USE OF FIRE AND EVACUATION MODELS IN PRACTICE OF FIRE AND RESCUE SERVICE OF THE CZECH REPUBLIC

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ABSTRACT

The Fire and Rescue service of the Czech Republic provides a wide variety of services for Czech citizens. It is not responsible only for rescue operations, but is an authority having jurisdiction in building fire safety. It is also responsible for fire investigations and last but not least, conducts research in the field of fire protection. There are two main areas where fire models are used in the scope of work of fire rescue service. Authorities having jurisdiction are responsible for authorizing the building fire protection designs, using fire models made by fire engineers. The second area is fire investigations, where models are used as a support for fire and police investigations. The majority of these simulations are done at the Technical Institute of Fire Protection, which is also responsible for fire research within the Fire and Rescue service.

The outcome of this presentation is to show how fire models are used for fire investigations, what are the main challenges during the cooperation of researchers preparing the models and fire and police investigators. An example of this cooperation is an investigation of a recent fire in a nursing home which led to significant life losses. During the investigation, both the CFD fire model and evacuation model were done as well as an animation of events before the fire. Thanks to the work of the investigation team, this event led to a significant change in the Czech building safety code in terms of fire safety of such buildings.

INTRODUCTION

Technical Institute of Fire Protection is a part of Fire and Rescue service of the Czech Republic. It is based in Prague and it is a part of General Headquarters of Fire and Rescue service. Its main tasks are testing fire fighting equipment and its certification, fire investigation and also applied research in a field of fire protection. Use of the fire models such as FDS is either part of the research projects or support for fire investigations.

SYSTEM OF FIRE INVESTIGATION IN CZECH REPUBLIC

Every fire where property loss is not negligible have to be investigated. Investigation is carried out in cooperation of the fire investigators from fire and rescue service and police investigators. Fire investigators are responsible for determining the cause of the fire (eg. technical failure, intention, negligence or any other cause) and the police investigators then investigate if any individual or group of people or company is responsible and also if fire can by classified as a minor offence or if crime was committed.

The Czech Republic is divided into 14 regions, each of them having a fire investigation unit. The role of fire investigation department of TIFP is when fire caused significant property loss or led to

multiple fatalities or when advanced examination of chemical or electrical appliances samples is needed to determine the cause of fire. In these cases, regional fire investigator requests cooperation of TIFP investigators. If a fire model is beneficial for the course of investigation, the model is done by the research and development department of TIFP.
The most frequent request by investigators is to help to confirm or rule out hypothesis about type or amount of the ignition source (material) or location of the fire origin. Often fires are connected with violation of fire codes, which leads to severe consequences. Then TIFP is asked to show difference between consequences of actual fire which happened and the consequences of fire if all the fire code requirements would be fulfilled.

TYPICAL QUESTIONS OF POLICE OR FIRE INVESTIGATORS

Fire investigators in the Czech republic usually don't have an experience and knowledge of use and applicability of fire models. This is especially true when investigator consult the case with fire modeler for the first time. This often result in exaggerated expectations of the model capabilities. Very often the first question is if the models are capable to determine the time of origin of fire with the accuracy in order of minutes or to predict what would have happened if the fire would not be extinguished.
Because of that it is always necessary to meet with the fire investigator and consult each particular case to find out if model can or cannot be beneficial for the course of the investigation. Good example is a model of a bus fire which was investigated couple of years ago.
The fire started from chemicals used in an improvised explosive device in a baggage compartment of the bus but fire soon extinguished due to lack of oxygen. The question of the police investigator was: "What was the possible threat to passengers in case of the explosive device successful initiation?." Such a general question could not be answered by a fire model. After discussion with the police investigator, series of specific questions which can be answered by fire model and can help investigators to evaluate the threat level of this act were formulated.

- What temperature can be reached by burning of one piece of luggage in baggage compartment.
- Is this temperature sufficient to ignite more pieces of luggage in the baggage compartment?
- Is this temperature sufficient to ignite bus electrical installation?
- Would smoke spread to the passenger compartment?
- In which phase would fire be probably noticed by anybody in the bus?

