Towards a High Performance Hybrid Computing

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Quantum Computing Consultant
14/12/2023

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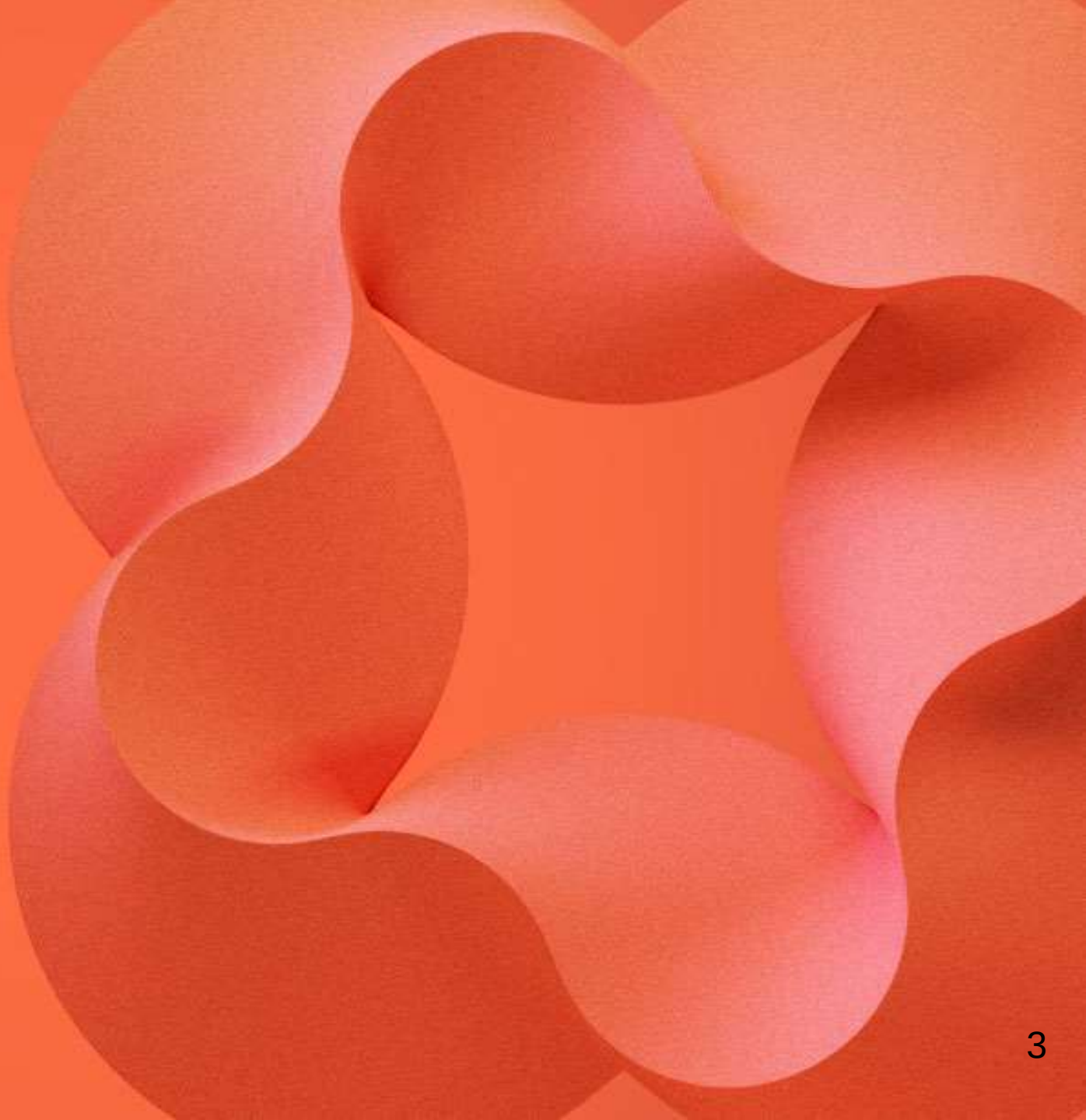
01 Qaptiva™



A new strategy to adapt to a dynamic market shift

From learning Quantum Computing to building real-world QC applications

Up until now
Learn the quantum computing paradigms

We helped academics and Industries gear up

We led emulations in HPC and Quantum

We sold appliances

Make the impossible possible

Starting now
It's time to build real-world applications

We offer the best vertically integrated QC Application Platform

We target a large ecosystem of enterprises, organizations, and research centers

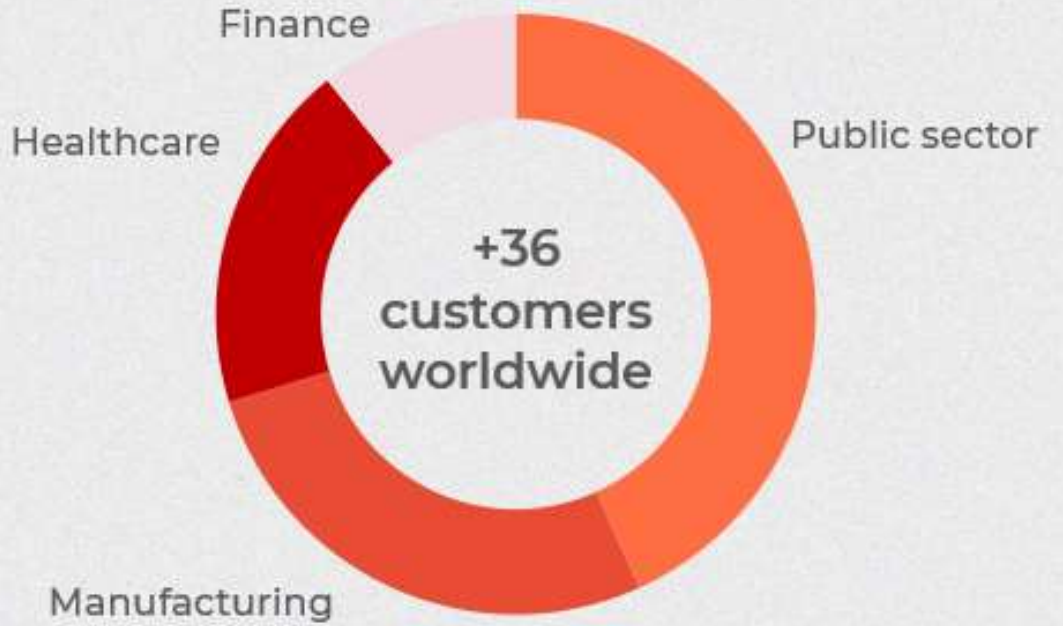
We have a new go to market strategy

Qaptiva™ ID card

Pioneering since 2016

+83 patents
#1 in France #2 in Europe

+15 international research projects



Quantum emulation on noisy and noiseless qubits

Emulation of quantum annealing up to 50000 spins & hundreds of Qubits

Quantum Computing as a Service
or
On-premises

Leaders in HPC & Quantum hybridization

Use-case specific quantum libraries

Access to physical QPUs

Leaders' quadrant according to Technology Business Research TBR

Qaptiva

Scalable solutions for quantum computing programming, emulation, simulation, and hybridization.

