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Focus on the experimental investigations in support of fire PSA concerning the French 1300 MWe Nuclear Power Plants

Fire PSA

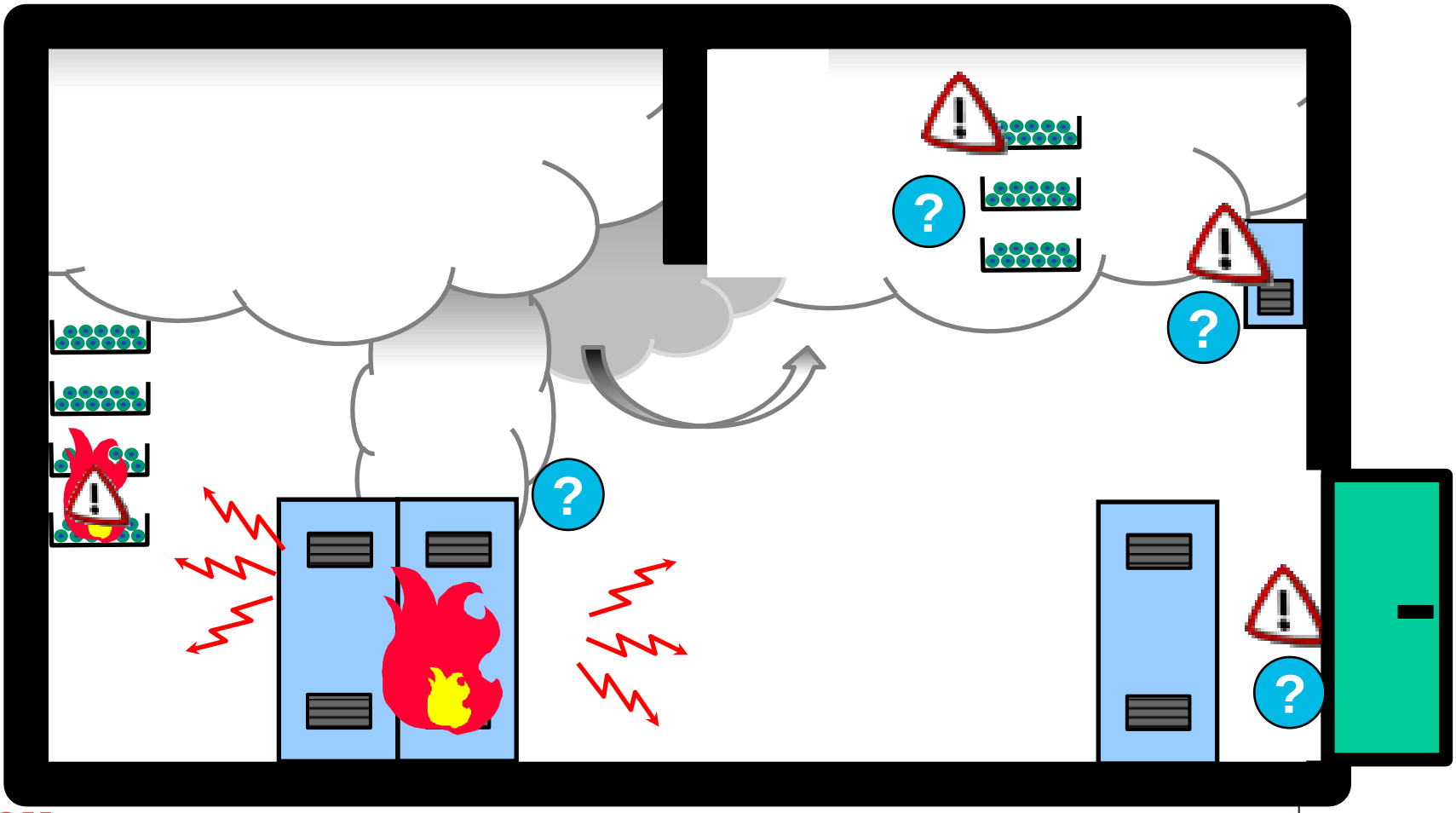
- PSA objective: assess core damage frequency
  - Event tree structure: initiating event = fire
  - Fire PSA focuses on the most critical safety equipment during fire scenarios in terms of fire-related risks
  - Need quantification of effects of a given fire scenario

