

What is Computational Fluid Dynamics?

Modelling wind and dispersion in urban environments

Text book references: Computational Fluid Dynamics , a practical approach, J.Tu et al.

Learning Objectives:

After this class, you will be able to:

- Understand what CFD is
- Understand the advantages and limitations when using CFD
- Know the reasons why CFD might be relevant in science, industry and your own career

Outline of the class:

1. What is Computational Fluid Dynamics?
2. Advantages and limitations of CFD
3. Why should you care about CFD?
4. The fields that benefit from CFD
5. How can CFD shape your future?

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Think, pair, share

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What is Computational Fluid Dynamics?

Computational fluid dynamics

 30 languages 

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This article includes a list of general [references](#), but it **lacks sufficient corresponding inline citations**. Please help to [improve](#) this article by [introducing](#) more precise citations. *(September 2014)* ([Learn how and when to remove this template message](#))

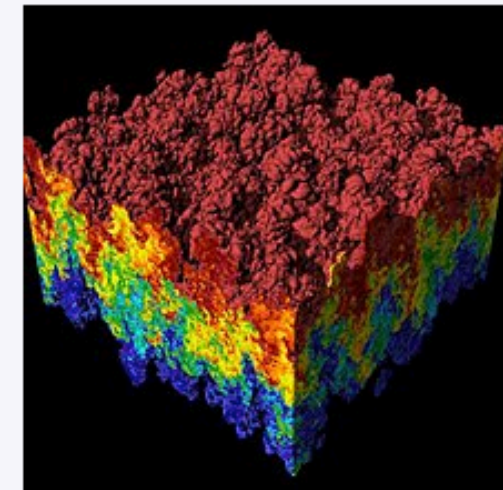
Computational fluid dynamics (CFD) is a branch of [fluid mechanics](#) that uses [numerical analysis](#) and [data structures](#) to analyze and solve problems that involve [fluid flows](#). Computers are used to perform the calculations required to simulate the free-stream flow of the fluid, and the interaction of the fluid ([liquids](#) and [gases](#)) with surfaces defined by [boundary conditions](#). With high-speed [supercomputers](#), better solutions can be achieved, and are often required to solve the largest and most complex problems. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as [transonic](#) or [turbulent](#) flows. Initial validation of such software is typically performed using experimental apparatus such as [wind tunnels](#). In addition, previously performed [analytical](#) or [empirical](#) analysis of a particular problem can be used for comparison. A final validation is often performed using full-scale testing, such as [flight tests](#).

CFD is applied to a wide range of research and engineering problems in many fields of study and industries, including [aerodynamics](#) and aerospace analysis, [hypersonics](#), [weather simulation](#), natural science and [environmental engineering](#), industrial system design and analysis, [biological engineering](#), fluid flows and [heat transfer](#), [engine](#) and [combustion](#) analysis, and visual effects for film and games.

Background and history [\[edit \]](#)

The fundamental basis of almost all CFD problems is the [Navier–Stokes equations](#), which define many single-phase (gas or liquid, but not both) fluid flows. These equations can be simplified by removing terms describing [viscous](#) actions to yield the [Euler equations](#). Further simplification, by removing terms describing [vorticity](#) yields the [full potential equations](#). Finally, for small [perturbations](#) in subsonic and [supersonic](#) flows (not [transonic](#) or [hypersonic](#)) these equations can be [linearized](#) to yield the linearized potential equations.

Computational physics



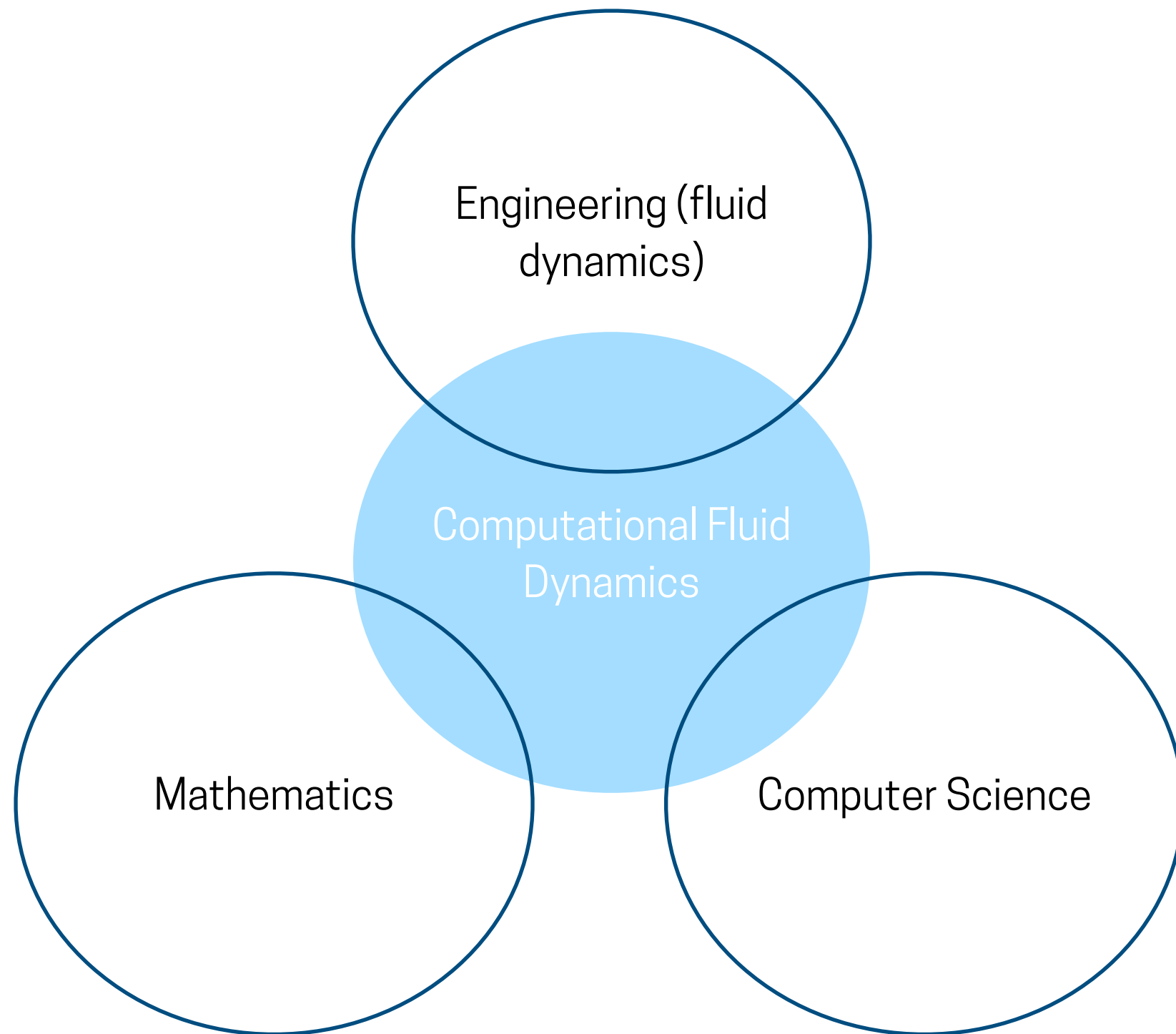
[Mechanics](#) · [Electromagnetics](#) · [Thermodynamics](#) · [Simulation](#)

Potentials [\[show \]](#)
Fluid dynamics [\[show \]](#)
Monte Carlo methods [\[show \]](#)
Particle [\[show \]](#)
Scientists [\[show \]](#)

