Italian exists …





Textbook

- **Fundamentals of Fluid Mechanics**, Wiley, 2012
  Bruce R. Munson (Iowa State), Theodore H. Okiishi (Iowa State), Wade W. Huebsch (West Virginia), and Alric P. Rothmayer (Iowa State)

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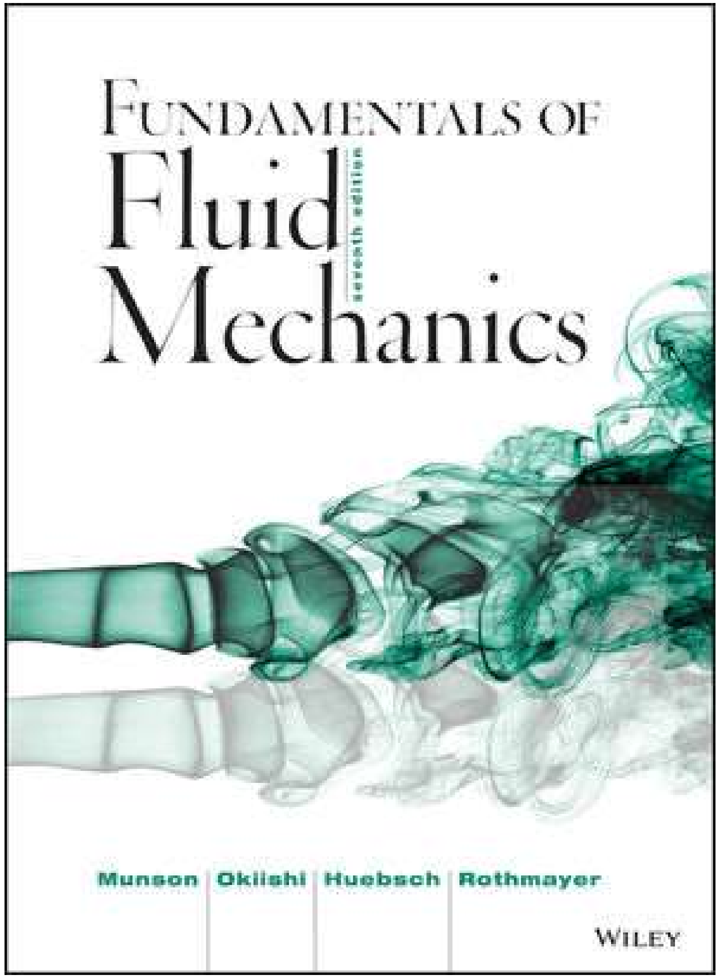
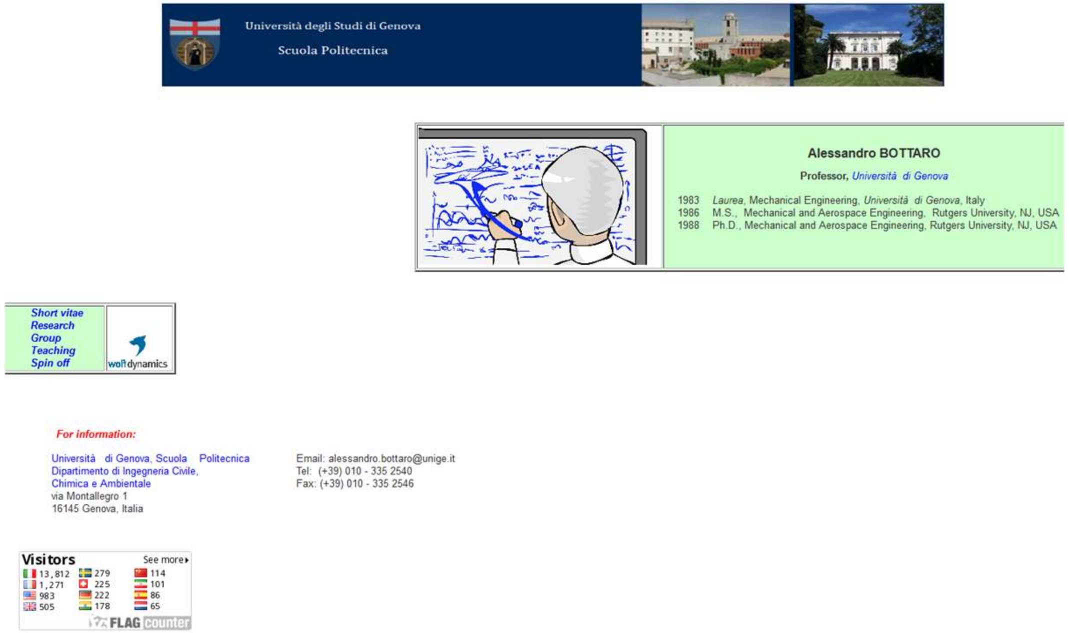


Web site

- All class material and announcements will be posted on aulaweb. There is also a course web site: http://www.dicat.unige.it/bottaro/fmnew.html

  - Syllabus
  - Schedule/Calendar
  - Lecture notes
  - Message boards
  - Past mid terms and finals
  - Exam rules
  - Grades
  - etc



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  - Schedule/Calendar
  - Lecture notes
  - Message boards
  - Past mid terms and finals
  - Exam rules
  - Grades
- Other interesting links can be found at

http://www.dicat.unige.it/bottaro/teaching.html

Roberto Verzicco
Jean Pierre Petit

IL VOLO, Jean Pierre Petit

Grading

- Mid-term exam: 50%
- Final exam: 50%

} **Strongly encouraged!!!!**

- For those doing "mid-term + final" the oral exam is optional (to be done in June/July, 2025)
  - The grade of the oral exam (required for those with a grade G with $15 \leq G < 18$) averages out with the written tests. Cut-off grade: 12.
- For those not doing a "mid-term+final":
  - Comprehensive written exam +
    compulsory oral exam

Partial exams date

- Mid-term exam: April 4th, 2025 14:00 – 17:00
- Final exam: May 30th, 2025 14:00 – 17:00

Both midterm and final will be held in B1

Dates of the "regular" exam

June 5th, 2025	2pm
June 20th, 2025	2pm
July 18th, 2025	9am
September 12th, 2025	9am

We meet 15 minutes ahead of schedule to check ID's. Students must formally register for the exam at least 5 days before the exam date. The exam will consist of a **written test** followed by an **oral** exam for those who have achieved a score of at least 15/30 in the written part.

Closed books!

Exam policies

- Philosophy
  - Fluid mechanics is not easy …
  - One of the best ways to learn something is through practice and repetition
  - Therefore, exercises are extremely important in this class!
  - If you study and understand the exercises in the book and elsewhere, you should not have to struggle with the exam/quiz

BONUS POINTS!

The *UNIGE-ME fluid photo/video competition*

- Keep an eye on fluid flow phenomena, and take pictures/videos!
- Send me your best original shots/videos, with indications of date/location/brief description (max 100 words) of the phenomenon you are observing.
- The best photographs/videos will gain **3/2/1** points to be added to your final grade.
- Only one entry per student. No group entries.

BONUS!!

