CFD
A fire fighting perspective

I can't give you "The vision" of fire fighters,

but I'm glad to share "a vision"

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CFD (Computational Fluid Dynamics)

- The focus of this presentation is to show you what CFD is and what the value may be in education of fire fighters.
- It's not the aim to perfectly simulate any fire, more important "***did the fire fighters achieve the learning goals ? Are they better prepared for their job ?***"
- If you want…, it's engineering/mathematics meeting the fire fighters. I guarantee you, it are different worlds ☺.

Topics

- **CFD model**
- **CFD and knowledge of fire / investigation**
- **CFD and education of fire fighters / look “inside” the fire**

CFBT vs CFD

- It is “easy” to let fire fighters believe that CFBT is “the real thing”, however…
- Reality demonstrates that real fire behaves sometimes different (see also UL tests).
- Real fires doesn’t “listen” to the boundary conditions of “the container”
- Therefore it is important to understand that CFBT is also “a model”. Very usefull to study some phenomena and to practice some skills.

You can't "stretch" the result of "the container"

CFBT a model

- Limited dimensions
- Fire loads
- Wall characteristics
- Testing must stay on the “safe/controllable” side

Does this cover reality ?

- well insulated buildings ?
- huge industrial halls ?
- deep freeze storage ?
- chemical fires ?
- in brief, all the stuff where UL worries about…

CFD : a model

- CFD is a mathematical model of a real situation. Like CFBT, *it is also only a model*. But it is a model and it is much more difficult to convince fire fighters that there is "value" in this model.
- The real world is devided in space and time. The space is subdivided into volumes we consider to be "homogeneous" and "computable" (the mesh). We divide time in "time steps" which are small enough, so that this discretisation is "allowed".
- A CFD model is almost always set for one particular situation.

CFD and submodels

- Fire is “hard” to model. As well in practical testing as in computer models. The reason is that chemical and physical processes play an important role on very different lenght and time scales.
- Chemical scale is typically 10^{-10} to 10^{-5} m
- Physical scale (e.g. eddies in turbulent flow) 10^{-3} to 10 m.

It is impossible to incorporate all these phenomena into one model. So submodels are needed.

CFD and submodels

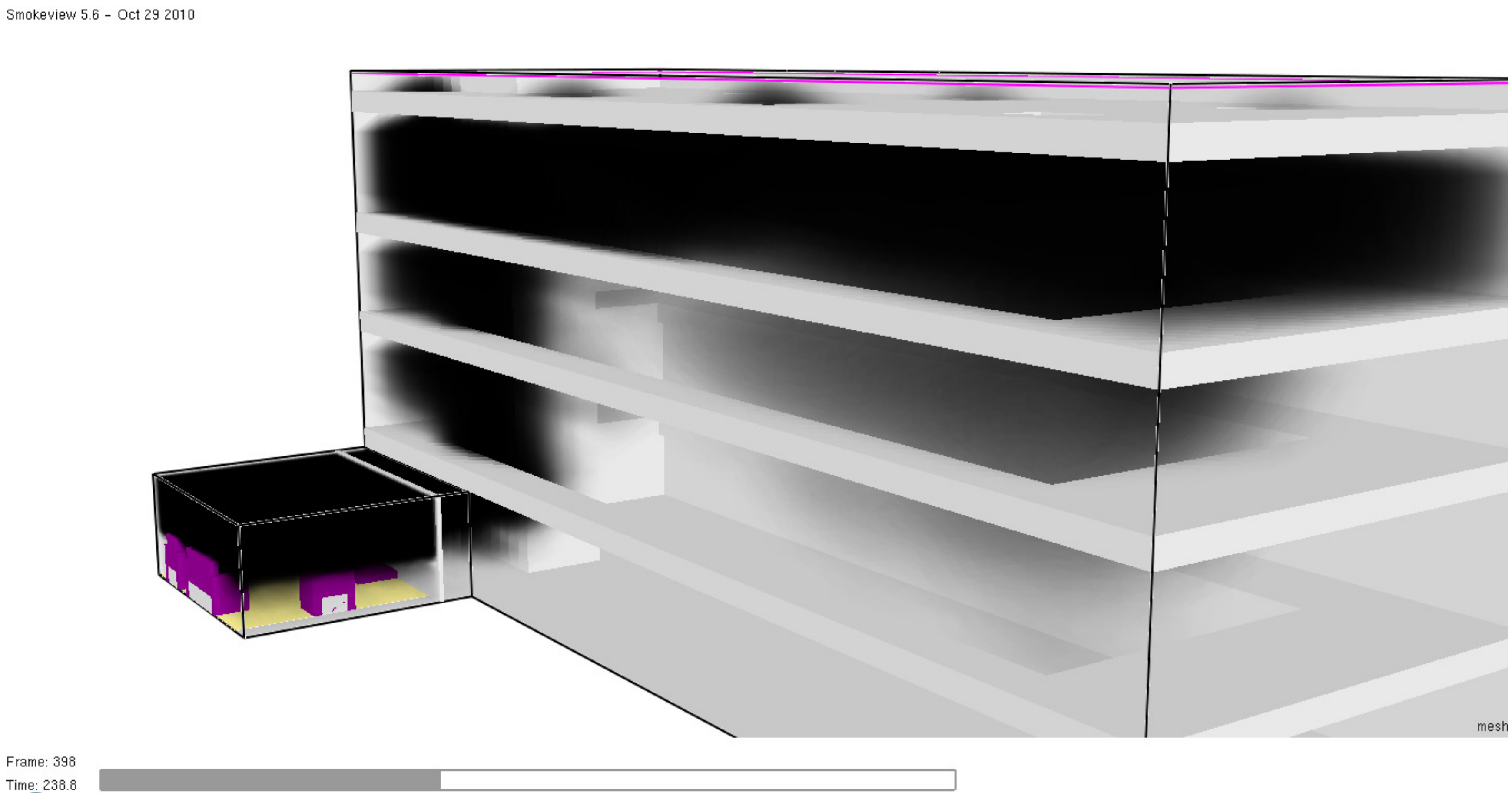
- There are a lot of submodels needed
  - radiation
  - turbulence
  - combustion
  - pyrolysis
  - soot production
  - convection
  - …