CASE STUDY – DEADLY FIRE IN A NURSING HOME

Introduction

Good example of fire expertize where fire model was used is a fire of a nursing home for clients with mental illnesses. It was a building from the year 1985, which was converted from the home for elderly people to home for people with mental illnesses without any specific changes in terms of fire protection measures. There were 34 clients accommodated in the facility. Fire started early in the morning between 4 and 5 am. During the night shift, there was only one member of staff. Fire started in the common room, which was in the same fire compartment as five client bedrooms for 17 clients. Fire resulted in 8 fatalities and 5 clients seriously injured making this fire one of the most severe fire in the history of the Czech republic. Investigation showed that the fire was set by one of the clients, who set small pillow on a couch on fire. Fire propagated for almost 30 minutes unnoticed because the building was not equipped with the fire detection. There was no requirement for placing the smoke detectors into this kind of buildings for their approval in 1985. Direct offender of the fire was found not responsible because of his mental health and prosecution was ended. Investigation of possible violation of the building codes is still ongoing and cannot be discussed in detail.

The fire modelers were invited to the fire scene couple days after the fire itself, so all the details of the building construction and fire itself could have been studied from the point of view of the model input parameters or traces that can be used to calibrate the model or validate its prediction. Best traces, which were used in calibrating the model was height of the smoke layer determined by soot deposits on the walls and temperature profile, which was determined by various items (eg. light switches, posters on the wall etc.) found on fire scene and their level of heat degradation.

Fire model and fire scenarios

First, an animation was done that showed the chain of the events (eg. Action and movements of clients, fire doors being blocked in open position by one of the clients, actions and movements by the member of staff.) before the fire which defined the boundary conditions for the fire development and smoke spread through the building. This animation was done by colleagues from documentary department of Fire and rescue service.

Then three fire models were done. First model showing the most probable version of fire. The biggest challenge of the model was to determine the fire curve. The length of the fire development phase was determined from witnesses statements and by outside camera footage from nearby building which showed the windows breakage. The maximum fire intensity was determined from the amount of air that can be entrained in the fire section through openings.

When fire source was satisfactory calibrated based on the evidence from the fire scene, two more scenarios were modelled. These models were used to demonstrate the influence of properly installed and maintained fire protection measures on the course of the fire and its consequences. One model showed the influence of fire compartmentation through proper use of fire doors installed in the building at the time of the fire. The last simulation showed the course of the fire where all fire safety devices which should be present in the building according to current standards were used.

After the fire model was done, evacuation model was prepared by colleagues from Brno University of Technology for all free fire models showing the difference in the evacuation time in case of use of fire detection.

For the preliminary analysis zone-model CFAST was used. Geometry of the model can be seen on Figure 1. Later, CFD simulation using FDS software was performed. Geometry was similar to one used in CFAST and can be seen on Figure 2:

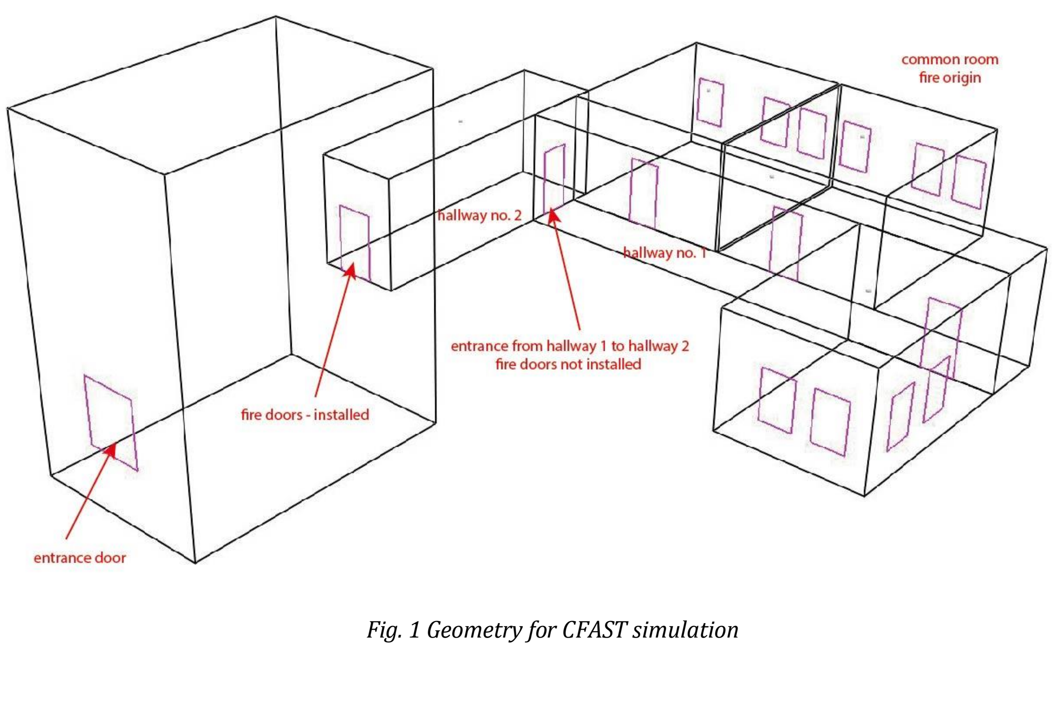


Fig. 1 Geometry for CFAST simulation

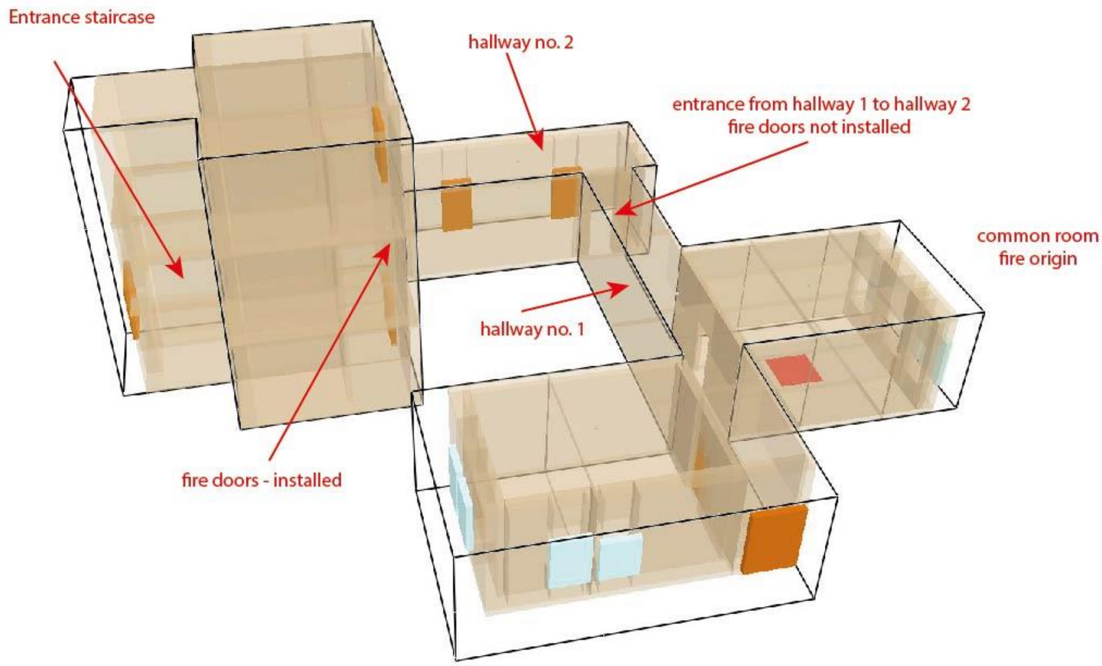


Fig. 2 Geometry for simulation

Fire source

Fire occurred during the winter, also building was equipped with modern well sealed windows. It was assumed that the fire was ventilation limited. Maximum heat release rate was derived from term

$HRR_{max} = 1500\ A_0\sqrt{H_0}$,

Where A_0 is area of vents and H_0 is height of available vents.
From video footage was found that all windows in common room broke during fire and time of breakage was obtained. Maximum HRR for oxygen available from this three windows was calculated as $HRR_{max} =$ 6,7 MW, since the third window broke with a small delay HRR_{max} for only two windows was also calculated and has a value of 4,5 MW.
HRR from assumed beginning of the fire to the maximum assumed HRR was approximated as a t-squared fire. Curve used as a fire source is shown on a figure 3 .

