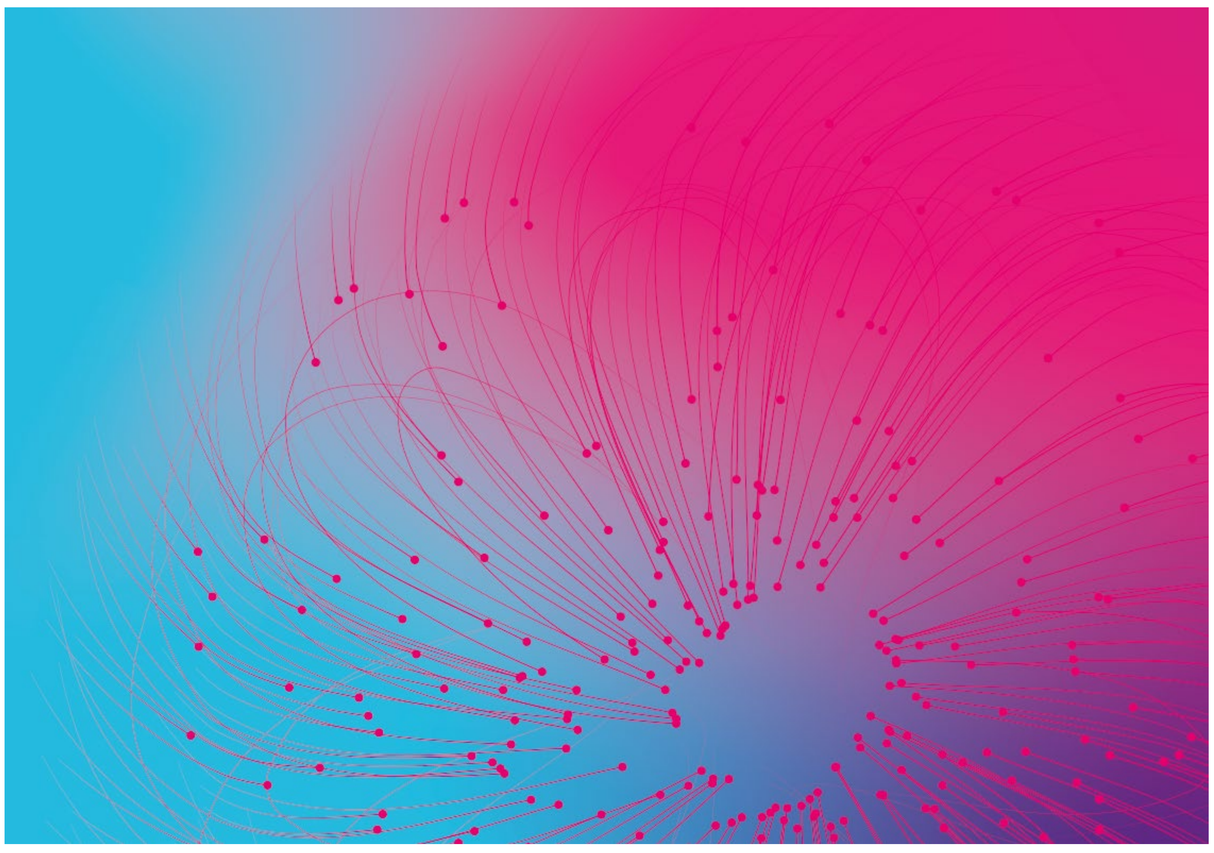
# ALQU

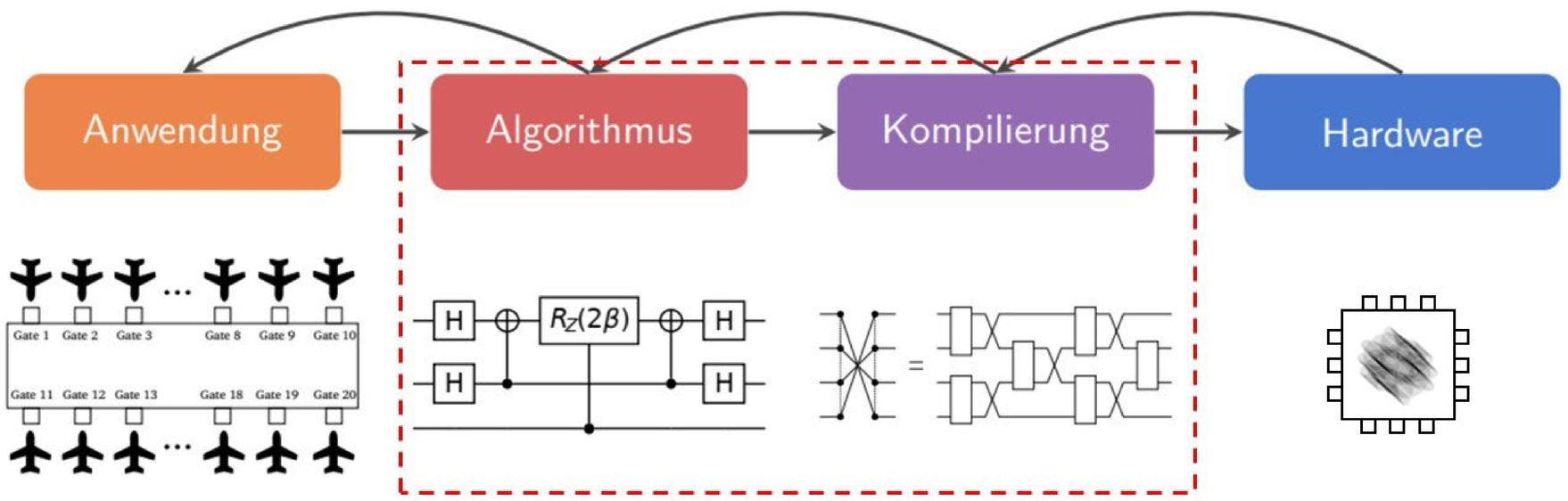
# Algorithms for quantum computer development in hardware-software codesign

- We are developing customised compilation strategies for the DLR QCI's quantum computers and customised quantum algorithms