This is all needed because “reality” even devided into “small volumes in small time steps” is still to complex to manage in an acceptable computing time.

CFD and the problem

- The object under investigation must be modelled in a correct way.
- The right submodels must be selected
- In function of the questions, there must be a good selection of fire scenarios (e.g. place and heat release rate of the fire).
- And… the results must be analysed and presented in a proper way.

What does it look like ?



Is CFD capable of simulating “the real thing” ?

- The station night club fire (Rhode Island) : 20 february 2003 : 100 deaths !
- Fire works ignites the PU wall covering.
- Report june 2005 (ca**. 2 year investigation**)
- Very good match between reality and retrospective analysis with FDS
- Reports are available on the internet : every instructor should go through this kind of reports. http://www.nist.gov/el/disasterstudies/fire (All these studies are done with FDS)

How is such good agreement possible?

- They exactly measured and consequently modelled the characteristics of the materials (pyrolysis properties, HRR, thermal properties,…) (4-22)

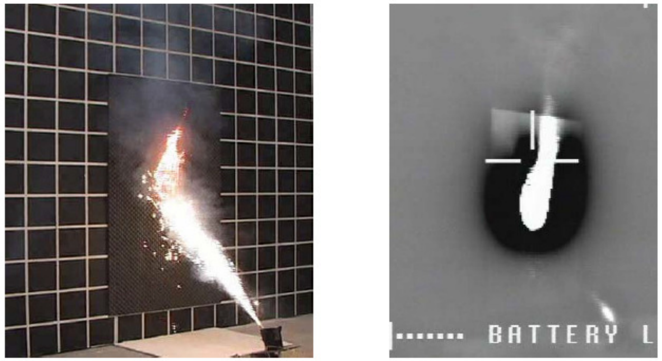


Figure 4-13g. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 15 seconds.

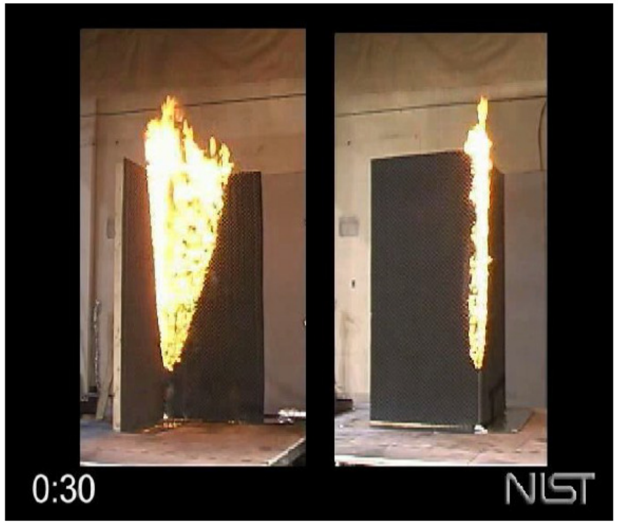


Figure E-3. Video of External and Internal Corner Burns

How is such good agreement possible?

Polyurethane Foam	PUF-NFR-A-01	PUF-NFR-A-2	PUF-NFR-A-3	Average
External Heat Flux 35 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	9.00	7	6	**7.3**
Peak Heat Release Rate (kW/m^2):	620	676	520	**605**
Time to Peak Heat Release Rate (s):	32.0	30	28	**30.0**
Total Heat Release (MJ/m^2):	15.6	16.3	15.4	**15.8**
60 s Average Heat Release Rate (kW/m^2):	262	268	248	**259**
Total Mass Loss (g):	6.25	6.2	5.94	**6.13**
Average Mass Loss Rate (g/s):	0.174	0.148	0.117	**0.146**
Average Effective Heat of Combustion (MJ/kg):	24.9	26.4	25.9	**25.7**
Average Smoke Extinction Area (m^2/kg):	206	285	235	**242**
Average CO_2 yield (g/g):	1.56	1.88	2.03	**1.8**
Average CO yield (g/g):	0.0136	0.0112	0.0129	**0.0126**

How is such good agreement possible?

- They rebuild the space and did real fire test which they compared with simulation results.

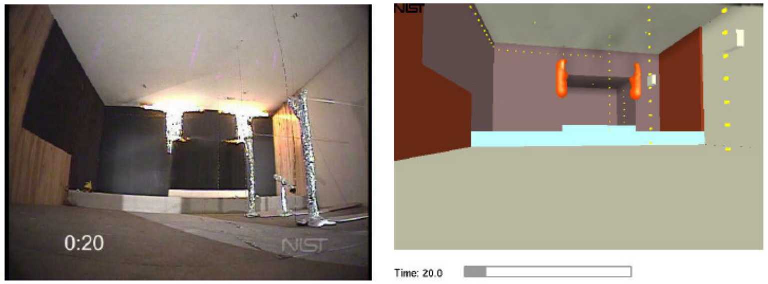


Figure 5-4. Flames impinging on ceiling, t = 20 seconds after ignition.

