HSE
Occupational Health & Safety and Environmental Protection unit

FEMTC 2020
Evacuation analysis of a large experimental cavern of the CERN accelerator complex

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Outline

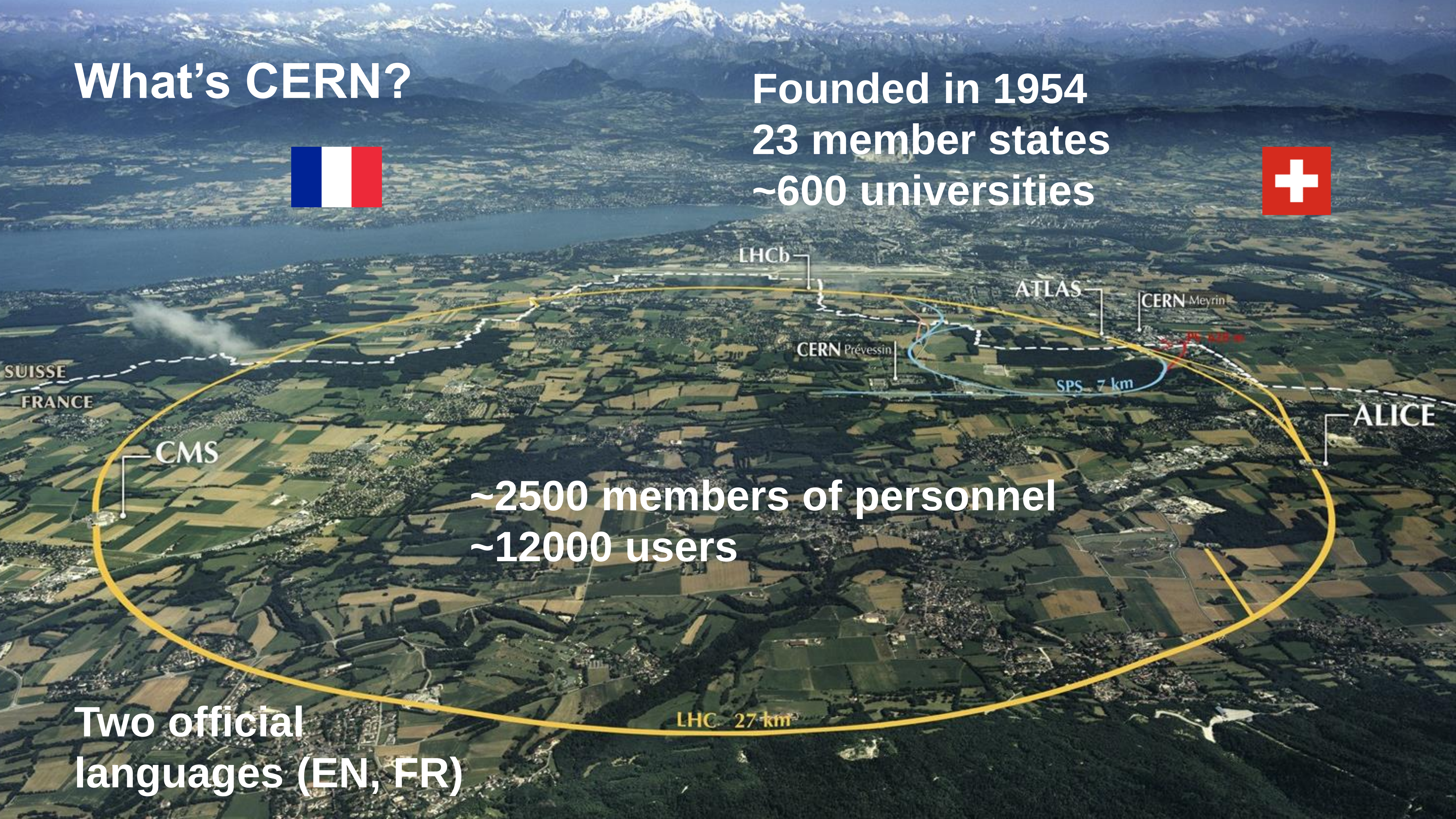
- Introduction to CERN
- Case study
  - Description of the facility
  - Description of the Pathfinder model
  - Results
- Conclusions

What's CERN?

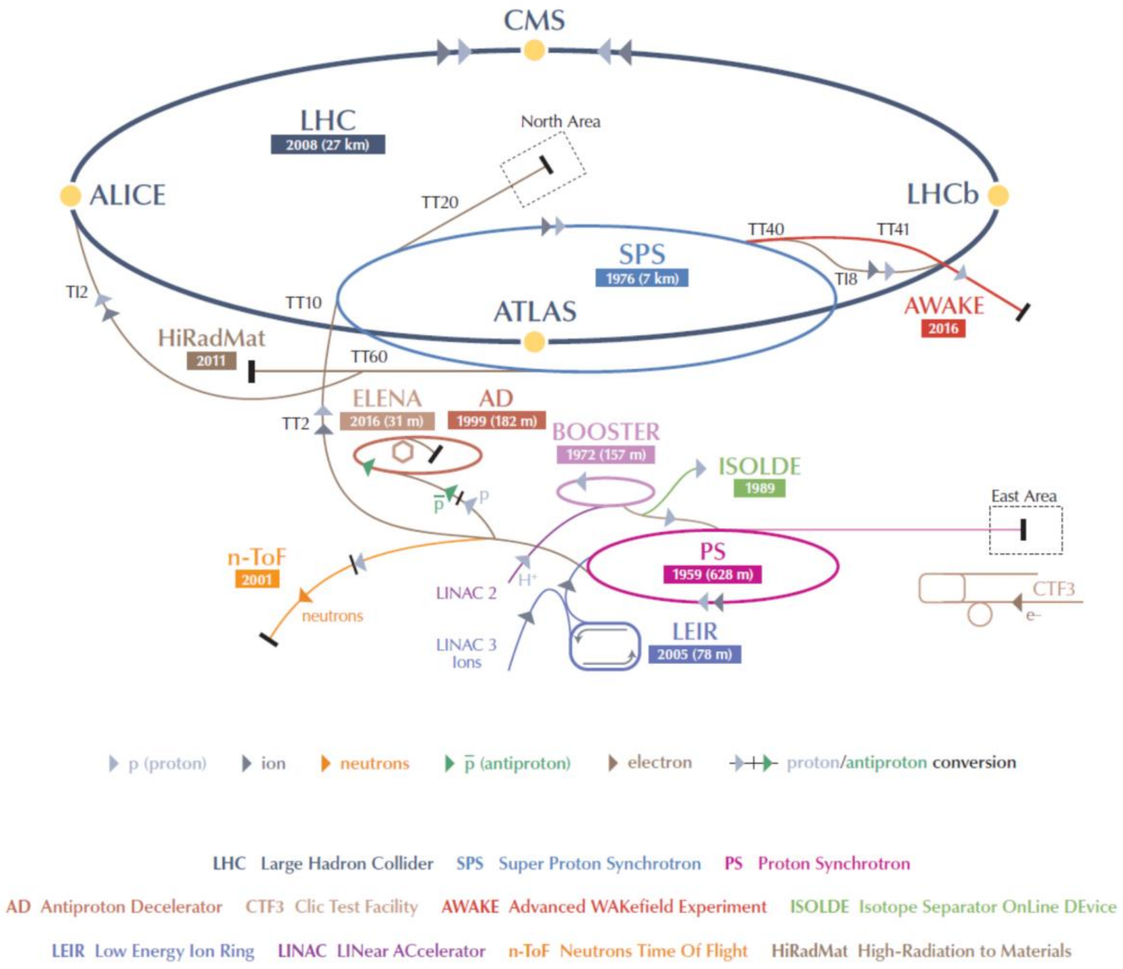
Founded in 1954
23 member states
~600 universities

