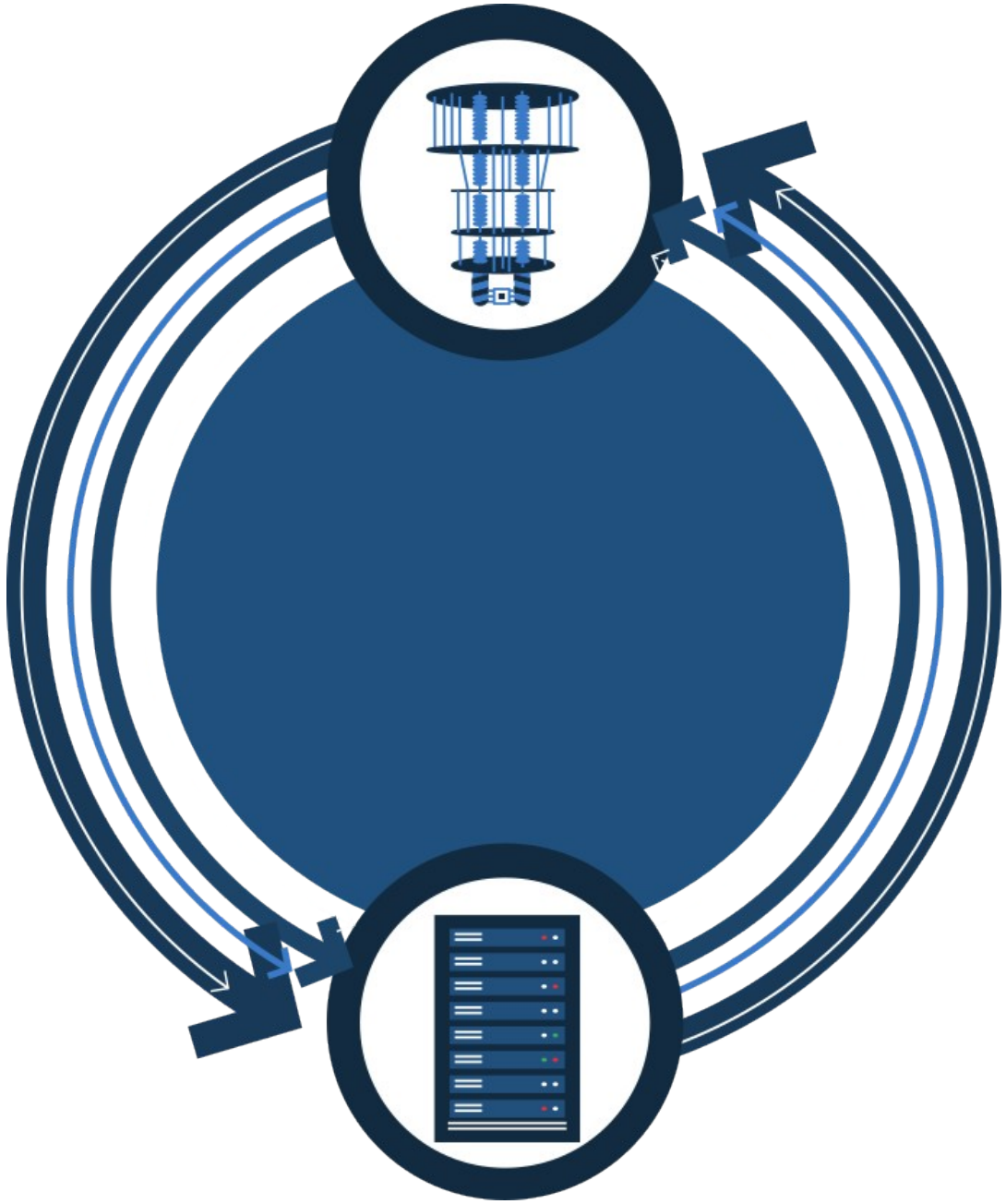
Quantum @ SURF

Ariana Torres Knoop



+100 institutions work together at SURF to develop ground-breaking ICT innovations for research and education.

