Fujitsu International Quantum Center

Bridging the gap between
quantum research and business

Fujitsu Computing Technologies

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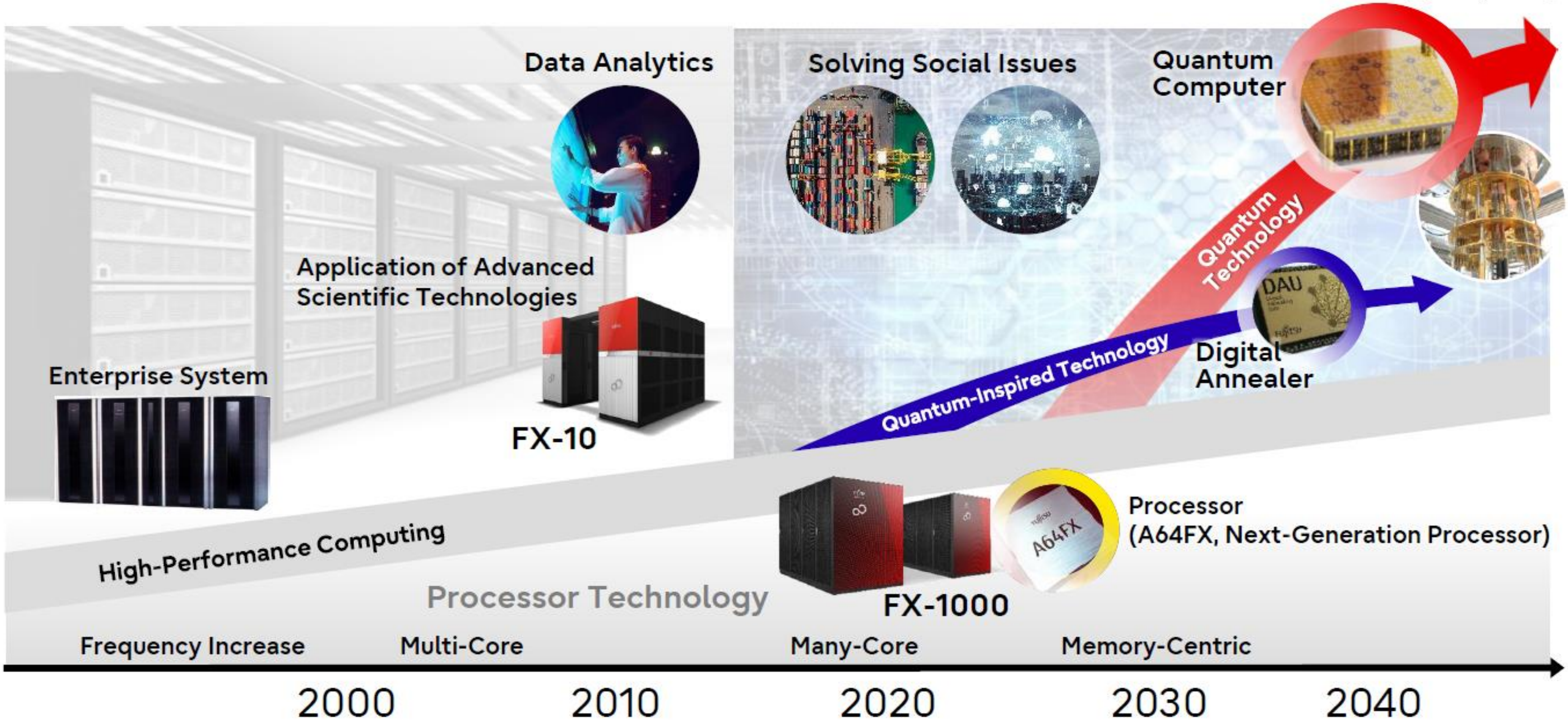

Quantum Computing Roadmap

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FY 2022 | 2023 | 2024 | 2025 | 2026 | 2030 | 2035