- Need of support studies
  - Objective: assess safety equipment damage during a fire scenario
    - Numerous computations: time efficient method needed
    - Extensive amount of data required

Fire PSA – Support Studies - Data required

- The room data required are:
  - Room dimension and wall composition
  - Ventilation inlet and exhaust area and position
  - Electrical/mechanical component position, dimensions and fire load
  - Cable trays position, length and fire load
  - Fire protection equipment: fire dampers, detection, sprinkler…
  - Doors/openings positions and types
- The ventilation data required are:
  - Air flow-rates (inlet and exhaust) of each room
  - Leakage rates through the doors of each room
  - Pressures and air flow-rates through duct ventilation and element (fans, filter…)
- **Files provided by licensee in safety assessments don't contain all these data**
- **Plant visit requested to collect all the necessary data and provide a comprehensive building model**

Fire PSA – Support studies – Problem description



Support Studies – IRSN approach

- Data required for support studies
  - Fire characterization (HRR, growth rate, MLR, combustion products…)
  - Malfunction criteria of electrical equipment (relays, boards, switch, cables…)
  - Aeraulic response to fire effects of compartmentation device
- IRSN approach is based on experimental tests, allowing:
  - Acquisition of a general knowledge and key parameters involved
  - The set up and validation of numerical models
  - The definition of failure criteria

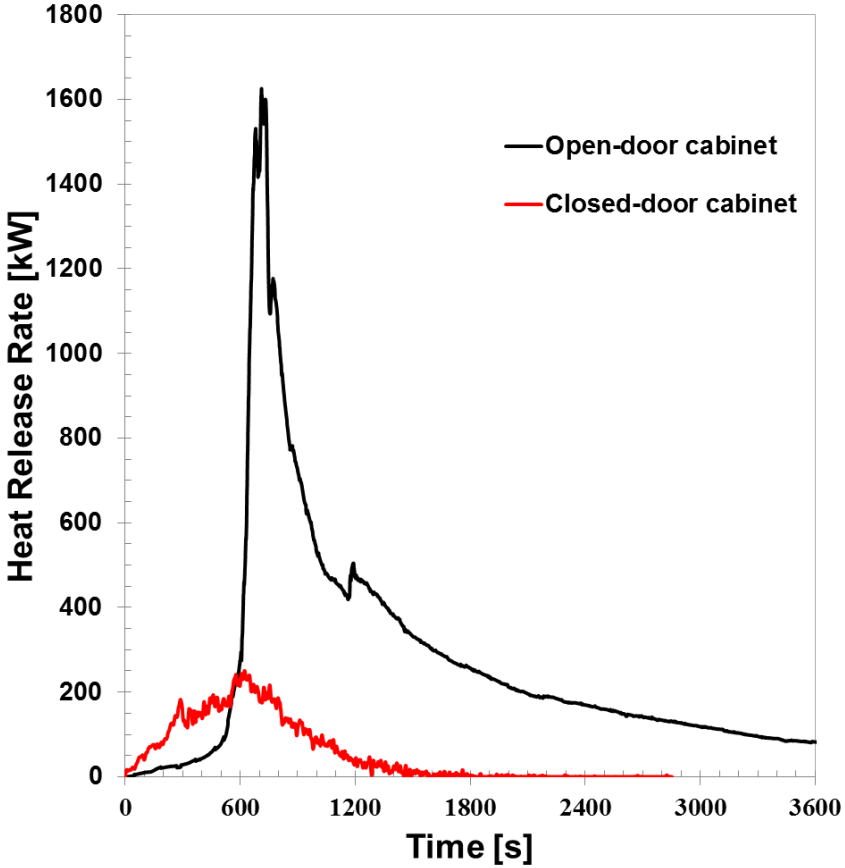
Electrical cabinet fire characterization

