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Global Summit and Expo on
Fluid Dynamics & Aerodynamics
August 15-16, 2016 London, UK

# Recent Developments in Train Aerodynamics

Dr Hassan Hemida
Director of MRes in Railways and Deputy Director of Research,
School of Engineering,
University of Birmingham, UK
E-mail: h.hemida@bham.ac.uk

# Context

- Early days
- Train aerodynamics
- Recent projects
- Current projects
- What is next?




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# Aerodynamic effects

Aerodynamic effects $\propto$ (Train velocity)$^2$




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# Early days

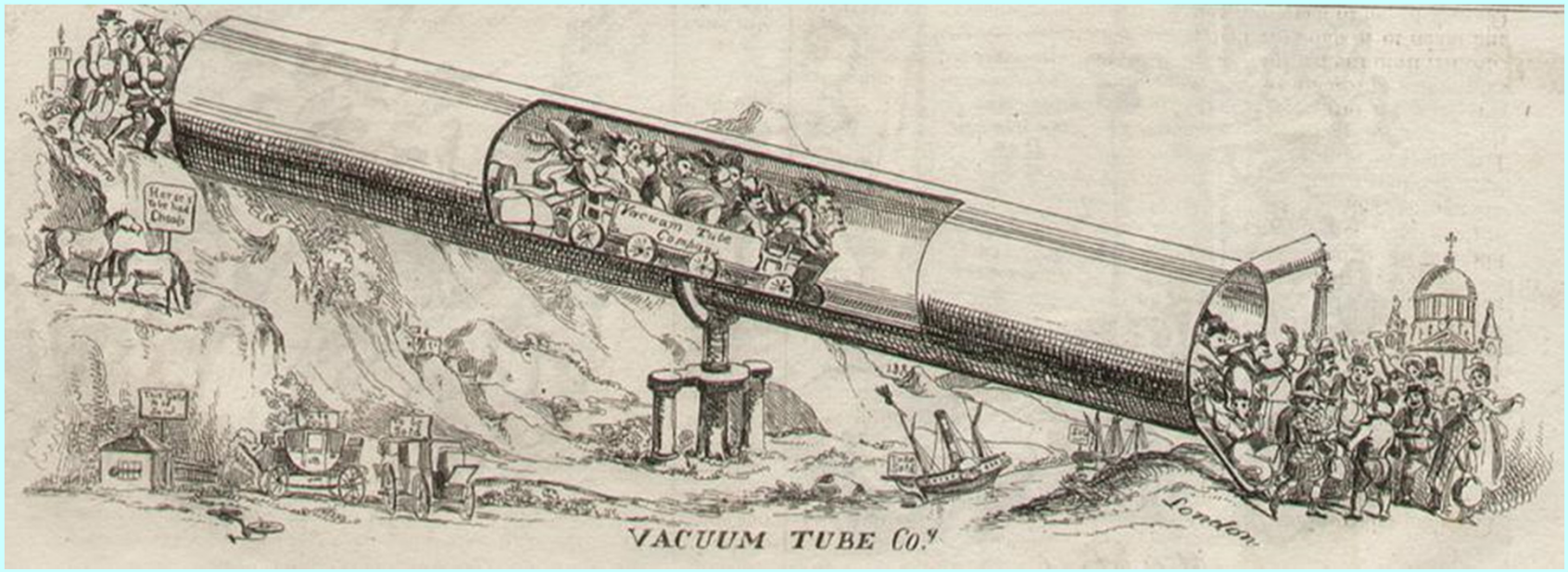
- Baker, "Train Aerodynamics: Past, Present and Future", International Journal of Railway Technology, 5(1), 1-22, 2016. doi:10.4203/ijrt.5.1.1




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# Early days

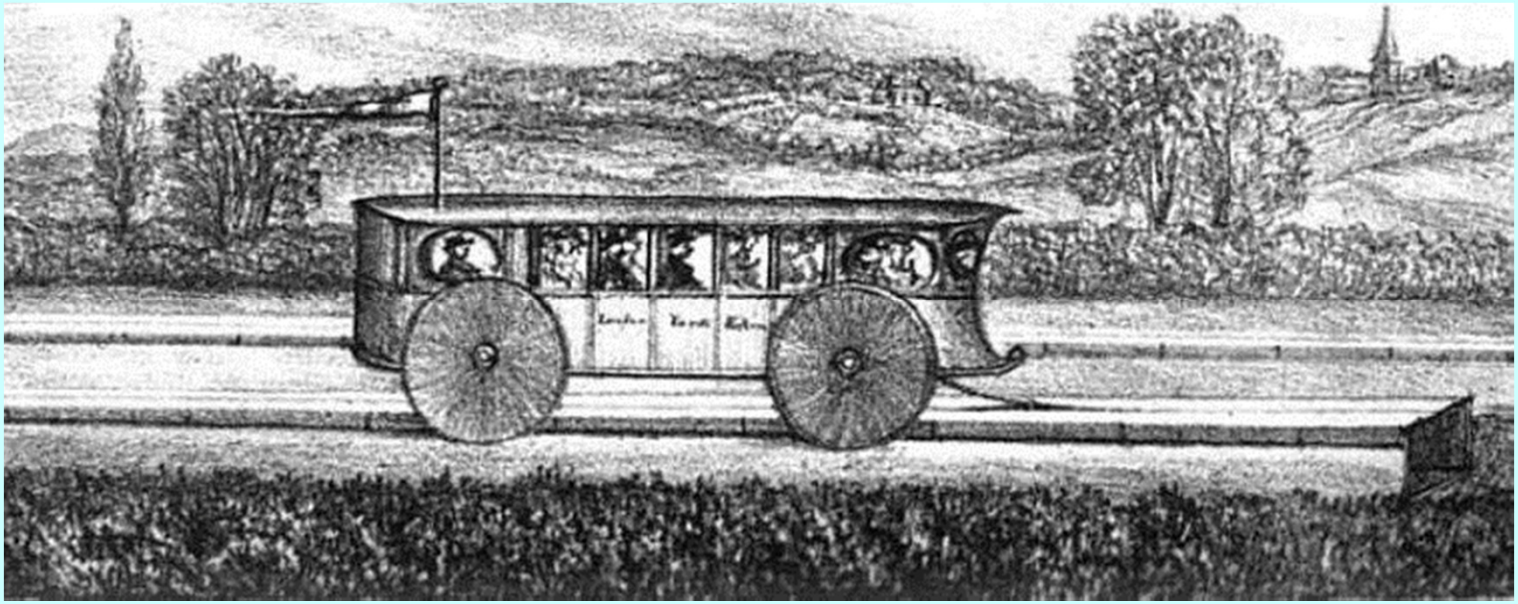
- Railways exists long time ago.
- George Medhurst 1812 – Vacuum tube




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# Early days

- The Atmospheric Railway
  - George Medhurst 1812



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# Early days

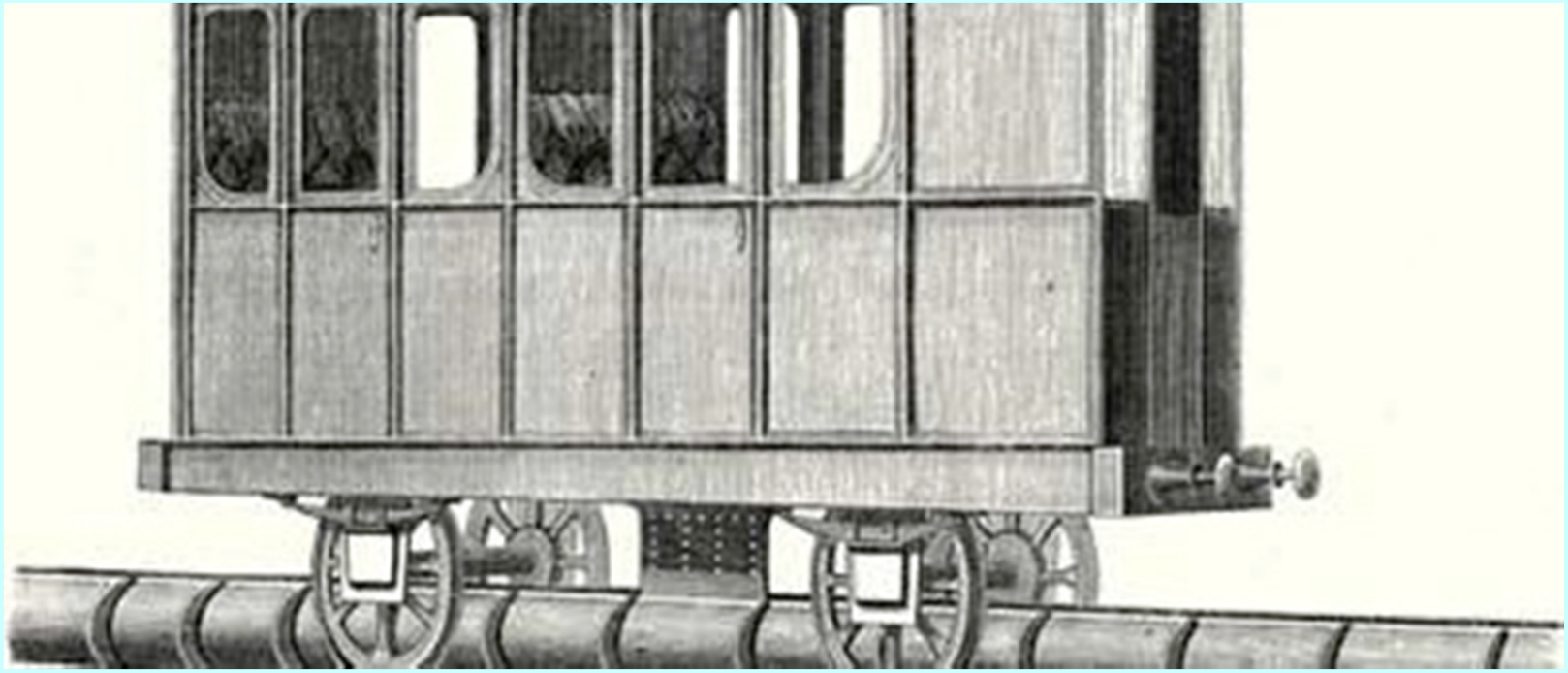
- The Dalkey Atmospheric Railway
  Charles Vignoles, Dublin 1843 to 1855
- Isambard Kingdom Brunel South
  Devon Railway 1846 to 1848