March
36
- qubit
Simulator

July
40
- qubit
Simulator

October
64
- qubit
quantum computer

Developed by RIKEN RQC - Fujitsu Collaboration Centre

March
256
- qubit
quantum computer

Computer with quantum-classical hybrid applications

December
1.024
- qubit
quantum computer

10.000+
- qubit
(250 logical qubits)
quantum computer

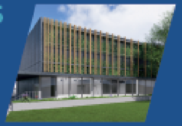
1.000
- logical qubit
quantum computer

March
Helped RIKEN release first Japanese domestic quantum computer

August
Establishment of high-speed execution method of practical algorithm using original quantum computing technology STAR architecture

2024
64 qubit machines x HPC hybrid calculation

September 2025
Completion of quantum building



December 2026
1.024 -qubit machine xHPC (Fujitsu-MONAKA) Hybrid calculation center

2031
10.000+ -qubit machine xHPC (MONAKA-X, GPU servers) Hybrid calculation center

Diamond-Spin Modular Technologies for Scalable Quantum Computing

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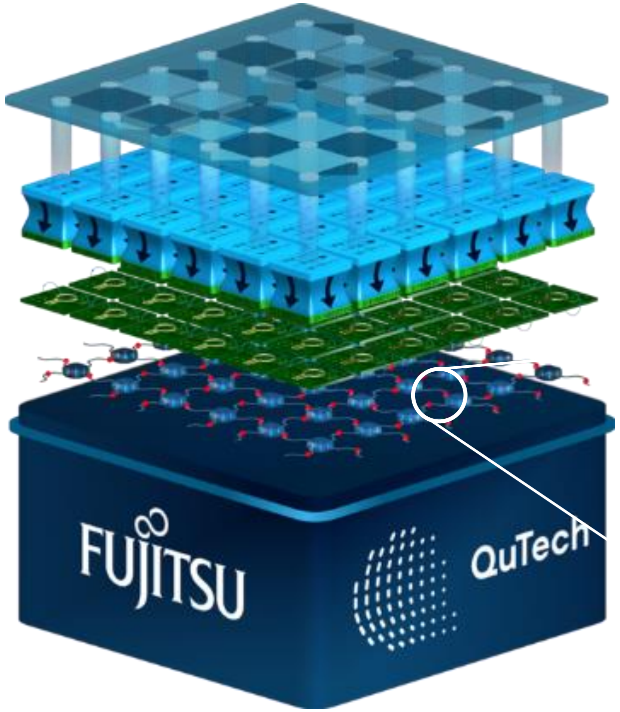
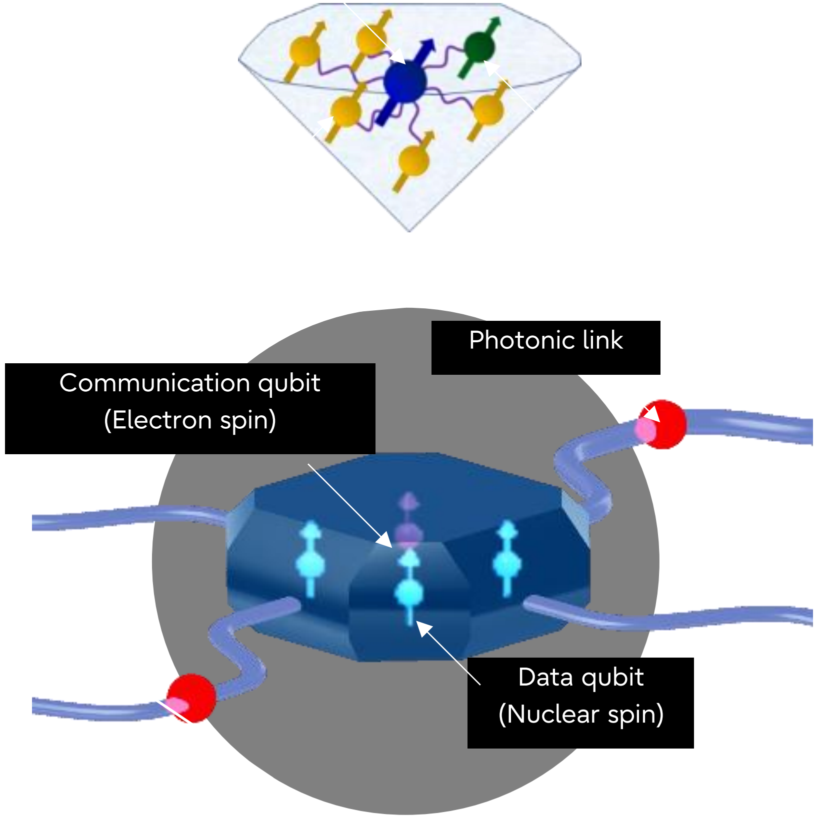
- Each quantum module consists of an electron spin and nuclear spins in a diamond.
- Quantum modules are connected by photonic links, which can be used as a single quantum computing system.
- This approach can allow for high-temperature operation (> 1 K) and good scalability

