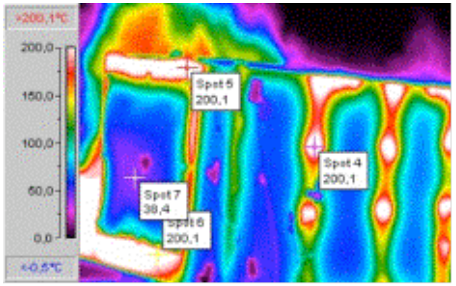



Laboratoire national de métrologie et d’essais

Fire behaviour division

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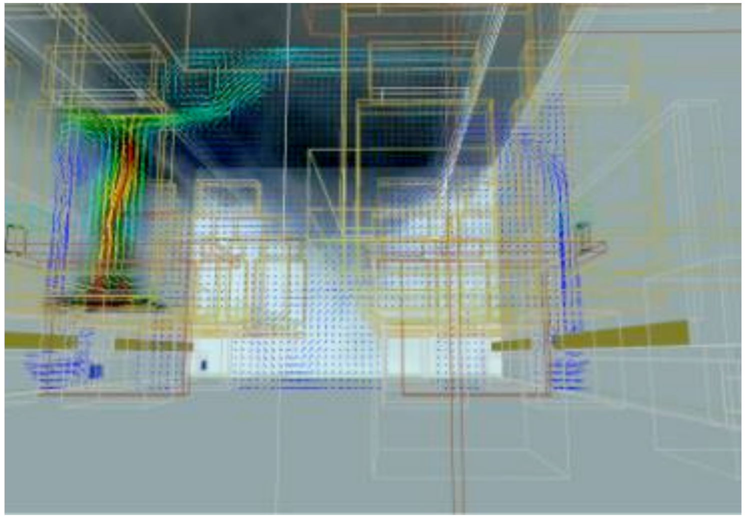
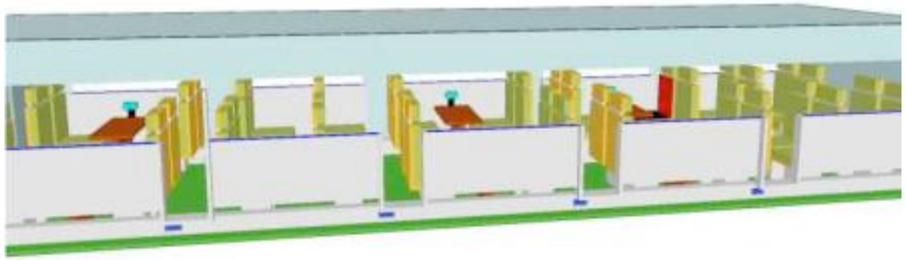
Validation and usage of fire safety engineering techniques in railways





Eric GUILLAUME - LNE
Franck DIDIEUX – LNE

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November 2008

Why FSE for railways rolling stock ?

- European Technical Specification for Interoperability of High speed trains (2002 version) :
  Trains must be able to drive at 80 kmph during 15 minutes with a fire on board

- Derogations to EN45545-2 and –3 requirements (i.e. ISO 834 curve compliant with fires in luggage spaces ?)

- Need for a simulation tool able to calculate fire growth to study different scenarios of fire ignition and their effect :
  - ✓ on people (escape to a place of relative/ultimate safety)
  - ✓ on essential functions of train : power lines (electric), brake lines (pneumatic), structure…

Ignition scenarios listed in EN 45545-1

- **EN 45545 is designed to give an answer to the following reference ignition scenarios**

1) Flaming source is 3 min duration and average power output of 7 kW generating a flux of 25 kW/m^2 to 30 kW/m^2.

2) A radiant flux of nominal value 25 kWm^{-2} applied to an area of 0,1 m^2.

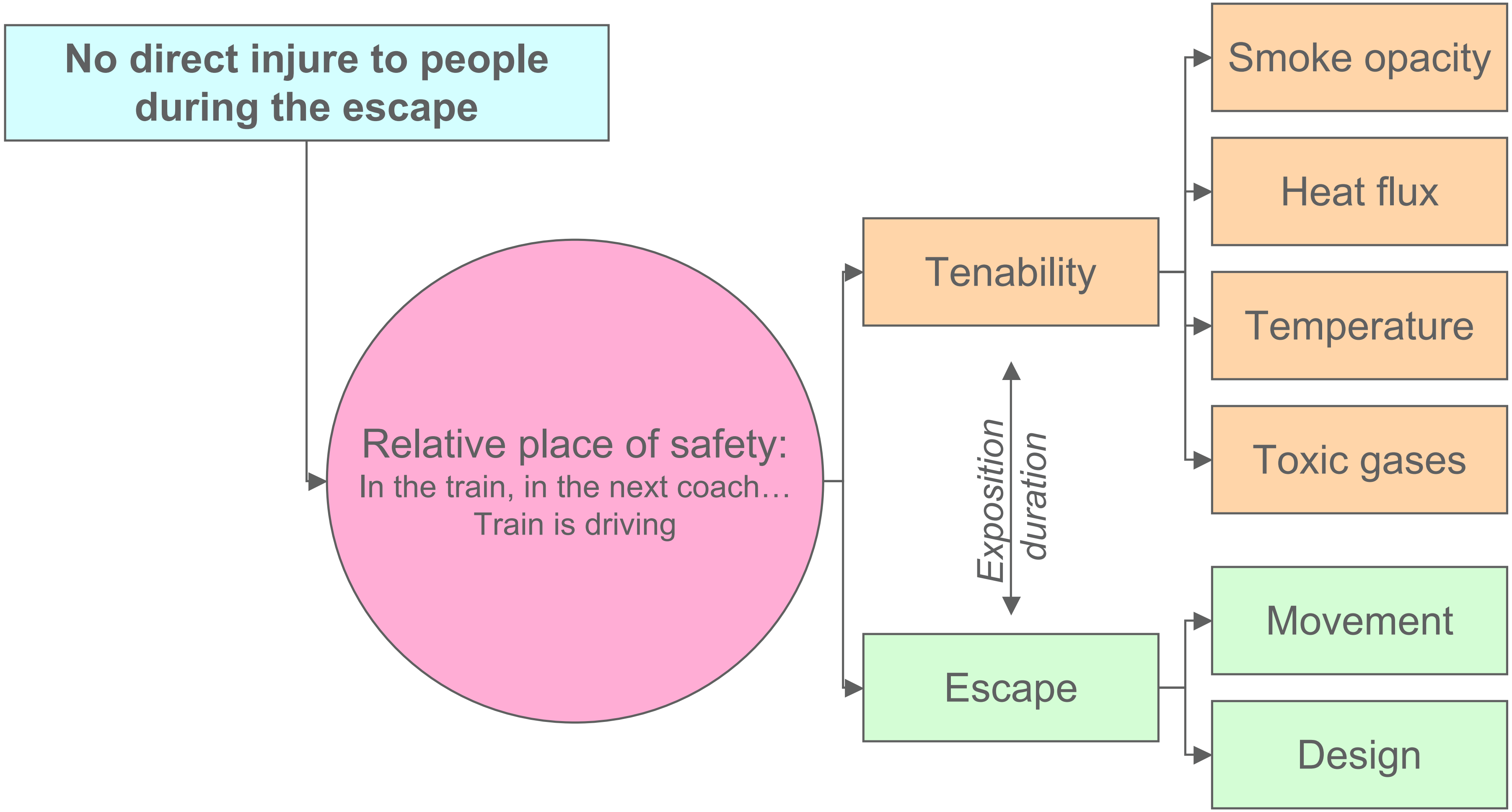
3) A radiant flux of nominal value 50 kWm^{-2} applied to an area of 0,1 m^2.

4) Flaming source of power 1 KW and 30 s duration.

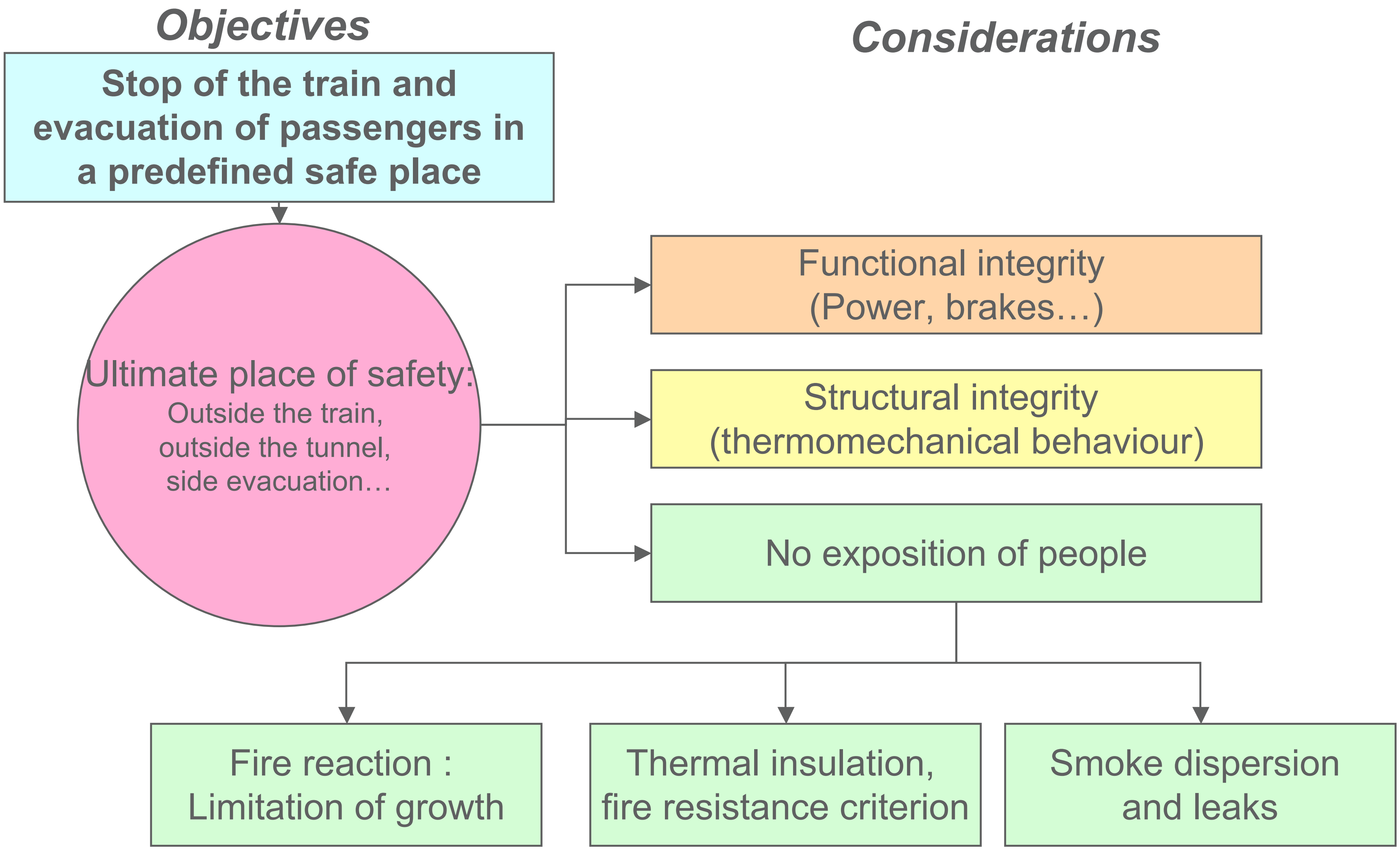
5) A flaming source generating a radiant flux of nominal value in the range 20 kWm^{-2} to 25 kWm^{-2} applied to an area of 0,7 m^2 with an average heat of 75 kW for a period of 2 min followed immediately by a flux of nominal value in the range 40 kWm^{-2} to 50 kWm^{-2} applied to the same 0,7 m^2 area with an average heat of 150 kW for a period of 8 min.