→ SURF develops, implements and maintains the national research and education network (NREN) of the Netherlands

→ SURF provides IT infrastructure (network, data storage, data processing, etc)

→ SURF host and operates the National supercomputer Snellius

→ Soon to be host of a EuroHPC quantum computer

https://www.surf.nl/en

SURF and quantum

- **Drive innovation**
- **Provide a first class IT infrastructure to Research and Education (R&E)**
- **Facilitate adoption of quantum technologies**
- **Facilitate knowledge and expertise development around quantum technologies**

SURF and quantum

QUANTUM COMPUTING

Enable access and use of quantum infrastructure (emulators, simulators, computers)

Stimulate the development of quantum applications and use cases

Enable the implementation and execution of quantum applications

Support the integration of the quantum and classical IT ecosystems and infrastructure

QUANTUM COMMUNICATION

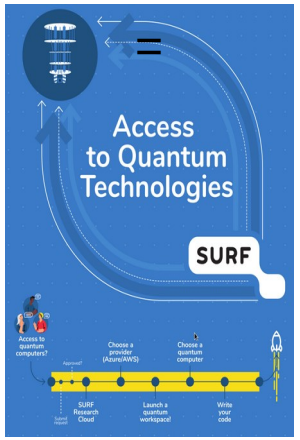
Understand how to build a reliable and specialized quantum enhanced network

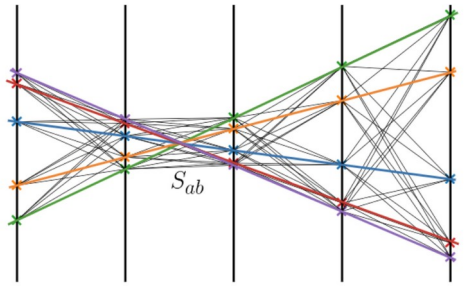
Prepare for migration to quantum-safe infrastructure

Explore how quantum networks can support novel applications and workflows

Support ongoing research into next-generation quantum internet architectures

SURF and quantum





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QCIned Hackathon: Build your quantum-safe app on SURF's QKD testbed

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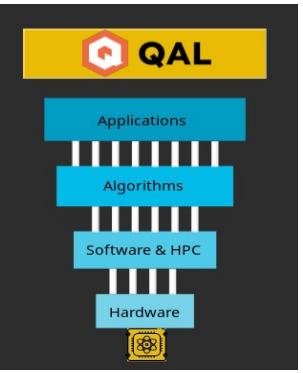
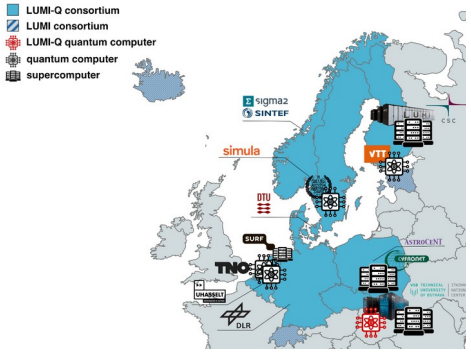
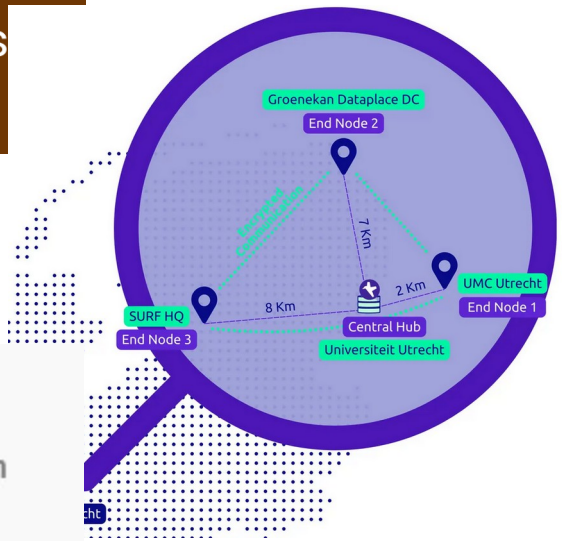
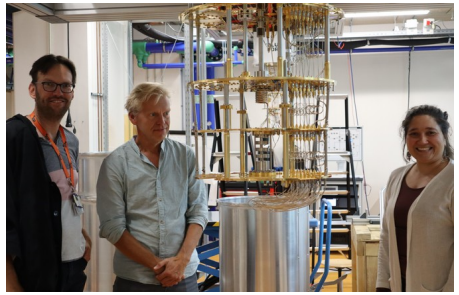






