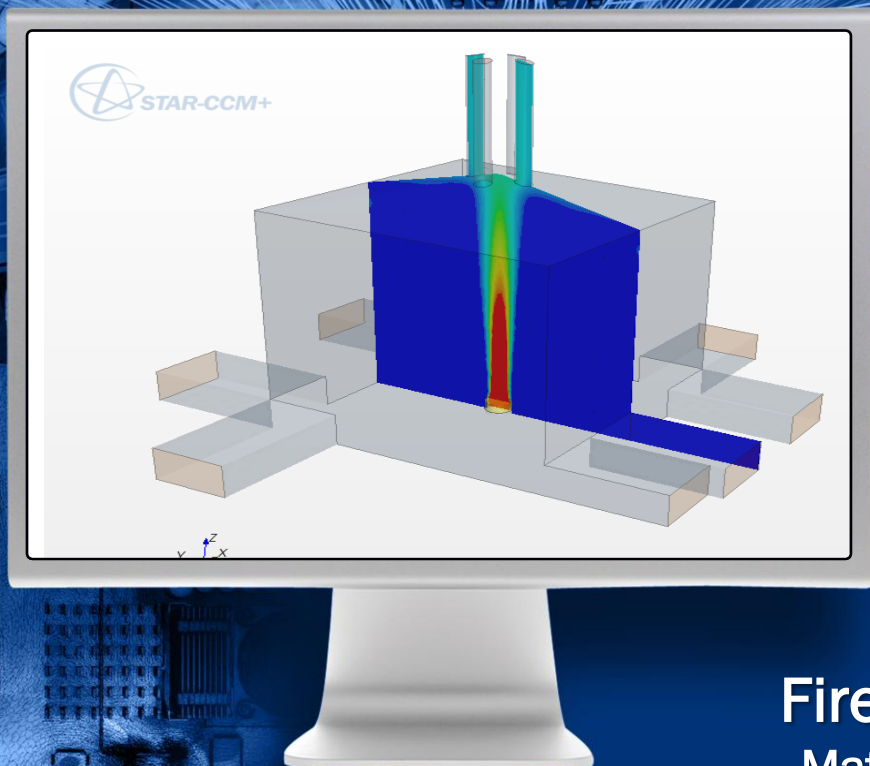

Fire and Smoke Modelling

Matthieu Stasia, Fred Mendonça

24th June 2014

CD-adapco

Contents

- Overview
- Fire and Smoke Wizard
- Model settings for the Murcia Atrium Benchmark
- Sensitivity analysis on Murcia Atrium benchmark
  - Mesh sensitivities (coarse, medium, fine meshes)
  - Turbulence model sensitivities (uRANS, LES)
  - Sensitivity to heat transfer mechanisms (Radiation)
- Enhancing capabilities
  - Spray Cooling Simulations
  - Combustion Modelling
- Summary and outlook

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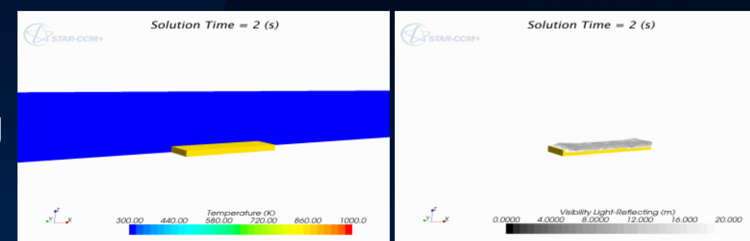
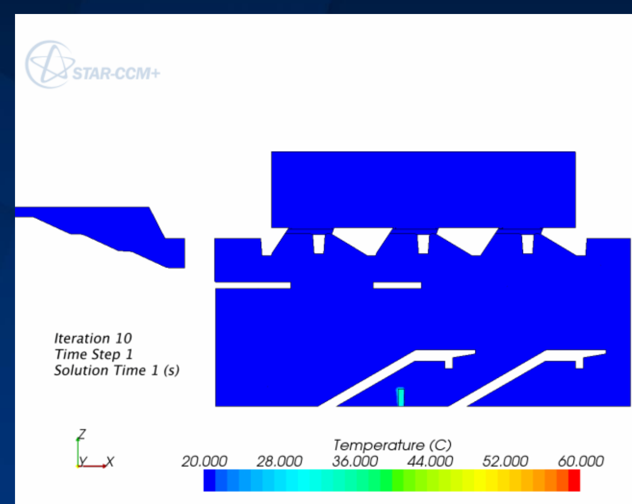
Overview

- **Applications to :**
  - <u>Building environment</u>
    - Example shown in today's demonstration
  - <u>Tunnels</u>
    - Ventilation and smoke back-layering



  - <u>Transportation</u>
    - Stations
    - Carriages



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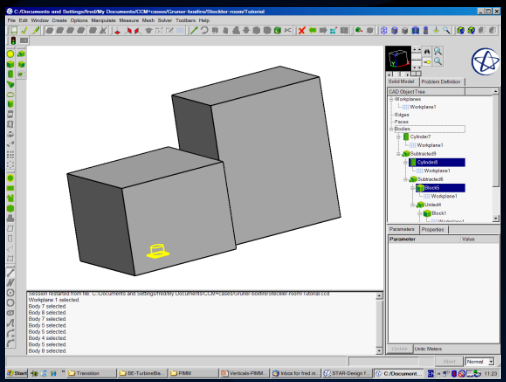
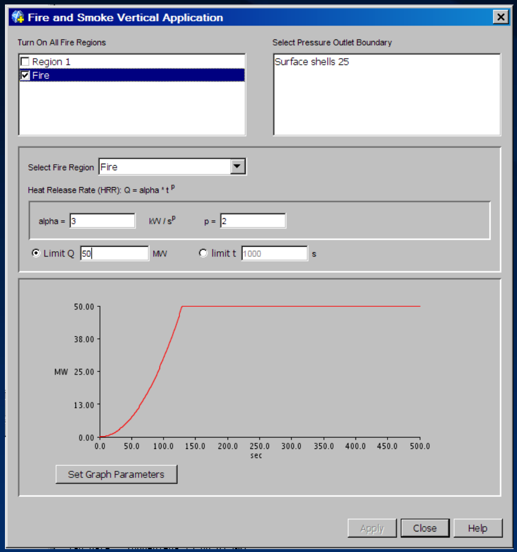
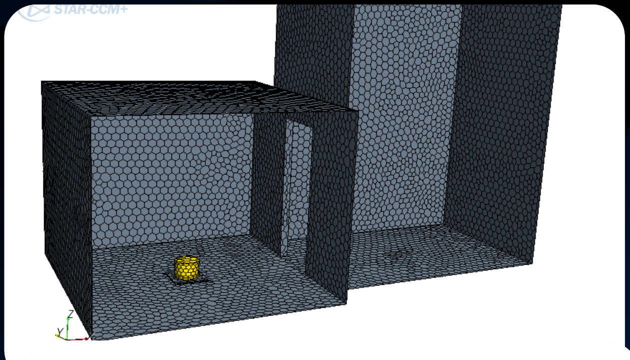
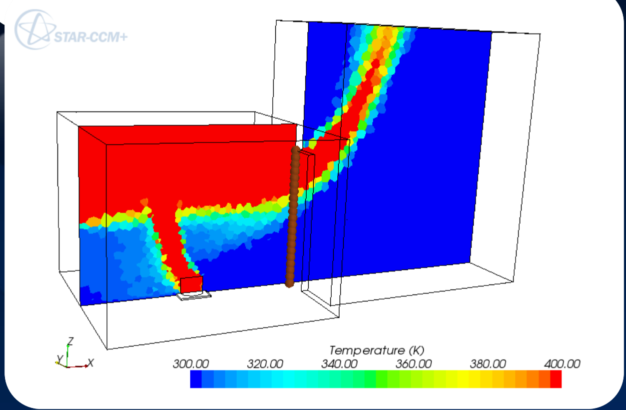
Fire and Smoke Wizard

