REX INDUSTRIES USER GROUP

Make it Industrial

EDF · Teratec · THALES Building a future we can all trust · RENAULT · NAVAL GROUP · LA POSTE · CA · SNCF · cea

Make it Industrial

CONTEXT

- During the last summer, we asked the same questions to some companies from banking, railway, defense, energy and logistic
- We wanted to list the requirements identified in terms of hardware, software, pricing, HR in order to make Quantum usable for industries

EDF Teratec THALES Building a future we can all trust RENAULT NAVAL GROUP LA POSTE SNCF cea

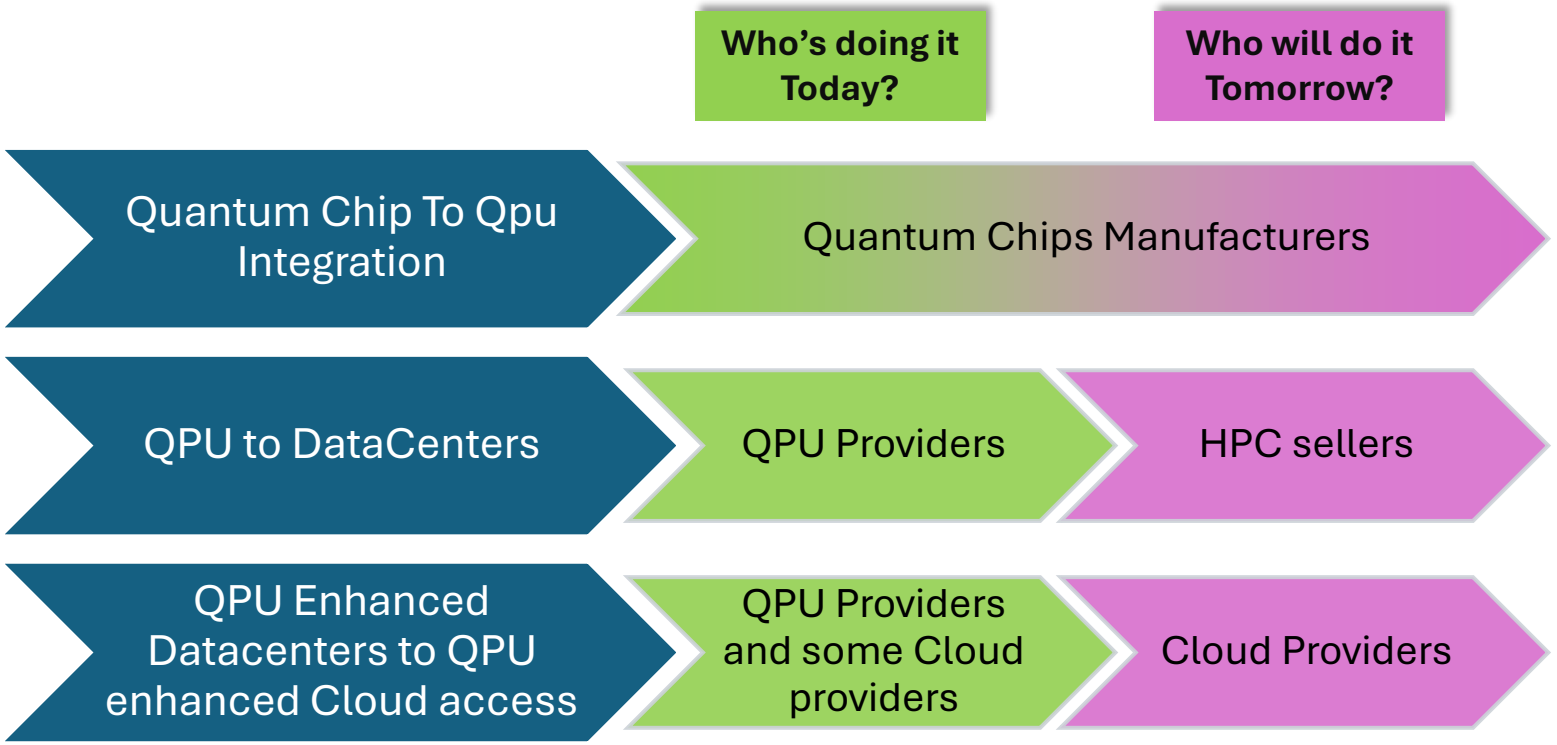
Integration

Integration Cartography Filled & Missed Actors

Quantum Chip to QPU integration

QPU to datacenter

QPU enhanced datacenter



On the necessity of an efficient Quantum Chip Integration

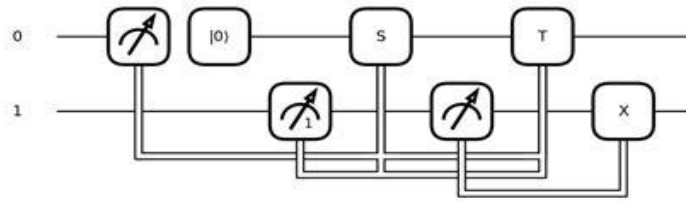
Quantum Chip to QPU integration

QPU to datacenter

QPU enhanced datacenter

Unlike CPU and GPUs, a quantum Chip alone does nothing on its own.

Algorithms require a deep integration between the Quantum Chip and the CPU/GPU; the closer the CPU is from the Quantum Chip, the wider the class of the algorithms we can use



Mid circuit measurement with a CPU that changes the circuit angles is required by some algorithms

➔ **Defining a QPU as the pair the Quantum Chip forms with the associated CPU/GPU allows to keep the integration in mind and avoiding a decoupling between the Quantum Chip and the CPU/GPU.**

Quantum Chip to QPU integration

QPU to datacenter

QPU enhanced datacenter

Integrator & Installer Role has to emerge

- End Users will need to forget about the quantum chip and think about integration : Where the computation is done? Where the data are stored ?

➔ Some actors (not necessarily hardware providers companies) have to take on the role of integrator

Quantum Chip to QPU integration

QPU to datacenter

QPU enhanced datacenter

HPC & QPU : may each take a step towards the other

- HPC is rich in 50 years history
- Even the integration of GPUs has not been easy. So integrating QPUs into data centres will be challenging.
- HPC people need to be trained on Quantum and they are currently doing it

  ⇒ It's never easy to go and intervene on a system that you don't understand.
- To what extent Quantum Physicist Engineers are trained on HPCs?

➔ To the HPC World, QPU is more than just another standard after CPU, GPU, TPU; QPU hardware providers need to be fluent in the environment, standards and history of HPCs and have to give as much inputs as possible to HPC managers

Quantum Chip to QPU integration