for difficult, industry-relevant computational problems.

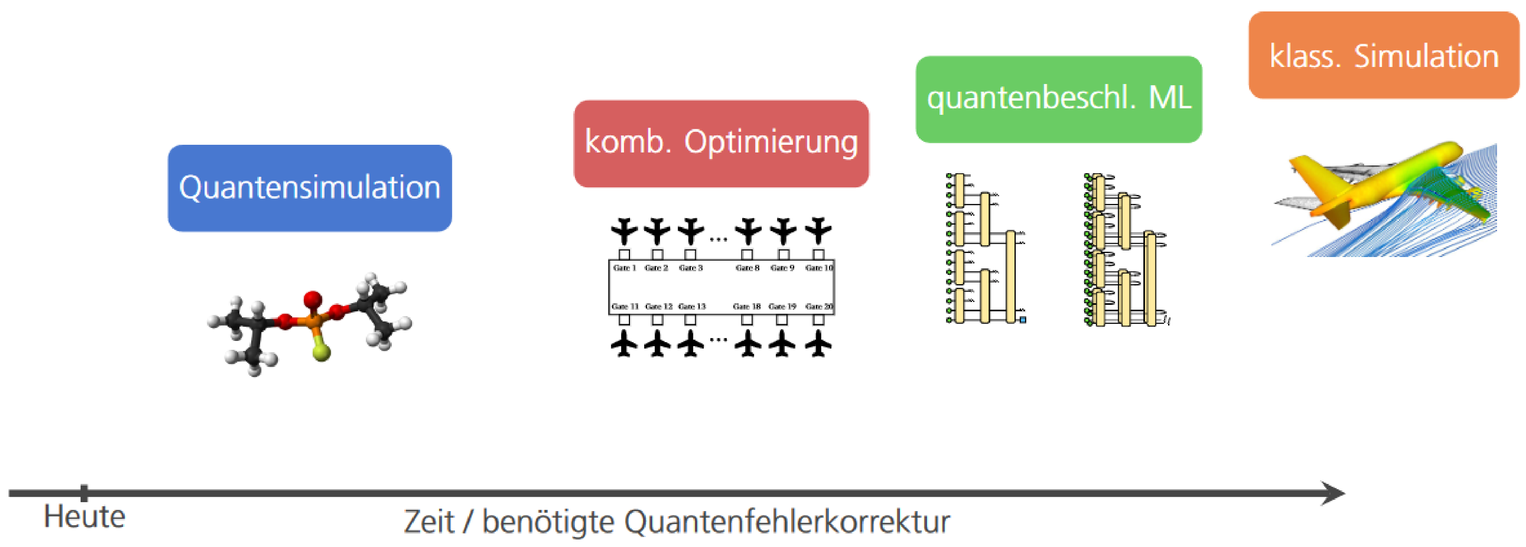
- Hardware-Software-Codesign
- Error-aware compilation
- Quantum algorithms for industrial planning problems
- Quantum simulation in materials science
- QC stack and software integration