The *UNIGE-ME fluid photo/video competition*

- All photos/videos will be judged by the instructors on the basis of three criteria:
  - **aesthetic appeal**,
  - **uniqueness of the phenomenon**, and
  - **quality of explanation of the observed phenomenon**.
- All photos/videos will be published in a special section of the instructor's web site:

http://www.dicat.unige.it/bottaro/photovideo.html

EXAMPLES

https://youtu.be/yjgACB7urOo?feature=shared

https://www.youtube.com/watch?v=oGGRxE2ijl0

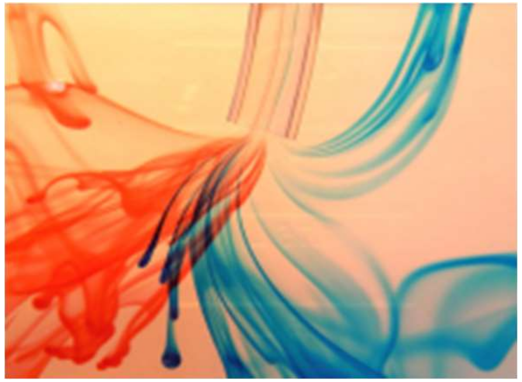
https://www.youtube.com/watch?v=7wjFNI_FAnI&t=17

https://www.youtube.com/watch?v=_z099yZzQik

EXAMPLES (UNIGE-ME FLUID PHOTO/VIDEO COMPETITION 2016/17)

EXAMPLES

1st prize UWA photo contest 2013
Paint on a speaker



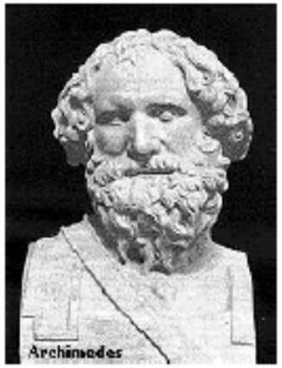
2nd prize UWA photo contest 2013
Dye flowing into a syphon

3rd prize UWA photo contest 2013
Water balloon to the face

Motivation for Studying Fluid Mechanics

- Fluid Mechanics is present almost everywhere
  - Aerodynamics
  - Bioengineering and biological systems
  - Combustion
  - Energy generation
  - Geology
  - Hydraulics and Hydrology
  - Hydrodynamics
  - Meteorology
  - Ocean and Coastal Engineering
  - Water Resources
  - …numerous other examples…
- Fluid Mechanics is beautiful