- Experimental tests on the behaviour of an electrical cabinet fire with open or closed doors: PICSEL_A and CARMELO programs
- **Programs objectives:**

  Characterize the behavior of an electrical cabinet fire in free atmosphere

- Experimental setup: SATURNE hood
- Data obtained:
  - Mass loss rate
  - Fire heat release
  - Heat flux emitted by the fire
  - Amount of gas and soot produced

Electrical cabinet fire characterization



During fire

Post fire

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Damage criteria – Electrical device malfunction

- Experimental tests on the behaviour of an electrical relay board under thermal stress: CATHODE program
- **Programs objectives:**

Getting further information about malfunction of electrical equipment during a thermal stress

- Experimental setup: SIROCCO furnace
- Data obtained:
  - Malfunction ambient temperature

Damage criteria – Electrical device malfunction

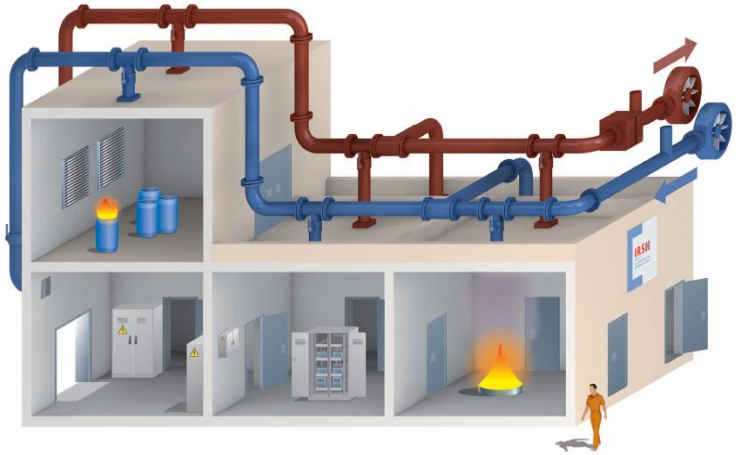
- Experimental tests on the behaviour of an electrical relay board exposed to the effects of a real fire: CATHODE_SUIES program