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# Early days

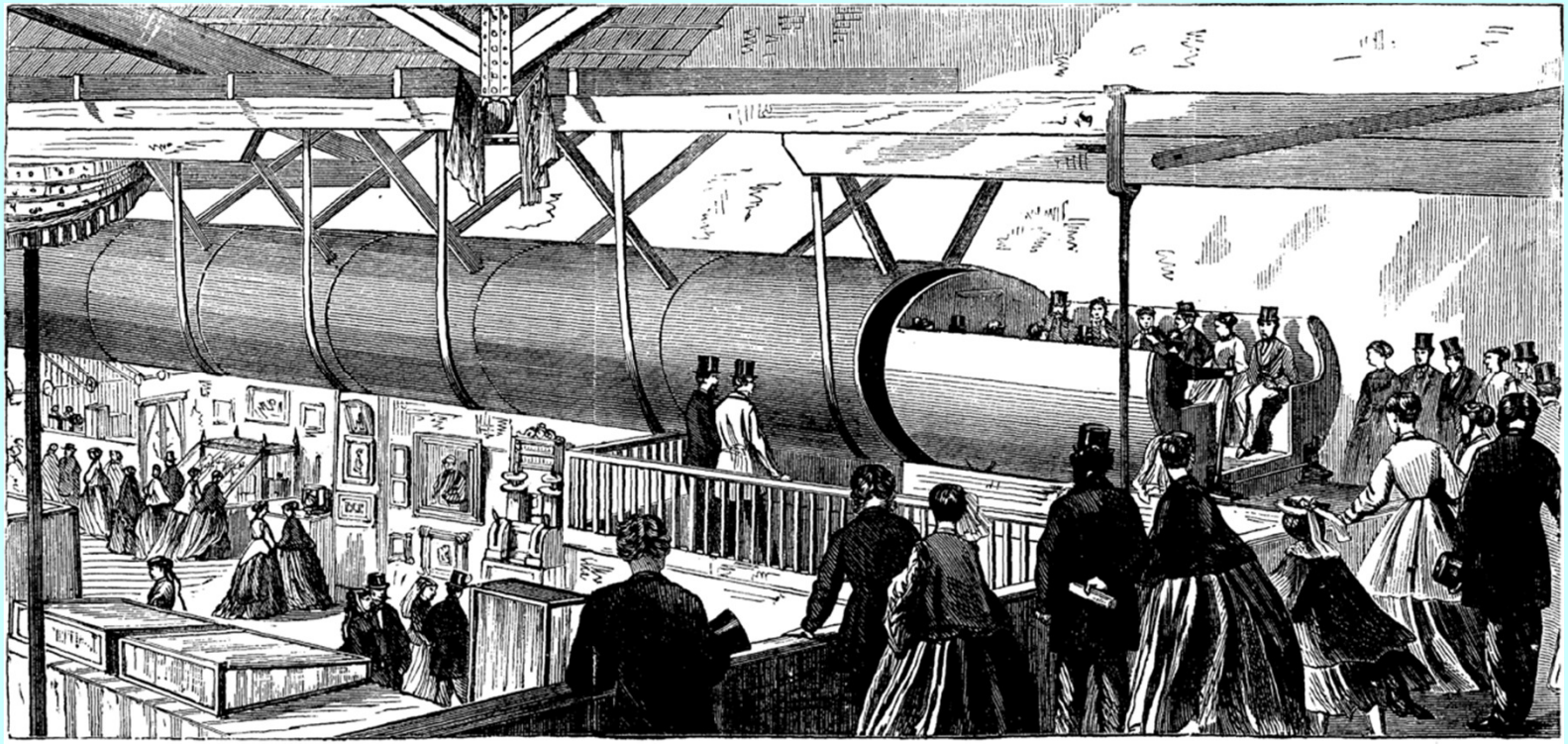
- Pereire brothers Paris to Saint Germain 1847 to 1850



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# Early days

- Alfred Beach Pneumatic subway 1870 to 1873



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# Early days

- Bennie's Railplane 1930






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# Train Aerodynamics

- 1930-1950 Streamlining and drag reduction
  - Wind tunnel testing



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# Train Aerodynamics

- 1950-1980 The emergence of new issues



Shinkansen Series 0

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# Train Aerodynamics

Aerodynamic stability in high winds

Wind loading

Train slipstream effects on the external environment



Effect of train pressure pulses on other trains

Tunnel pressure effects on train interiors.

- Aerodynamic noise
- Drag reduction using active and passive flow control
- Aerodynamic shape optimization
- Flying object around trains

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# Full Scale Experiment



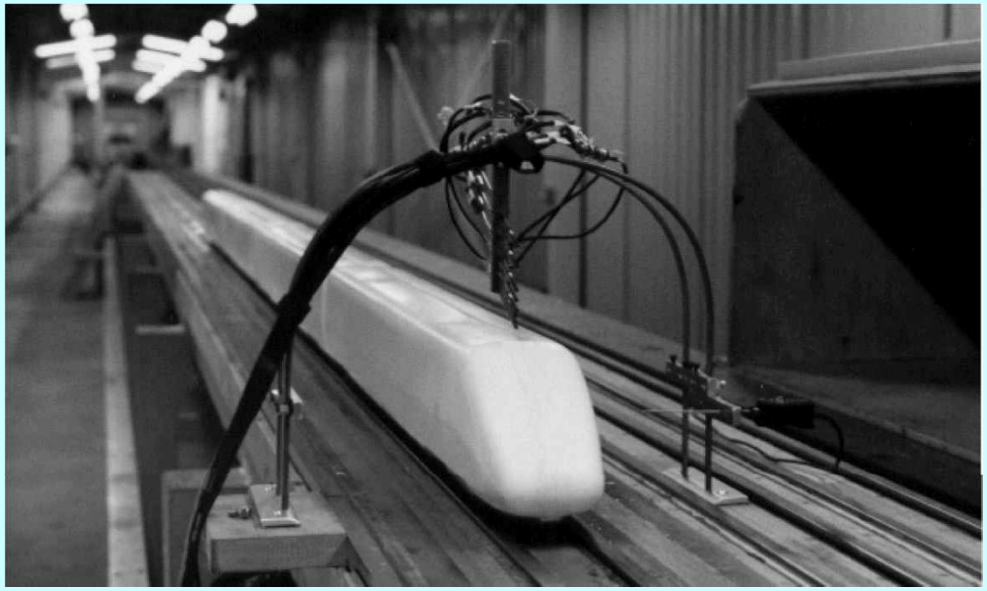
http://www.youtube.com/watch?v=jx7BUDsnjfA

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# Physical modelling

Using non-dimensional parameters we can use wind tunnel experiments to investigate the problem of full scale trains





Moving train rig in Derby

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TRAIN Rig
Transient Aerodynamic Investigations
University of Birmingham

# Computational Fluid Dynamics (CFD)

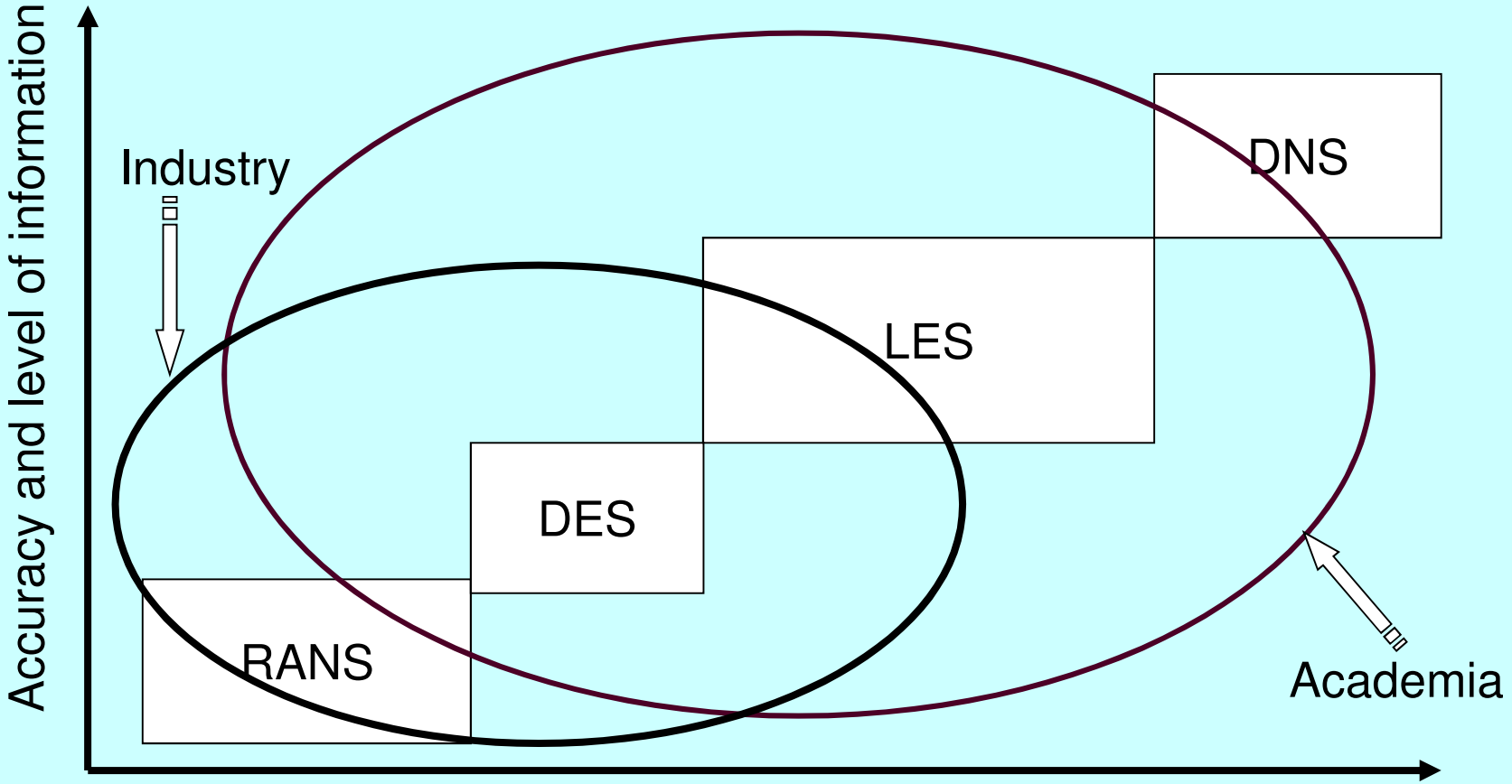
Continuity → $$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u_i)}{\partial x_i} = 0 \qquad i = 1, 2, 3$$