NetSquid

The Network Simulator for Quantum Information using Discrete events



Quantum Internet Alliance

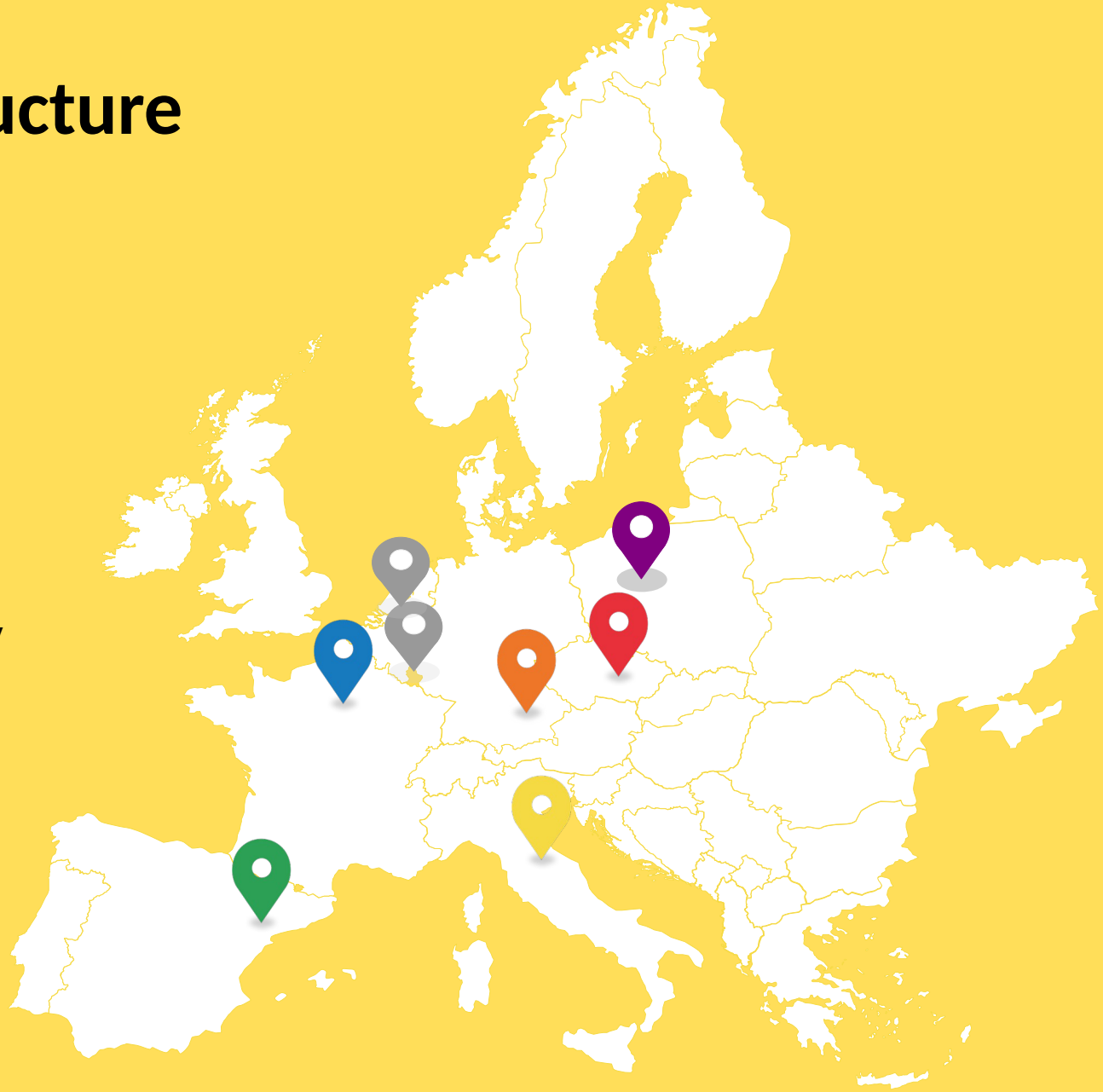
Building a global Quantum Internet made in Europe