- **Programs objectives:**

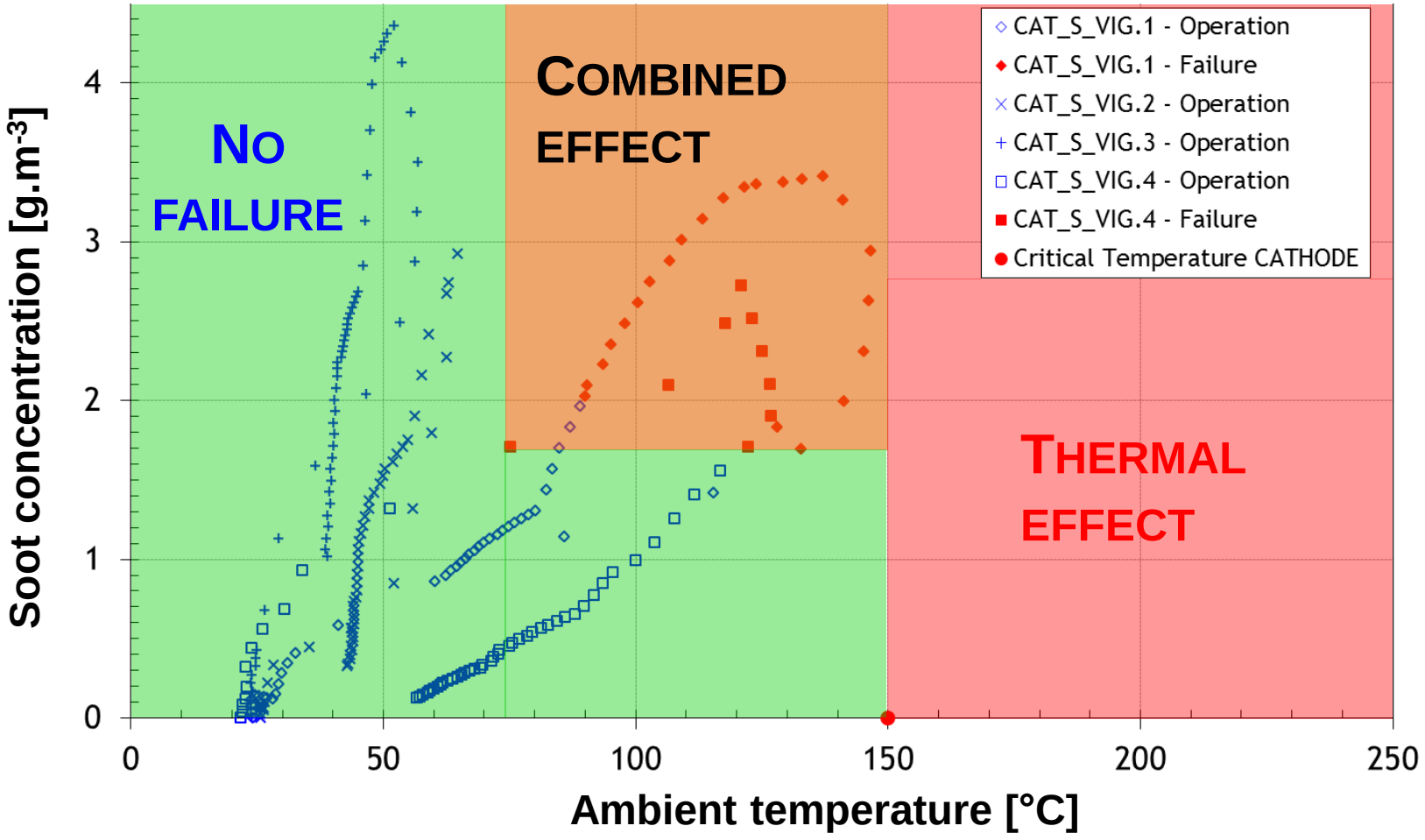
  Investigating the malfunction of electrical equipment due the effect of soot released during a real fire

- Experimental setup: DIVA facility
- Data obtained:
  - Malfunction ambient condition

    (gas temperature and soot concentration)