QPU to datacenter

QPU enhanced datacenter

Cloud or/and *On Prem?*

Most of us are still relying on *On premise HPC*

If the QPU is on Cloud,

One key feature is to have a high disponibility rate

If the QPU is on Prem,

What will we need to integrate QPUs into our Data Center :

PhD in Quantum physics?

New rooms? Lab conditions ? Clean Room? Environnement Control ? Intervention Frequency? Need for Maintenance?

The disponibility rate has to be sufficiently high (approx 100%)

➔ The *cloud only* answer to the integration is not satisfactory for everyone: defense industry can't rely on cloud;

➔ In both case, disponibility rates as high as the ones of classical HPC is required

Software Stack

Middleware

Parallelisation

Emulators

Software Quality

Schedulers

Benchmarks

+

o

Software Stack Cartography

Filled & Missed Actors

	Who's doing it Today?	Who will do it Tomorrow?
Firmware	Quantum Chips Manufacturers	
Middleware	Missed	Hopefully, open source community?
Interfaces	Hardware Companies	Hopefully, open source community?
Parallelization in Open MP / MPI Stack	Missed	Hopefully, open source community?
Emulators	HW providers, HPC manufacturers	Same guys will have to pursue the effort
Software Quality	Missed	Hopefully, open source community?
Schedulers	HW providers, HPC common solutions	Hopefully, open source community?
Benchmarks	End users & HW providers	End users

Middleware

The firmware stack is handled by hardware providers

The interface is used by end users

What about the middleware?

The path we are taking now is one Full Stack approach per QPU provider.

⇒ **Such approach is not desirable. Standards are required. Providers have to be implied in their elaboration**

Middleware

Parallelisation

Emulators

Software Quality

Schedulers

Benchmarks

Assembly Language and Quantum Objects

What is the assembly language of Quantum Computing ?

We need an open source shared one

However Open Source can be developed within a mature environnement

What are the shared protocols?

⇒ First of all, we need to define the Stack and the objects properly

⇒ We'd need an international consortium to impose standards ? De facto standards ?

Distributed Quantum Computing

- Distributed Quantum Computing (i.e. parallelization) is on the roadmap of multiple QPU providers (ionQ, IBM, Quandela, Pasqal, …)
  - Do end users will need to rewrite algorithms for parallelization ?
  - What will be the Open MP/MPI equivalent ?
  - What kind of problems have to be segmented ?
  - What level of connections will we have ?