N. S. Equations → $$\frac{\partial (\rho u_i)}{\partial t} + u_j \frac{\partial (\rho u_i)}{\partial x_j} = \frac{-\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}(\Gamma \frac{\partial u_i}{\partial x_j}) + S_\phi$$




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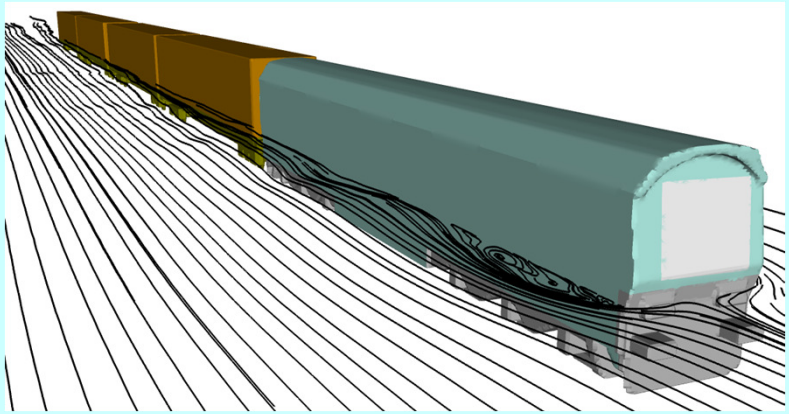
# Turbulence Modeling

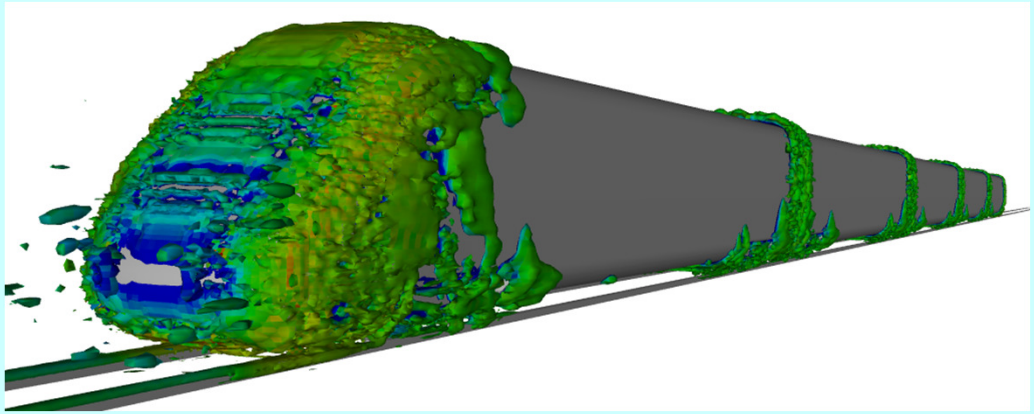


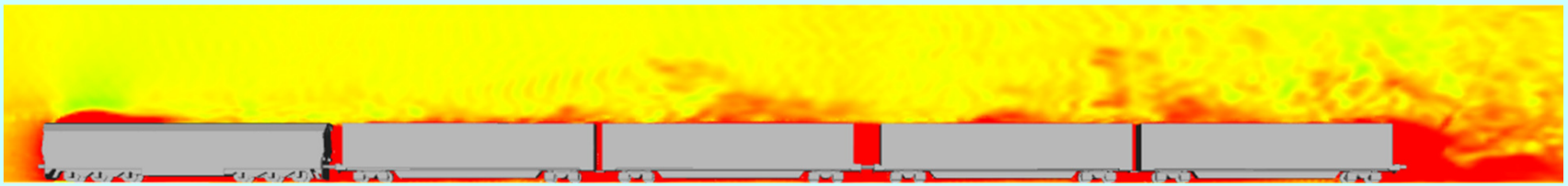

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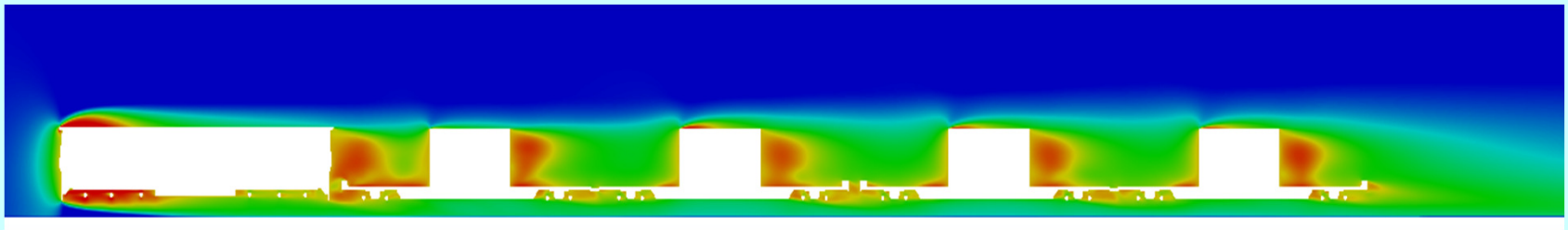
# Recent projects

## 1- Train slipstream









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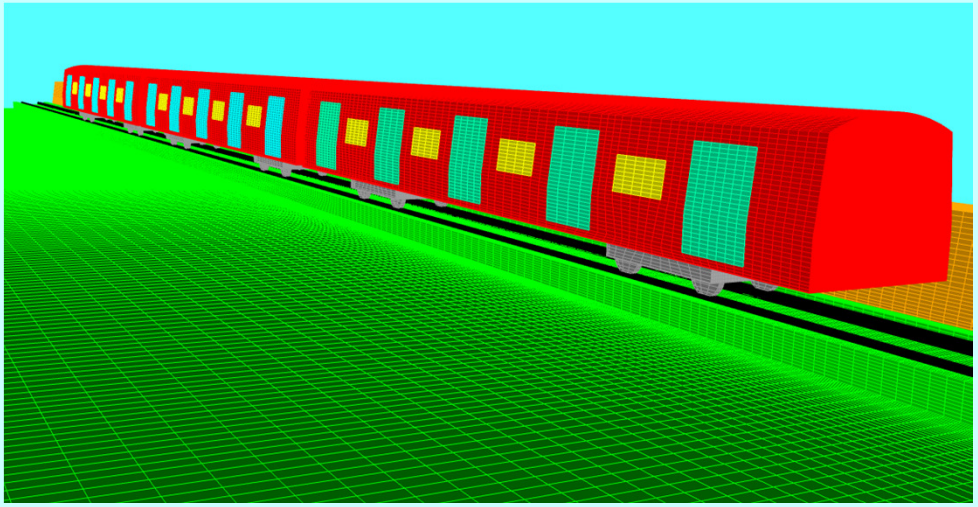
H Hemida, C Baker, G Gao (2012) “The calculation of train slipstreams using large-eddy simulation” Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit