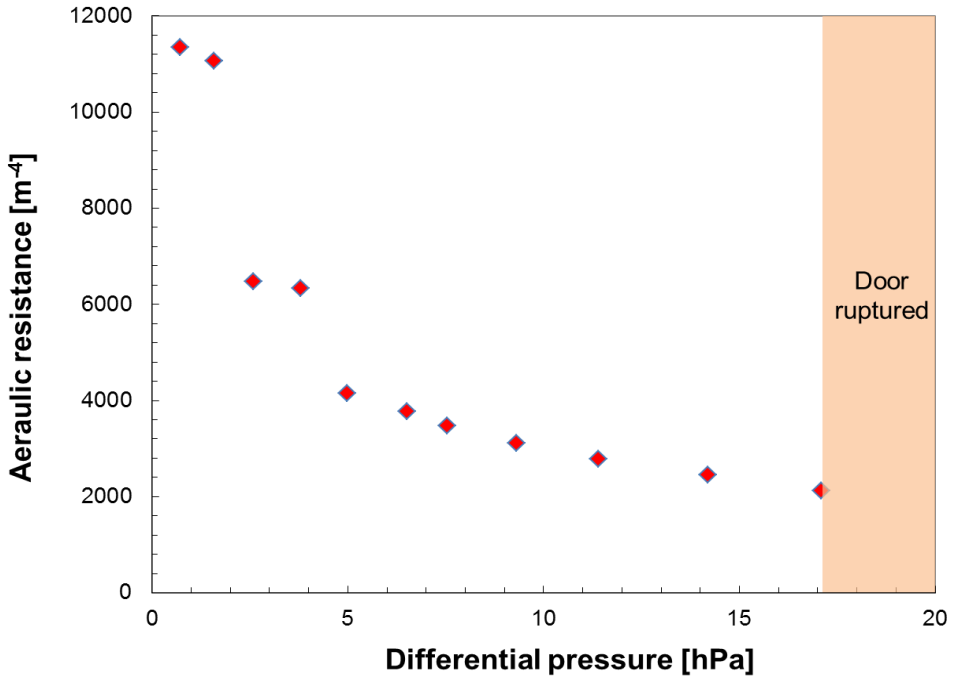


Damage criteria – Electrical device malfunction



Aeraulic resistance and rupture threshold

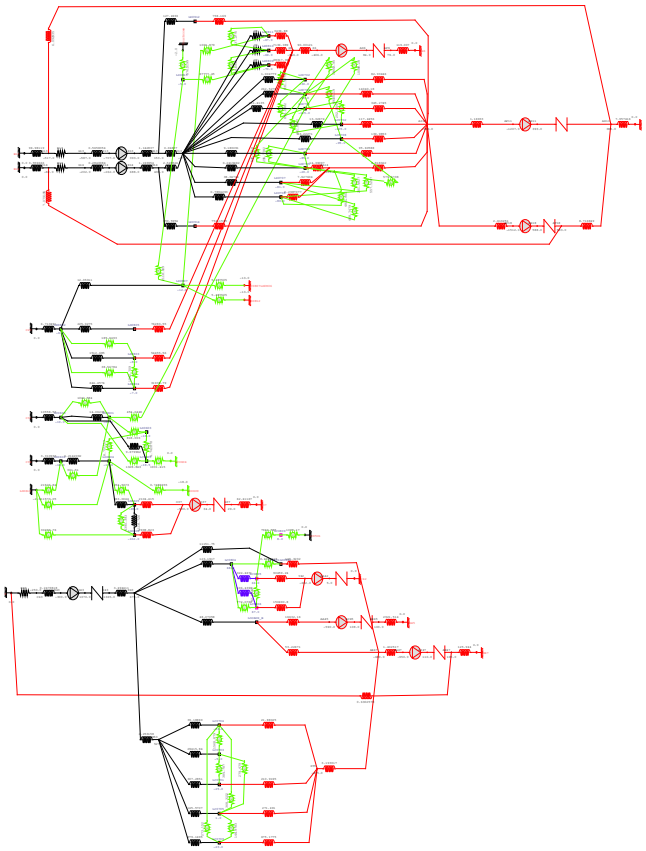
- STARMANIA aeraulic loop facility
- Aeraulic resistance determination $(\Delta P = f(Q_{leak}))$
- Temperature and humidity control



Numerical Tools

The SYLVIA software system, developed by IRSN, simulates the consequences of a fire in an industrial facility featuring a ventilation network

- It calculates the development of the fire, the transportation of hot gases and the damage of isolating equipment such as firebreak doors and fire dampers
- Modelling of the fire is a zone-based approach: the volume of each room is divided into two zones of variable height in which the thermodynamic properties (pressure, temperature and concentration of species) are uniform
- The ventilation network is modelled using a set of elements, conduits, valves, fans, etc. Mass and heat exchange correlations (between zones, flames and walls) supplement the mass and energy balance equations for the zones

