

# ORPHEUS – Fire Safety in the Underground



Public transport systems form a fundamental part of our cities and play a major role in our society. Thus, civil safety aspects of underground transport facilities are of crucial importance.

Risks and danger manifest in large disasters that take many innocent lives and therefore draw large attention (like 1987 in London, Great Britain or 2003 in Daegu, South Korea, to name only a few). However, there are many more incidents that do not trigger strong medial attention (like recently in Washington, USA, and London, Great Britain, 2015).

The demand of safety research in this context is represented by recent projects such as the Swedish project METRO [1] or the German projects OrGaMIR / OrGaMIRPLUS [2]. Both research projects covered selected safety aspects of underground metro stations.

So far, there exist only limited concepts to construct smoke extraction systems in complex underground facilities. Such systems play a major role for the personal safety during fire hazards and therefore smoke extraction systems represent the main aim of the ORPHEUS project – abbreviated **"Optimierung der Rauchableitung und Personenführung in U-Bahnhöfen: Experimente und Simulationen"**. Thereby, the main obstacle in designing safety concepts for underground sta-

tions is the thermally driven movement of hot smoke or toxic gases. The gas dynamics may become very intensive and hard to control. This puts the passengers in a very dangerous situation, since smoke has a very negative impact on the rescue process, as it limits the mobility and visibility of the occupants and the rescue teams. Hence, most fatalities occur due to the toxic nature of smoke. In contrast to common stations or street tunnels, underground stations often have a very low ceiling height and therefore cannot sustain a smoke free layer, which is large enough to prevent suffocation.

As a consequence, fires in underground stations massively challenge the rescue operation and demand an

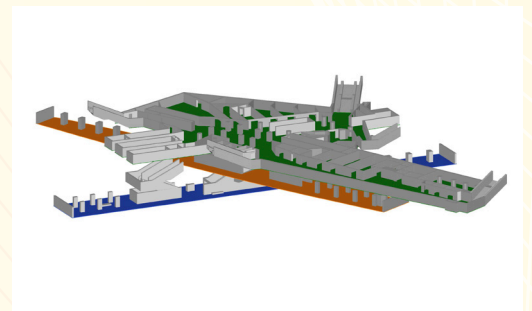


Figure 1: Typical metro stations are complex and compact structures. Hot smoke and passengers have in general the same movement paths to the surface. The figures illustrate the metro station "Osloer Strasse" in Berlin.

effective inter-organisational crisis management. Considering the high relevance, the presented project investigates concepts and strategies to improve the safety of underground stations during a fire with an intensive smoke yield. This covers technical as well as inter-organisational aspects. February 2015 saw the start of the ORPHEUS project, which is funded by the Federal Ministry of Education and Research (BMBF) for 36 months [3]. The consortium is coordinated by JSC's division "Civil Safety and Traffic" [4] and consists of the following funded partners:

- Bundesanstalt für Materialforschung und -prüfung
- IBIT GmbH
- Imtech Deutschland GmbH
- Institut für Industrieaerodynamik GmbH
- Ruhr-Universität Bochum, Lehrstuhl für Höhlen- und U-Bahnklimatologie

and the associated partners respectively subcontractors

- Berliner Feuerwehr
- Berliner Verkehrsbetriebe
- Deutsche Bahn Station&Service AG
- Hekatron Vertriebs GmbH
- Karstadt GmbH
- NVIDIA GmbH
- Team HF PartG

All of them met at the project kick-off meeting in Jülich on 12 March 2015. The proposed research plan is divided into three main parts:

- 1) Fire experiments in existing stations and assessment of the current state-of-the-art of technical fire safety engineering systems and methods, safety concepts, detection systems as well as the validity of numerical tools.
- 2) Technologies and concepts for personal and operational safety in case of fire with emphasis on people with special requirements and handicaps covering physical and numerical modelling of smoke extraction and guiding systems as well as numerical pedestrian simulations.
- 3) Reactive situation detection and support systems for rescue teams with integration of the project's results in inter-organisational crisis management systems.



Figure 2: Participants of the kick-off meeting in Jülich



## Fire Experiments

The first of the three main parts consists of the execution and validation of experiments in an operative metro station in Berlin. Outside of operating hours, real fire experiments will be carried out in a fully monitored station. The target station (Osloer Strasse) has a complex structure with three levels. Multiple experiments will be carried out with real fires. These technical fires produce no soot or toxic gases and are only used as a dynamic heat source to model thermally driven flows. The diagnostic is based on tracer gases (e.g.  $\text{SF}_6$ ) that are added to the fire plume. The obtained data (e.g. velocity, temperature, and tracer gas concentrations) measured at many locations will be used to validate small scale and numerical models. These experiments are accompanied by long-term underground climate measurements and will apply novel techniques that make use of existing communication cables in the tunnels. The collected climate data will also be considered during the concept phase.