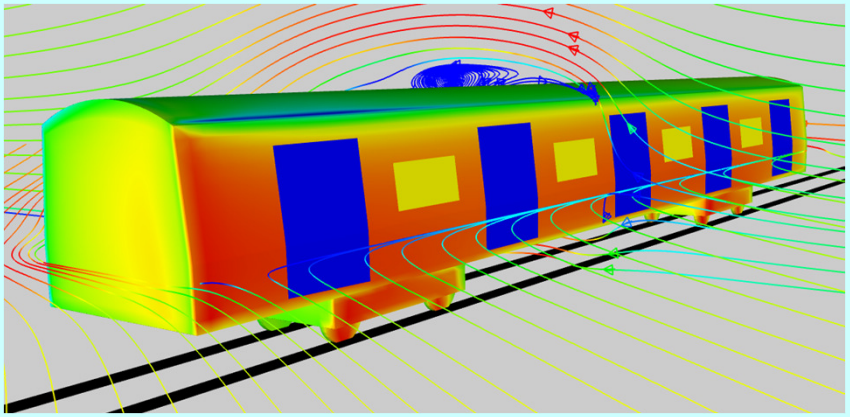


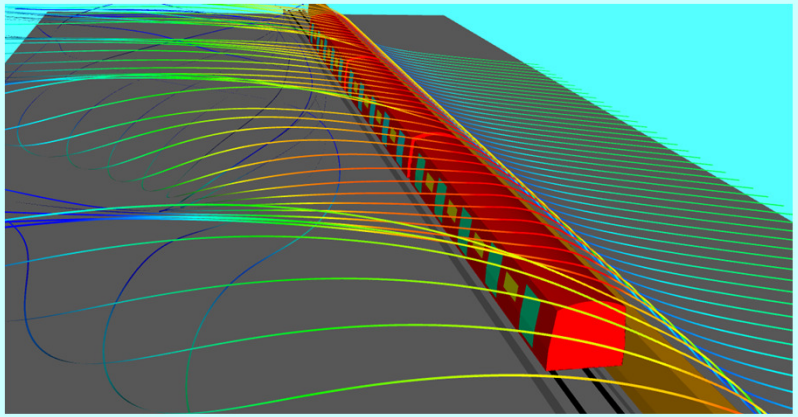

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# Recent projects

2- Side wind flow around trains



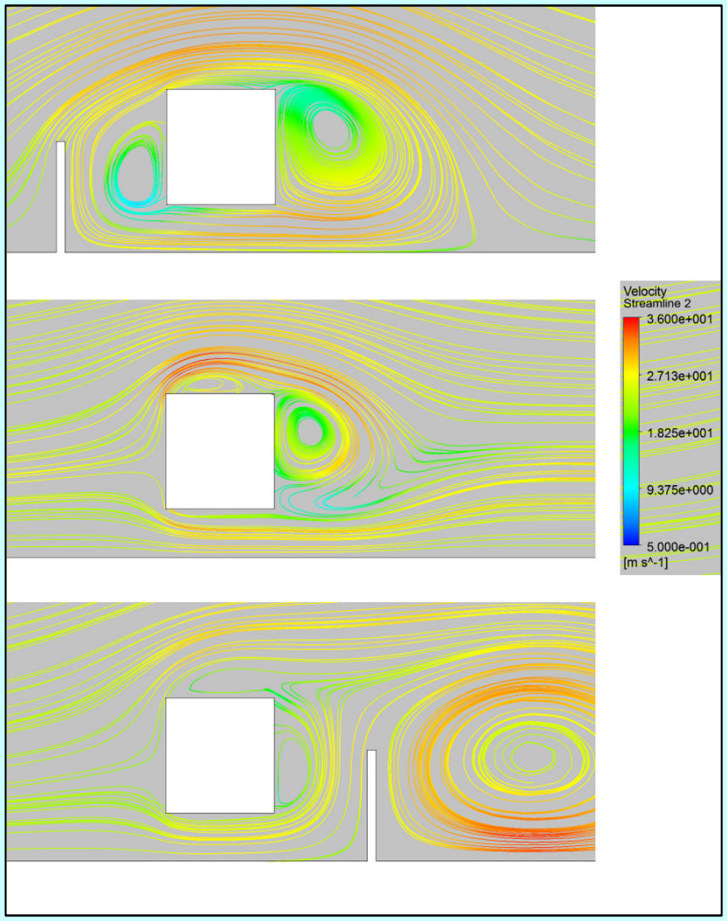


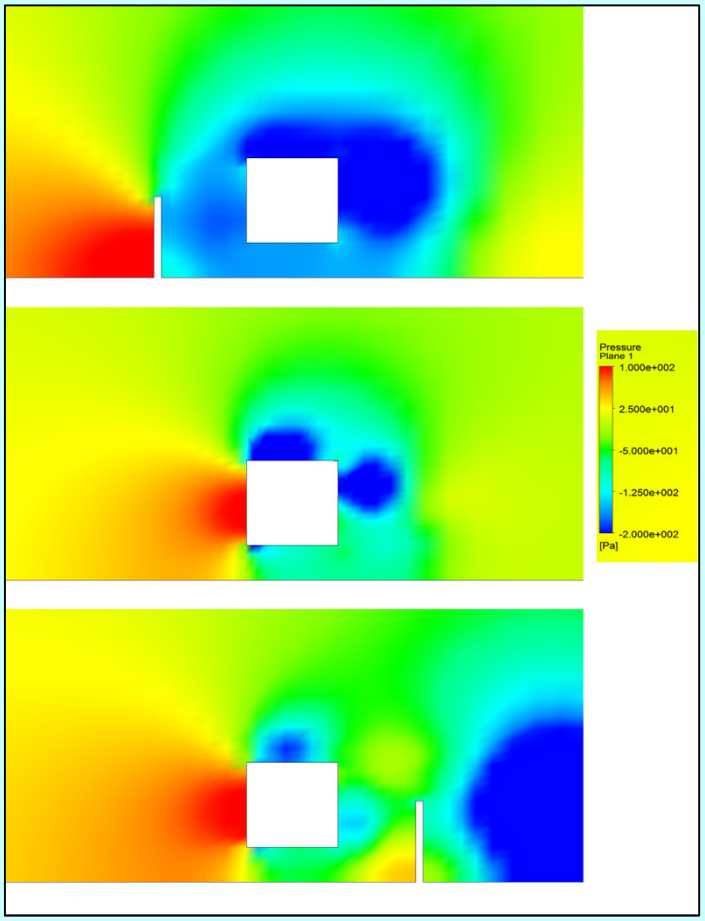


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# Recent projects

3. Effect of wind fences on train aerodynamics

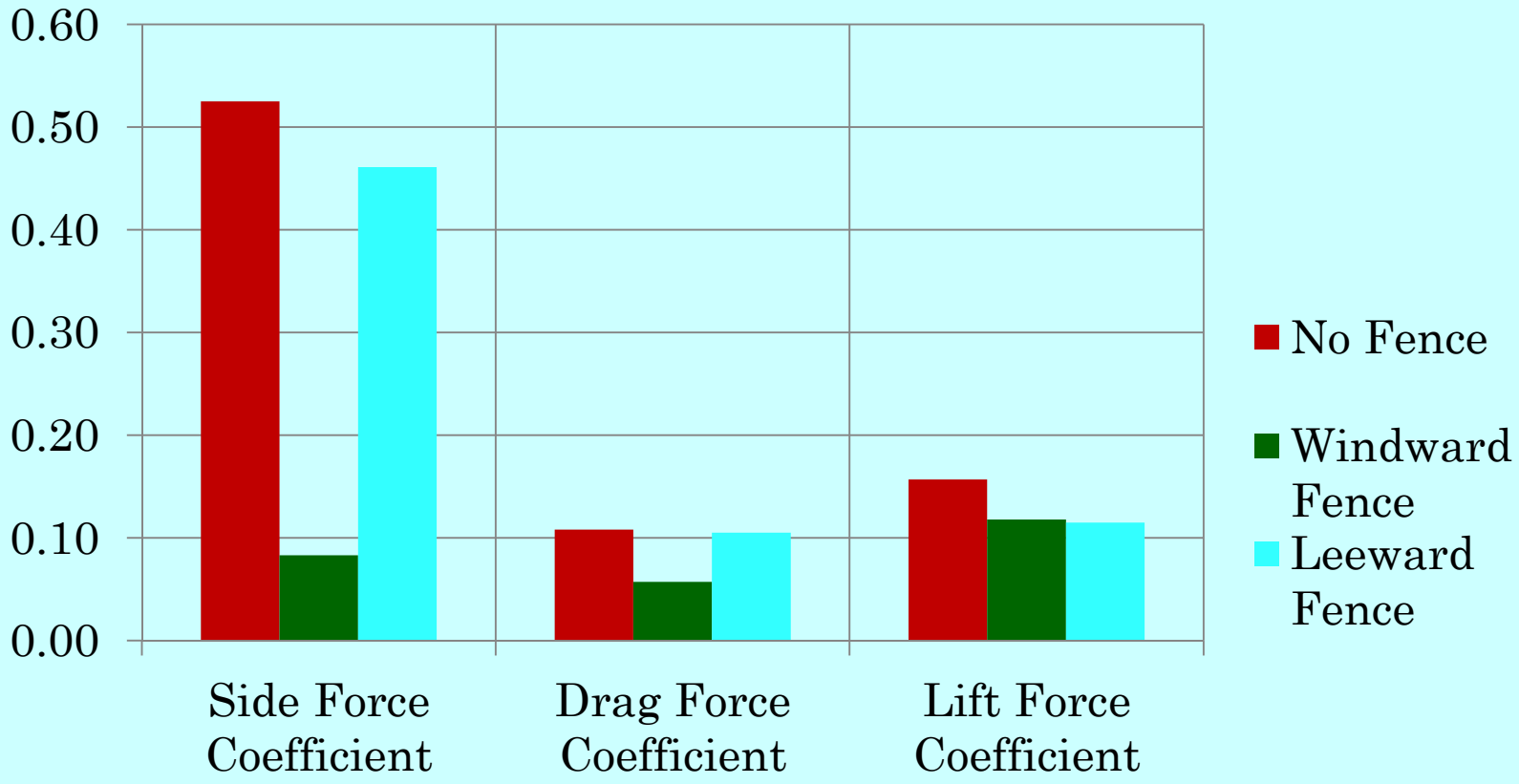



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# Recent projects

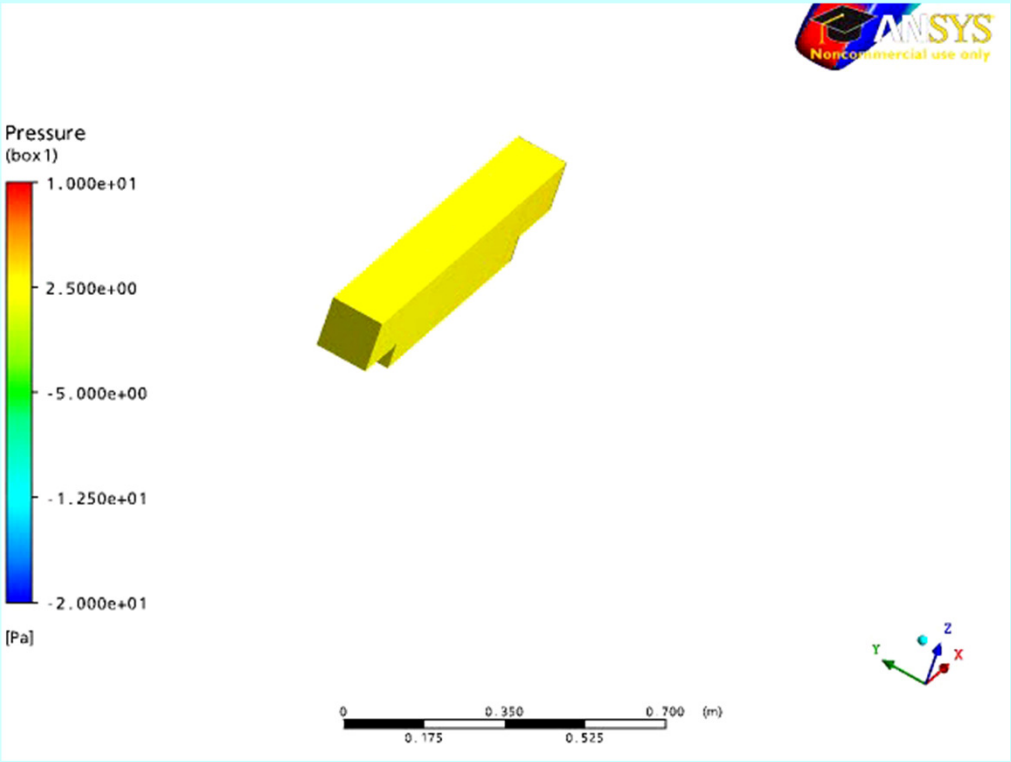
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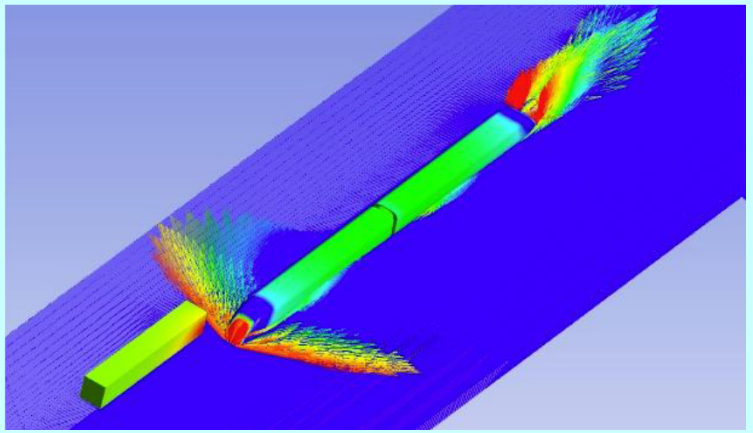



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# Recent projects