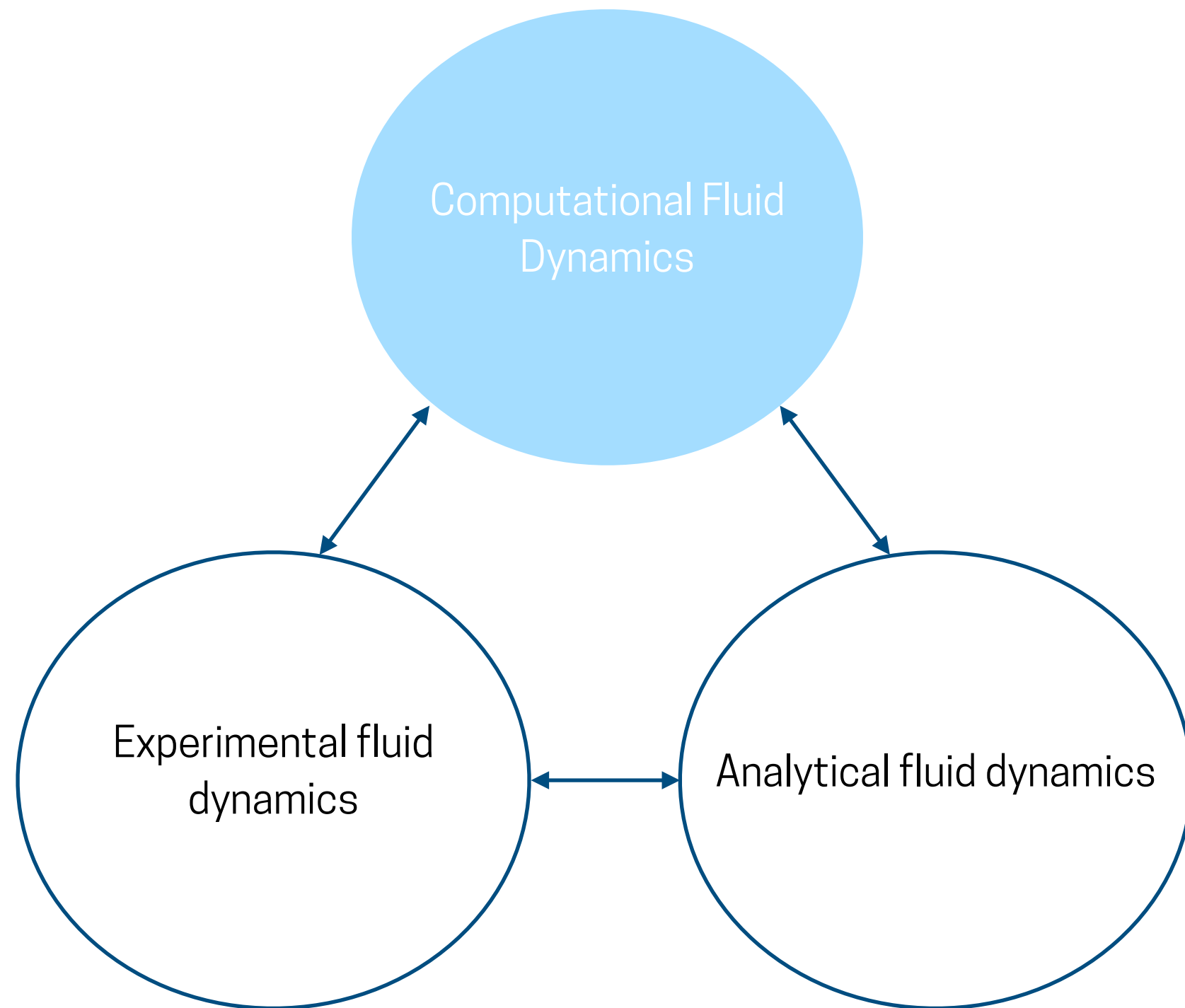
[V](#) · [T](#) · [E](#)

https://en.wikipedia.org/wiki/Computational_fluid_dynamics

What is Computational Fluid Dynamics?



What is Computational Fluid Dynamics?



Outline of the class:

1. What is Computational Fluid Dynamics?
- 2. Advantages and limitations of CFD**
3. Why should you care about CFD?
4. The fields that benefit from CFD
5. How can CFD shape your future?

Advantages/limitations of CFD

Advantages

- Study different terms in equations
- Complements experimental/analytical with cost effective simulations
- Reduces lead times and costs in design and production (low cost in time/money)
- Allows to reproduce scenarios/conditions non-explorable in labs
- Provides detailed, visualised and comprehensive information
- Permits alternative designs to be evaluated over a range of non-dimensional parameters
- Ability to simulate ideal/real conditions (hypersonic)

Limitations

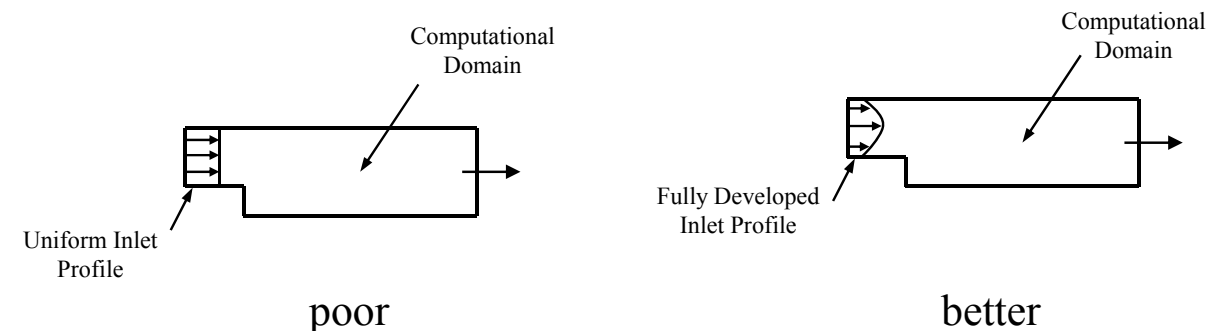
Advantages/limitations of CFD

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Limitations

- Physical models of real world problems
- Numerical errors exist: numerical results are different from reality (round-off, truncation)
- Erroneous solution might look equally good!



- Numerical results always require a critical eye before they are believed
- Computer resources are still required

Outline of the class:

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2. Advantages and limitations of CFD
3. **Why should you care about CFD?**
4. The fields that benefit from CFD
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Outline of the class:

1. What is Computational Fluid Dynamics?
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- 3. Why should you care about CFD?**
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Think, pair, share

Why should you care about CFD?

Instructions: go to menti.com enter code: 61051114

Then reply to the question: how do you plan to use CFD in the future?

Why should you care about CFD?

When you think about the planet we live in, almost everything revolves in one way or another around a fluid or moves within a fluid:

- Wind prediction for wind energy resource
-
-
-
-

Why should you care about CFD?

Instructions: go to menti.com enter code: 8211618

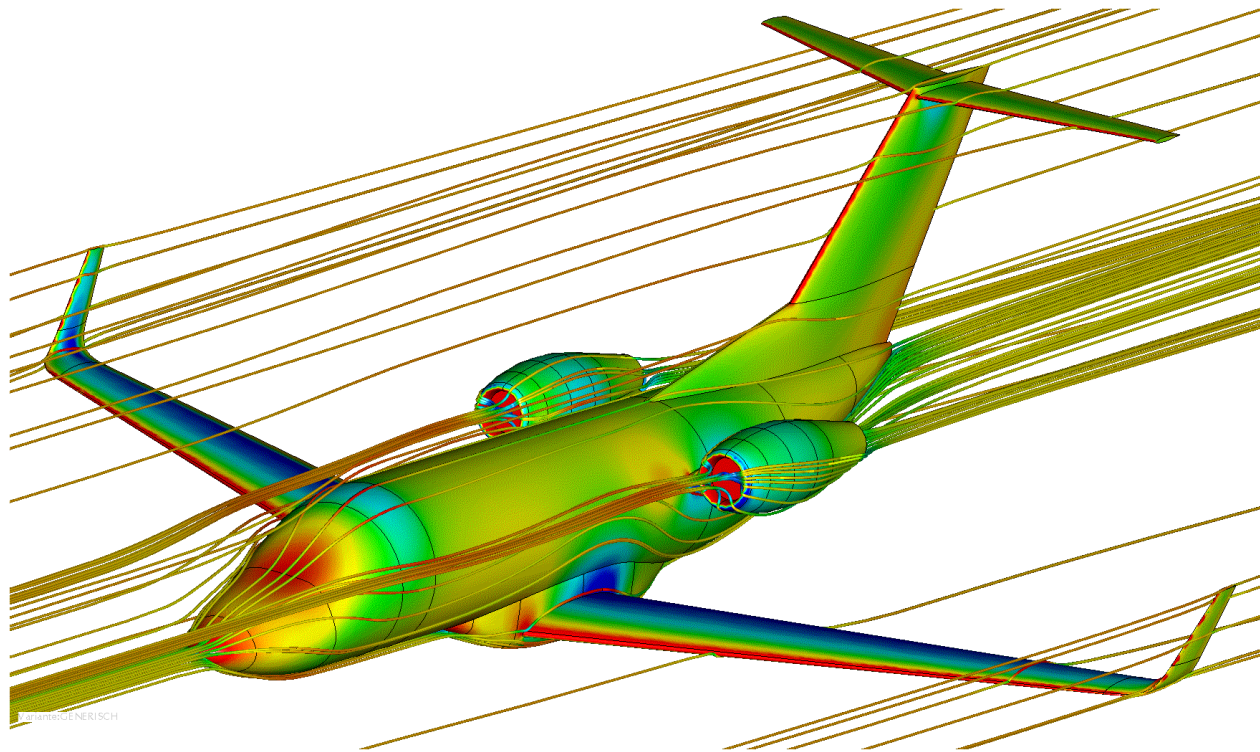
Can you give an example where CFD could be applied?