Relative place of safety by FSE

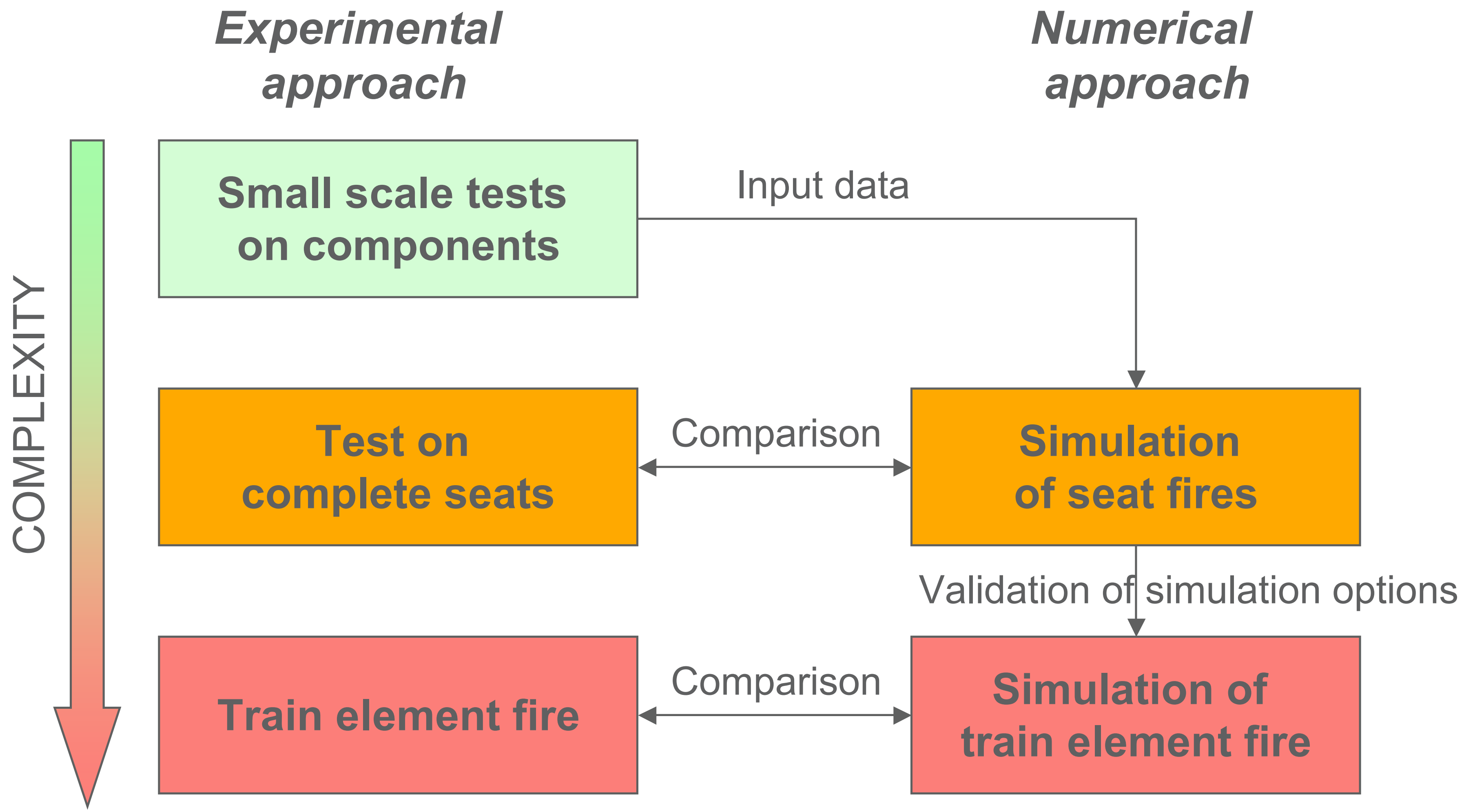
Objectives *Considerations*



Ultimate place of safety by FSE



Example validation – Case of seat fire

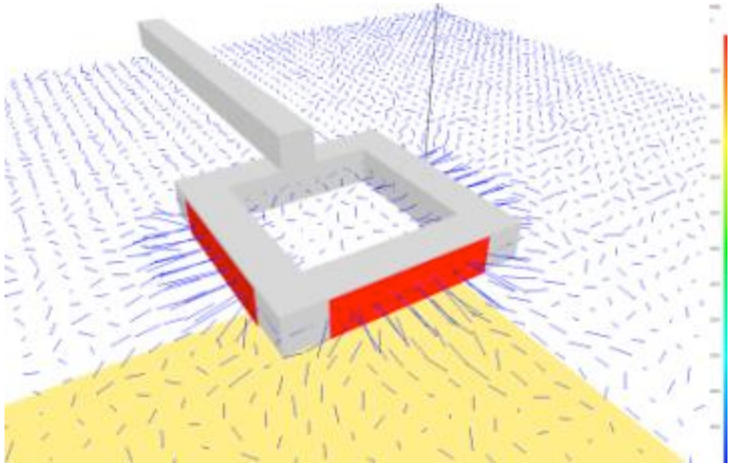


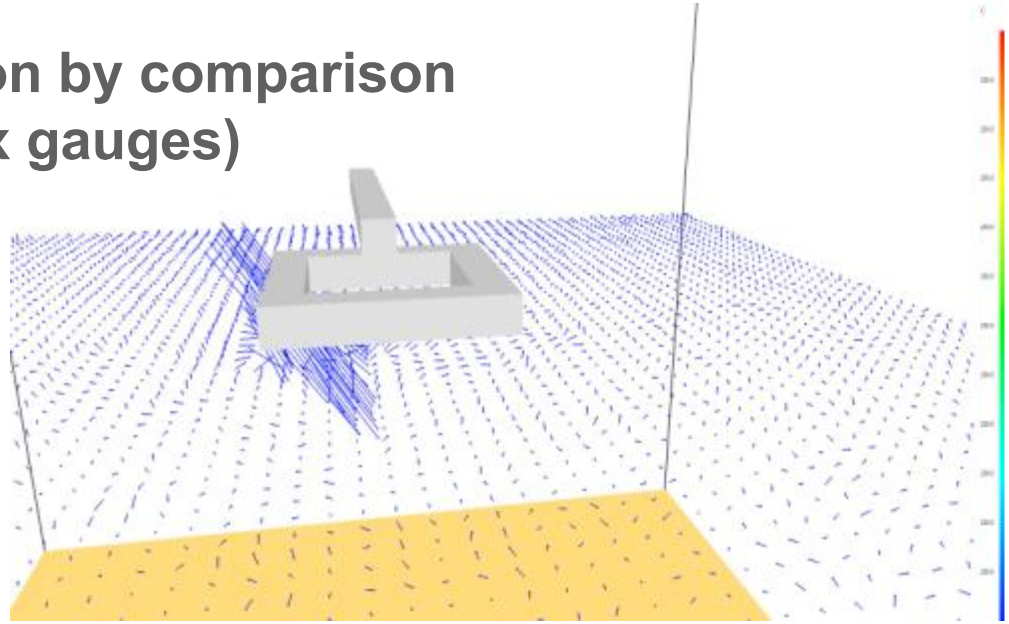
Simulation options

- Tool : NIST FDS in pyrolysis mode (for propagation)
- Technical choices and simulation options (meshes…) defined in function of needs and possibilities (calculation duration, complementary developments…)
- Reaction : selection of main material (PU), evaluation of reactions corresponding to other materials effect
- Input data set (tests, literature)

Example Burner modelling

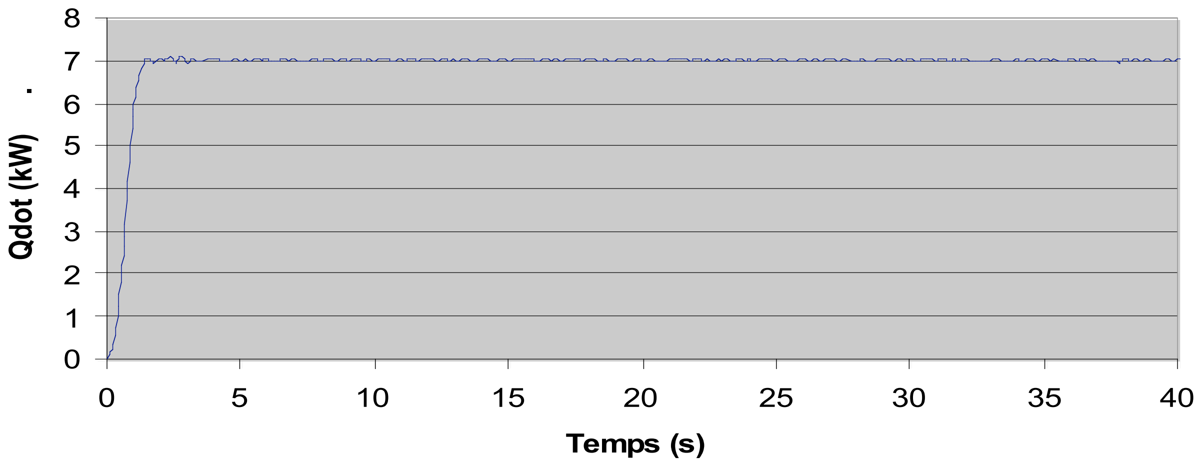
- EN 45545 Belfagore burner
- Global 7 kW HRR
- First step : global validation on HRR
- Second step : local validation by comparison with Firestarr data (Heat flux gauges)



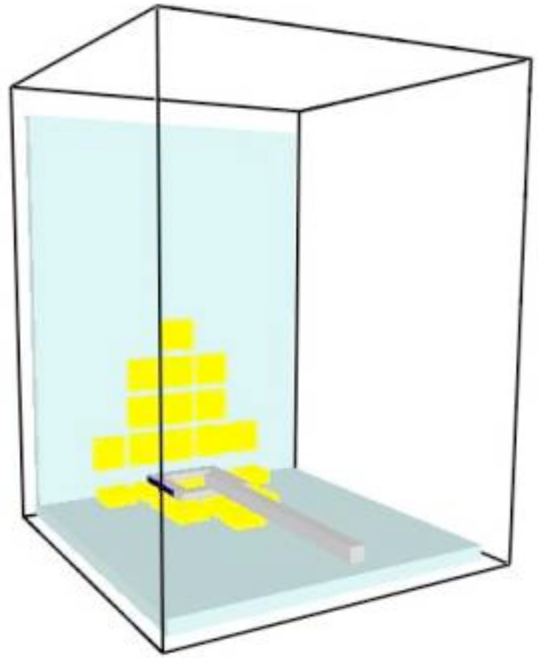


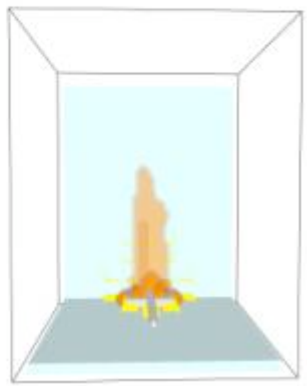
Burner modelling – global validation

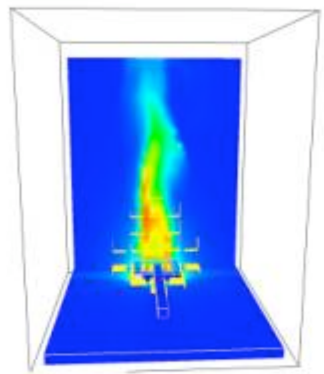
- HRR of 7 kW validated



Time (min)

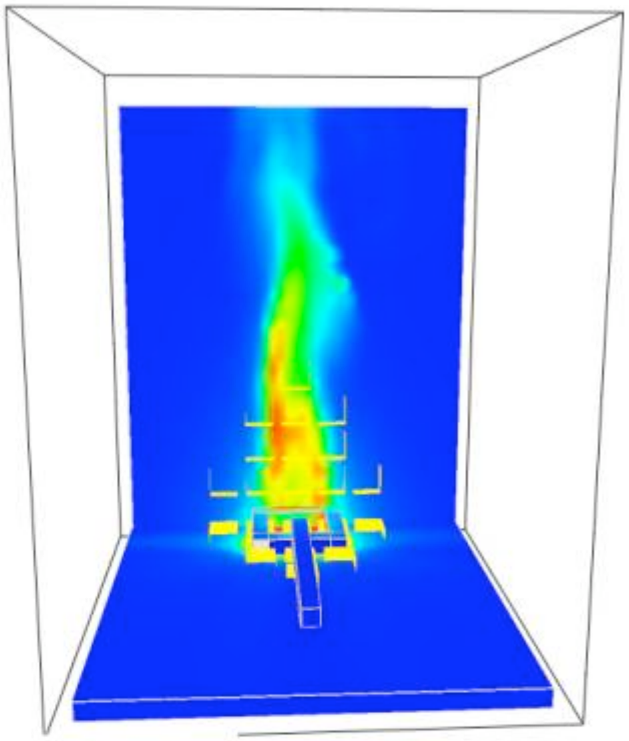






Burner modelling – local validation

- Reproduction of Firestarr test on Calcium silicate seat equipped with heat fluxmeters
- Seat back : about –20% of heat flux
- Seating : about +10%
- Sufficient agreement considering experimental uncertainties
- Trueness can be better when meshes are refined, but with non acceptable computation times