SURF

SURF to host European Quantum Computer in the Amsterdam Science Park

EuroHPC quantum infrastructure

- EuroQ-Exa, LRZ Superconducting +50 qubits, lattice, IQM
- EuroQHPC-Spain, BSC, Superconducting analogue
- EuroQHPC-Italy, CINECA Neutral Atoms
- EuroQHPC-Poland, PSNC, Trapped ions
- EuroQHPC-France, GENCI, Photonics, Quandela
- LUMI-Q, IT4I, superconducting fully connected (star-shape), IQM
- EuroSSQ-HPC, SURF, Spin Semiconducting
- MeluxinaQ, LuxProvide, Spin Semiconducting



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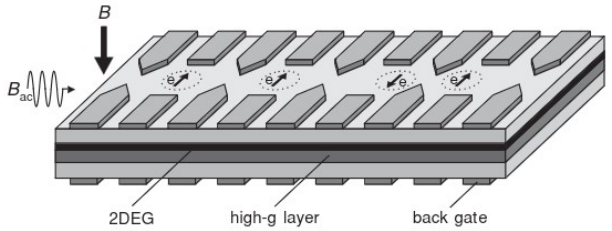
EuroSSQ-HPC

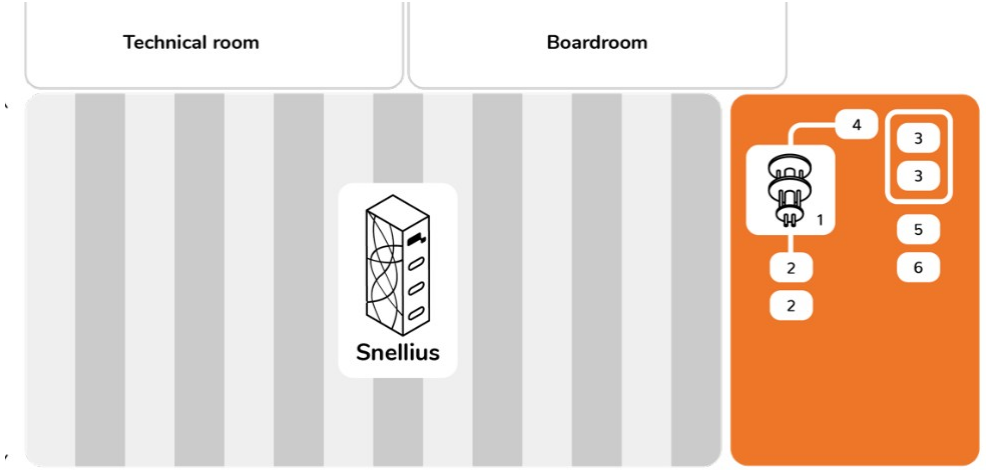
Consortium
University of Antwerpen (BE),
GENCI (FR),
NL eScience Center (NL),
Leiden University, aQa (NL),
Delft University of Technology (NL),
National Institute of Subatomic Physics, UM (NL)
SURF (NL)

System
Spin Semiconducting qubits (+16)

Location
Amsterdam Science Park, DigitalRealty Data Center



Semiconductor Few-Electron Quantum Dots as Spin Qubits, J.M. Elzerman et al.



Why HPC-quantum at SURF?

