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Transforming CFD in Industry through High Performance Computing and High Performance Collaboration

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Outline

1. Renuda at a glance
2. Illustrative projects
3. HPC, Tools, Users and Collaboration
4. Summary

1. Renuda at a glance

- **Blue Chip Clients**
  - Applications from single phase pipe flow to turbomachinery, multiphase flow, coupled heat transfer, mechanical calculations
  - Industries: transport, automotive, processing, nuclear, power generation, civil engineering

Research Partnership And Collaborations

- Research and development is very important
- Collaborative research relationship with EDF R&D on the development of *Code_Saturne*
- Collaborative development of the Khala™ steam turbine performance code:
  - Real gas, all flow regimes, very large industrial turbines – turnaround in a matter of hours
  - Research projects on code acceleration: SHAPE, etc.
  - Fully integrated GUI developed as an independent module in SALOME
- Part of the UK Consortium on Turbulent Reactive Flow
  - SiG on Sprays
  - SiG on Combustion
- NAFEMS CFD Working Group

Research Partnership And Collaborations

- Collaboration with different universities and research labs
  - University of Manchester
  - Daresbury Laboratory (Science and Technology Facilities Council) – HPC research and application
  - University of Edinburgh (software parallelisation)

Context

- My system/product does not work, can you tell me why?
  - I need to report tomorrow
- We know we have an issue – someone in my office or another department thinks we have an issue
- We don’t know how our system works
- We would like to improve our system – we would like to optimise our system

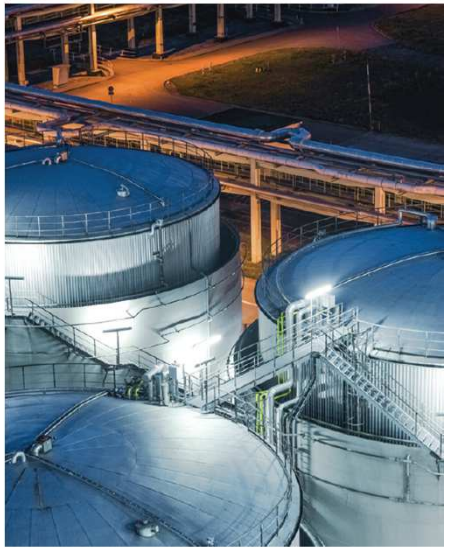
- We would like to design a new system for ourselves – we would like to design a new system for one of our customers - we would like to design a new system for a bid with new customers and a new area
- We need to verify that our system works as we think – we need to verify that our system satisfies certain criteria or norms – we need to verify that our system is safe

Context

- We need a new software capability
  - From scratch
  - Built on an existing proprietary one
  - As an extension of a non-proprietary code
- We need to accelerate our code
- For our modelling we need to extend or develop new capabilities

Examples of Queries

- Car park fires and ventilation tool
  - To assist in the selection and sales of systems
- Oil storage tank in Saudi-Arabia
  - Heaters to ensure minimum temperature
- New design of sail battens
  - Influence on air flow
- Glass manufacture
  - Gas heaters positioning and heat transfer in the pool
- Methane extraction from Lake Kivu between Rwanda and the Democratic Republic of Congo



2. Illustration through a Selection of Industrial Projects

Illustrative Projects

- Optimisation of resources
- Better designs
- Practical examples of CFD in industry

- Multiphase
  - Water treatment plant
  - Particle board manufacturing
  - Cooling tower modelling
- Rotating machinery
  - Francis turbine
  - Industrial mixing
- Reactive flow
  - Detonative device
  - Fires in enclosed spaces

Water Treatment plant

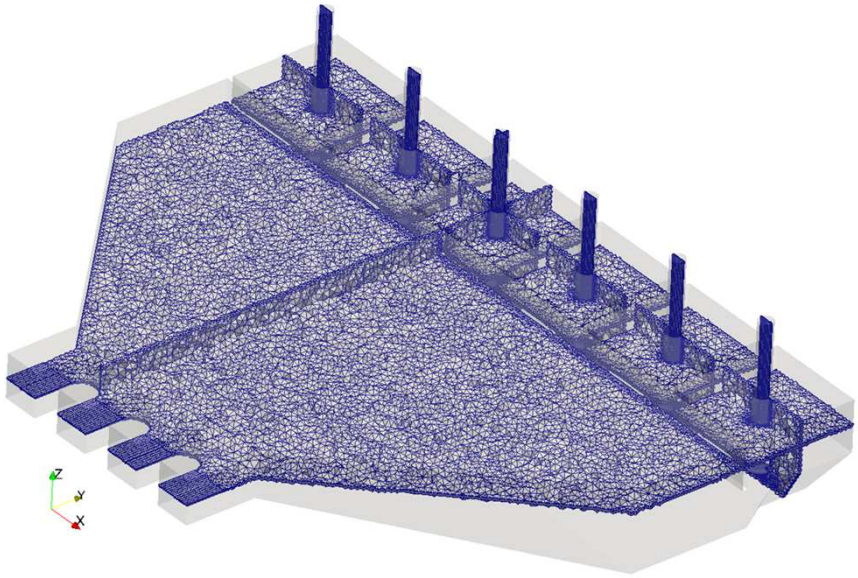
- Plant planned in Ivory Coast to supply drinking water
- Treat water from the river Mé to strengthen the supply of drinking water to the city of Abidjan

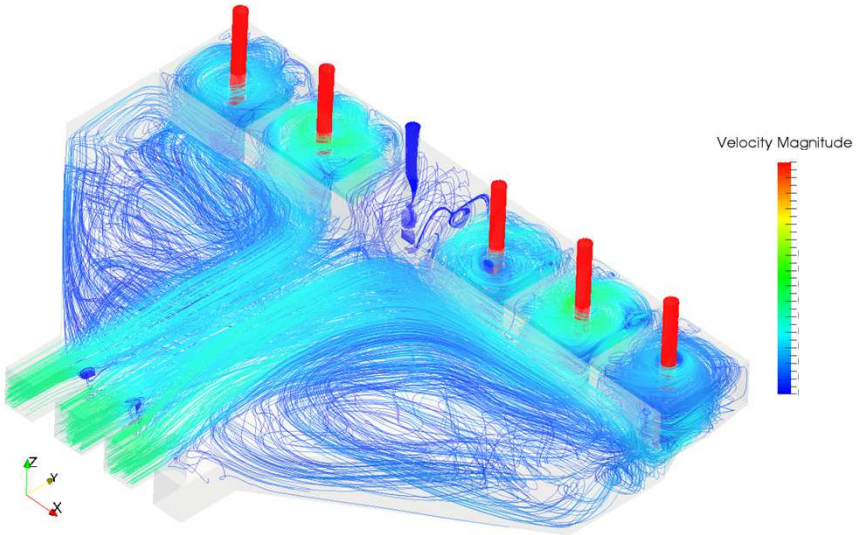
Challenge: Limit the amount of pre-rotation upstream of the pumps

Credit: BESIX Group
https://press.besix.com/besix-in-ivory-coast-civil-engineering-works-for-a-drinking-water-treatment-plant

Raw Water Collection

- Analysis of the design of the raw water collection station
- Series of calculations and analysis showing first large recirculations, then redesign, adding structures to distribute the flow more evenly

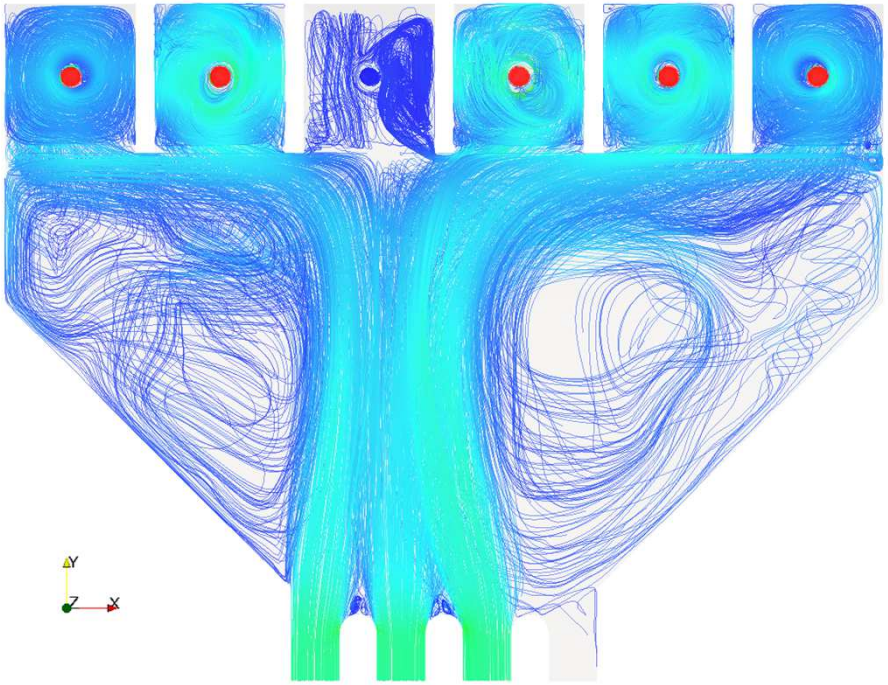




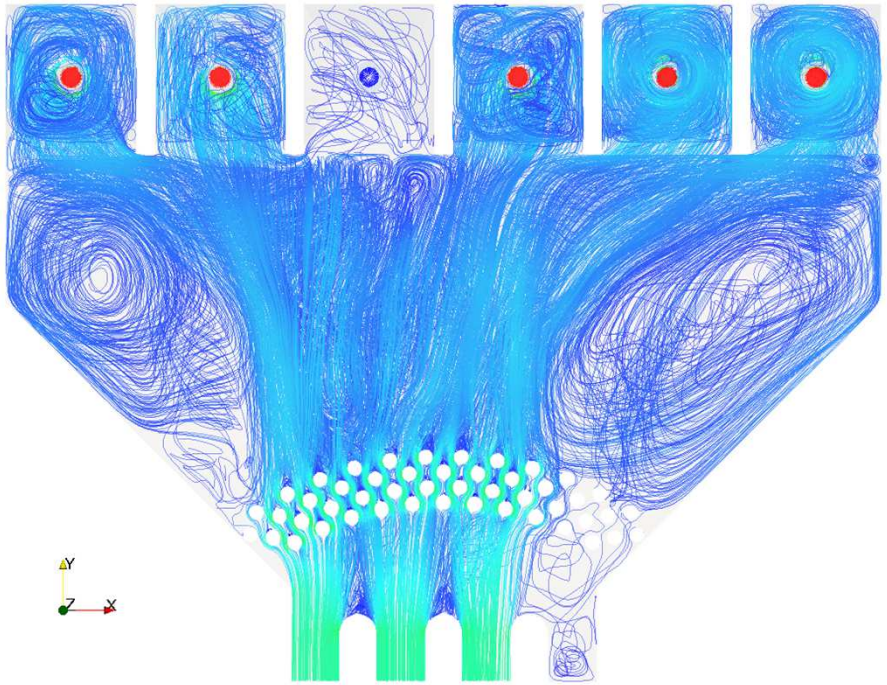
Comparison

- The columns contribute to diffusing the flow sideways and the pre-rotation in the pump chambers is significantly reduced