~2500 members of personnel
~12000 users

Two official languages (EN, FR)



Some key figures



- 45 km of accelerator tunnels
- Radioactive and chemical laboratories
- Workshops
- 60 access points
- 160 experiments
- 800 buildings
- 19’000 installations
- 3 hotels
- 1 nursery

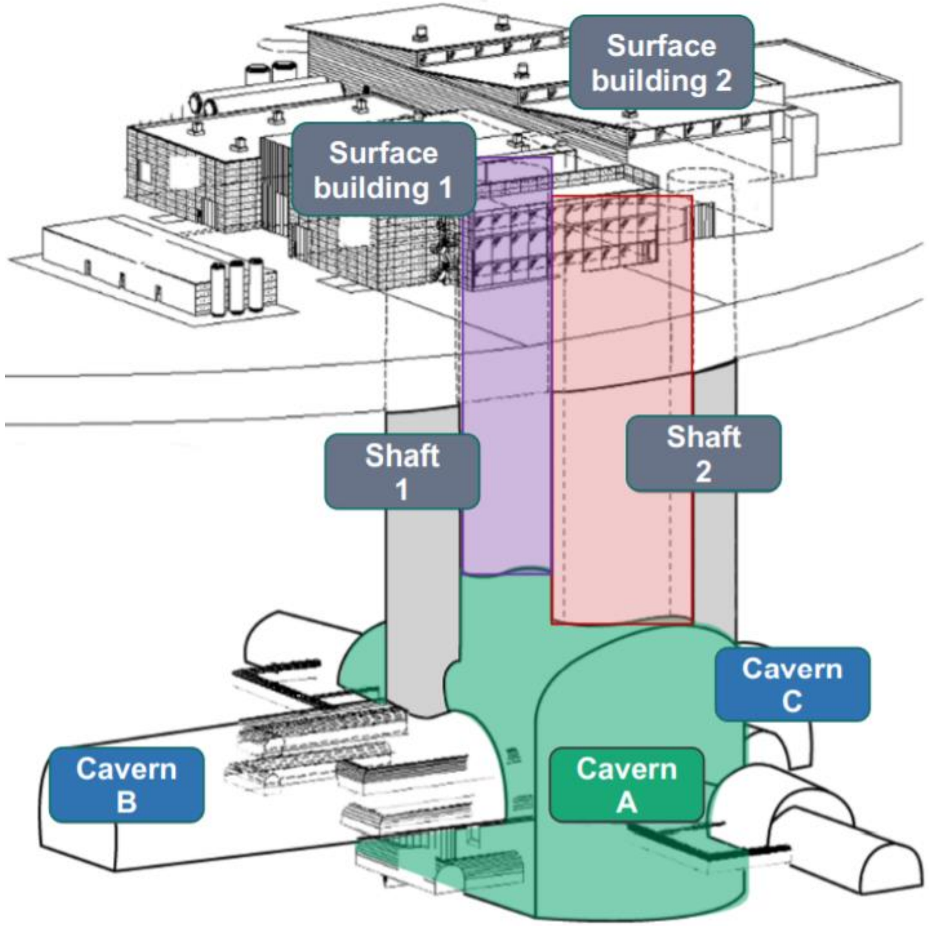
FIRIA project

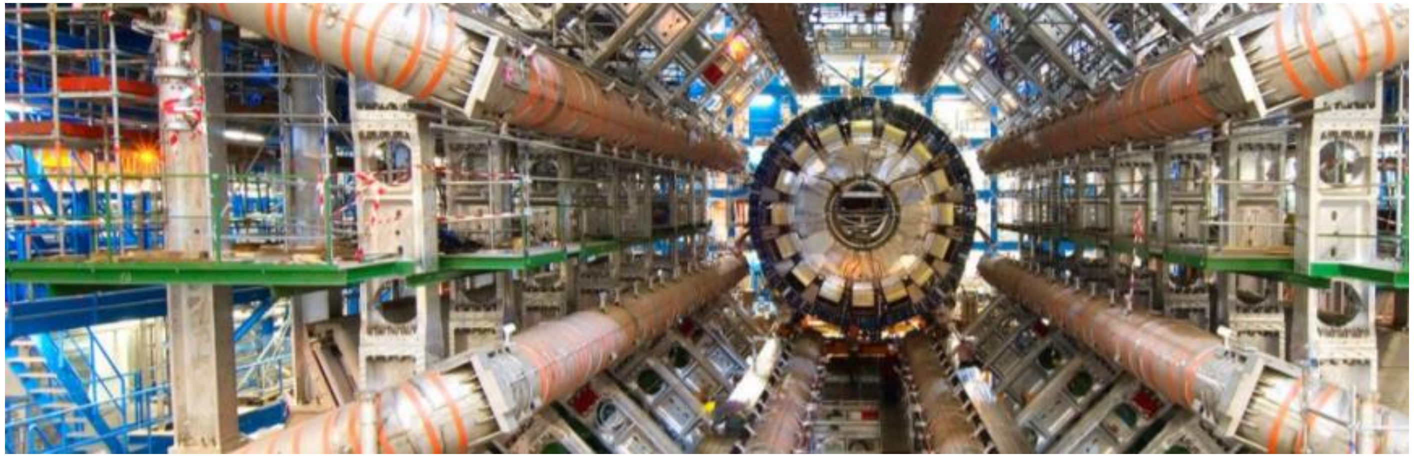
This study was carried out in the framework of the Fire-Induced Radiological Integrated Assessment (FIRIA) project (https://hse.cern/content/firia) – 1.6 MCHF project launched by the CERN HSE Unit in early 2018

LUND UNIVERSITY

Strong collaboration with **Lund University** for the development of the **FIRIA risk-based methodology** including **detailed evacuation analysis**