## 4- Train passing phenomena



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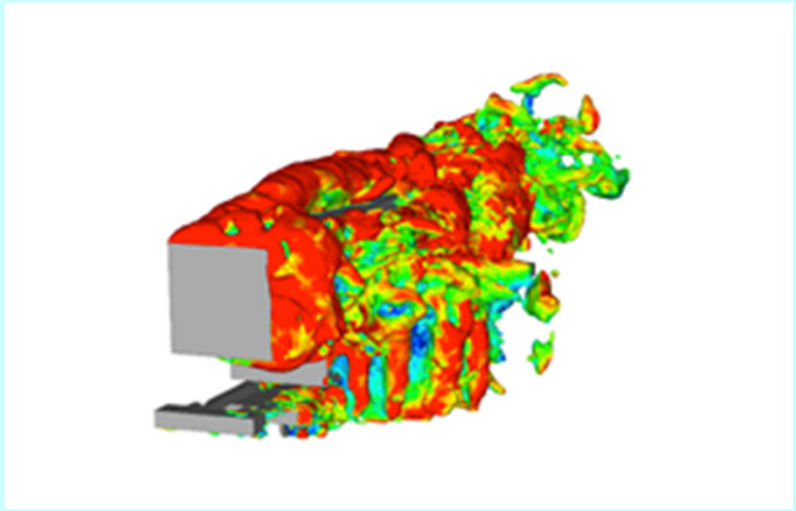
Y Liu, H Hemida, Z Liu (2014), “Large eddy simulation of the flow around a train passing a stationary freight wagon” Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit

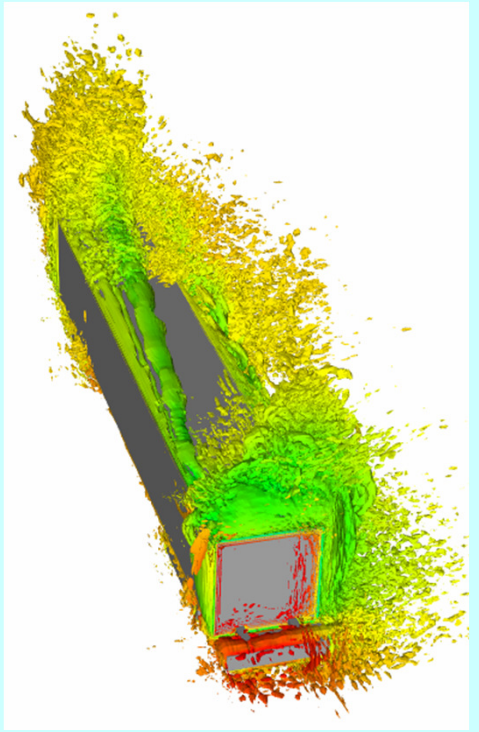


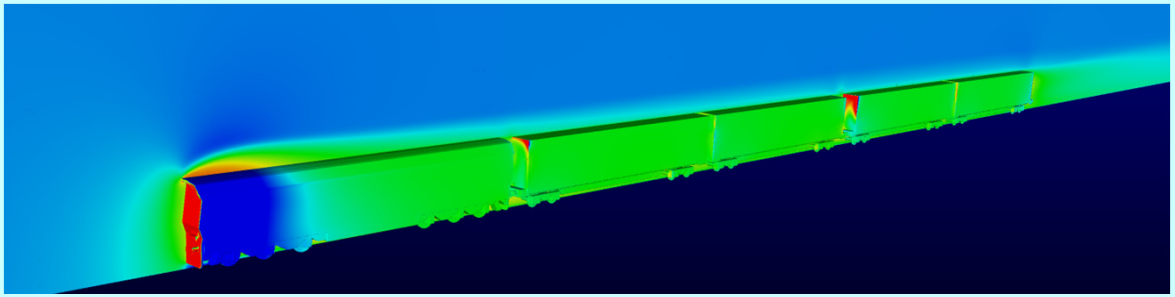

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# Recent projects

## 5- Numerical Simulations of the Flow around Freight Trains







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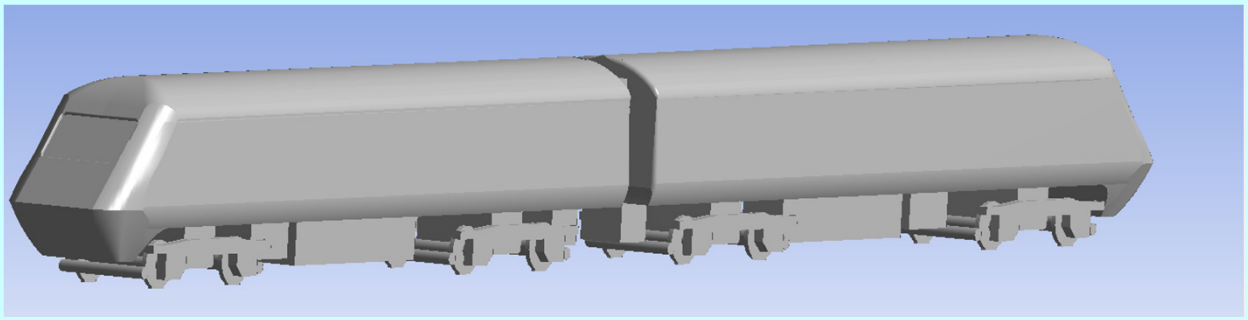
H Hemida, C Baker (2010) “Large-eddy simulation of the flow around a freight wagon subjected to a crosswind”
Computers & Fluids 39 (10), 1944-1956