Some *Faces* in Fluid Mechanics



Archimedes


Da Vinci


Newton

Leibniz

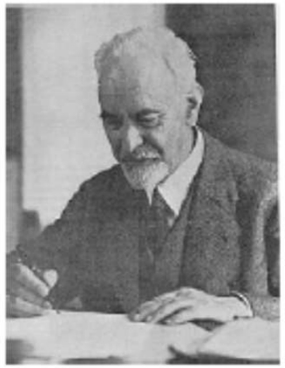

Euler


Bernoulli


Navier

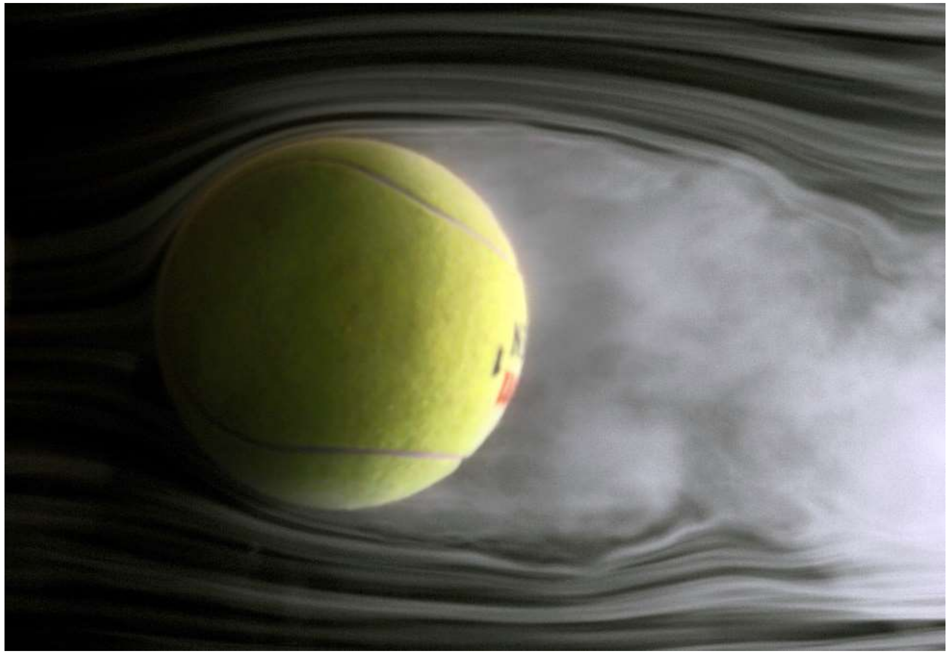

Stokes

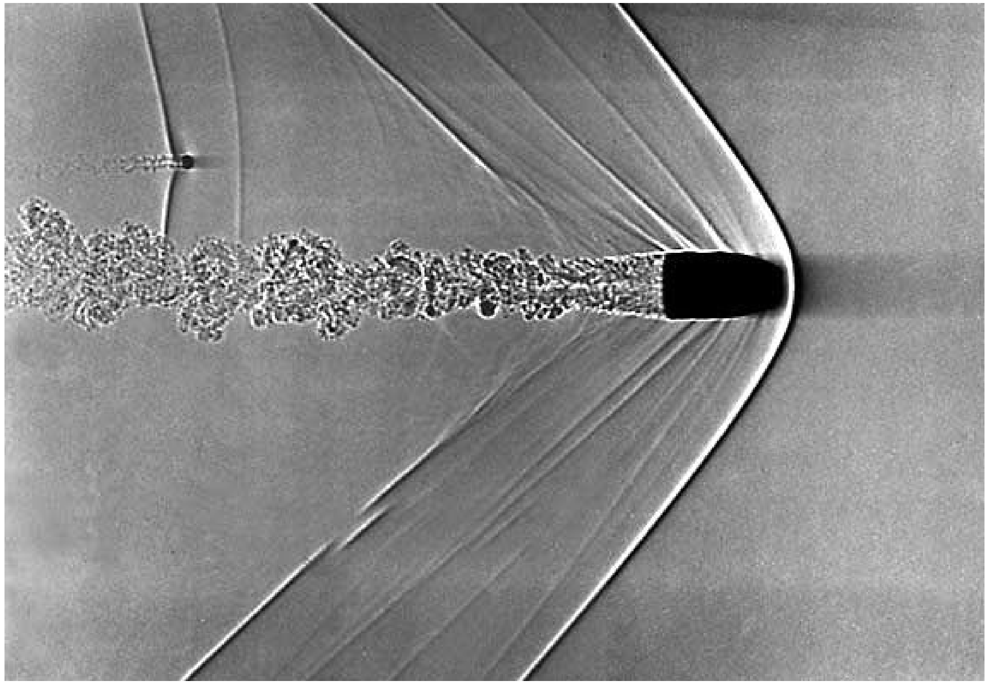

Reynolds


Prandtl

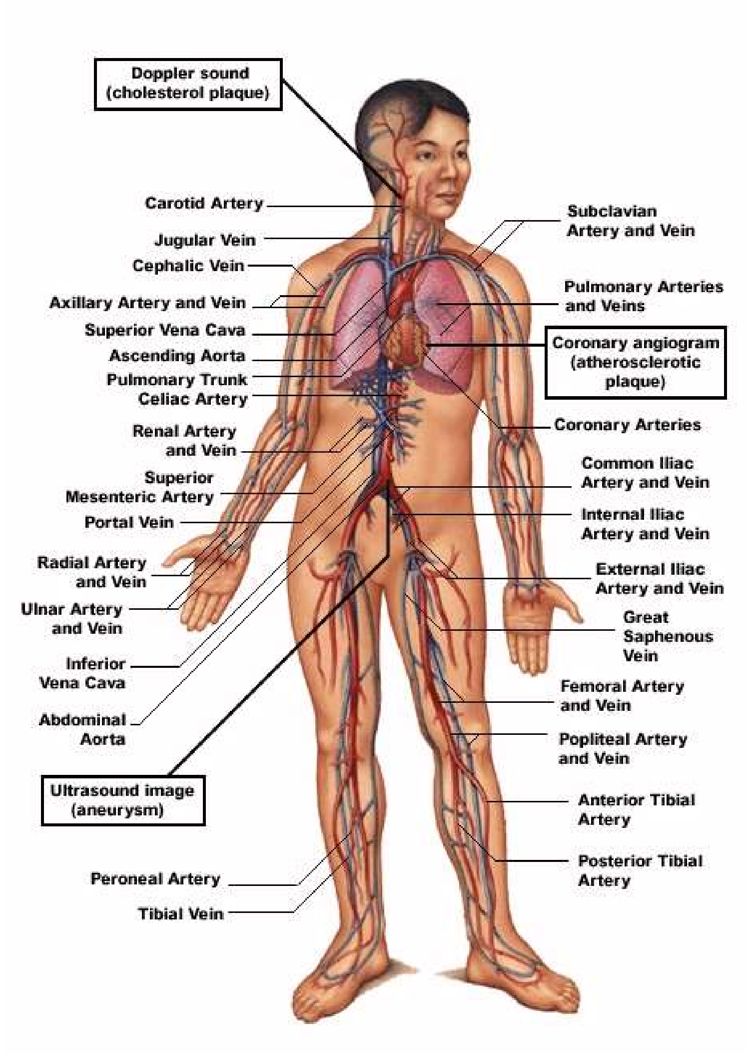
Aerodynamics

Aerodynamics





Bioengineering



Energy generation

Geology

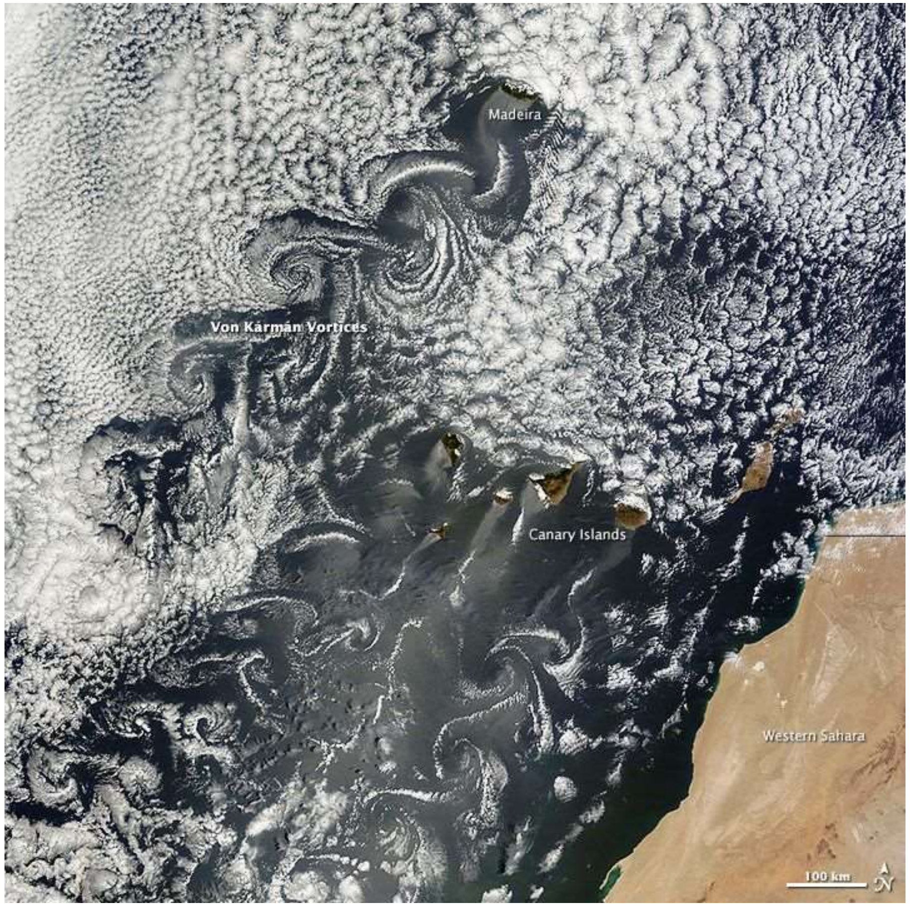
River Hydraulics

Hydraulic Structures

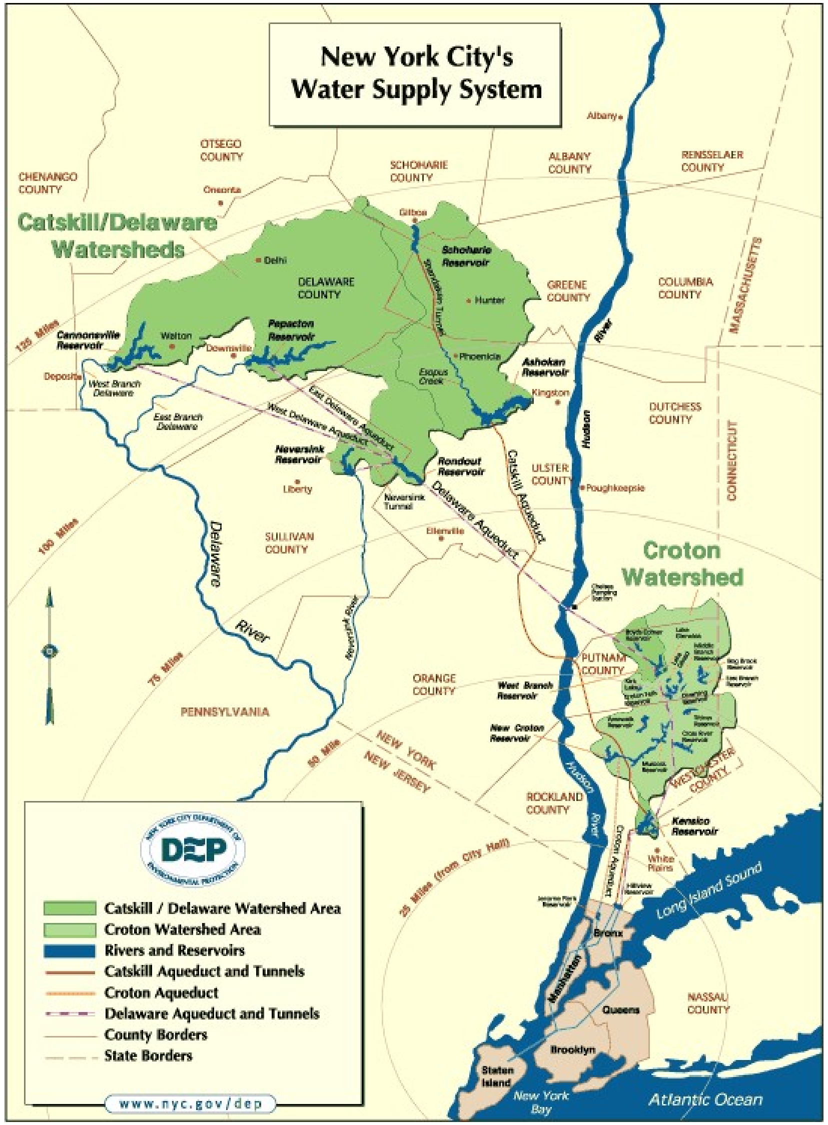
MOdulo **S**perimentale **E**lettromeccanico