EU positioning
Become a node in the European HPC-quantum infrastructure

Competitive advantage
Easy access for scientific users (researchers & students)

Capacity building
Development of experience with quantum technology

Extend and sustain a community of experts
Co-design the quantum infrastructure

Stay in the forefront
Leverage current position into European large-scale computing ecosystem

Prepare to take full-advantage
Opportunity to experiment, learn and develop expertise and capacity

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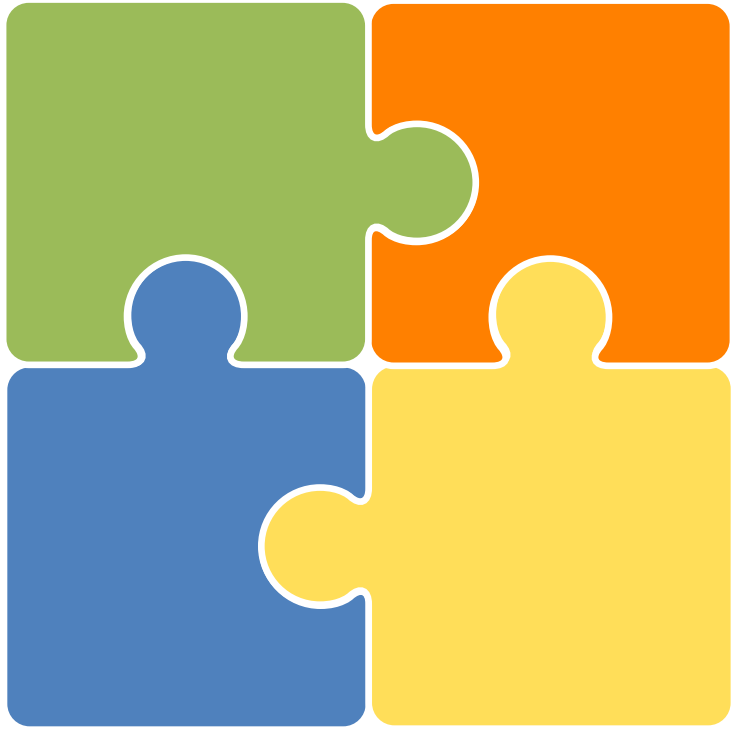
“The question is not longer only about theoretical capability but also practical applicability in real computing environments”

(HPCwire)

How do we get there? We need...

More and more robust qubits

Qubits are still very fragile



Robust software stack

We need to develop tools and libraries to enable the implementation of quantum algorithms

More algorithms

We need to continue develop fundamentally different algorithms for NISQ and FT

More applications

We need more applications to help guide the development of hardware and software

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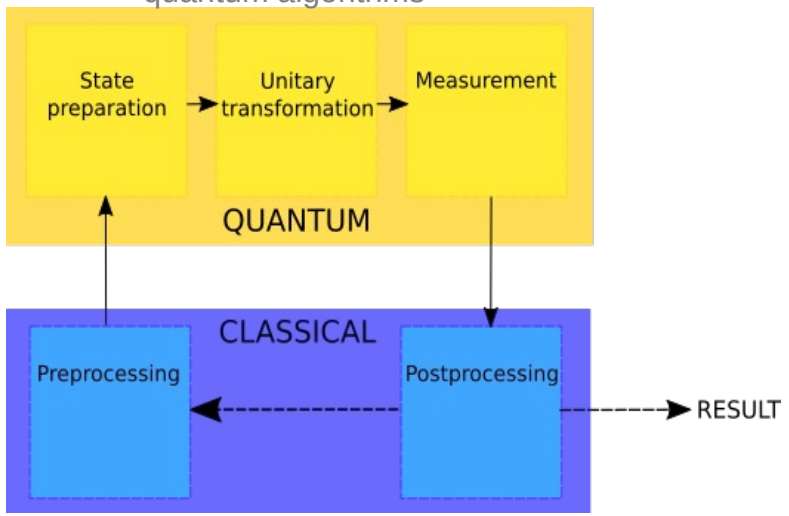
Integration to the existing classical ecosystem!
- Hardware, Facilities, Access, Software, Expertise