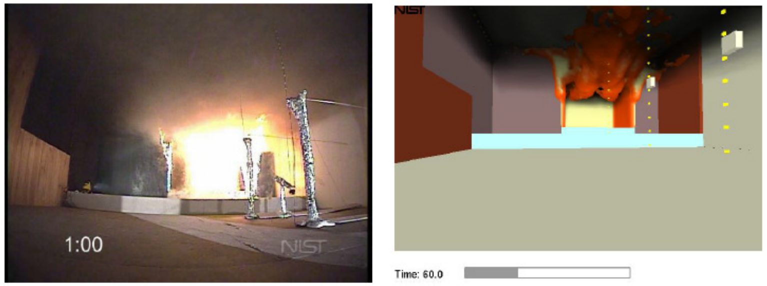


Figure 5-8. Flashover has occurred in alcove area, t = 60 seconds after ignition.

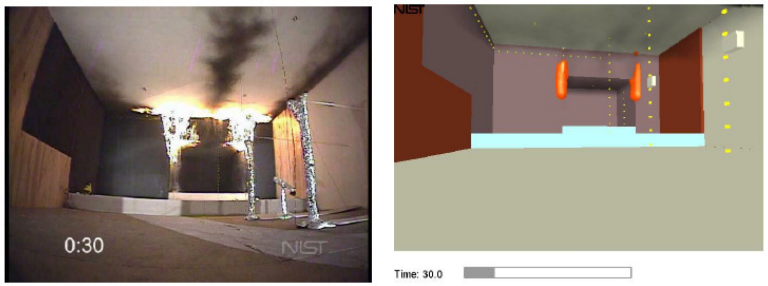


Figure 5-5. Visible smoke spreading across ceiling, t = 30 seconds after ignition.

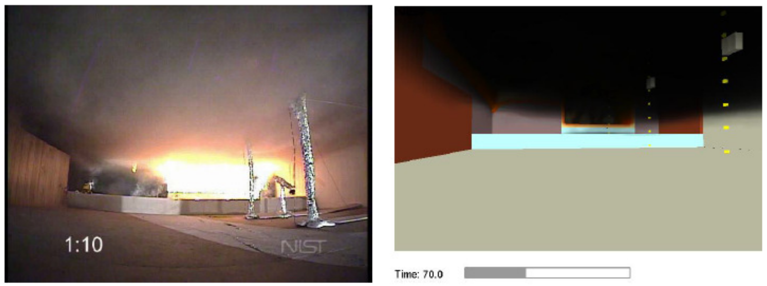


Figure 5-9. Smoke layer has dropped to 1.5 m above floor, t = 70 seconds after ignition.

How is such good agreement possible?

- The real fire was simulated. Ventilation was modelled using real films and photos taken at the moment of the fire !
- It is important to realise that good agreement was only possible, because they could “input” the moment that a window broke or ventilation conditions drastically changed. Only if this info is available, good agreement between simulation and reality is possible !

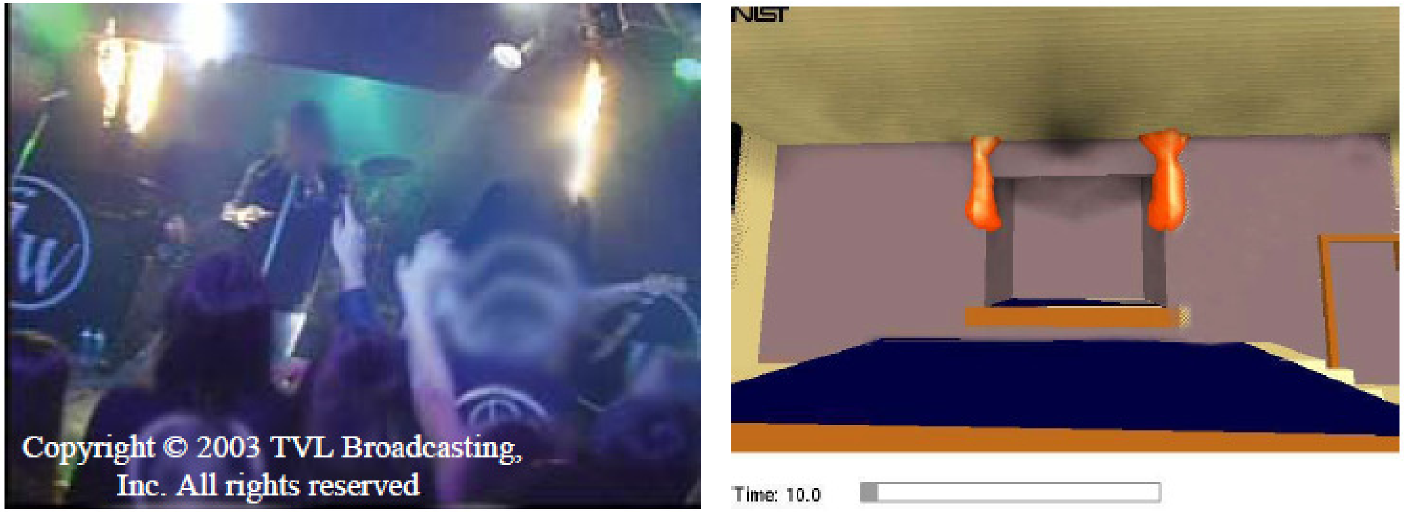


Figure 5-43. Initial growth of fire on foam at corner of the alcove (10 seconds)