Outline of the class:

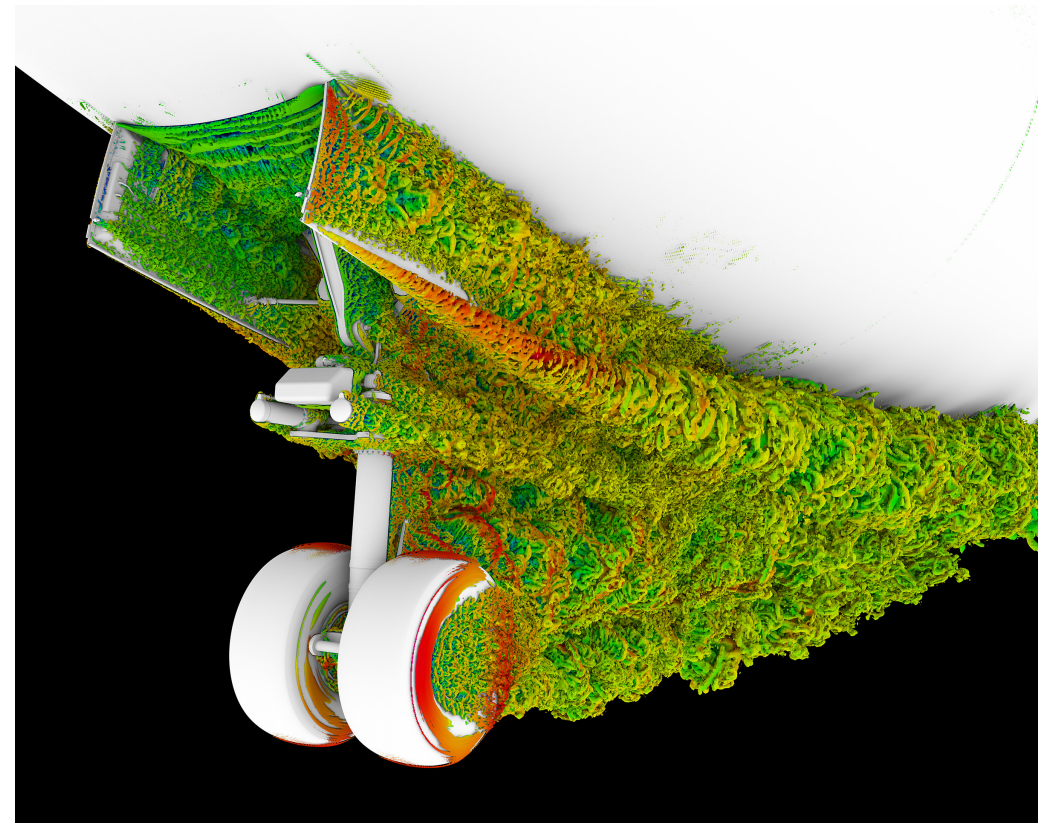
1. What is Computational Fluid Dynamics?
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The fields that benefit from CFD

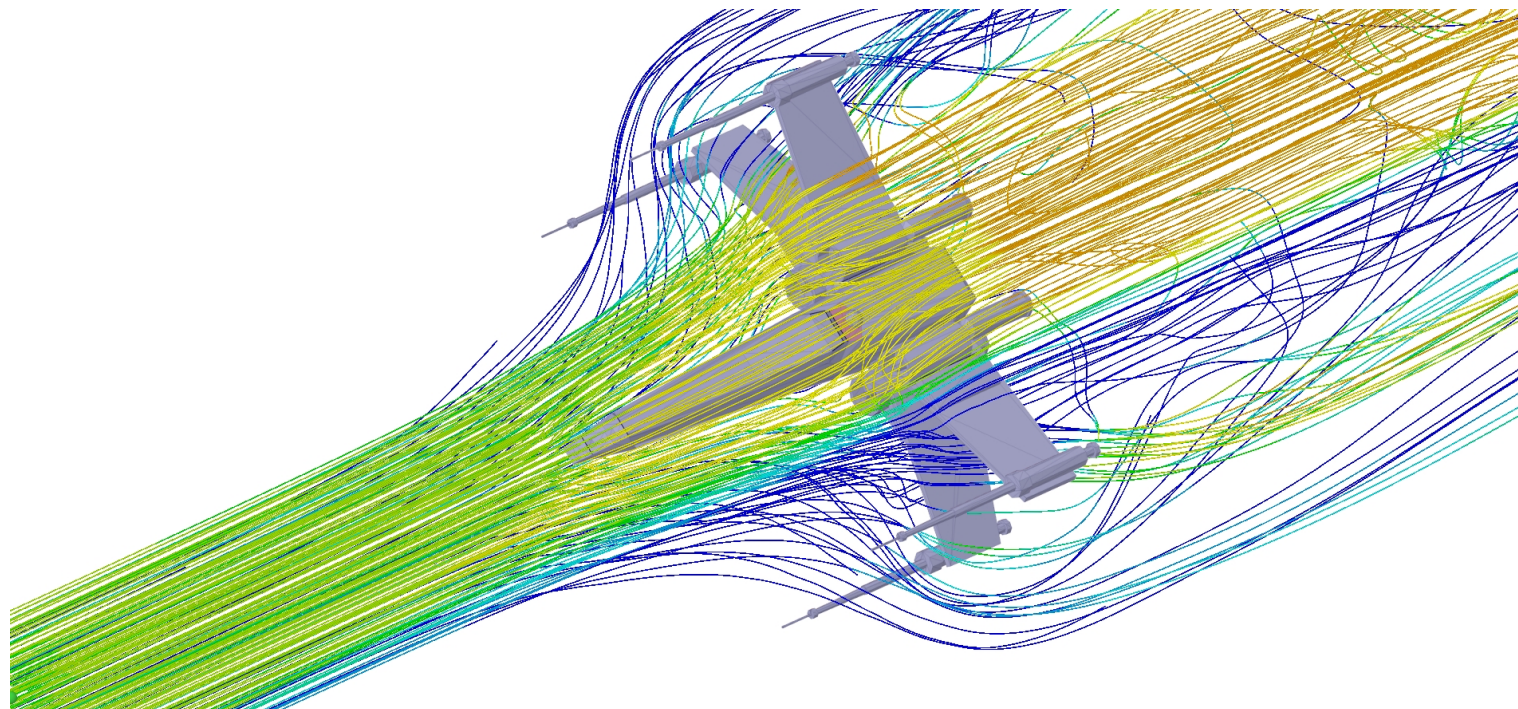
Aerospace



[thermoflow.com]