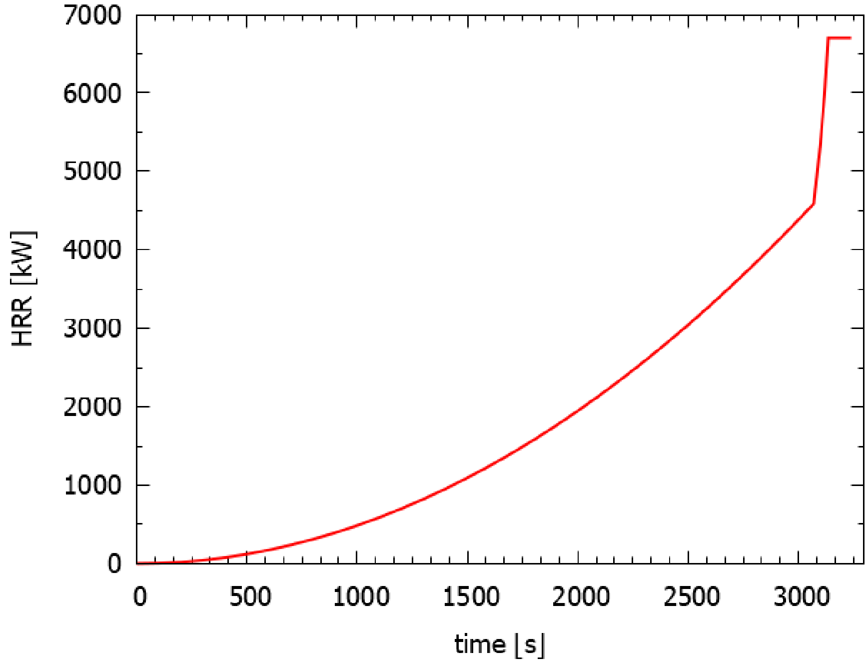
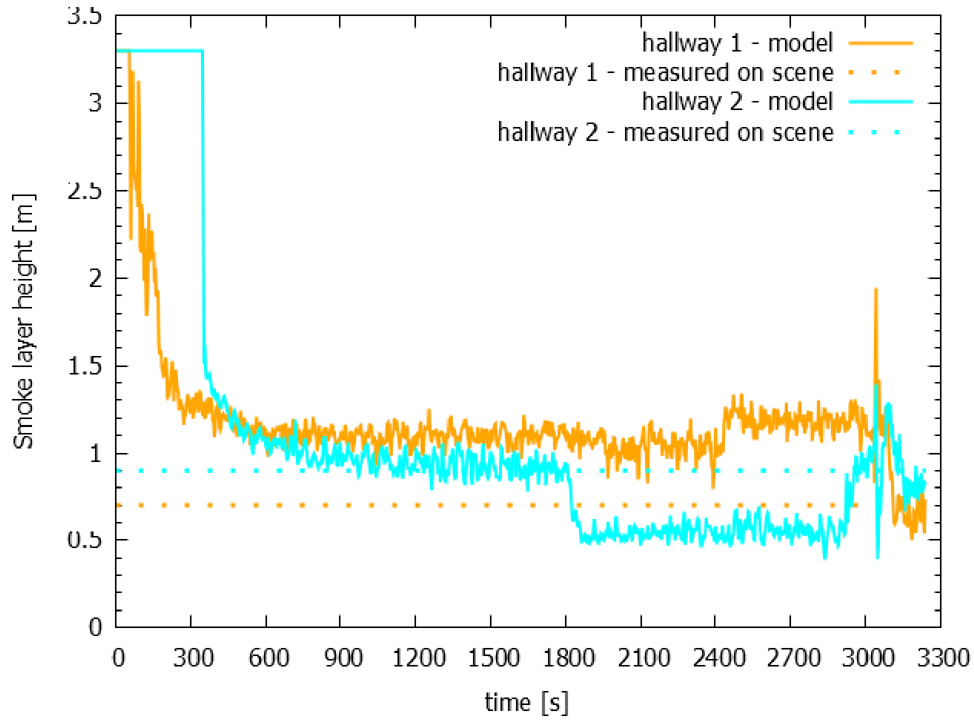


