EARLY APPLICATIONS OF QUANTUM COMPUTERS
Matthias Steffen
IBM Research Center, USA

ABSTRACT
Time, memory and (physical) space are examples of resources required to solve any computational problem. Computational complexity theory categorizes problems according to how the resource requirements grow as the problems size increases. Some problems require an exponentially growing number of resources while others do not, regardless of which classical computer (or supercomputer) the problem is run on. Remarkably, a quantum computer changes this picture! A quantum computer could solve some problems requiring fundamentally fewer resources compared to a conventional classical computer. This feat is what draws significant attention to quantum computing.

Yet, because of the delicate nature of entangled quantum states, the construction of a quantum computer poses enormous technical challenges, engaging many experts from fields including physics, mathematics, quantum information, materials science, and microwave engineering – just to name a few. It is hypothesized that ultimately millions or even billions of quantum bits (qubits) are required for a fault-tolerant (i.e. error-free) quantum computer. This contrasts with state-of-the-art quantum processors containing on the order of 20-50 qubits. While this number appears tiny compared with what may ultimately be needed, these small quantum processors are quite remarkable scientific objects and critical learning instruments for quantum computing applications.

There is significant optimism and hope that even a few hundred of qubits could begin to address some interesting problems of practical value. Even though small quantum processors exhibit errors, they may still be able to approximately simulate important problems including quantum chemistry or optimization problems. In this talk, I will present the latest research results, mostly from our perspective, on what has and could possibly be done using small quantum computers, as well as a description of superconducting qubits that are used a IBM.