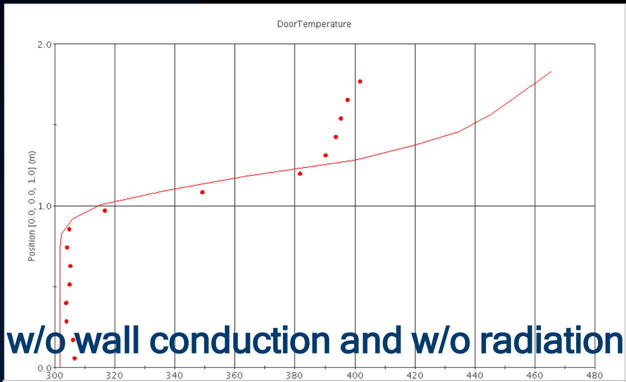


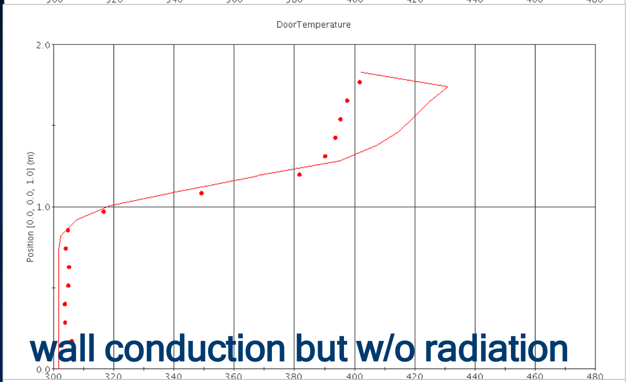


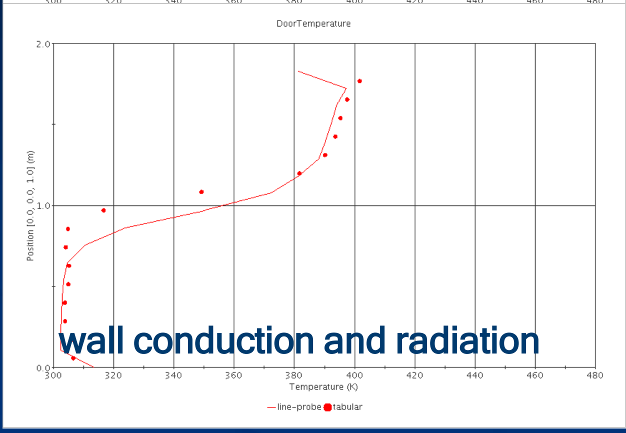




- Complex Geometry handling
- Automated meshing
- Fire source model
- Advanced Radiation model
- Smoke movement
- Ventilation
- Fire Barrier
- Fire Spread model



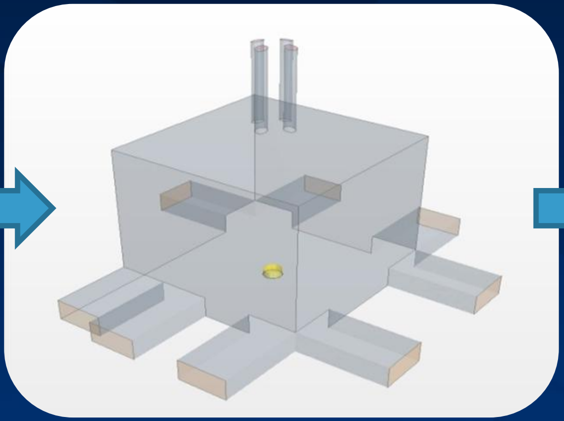


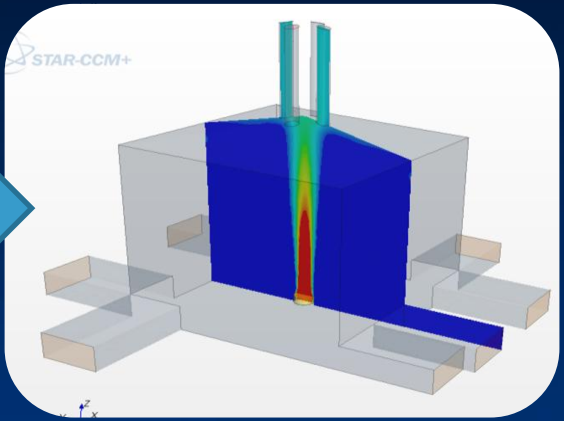


Contents

Murcia Atrium

- Study Case : Murcia Atrium - full-scale facility built for the ongoing validation of fire models
- STAR-CCM+ gives an extra insight into the flow field
  - Interrogate the 3D flow-field : fire and smoke patterns, soot spreading…
  - Extract values of interest (Temperature, Opacity, etc…)
  - Assess rapidly changes due to different configuration (ventilation, etc…)