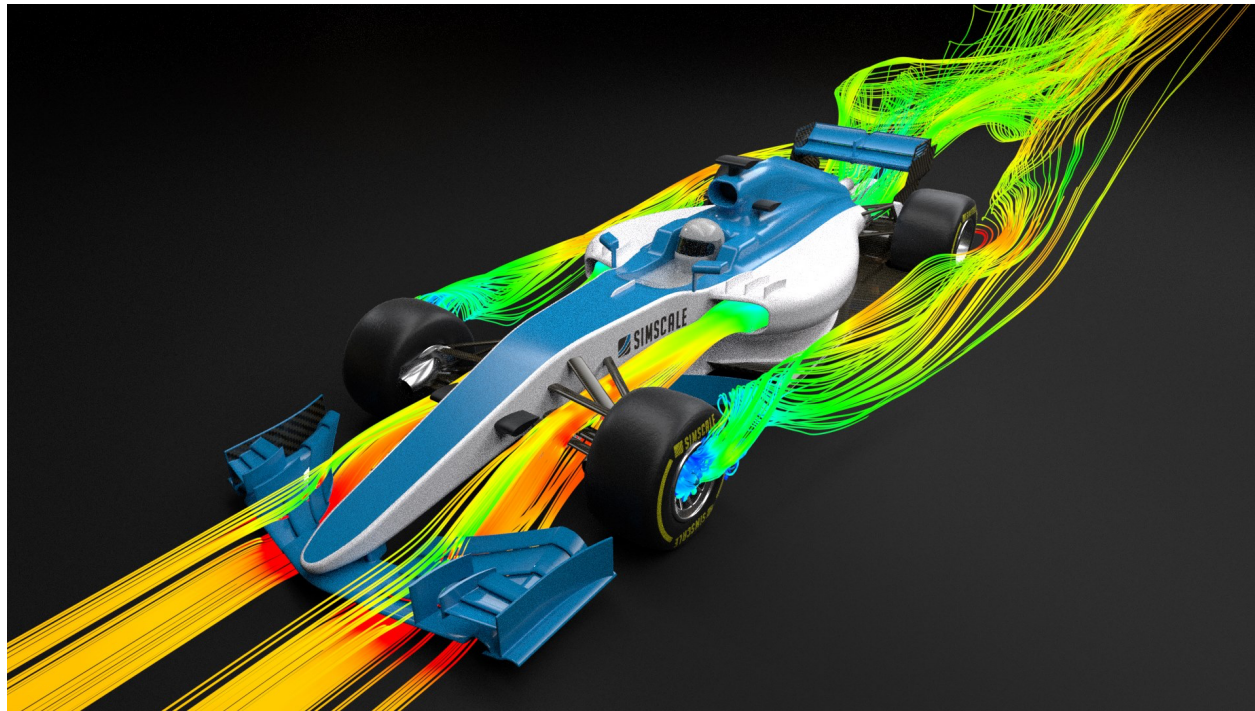
[nasa.gov]



[<https://s3-eu-west-1.amazonaws.com/fetchcf/original/file-1513290801689.jpg>]

The fields that benefit from CFD

Automotive



[[simscale.com](https://www.simscale.com)]



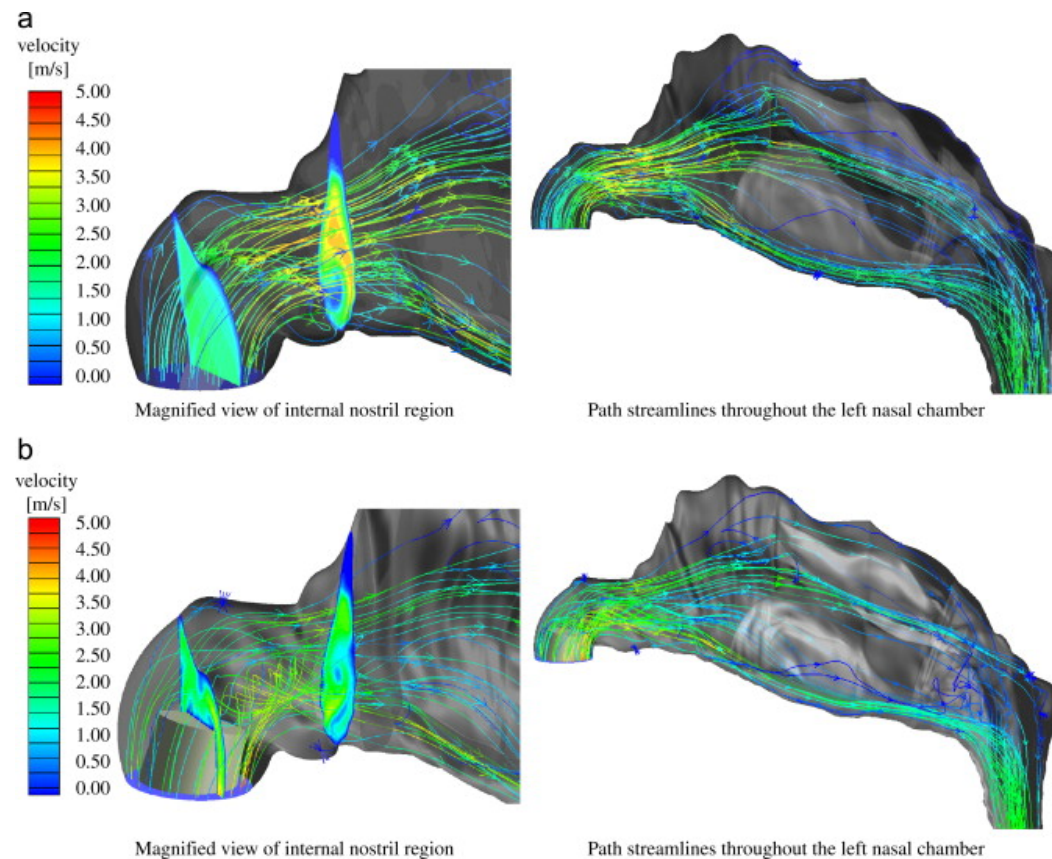
[<https://www.engineering.com/portals/0/BlogFiles/CFD-OpenFOAM-Import-VA-One.jpg>]



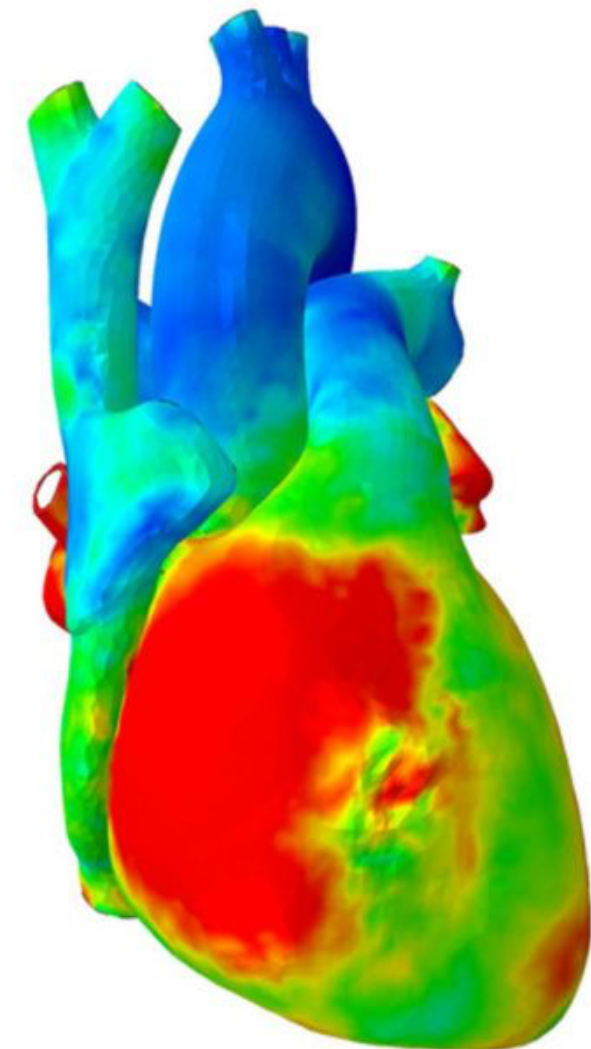
[<https://www.greencarcongress.com/2019/12/20191214-mirrorcam.html>]