Initial design



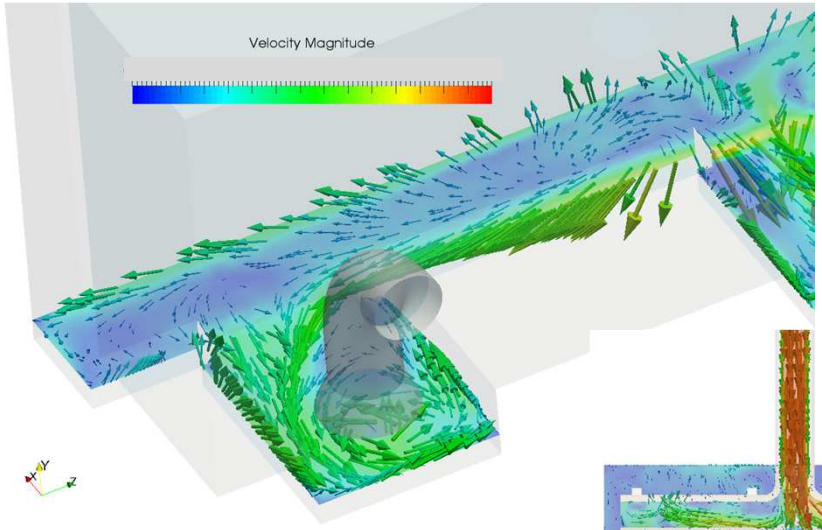
With the added columns



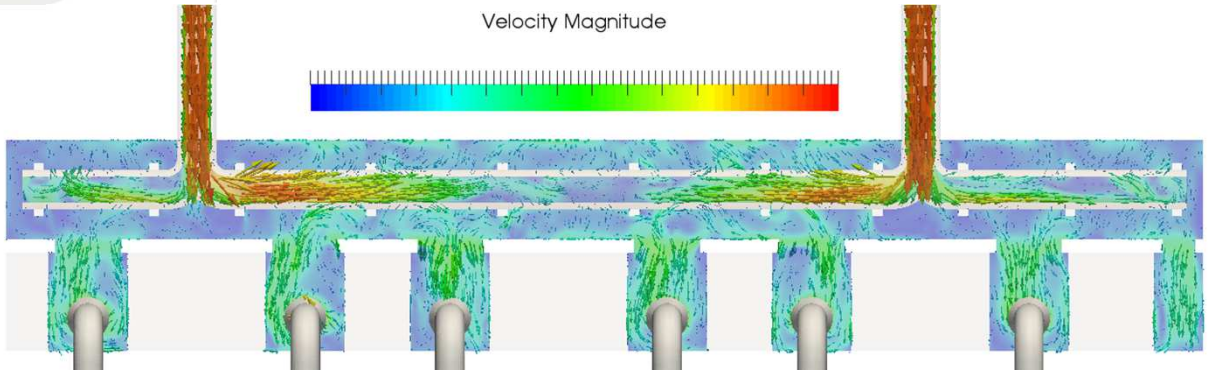
Treated Water Pumping Station

- Go through a series of designs to limit the vortices under the pumps

Initial design

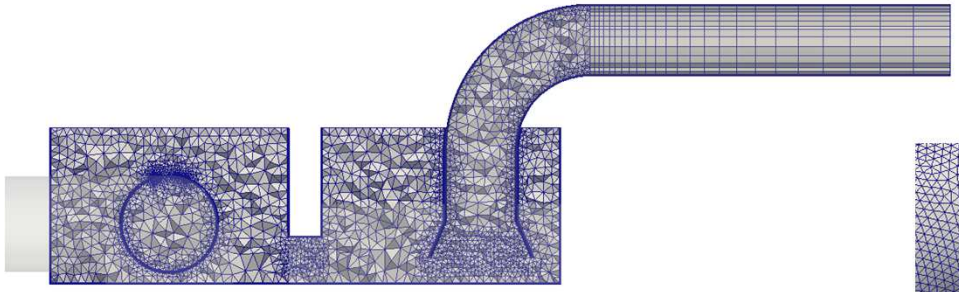


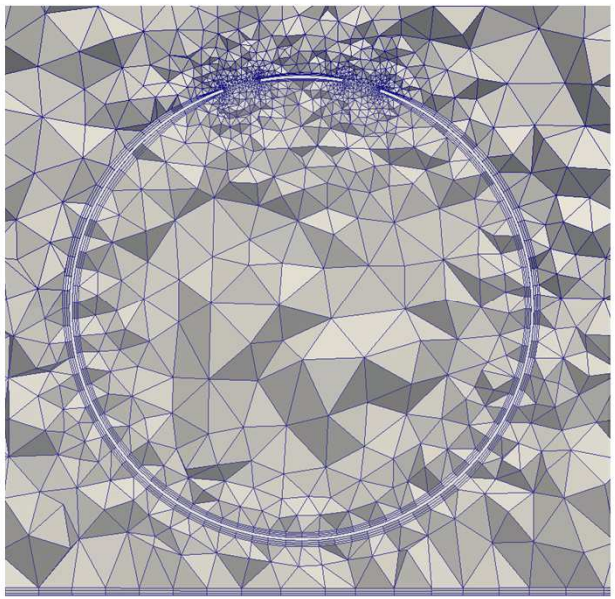
Third design

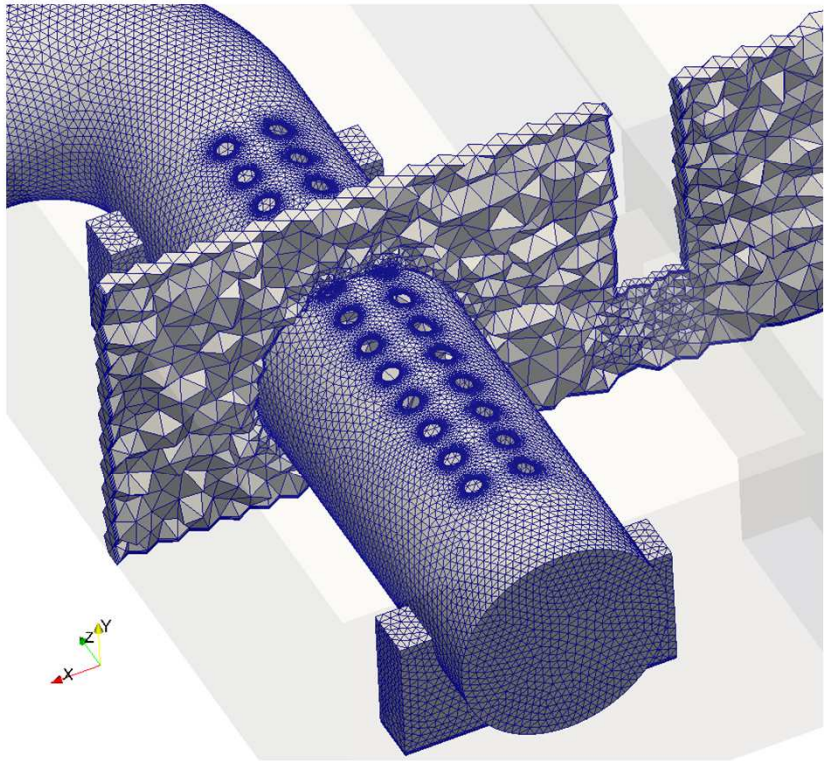


Treated Water Pumping Station

- Extrusion and wall layers all built in *Code_Saturne*





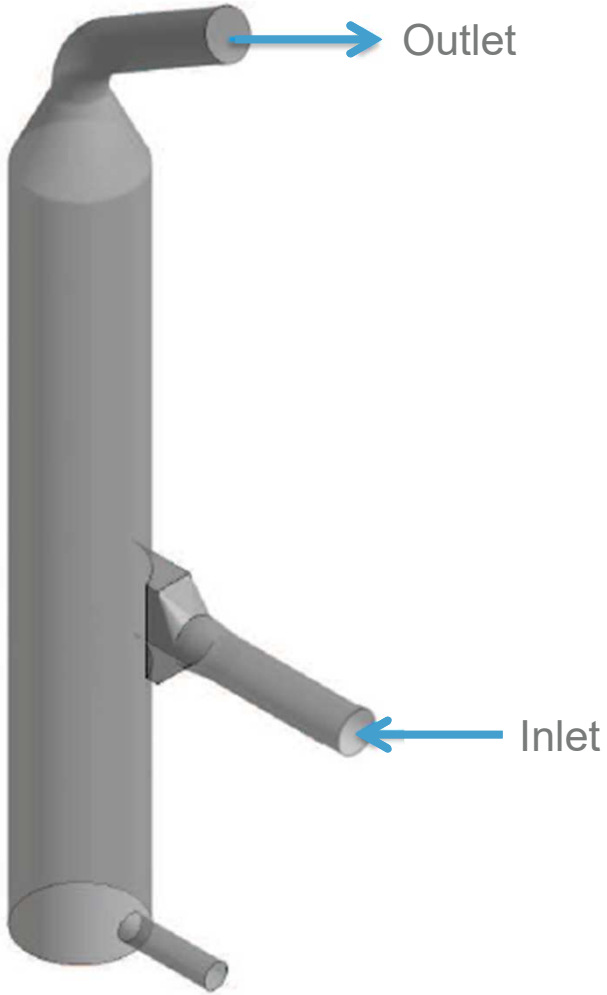


Wood Particles Removal

- Siempelkamp Group is a very large manufacturer:
  - Siempelkamp machine and plant engineering: wood-based panels, metal forming, composite and rubber
  - Siempelkamp foundry: castings
  - Siempelkamp NIS Ingenieurgesellschaft mbH: components and services for the Nuclear industry