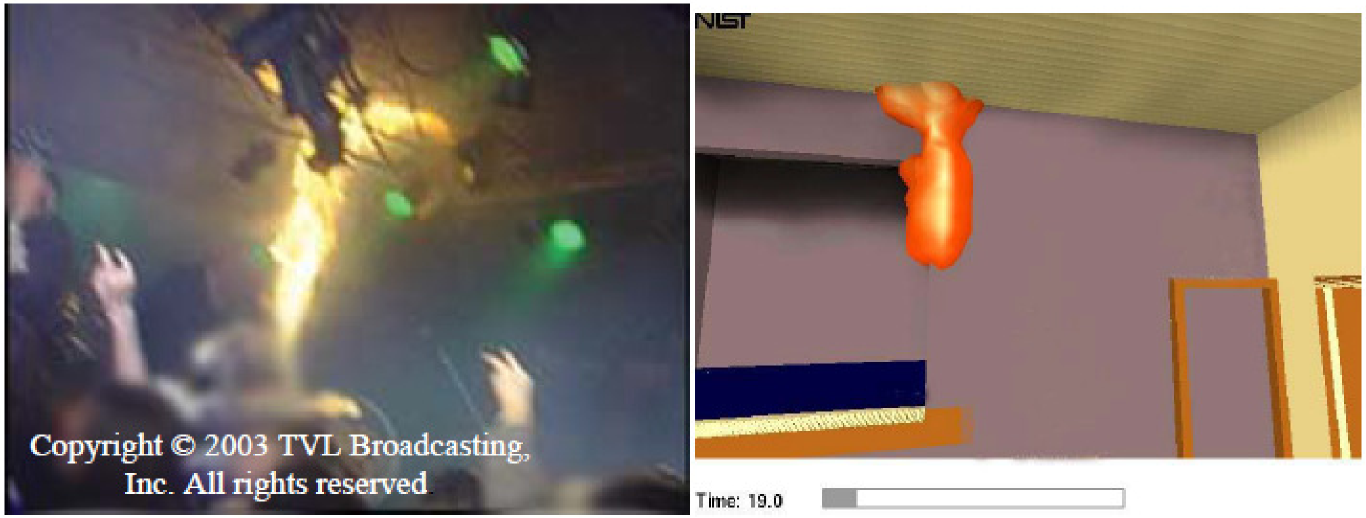


Figure 5-44. Flames impinging on ceiling (19 seconds)

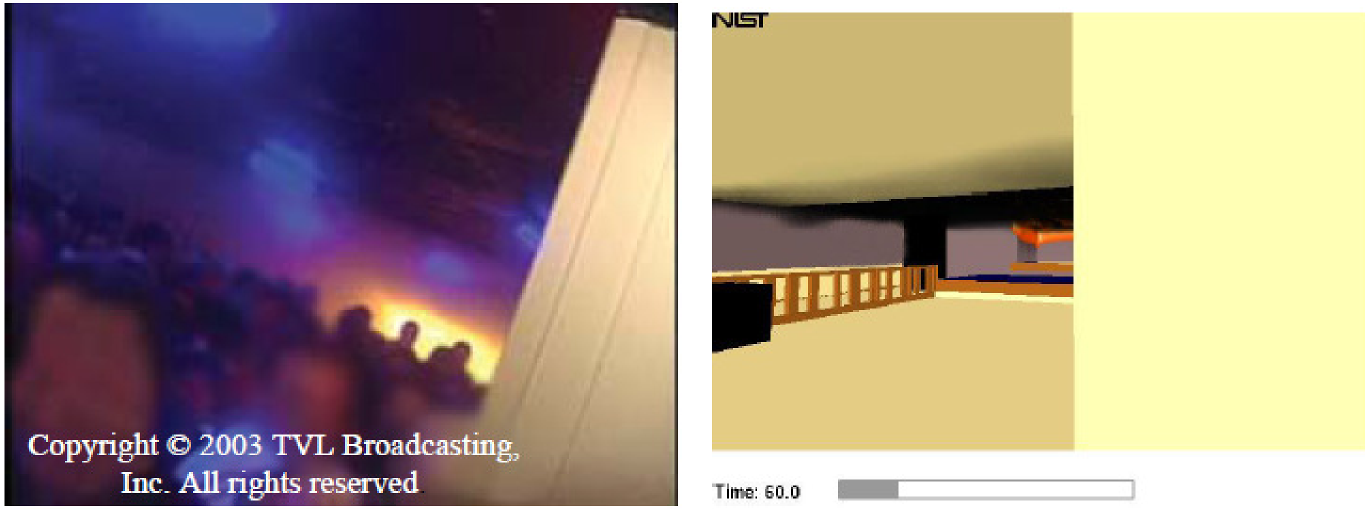


Figure 5-46. Smoke beginning to roll across ceiling (video 53 seconds, simulation 60 seconds)