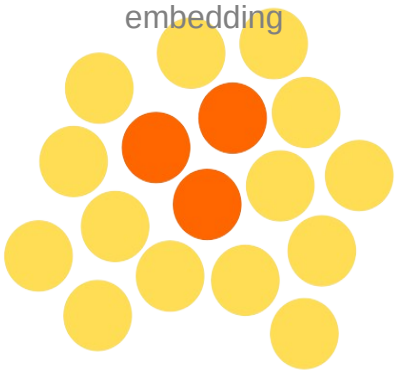
Integration to classical ecosystem: HPC

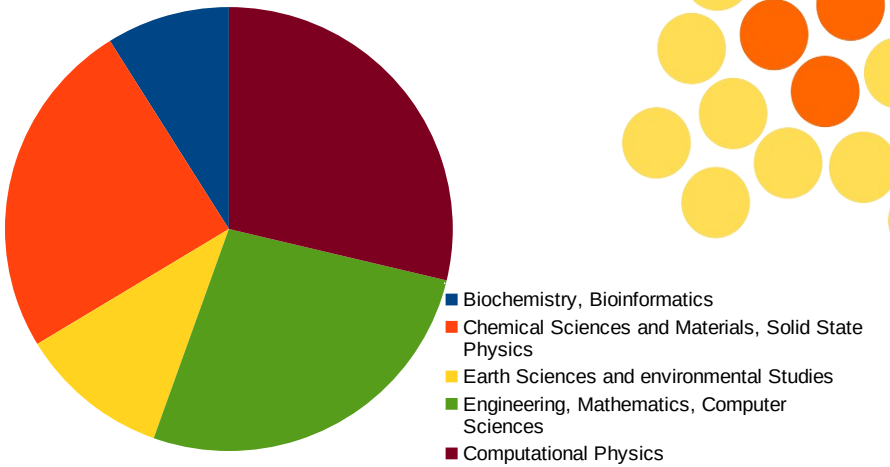
- Hybrid quantum algorithms are currently the only way to exploit NISQ devices.
- The execution of quantum algorithms will most likely always be part of a larger hybrid workflow
- Many of the most promising applications overlap with existing applications of HPC
- Simulation of quantum computers requires large computational resources
- **User base and infrastructure**

Schematic of quantum algorithms



Molecular embedding





EuroHPC access request s for HPC

“Use of quantum computers to address existing computing challenges while leveraging the plethora of existing HPC tools, systems and workflows”

(2021 IEEE, Quantum Computers for High Performance Computing, Humble et al.)

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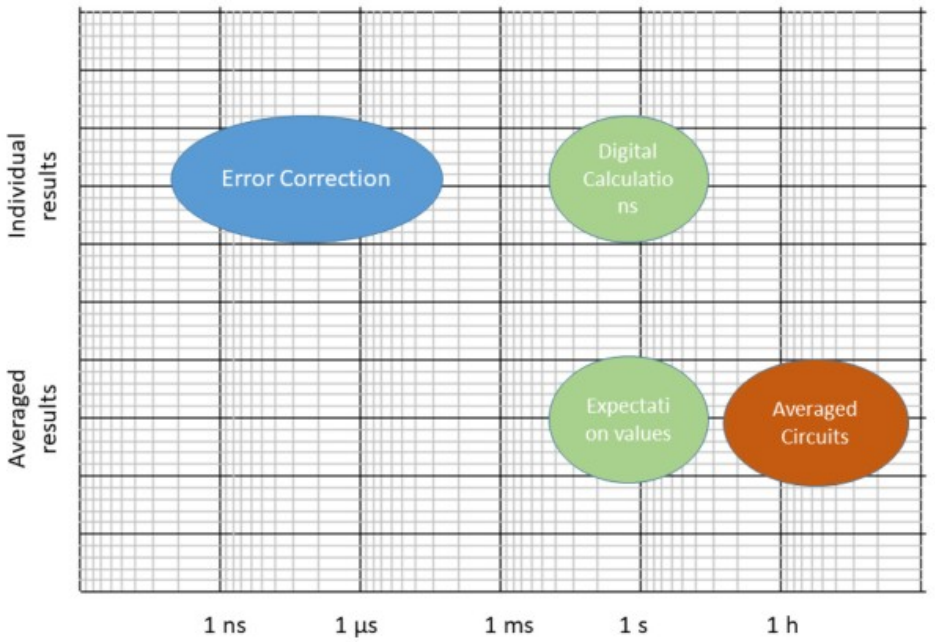
Quantum for HPC & HPC for Quantum