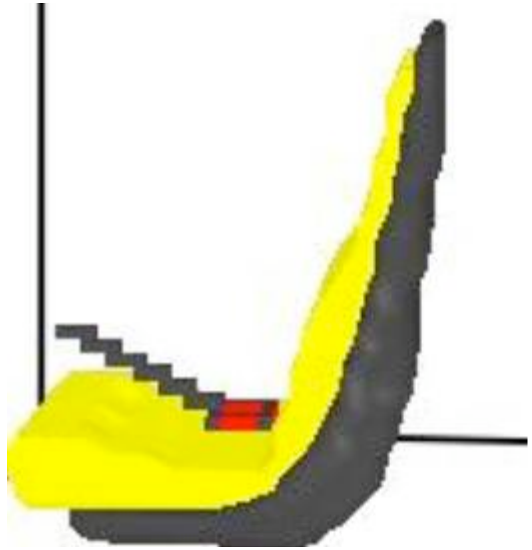


Seat modelling

- Fine modelling of a seat foam (without seat cover)

- Foam properties studied :
  - ✓ Thermal capacity and conductivity,
  - ✓ Ignition temperature,
  - ✓ Critical mass loss rate,
  - ✓ Heats of gasification and combustion…

- Modelling option
  - ✓ Disappearing of burnt elements



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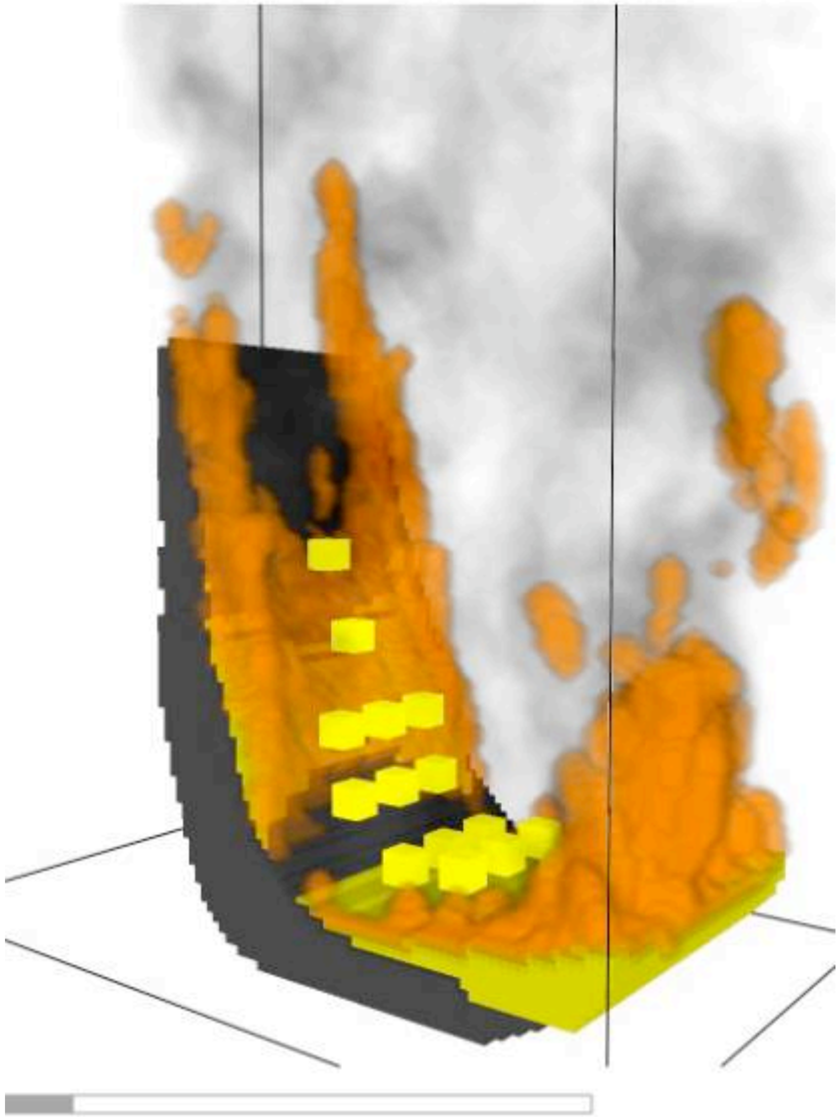
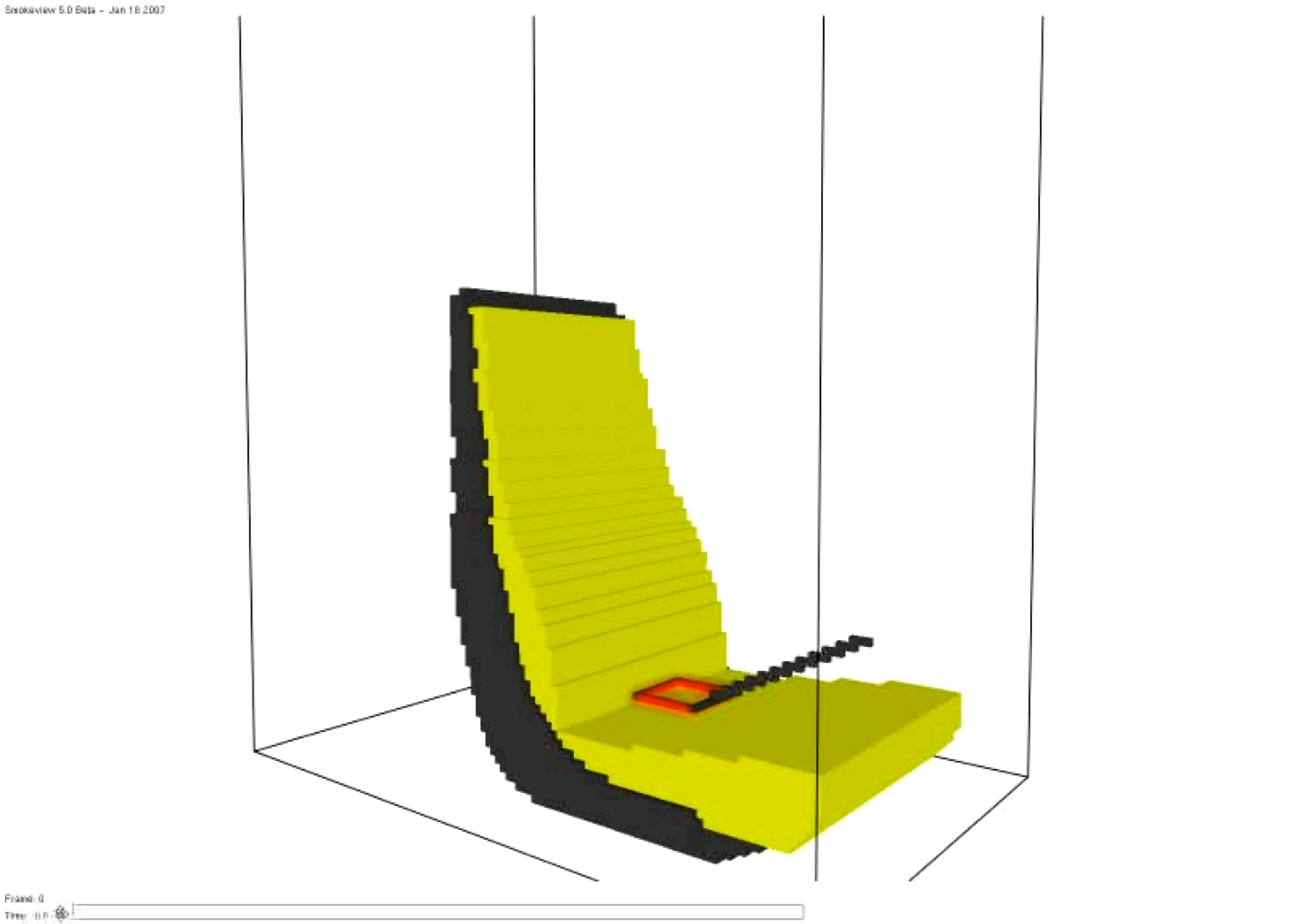
Seat modelling - validations

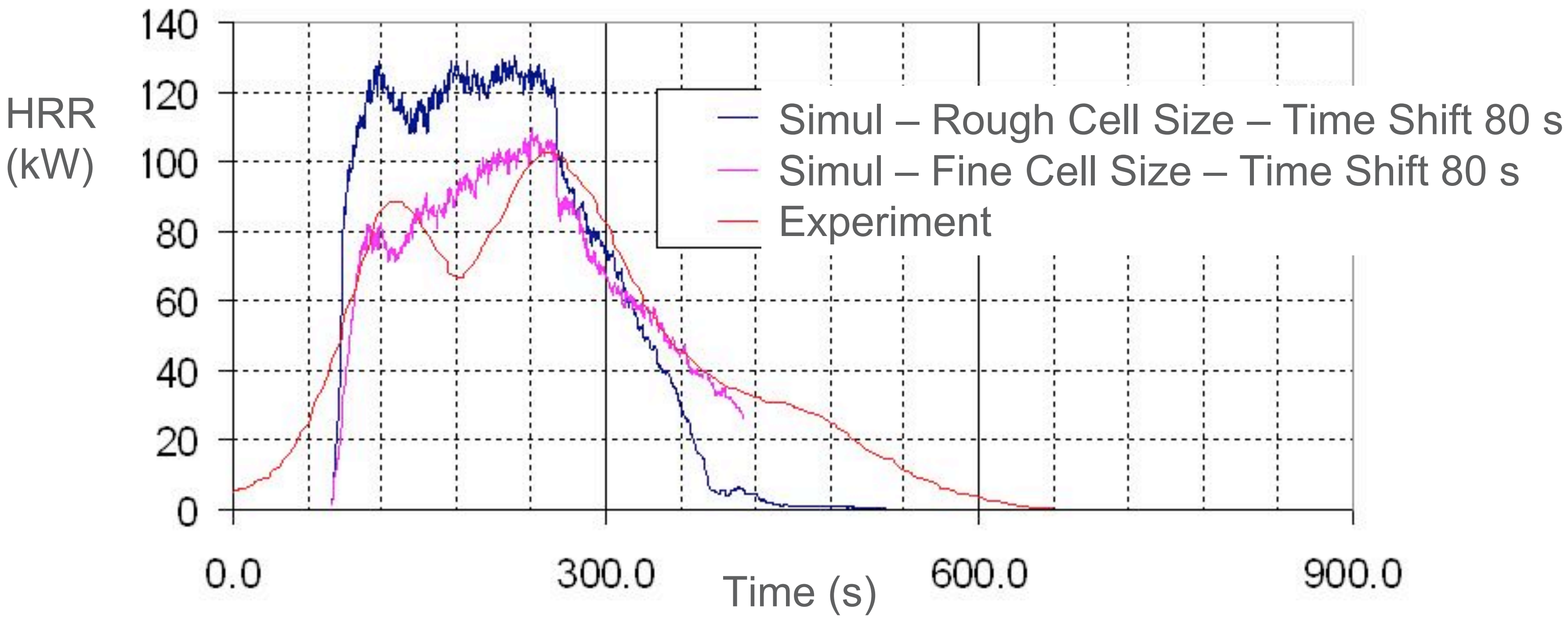
- Comparison following ISO 16730 between experiment and model

- Evaluation of sensitivity to cells size (1cm – 2 cm – 4 cm)