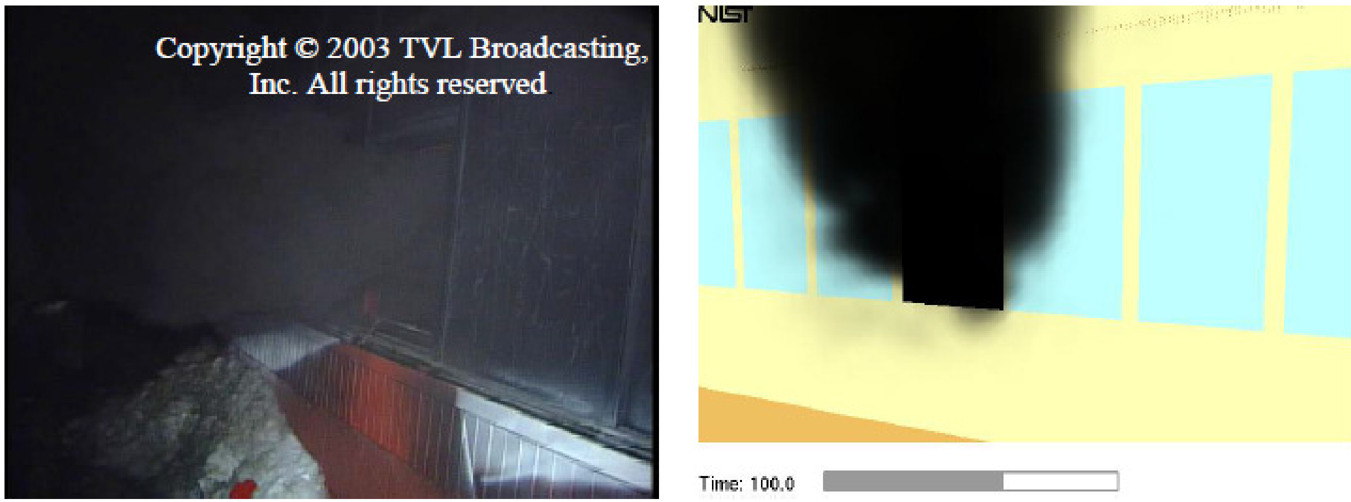


Figure 5-47. Smoke billowing outside from broken sunroom window (100 seconds)

Figure 5-50. View of smoke plumes from front windows of horseshoe bar area (176 seconds)

Figure 5-51. Looking into stage door exit (289 seconds)

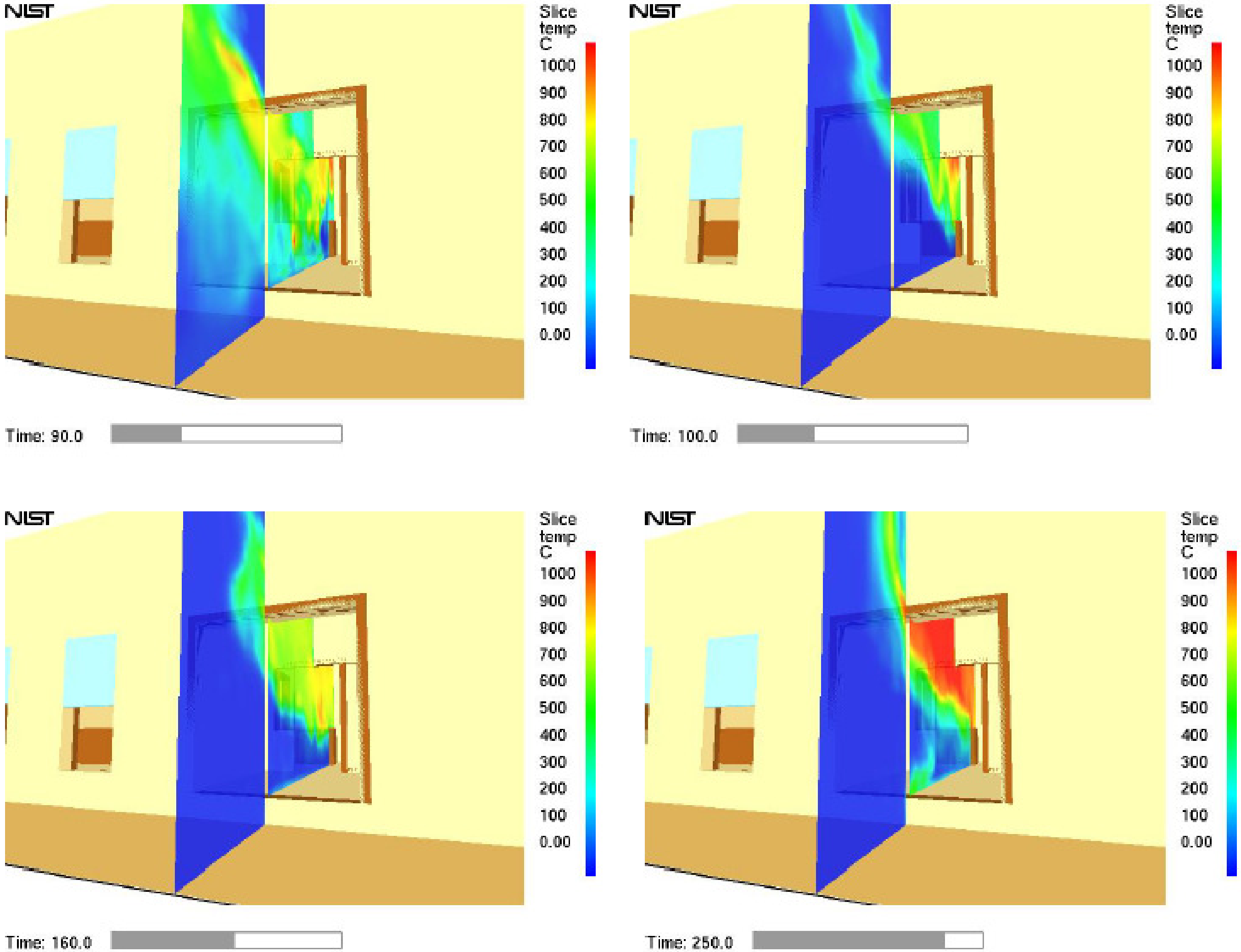


Figure 5-57. Temperature profile through the center of the entry foyer, 80 seconds to 250 seconds