FUJITSU TUDelft QuTech





Fujitsu Computing technologies

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Solve different problems with computer technologies

Own IP + Alliances

Drug Discovery

Material Discovery

Finance

Disaster Recovery

Cryptography

High Performance Computing (HPC)

A64FX Technology

Quantum Technology

Universal Quantum Computers

Standard x86 Solutions

WEKA lustre BeeGFS

Parallel Filesystems

Storage + Networking

Digital Annealer

Quantum Simulator

Fujitsu Quantum Emulator

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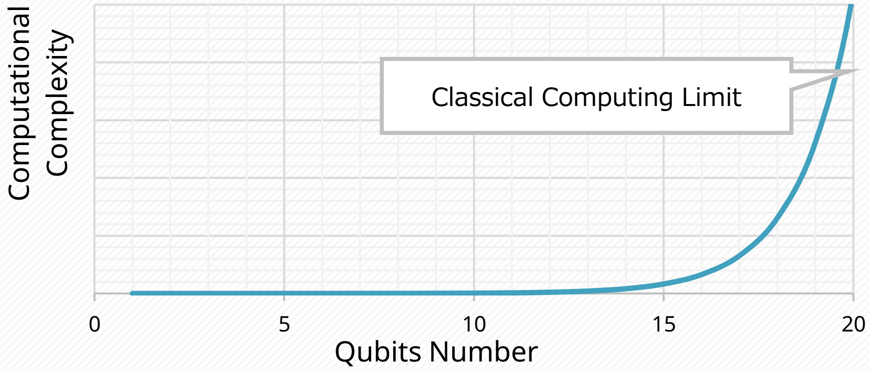
Quantum Emulators are essential for developing quantum algorithms and quantum computing research. Emulation technology allows intermediate measures and noise absence simulations, which are impossible for quantum computers

- Each additional qubit involves **doubling** the required memory

Fujitsu HPC Technology solves the problem

- Fujitsu emulation technology combines Qulacs emulation framework with Fujitsu HPC technology based on A64FX chips



Fujitsu Digital Annealer

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Quantum inspired to solve real optimization problems

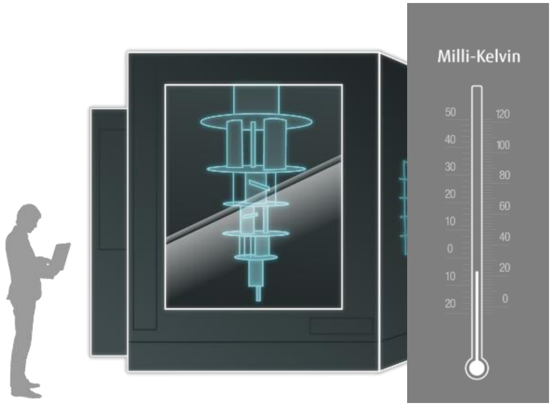
Technical Challenges of Quantum Computing

Stability

High infrastructure costs

Accuracy

Low connectivity



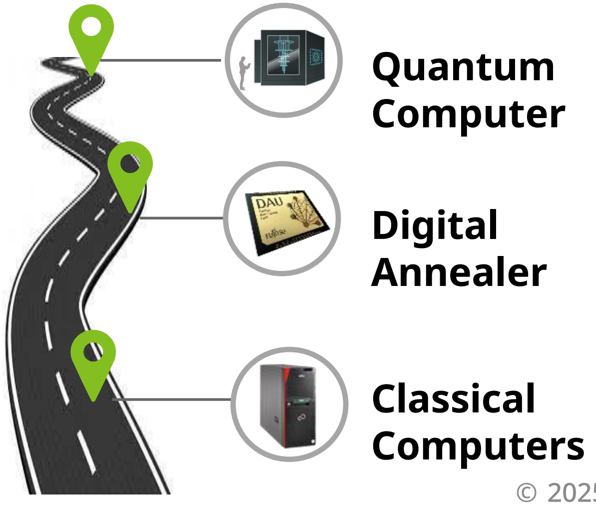
Digital Annealer: First step towards Quantum Computing

What is Digital Annealer?