Smokeview 5.0 Beta - Jan 18 2007
Frame: 0

Seat modelling – validation following ISO 16730



- Use of hybrid vectorial space
- Good agreement on HRR
- Time shift (about 80 s)

Seat modelling – Explanation of time shift

- **Physical part :**
  - ✓ Response time of gas analysers (not only shift)
  - ✓ O_2 diffusion in calorimeter
  - ✓ Test uncertainties
  - ✓ Complementary experiments made on heptane showed an effect of about 40s

- **Numerical part :**
  - ✓ Effect of foam skin : bad reproduction of properties (density, thermal properties…)
  - ✓ Uncertainty on input data
  - ✓ Robustness of the pyrolysis model

- **Both effects are concomitant**

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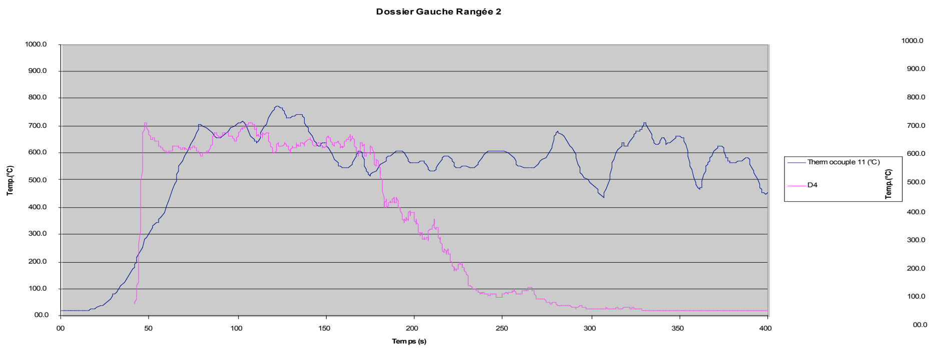
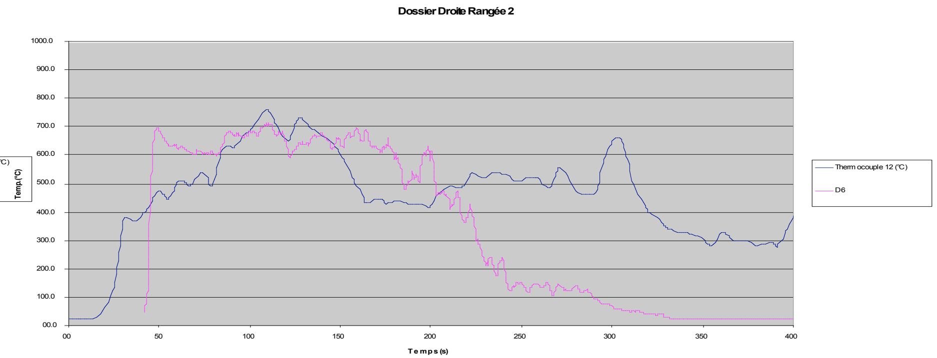
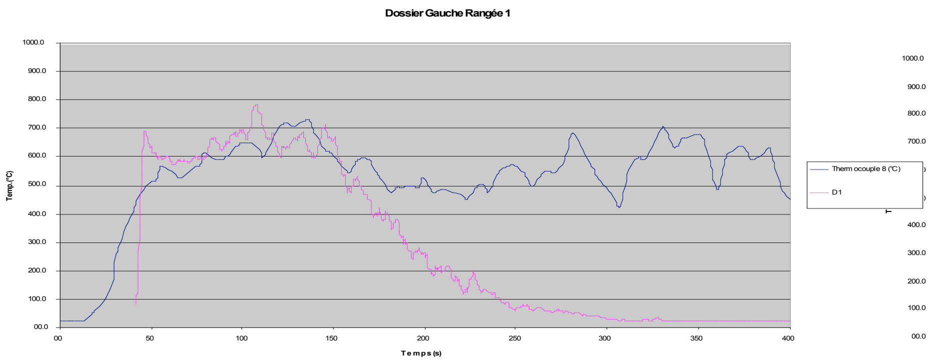
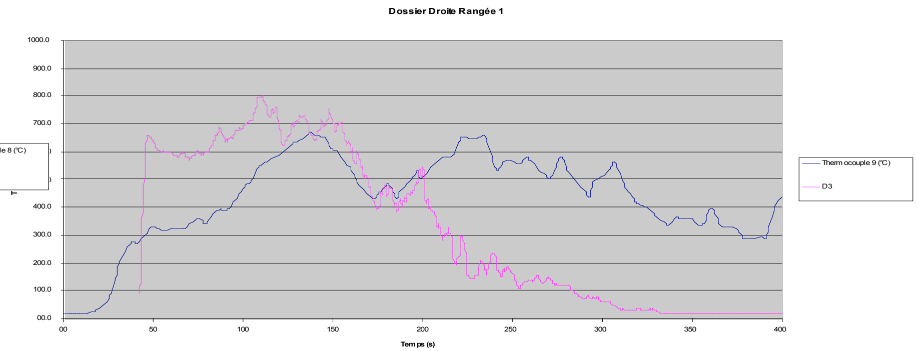
Positions on seat back









Note : virtual measurement is incorrect when cell behind TC is removed after few minutes

Seat modelling conclusions

- **Mesh size 2 cm (Rough cells size) :**
  - ✓ Too fast estimation of fire growth,
  - ✓ Small overestimation of HRR.
  - ✓ Fast calculation.

→ Adequate with FSE usage

- **Mesh size 1 cm (Fine Cells Size) :**
  - ✓ Too fast estimation of fire growth,
  - ✓ Good agreement of HRR.
  - ✓ Excessive calculation time

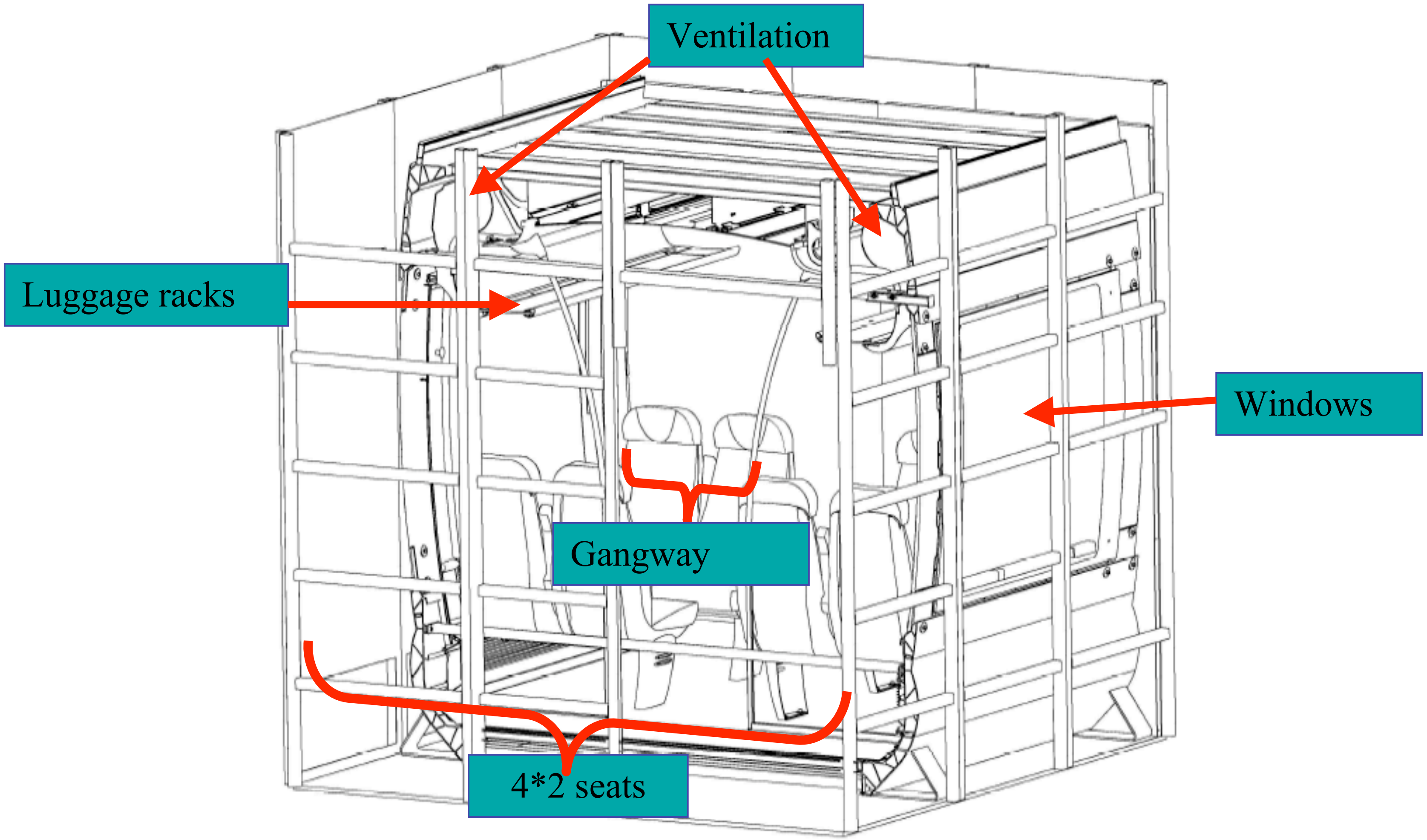
→ Adequate with forensic

- **Better agreements can be obtained through refining input data**

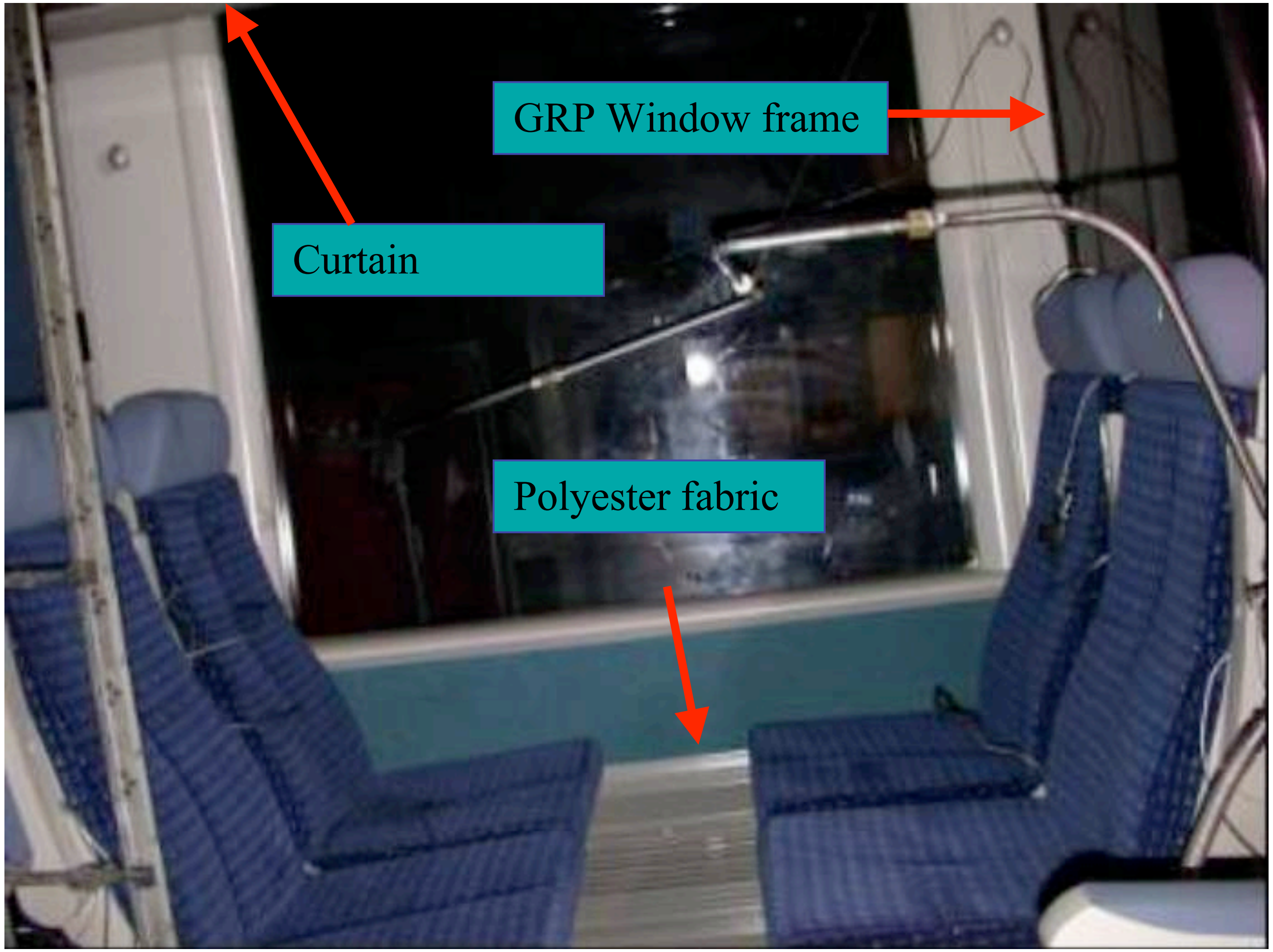
Choice of validation case (SNCF/ALSTOM/LNE study)