The fields that benefit from CFD

Biomedical



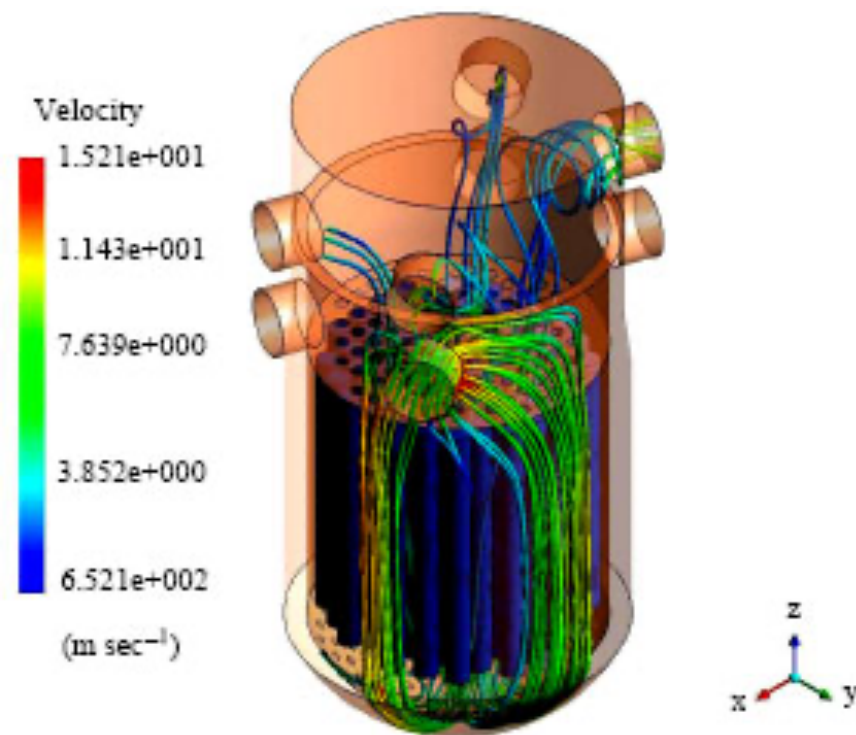
[<https://doi.org/10.1016/j.jaerosci.2010.11.008>]



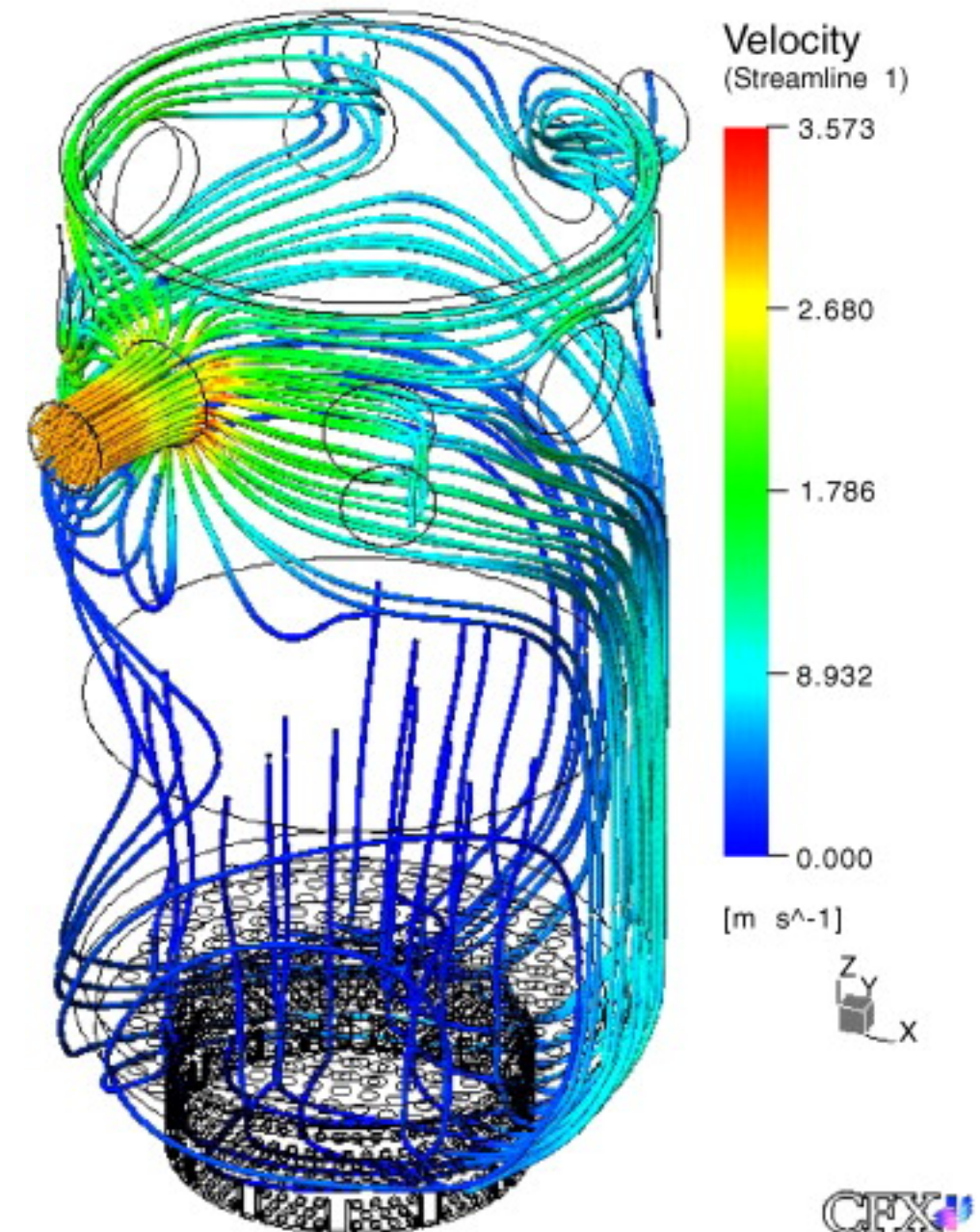
[<https://www.nextflow-software.com/nextflow-joins-the-living-heart-project/>]

The fields that benefit from CFD

Nuclear safety



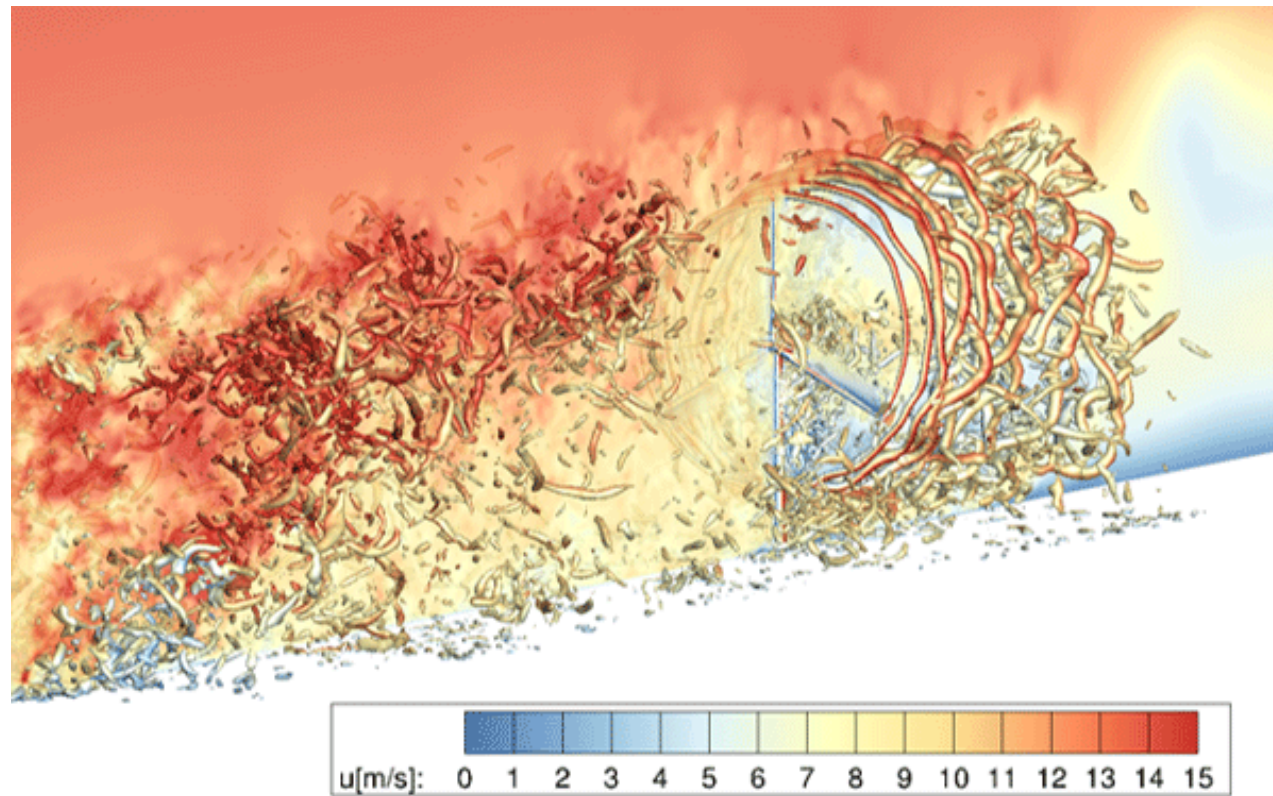
[<https://scialert.net/fulltext/?doi=jas.2008.780.787>]