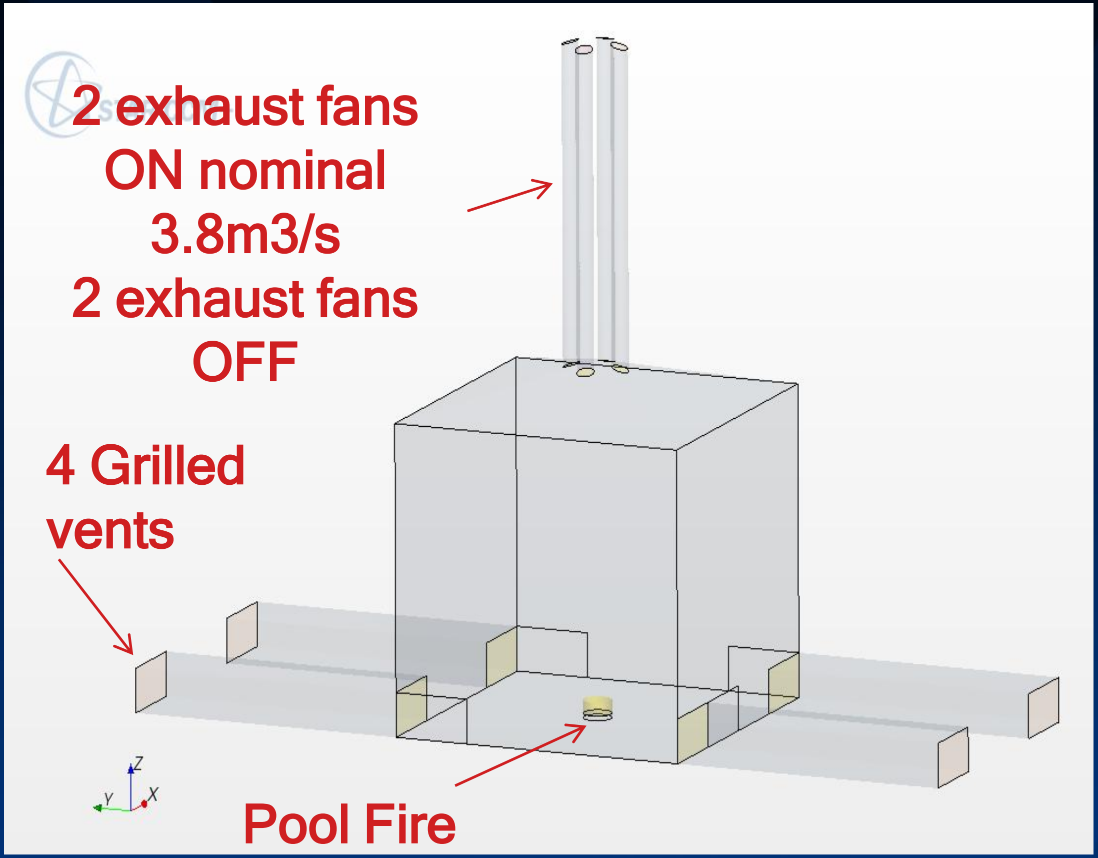


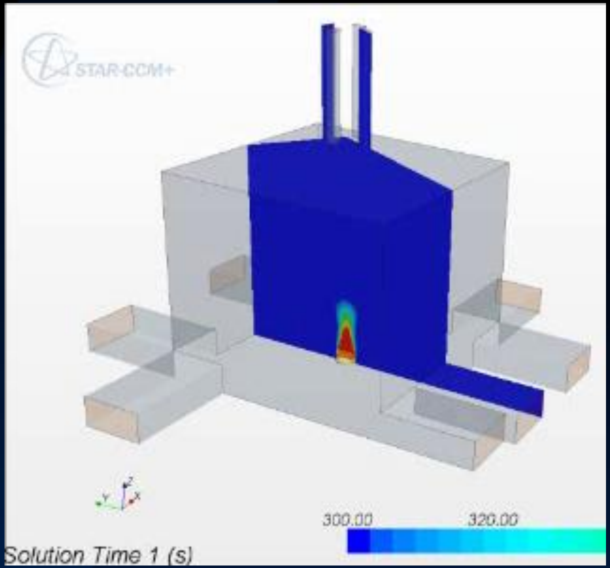


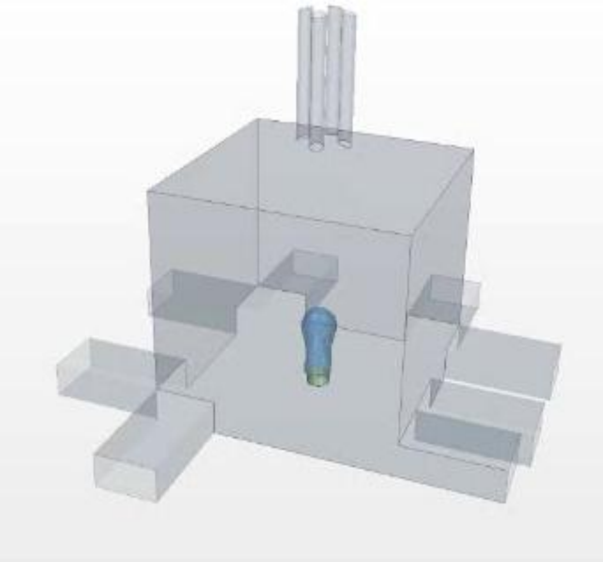
C Gutiérrez-Montes, E Sanmiguel-Rojas, A Viedma, G Rein, *Experimental Data and Numerical Modelling of 1.3 and 2.3 MW Fires in a 20 m Cubic Atrium Building and Environment 44*, pp. 1827–1839, 2009.

Problem Description and Test Conditions

- Ambient Conditions
  - Temperature = 13 C
  - Pressure = 1014 mbar







Fundamentals of modelling to be addressed

- What constitutes a reasonable mesh size for fire simulation?
- Turbulence models - what are the relative merits of uRANS vs LES?