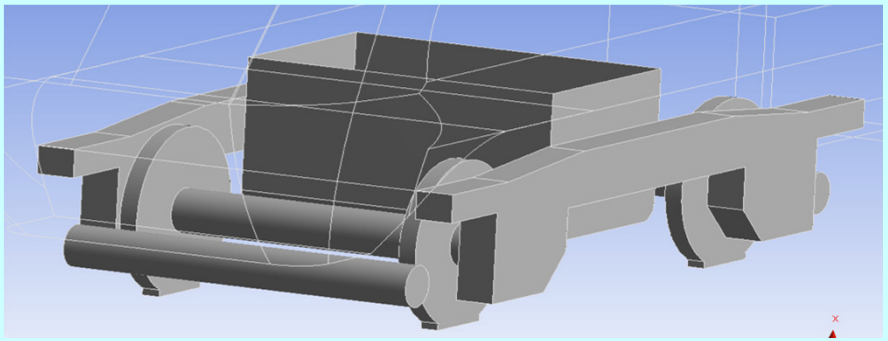

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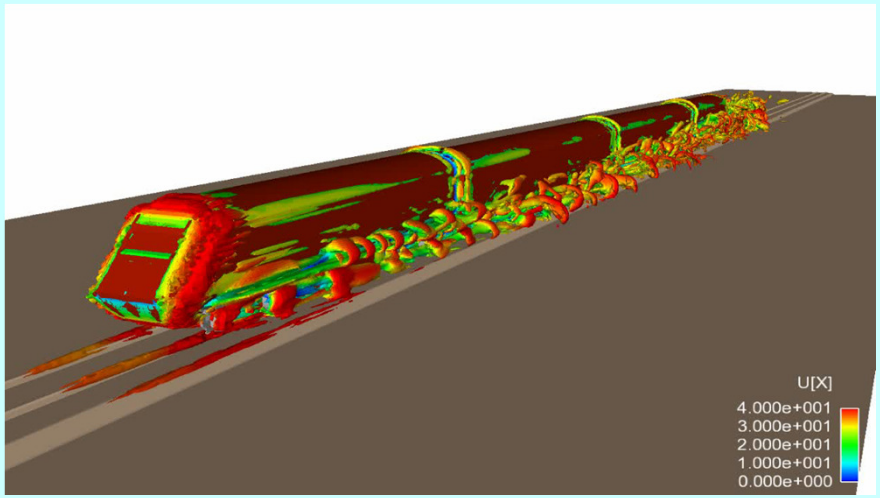
# Recent projects

## 6- LES of the Flow around Passenger Trains



HST train






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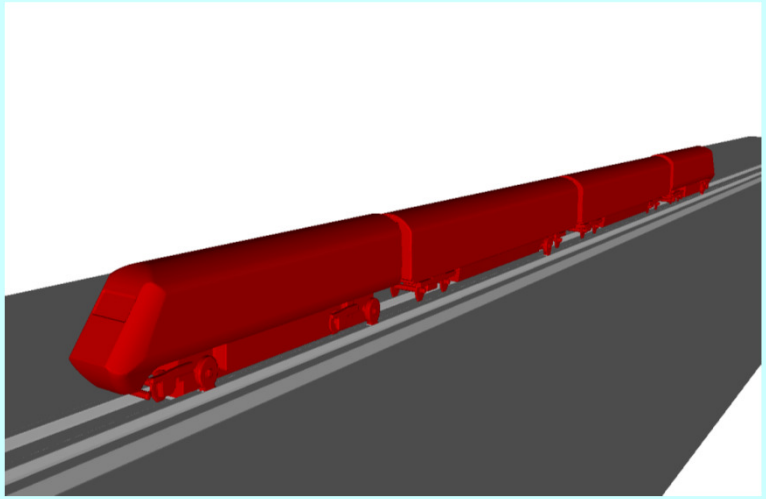
J Morden, H Hemida, CJ Baker (2014), "Comparison of RANS and Detached Eddy Simulation Results to Wind-Tunnel Data for the Surface Pressures Upon a Class 43 High-Speed Train" Journal of Fluids Engineering 137 (4), 041108




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# Recent projects

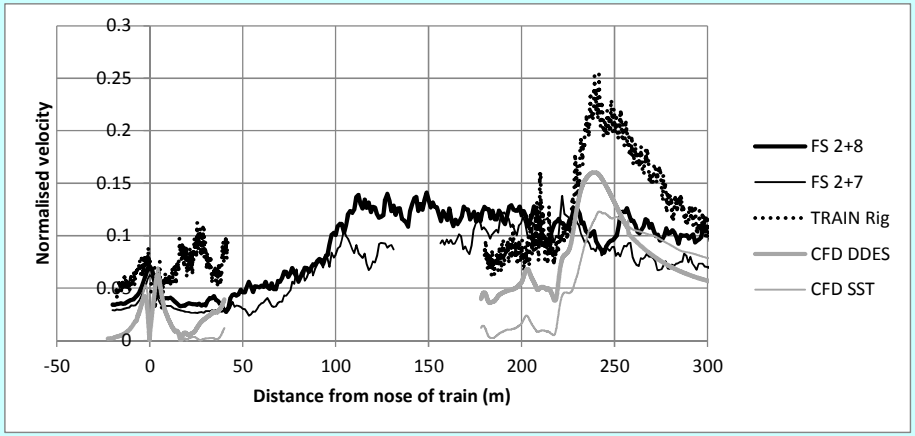
## 7- Real world trains











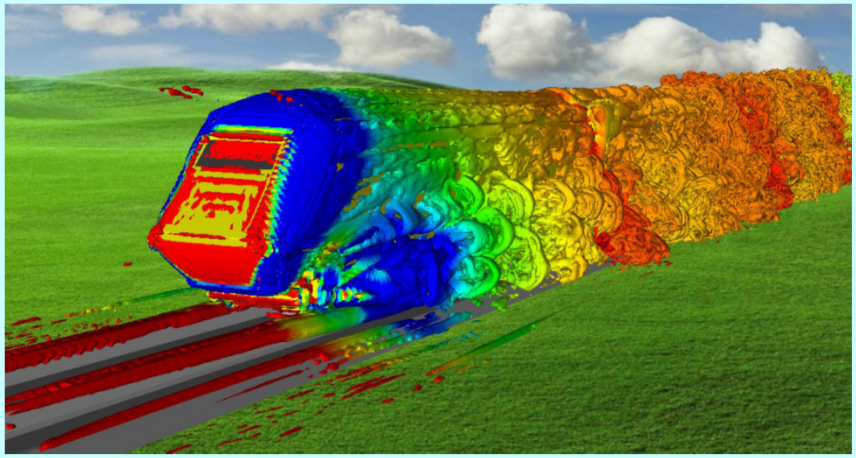

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# Recent projects

## 7- Real world trains









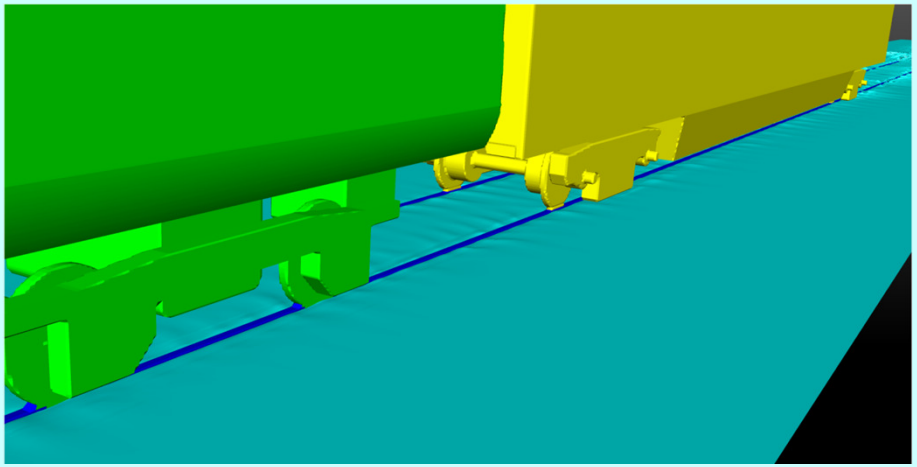
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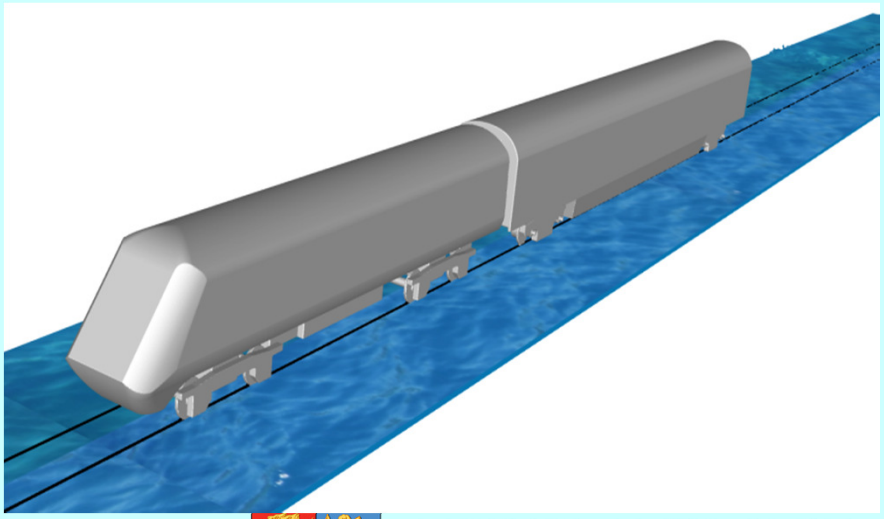
# Recent projects