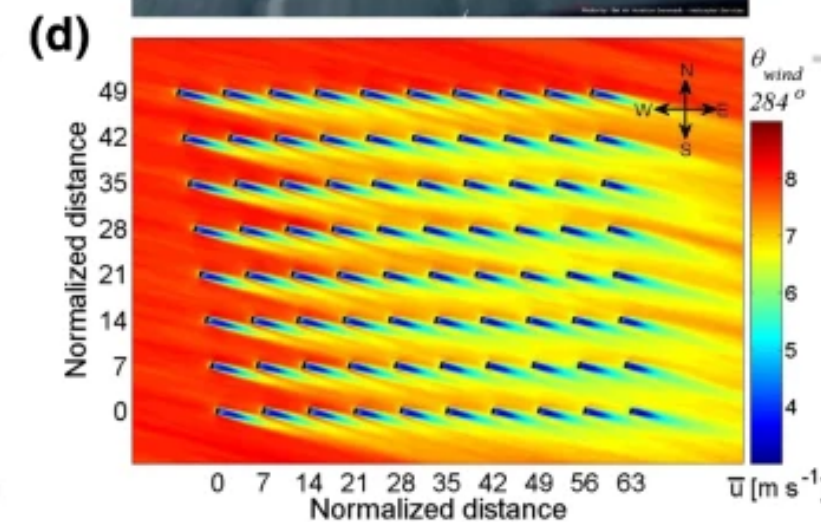
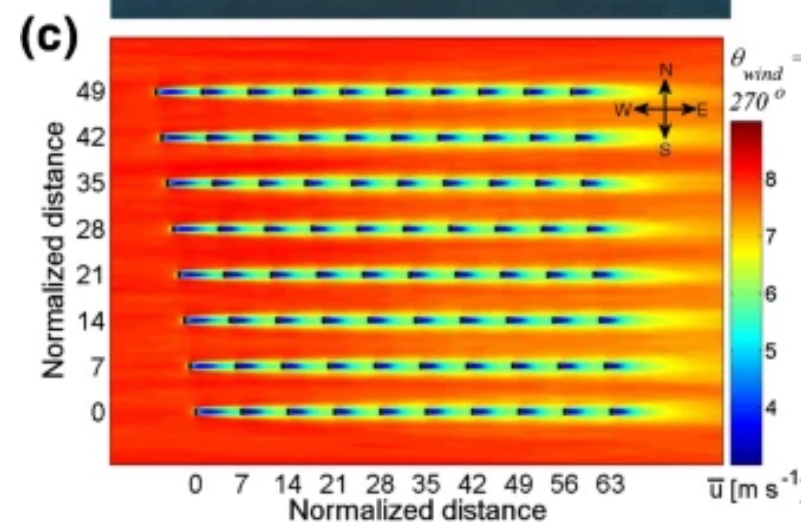
[<https://doi.org/10.1016/j.nucengdes.2007.03.015>]

The fields that benefit from CFD

Power generation/ renewables

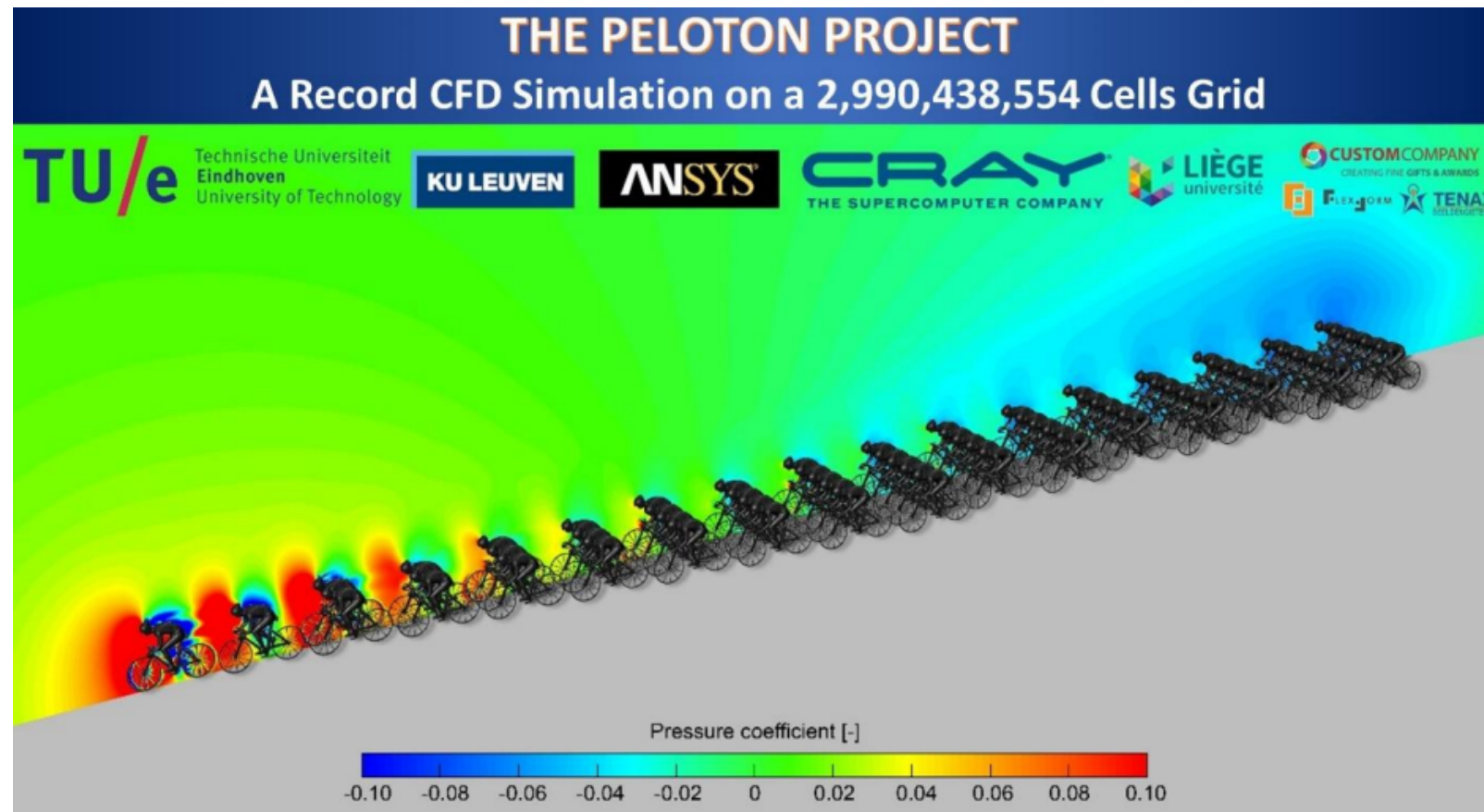


[\[https://doi.org/10.5194/wes-3-71\]](https://doi.org/10.5194/wes-3-71)