- Conception of railways coaches very different from Firestarr compartments
- Choice of ATER train (regional train built at more than 300 copies)
- Specificities:
  - ✓ Centralized ventilation, blown at the top of windows,
  - ✓ Aluminium structure, covered with GRP
  - ✓ Insulation with melamine foams glued on structure,
  - ✓ GRP covered with polyester fabrics
  - ✓ Floor equipped with PU elements and plywood panels
- 2 meters long slice of compartment tested

View of the element in the calorimeter structure

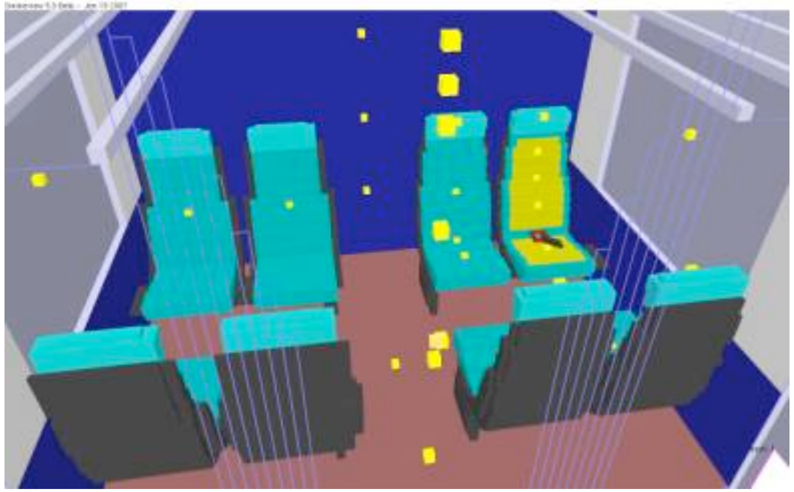


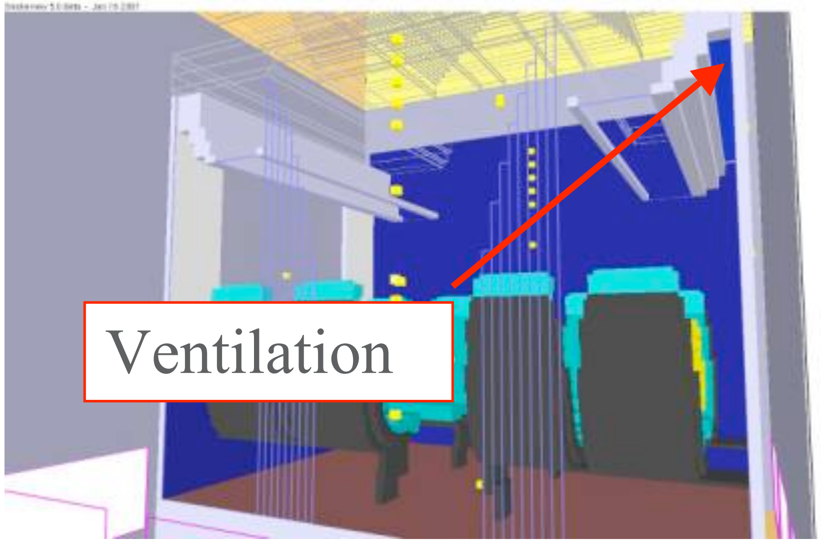
Interior view



Simulation of the test

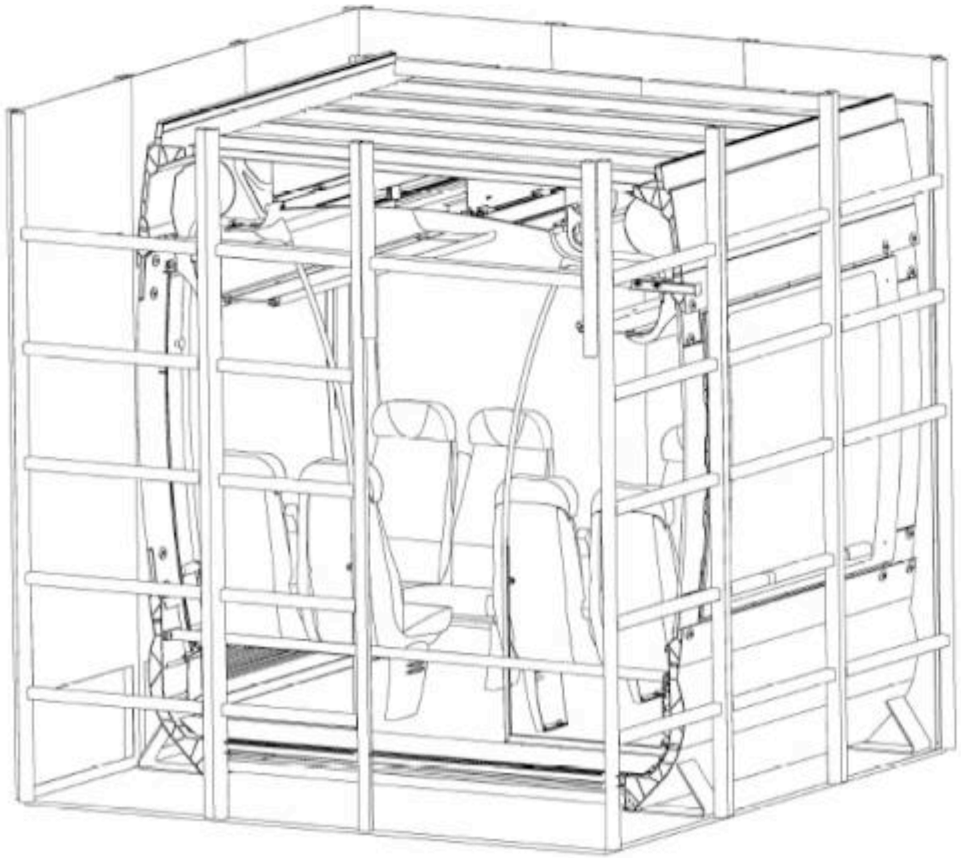
- Geometry and ventilation reproduced
- 2 cm cubic cells at the fire source location
- All materials tested for own input data
- Blind Simulation
- Many comparisons (200 sensors during tests : Heat Flux gauges, Thermocouples, air velocities, pressure, gas composition at different points…