## 8- Train on a flooded rail





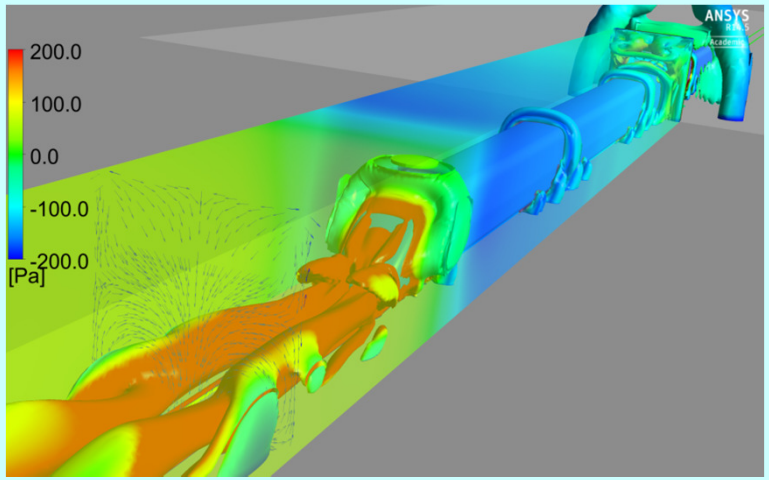


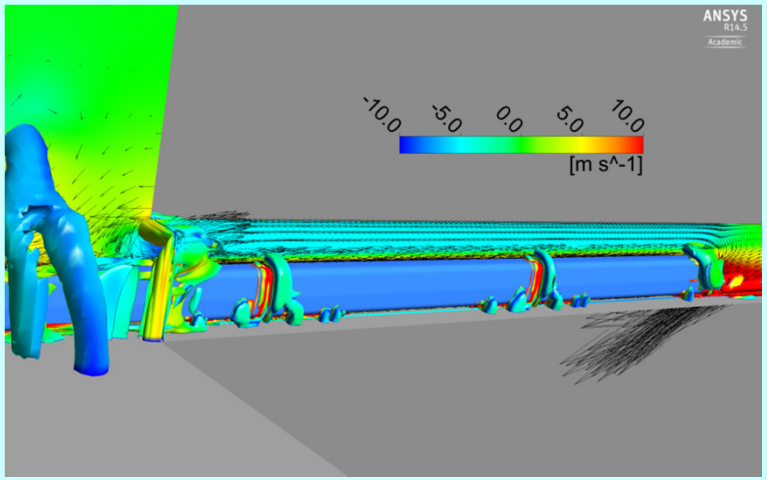


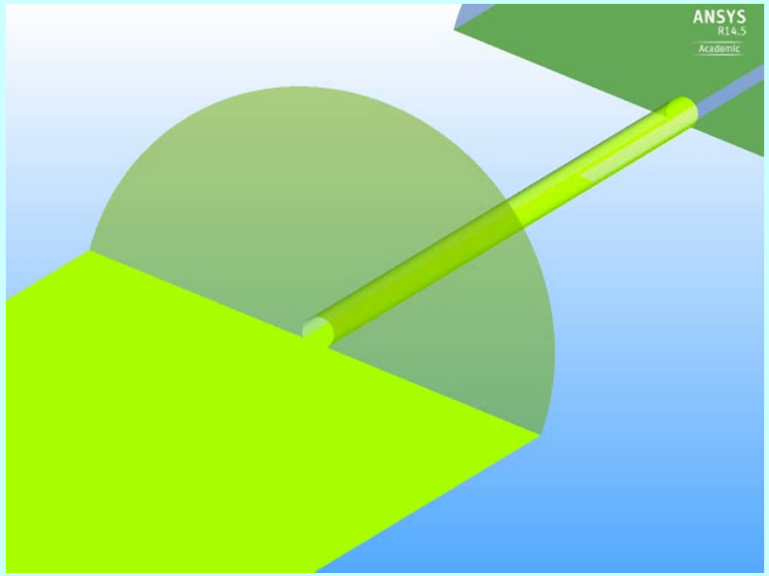
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# Recent projects

## 9- Pressure pulses on tunnels




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S Faramehr, H Hemida (2016) “Aerodynamics of Trains in tunnels” DOI: 10.13140/RG.2.1.3626.0244 2016-04-19 T 01:25:09 UTC




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# Recent projects

## 10- Slipstream of freight trains

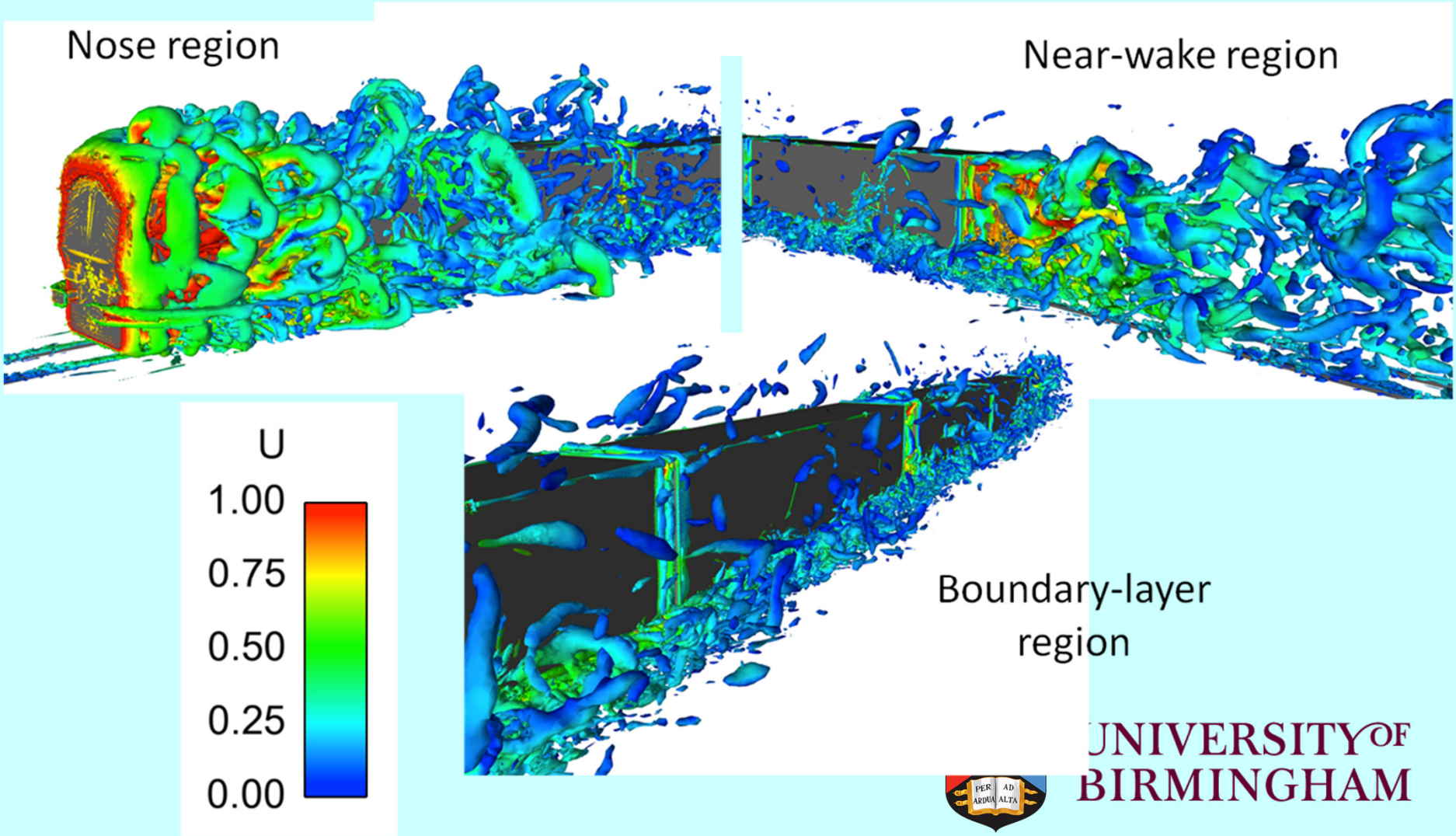
- When a train moves through the it generates a slipstream
- Slipstreams are winds that are pushed in front of, and pulled along and behind trains
- Slipstreams are felt by passengers on station platforms when trains pass through the station





# Recent projects

## 10- Slipstream of freight trains




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# Current projects

- 19- Track systems for High Speed Railways (2014-2016)
- 20- The safety of pedestrians, cyclists and motor vehicles in highly turbulent urban wind flows (2015-2017)
- 21- The Aerodynamics of Close Running Ground Vehicles (2016-2018)
- 22- Investigation of wind tunnel ground configurations on aerodynamic forces
- 23- Crosswind effects on urban trains

Total value around £2.1m




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# Track systems for High Speed Railways

- Joint project led by Southampton to understand the ballast flight issue using
  - Full scale experiments on HS1
  - TRAIN Rig tests with upside down train
  - LES Calculations of train underbody flow

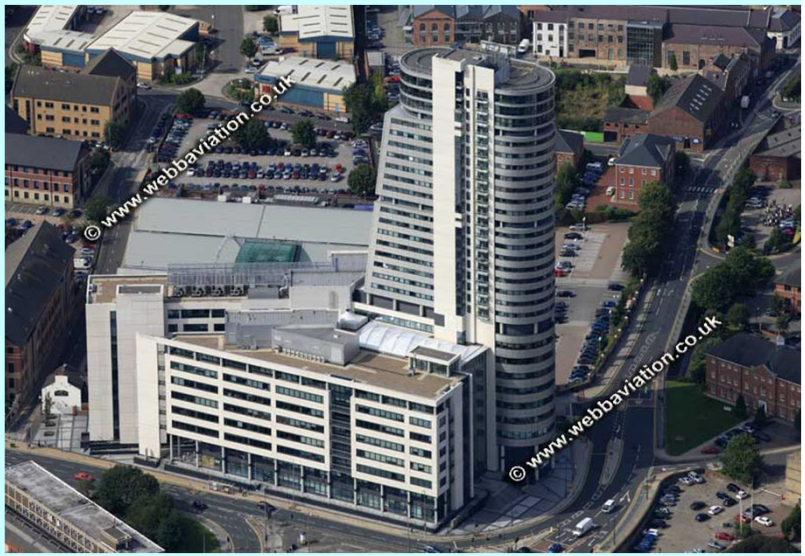


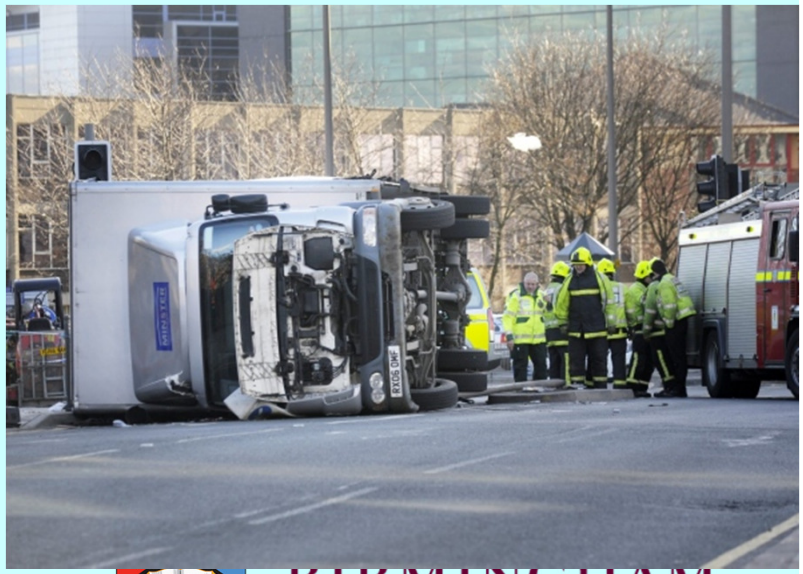


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# The safety of pedestrians, cyclists and motor vehicles in highly turbulent urban wind flows