Consulting & Training

Appliances & Servers

- Qaptiva™ 800
- Qaptiva™ Access

QC as a Service

Python Package myQLM

Welcome page — myQLM documentation documentation

Software Enablers

- 3rd party libraries
- Emulation on HPC
- HPC Hybridization
- Qaptiva™ Q-Pragma

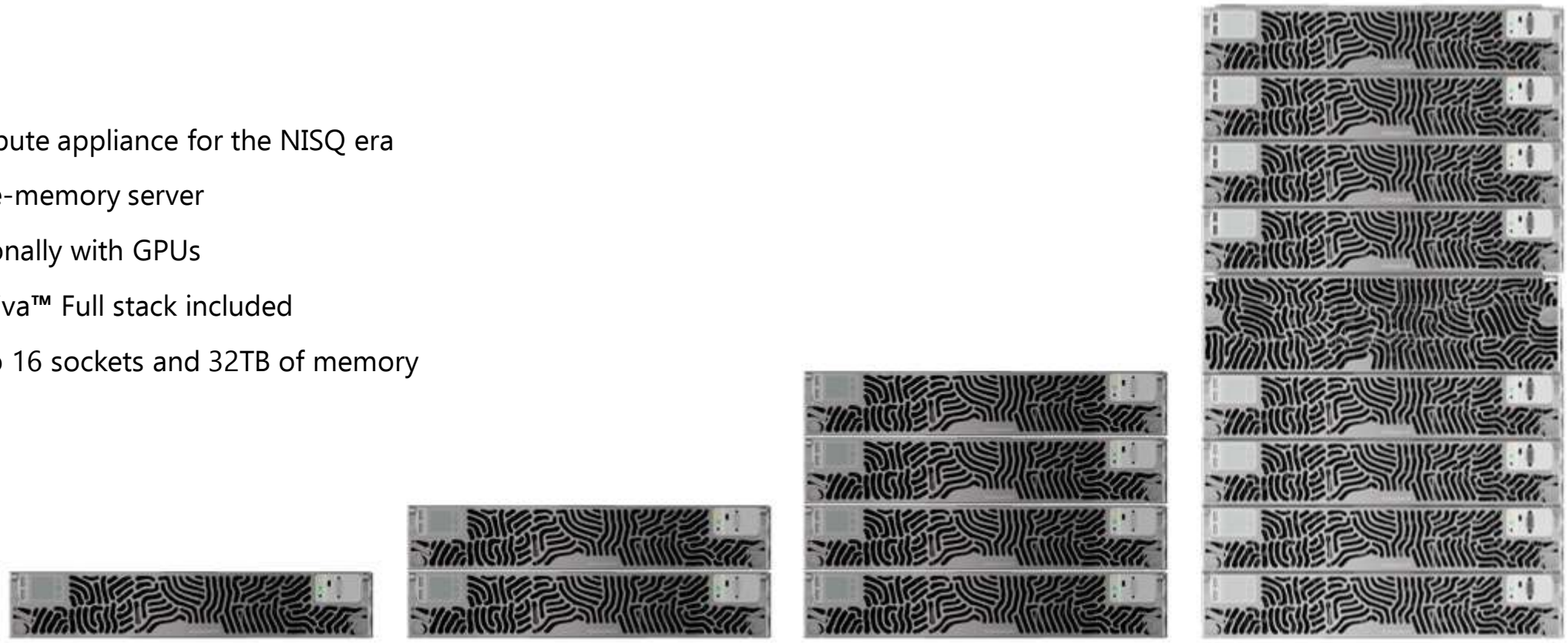
Strong Partnerships

- QPU Makers
- Industry-specific Software

Qaptiva™ Hardware - 800 series

Classical hardware appliances

- Compute appliance for the NISQ era
- Large-memory server
- Optionally with GPUs
- Qaptiva™ Full stack included
- Up to 16 sockets and 32TB of memory