Learning here is based on the Murcia Facility benchmark case

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Murcia Atrium benchmark studies

- Meshes
  - Coarse (0.5 m base size = 94,388 cells)
  - Medium (0.3 m base size = 356,771 cells)
  - Fine (0.2 m base size = 987,988 cells)

- Turbulence models
  - uRANS – low-Reynolds number formulation
  - LES - Smagorinski

- Numerical and control settings
  - SIMPLE-transient algorithm
  - Second-order space and time discretisation
  - Best practise solver settings (based on 1sec per time-step)

- Physics settings
  - (Optional) Radiation – DOM S2-ordinates
  - (Optional) Wall heat transfer – 1D wall-conduction to environment
  - 1.3MW fire – fast ramp to steady state between 200 and 300s

Murcia Atrium benchmark Case Matrix

- Sensitivity analysis on Murcia Atrium benchmark
  - Mesh sensitivities (coarse, medium, fine meshes)
  - Sensitivity to Radiation and Wall Heat Transfer
  - Turbulence model sensitivities (uRANS, LES)

	uRANS	LES	uRANS Radiation	uRANS Radiation + conduction	LES Radiation
Coarse	X				
Medium	X		X	X	
Fine	X	X			X

Murcia Atrium benchmark Case Matrix

- Sensitivity analysis on Murcia Atrium benchmark
  - **Mesh sensitivities (coarse, medium, fine meshes)**
  - Sensitivity to Radiation and Wall Heat Transfer
  - Turbulence model sensitivities (uRANS, LES)

	uRANS	LES	uRANS Radiation	uRANS Radiation + conduction	LES Radiation
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Murcia Atrium benchmark Case Matrix

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Coarse	X				
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Murcia Atrium benchmark Case Matrix

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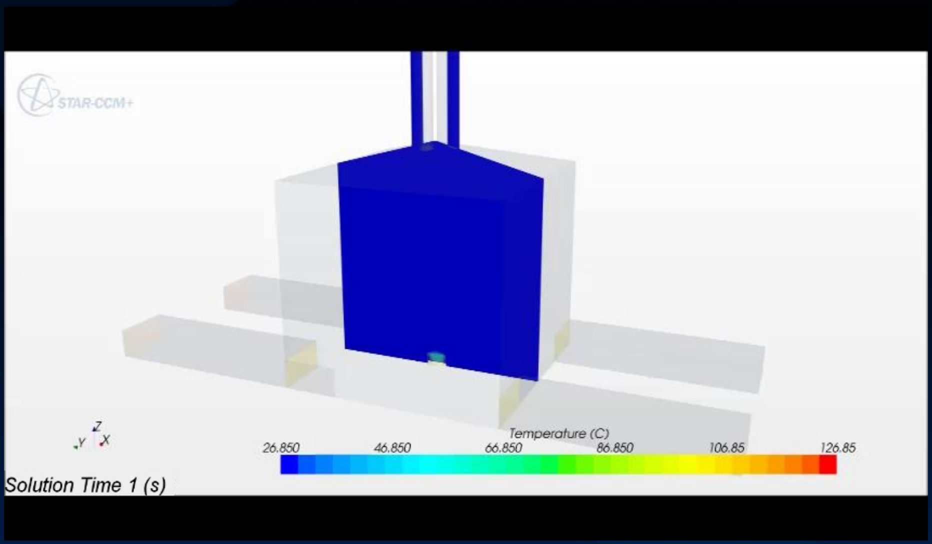
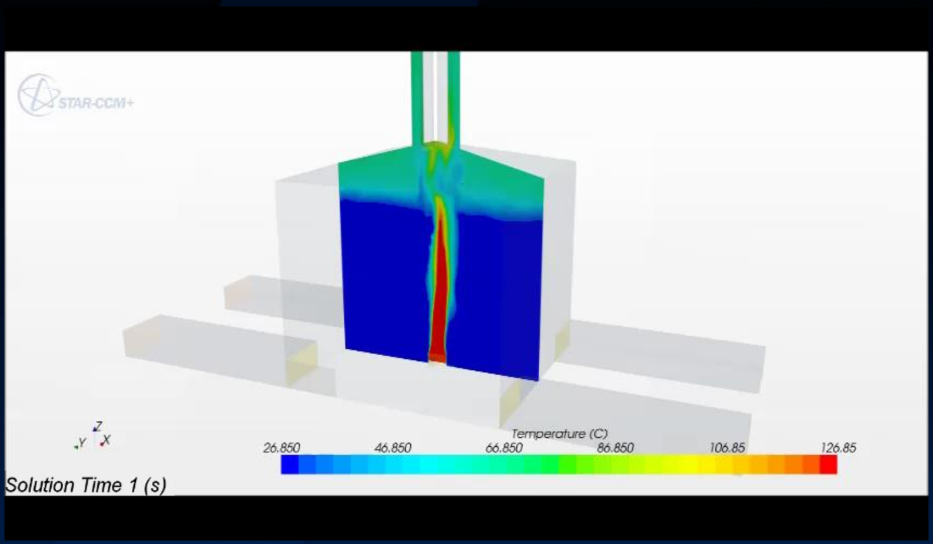
	uRANS	LES	uRANS Radiation	uRANS Radiation + conduction	LES Radiation
Coarse	X				
Medium	X		X	X	
Fine	X	X			X

uRANS and LES Transient Animations



uRANS

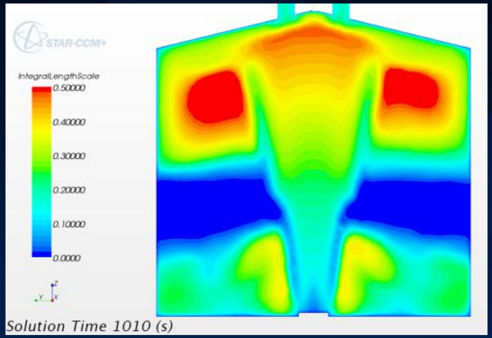


LES (default)

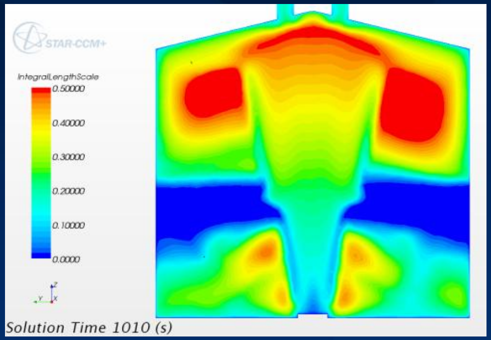
Analysis of turbulence integral scales

- uRANS k-epsilon models allow contain information from which to derive the dissipative integral scales of the turbulence.
- It is reasonable to aim to resolve these integral scales in LES