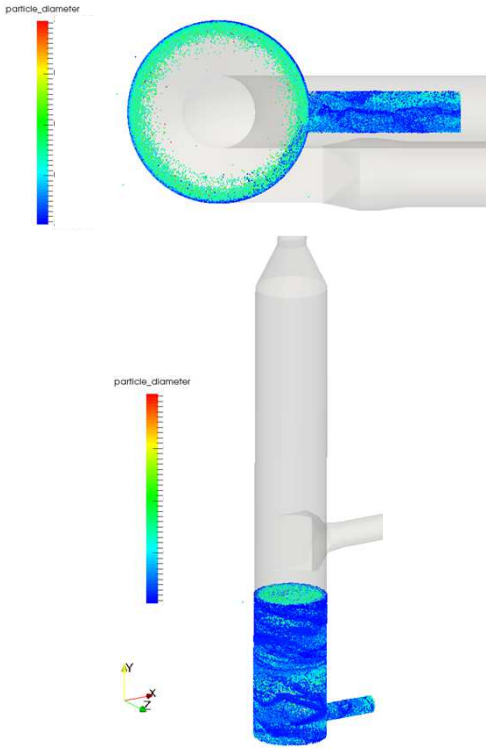
Scrubber

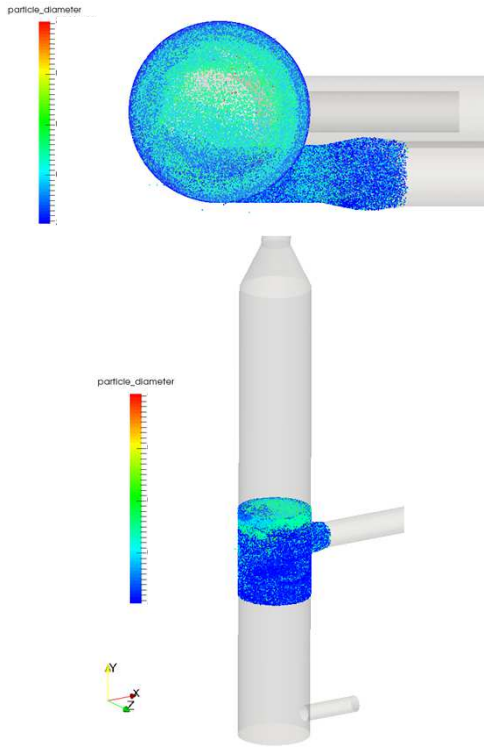
- Filtration system to clean the ventilation air
  - Extract the left-over wood particles
- CFD modelling to analyse the flow field and improve the system if required

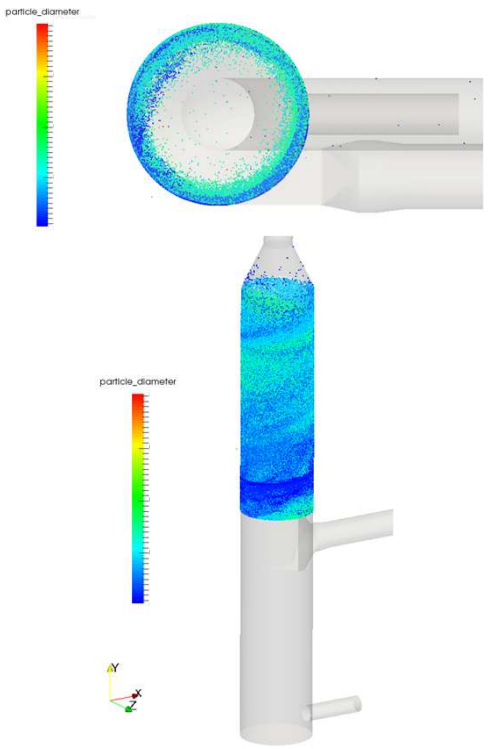


Lagrangian Two-Way Modelling

- Series of CFD calculations indicates a higher concentration of particles in the central part of the system
  - System augmented with downward water sprays

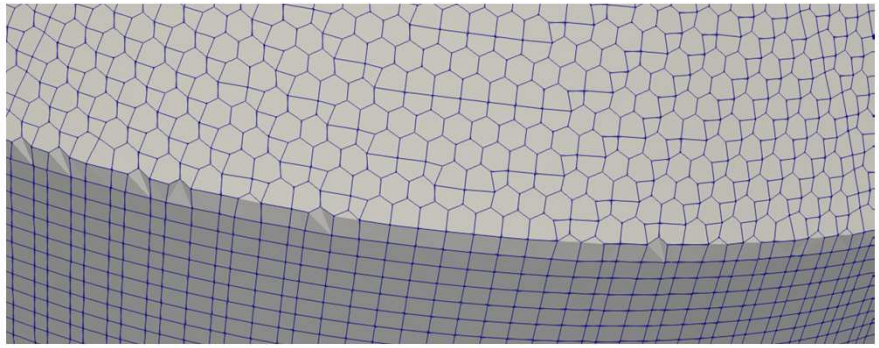


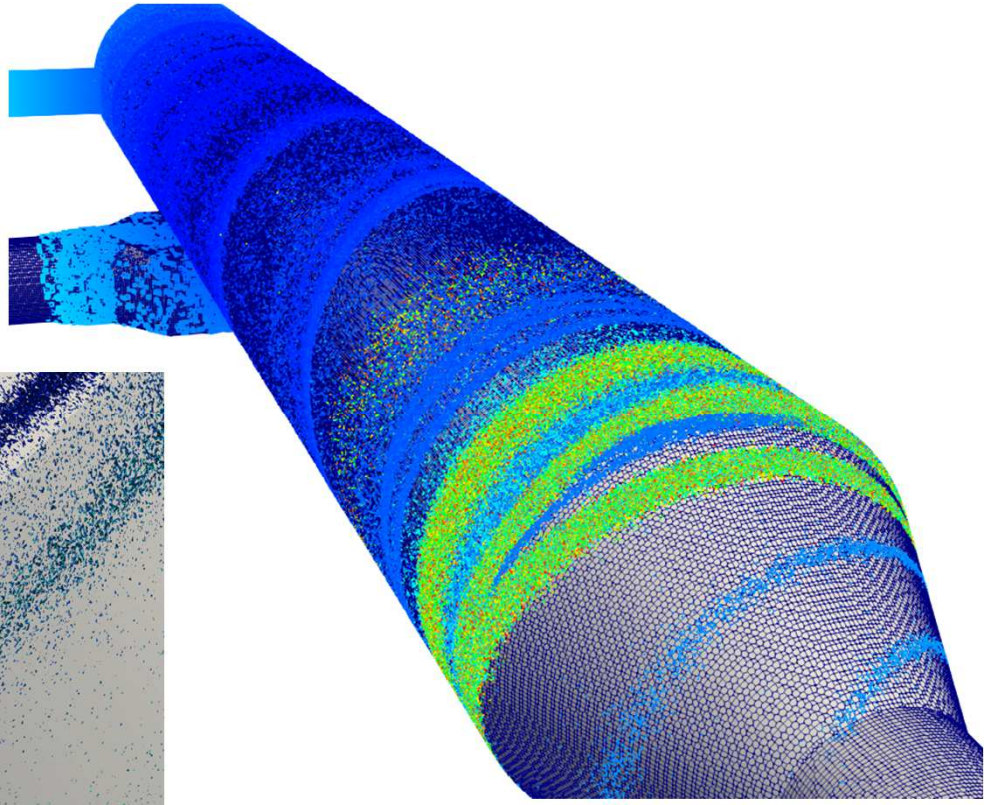


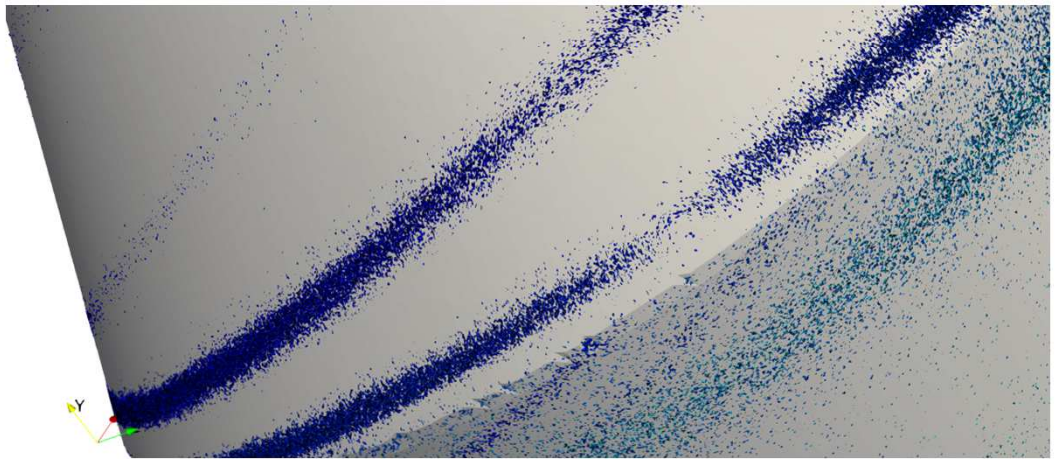


Wood Particles Removal

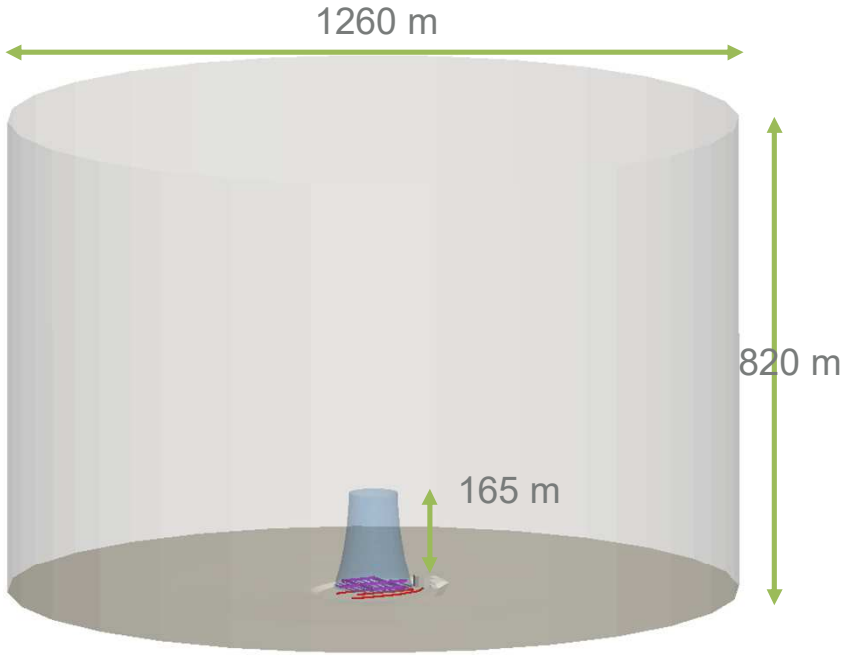
- Significant increase of robustness by the *Code_Saturne* team to tolerate particle interactions with deformed boundary faces