➔ Despite some announcements, parallelization won't be transparent to end users. Let's build up the whole software stack that took decades on the HPC side to be develop.

Emulators fidelity

Today emulators do not always reflect the machine implementation perfectly.

➔ The transfer to the real machine needs to be optimised to reproduce the same results on the emulator and on the physical machine

Software quality

How can we be sure that a software does what it is asked to do?

Will we be sure that results are reproductible ?

Will it depend on the exterior conditions ?

Will we stay on Python or will we move to C++ ?

Software engineering stack (e.g. Debugging) are missed

Given the state of the art of the software quality stack, quantum Algorithm will be only applied for non safety codes at first

➔ AI adoption has been slowed down within industries due to the Black Boxes charges. Confidence in Quantum must be considered now

➔ Open source may ease confidence in Quantum

Scheduler

What is the scheduling framework (equivalent of Slurm)

⇒ How to optimize the QPU runtime without turning the whole stuff into a Black Box?

Benchmarks

- Application benchmarks such as those of Bacq are one important step for applicative applications : which technology for each use case
- Quantum actors (eg academics) have to demonstrate the value versus other technologies as tensors networks, AI,….

➔ Comparison with updated state-of-the-arts are mandatory

- Is it desirable to adapt *low level LinPack's types* mechanisms to QPU ?
- Which objective and measurable KPI understandable by the ecosystem to mesure performance of the system?
- Fidel enough emulators are important for testing over different technologies

➔ Unlike Linpack, Quantum benchmark are not just a matter of speed. We need three levels :

Applicative benchmarks
Installation & integrability metrics
Energetical cost metrics

Algorithms

NISQ/FTQC (what a bad naming)

- There’s some disilusions regarding “Nisq Variational Algorithms” but don’t throw them too soon ! There’s room for them with low error rate machines, even in FTQC regime

- As ML at its preindustrial phase, Variational Algorithms need either a strong theoretical guarantee or a massive and free amount of computation time to deliver value

➔ The processus will be incremental
NISQ and FTQC algorithms and technologies do not have to be opposed

PoCs and their limitations

- As industrials, we must be able to demonstrate value without clear ROI identified at this stage (difficulty to invest) .

⇒ We risk entering a dead end: startups that need funding and customers who are out of breath to pay.

⇒ We need to display usability

- The Pocking phase seems to be behind the most advanced users
- Despite the arise of 100 qubits QPUs, emulation is still important at this stage to have a better chance that the industrial scale level test will work

⇒ The next generation of tests has to be at the industrial scale level.

This includes size of the problem, software quality, Operational integration capacity.

Sovereignty

European Sovereignty is a challenge. Coding Languages / Libraries, even open sourced are mostly US private ones

How to keep hardwares and softwares in Europe ?

It’s very hard to find academic supervisors for algorithms thesis.

➔ All algorithms are US ones : We miss european labs that focus only on algorithms

New usages vs Too Early simplification

- We started a first phase with the objective of solving problems that are causing classic HPCs to fail and sometimes forgot the brand-new possible usages
- It's nice to provide companies that can't rely on black boxes with packages that hide the Quantum complexity behind user friendly interfaces

BUT

- These companies do not need the field to be simplified too quickly as we have to understand the field to derive new usages.

➢ This needs a deep understanding of the industries business and of the quantum possibilities
➢ Reducing energetical impact may be a new and mandatory usage of quantum technologies
➢ Given the disponibility rate, the shared access of QPUs and the computation time, it seems that real time might not be for now.

End users'HR & INNOVATION POLICY

Creating and maintaining a team

- The sustainability of an expert team is a challenge.
- Quantum engineer experts are an expensive & dangerous resource to hire (Resource are difficult to retain if they are not at 100% quantum, engineers may not want to move outside quantum topics, …)

➔ We also need internal training of internal experts

- We are in the identification of the potential of QC. For now, it's most of the time one single team per company whereas the applications are dealt by different entities from different directions.

➔ What the target for company organization ? Centralized ? As divergent as ML organization?

Users may have to work together

➔ Big Industries may work together on common cases on various QPUs / Inter-industrial use case structure: prototypes / Use case sandbox / With expert support

➔ Reproduce the same User groups that have been created for other technologies

➔ Build task forces to benefit from synergies as a response to common challenges (eg several industrial have funded different PhD thesis on the same topic)

Make it Industrial

CONTACTS

Joseph MIKAEL
joseph.mikael@edf.fr

Emmanuelle VERGNAUD
emmanuelle.vergnaud@teratec.fr