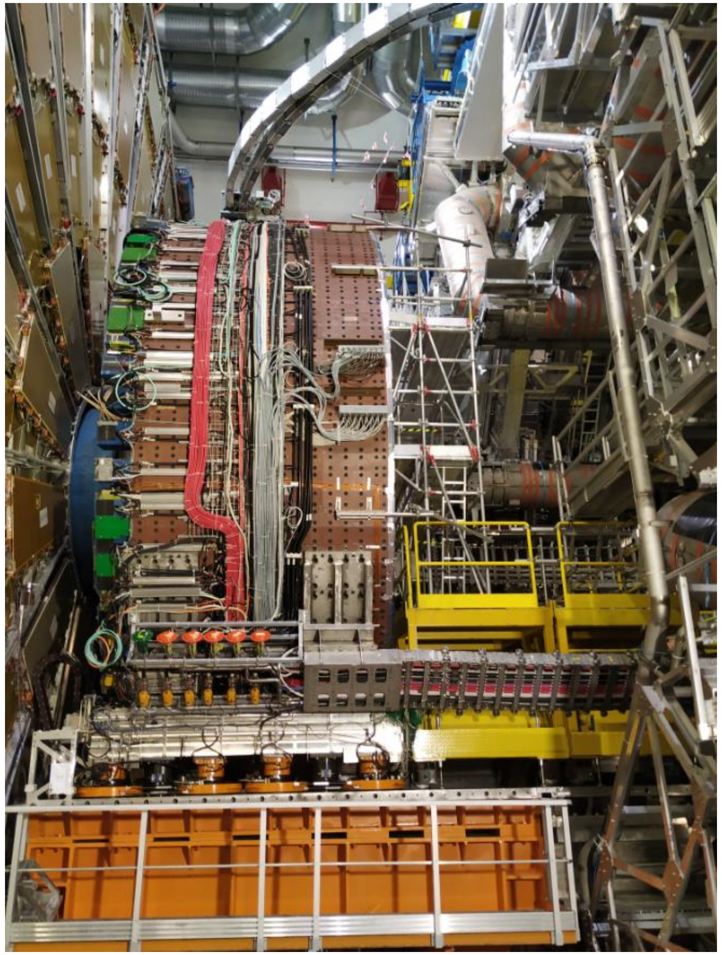
Object of the study: Cavern A

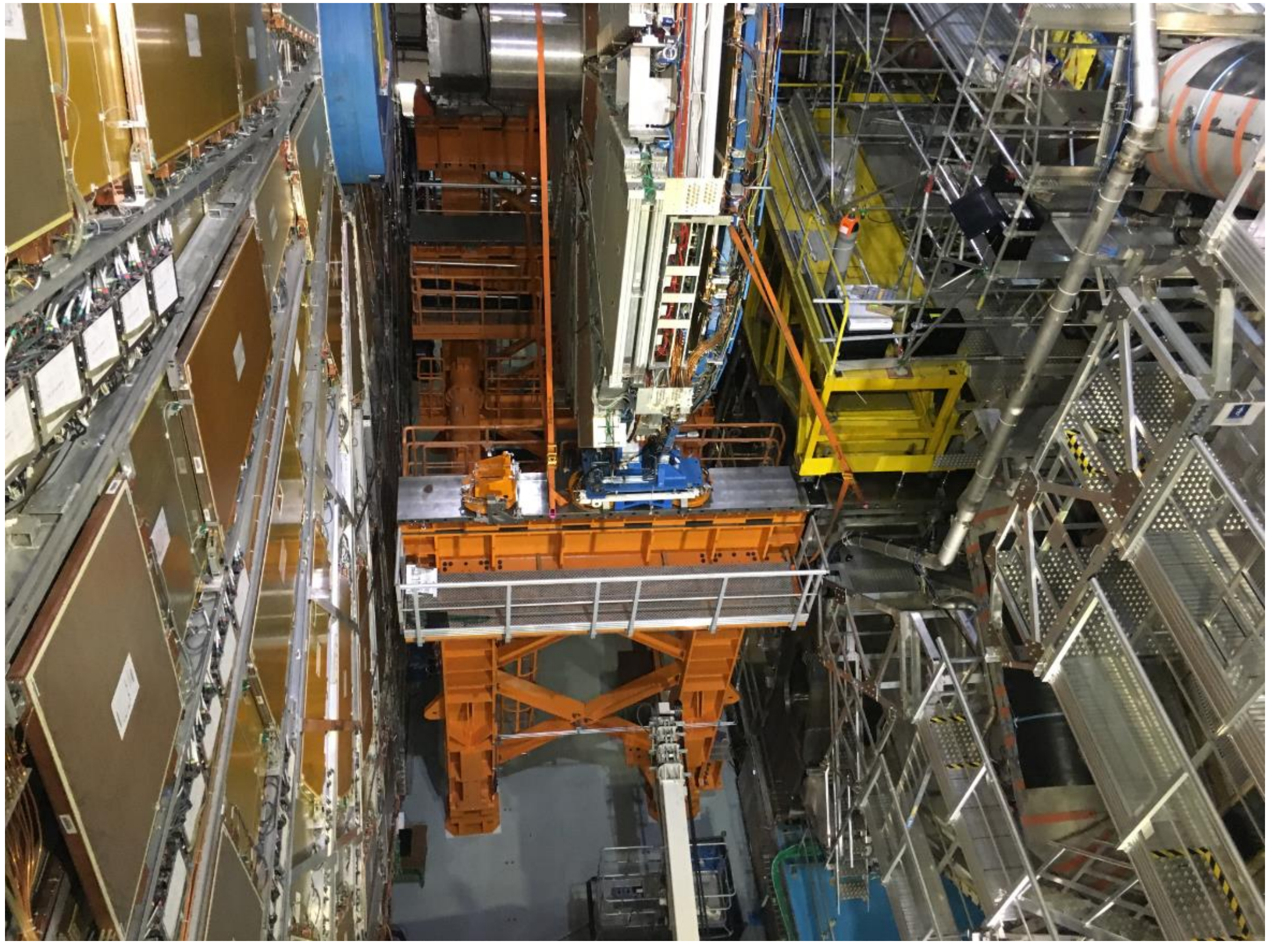




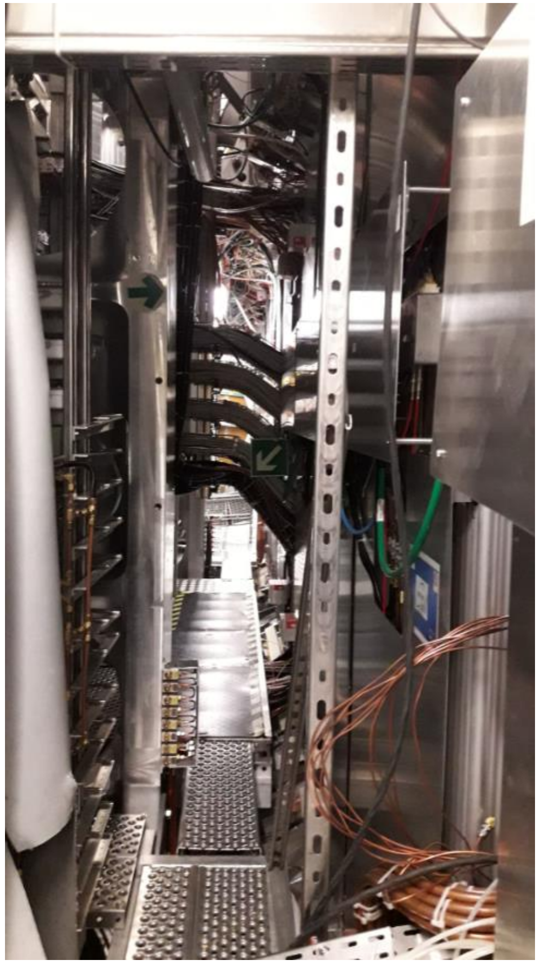
- 100 m below ground
- Large
  - *47000 m^3 volume*
  - *50 m x 30 m x 35 m*
- Experimental
  - *Particle detector*