- **Usage of real quantum resources to extend classical capabilities: simulate quantum systems, optimizations, QML, CFD...**
- Usage of classical resources to compute the theoretical output of a quantum algorithms (emulation)
- Usage of classical resources for pre- post-processing (including error mitigation)
- Usage of classical resources for variational optimization
- Usage of classical resources for circuit cutting and knitting
- *Usage of classical resources for error correction (conditional preparation of quantum states based on intermediate measurements)*



(2021 IEEE, Quantum Computers for High Performance Computing, Humble et al.)

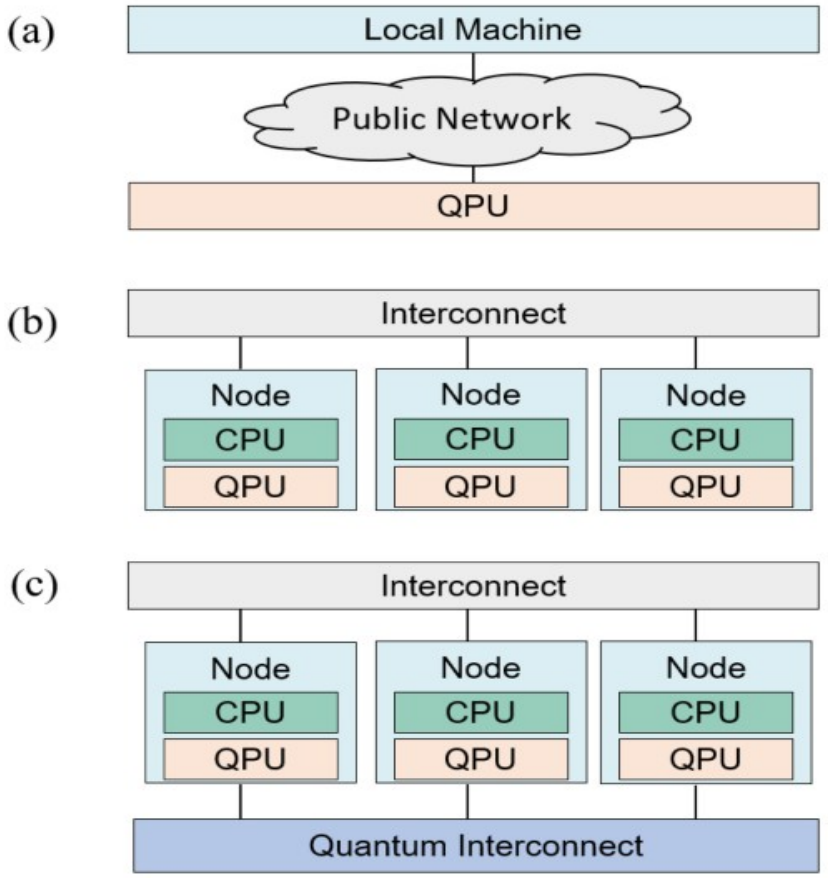
What is the expected resource balance?
How tightly do the resources need to be coupled?
What is the latency needed?

What is peculiar about Quantum?

- Tightly couple, unbalanced
- Scarce resource
- One user at the time
- Calibrations
- Non-homogeneous qubits
- …

→ More of a system-to-sytem integration

How should we schedule the jobs?
What needs to be optimized?
How do we share resources?
Access and authentication?
Resource monitoring?
How should the macro and micro architecture look like?



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Questions?

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