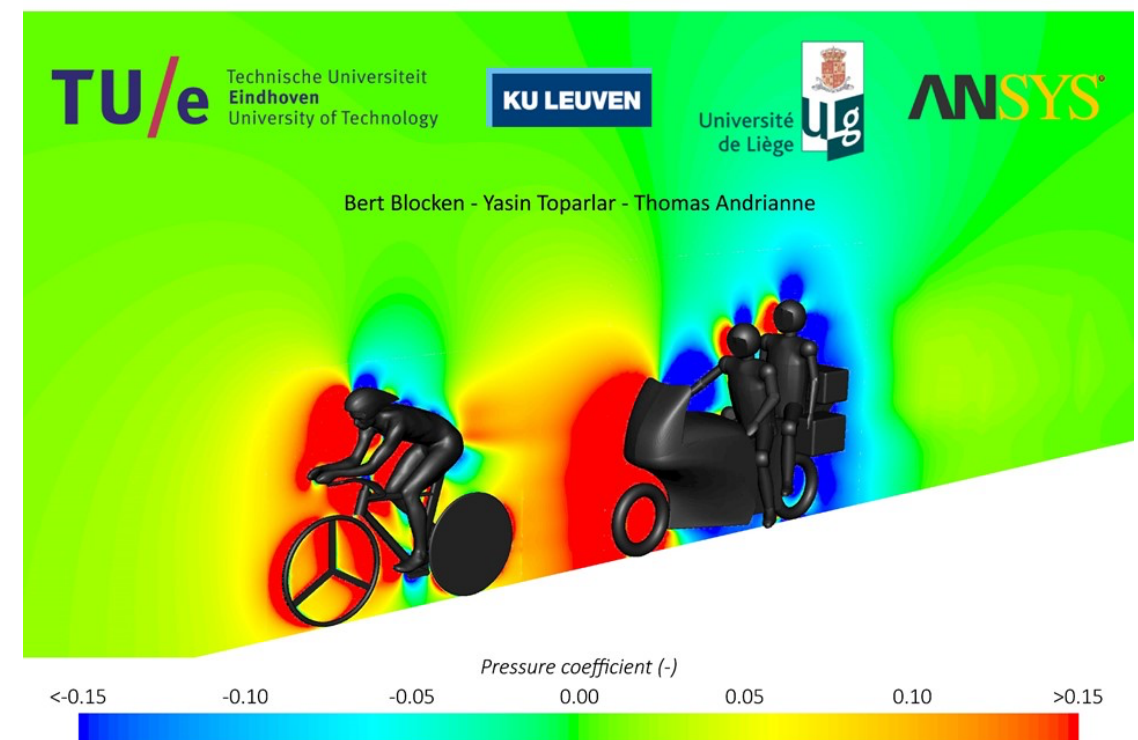


The fields that benefit from CFD

Sports



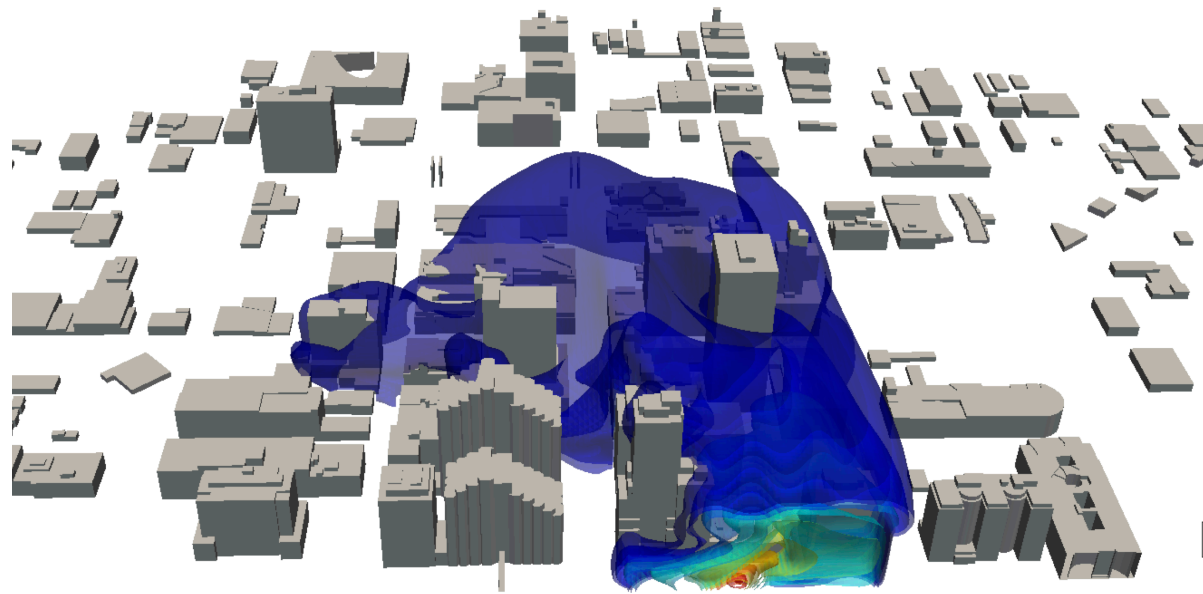
[<https://www.hpcwire.com/2018/07/05/aerodynamic-simulation-reveals-best-position-in-a-peloton-of-cyclists/>]



[<http://www.urbanphysics.net>]

The fields that benefit from CFD

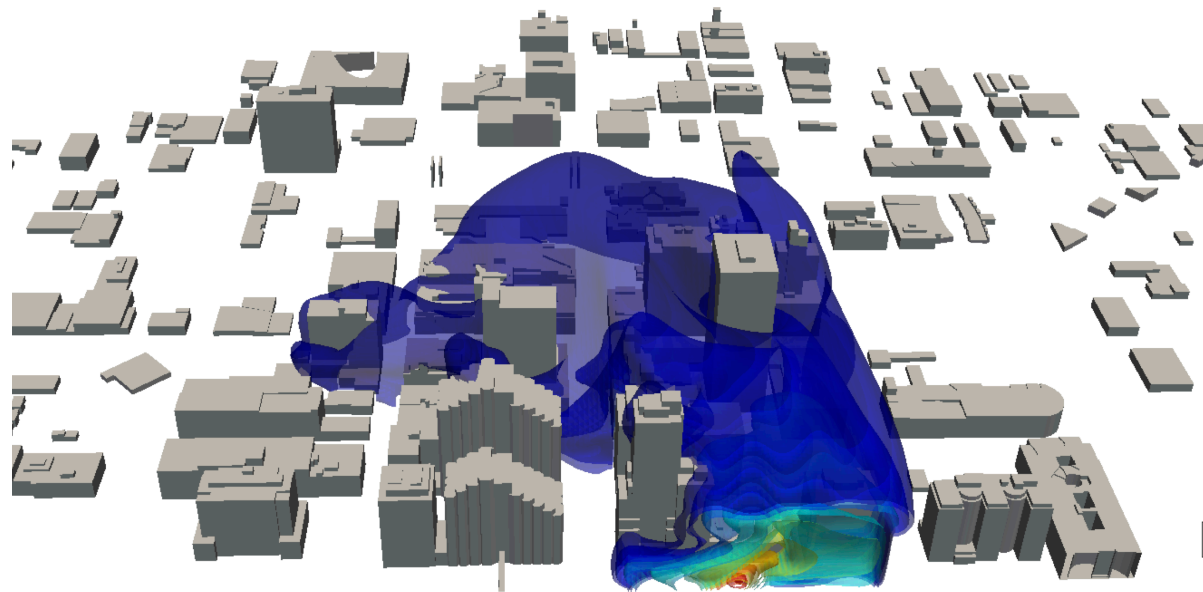
Civil/Environmental



[C. García-Sánchez, PhD thesis, 2017]

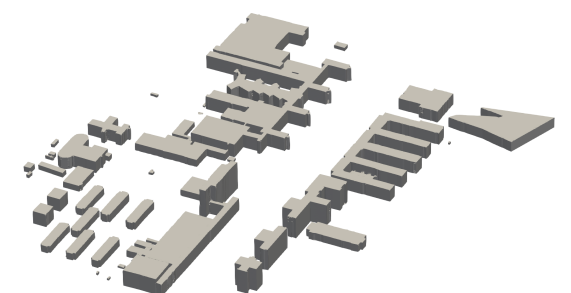
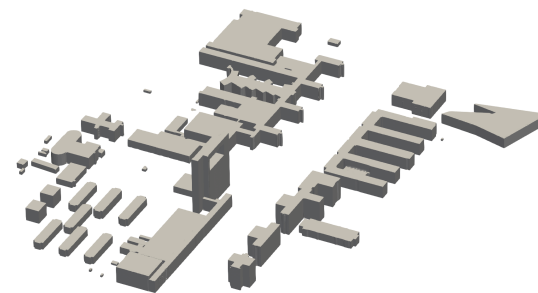
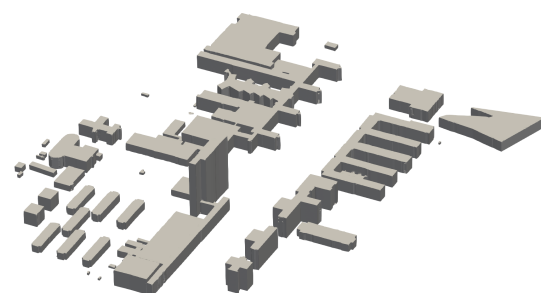
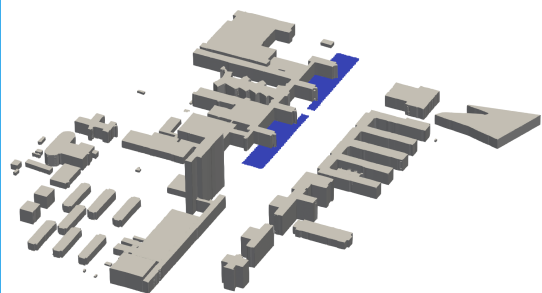
The fields that benefit from CFD