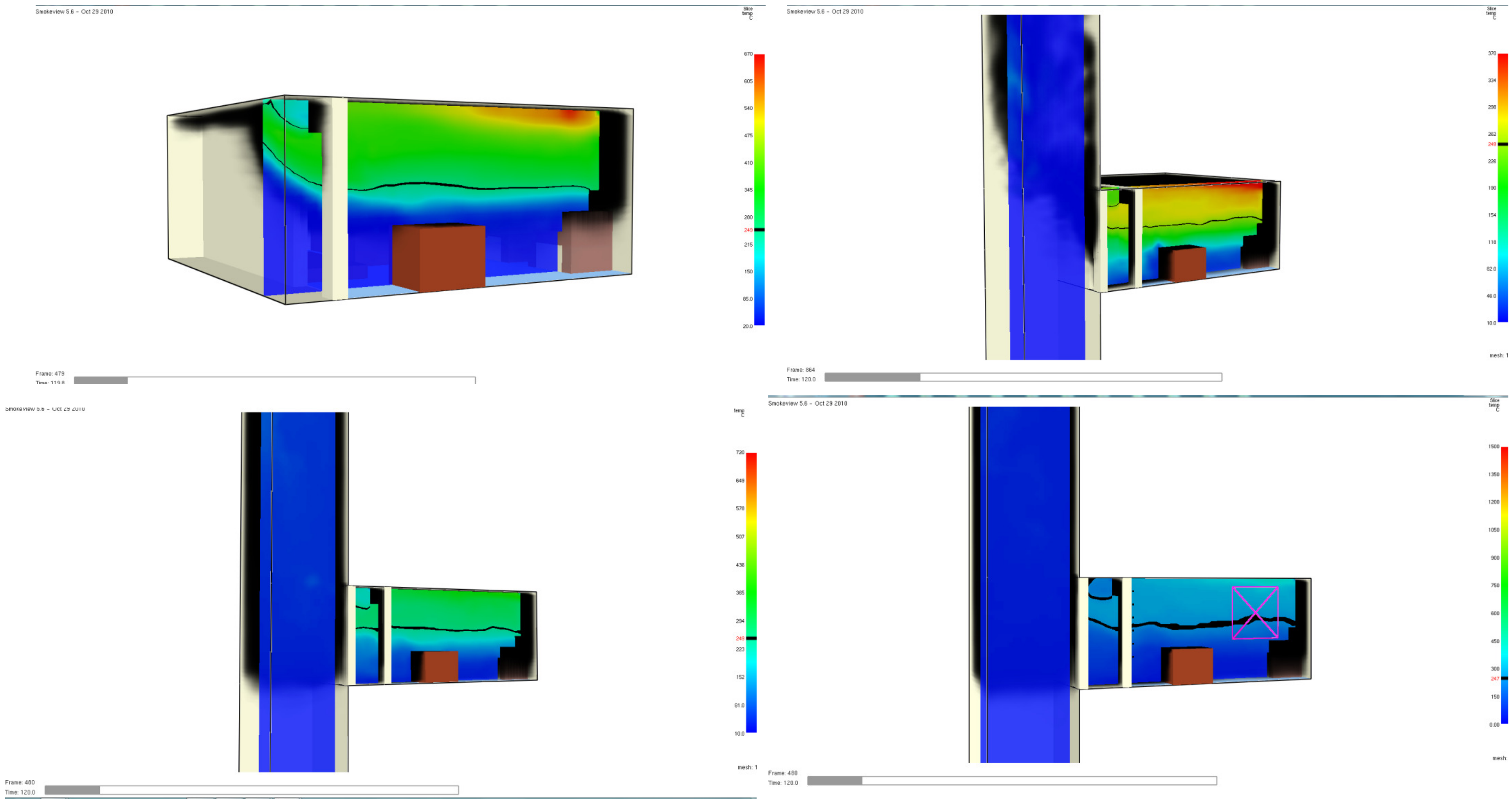
A priori however …

- Under ventilated fires are very difficult to predict in an accurate way with CFD … Let's think about that, the next simulation you make to consider "life safety" !
- To "know" when ventilation conditions will change (e.g. a window that breaks) is very hard to simulate. The best guess is probably to change the ventilation conditions on different times in different simulations.
- Ventilated fires are "easier", but material properties are often difficult because they are often influenced by temperature ! ***The influence of temperature on material properties is often neglectid.***
- Until today, no succesfull predictions of great full scale experiments …

