# ORPHEUS–Fire Safety in the Underground

In January, 2018, the three-year JSC-coordinated research project ORPHEUS ended. ORPHEUS' aim was the investigation of new experimental and numerical methods for fire safety in underground stations. A consortium of 13 partners from academia, industry, and fire brigades contributed to achieve these goals [1].

One of the most prominent aspects of the project were real-scale fire experiments. These experiments were carried out in the Berlin metro station 'Osloer Straße' during off-hours, i.e. between 1 am and 3 am. The experiments were mainly used for underground climate investigations and model validation. The project partner from Aachen (Institut für Industrieaerodynamik Aachen) set up propane burners to physically simulate the thermal and flow conditions, that may be found during the initial phase of a fire (Figure 1). The resulting flows and air temperatures were measured by colleagues from the Ruhr-University Bochum and the smoke detector manufacturer Hekatron Vertriebs GmbH. With over 600 temperature, concentration and flow velocity sensors, they were able to map the full station. Additionally, artificial smoke was added to the burner plumes to visualise the smoke spread and stratification

Fig. 1: Real-scale fire experiment in the metro station 'Osloer Strasse' in Berlin. Propane burners simulate the initial phase of a fire, while the full station is monitored with temperature and concentration sensors. © Lukas Arnold

inside the station. After the measurements, Berlin's fire brigade used the smoke-filled station to critically evaluate their new firefighting tactics in metro stations (Figure 2).


Fig. 2: Berlin's fire brigade trains new tactics and tools in a smoke-filled station. © Ralf Eisenbach

Besides the real-scale fire experiments, the project partner ROM Technik from Hamburg designed novel smoke extraction systems. These concepts were successfully evaluated in small scale experiments, where the physical model represented the full metro station in a 1:15 scale (Figure 3). In order to compare the experimental data to simulations, all experimental studies were accompanied by numerical simulations using FDS (Fire Dynamics Simulator) and Ansys CFX. Whereby most of the production level computations were carried out by the Bundesanstalt für Materialforschung und -prüfung.

JSC's scientific contribution to the ORPHEUS project was the development of new numerical methods. Four JSC PhD students contributed to the research activities in the fields of pedestrian and smoke dynamics. The intersection of these two fields was the focus of Benjamin Schröder's dissertation [2]. He investigated the analysis of life safety in a complex underground infrastructure. His work includes the definition of a large scenario ensemble that covers multiple fire locations and design fires. Based on this ensemble, a spatio-temporal analysis was carried out in order to evaluate the criticality of each scenario. For the first time, this approach allows to identify critical locations in a complex building (Figure 4).

Other JSC work packages covered the development of new numerical approaches to simulate the smoke spread. Here, two paths were investigated: adaptive mesh refinement and GPU-based real-time concepts. The GPU-based implementation aims at smoke spread

Fig. 3: Inside view of the 1:15 scaled model of the metro station 'Osloer Strasse'. Small-scale smoke sources are used to model the smoke spread. © Lukas Arnold

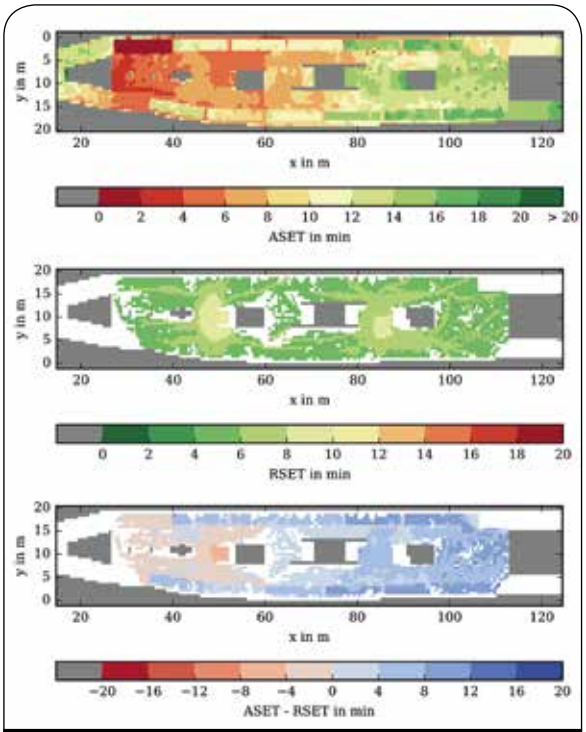


Fig. 4: Identification of critical locations in a complex building. Shown is the lowest level of the metro station 'Osloer Strasse' for a single scenario with a fire seat located at the top right corner of the platform. The top figure shows the computed available time for a safe evacuation at all platform positions. This time is compared to the required time (middle figure), which is based on evacuation simulations. The combination of both results in the difference map is shown at the bottom. Locations with negative time differences indicate critical locations with respect to life safety.

simulations in real-time, while using a portable programming approach [3]. Both activities lead to first proof-of-concept implementations and their development will be further continued in follow-up projects.

In ORPHEUS, new fire safety engineering methods and tools were applied, evaluated and developed in the context of underground stations. However, many of these concepts can be

Fig. 5: The ORPHEUS consortium. © Alexander Belt

transferred to other complex infrastructures like airports or stadiums. In total, the project members published more than 20 contributions in national and international conferences and journals, where an overview of the achieved results of all project partners was given in a public event held in January, 2018 in Berlin [4].

## References

[1] **ORPHEUS project webpage:**
http://www.orpheus-projekt.de

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Multivariate Methods for Life Safety Analysis in Case of Fire. Dissertation at the Bergische Universität Wuppertal 2017, http://elpub.bib.uni-wuppertal.de/servlets/DerivateServlet/Derivate-7013/dd1611.pdf

[3] **Anne Küsters, Sandra Wienke and Lukas Arnold:**
Performance Portability Analysis for Real-Time Simulations of Smoke Propagation Using OpenACC. Lecture Notes in Computer Science 2017. http://dx.doi.org/10.1007/978-3-319-67630-2_35

[4] **ORPHEUS Abschlusstreffen Januar 2018:**
http://www.orpheus-projekt.de/SharedDocs/Meldungen/ORPHEUS/DE/020_abschlusstreffen.html

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