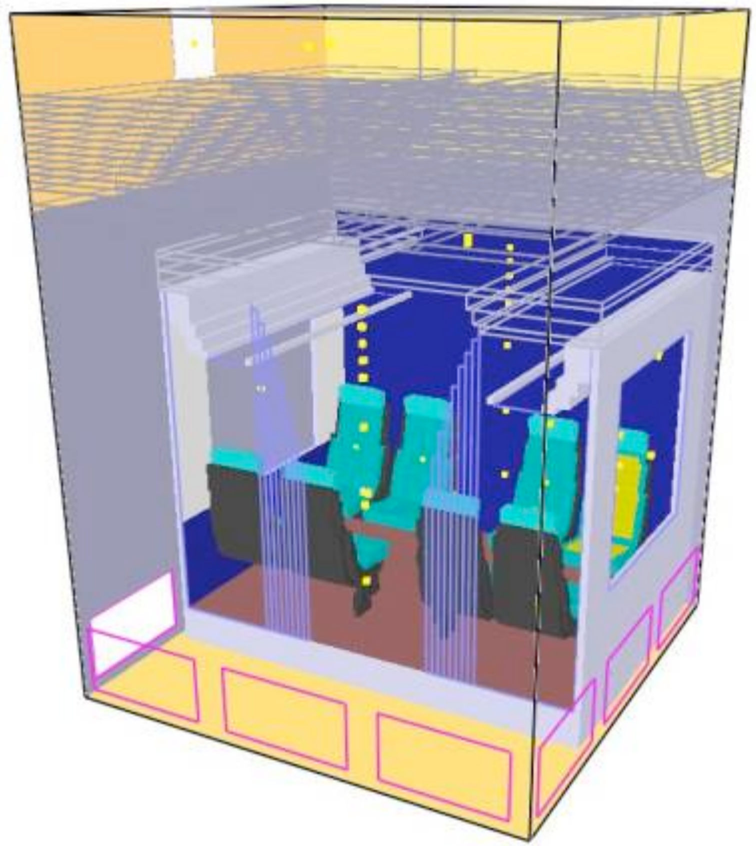




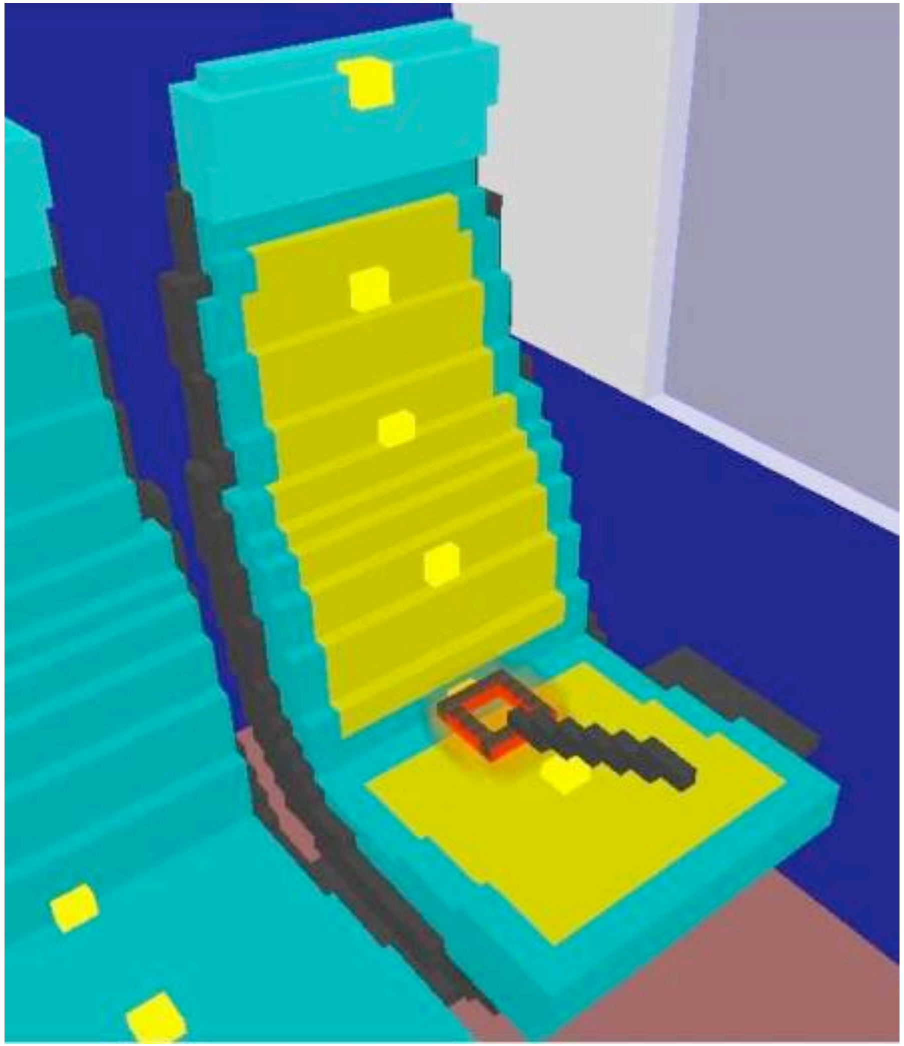
Simulation of the test

- CAD and model perspective view

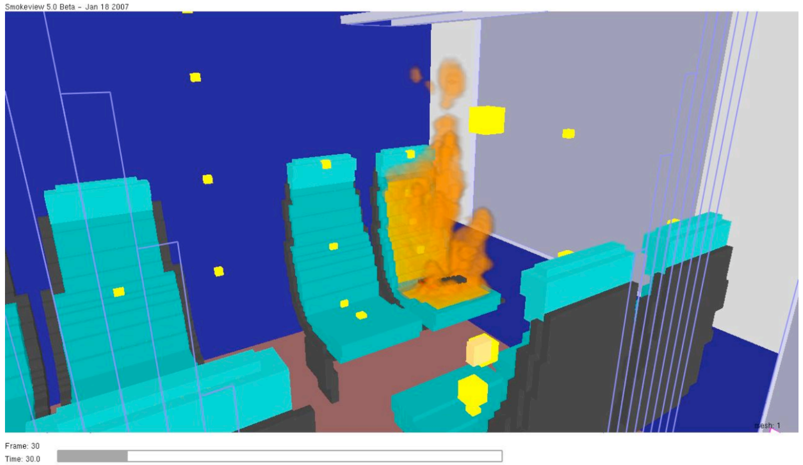




Source

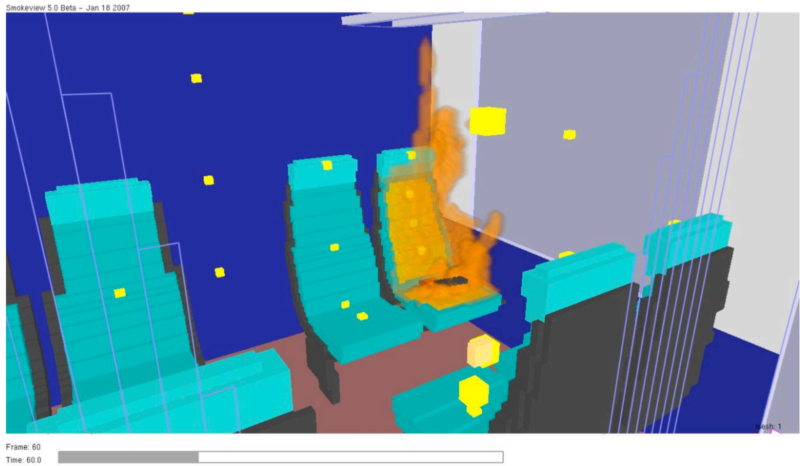


Simulation vs Test



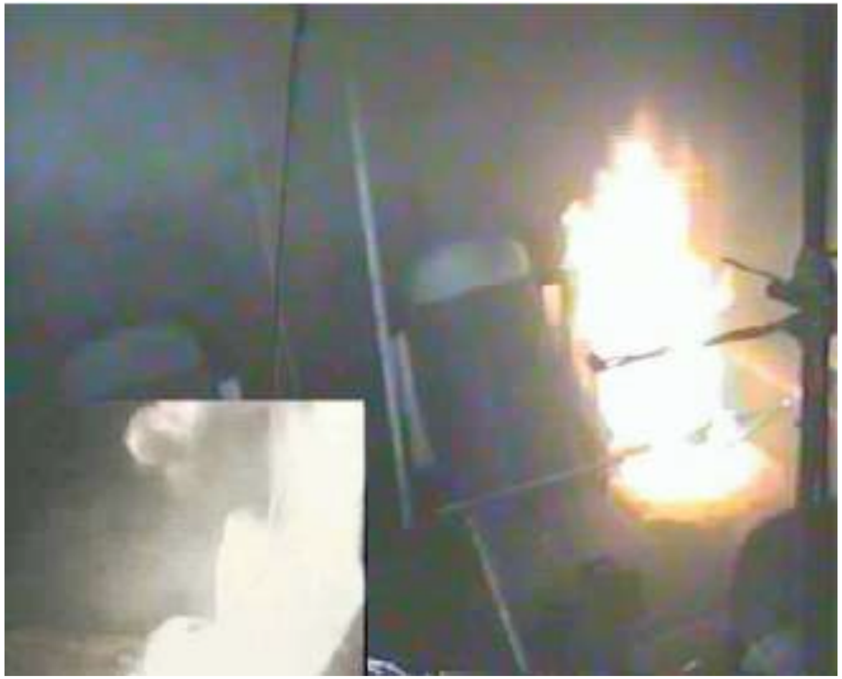
30 s

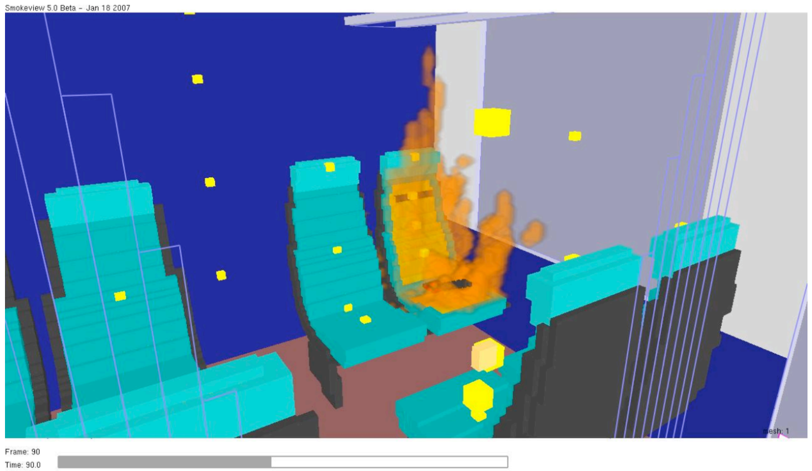
Simulation vs Test



60 s

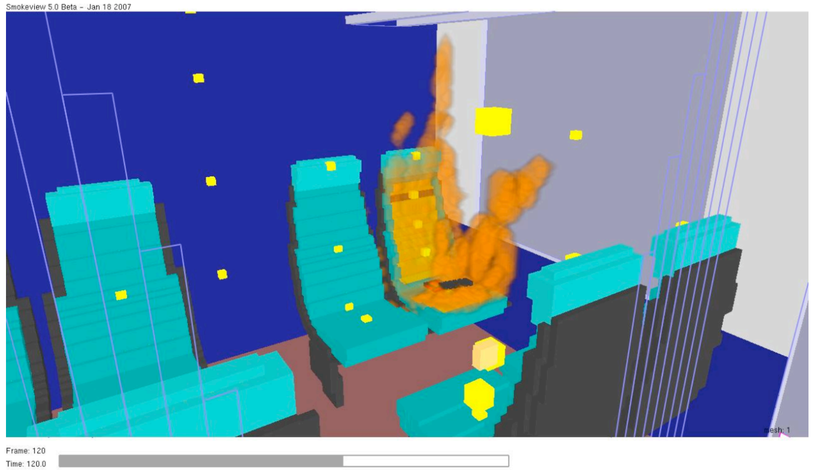
Simulation vs Test