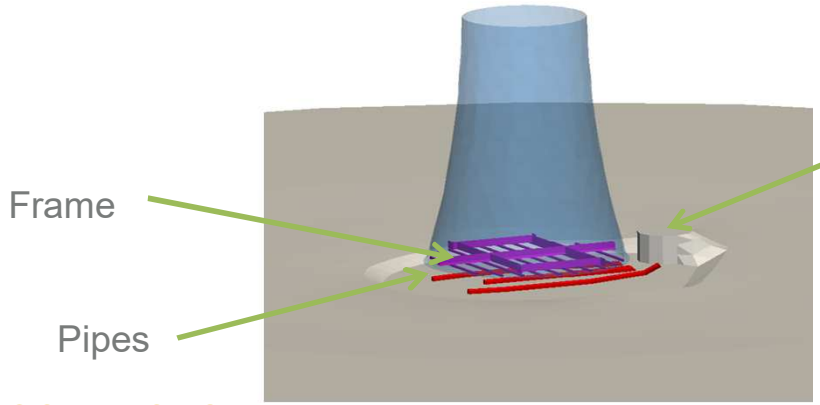






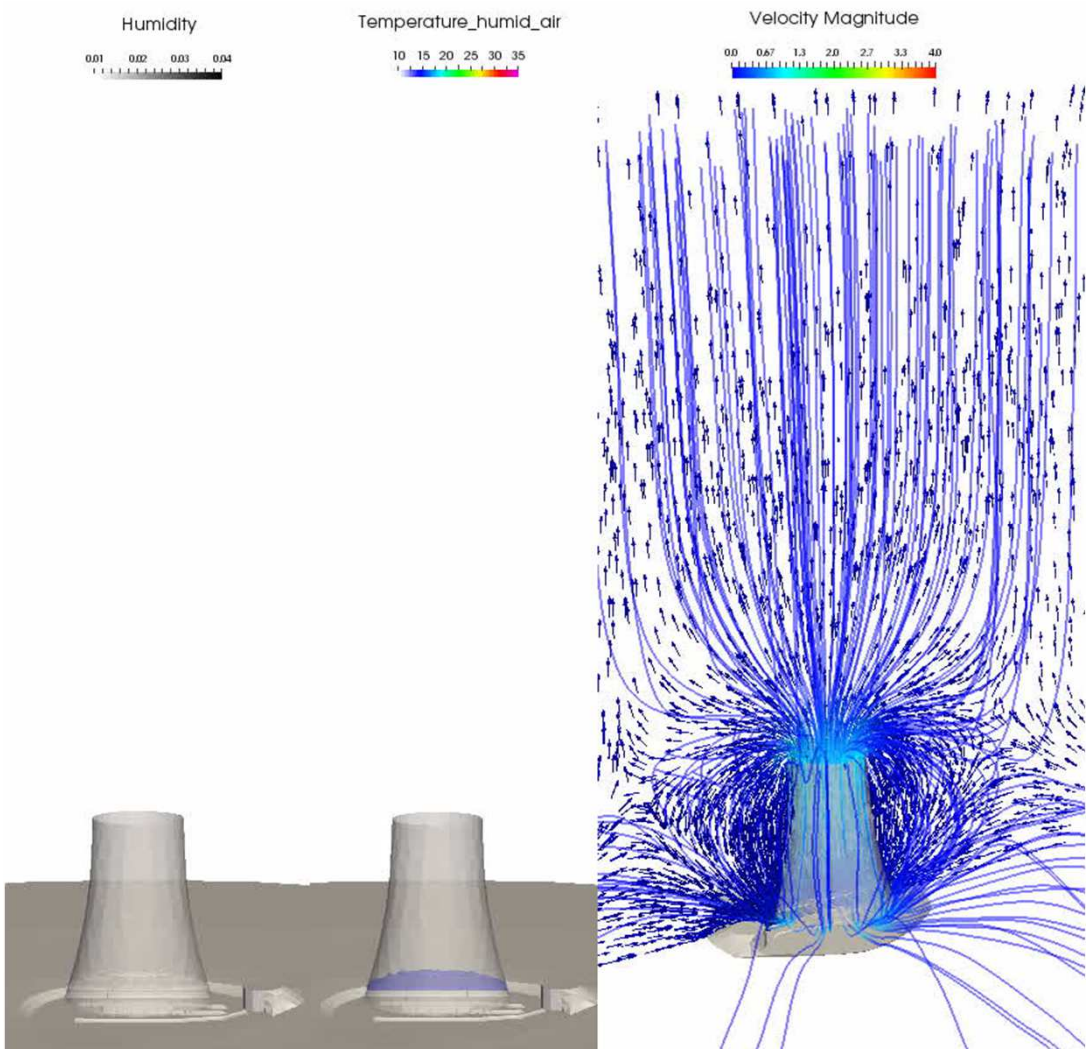
Golfech Nuclear Power Station





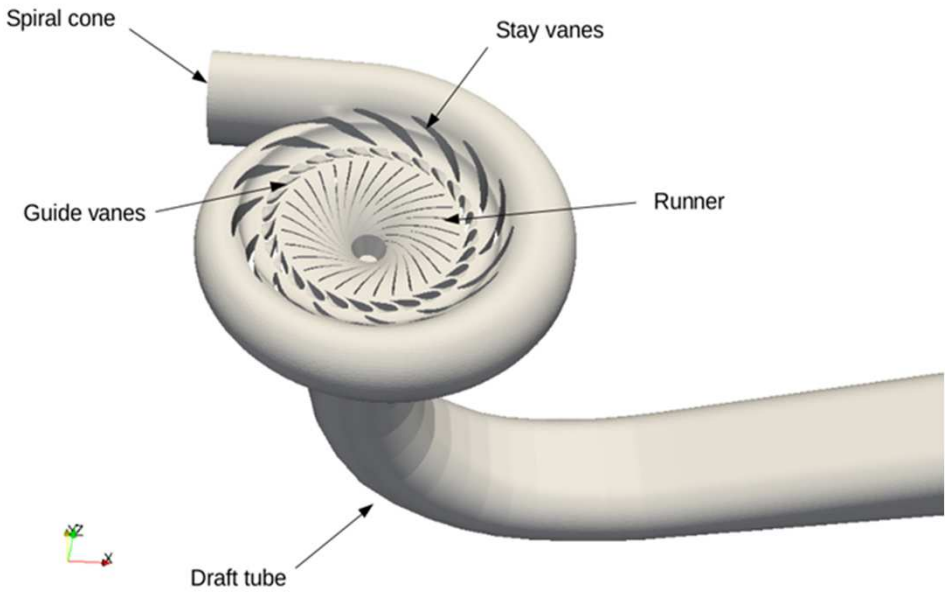
- Tower supports represented by pressure losses

Golfech Results



Tokke Francis 99 Second Workshop

- Tokke turbine
- https://www.ntnu.edu/nvks/second-workshop

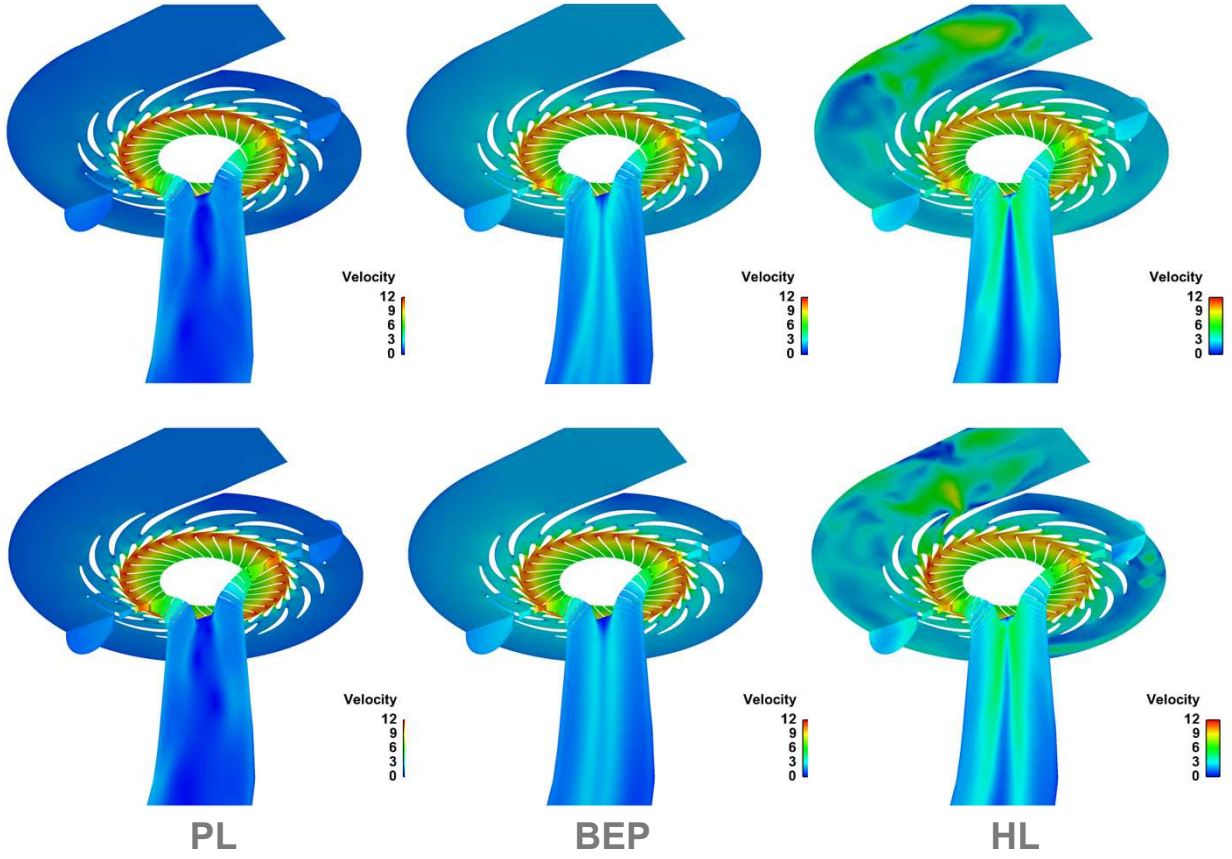


https://www.ntnu.edu/nvks/francis-99
Source-Chirag Trivedi 29 May 2012.