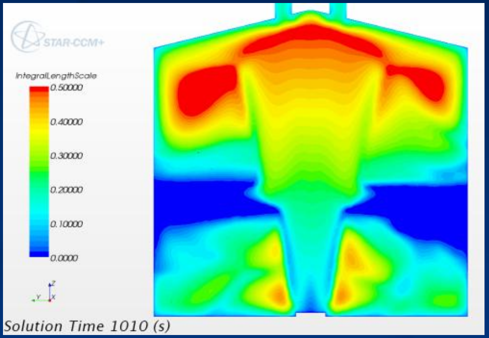
Turbulence Integral length scale, l = 0.1643 * $k^{1.5}$ / ε



Δ=0.5m



Δ=0.3m



Δ=0.2m

Mesh sensitivities (coarse, medium, fine meshes)

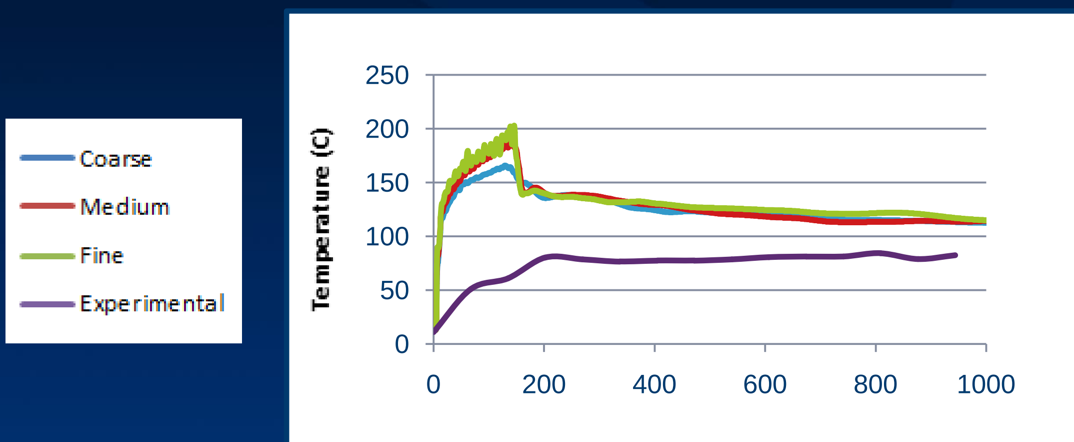
- Sensitivity analysis on Murcia Atrium benchmark
  - **Mesh sensitivities (coarse, medium, fine meshes)**
  - Sensitivity to Radiation and Wall Heat Transfer
  - Turbulence model sensitivities (uRANS, LES)

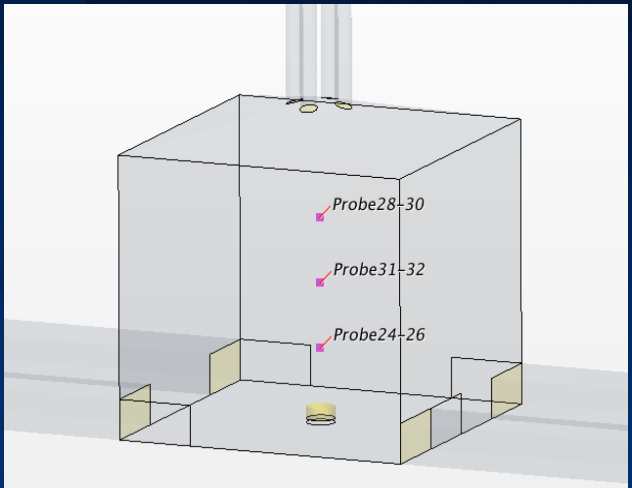
	uRANS	LES	uRANS Radiation	uRANS Radiation + conduction	LES Radiation
Coarse	X				
Medium	X		X	X	
Fine	X	X			X

Mesh sensitivities (coarse, medium, fine meshes)

- Conclusions :
  - Integral Length Scale suggests LES should be run with 0.2m base size
  - RANS results demonstrates close to mesh independence at 0.3m (~300,000 cells) and 0.2m base size (~1,000,000 cells)

Probe 31





Sensitivity to Radiation and Wall Heat Transfer

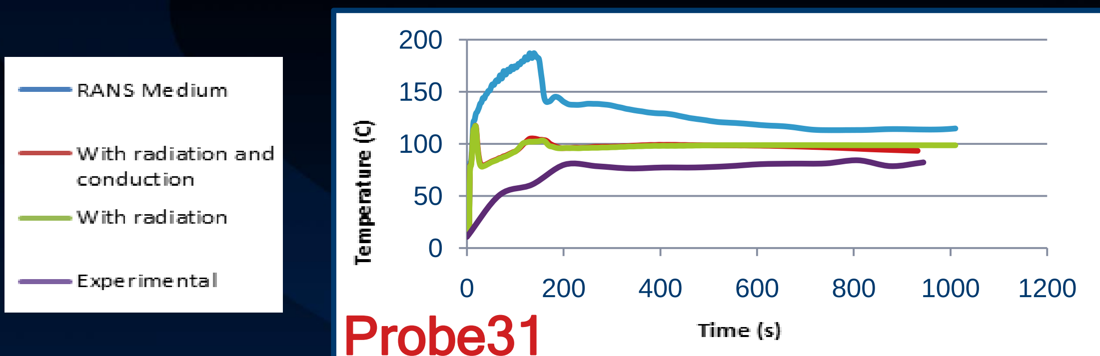
- Sensitivity analysis on Murcia Atrium benchmark
  - Mesh sensitivities (coarse, medium, fine meshes)
  - **Sensitivity to Radiation and Wall Heat Transfer**
  - Turbulence model sensitivities (uRANS, LES)

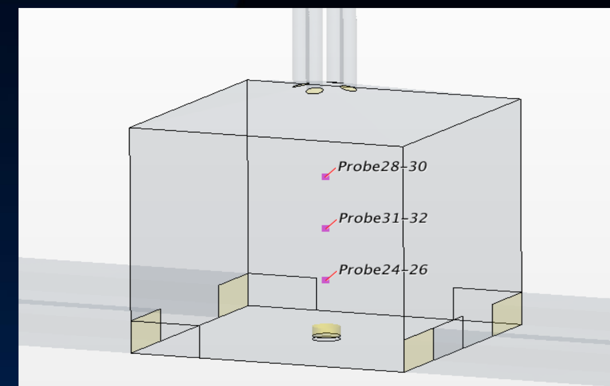
	uRANS	LES	uRANS Radiation	uRANS Radiation + conduction	LES Radiation
Coarse	X				
Medium	X		X	X	
Fine	X	X			X

