Abstract
Development of a framework for the thermal modeling of an eVTOL

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The innovative idea of eVTOLs (electric vertical take-off and landing vehicles) aims to transport people autonomously over various distances in urban areas using an electrically powered aircraft. The range of the aircraft is limited by the available battery capacity, as electricity is required for the power electronics, drive components and the cabin. In this project, research is being conducted into optimizing the thermal management of the overall architecture of an eVTOL to optimize the efficiency and performance of these aircraft. A comprehensive framework for thermal modelling enables simulation-based optimizations based on a detailed modelling structure that considers both individual thermal subsystems and the overall system. The cabin, cockpit with dashboard zone, avionics bays and the battery bays were modeled as individual components. Each subsystem is analyzed considering its specific thermal properties and interactions with other components. The simulation of these subsystems is carried out using suitable thermodynamic and fluid dynamic models, with which the temperature distributions, heat transfers and heat dissipation can be predicted in realistic operating scenarios. When modeling the overall system of the eVTOL system architecture, the interactions between the subsystems are considered in order to obtain a comprehensive picture of the thermal processes. This makes it possible to identify and analyze the thermal challenges in different operating states and environmental conditions. To achieve this, the overall system is divided into 3 subsystems. One is an open air-circuit for cooling the cockpit, cabin and optionally the avionics compartment to create a comfortable indoor climate and to cool electrical components. On the other hand, the battery modules are cooled in an external liquid circuit. There is also a refrigerant cooling system that provides the required cooling capacity in the air or liquid circuit. The systems are illustrated in the figure 1.

An additional component of the framework is the identification of parameters that can be varied to optimize subsystems and the overall architecture. Therefore, the following parameters were identified:

- Subsystems
    - Thermal isolation (Cabin, Cockpit, Avionic Bay)
    - Heat load distribution
    - Permitted temperature ranges (Cabin, Cockpit, components)
- Overall system
    - Different system architectures
    - Massflow of the liquid cooling circuit/cooling circuit
    - Transfer surfaces of the heat exchangers

- Valve control for air and refrigerant circuit

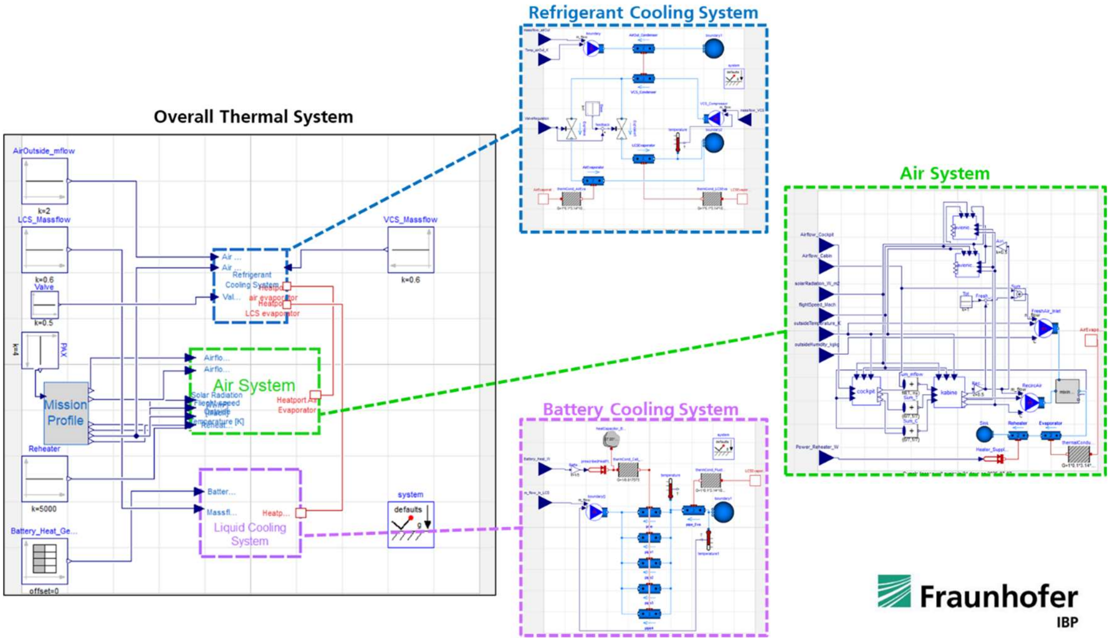

Figure 1: Modeling framework of the overall thermal system with its subsystems

The current model can be used to demonstrate that the temperature ranges in the cockpit and cabin can be maintained in accordance with FAR25 / ASHRAE161 between 18,3 °C and 26,7 °C. The batteries and the avionic bays do not exceed a temperature of 50 °C. The temperature distributions in the sub-compartments are shown in figure 2.

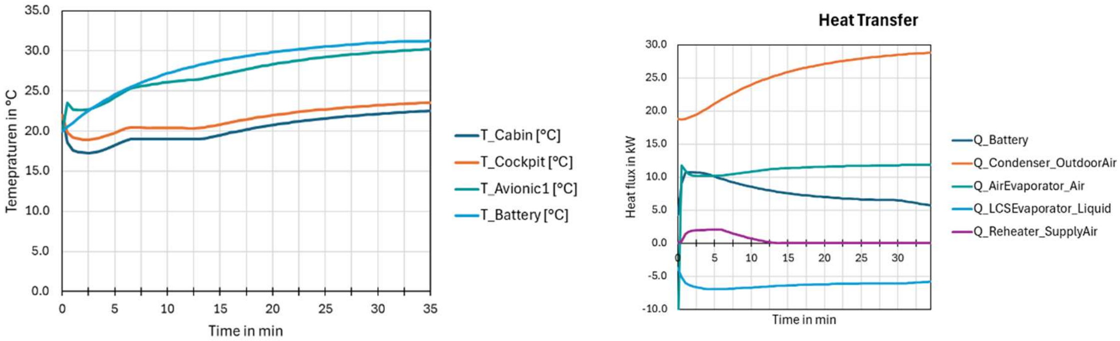

Figure 2: Temperature distributions (left) and heat transfer (right) in the overall thermal system of an eVTOL

The next step is to set up a test platform that allows the validation of the modeling framework. This will enable the model parameters to be set based on experimental data and real operating experience.

The developed framework is intended to provide a flexible platform for the thermal modelling of eVTOLs to carry out simulation-based optimizations. A comprehensive consideration of the overall thermal system architecture and parameter identification are key factors for the successful design and efficient operation of eVTOLs.

Biography
Christina Matheis

My name is Christina Matheis, M.Eng. and I am a research assistant and PhD student at the Fraunhofer Institute for Building Physics in Valley. I studied energy and building technology with a focus on energy efficiency and design. My research focuses on the development and validation of indoor climate simulation models as well as the planning and data analysis of indoor climate measurement experiments.