Hydrodynamics

Meteorology



Water Resources



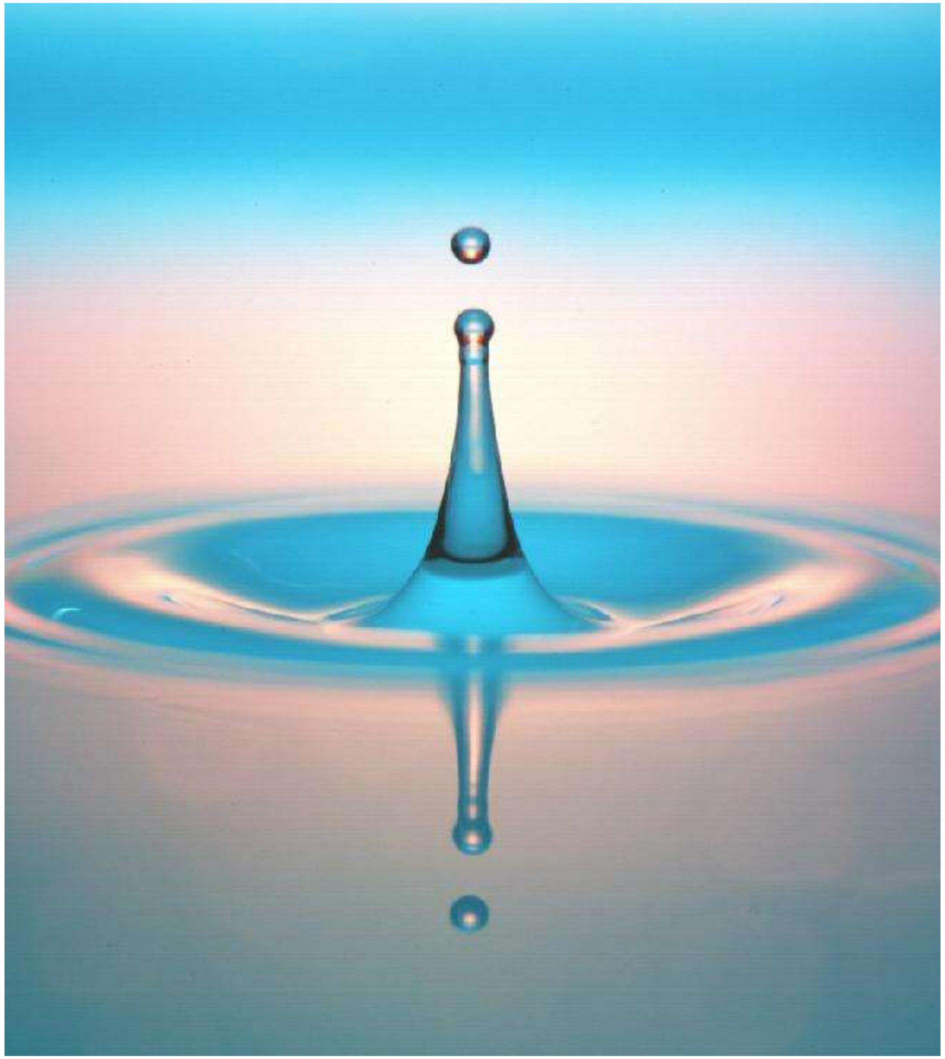
Flows of unusual materials: *Rheology*

- Foods
  - Emulsions (mayonaisse, ice cream)
  - Foams (ice cream, whipped cream)
  - Suspensions (mustard, chocolate)
  - Gels (cheese)
- Biofluids
  - Suspension (blood)
  - Gel (mucin)
  - Solutions (spittle)
- Personal Care Products
  - Suspensions (nail polish, face scrubs)
  - Solutions/Gels (shampoos, conditioners)
  - Foams (shaving cream)
- Electronic and Optical Materials
  - Liquid Crystals (Monitor displays)
  - Melts (soldering paste)
- Pharmaceuticals
  - Gels (creams, particle precursors)
  - Emulsions (creams)
  - Aerosols (nasal sprays)
- Polymers

Flows of unusual materials: *Rheology*

Die swell

Fluid Mechanics is Beautiful



Tsunamis

- Tsunami: Japanese for “Harbour Wave”
- Created by earthquakes, land slides, volcanoes, asteroids/meteors
- Pose infrequent but high risk for coastal regions.

“La grande onda presso la costa di Kanagawa”, di Katsushika Hokusai, circa 1832

Tsunamis

- La Palma Mega-Tsunami = geologic time bomb? Cumbre Vieja volcano eruption could cause western half of La Palma (Canary islands) to collapse into the Atlantic and send a 100 m tsunami crashing into Eastern coast of U.S.

Methods for Solving Fluid Dynamics Problems

- *Analytical Fluid Dynamics (AFD)* Mathematical analysis of governing equations, including exact and approximate solutions. This is the primary focus of this course
- *Computational Fluid Dynamics (CFD)* Numerical solution of the governing equations
- *Experimental Fluid Dynamics (EFD)* Observation and data acquisition.

Analytical Fluid Dynamics

How fast do tsunamis travel in the deep ocean?

Incompressible Navier-Stokes equations

$$\frac{\partial \mathbf{U}}{\partial t} + (\mathbf{U} \cdot \nabla)\mathbf{U} = \frac{1}{\rho}\nabla p + \nu \nabla^2 \mathbf{U}$$

Linearized wave equation for inviscid, irrotational flow

$$\nabla^2 \phi = 0, \mathbf{U} = \nabla \phi$$

$$\frac{\partial \phi}{\partial z} = 0 \text{ on } z = -h$$

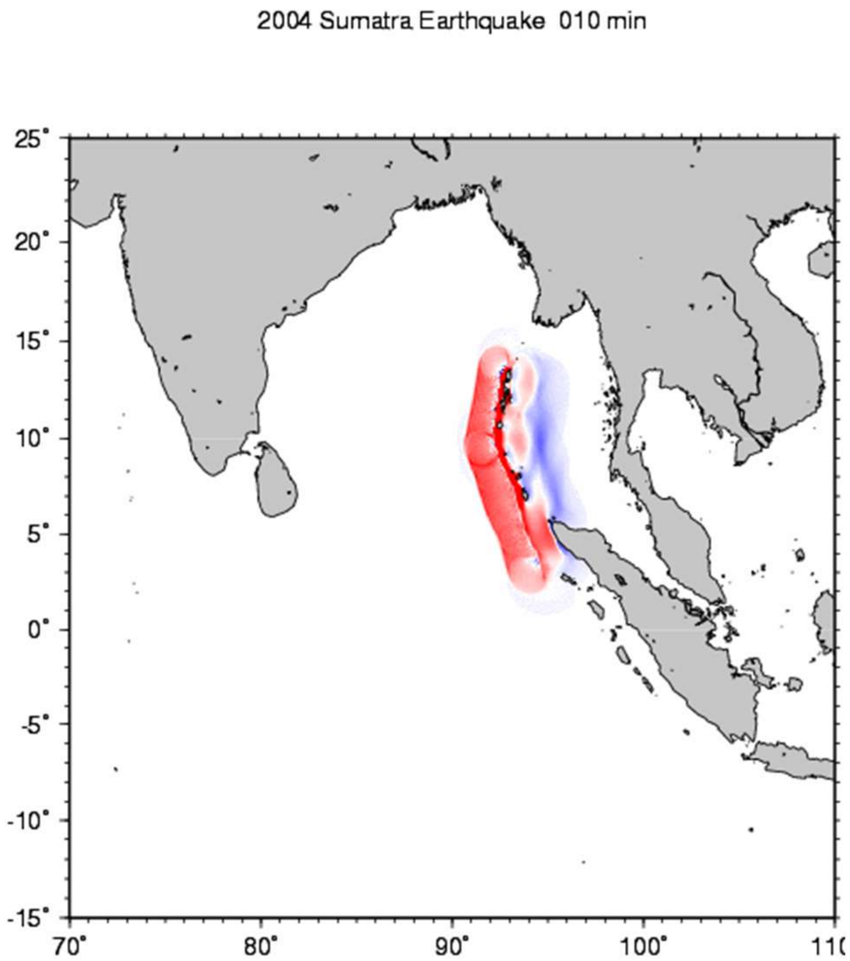
$$\frac{\partial^2 \phi}{\partial t^2} = -g\frac{\partial \phi}{\partial z} \text{ on } z = 0$$