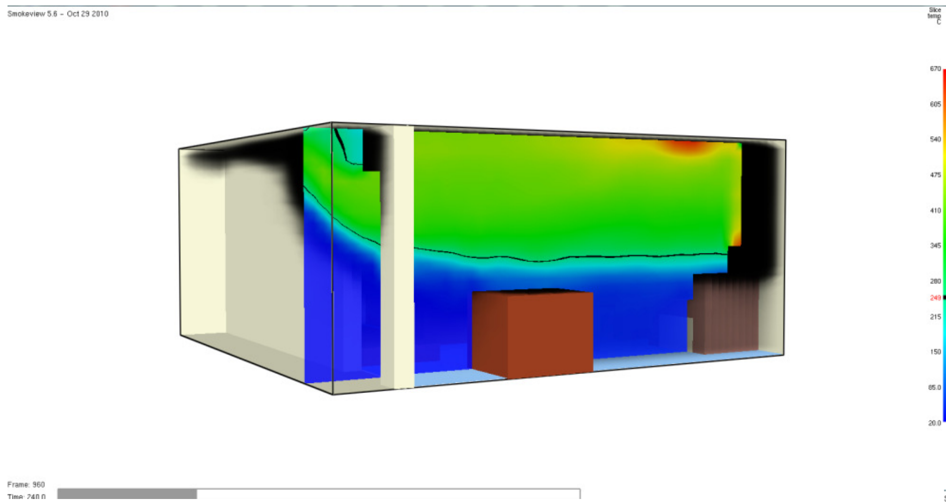
CFD and education/knowledge

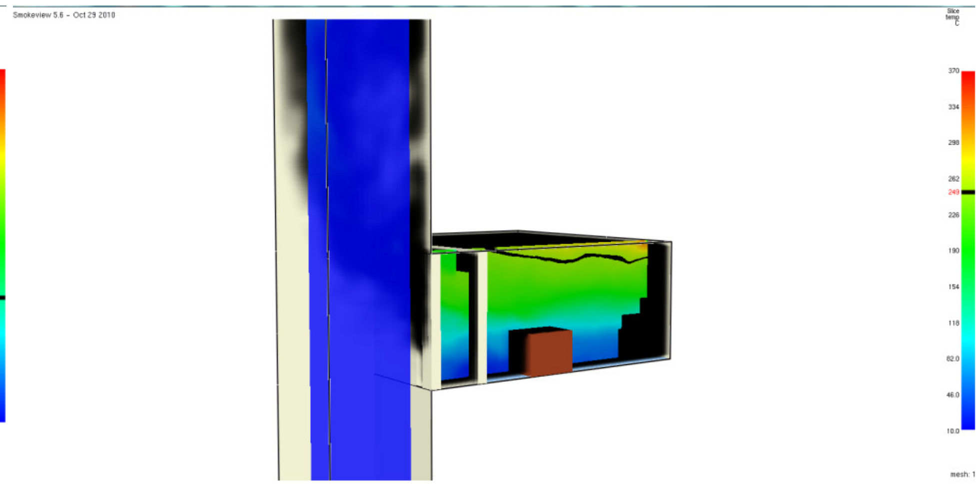
- CFD can contribute to the insight in fire behaviour, certainly regarding smoke movement en smoke control mechanism.
- I really want to brake a lance for analysing different scenario’s and different ventilation conditions. Comparing the results in a qualitative way, can expand the “frame of reference” in your mind. By doing this, you gain “experience” without need for multiple real fires…
- In comparing different scenario, it is important to “relatively” compare the results. Not the exact figures, but the variation between the scenario is the most important thing to consider.
- Let’s look at some examples…

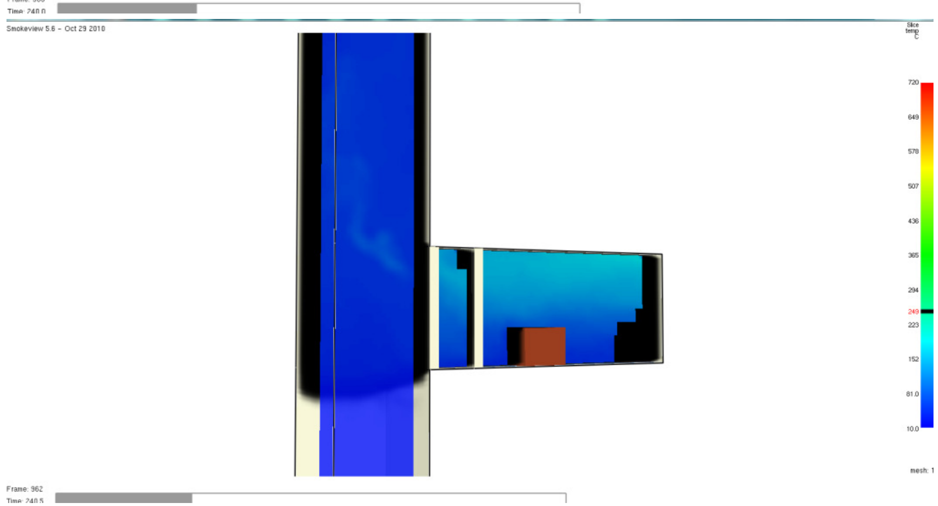
Analysing “the same fire” in different conditions… 120s (thin black line is 250°C)