Fig. 3 HRR used as a fire source

Model results

Smoke layer height

Smoke layer height was one of the parameters which was chosen to compare if model is a good approximation of the real fire. At the fire scene smoke layer height was determined from the soot deposits on the wall. In hall closer to the fire it was about 0,9 meter and in the second hall it was 0,7 meter. FDS model showed values 1,1 and 0,9 meters which was considered as a good enough approximation for this case.



Smoke detectors activation

One of the results presented in a final report was expected time of fire detector activation in different places. Default settings of fire detectors were used and results both from CFAST and FDS simulation was used to show time of detection for different versions.

Time to detection		**Common room**		**Hallway 1**		**Hallway 2**	
Used model		CFAST	FDS	CFAST	FDS	CFAST	FDS
Version A	(sec)	120	16	245	78	351	206
	(min:sec)	02:00	0:16	04:05	1:18	05:51	3:26
Version B	(sec)	120	16	245	83	351	217
	(min:sec)	02:00	0:16	04:05	1:23	05:51	3:37
Version C	(sec)	120	16	242	88	Not activated	Not activated
	(min:sec)	02:00	0:16	04:02	1:28		
	(min:sec)		00:41		01:29		

Version A have all the fire doors open and it is considered as the most dangerous. Version B have also all fire doors open at the beginning of the simulation, but the main fire doors were repeatedly opened and closed as whitnesses reported. This version is considered to be closest to the real situation. Version C had all the fire doors closed during the whole simulation and represents the ideal case.

Because CFD and zone model was used, results shows high variability, also when taking into account validation of both softwares predicted time of fire detection in common room lies between 16 to 660 seconds which is really wide range but conservative value. To conclude, detection time in order of minutes can be expected, which is quite faster than actual time between 30 or 45 minutes in a real case.

Fire spread

To show importance of using the fire doors, visualization of smoke spread was done. Comparison of version B (real situation) and C (ideal situation) was done. Several pictures in different times was done. For this purpose, fire doors were considered as ideally sealed so smoke didn't spread to the halls after them. As can be seen on the pictures in variant B smoke spread through the whole building in comparison to variant C where smoke stayed in one fire section.