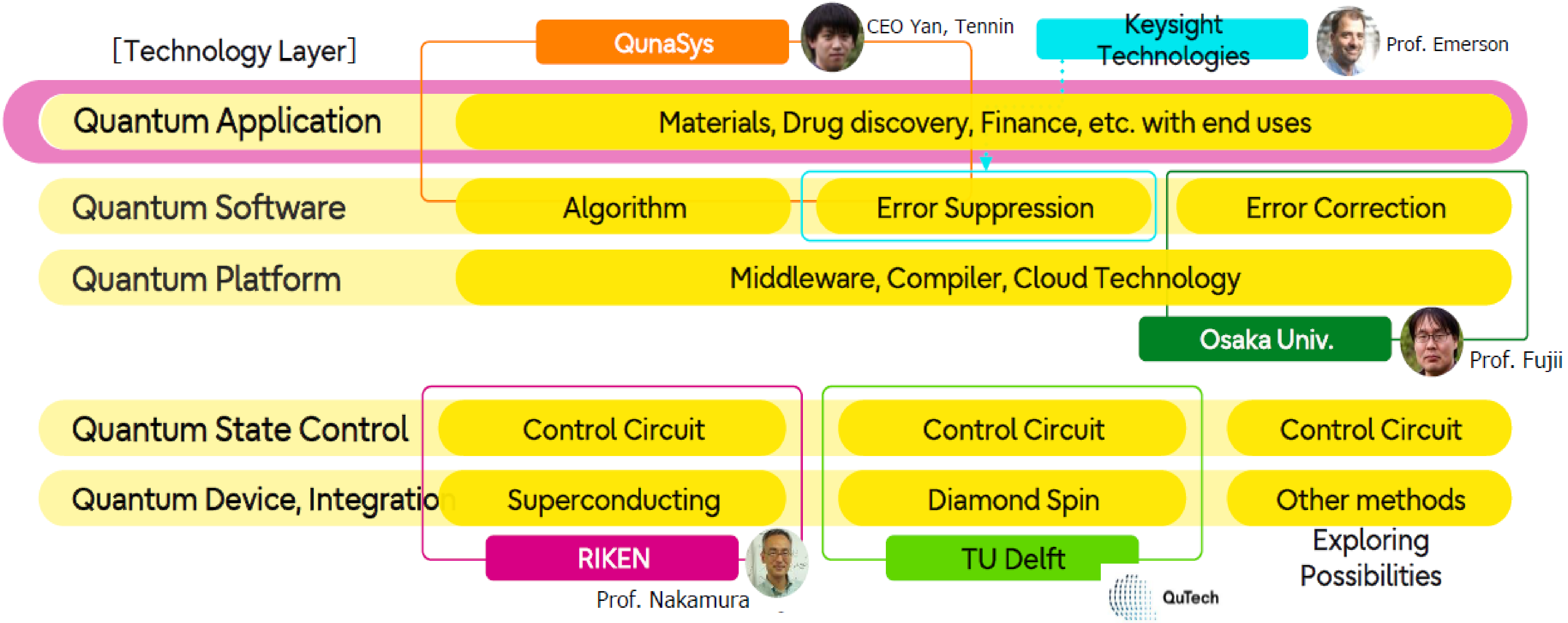
Digital Annealer is a mixed solution (hardware + software) inspired on Quantum Computing, which allows for very efficient resolution of combinatorial optimization problems with up to **100K variables**.

Why Digital Annealer?

- Allows for the early development of quantum applications.
- Mature technology from the hardware standpoint.