Qaptiva™ 802
2 sockets
2 TB memory

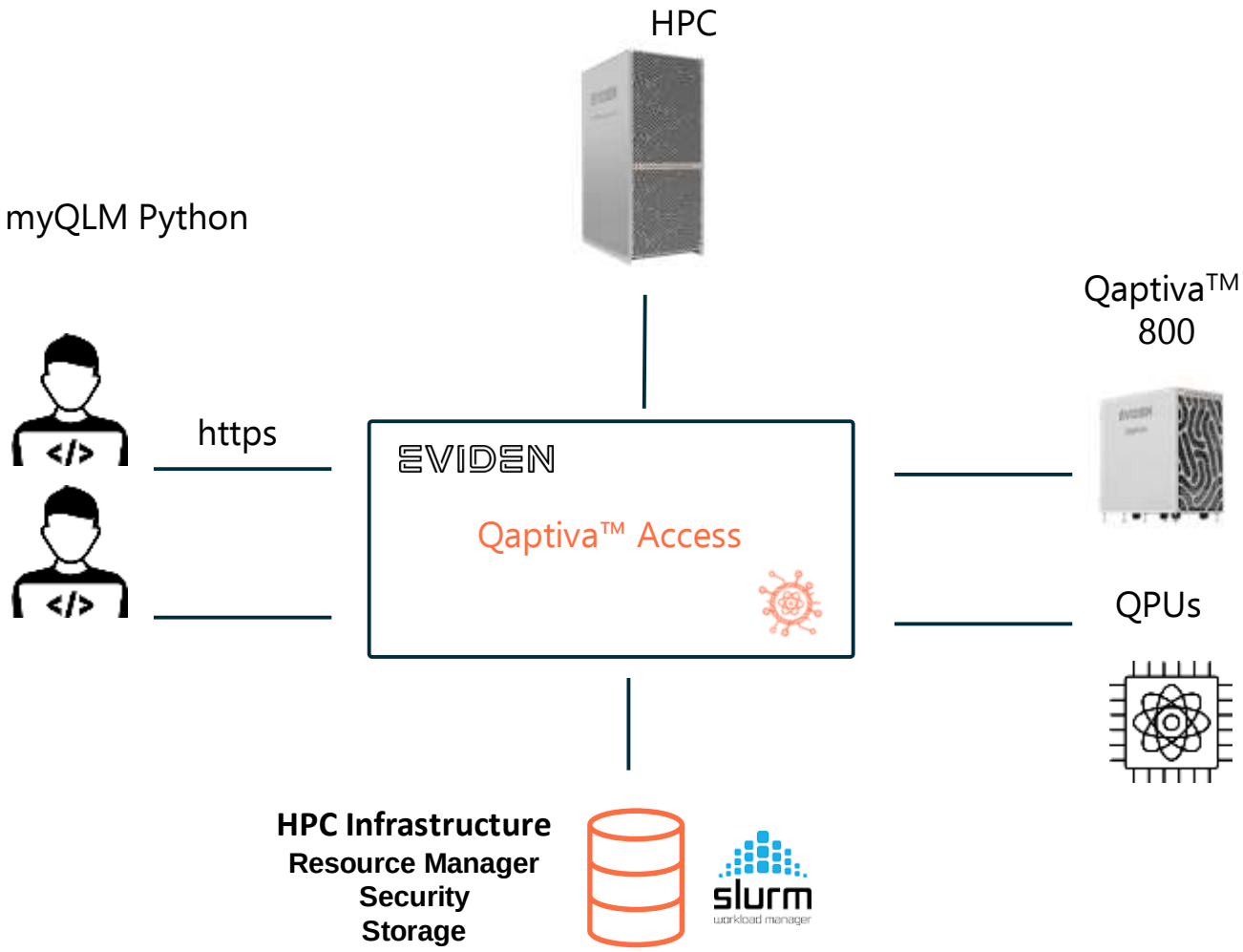
Qaptiva™ 804
4 sockets
4 TB memory

Qaptiva™ 808
8 sockets
8 TB memory

Qaptiva™ 816
16 sockets
32 TB memory

Qaptiva™ Access Server

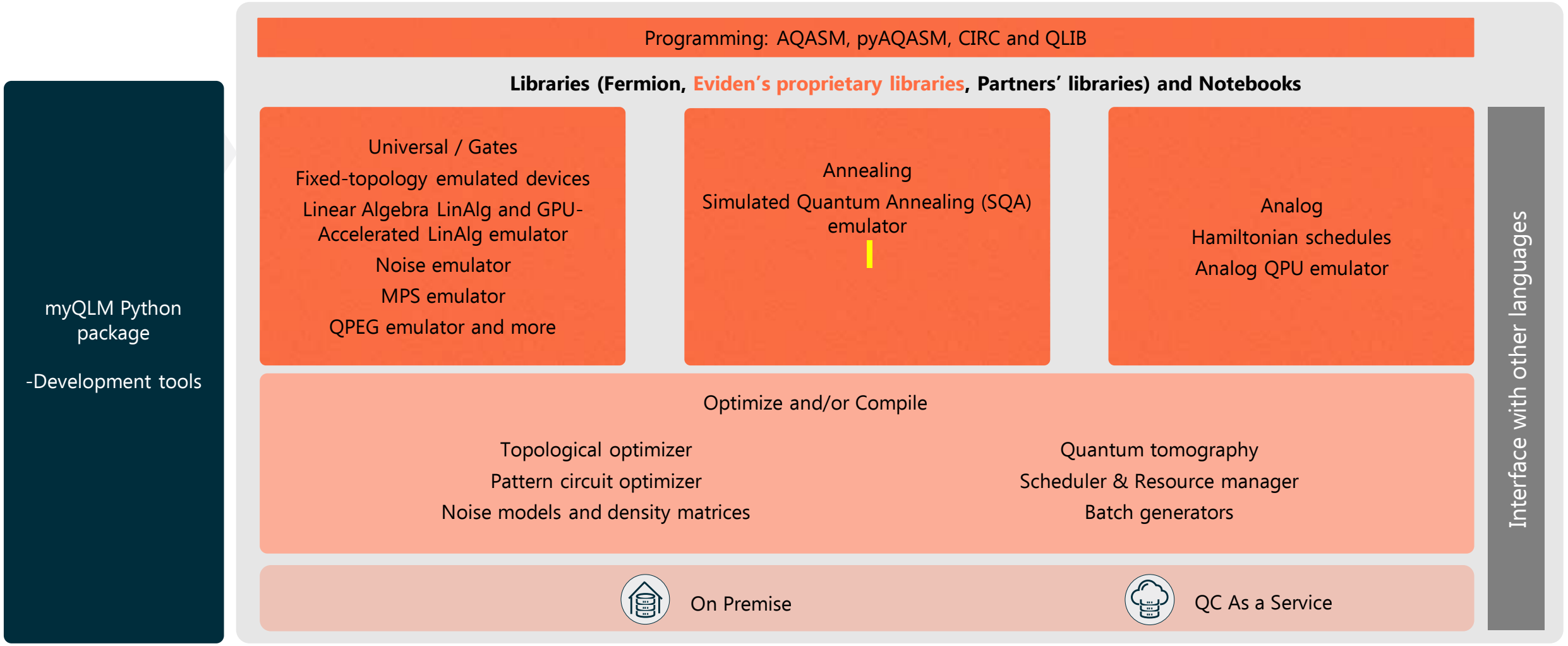
Front-end server to orchestrate quantum resources and enable HPC and quantum hybridization



It enables the integration of any quantum processing unit (QPU) and emulator into the high-performance computing (HPC) infrastructure.

- Real scheduling of QPUs with SLURM
- Scale-out numerical simulation (MPI + GPU)
- Used in several HPC-QC pilots:
  - HPC-QS by EuroHPC
  - HQI in France
  - Qsolid in Germany

Qaptiva™ Application platform



Qaptiva™ Q-Pragma

C++ Framework for FTQC Computing

It is a powerful tool for HPC centers that helps optimize programs and continuously accelerate classical supercomputers.

Q-Pragma allows the creation of algorithms that can integrate quantum routines into existing HPC applications. HPC centers can use HPC-Quantum hybridization to enhance current applications, integrate C++ programs, and enable heterogeneous computing.

First deployment in HQI project, in collaboration with Genci & CEA

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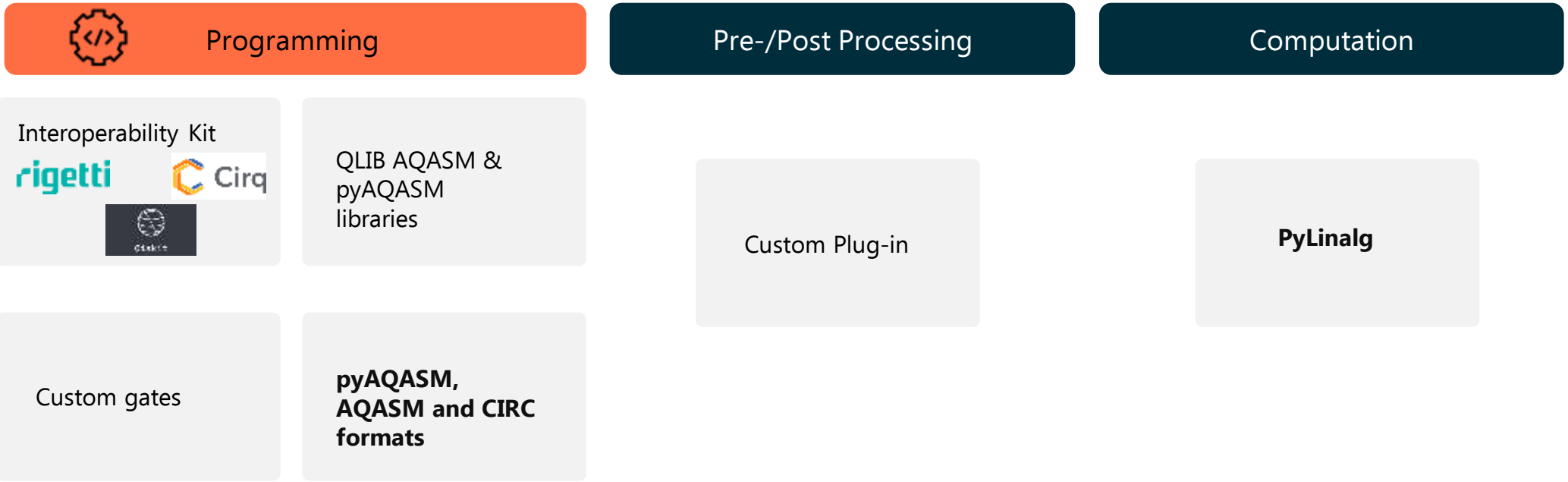
Qaptiva™ myQLM – Python Package

Test and develop quantum algorithms on any device

- Freeware Python package with interoperability connectors that provides basic programming features, and serves as a rich client to Qaptiva™ access
- It allows for easy integration and collaboration with other tools and systems, making it a versatile and accessible solution for working with quantum computing applications.
- Available for download



Qaptiva™ Partner Ecosystem

Software & Consulting Partners

ColibrITD

Multiverse Computing

QbitSoft

QuantFi

Qubit Pharmaceuticals

QuRISK Advisory

Aerospace
Automotive
Defense
Finance
Healthcare
Logistics

QPU Makers

Alice & Bob

IQM

Pasqal

Quandela

quobly

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With its strong partnerships and joint go-to-market strategies, Eviden is realizing its commitment to offering end-to-end solutions.