Shallow-water approximation, $\lambda/h >> 1$ (also $kh << 1$)

$$c = \sqrt{\frac{g}{k}\tanh kh} \Longrightarrow c = \sqrt{gh}$$

For $g = 9.8\ m/s^2$ and $h = 3000\ m$, $c = 171\ m/s = 617\ km/h$

Computational Fluid Dynamics



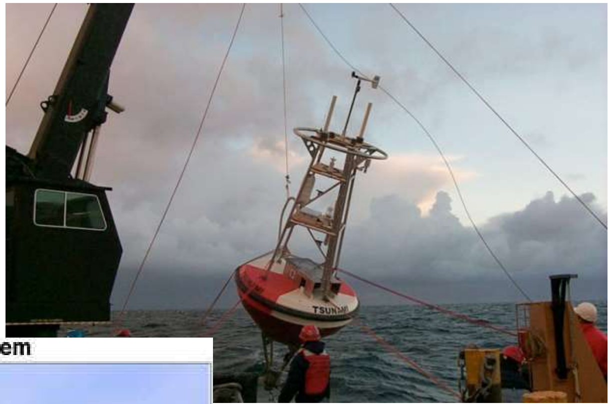
Animation by Vasily V. Titov, Tsunami Inundation Mapping Efforts, NOAA/PMEL

- In comparison to analytical methods, which are good for providing solutions for simple geometries or behavior for limiting conditions (such as linearized shallow water waves), CFD provides a tool for solving problems with nonlinear physics and complex geometry.

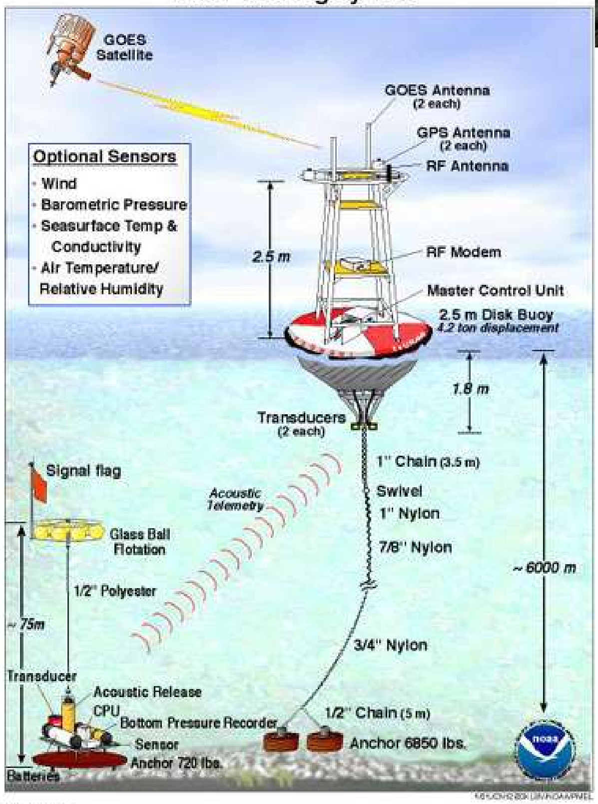
Experimental Fluid Dynamics

- Oregon State University Wave Research Laboratory
- Model-scale experimental facilities
  - Tsunami Wave Basin
  - Large Wave Flume
- Dimensional analysis is very important in designing a model experiment which represents physics of actual problem

Experimental Fluid Dynamics



DART Mooring System

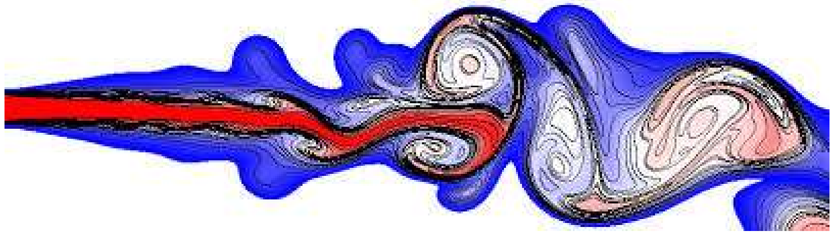


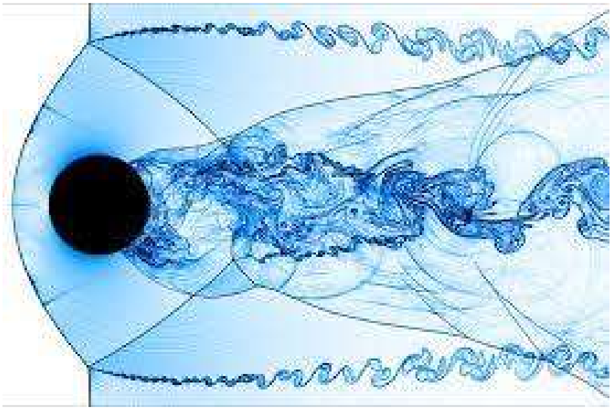
Courtesy of PMEL

- Experiments are sometimes conducted in the field or at full scale
- For tsunamis, data acquisition is used for warning
- DART: Deep-ocean Assessment and Reporting of Tsunamis