Sensitivity to Heat transfer mechanisms

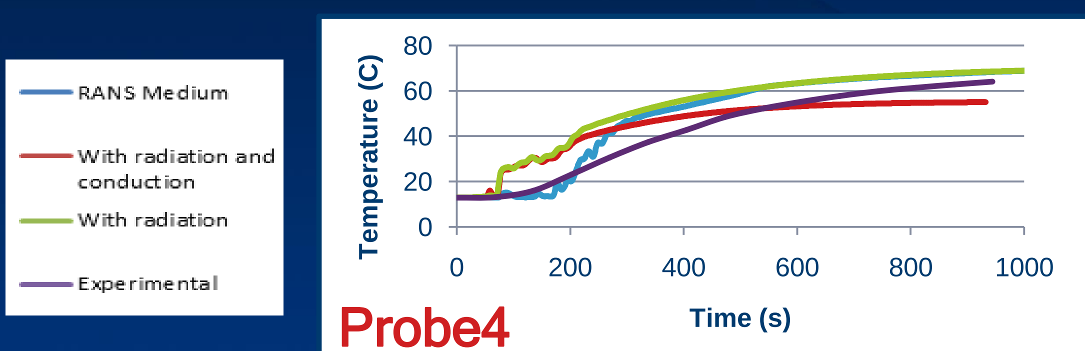
- Conclusions :

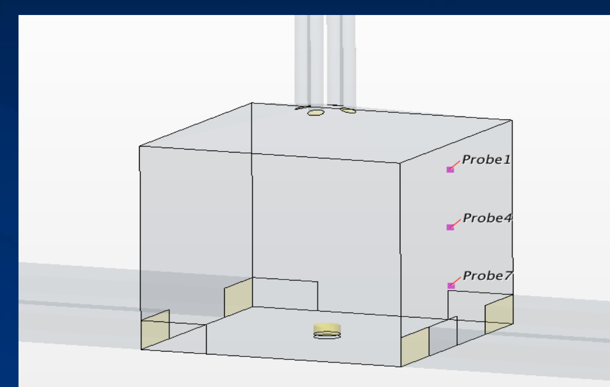
- Radiation equalizes the temperatures in the atrium and improves the plume and wall temperatures compared with experiment





- Wall heat (conductive) transfer coefficients are uncertain, and drop temperatures below measurements near the walls





Turbulence model sensitivities (uRANS, LES)

- Sensitivity analysis on Murcia Atrium benchmark
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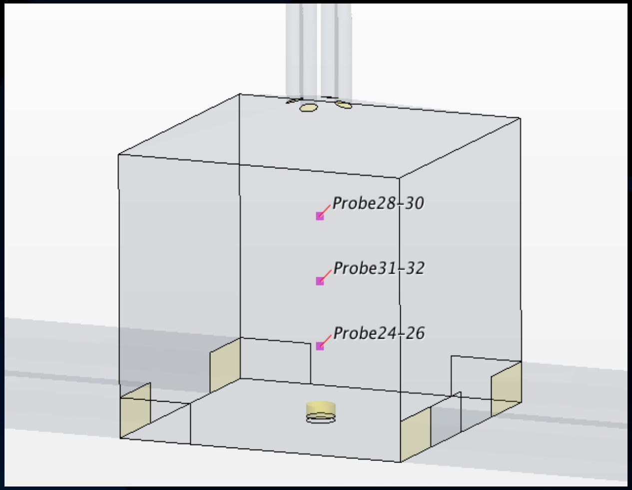
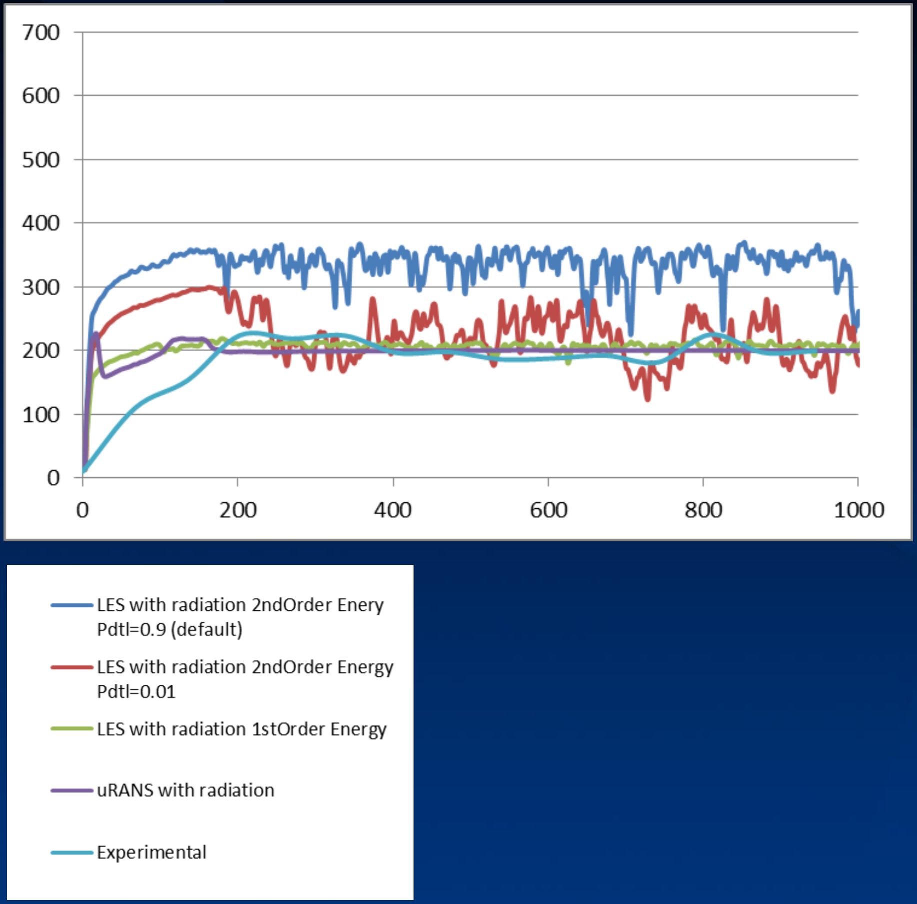
  - Sensitivity to Radiation and Wall Heat Transfer
  - Turbulence model sensitivities (uRANS, LES)