Qaptiva™ Partner Ecosystem

Expanding offerings and capabilities to deliver more value

Photonics

2 to 12 optical qubits

Co-design approach or ready-made hardware

Available now on Qaptiva™ as a Service

- Hosted by Quandela
- VQE example
- 10000 shots - 20 seconds execution – few euros to run

Superconducting

Gate-based paradigm

World-class error rates

Co-design approach or ready-made hardware

Use-case-specific hardware design

- As a Service in 2024
- Plan to be hosted by Eviden
- 5 qubits capabilities

Neutral atoms

Analog and gate-based computing paradigm

Up to 200 qubits

Deep integration with myQLM tools

CAT Qubits

Innovative hardware-efficient design will reduce the hardware requirements for a fault-tolerant quantum computer

Eviden Quantum Computing

Client success

+36

Appliance customers

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02 NISQ QPUs into an HPC center

Noisy Intermediate Scale Quantum

Defining NISQ

NISQ *(Noisy Intermediate Scale Quantum)*

→ ~hundreds of noisy qubits

→ ~hundreds instructions

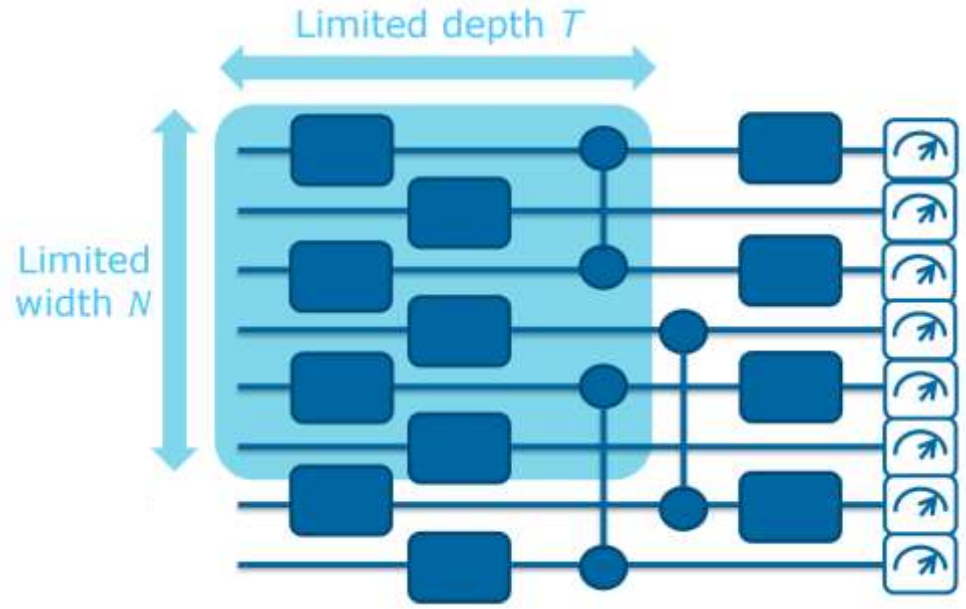
Programming model:

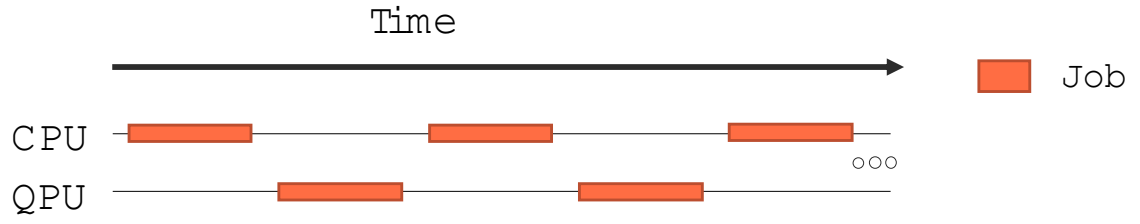
Control flow managed by CPU

Quantum circuits created by CPU

Repeated evaluation of circuit by QPU

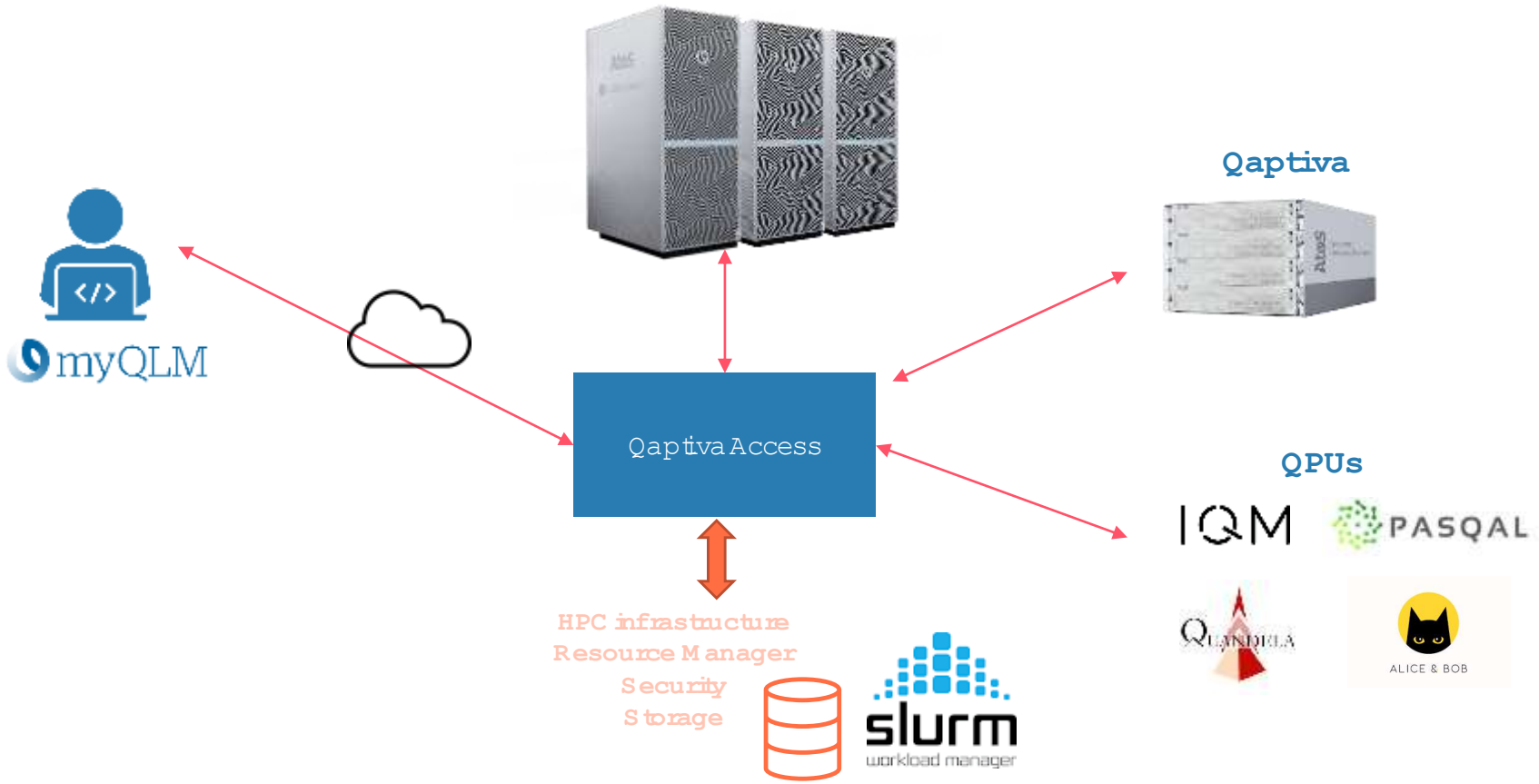
⇒ **QPU online slave of CPU**





Integrating NISQ QPUs into an HPC datacenter

- EuroHPC project HPC-QS, France HQI

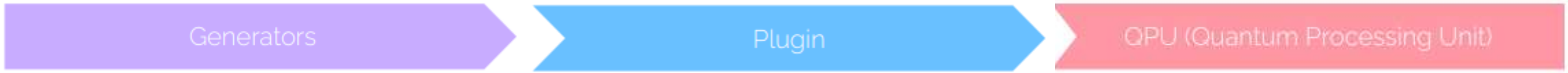


Qaptiva & Hybrid computation stacks

The computation chain

Qaptiva defines 3 types of services:

- Generates inputs (i.e. quantum jobs)
- (Classically) pre / post processes quantum jobs
- Executes a quantum job, can either be:
  - An emulator (running on CPU, GPU…)
  - A QPU



Qaptiva & Hybrid computation stacks

The computation chain

A computation chains can be built by stacking services.

A chain is composed of:

- A list of quantum jobs *or* a strategy to build jobs
- One or more plugins *(Optional)*
- One QPU

Qaptiva & Hybrid computation stacks

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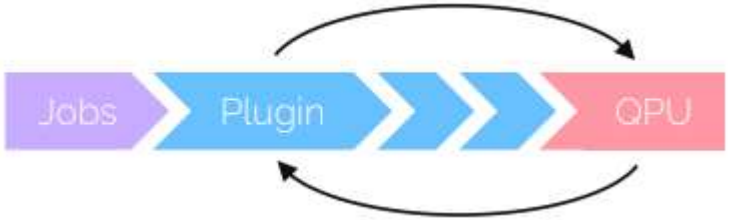
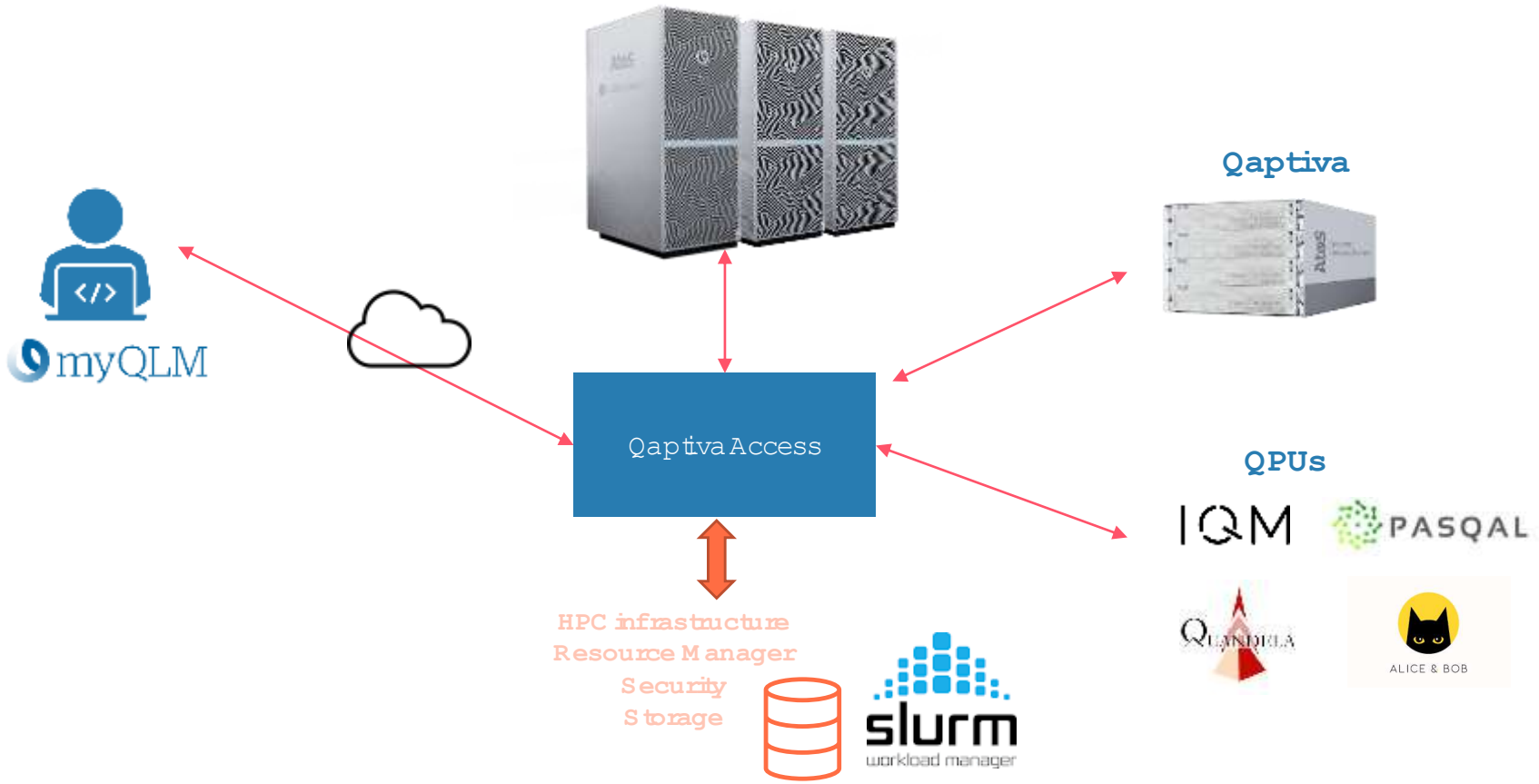