## Preventive Fire Safety Concepts

The second part aims to investigate concepts for novel smoke control and extraction systems as well as evacuation aspects. During the initial phase of the project, the fire safety objectives will be defined and used to compare different safety systems and concepts. Small-scale

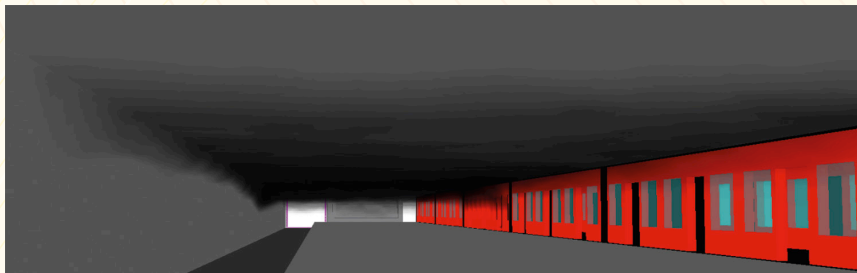


Figure 3: A snapshot of a smoke spread simulation in an underground station

physical experiments (1:5 and 1:20) and numerical simulations of smoke and heat propagation in underground stations will form the basis for the project studies.

Besides the application of existing CFD (Computational Fluid Dynamics) models, new concepts for mesh-adaptive methods will be developed by JSC. They will allow refining the numerical mesh in regions of high dynamics and gradients, while passive regions will be resolved by a coarse mesh. These techniques are crucial to provide sufficient numerical resolution

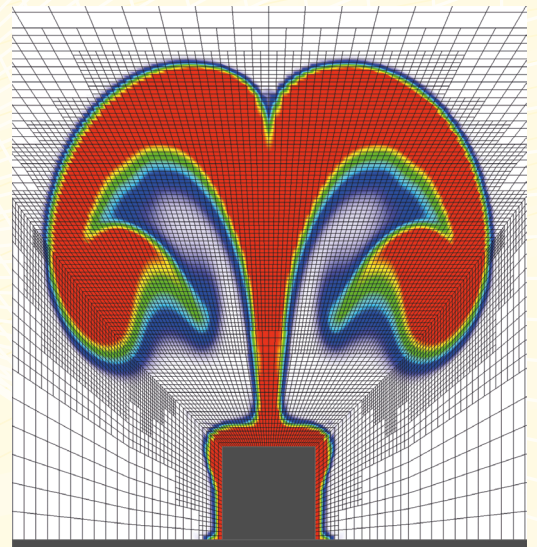


Figure 4: First steps toward mesh adaptive simulations. Here, the structure of a hot plume is well resolved, while the surrounding may stay coarsely represented.

inside small subdomains of a large and complex structure. An accompanying goal is to develop a fire simulation model that can make efficient use of HPC systems.

Special emphasis is put on the availability of evacuation paths and routes used by fire fighters. Therefore, pedestrian simulations will accompany the work on preventive technical systems. These simulations will be coupled to fire simulations and will therefore allow evaluating the impact of smoke on the evacuation (e.g. visibility or toxic affect-

tion). Additionally, the pedestrian simulation model JuPedSim [5], developed in-house at JSC, will be expanded to include psychological decision models.



Figure 5: Mobility and vision handicapped people pose special requirements, which are considered in this project.

Humans with special requirements, like sight and/or mobility handicapped people (e.g. elderly), will play a major role in the analysis and optimisation of evacuation routes.

## Support During Rescue Operations

The third part covers the interaction between the operators, emergency services, and third parties, like shopkeepers. In the case of fire, processes on the surface are essential for rescue attempts. Revision of past events and interviews with organisations involved will allow a communication pattern

analysis – also with respect to warnings and alarms. Besides the individual organisation analysis, the cooperation and interaction between affected organisations before and during an incident is studied. The investigation covers the transfer of knowledge and information between the emergency services and the communication to infrastructure users and concerned residents.

To tackle the complex interaction scheme, an inter-organisational map and interfaces will be developed. The interfaces include communication paths as well as interaction points in the individual crisis management. This work will allow identifying inconsistent processes and potential for optimisation. Other important communicative aspects are warnings and alarms. Thereby, investigated topics are the contents and forms of the messages sent to the occupants.

To support rescue teams and technical systems, JSC will also examine a real-time smoke propagation prognosis model. This CFD based model is supposed to run on GPGPU systems to provide a short time-to-solution and should be coupled to sensors to include live parameters such as the position or the intensity of the fire as well as climate data.



Figure 6: Surface events like markets may be located directly at the metro's exits and therefore amplify the complexity of a rescue operation.



## Conclusion

All concepts created in this project focus on underground metro stations. However, during the final phase of the project the outcome will be evaluated for the application to other transport infrastructures, like airports or car parks. The technical and organisational results form the scientific basis to develop production systems and tools for fire safety engineering.

## Funding

BMBF, call "Zivile Sicherheit – Schutz und Rettung bei komplexen Einsatzlagen"

## Funding amount

Euro 3.2 million

## Project duration

February 2015 – January 2018

## Project website

<http://www.orpheus-projekt.de>

## Links

- [1] <http://www.metroproject.se>
- [2] <http://www.bmbf.de/pubRD/OrGaMIR.pdf>
- [3] [http://www.bmbf.de/pubRD/Projektumriss\\_ORPHEUS.pdf](http://www.bmbf.de/pubRD/Projektumriss_ORPHEUS.pdf)
- [4] <http://www.fz-juelich.de/ias/jsc/cst>
- [5] <http://www.jupedsim.org/>

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