Object of the study: Cavern A





Object of the study: Cavern A

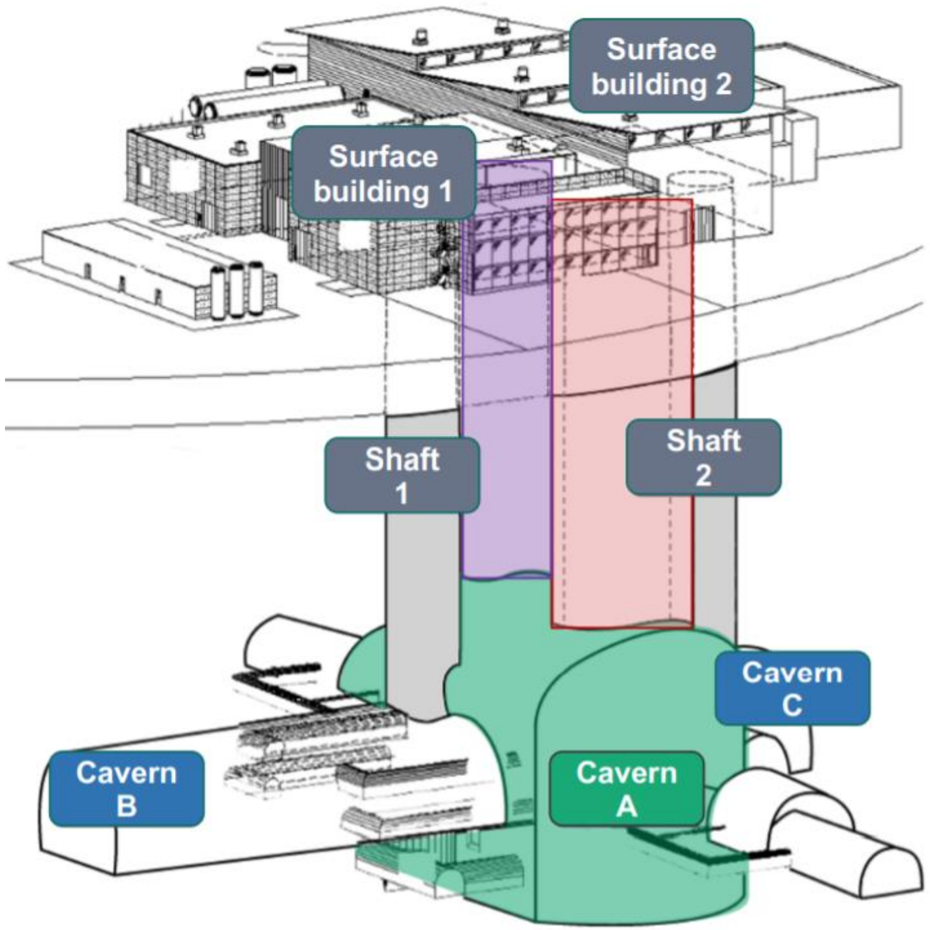


Self-rescue masks have to be worn before evacuating from the toroid

Object of the study: Cavern A

- Fire detection system
- Manual call-points (alarm push buttons)
- Evacuation sirens
- Evacuation signalisation