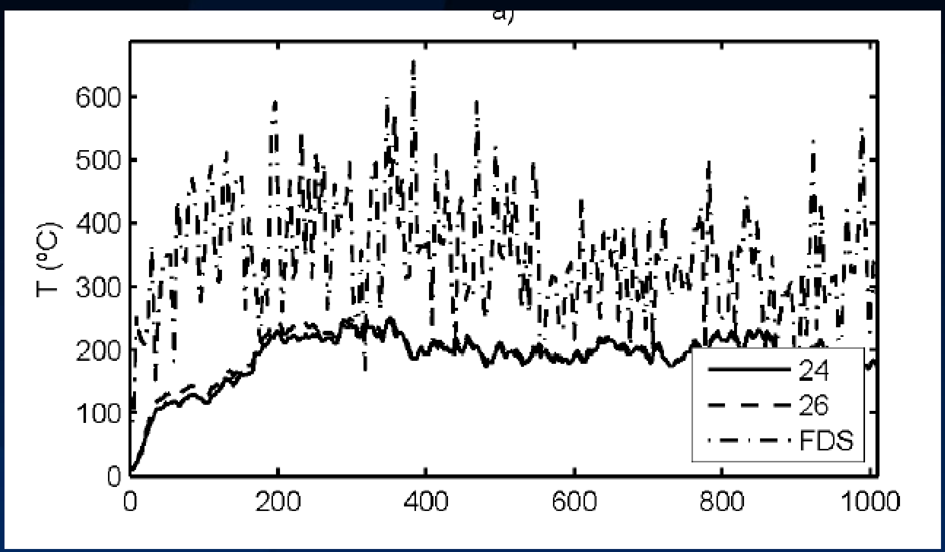
	uRANS	LES	uRANS Radiation	uRANS Radiation + conduction	LES Radiation
Coarse	X				
Medium	X		X	X	
Fine	X	X			X

LES Plume Temperatures

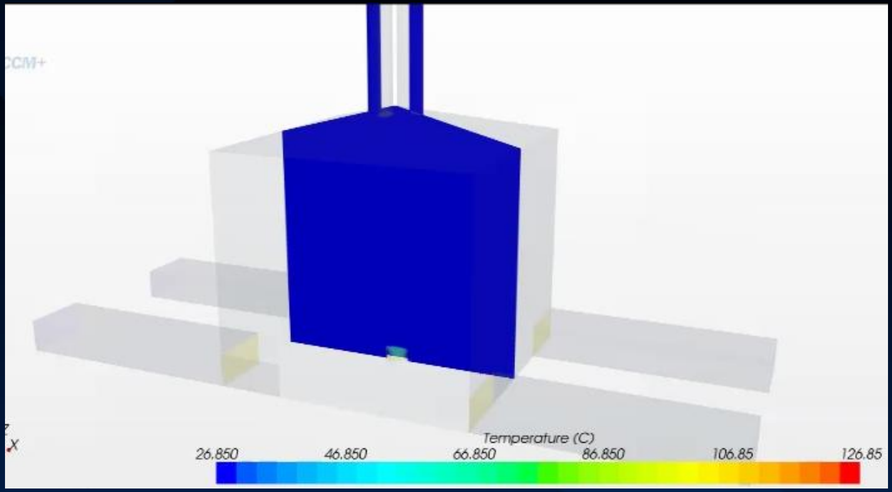


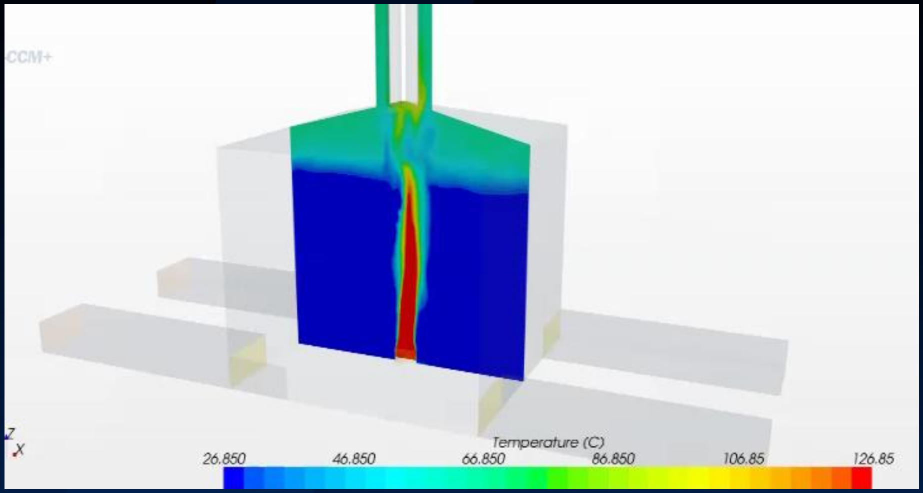
Probe24





LES Temperature stratifications comparisons





LES 1st Order Energy

Solution Time 1 (s)

LES 2nd Order Energy

Sensitivity to Turbulence model

- Conclusions :

  - LES compares reasonably well to FDS
    - Variants with Pr and T-equation discretisation tested

  - Inferior to uRANS when compared to test measurements

Summary

- Excellent features for
  - Complex building geometries and physics
  - Easy setup of fire scenarios
  - Good diagnostics

- Benefits of RANS
  - Quantification of the size of turbulence structures
  - Reynolds averaging approach produces a mean field which quickly becomes mesh independent

- Benefits of LES
  - Captures the thermally-driven dynamic flow structures

- Uncertainties
  - Wall conductive heat transfer
  - Radiation absorption in the field
  - Combustion (fuel-oxidant driven) modelling