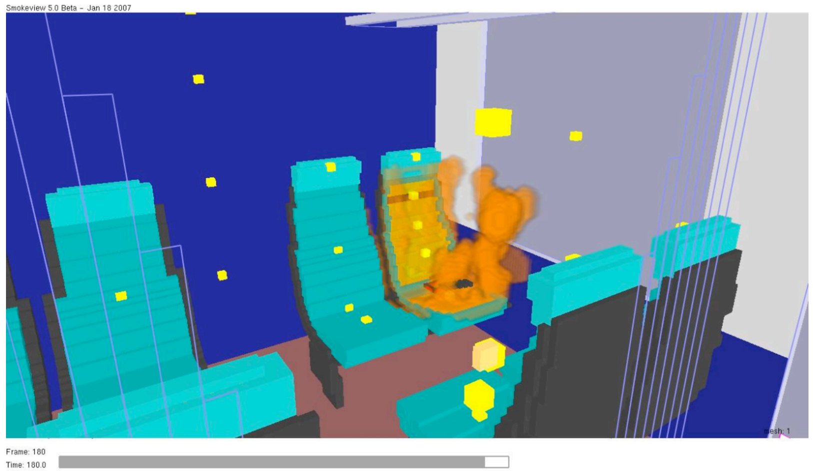
90 s

Simulation vs Test



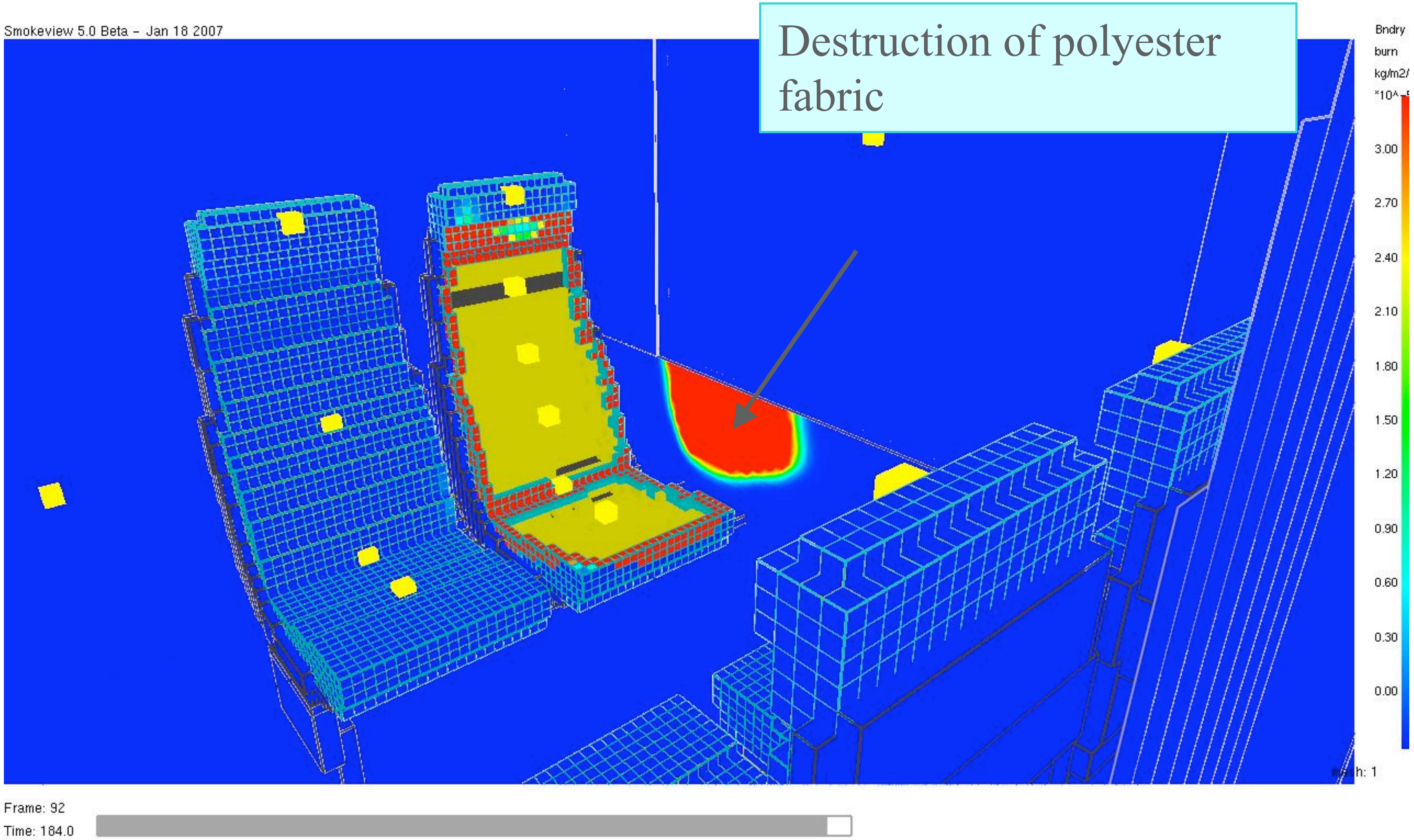
120 s

Simulation vs Test

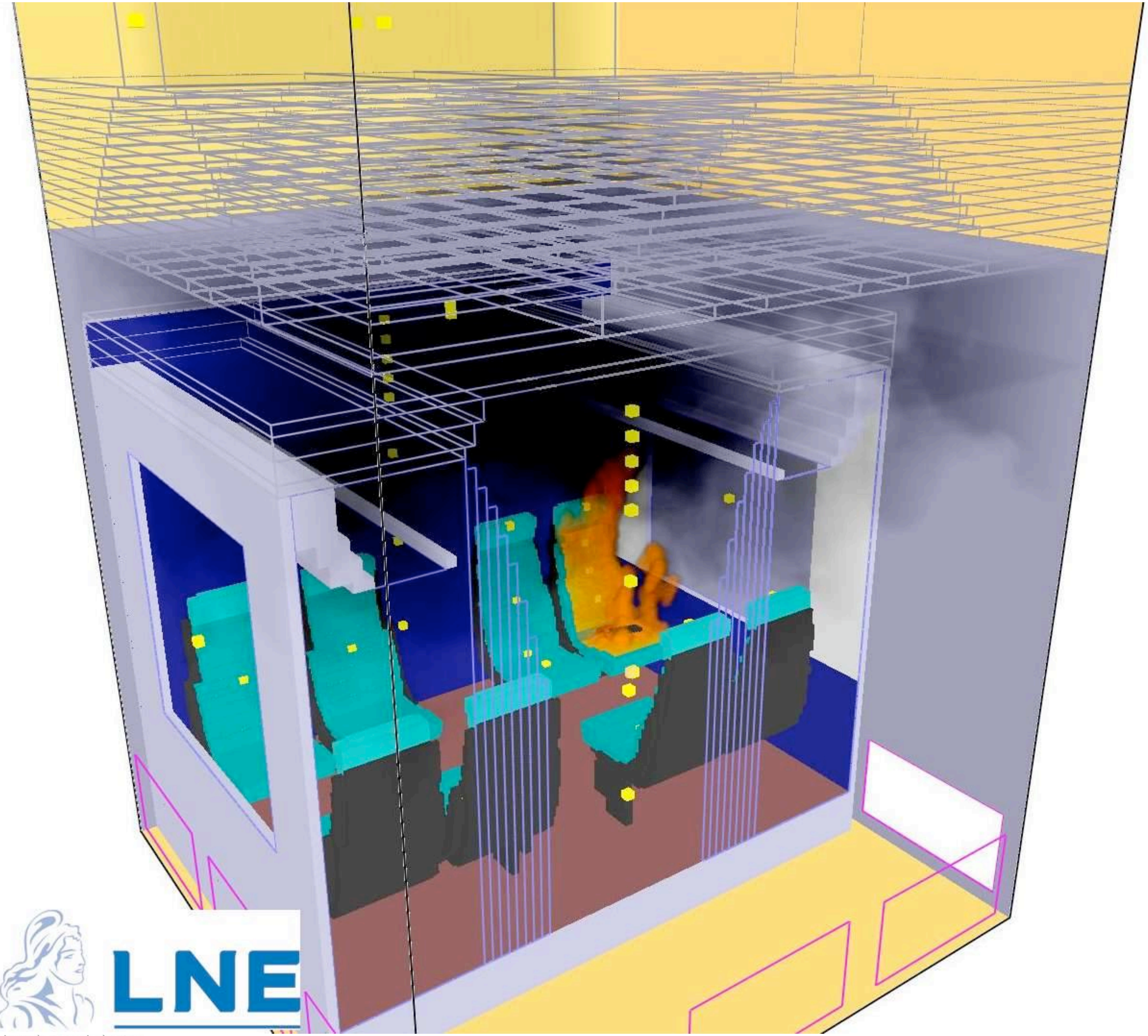


180 s (Burner removal)

Simulation vs Test



Burning Rate **(Just after burner removal, 180s)**



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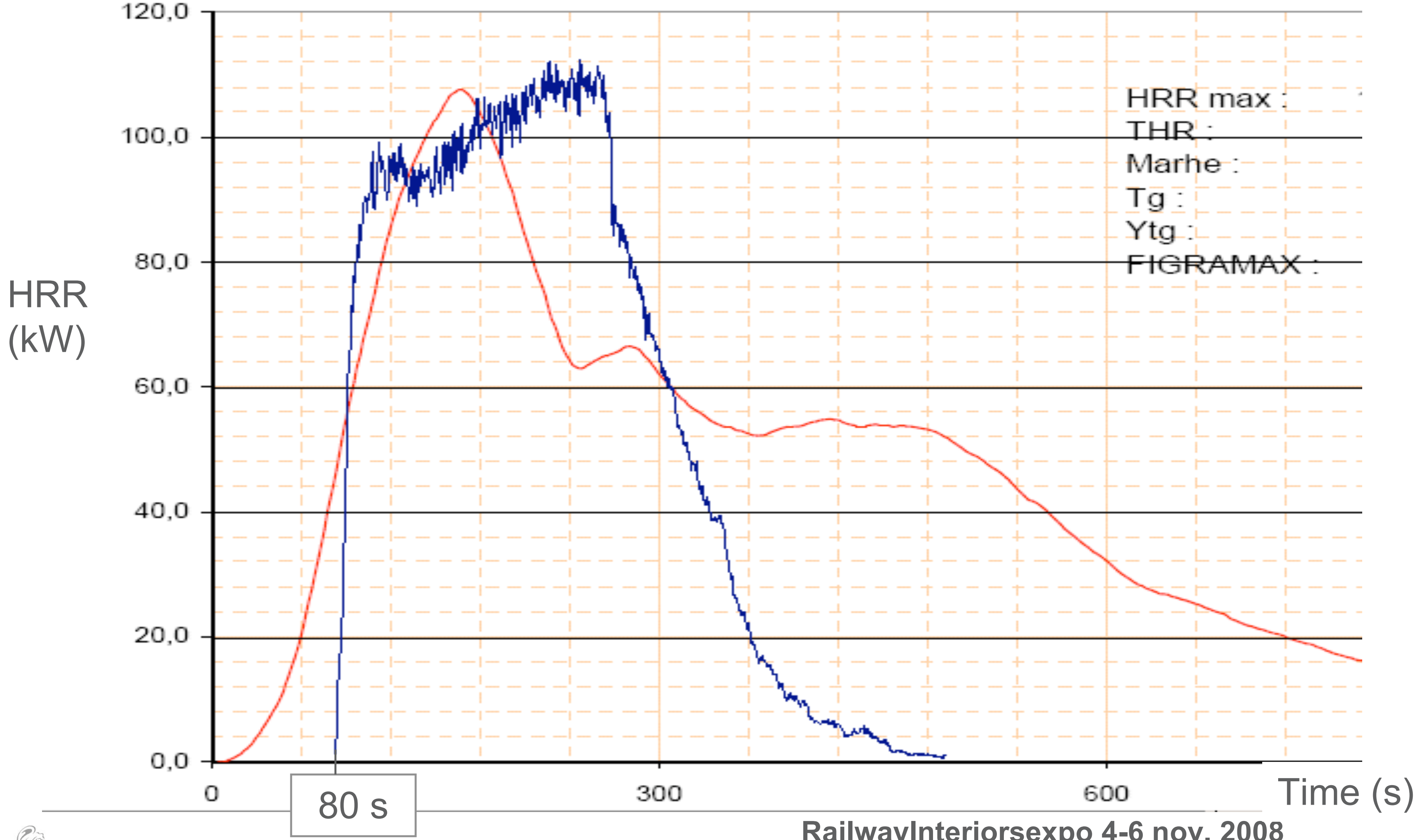
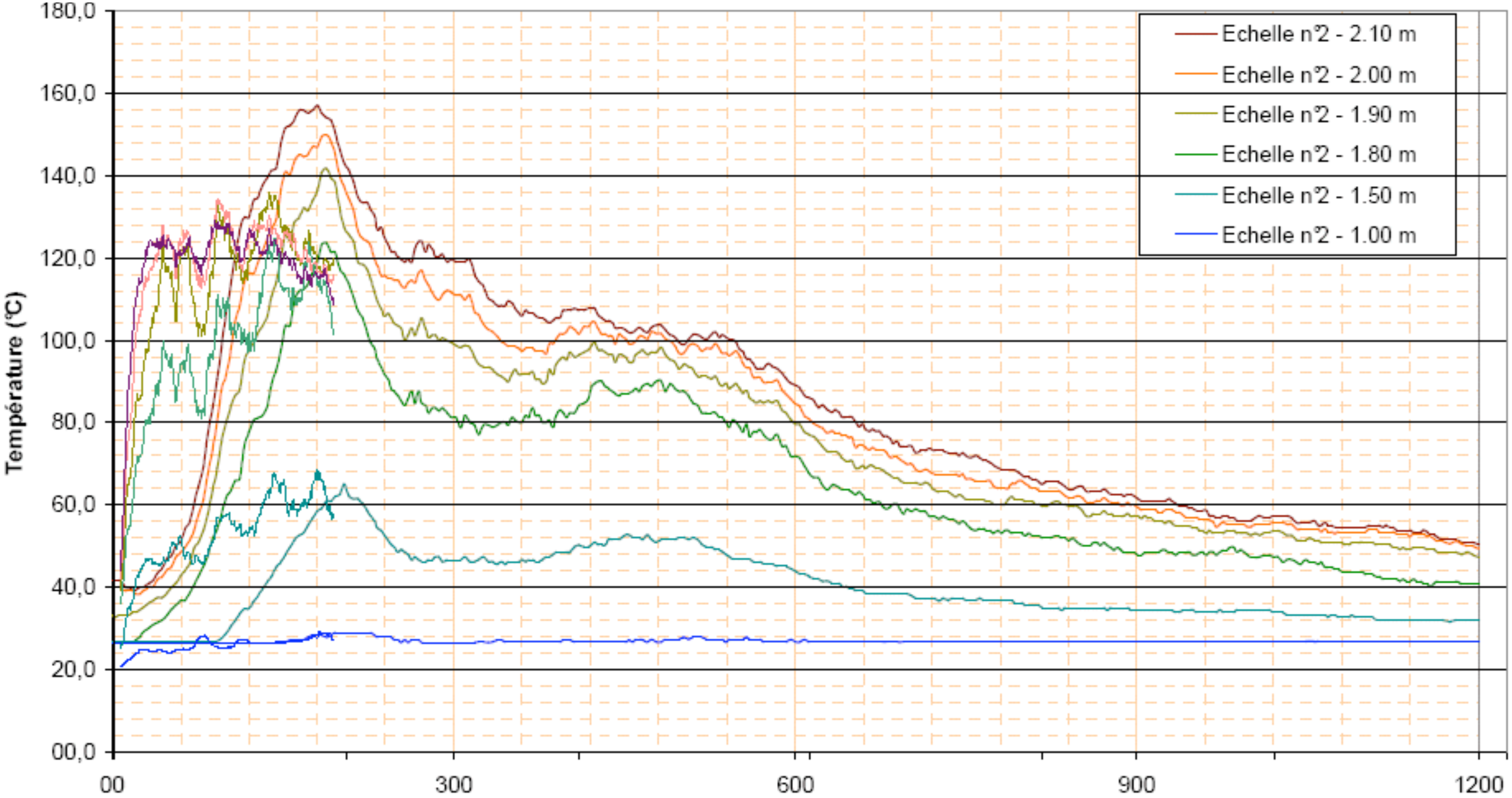
Heat released comparison (shifted)