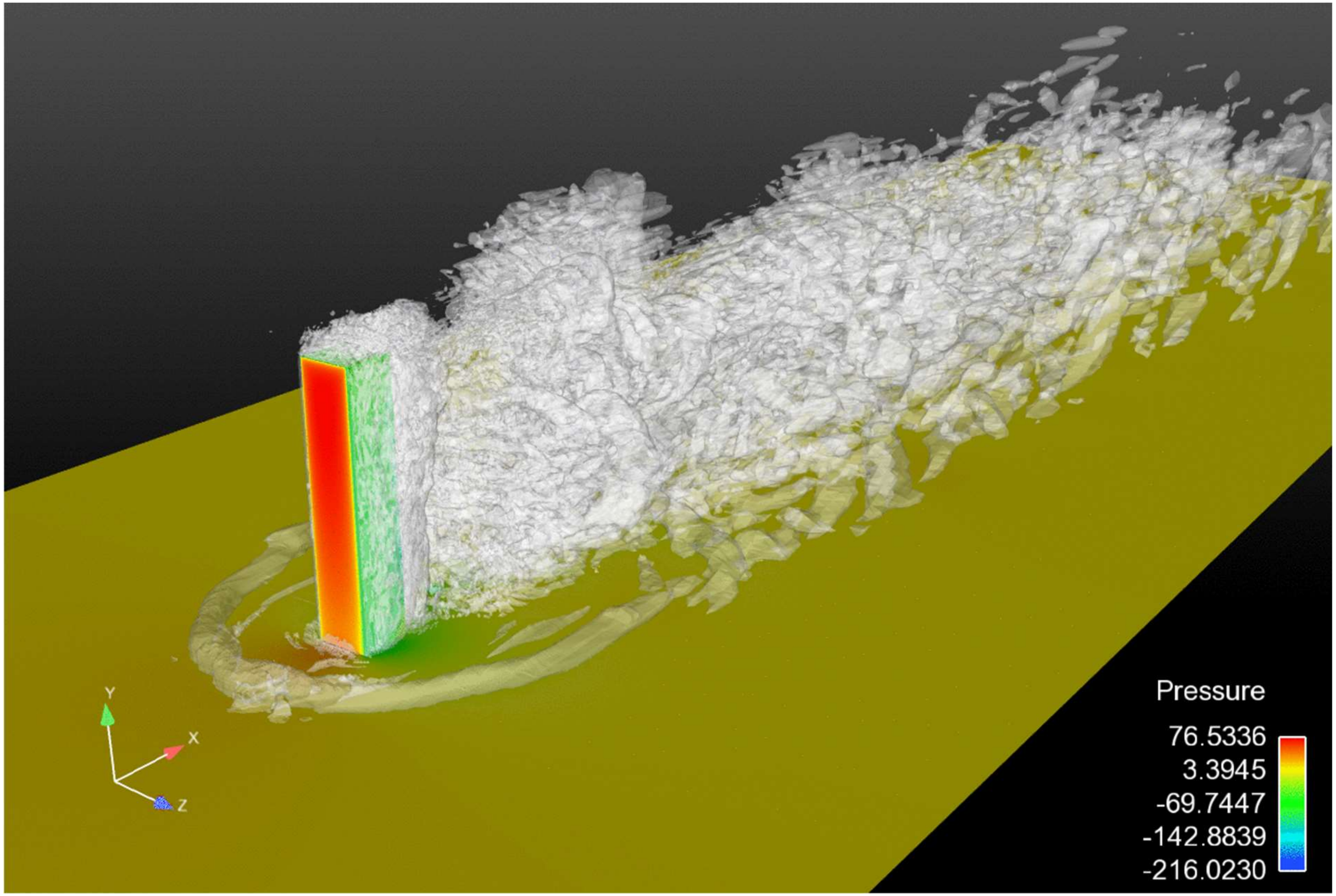
  (U.S. National Tsunami Hazard Mitigation Program)
- Primary sensor: Bourdon tube for measuring hydrostatic pressure