Fujitsu Research Q collaborations



Bridging the gap

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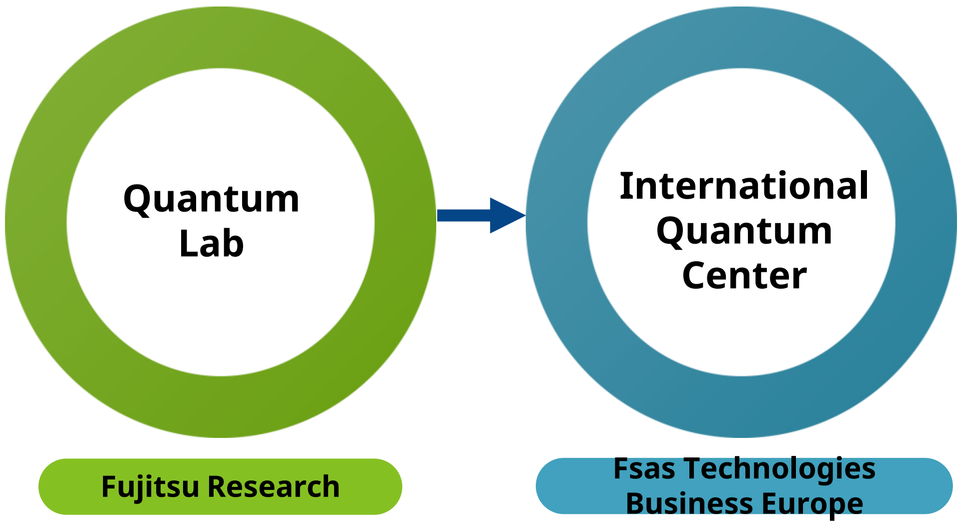
Bridging the gap between quantum research and business



Fujitsu IQC is an acceleration mechanism for the development, use, promotion, and commercialization of quantum technologies at EU level.

Fujitsu IQC Portfolio at a glance

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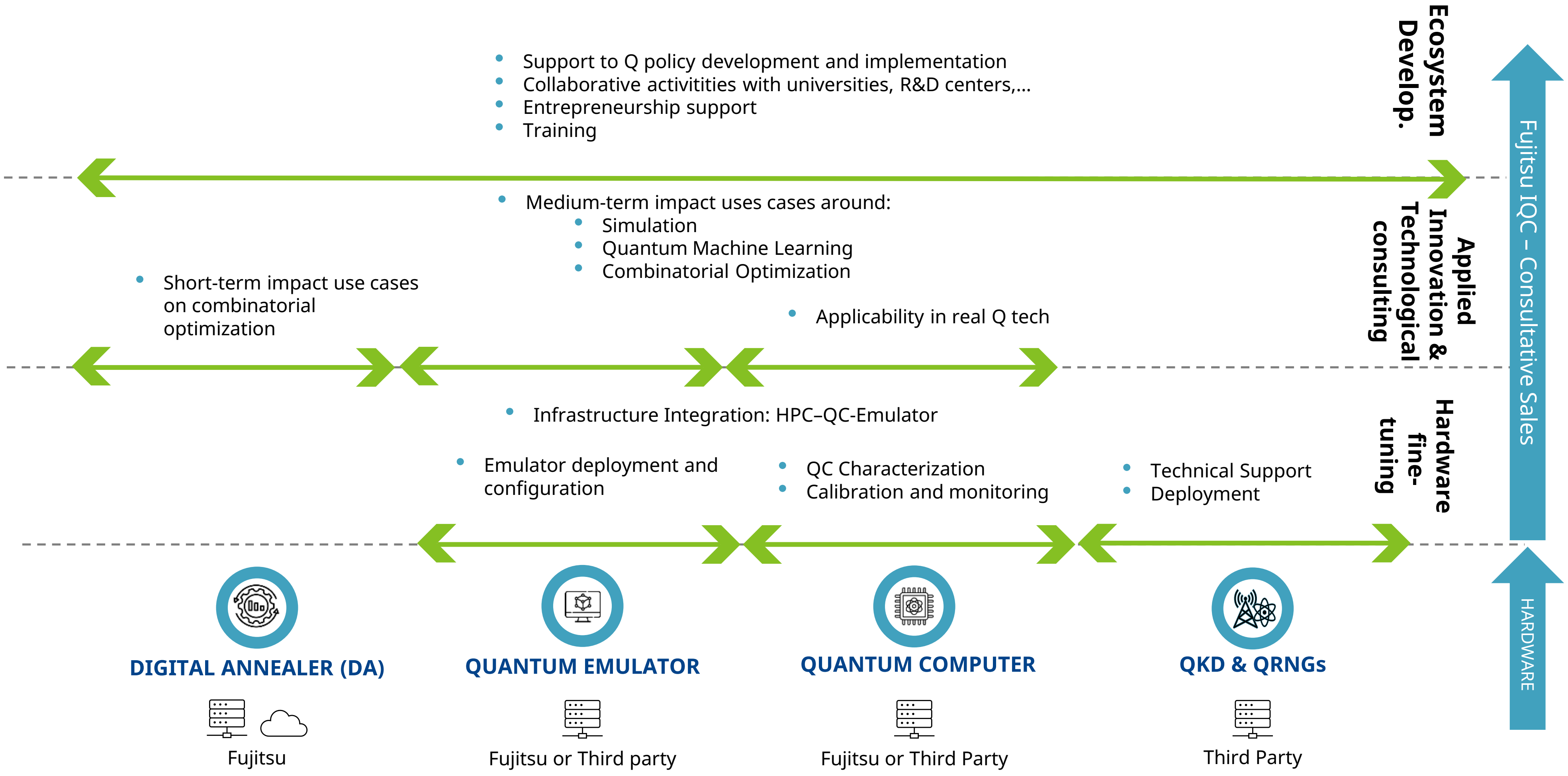