Civil/Environmental



[C. García-Sánchez, PhD thesis, 2017]

[GE05013, 2019]



Water surface

Normal EWI building

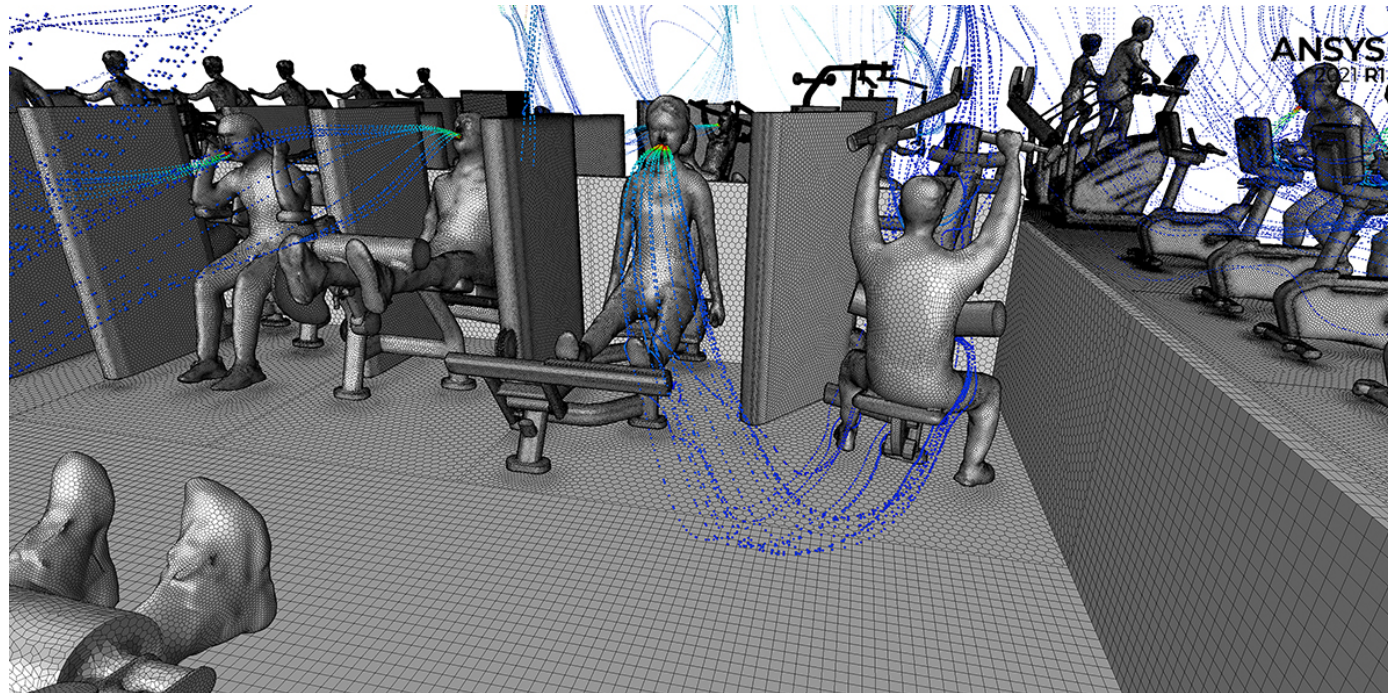
Terrace on top EWI building

Half EWI building

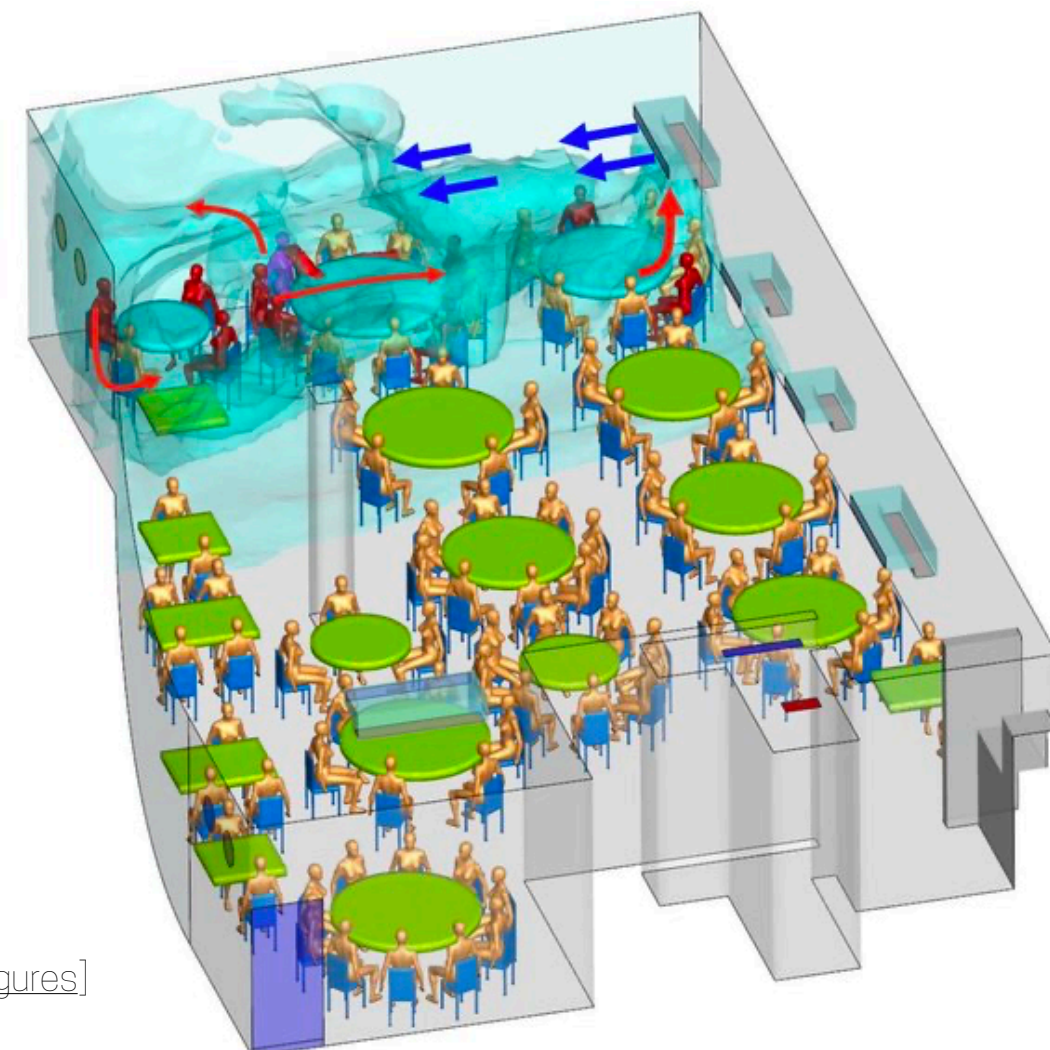


The fields that benefit from CFD

Indoor ventilation



[<https://www.ansys.com/advantage-magazine/volume-xv-issue-2-2021/breathe-easy-conquering-coronavirus-cfd>]



[https://www.researchgate.net/publication/343618144_The_Build-Up_of_DropletAerosols_Carrying_the_SARS-CoV-2_Coronavirus_in_Confined_Spaces/figures]

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How can CFD shape your future?

Skills collected: numerical methods, computer skills, data processing, physical and critical thinking for real world problems

- Buildings Consultancy (ARUP, Royal HaskoningDHV)
- Architecture firms interested in climate
- Air quality research institutions (RIVM, VITO, TNO)
- Uber eats, google
- Competitive sports teams (formula 1)
- Siemens, Dassault Systems, Simscale

Wrap Up:

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Next class:

An introduction to the atmospheric boundary layer