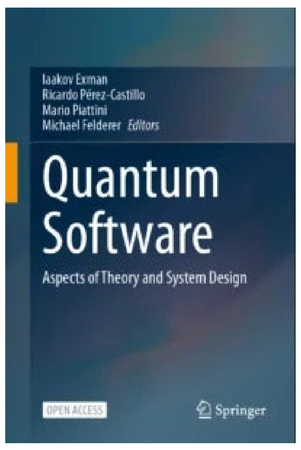


**Hardware/Software Co-Design**
For current quantum computers of the NISQ era, no algorithms are yet known that have a guaranteed runtime improvement over classical computers. Although many of these algorithms can manage without quantum error correction, precise knowledge of the errors is essential for achieving the quantum advantage. In order to realise a useful application on a quantum computer faster than on a classical computer, close cooperation in hardware and software development is therefore required. Only in this way can the key figures and error models of real machines be incorporated into algorithm development and, on the other hand, hardware development can realise precisely those goals that are most promising in terms of algorithms and possible applications. This approach is known as hardware-software codesign. Furthermore, a perspective orientation towards the potential end users is essential in order to achieve the common goal: to solve a useful application on a quantum computer faster than on a classical computer. This is why we are building a bridge between basic research and potential end users with our project.




**For which problems do NISQ computers promise a quantum advantage?**
It is not at all easy to find algorithms for error-prone quantum computers that promise a quantum advantage despite their susceptibility to errors. This is currently a key challenge! In particular, the identification of practically relevant tasks that are possible with current quantum-accelerated methods and their translation into a problem that can be solved by the quantum computer require some knowledge and experience. Due to the volatile development in the hardware sector, a high degree of adaptability is also always required. We must therefore thoroughly analyse the applications and algorithms for possible uses. At the same time, we must not lose sight of alternative developments. It must always be clear that it is not enough to simply map an application on a quantum computer. Rather, the goal must always be to solve the application faster or better than with the best algorithms on conventional hardware. In the ALQU project, we are focusing on application problems from materials science and combinatorial optimisation, as a quantum advantage is expected for such problems in the not too distant future.




**Quantum Software**
The implementation of the hardware-software code design requires quantum-specific software development along the entire QC software stack. The book "Quantum Software. Aspects of Theory and System Design" (Springer Verlag, eBook 2024) provides a comprehensive overview of the latest developments and challenges in the field of software systems for quantum computing. The chapter "Quantum Software Ecosystem Design" was written by experts from the Institute for Software Technology who are conducting research in the ALQU and CLIQUE projects of the QCI. The core of this chapter is the concept of hardware-software code design described above. Close integration between the application level of the software and the specific applications of the quantum hardware ensures that algorithms and applications are optimally matched to the underlying hardware in order to maximise the benefits of quantum computers.

**Research activities in ALQU**
The ALQU project is a potpourri of - at first glance - independent sub-projects from very different research areas (e.g. basic mathematics for compilation, combinatorial optimisation, theoretical solid-state physics, software development, QC integration, etc.), all of which, however, shed light on different aspects of hardware-software codesign. The various projects are realised in close cooperation with a number of industrial partners, who contribute their respective expertise to the corresponding sub-project.

**More information about the project can be found on our website.**

A project of

DLR Institut für Softwaretechnologie

Contractors

IQM · HQS Quantum Simulations · Single Quantum · parityqc · d-fine · Multiverse Computing · planqc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**Get in touch.**
We enable quantum!


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