N Tonello, Y Eude, B de Laage de Meux, M Ferrand, *Frozen Rotor and Sliding Mesh Models Applied to the 3D Simulation of the Francis-99 Tokke Turbine with Code_Saturne*, IOP Conf. Series: Journal of Physics: Conf. Series 782 (2017) 012009

Steady Operation – Models Comparison

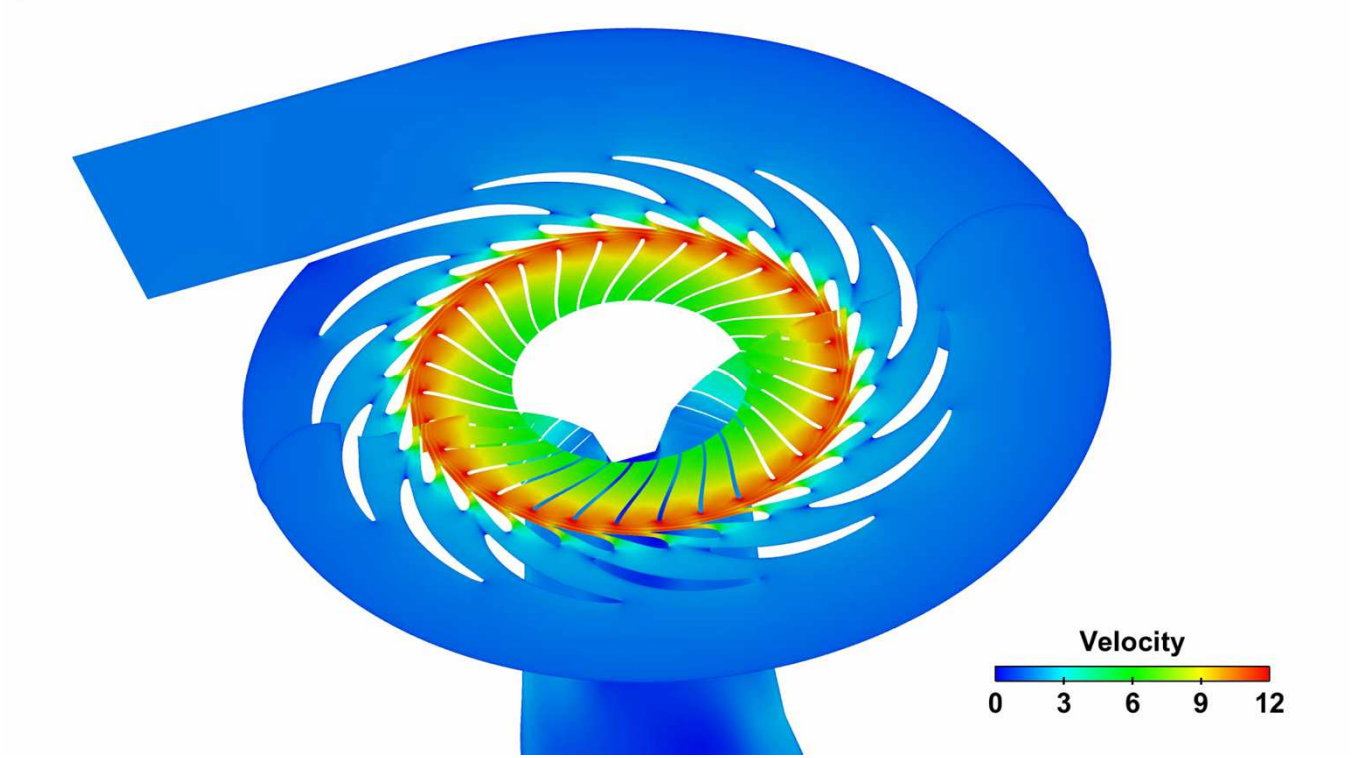
- Velocity fields comparison between the two models



Globally similar results but better resolved features in the draft tube for the sliding mesh calculations

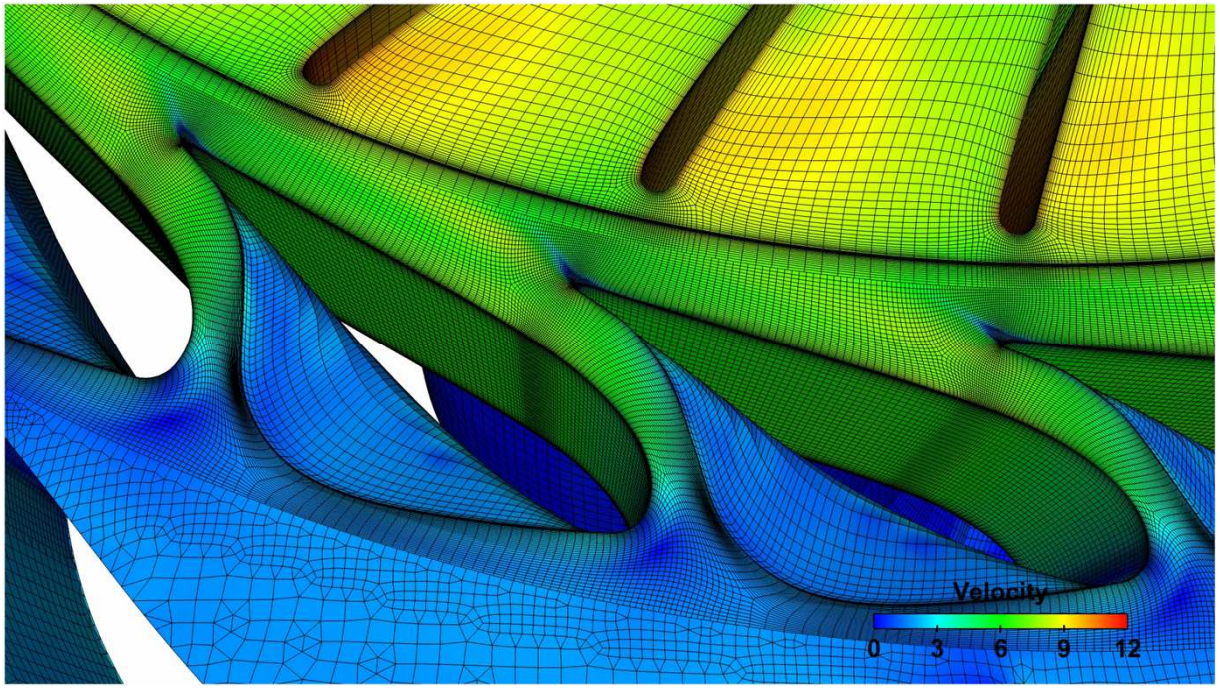
Steady Operation - Sliding Mesh

- Part Load, steady operation, sliding mesh model
- Simulation and visualisation by Benoit de Laage de Meux (EDF R&D)



Transient Operation

- Load reduction, BEP → PL, frozen rotor
- ALE algorithm to move mesh nodes to rotate the vanes
- Modelling and visualisation by EDF R&D



Combustion Challenges

- Combustion problems extend much beyond processes for power and propulsion
  - Explosions
  - Detonations
  - Fires
  - Pollution, climate change
- Industrial, commercial and public risk and safety, or sometimes it is the desired result
- A better, broader separation may be desired vs inadvertent or accidental combustion
- Two illustrative case studies:
  - Explosive device for avalanche protection
  - Fire in Nuclear Reactor Buildings

Active Avalanche Protection

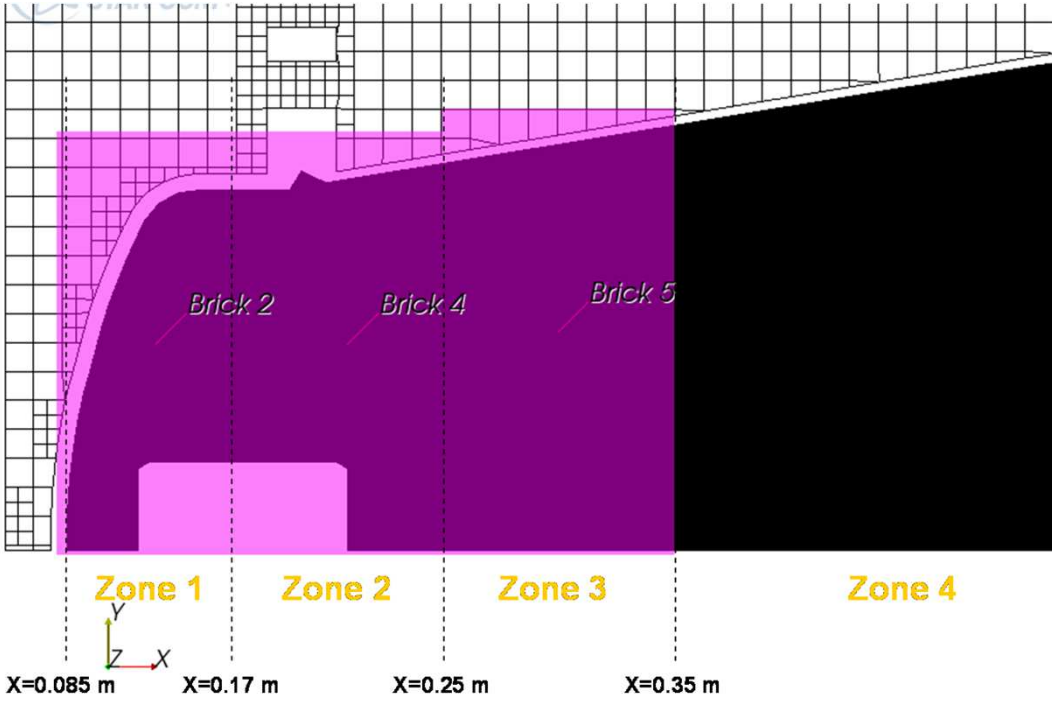
- Releasing small, controlled avalanches voluntarily to **avoid unpredictable, larger natural disasters.**
- Protection of roadways, tunnels, villages, and slopes in ski resorts.