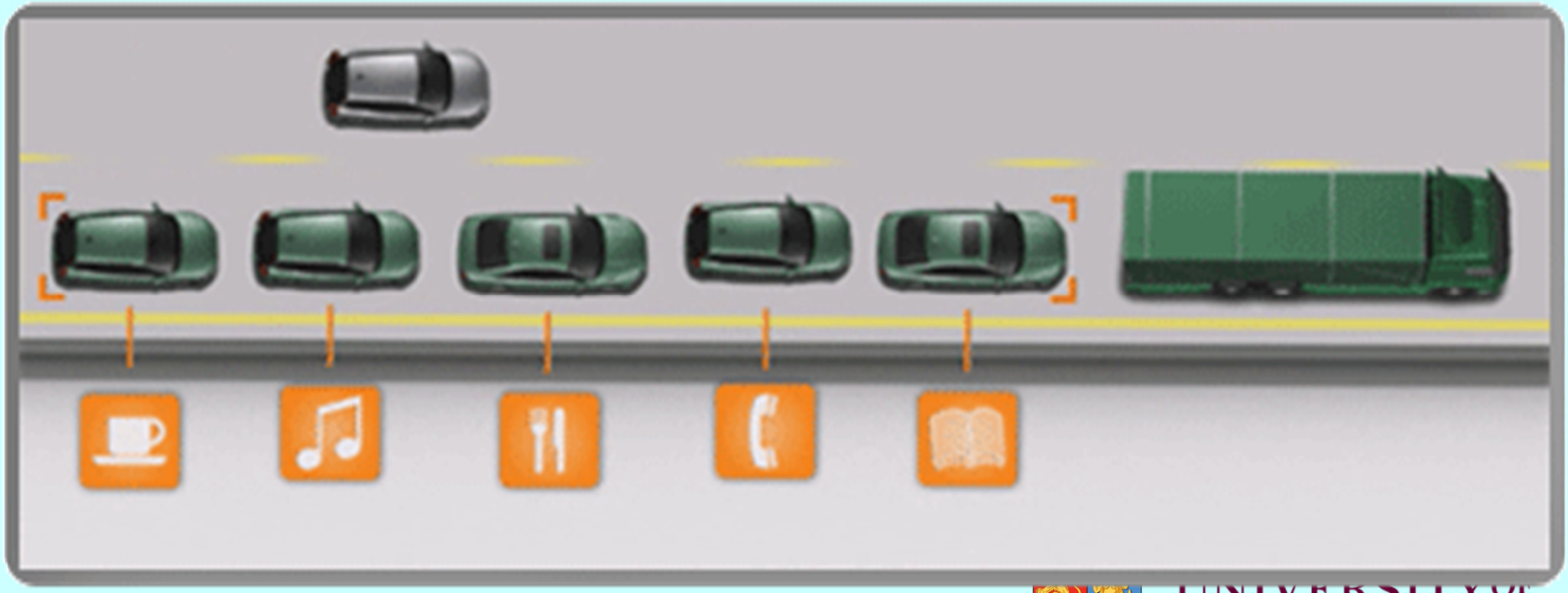
- Investigation of vehicle and pedestrian safety in high winds in urban areas using
  - Instrumented pedestrians and cyclists
  - Wind tunnel tests
  - LES CFD calculations
  - TRAIN Rig measurements in highly turbulent flows



# The Aerodynamics of Close Running Ground Vehicles

- Study of road vehicles running in platoon and close running rail vehicles using
  - TRAIN Rig measurements
  - RANS and DDES CFD

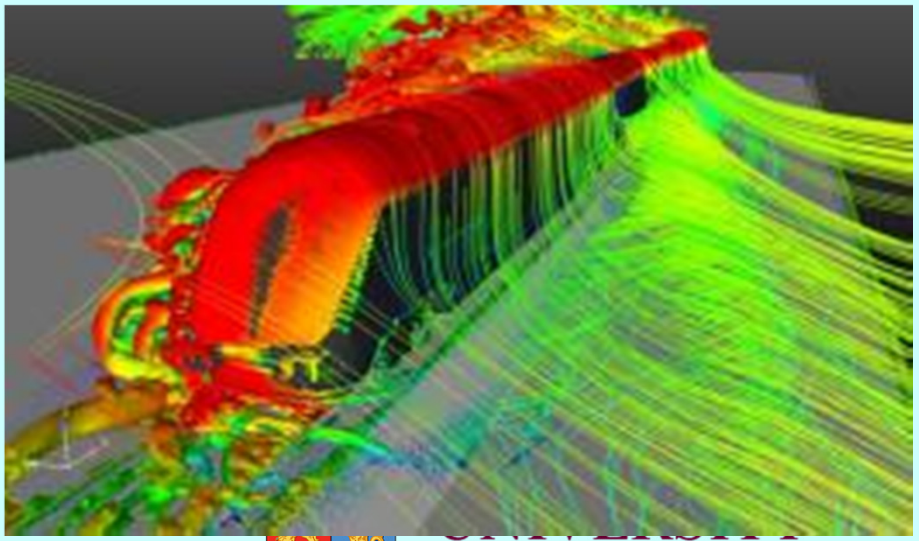


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# Investigation of wind tunnel ground configurations on aerodynamic forces

- The main aims of this research are to determine whether the ground configurations; flat, single ballast or double ballast track and the underbody shape of the train have a significant influence on the aerodynamic forces of trains.
- Analysis, CFD and Wind tunnel tests

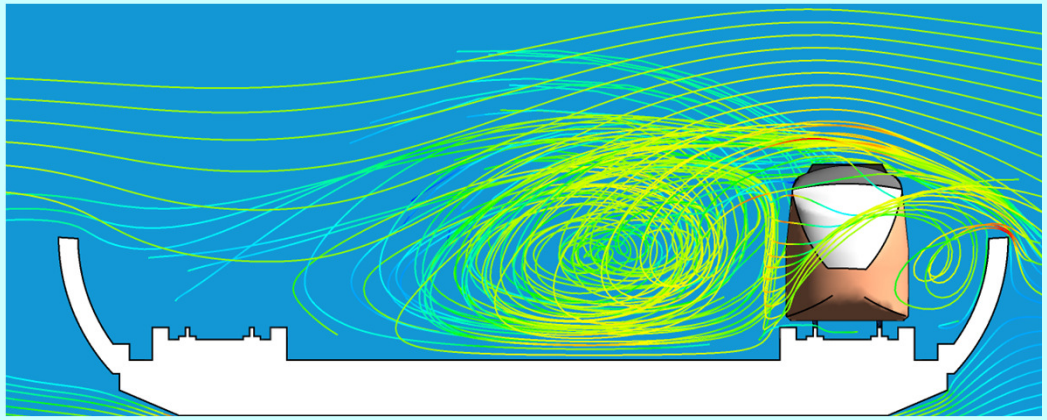


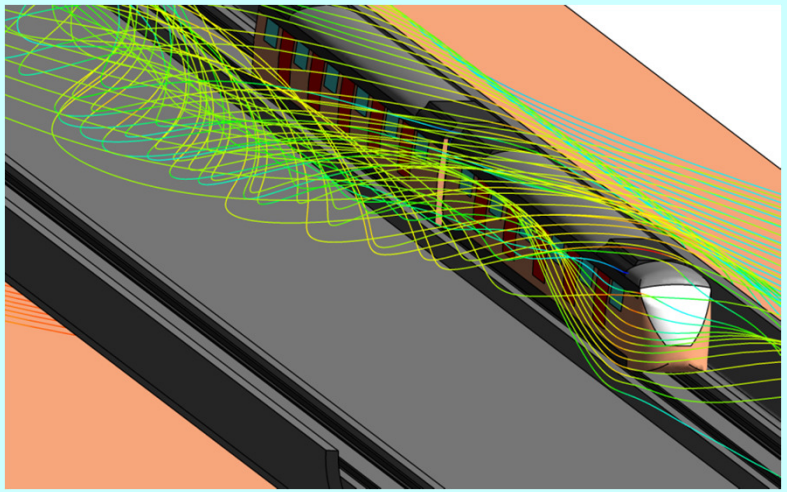


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# Crosswind effects on urban trains

- Trains running on urban environment are subjected to different wind characteristics than those running on open space. The aim is to determine the stability of trains subjected to urban atmospheric boundary layer.
- Methodology; CFD





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# Current interest

- Accurate estimation of high speed train lift force. (CFD, wind tunnel and moving train rig).
- Train running on flooded rail.
- Flow control
- Pressure transient in tunnels




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# Fun!