Object of the study: Cavern A



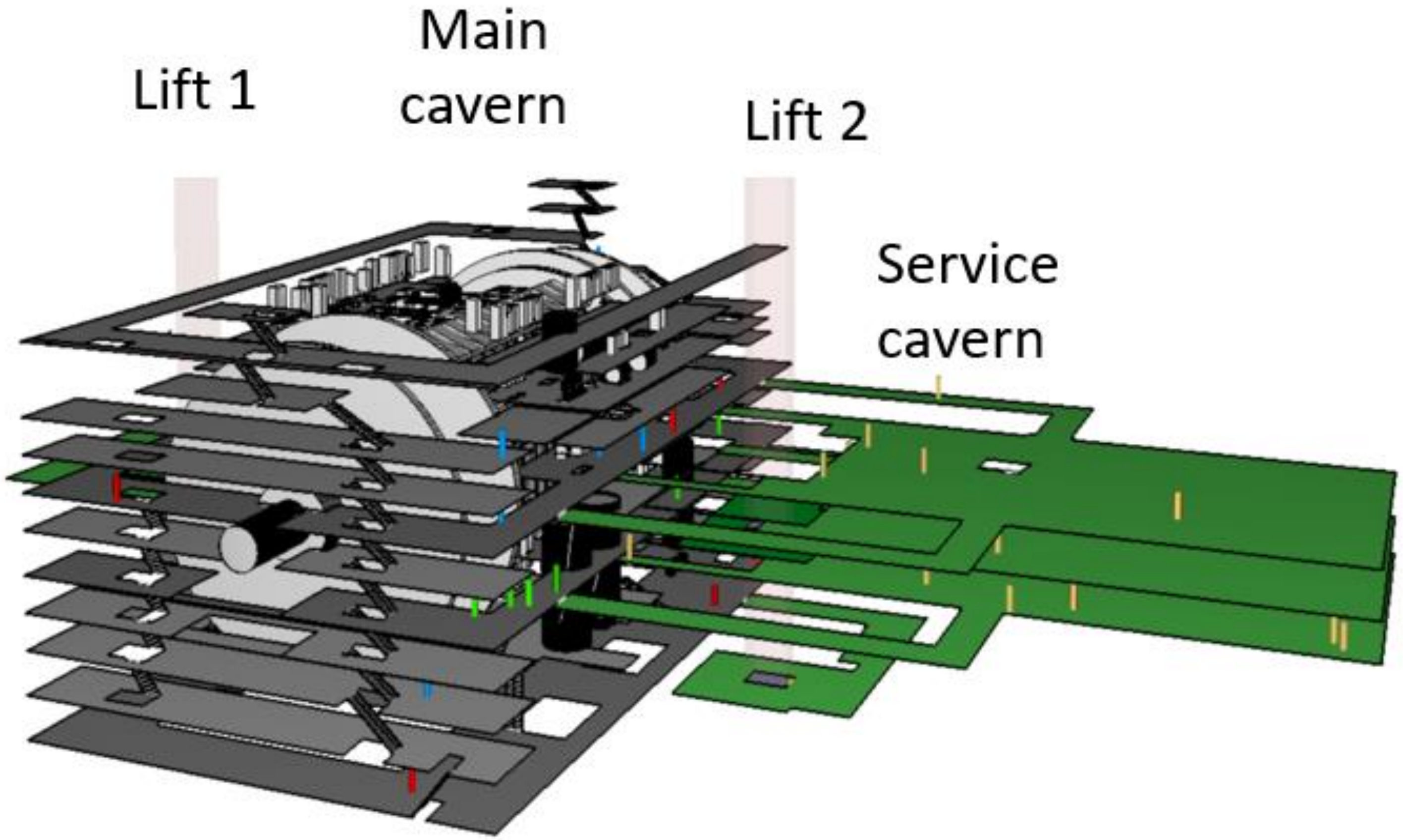
Evacuation concept

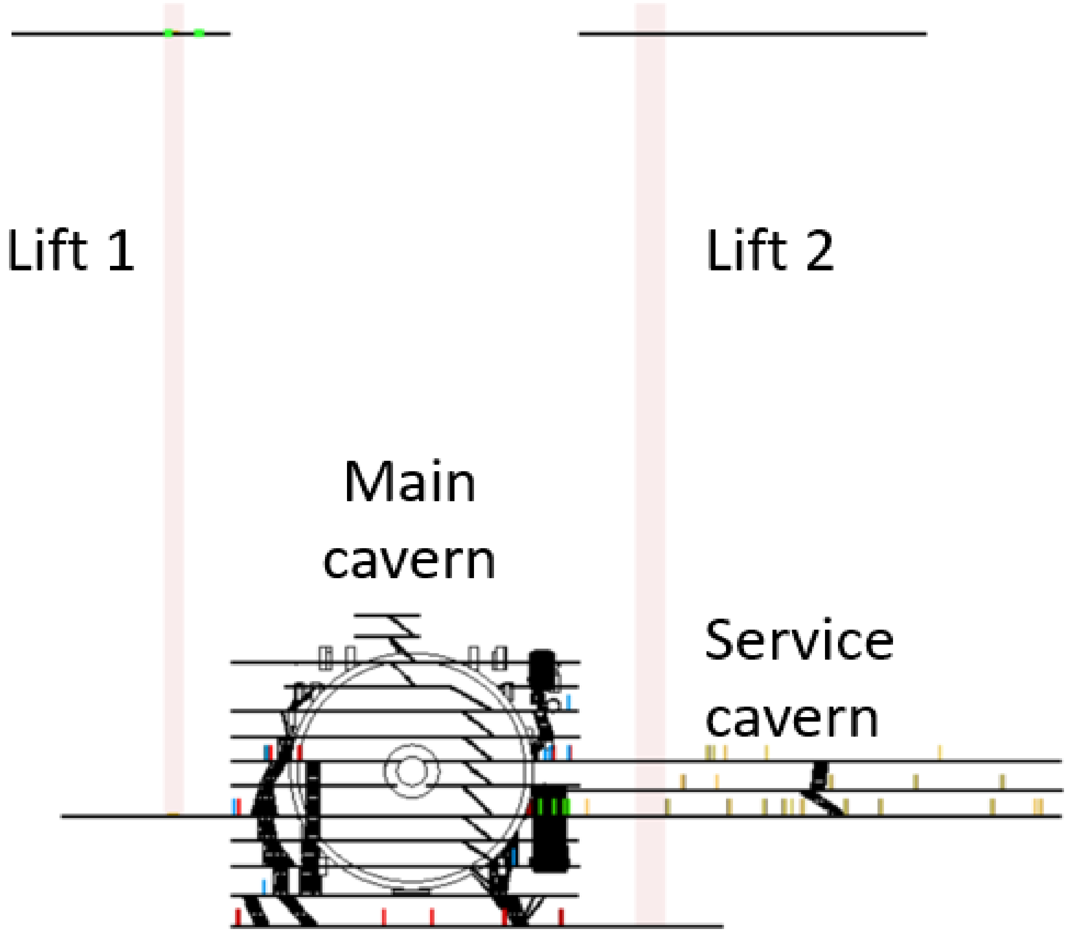
- Fire detection in Cavern A triggers an evacuation alarm in Cavern A and B
- Occupants can evacuate using two lifts located in the pressurized shafts (Shaft 1 and Shaft 2) leading to surface buildings

Approach

- Pathfinder
  - Geometry from PyroSim
  - Toxicity data from FDS simulations using the PL3D feature (CO, CO_2, O_2)
- Definition of model inputs to treat the behavioural uncertainty
- Evacuation analysis (MC mode, 50 runs)
- Rescueability analysis for victims (unable to evacuate independently)

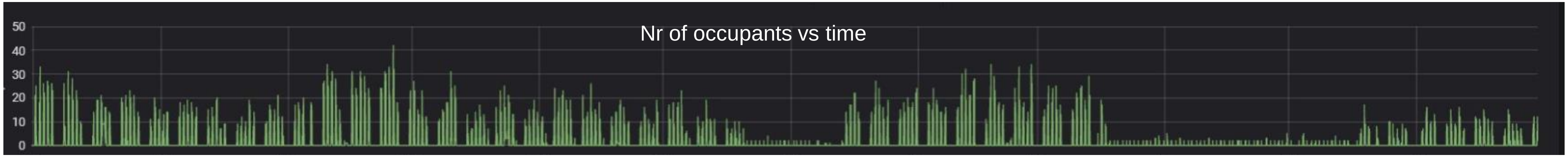
Pathfinder model

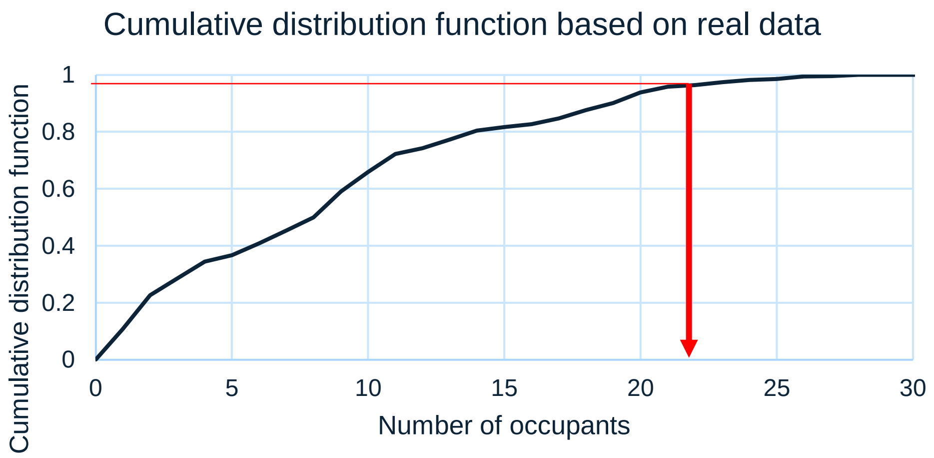




Treatment of the behavioural uncertainty

Model input #01: Number of occupants





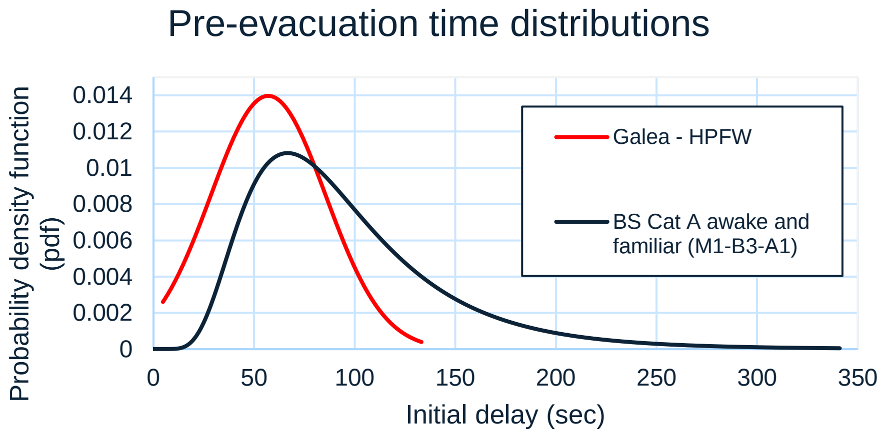
- Experimental cavern
  - **28 occupants**
  - **12 visitors**

Randomly distributed in the navigation mesh

- Service cavern
  - **22 occupants**

Treatment of the behavioural uncertainty

Model input #02: Delay time



HPFW: High Performance Formworks


Construction site evacuation safety:
Evacuation strategies for tall construction sites
iosh
Prof. E R Galea[1], Dr S Deere[1], Dr H Xie[1], Dr L Hulse[1], D Cooney[1]
[1] Fire Safety Engineering Group (FSEG), University of Greenwich, Park Row, Greenwich, SE10 9LS

The delay time is obtained by summing the following:

- Time to detect the fire: 60 s (FDS modelling)
- Pre-evacuation time distribution (workers & visitors)
- Travel time (60 s) inside the toroid estimated based on
  - Past evacuation exercises
  - Calculations based on critical paths and reduced walking speed

Treatment of the behavioural uncertainty

Model input #03: Walking speed

- Unimpeded horizontal walking speed
  - Truncated normal distribution (μ 1.35 m/s, σ 0.25 m/s, max 1.85 m/s, min 0.85 m/s)
- 50 % reduction in ascending stairs
- No reduction due to high density (p/m^2)
- No reduction due to smoke presence