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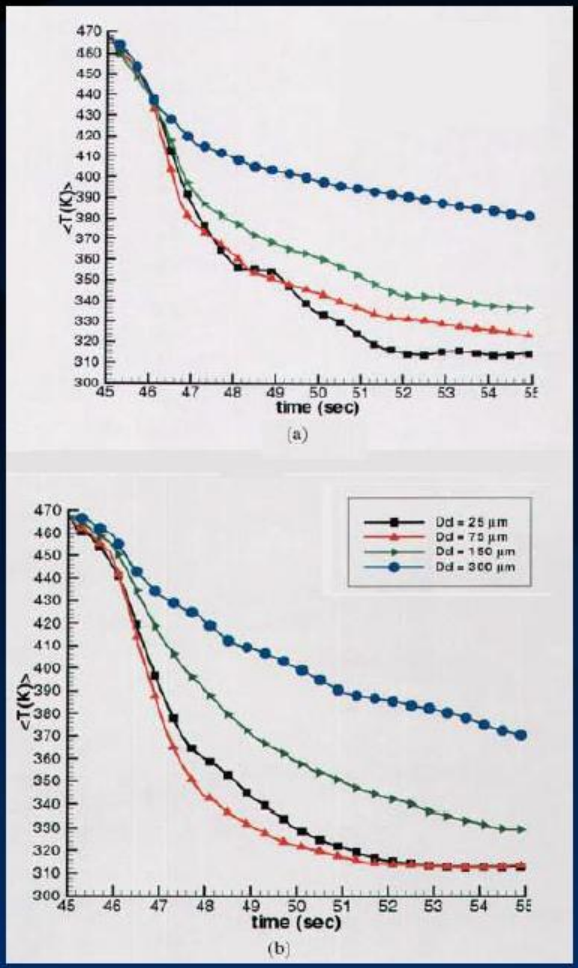
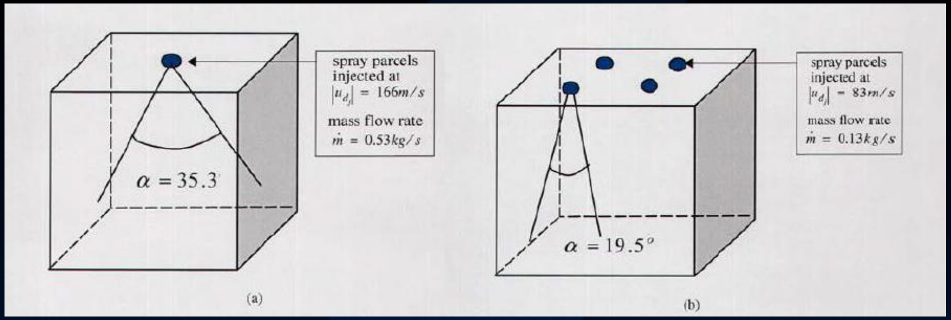
Spray Cooling

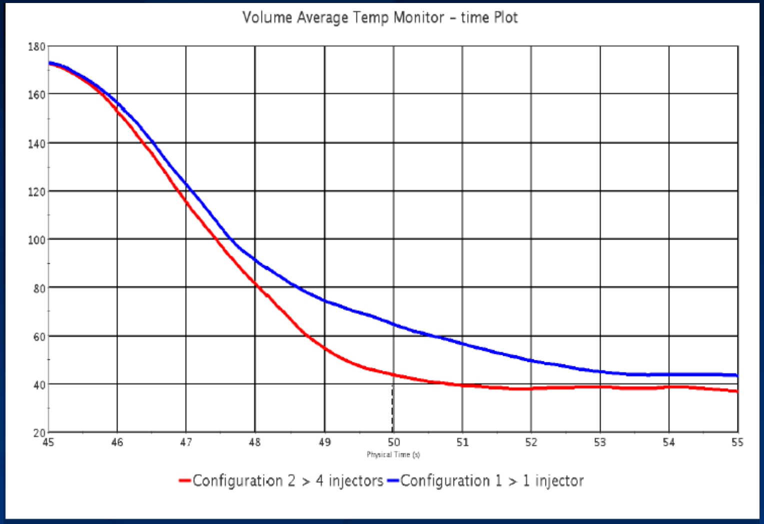
- Sandia Fire Example



Volume Avg Temperature
(Sandia Paper Simulations)



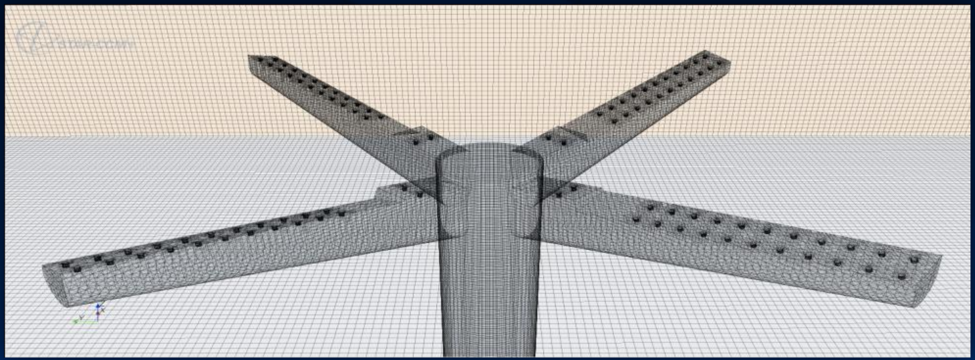
Schematic of spray system configurations using
(a) one single high pressure nozzle (config1)
(b) quadrant approach using four lower pressure nozzles (confiig2).

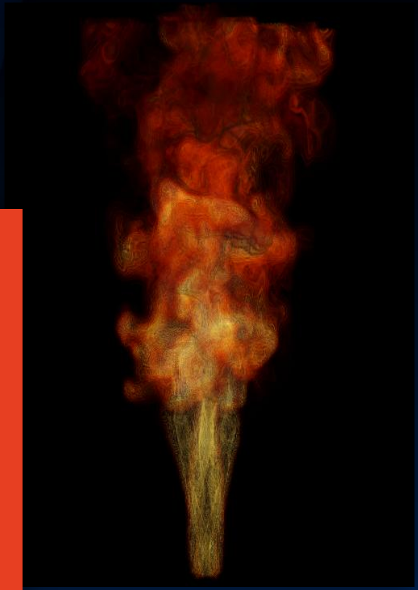


Volume Avg Temperature for 25um (STAR-CCM+ data)

Combustion Modelling

- Plume and flare analysis at the university of Utah
  - LES Combustion Validated with test rigs
  - Complex Burner geometries





Future Developments

- Fine tuning of the Fire and Smoke Wizard towards sector needs

- Enhancing capabilities
  - Combustion modelling for
    - Poorly ventilated fires
    - Improvement on heat release model
  - Sprinkler modelling and validation
  - Detection and Consequence scenarios

- We're attentive to the sector needs – embedded in the Wizard

- Validation, validation and more validation

Thank You for your Attention

For Further Information on STAR-CCM+ please contact:
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matthieu.stasia@gmail.com
Or visit us at:
www.cd-adapco.com