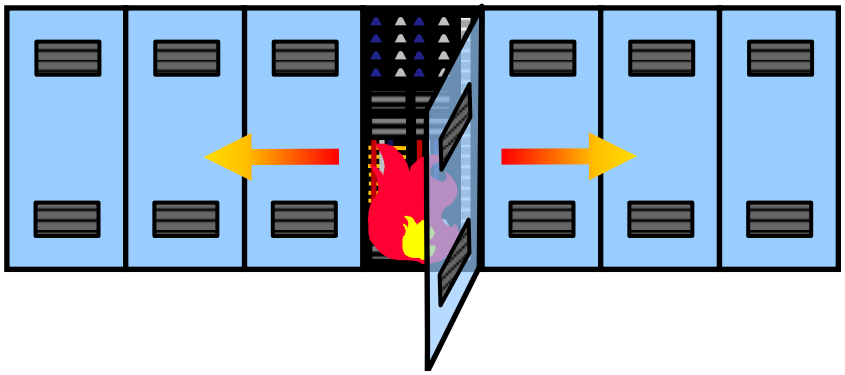


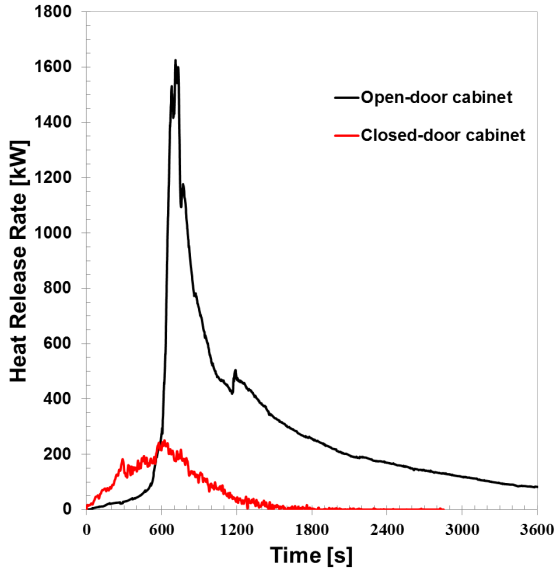
View of a full building model (SYLVIA)

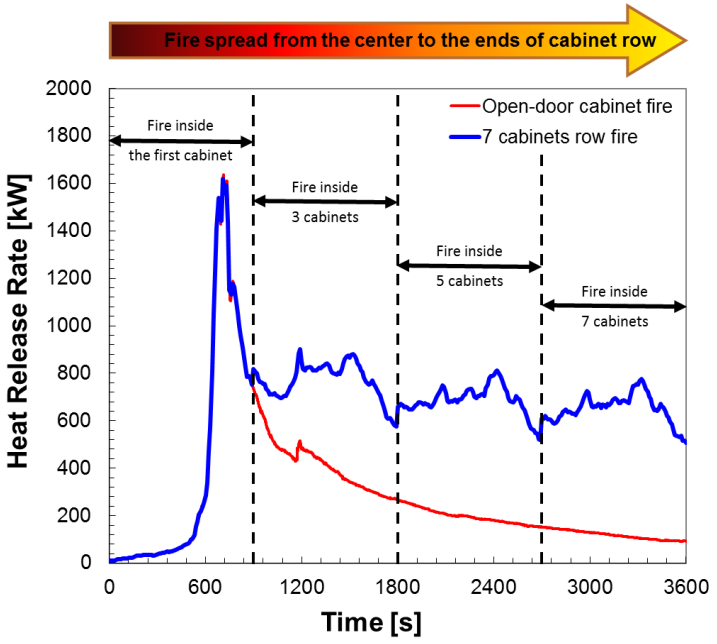
➡ SYLVIA allows to develop a whole building model

Fire modeling – fire of an electrical cabinet row

- Transition from a cabinet to the adjacent one
  - NUREG 6850
    - propagation assumed after 15 min
- HRR input built by stacking the HRR at propagation times







Conclusion

- With the combined use of SYLVIA software and experimental tests, a comprehensive method to perform studies in support of a fire PSA was developed
  - Simple and conservative approach for modelling electrical cabinets row
  - Comprehensive building model: allows to investigate multi-compartments scenario (door leakage and/or opening…)

- Pending and future works
  - Expansion of knowledge regarding cable trays fire (both in open atmosphere and confined configuration)
  - Development of a semi-empirical cable tray complex fire model
  - Setup of a dedicated experimental device to further investigate the soot/thermal stress on malfunction of electrical device