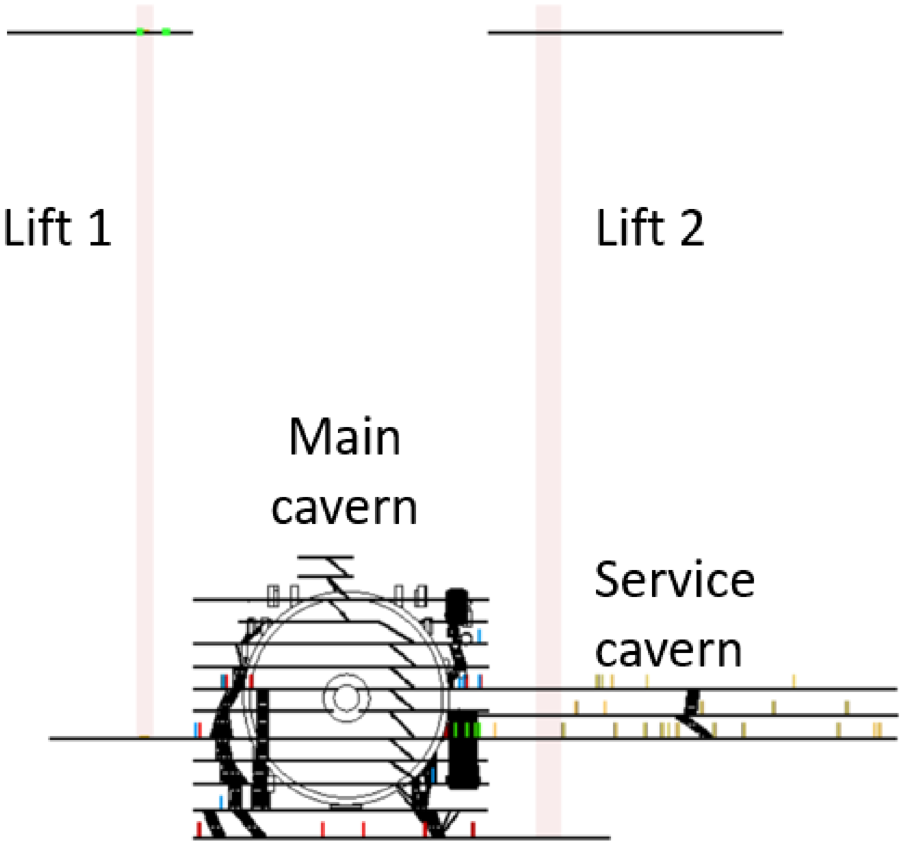
Fridolf, K., Ronchi, E., Nilsson, D. and Frantzich, H. (2019), “The representation of evacuation movement in smoke-filled underground transportation systems”, *Tunnelling and Underground Space Technology*, **90**, 28-41.

Treatment of the behavioural uncertainty

Model input #04: Exit choice

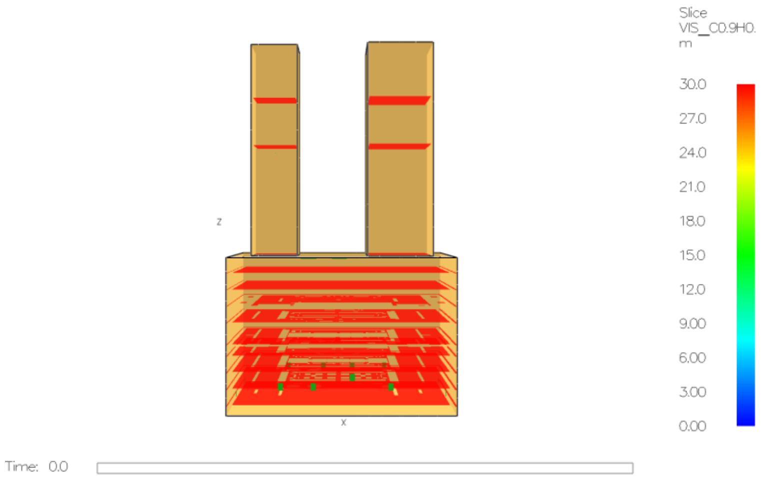
- All known exits

- Three scenarios for the main cavern:
  - Scenario 0 – all exits are available
  - Scenario 1 – only Lift 1 is available
  - Scenario 2 – only Lift 2 is available



Consequence analysis

- Performance criteria
  - Visibility > 10 m
  - Temperature < 60 °C
  - Heat flux < 2.5 kW/m^2



- FED along the evacuation paths

$$FED_{tot} = FED_{CO} \cdot V_{CO_2} + FED_{O_2}$$

$$FED_{CO} = 3.317 \cdot 10^{-5}\,[CO]^{1.036} \cdot (V)(t)/D$$

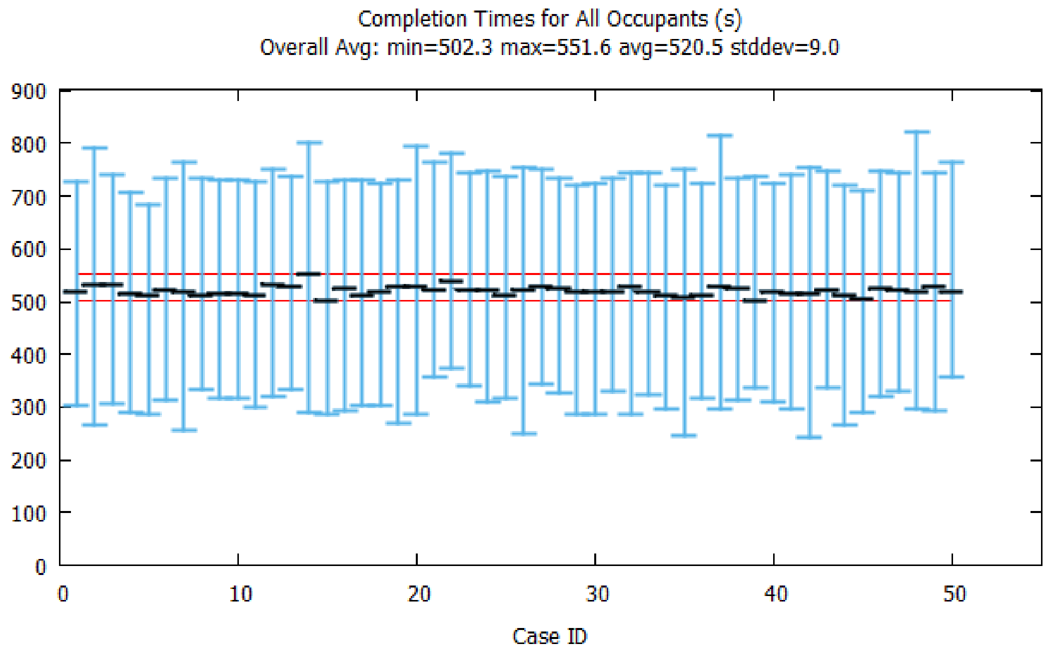
$$V_{CO_2} = e^{\frac{0.1903 \cdot \%CO_2 + 2.0004}{7.1}}$$