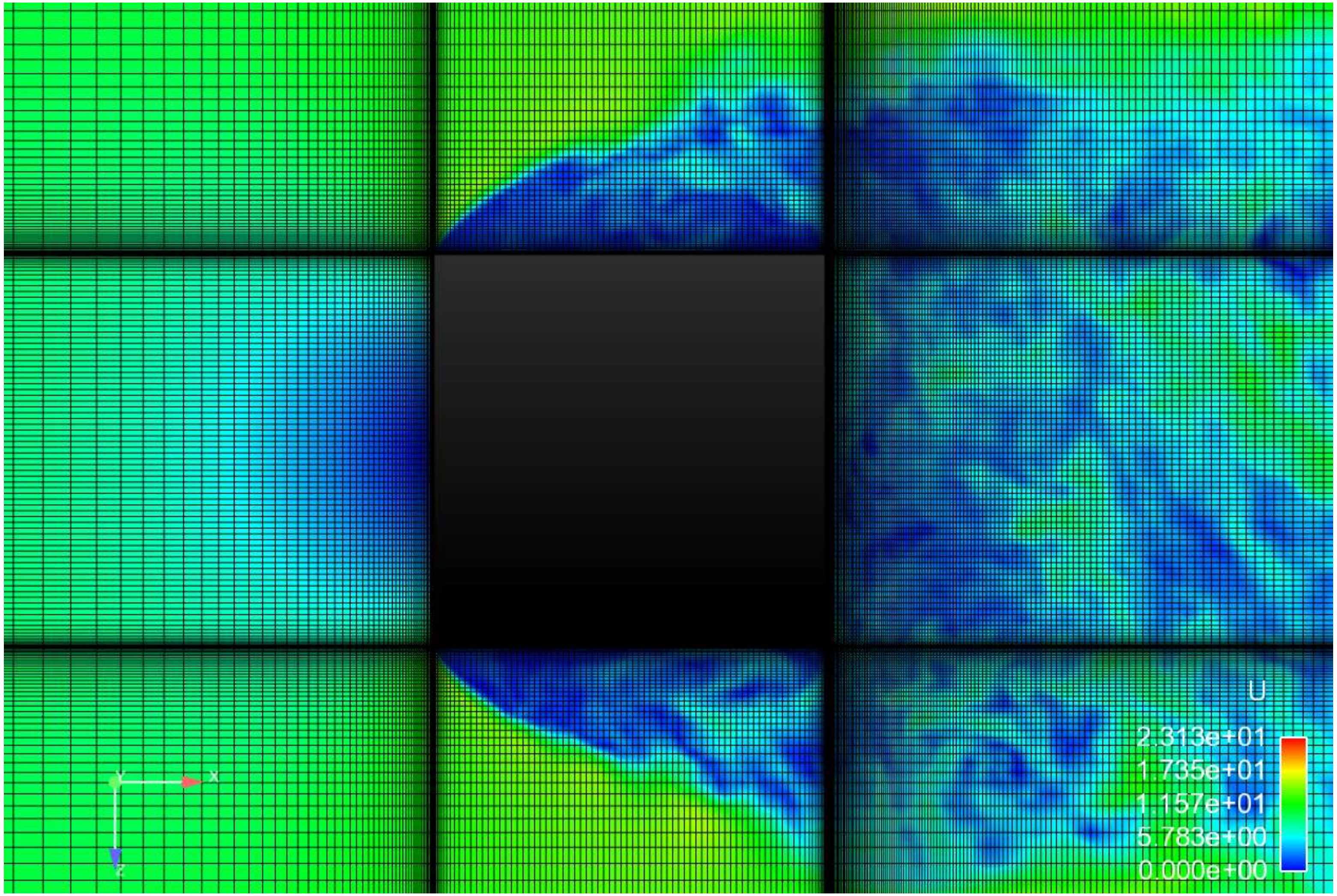
THE FLUID DYNAMICS GROUP AT DICCA

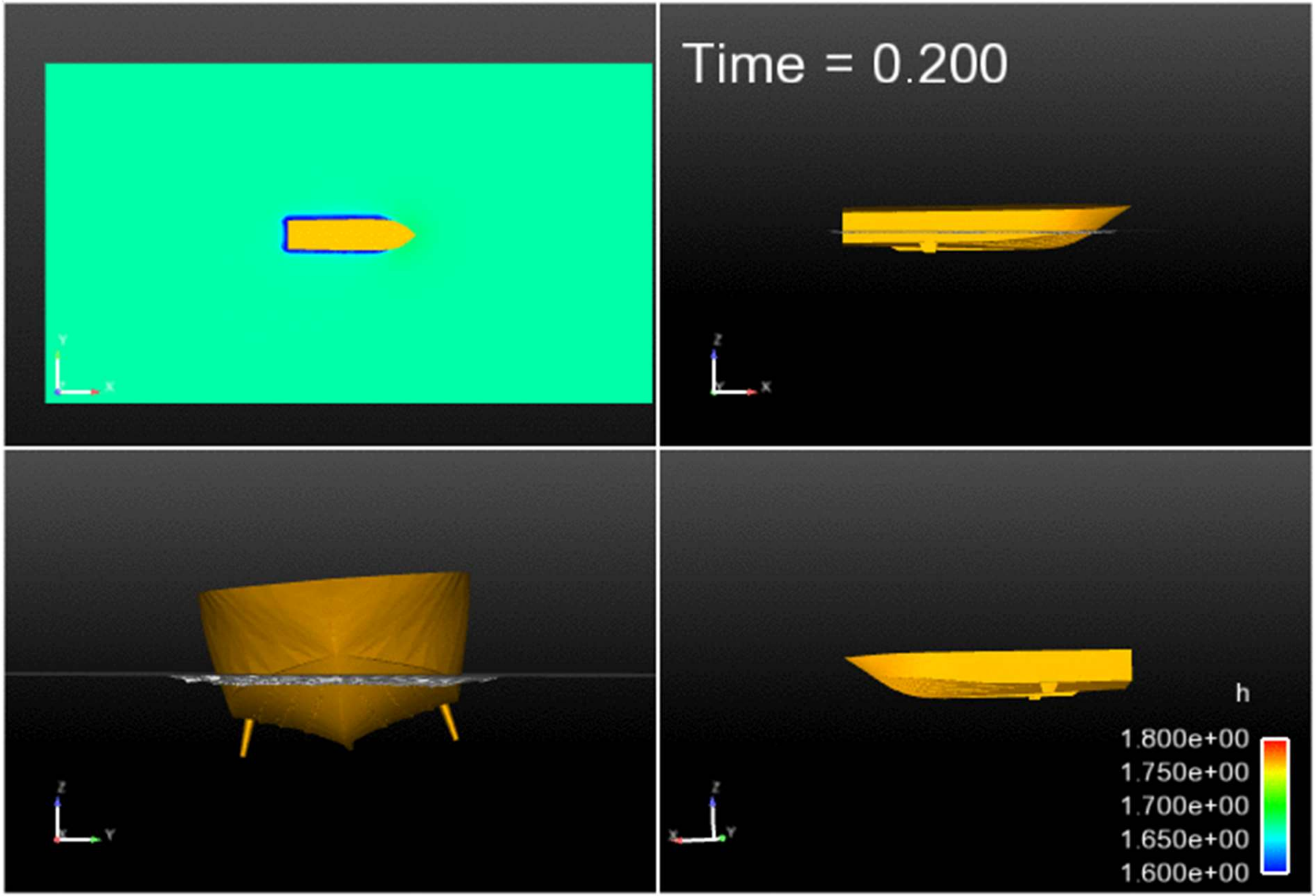


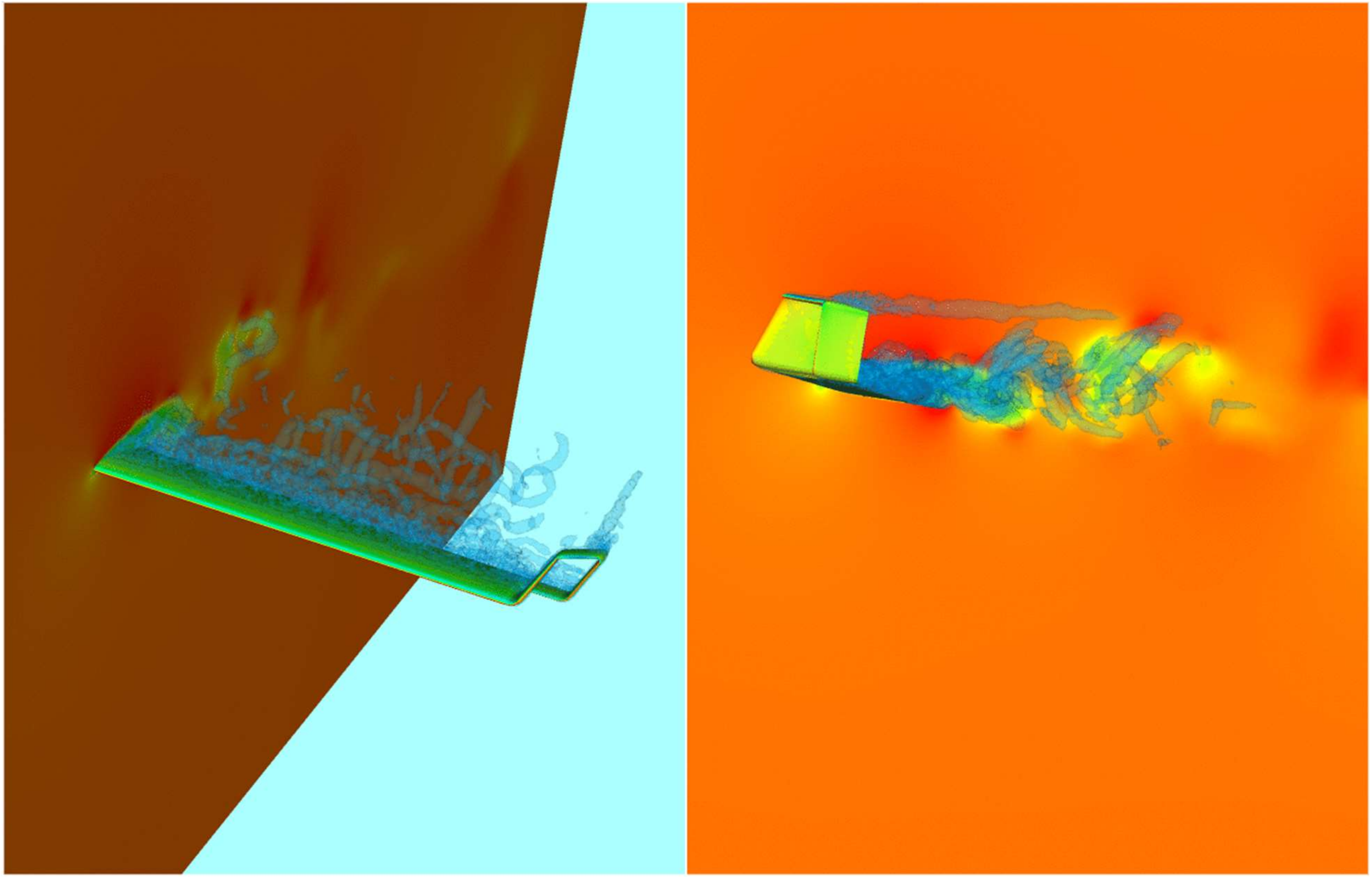


Dipartimento di Ingegneria Civile, Chimica e Ambientale,
Scuola Politecnica, Università degli Studi di Genova.


