



# HPC and QC Integration

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## Why HPC/QC Integration?

### Why Now?

- Quantum systems are becoming generally usable systems
- User demand is rising with requests from broad communities

### Why Integrated?

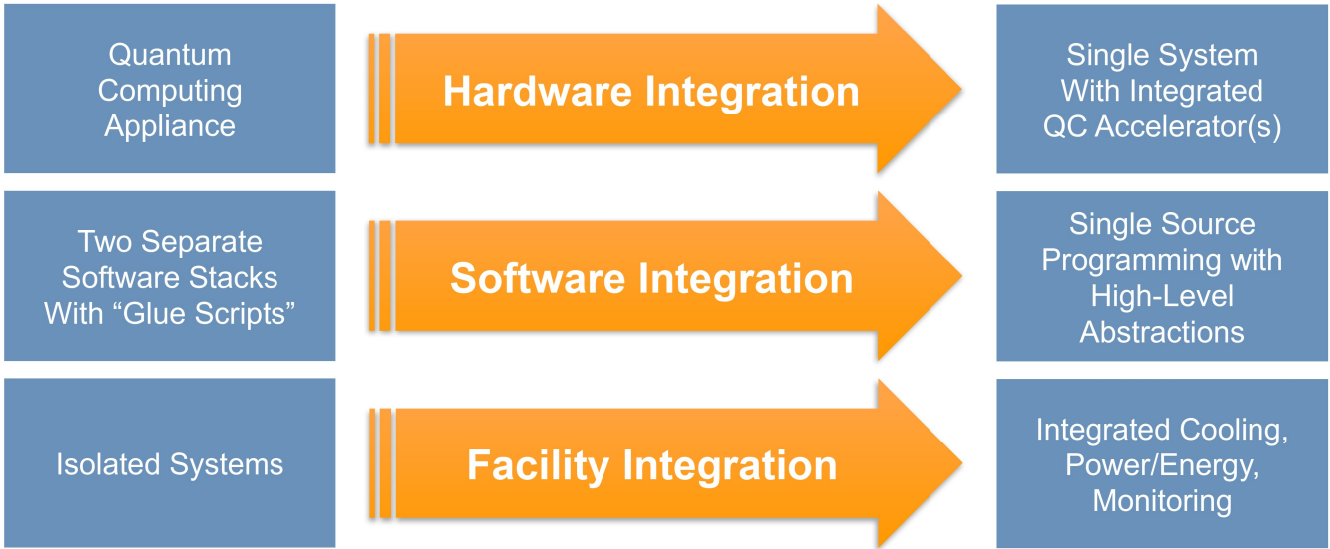
- Quantum systems require complex and high-performance binary components
- Applications will be hybrid and hence systems should be as well

### Who?

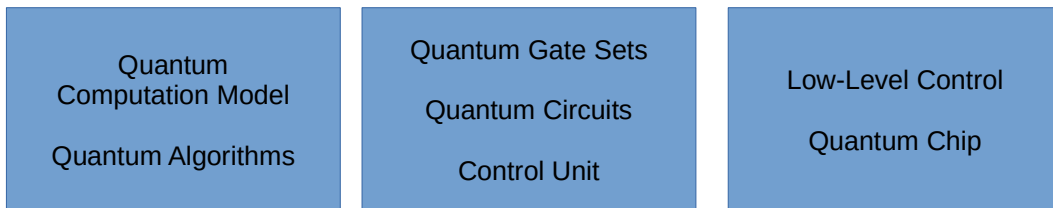
- Many starting activities: DoE, NordQuEst, Munich Quantum Valley to name just a few



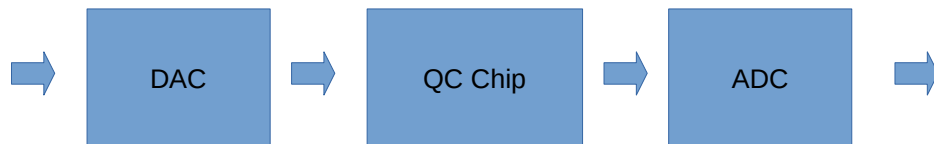
## Hot Development Areas



## Technology stack

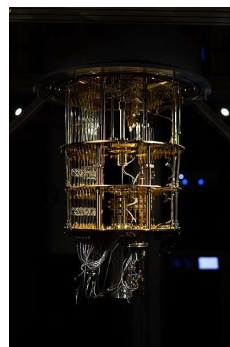


## The Quantum Chip is Analog



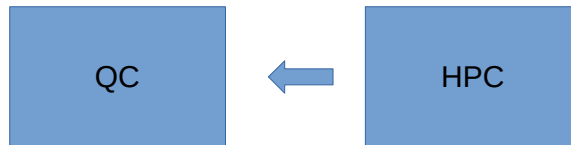
## Why is it so Complicated?

Control Unit	300 K
Intermediate electronics	10s K
QC Chip	mK



Source: [https://commons.wikimedia.org/wiki/File:IQM\\_Quantum\\_Computer\\_Espoo\\_Finland.jpg](https://commons.wikimedia.org/wiki/File:IQM_Quantum_Computer_Espoo_Finland.jpg), used with permission, Creative Commons Attribution-Share Alike 4.0 International

## QC Used as a Accelerator



```
void f(void)
{
  ...
  value = quantum_work(...);
  ...
}
```

```
void f(void)
{
  ...
  value = optimize(...);
  ...
}
```

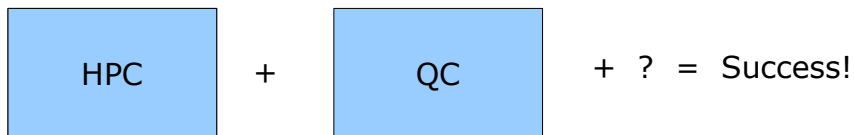
## QC and HPC Interplay



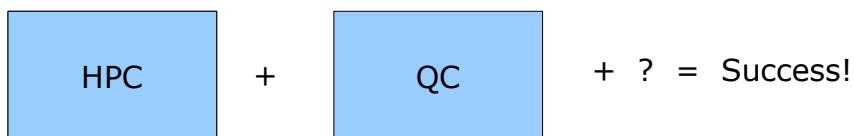
- QC will likely first be used as an accelerator of key HPC algorithms
- HPC can be used to overcome some of the key engineering challenges
  - It can also be used to optimize the processes



## The Challenge



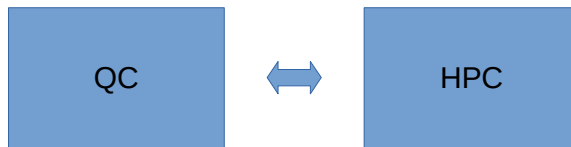
## The Challenge



- **Open question: How to integrate quantum devices into binary systems.**
  - Software? Programming models?
  - Workflows?
  - System software?
  - Hardware / Software co-design, binary *and* quantum
  - Computer architecture?
  - Hardware integration?



## QC and HPC Software Stacks



- Single user
- No system software
- No operating system
- Some firmware
- “Compiler”

- Multi user
- Security
- Scheduler
- Storage stack
- System software
- Networking stack
- Middleware, eg. MPI
- Operating system
- Full set of tools

Where to place QC?



## Summary



- QC is starting to take off
- Systems work for many applications
- Integration into HPC systems has not yet been done
- Fast moving open research area
- Many different approaches explored
- QC will likely be hidden in libraries and off-loading calls, similarly to GPUs