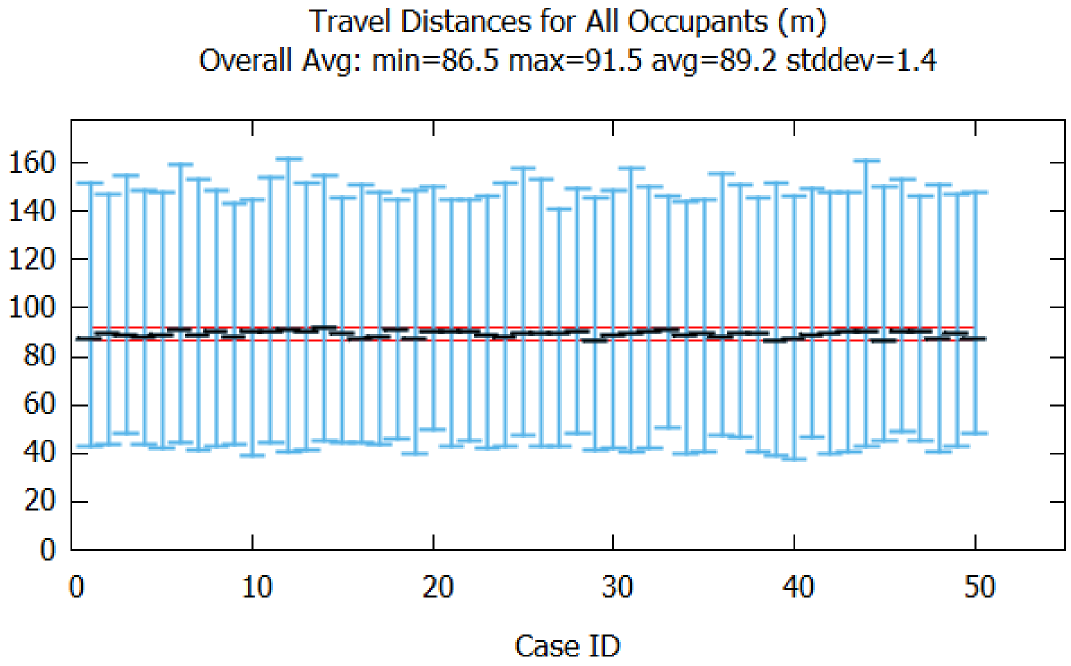
$$FED_{O_2} = \frac{t}{e^{(8.13 - 0.54(20.9 - \%O_2))}}$$

BSI PD 7974-6:2019 Application of fire safety engineering principles to the design of buildings. Human factors. Life safety strategies. Occupant evacuation, behaviour and condition (Sub-system 6)