Y
X
Z
Pressure
76.5336
3.3945
-69.7447
-142.8839
-216.0230

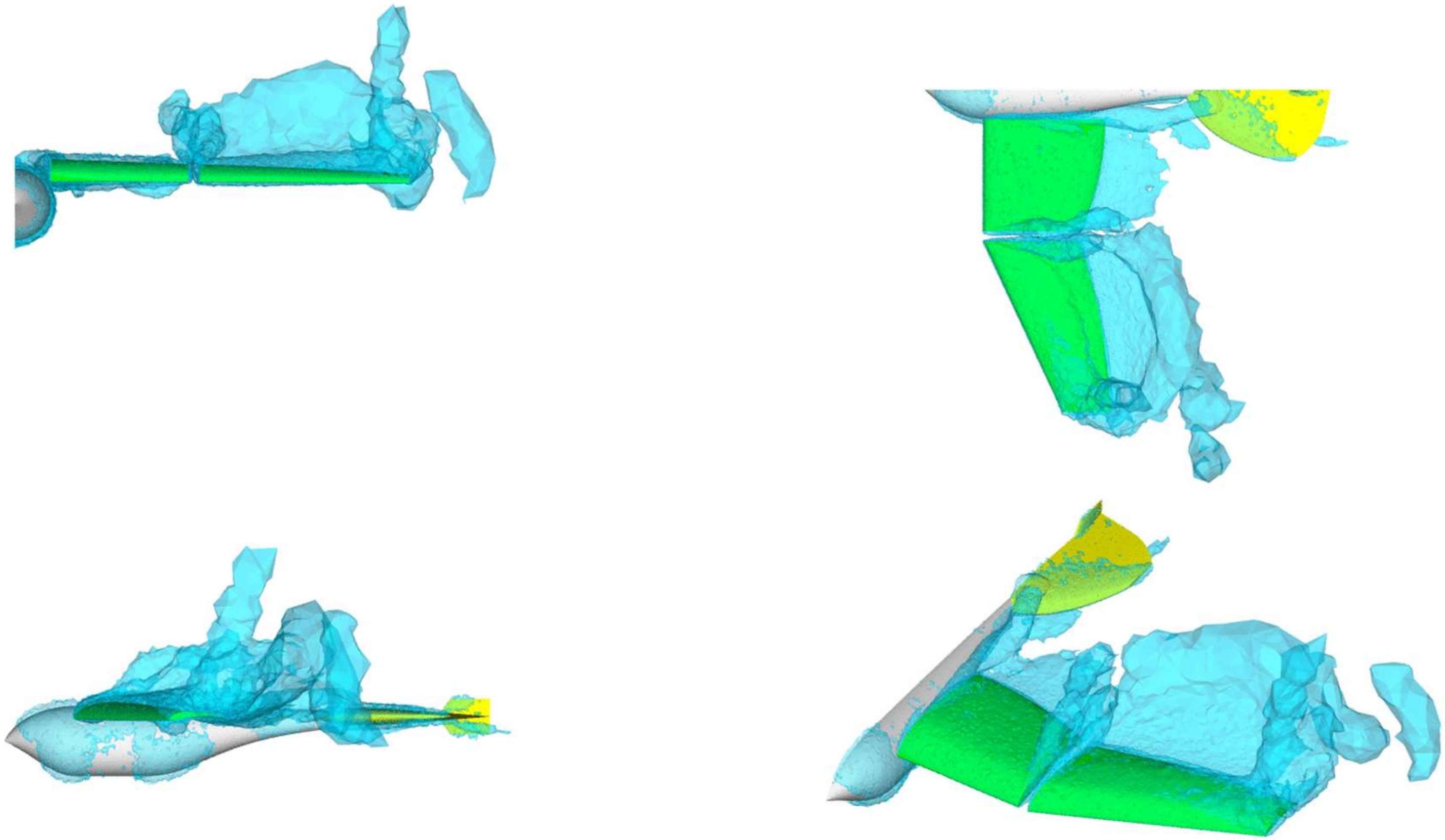

U
2.313e+01
1.735e+01
1.157e+01
5.783e+00
0.000e+00
x
z

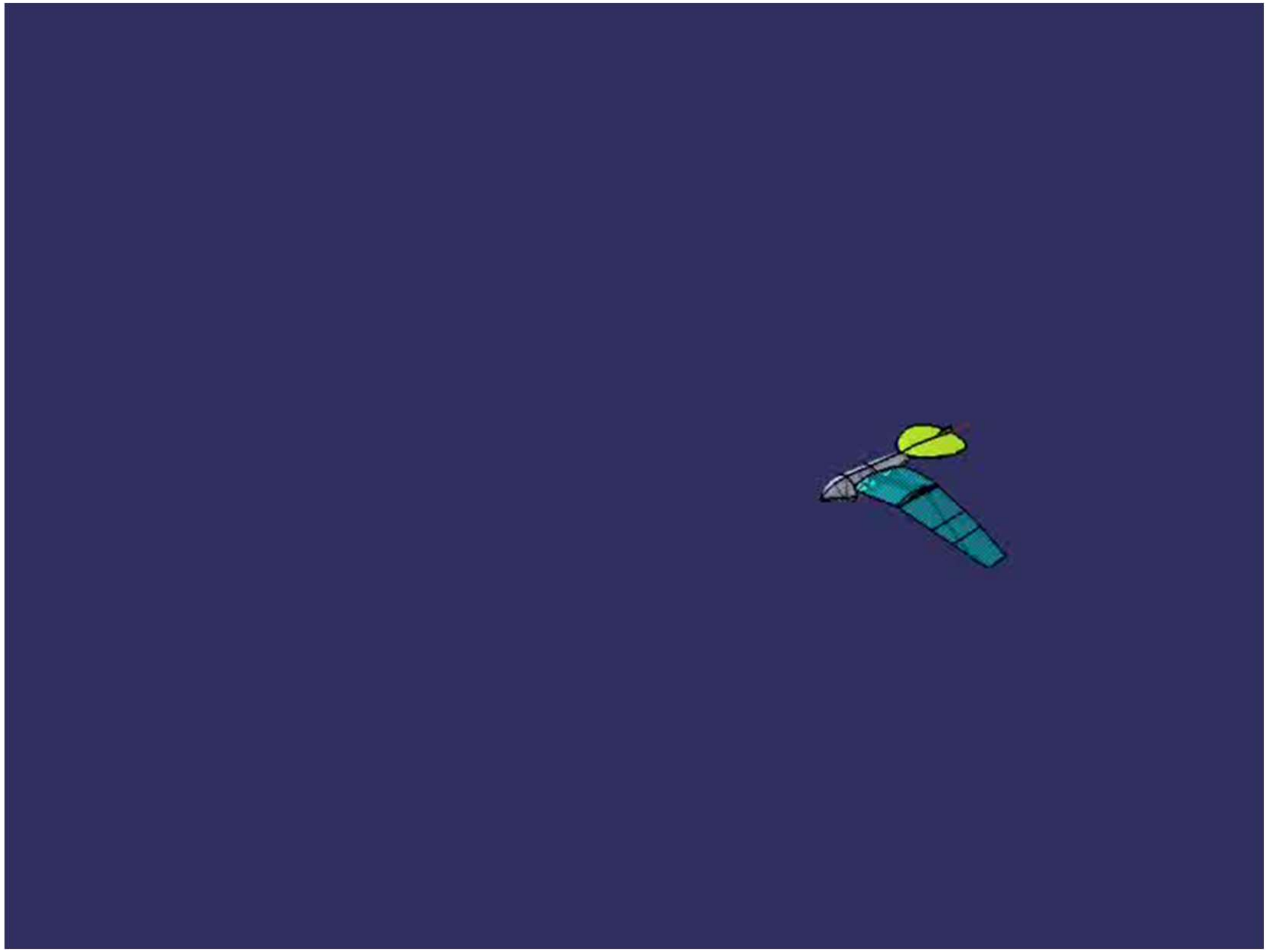

Time = 0.200
h
1.800e+00
1.750e+00
1.700e+00
1.650e+00
1.600e+00



project Ornithopter

July 8, 2006





Contents of the Fluid Mechanics course

1. Introductions and basic concepts
2. Properties of fluids
3. Pressure and fluid statics
4. Fluid kinematics
5. Mass, Bernoulli and energy equation
6. Momentum analysis of flow systems

7. Dimensional analysis and π theorem
8. Internal flows and Moody chart …
9. Differential analysis of fluid flows
10. Approximate solutions of the Navier-Stokes equations
11. External flows: drag and lift