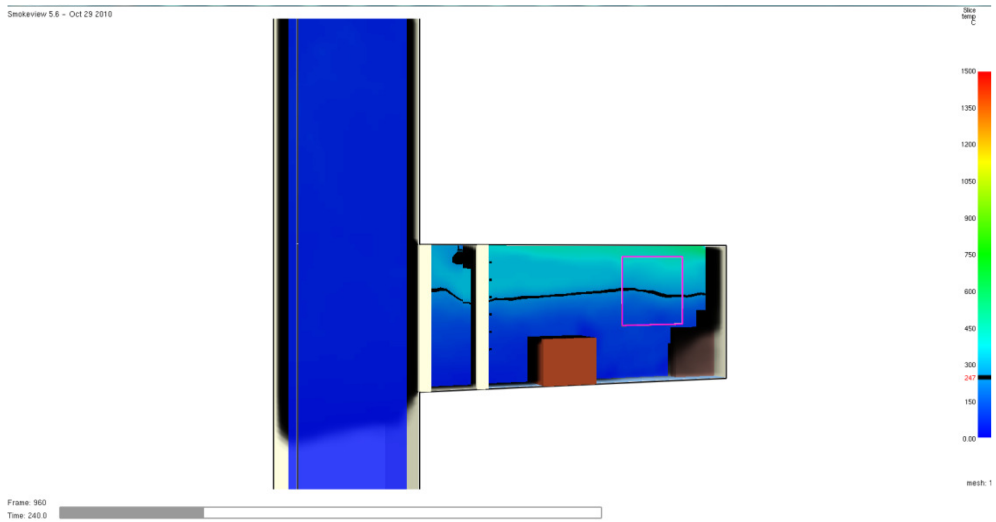


Analysing “the same fire” in different conditions… 240s (thin black line is 250°C)

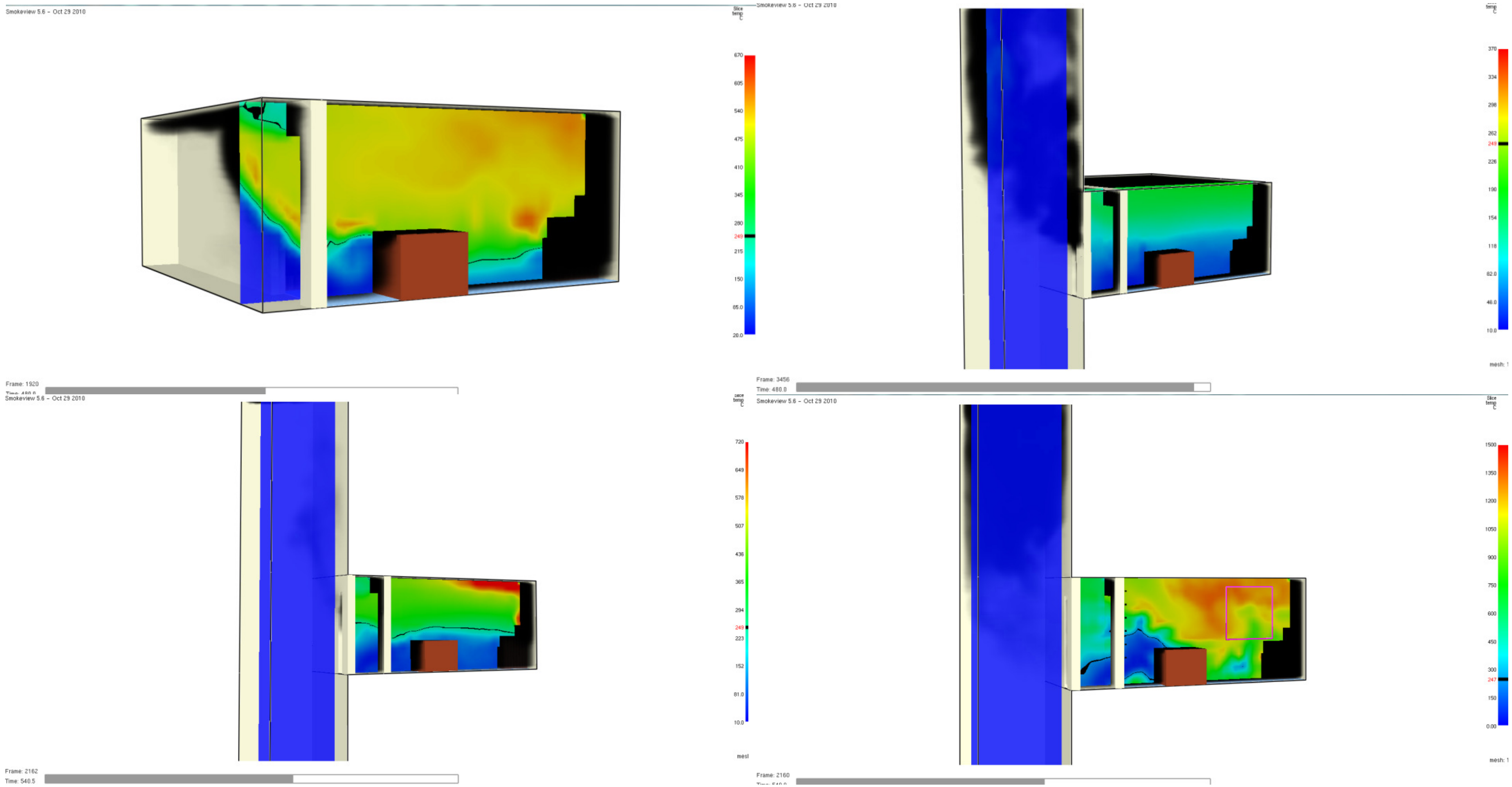








Analysing “the same fire” in different conditions… 540s (thin black line is 250°C)



A little encouragement

- Most of the people solve the problems of the present with the knowledge of the past… but some people shape the future.

- So, keep up the good work

CFD and fire brigades a future … ?