Evacuation analysis

Scenario 0 – All exits available

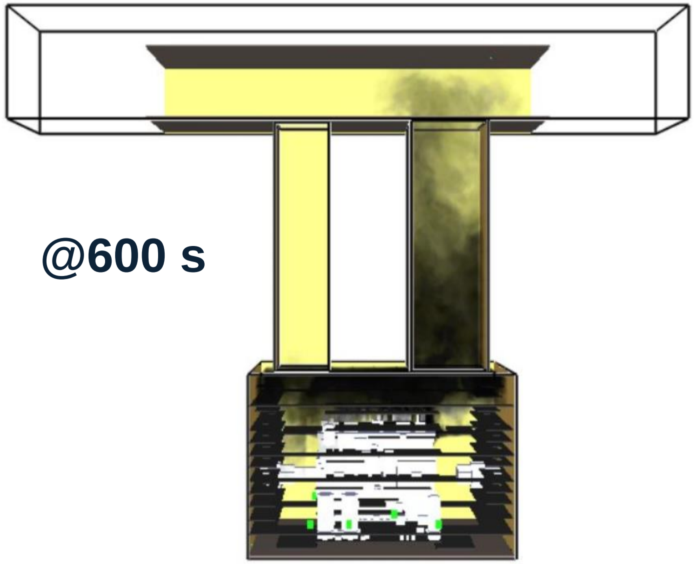


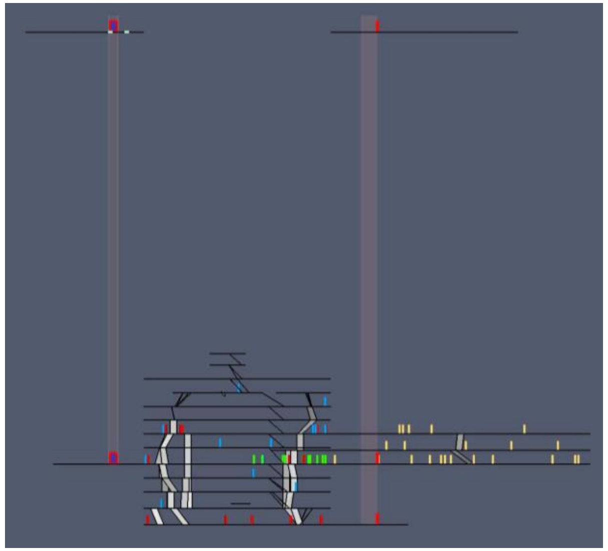


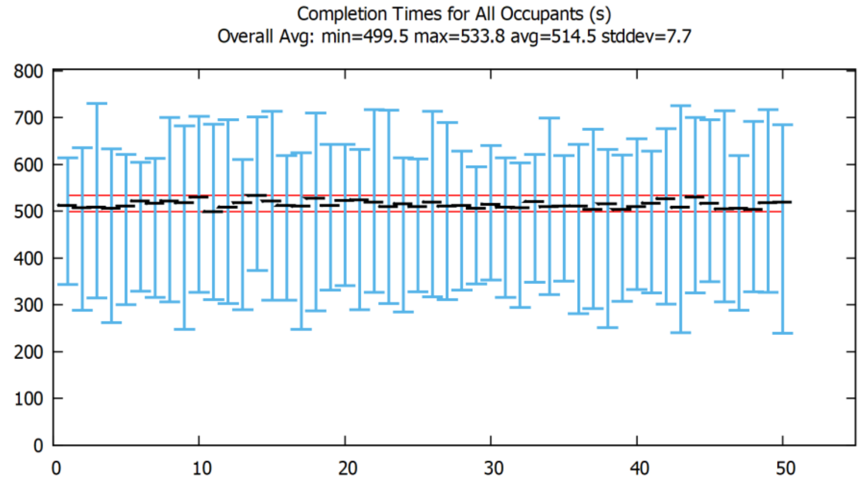
Evacuation analysis

Scenario 1 – Lift 1

@600 s

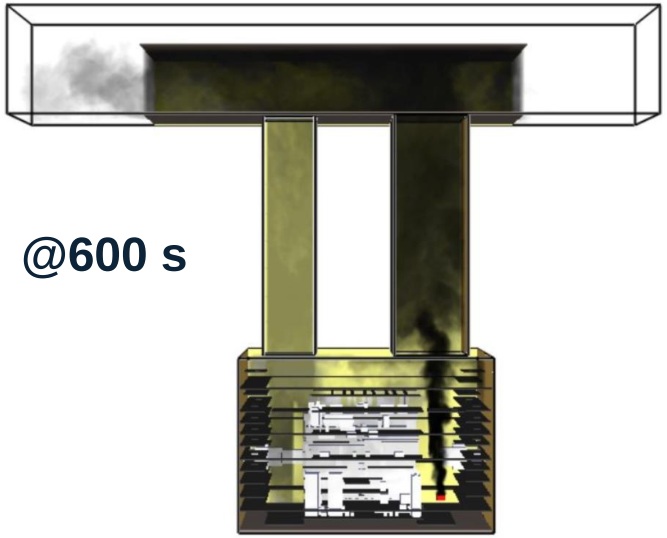


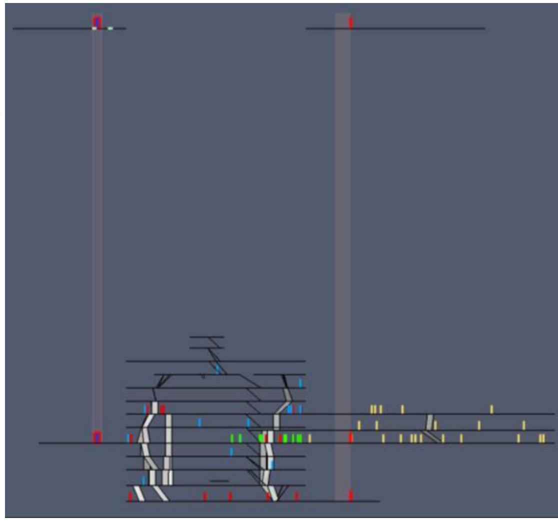


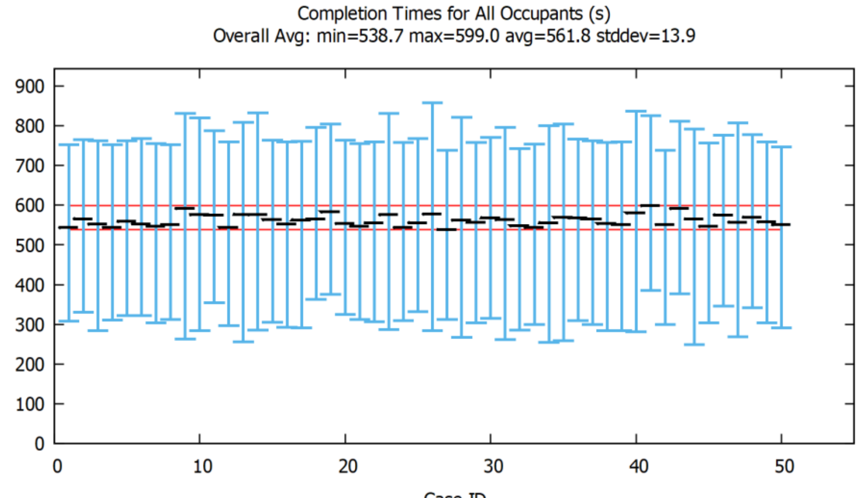


Scenario 2 – Lift 2

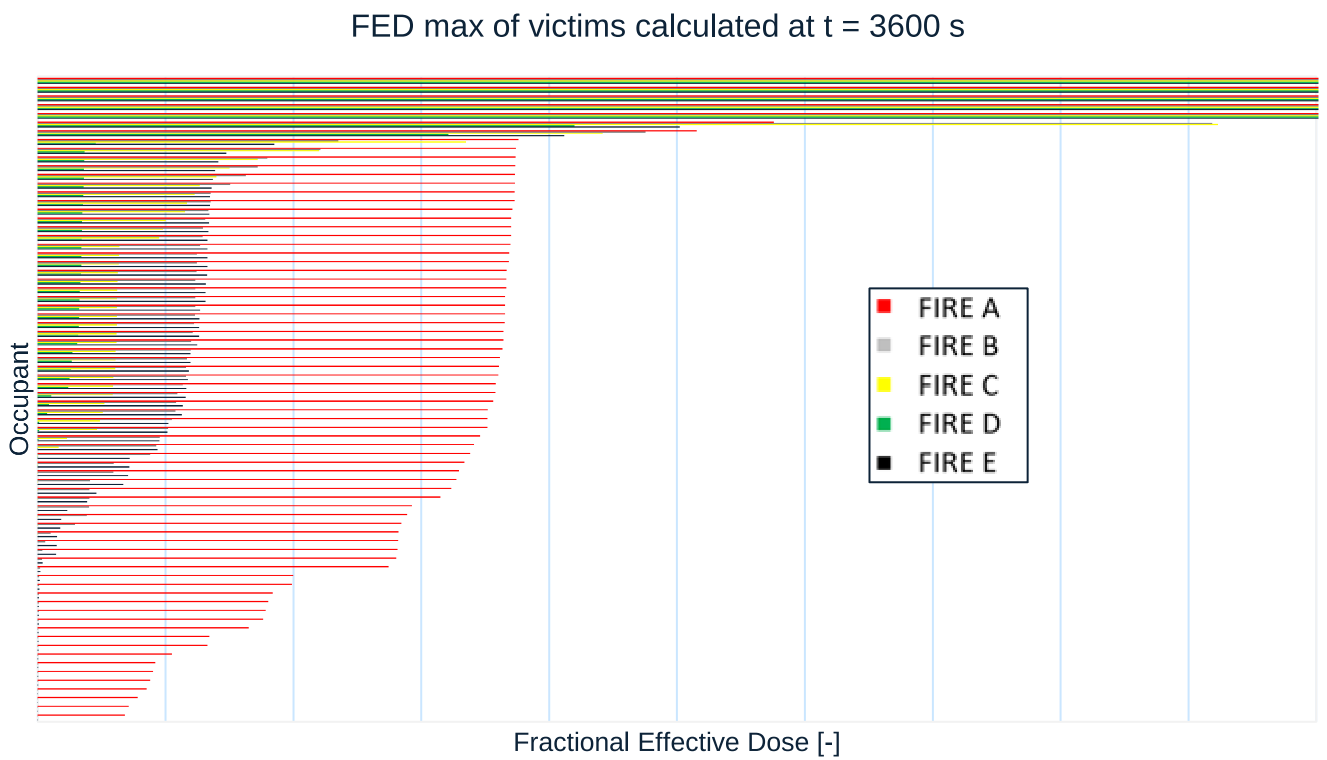
@600 s

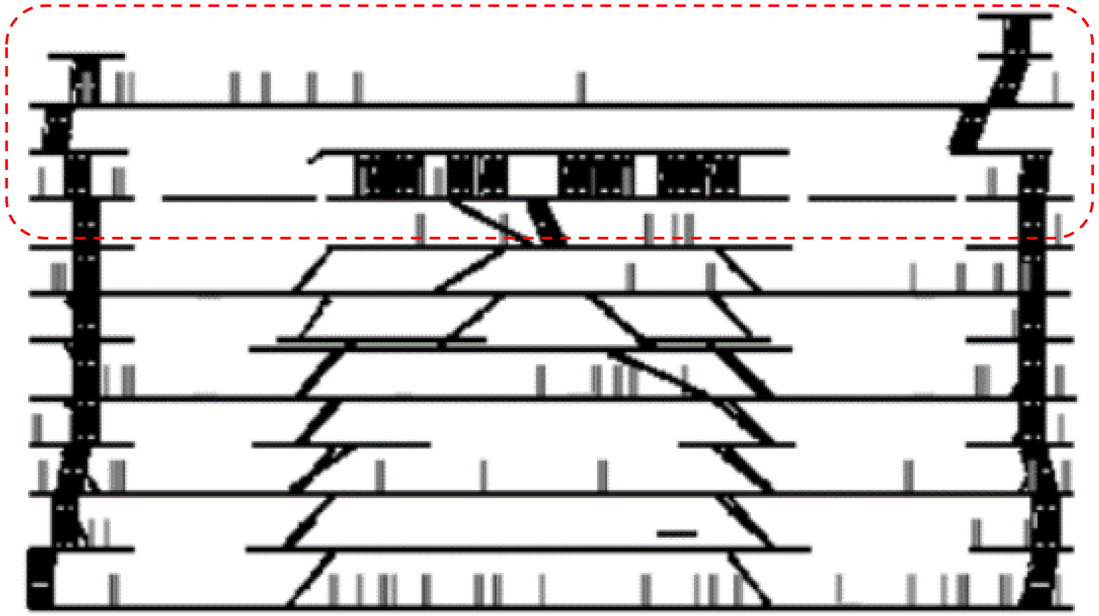






Rescueability analysis





Conclusions

- The case study shows the benefits of using an agent-based modelling with Pathfinder for complex facilities
  - Direct import of geometry and toxicity data from Pyrosim
  - FED calculated along the evacuation paths
  - Probabilistic treatment of behavioural uncertainty (also with MC mode)

- This type of evacuation analysis allows to provide cost-effective safety recommendations, acting only on the most penalizing scenarios and providing specific indications for areas of the facility where the tenability conditions and FED requirements are not satisfied.

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