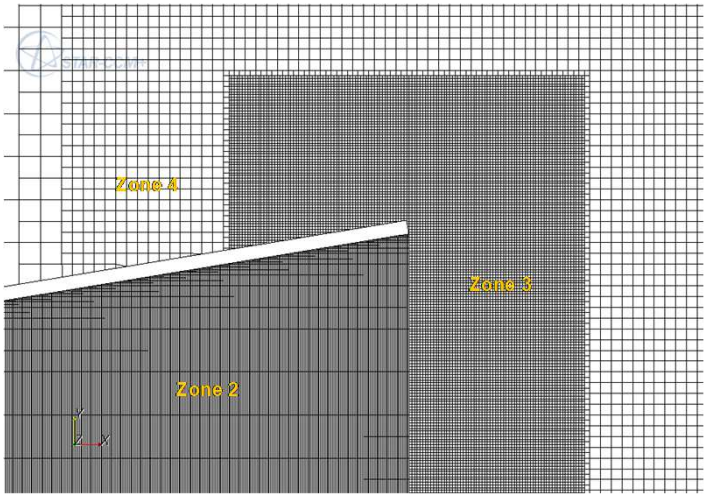
GAZEX: fixed, propane-oxygen

Daisy Bell®: mobile, hydrogen-oxygen

Approach

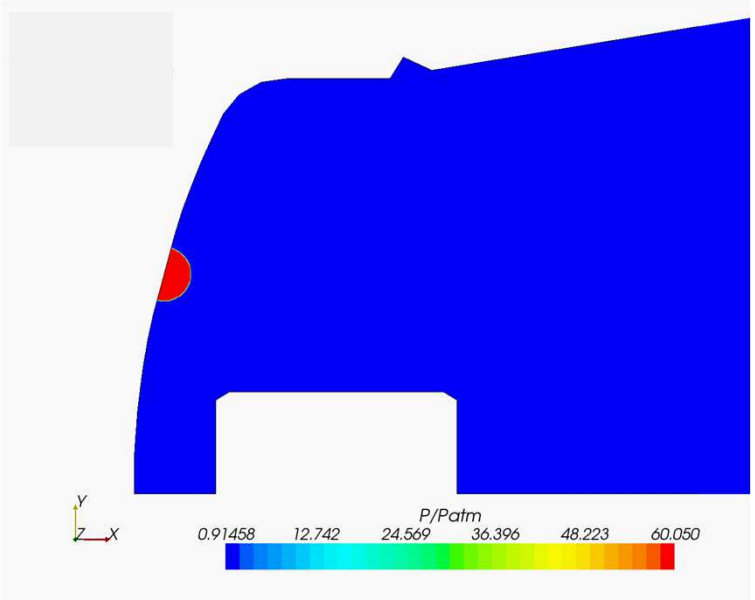
- Strong set of assumptions: well mixed, detonative regime
- PhD thesis model ‘shoe horned’ in commercial code
- Strong meshing limitations



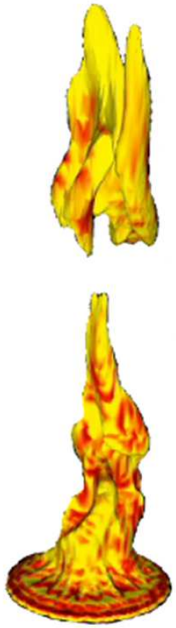


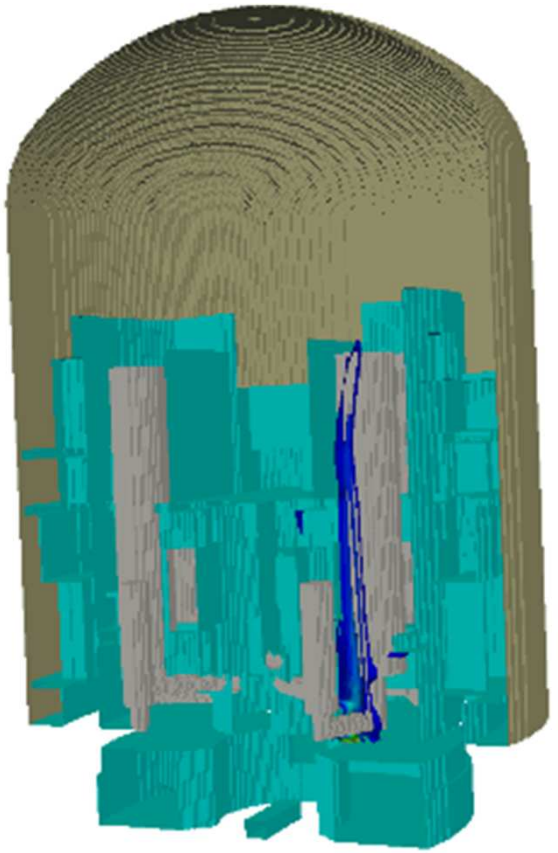
Daisy Bell Results

- Numerical modelling obtained significant results
- Limitations:
  - Ability to represent different spatial scales
  - Ability to apply to desired combustion model
- Unable to model unmixed and partially mixed combustion → Mixing efficiencies studies were realised later on cold flow only (still led to 30% fuel savings)
- Ignition, extinction, and transition phenomena were not studied



CFD Fire modelling at EDF





Fatiha Nmira
Abdenour Amokrane
Bertrand Sapa
Fire project

Martin Ferrand
Nicolas Tonello
Code_Saturne team

Inaugural UK Fire & Smoke Modelling Forum
London Fire Brigade

London, 03 November 2017

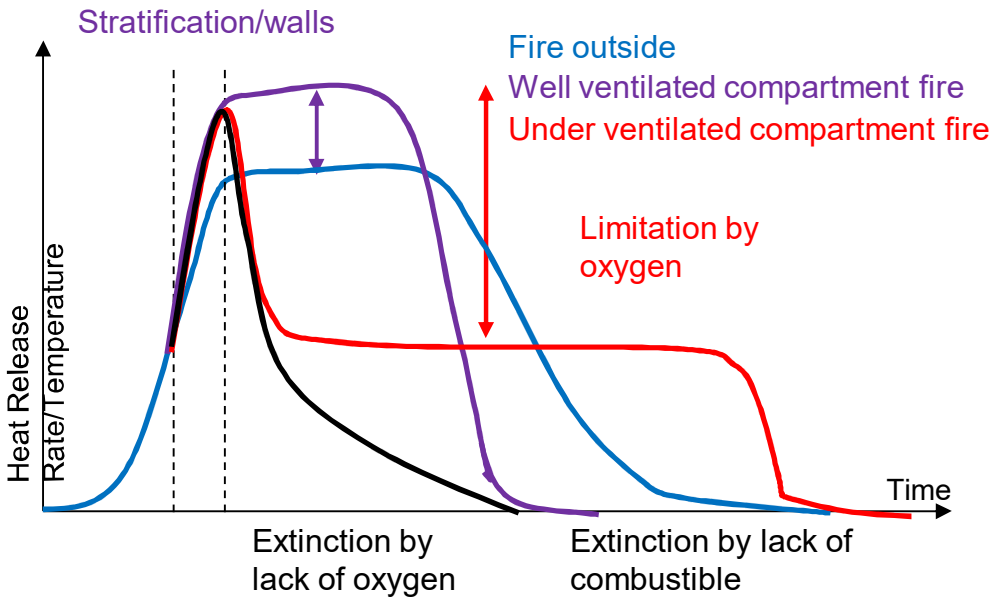
Fire risk at EDF

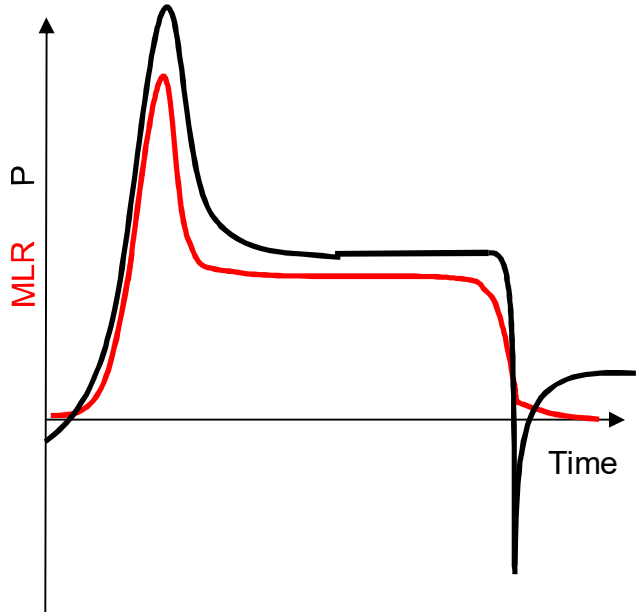
- Fire: internal hazard with the highest frequency
  - Risk of damaging important safety components
  - Risk of containment break and radioactive emissions outside

- **Combustibles**
  - Electric cables
  - Electric equipment (cabinets, …)
  - Oil (turbines, pumps, transformers)
  - Diesel (support generator)
  - Hydrogen (alternator)

- **Fire sources**
  - Electrical (short-circuit, overvoltage, arcing fault,…)
  - Mechanical (friction,…)
  - Thermal (spark, hot spot, welding, heating, …)
  - Chemical (solvents,…)