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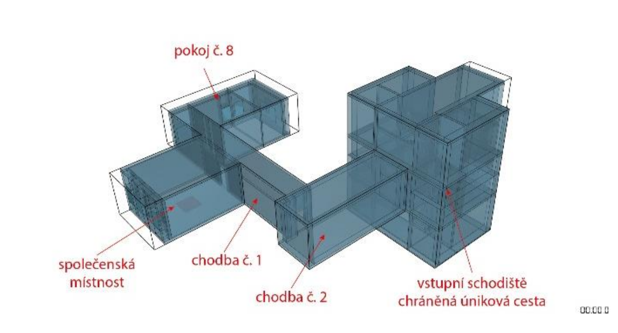
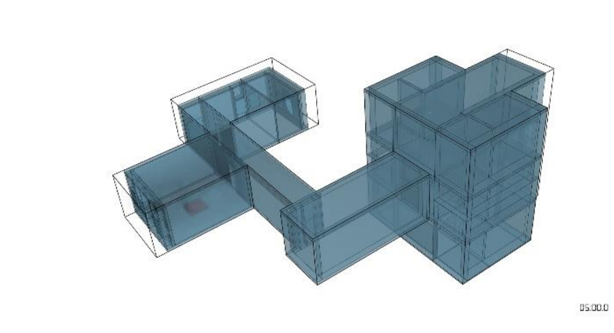
<tr><td>
</td><td></td></tr>
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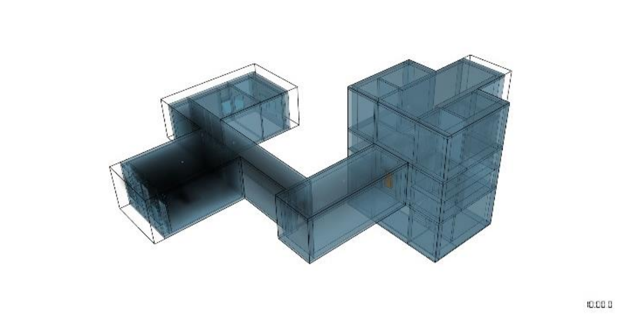
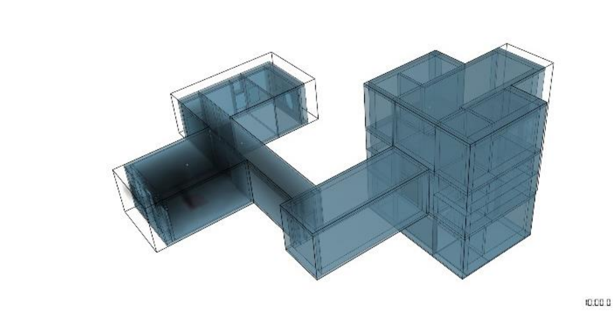
<tr><td></td><td></td></tr>
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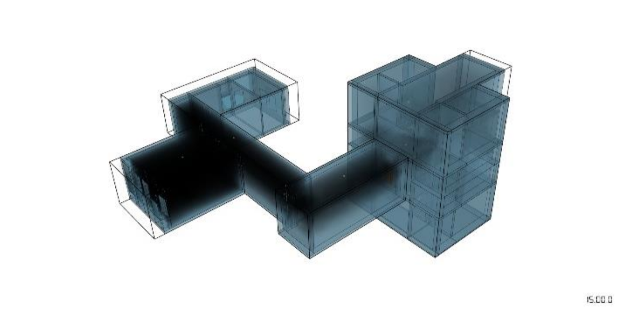
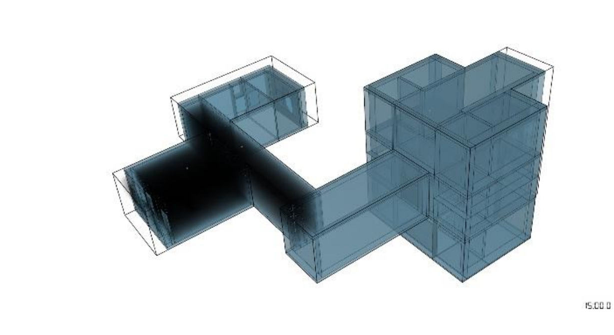
<tr><td></td><td></td></tr>
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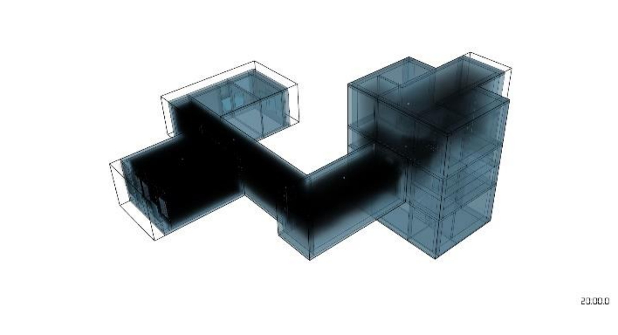
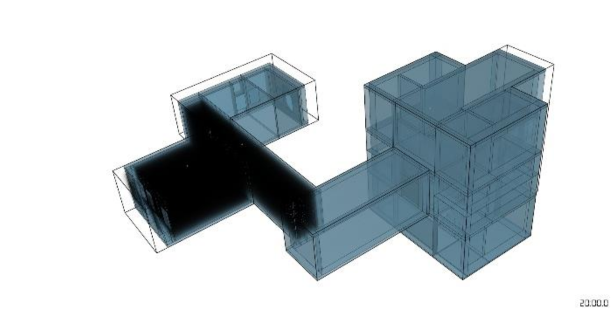
<tr><td></td><td></td></tr>
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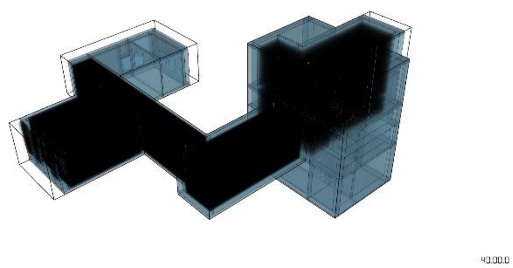	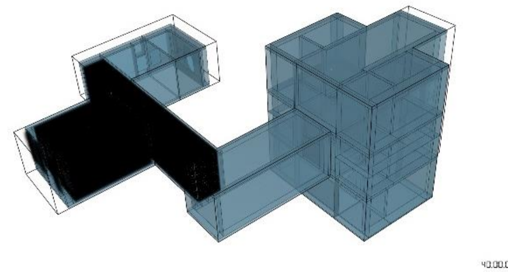
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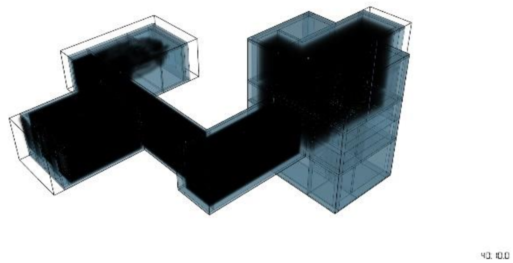	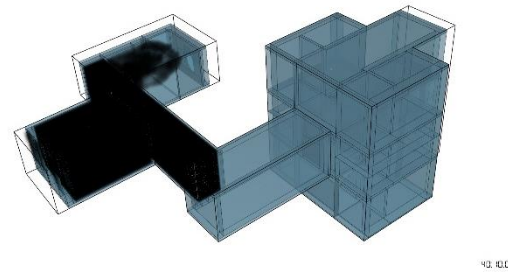
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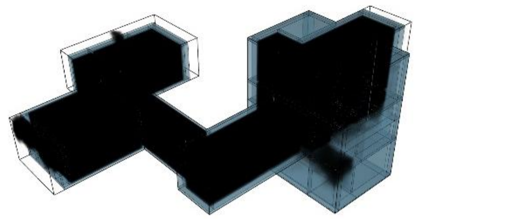	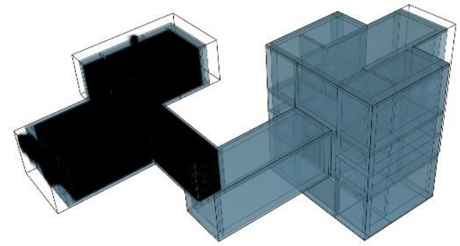
Version B – 50:40	Version C – 50:40

Conclusion

Simulation showed that if the building would be equipped and used in accordance with fire design from year of its construction the smoke spread would be limited only to the one fire compartment. Simulation also showed that if any kind of fire detection would be present it would significantly decrease the time of the fire detection. The long detection time is considered to be the most severe factor which made this fire so fatal.

Consequences after fire investigation

The fire model played an important role during the investigation and during the trial, The model, however, also served as an important source of information for a discussion on what can be done to prevent such fires in the future. The fatality of this fire together with the clear demonstration how simple measures can prevent such events, the fire code in the Czech Republic was changed. All buildings of this kind have to be equipped with either fire detection system (if more than 50 clients are present) or at least with autonomous smoke detectors (if less then 50 clients are present). This change was applied retrospectively so even older buildings needs to be changed in 3 year period to prevent such fire in a future.

The building where the fire occurred was reconstructed. Internal layout of the building was changed so the common rooms are the separate fire compartments. Every room was equipped with smoke detection system and fire doors were connected with fire detection system so it will automatically close in case of fire.