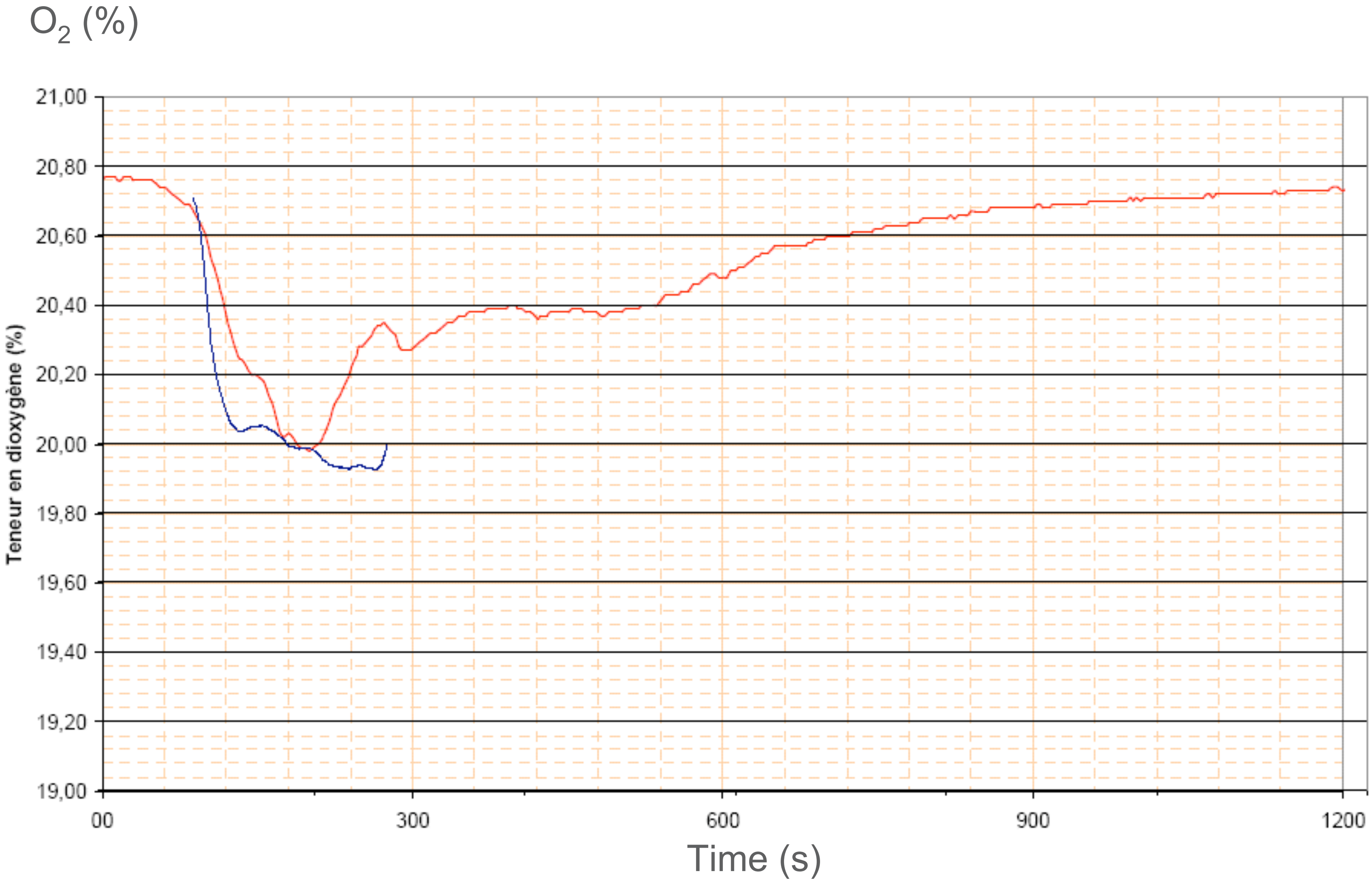
Simulation vs Test – Temperatures

Temperature (°C)



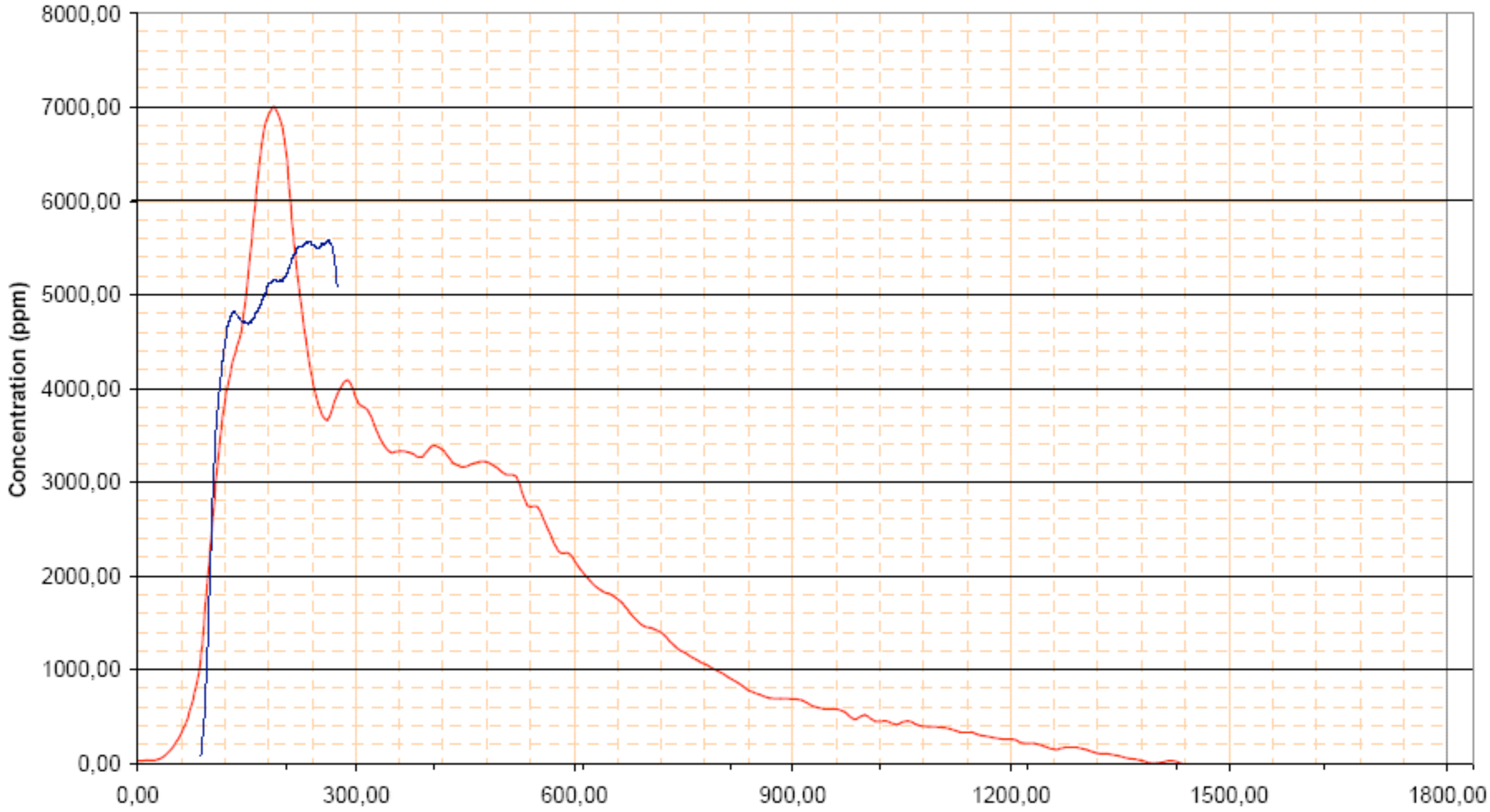
Time (s)

Simulation vs Test – O_2 concentration



Simulation vs Test – CO_2 concentration

Concentration (ppm)



Time (s)

Simulation vs Test - Comparisons

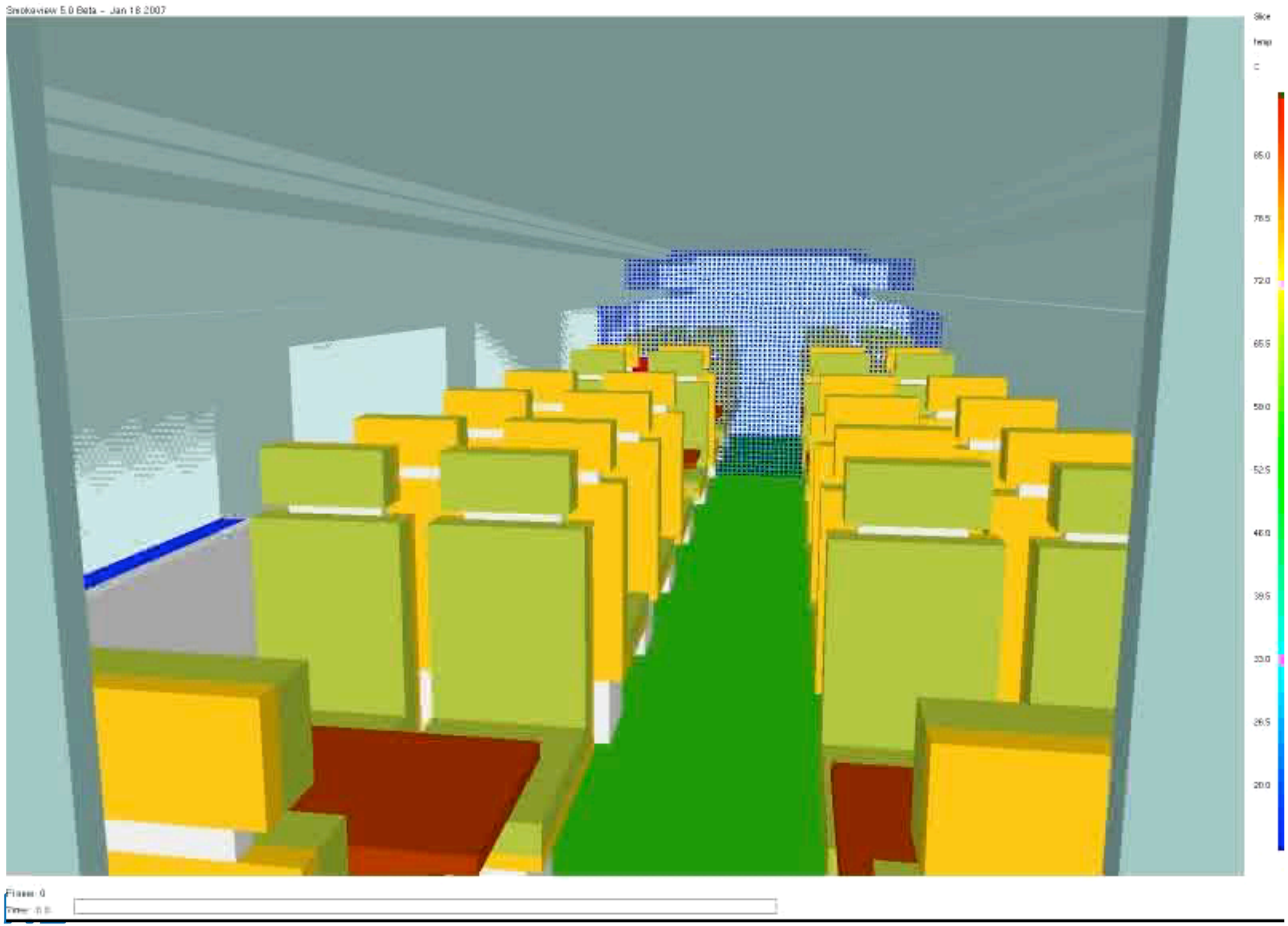
- Good agreement with levels
  - ✓ Heat released (especially max)
  - ✓ Gas concentrations in the compartment and in the duct
  - ✓ Temperatures near the source
- Less good agreement
  - ✓ Temperatures far from the source
- Same time shift than for seat : fire growth too fast

Conclusions

- FDS adapted to fire growth studies (in this scenario) :
  - ✓ For pre-dimensioning
  - ✓ For forensic, but with refinements (meshes, input data, limitation of uncertainties…)
- Input data effect is essential
- Step-by step study is needed and essential to go from "material" scale to "system" scale
- 4 years European study (7th EU Framework program), on FSE application to transportation

Example of application :

Fire growth and smoke movement on a double deck TGV



Perspectives

- Recent version of FDS (v5.2) allows a better pyrolysis model (multi-step) and the possibility to take into account skin effect on foam and multi-layered materials
- Improvements in determination of some properties (I.e. thermal properties at high temperature of foams by direct method vs diffusivity)
- Reduction of test uncertainties (fire tests : heats of gasification, combustion…)
- Development of pyrolysis model based on gas phase analyse (study)