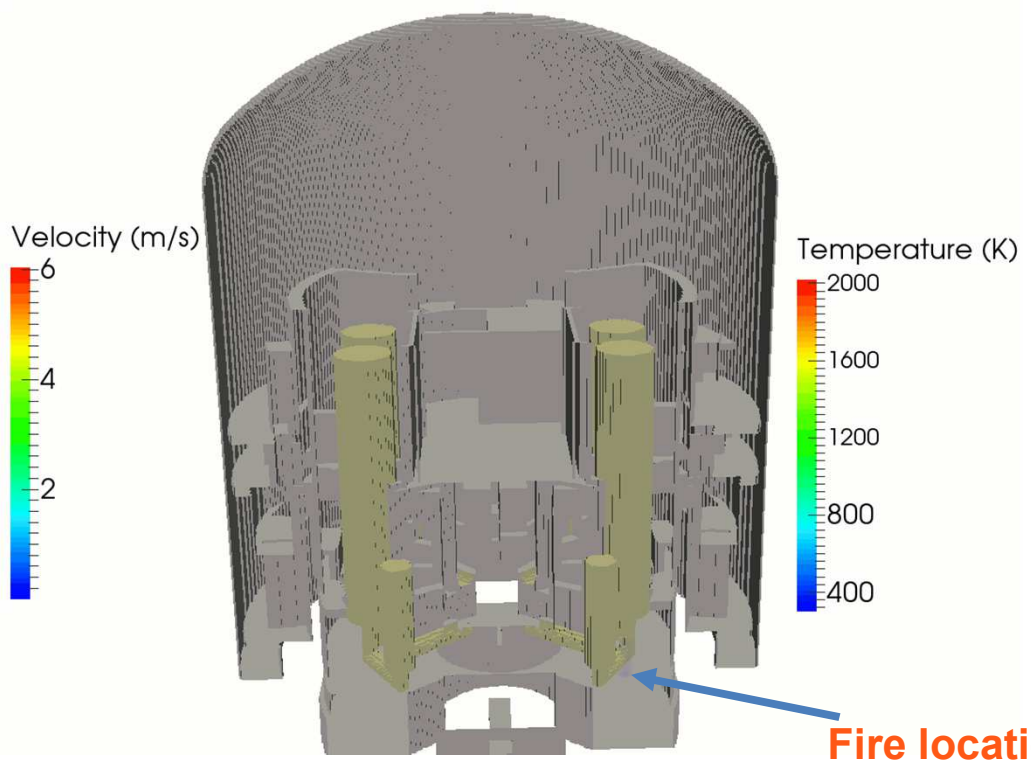
Physics of compartment fires

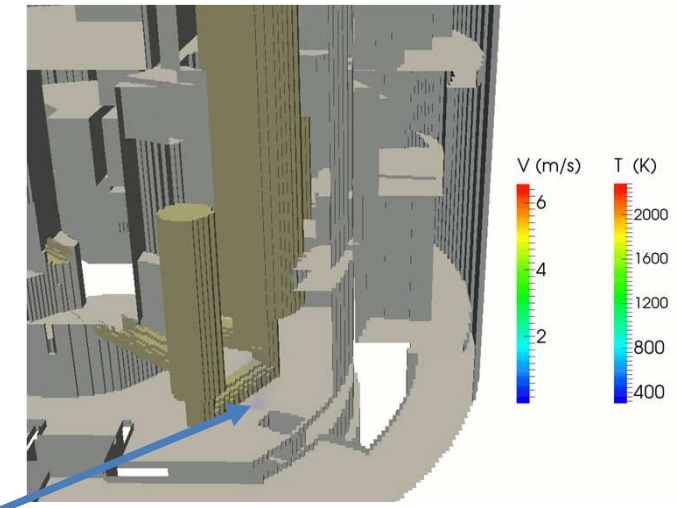




Example of Fire Studies

- GMPP fire modelling in the EPR BR
  - 50 L oil pool fire at GMPP at the bottom of the GMPP
  - 250 targets studied: cables, captors, electrical cabinets, valves, doors, …
  - 20 cm cells ➔ 10 M cells
  - 1 day of calculation on 392 cores





HPC and High Performance Tools Required!

- Multiphysics
  - Single and multiphase flow
  - Phase change
  - Reactive flow
  - Coupled CHT
- Moving systems
- Large systems and a variety of scales within the
  - Flow
  - Chemistry
- Unsteady flows with long time durations
- Other effects – MHD, etc.

All require HPC → Move towards higher end and large computational means – Variety and speed remain very challenging, stronger R&D – Industry collaboration is required

HPC + Tools + Skills

3. HPC, Tools, Users and Collaboration

Grand Challenges

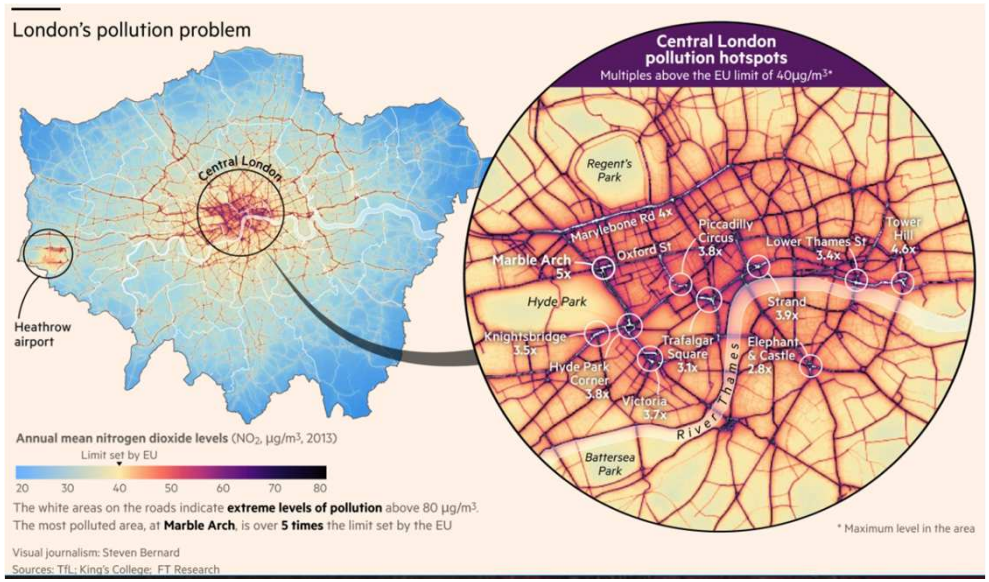
- Environment
- Fires
- Physics and speed

Source: Evening Standard
https://www.standard.co.uk/news/london/revealed-the-dossier-of-deadly-failures-at-grenfell-tower-a3814871.html

London

Ella Kissi-Debrah: new inquest granted into 'air pollution' death

Nine-year-old from London died after asthma attack possibly linked to pollution

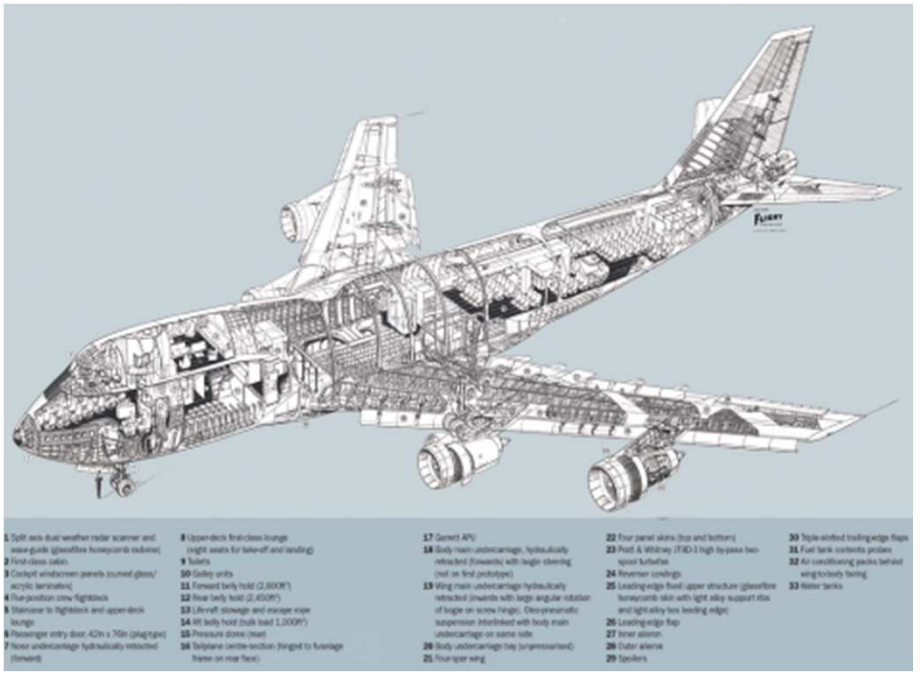


Source: Financial Times
https://www.ft.com/content/9c2b9d92-a45b-11e8-8ecf-a7ae1beff35b

Not all about Engineering!

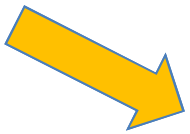
- As a thought provoking example: consumer good manufacturers now face product complexity similar to traditional manufacturers.

One line of products may involve as much as several thousand specs across all Categories with 25% of these changing per annum



One product: 4.5 million parts, 75 thousand drawings

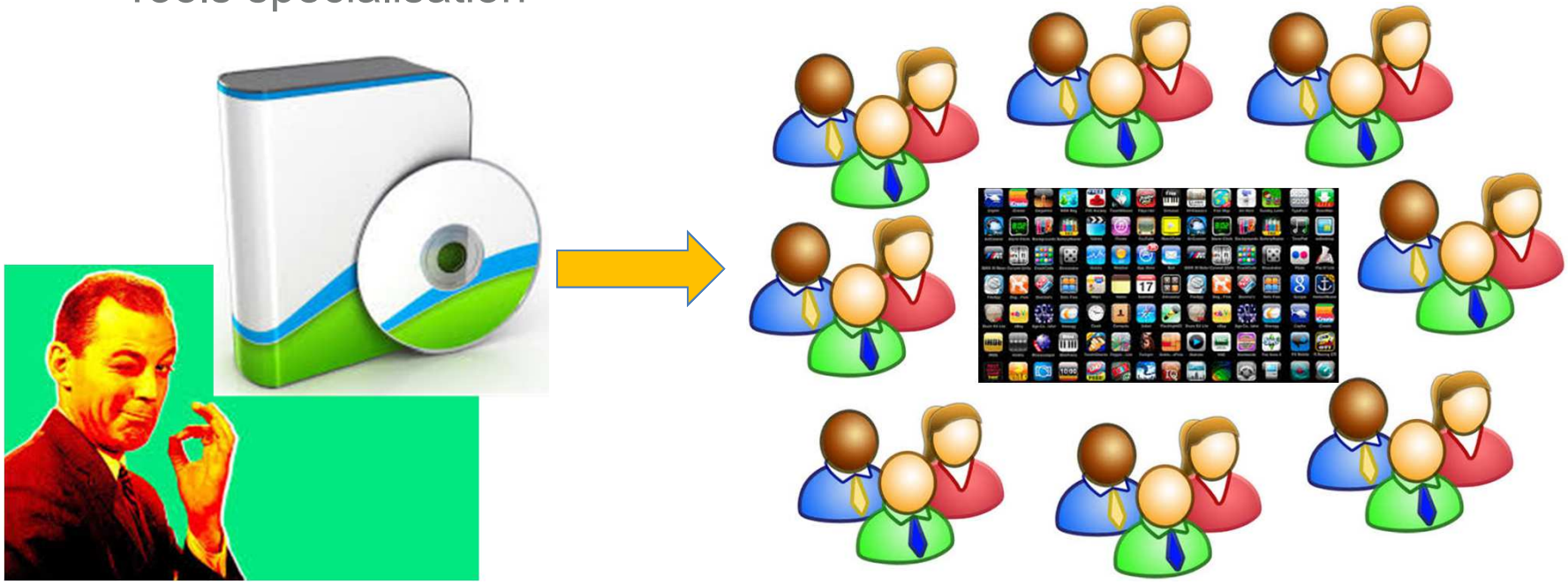
Digitalisation



- Digitalisation to deal with complexity and increase speed, in the entire process

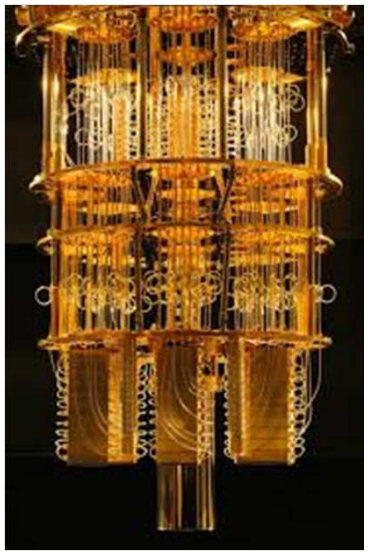
Usability and Collaboration Required!