Plugins can resubmit quantum jobs

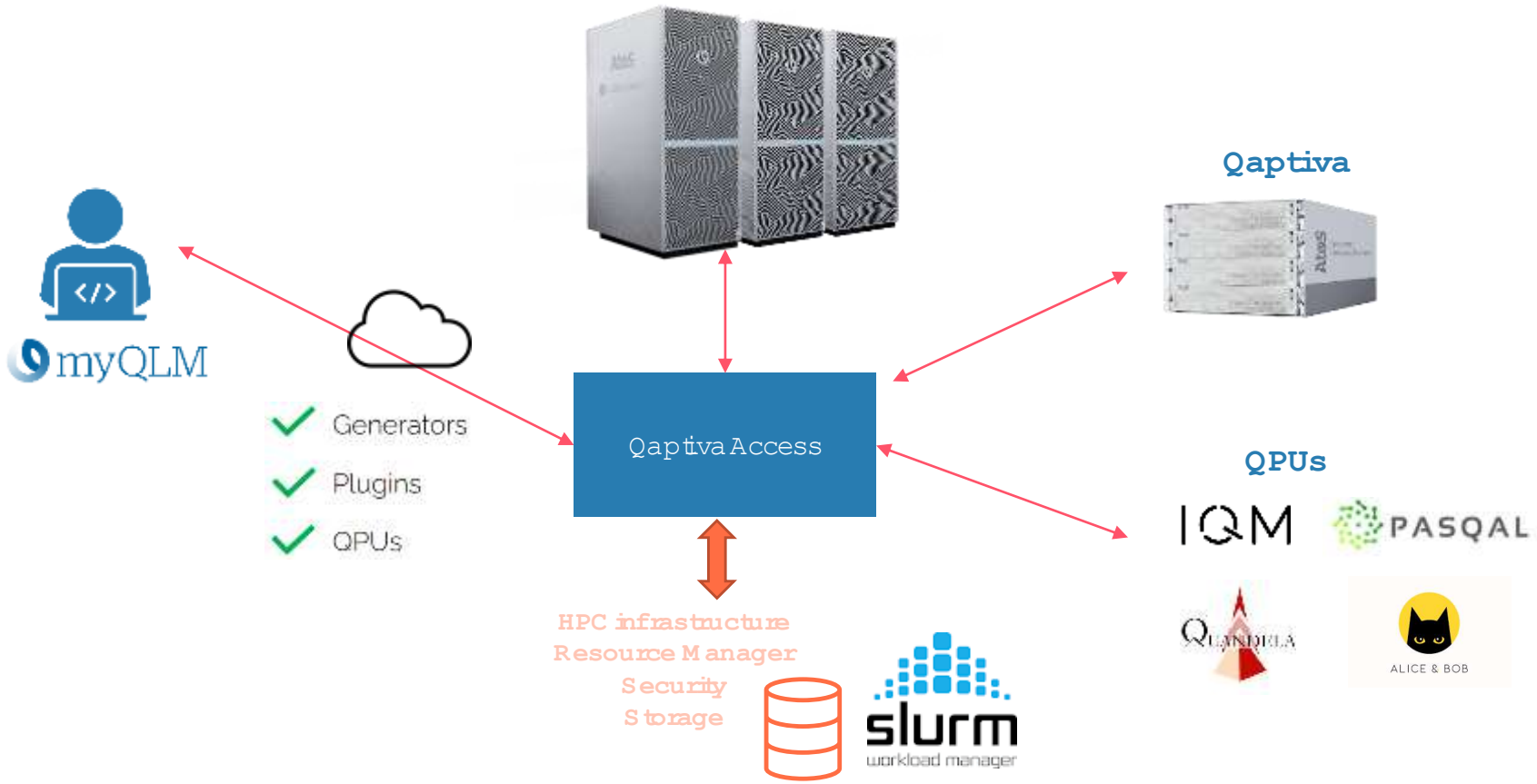
Accessing hybrid cluster remotely

Qaptiva Power Access



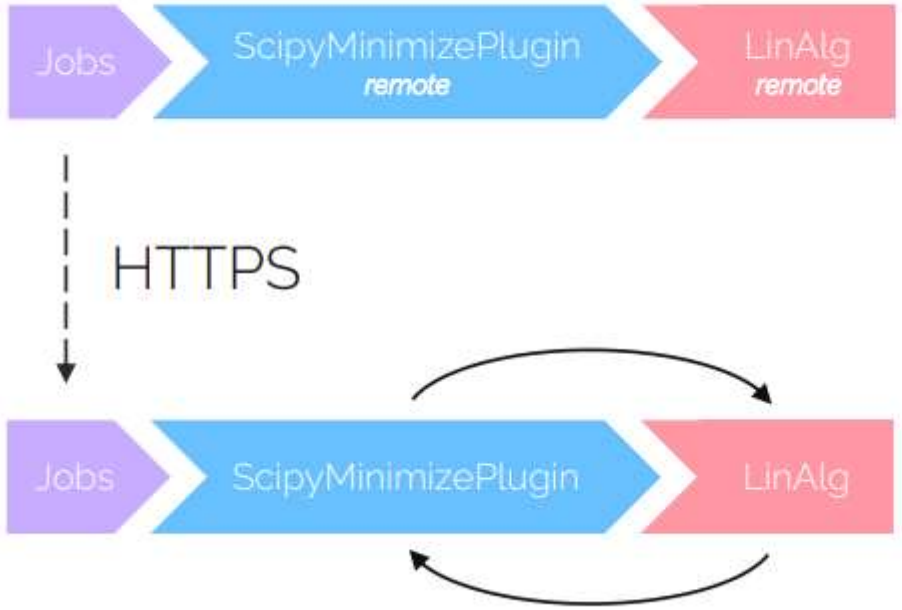
Accessing hybrid cluster remotely

Qaptiva Power Access



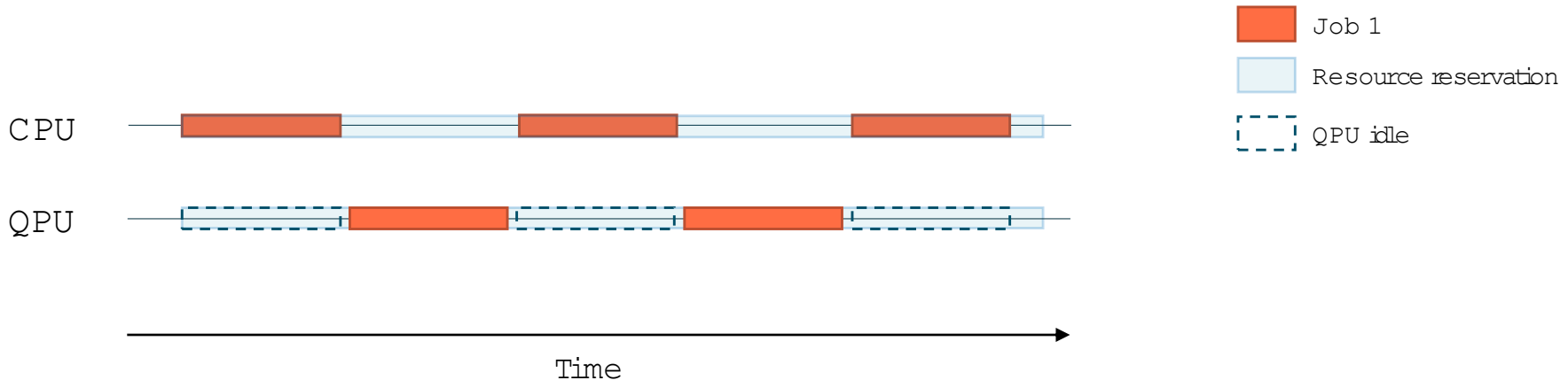
Accessing hybrid cluster remotely

Example of Qaptiva python code



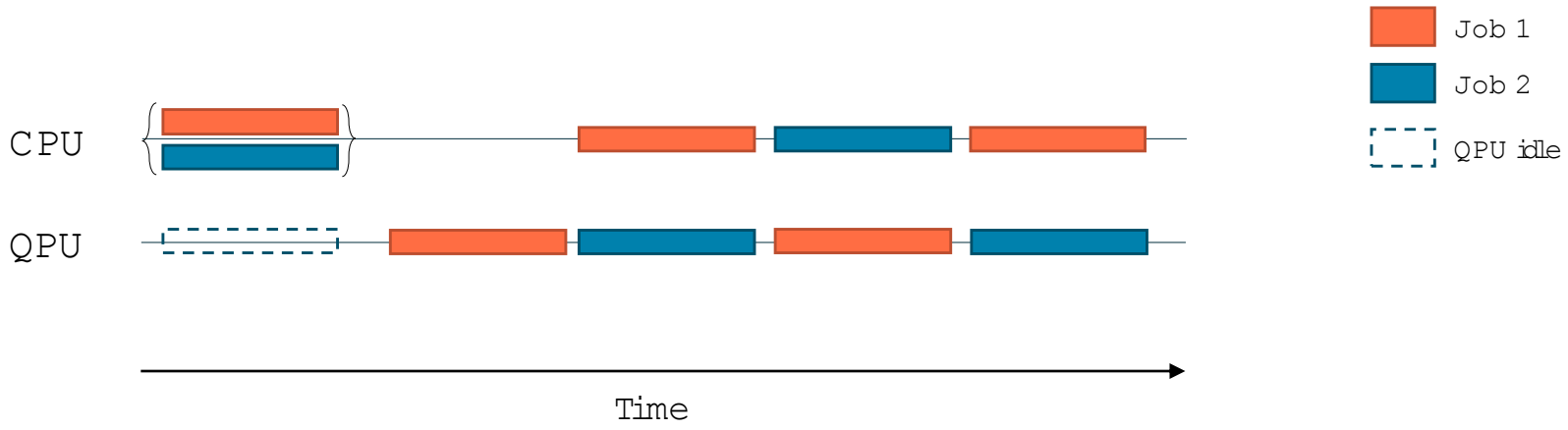
Scheduling quantum jobs

High-level scheduling and QPU idleness



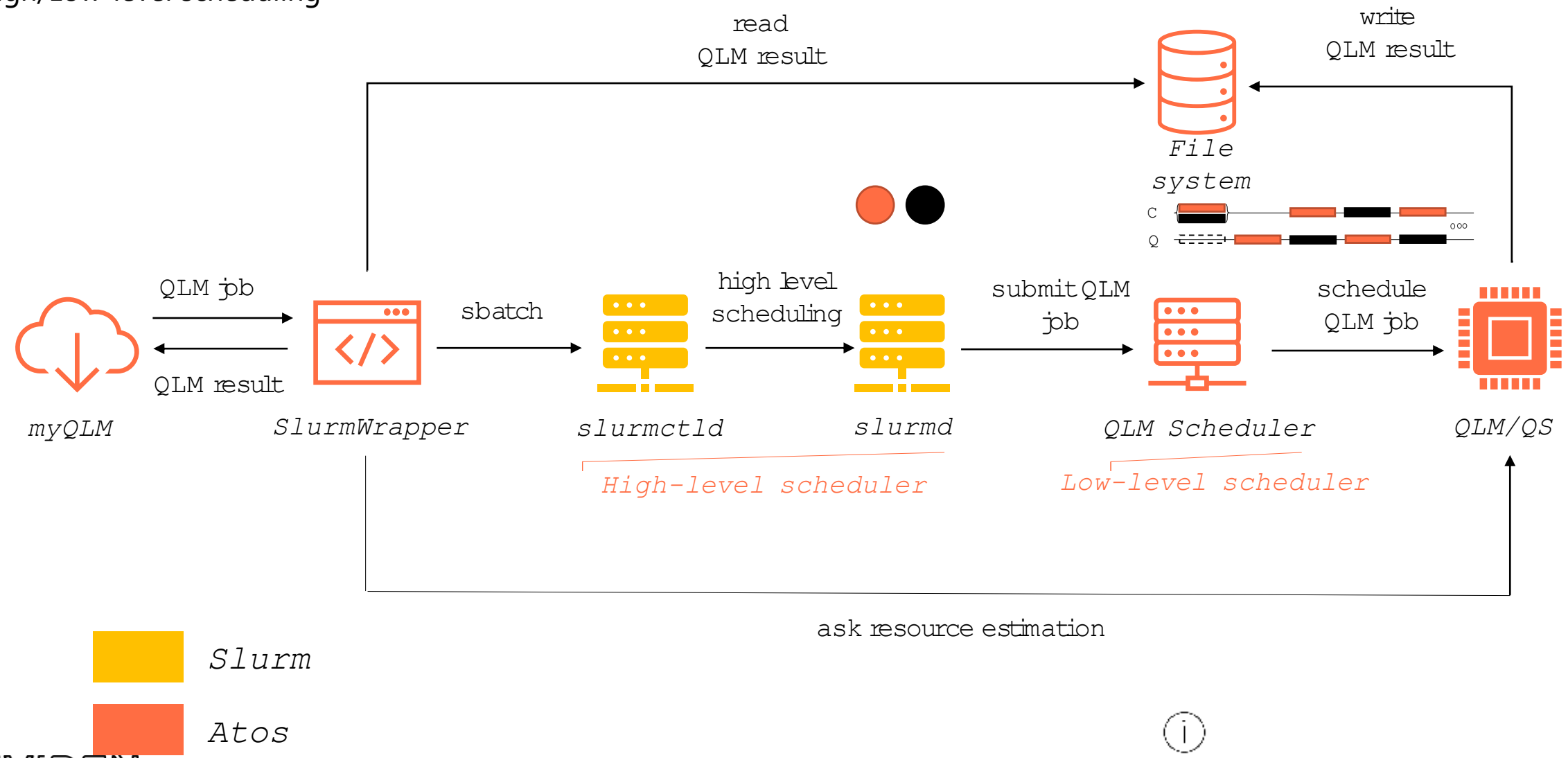
Scheduling quantum jobs

High/Low-level scheduling



Scheduling quantum jobs

High/Low-level scheduling



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03 Towards a High Performance Hybrid Computing (HPHC) Framework

High Performance Hybrid Computing

Defining HPHC

HPHC *(High Performance Hybrid Computing)*

→ ~thousands of perfect logical qubits (with QEC)

→ Multi-QPUs

→ Use of QPUs in HPC centers

Long term

Entire application, composed of classical and quantum parts

HPC programming languages
(compatibility with C, C++, Fortran, etc.)

What will an HPHC program look like?

› Architecture of HPHC quantum devices ?

QPUs will have classical capabilities

Architecture of an hybrid quantum device

QPUs willbe composed of:

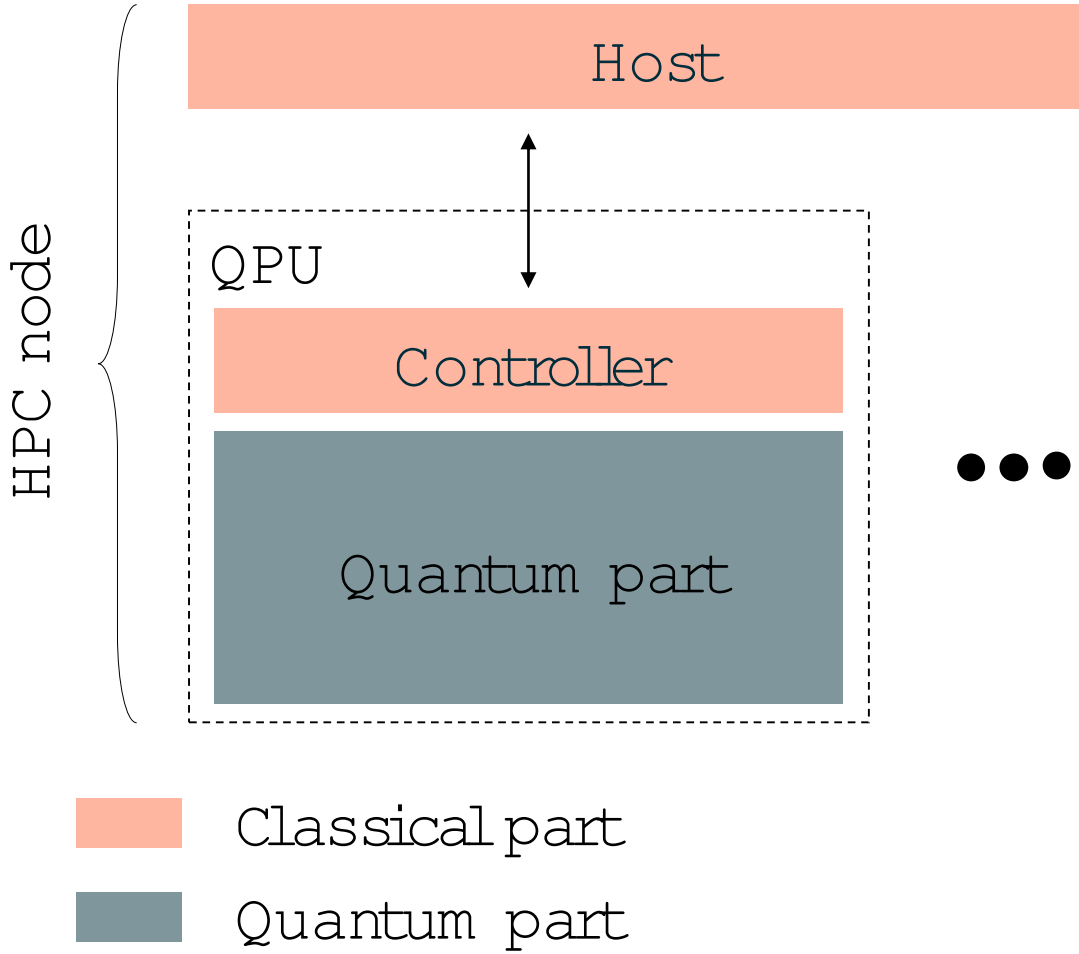
- A *controller* receiving instructions and scheduling them on the *quantum part*
- A *quantum part* being the core of the QPU

Controller purpose:

Manage quantum part

Quantum error correction

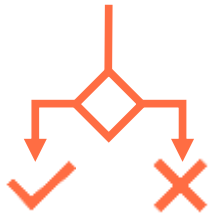
Execute classical user code?



Quantum capabilities

Defining quantum specific operations

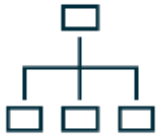
Quantum routines are reversible



Quantum routines controllable

Access to quantum memory

Safe uncomputation should be used to reset a register



Typing quantum memory

Q-Pragma – A C++ Framework for LSQ computing

A framework composed of a library and some pragmas

Q-Pragma C++ framework:

Pragmas to extend C++ language, to add:

- Hybridization capabilities
- Quantum capabilites

A library providing:

- Quantum types
- Quantum routines
- …

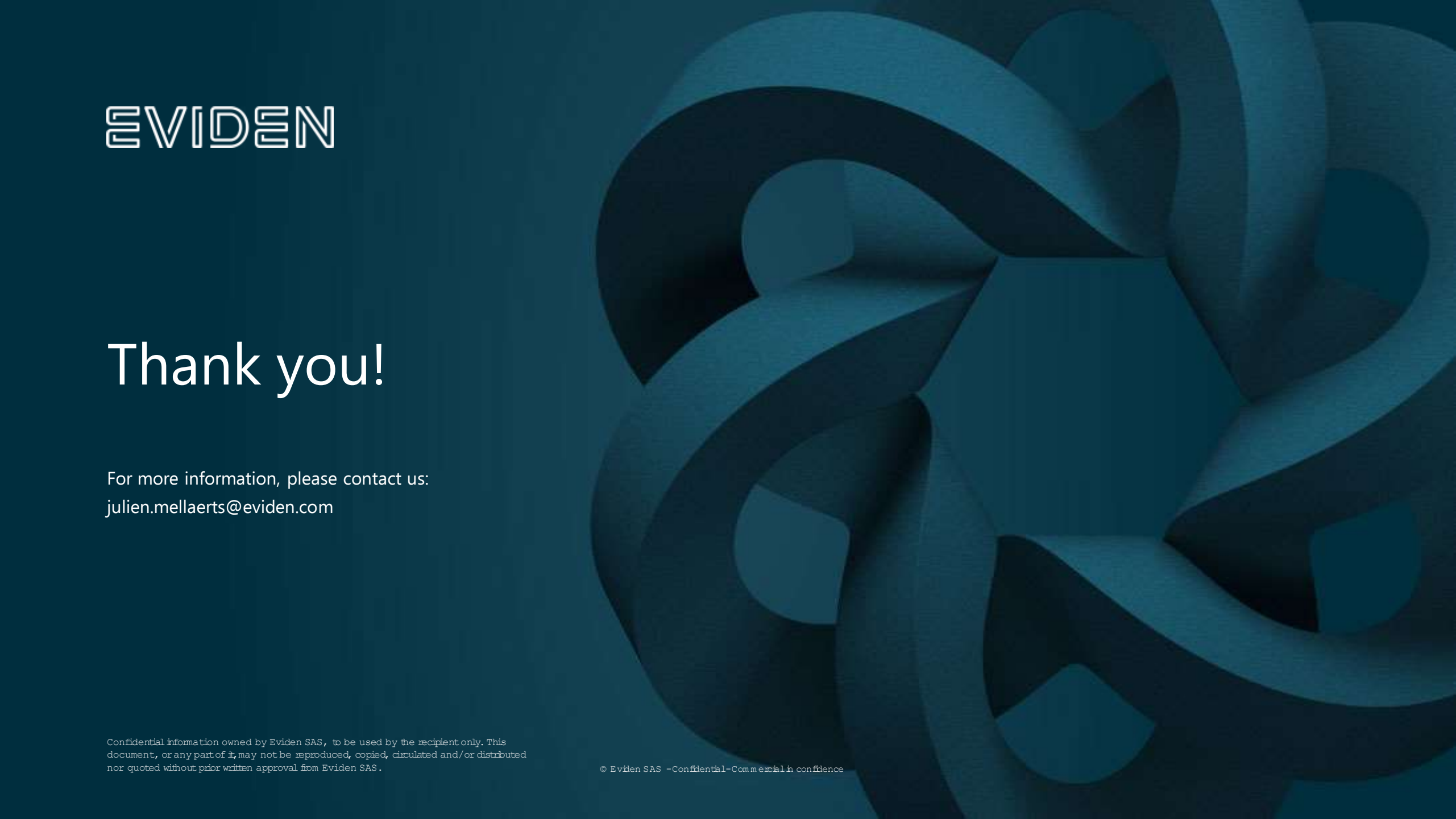
Q-Pragma example

```
#pragma quantum routine
void bell_pair(const qbool & qb0,
               const qbool & qb1) {
    H(qb0);
    CNOT(qb0, qb1);
}

int main() {
    …;
    ::bell_pair(qb1, qb2);
    ::bell_pair.dag(qb1, qb2);
    ::bell_pair.ctrl(qc, qb1, qb2);
}
```

Perspectives for Q-Pragma

- Open source specification
- Federate a community from HPC
- Continue co-design, guided by HPC use cases



Thank you!

For more information, please contact us:
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