- Downwards penetration of HPC and digital tools
  - Democratisation of HPC
- Spread of digital tools leads to a widening of the users base
- Tools specialisation



Future Directions

- Optimisation
- Big Data
- Data Analytics
- Machine Learning
- Edge to Centre Computing
- New machines architectures, Exascale, etc.
- Distributed computing



Features

- Move towards the higher end of computing
- Wider utilisation of software tools at all levels
- Complexification of tasks, variety of tools and skills

Copyright thinglink

- Very strong need for knowledge sharing and two-way transfer
  - R&D and Industry
  - Within Industry
  - Between Industries

Archer

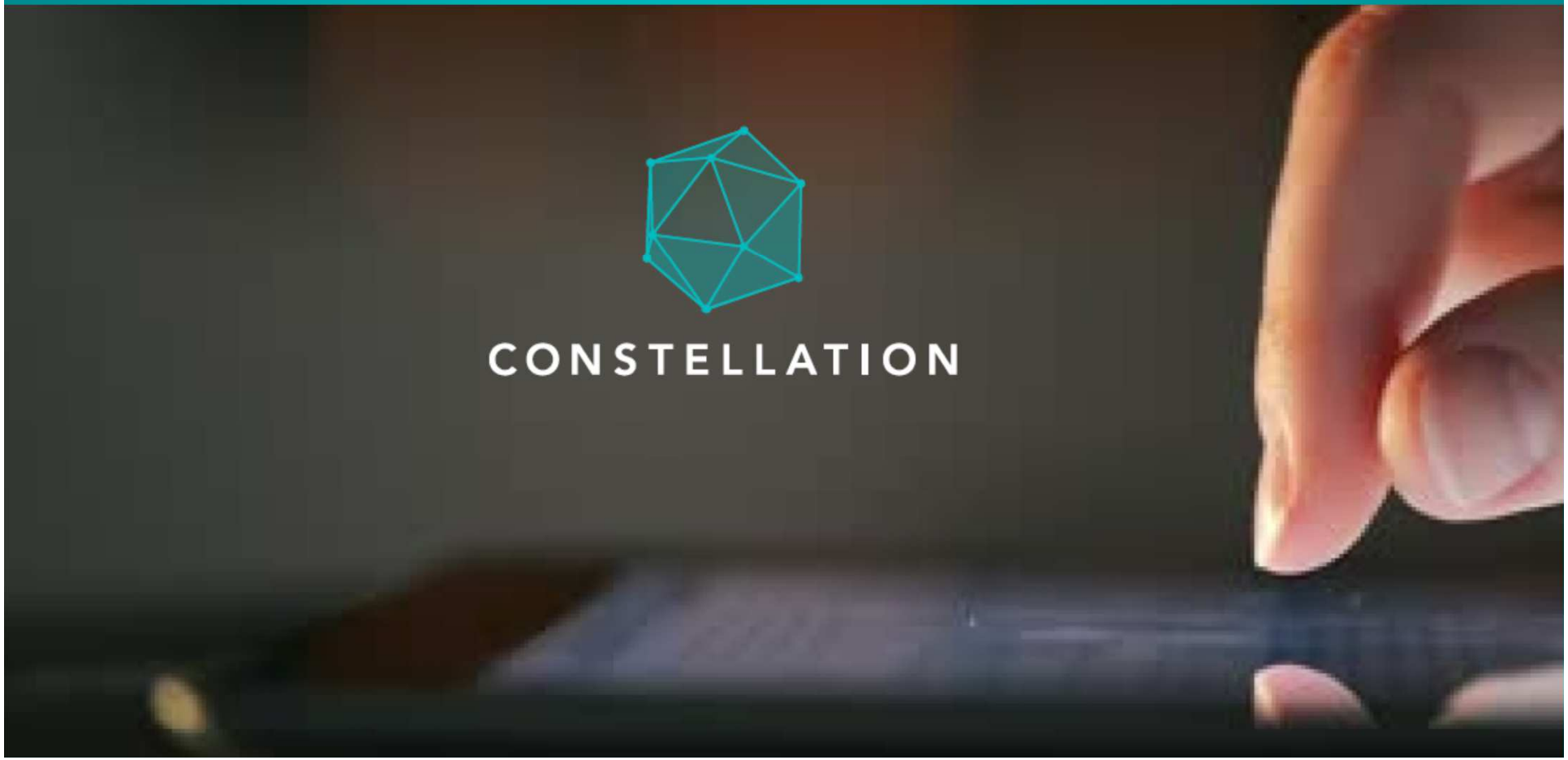
Shared tools, machines, platforms, collaboration

UK CTRF UK CONSORTIUM ON TURBULENT REACTING FLOWS

INDUSTRY

CONSTELCOM

HPC for All



About Constelcom

- HPC Open Access for All to deliver more science, innovation and discovery

“Anywhere, any time, self-managed, easy to use supercomputing at your finger tips“

CONSTEL COM

What is Constellation™?

- Web accessible HPC ecosystem for HPC users to
  - Manage and access resources: software, hardware, files, people
  - Run simulations, application agnostic
  - Share
  - Report and review
- All within the same private and self-managed environment
- Constellation™ removes barriers to access HPC and utilisation, simplifies, clarifies, speeds up and empowers users, freeing them to innovate, analyse and discover

CONSTEL COM

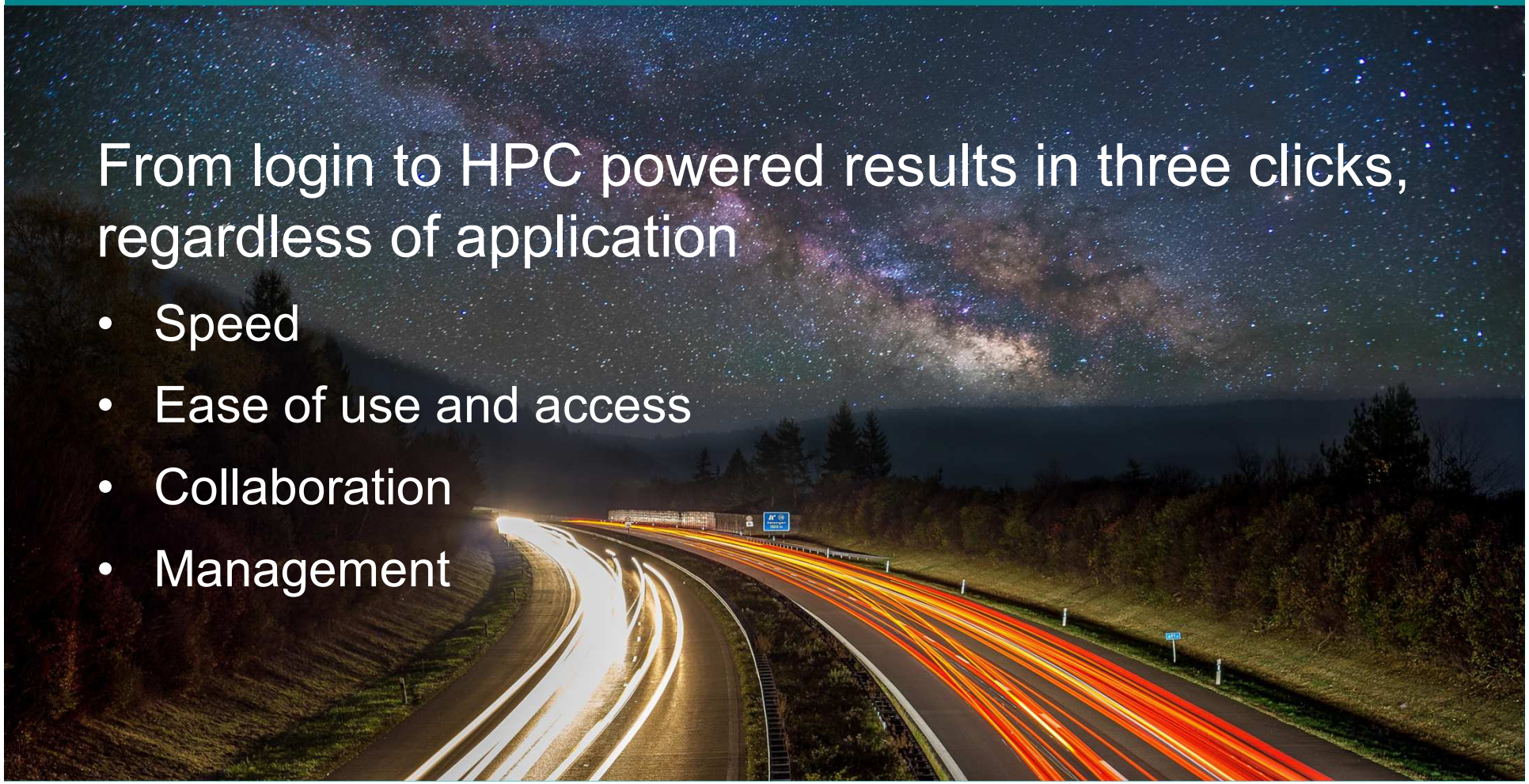
Harness Open Access HPC

CONSTELLATION

- End users access collaborative and unlimited HPC capability
- Secure and safe firewall
- On-premises computing, back-up and storage

CONSTELCOM

Constellation™



From login to HPC powered results in three clicks, regardless of application

- Speed
- Ease of use and access
- Collaboration
- Management

CONSTEL COM

Summary

- Within CFD and outside CFD, the trends show
  - Higher end simulations
  - Wider utilisation
  - Requirement for a variety of tools, from research to Apps
  - Requirement for data sharing
  - Requirement for a wide range of skills
  - Requirement for tools to be available to non-experts

- To address the requirements
  - HPC is necessary, the demand on performance will only be increasing
  - Sharing of codes, data, practices
  - Collaboration and communication between different experts and from edge to centre, promotion of live feedback between research and industry