Success cases on going – *Quantum & HPC*

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EuroQSS

European Commission | HORIZON EUROPE 2021-2027

Fsas Technologies a Fujitsu company · Fraunhofer · IQM · cea · AIRBUS

QUANDELA · ALICE & BOB · qruise · HQS QUANTUM SIMULATIONS

Fsas International Quantum Center participates in the EuroQCS project, a European initiative selected for funding by the European Commission and scheduled to start in the upcoming period, focused on the integration of High-Performance Computing (HPC) and quantum computing capabilities, and on the development of representative industrial and scientific use cases exploiting such hybrid infrastructures.

The project addresses multiple application domains, including computational fluid dynamics, quantum machine learning, and large-scale optimization. Within EuroQCS, Fsas-IQC will contribute primarily to the definition and structuring of use cases and will lead activities related to problem decomposition, hybrid quantum-classical optimization strategies, and the mapping of complex industrial problems onto quantum and quantum-inspired computational models.

Some Digital Annealer sucess stories

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- **+ 200 Proof of Concept at international level**

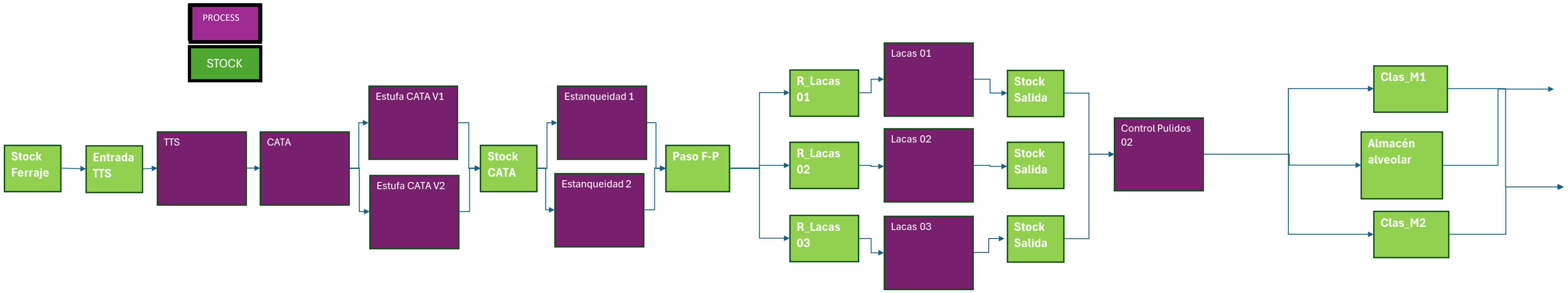
Some customers that have worked with us using Digital Annealer to solve their Business problems:

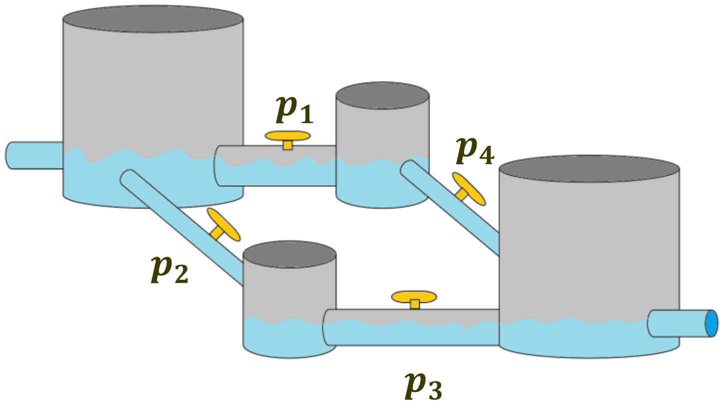
Stellantis Sucess Story

Stellantis Sucess Story

Goal of the Proof of Concept

Optimize the production within the Painting module.





Variables of the problem

$$x_{pt_it_f} = \begin{cases} 1, \textit{if stand } \boldsymbol{p} \text{ starts at instant } \boldsymbol{t_i} \text{ and stops at instant } \boldsymbol{t_f} \\ 0, \textit{otherwise} \end{cases}$$

$$P_{pT} = \begin{cases} 1, \textit{if stand } \boldsymbol{p} \textit{ takes a break at instant } \boldsymbol{T} \\ 0, \textit{otherwise} \end{cases}$$

Coste

$$C = \sum_p$$ Cost/hour stand **p** * time **p** is on

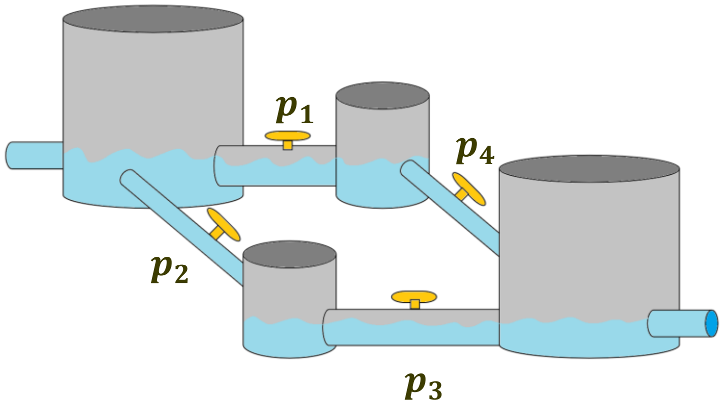
Stock We need to discretize the temporal window: $t_1, t_2,.., t_n$ for each instant:

$$s_{max} \geq$$ Occupation instant **t** $$\geq s_{min}$$

Goal

Minimize cost while making sure the production goal is met and stock constraints are satisfied.

Stellantis Sucess Story



Variables of the problem

$$x_{pt_it_f} = \begin{cases} 1, \text{if } stand\ \boldsymbol{p} \text{ starts at instant } \boldsymbol{t_i} \text{ and stops at instant } \boldsymbol{t_f} \\ 0, otherwise \end{cases}$$

$$P_{pT} = \begin{cases} 1, if\ stand\ \boldsymbol{p}\ takes\ a\ break\ at\ instant\ \boldsymbol{T} \\ 0, otherwise \end{cases}$$

Coste

$$C = \sum_p \left(\sum_{t_i,t_f} C_p(t_f - t_i) x_{pt_it_f} - \sum_T d_{st_p} C_p P_{pT} \right)$$

Stock We need to discretize the temporal window: $t_1, t_2,.., t_n$ for each instant:

$$s_{max} \geq s_0 + \sum_{t_i<\tilde{t}} \sum_{p<s} \left[\sum_{t_f} v_p(M - t_i - R) x_{pt_it_f} - \sum_{st_p} v_p d_{st_p} P_{pt_i} \right] - \sum_{t_i'<\tilde{t}} \sum_{p'>s} \left[\sum_{t_f} v_{p'}(M' - t_i' - R') x_{p't_i't_f'} - \sum_{st_{p'}} v_{p'} d_{st_p} P_{p't_i'} \right] \geq s_{min}$$

Initial occupation

Goal

Minimize cost while making sure the production goal is met and stock constraints are satisfied.

Stellantis Sucess Story

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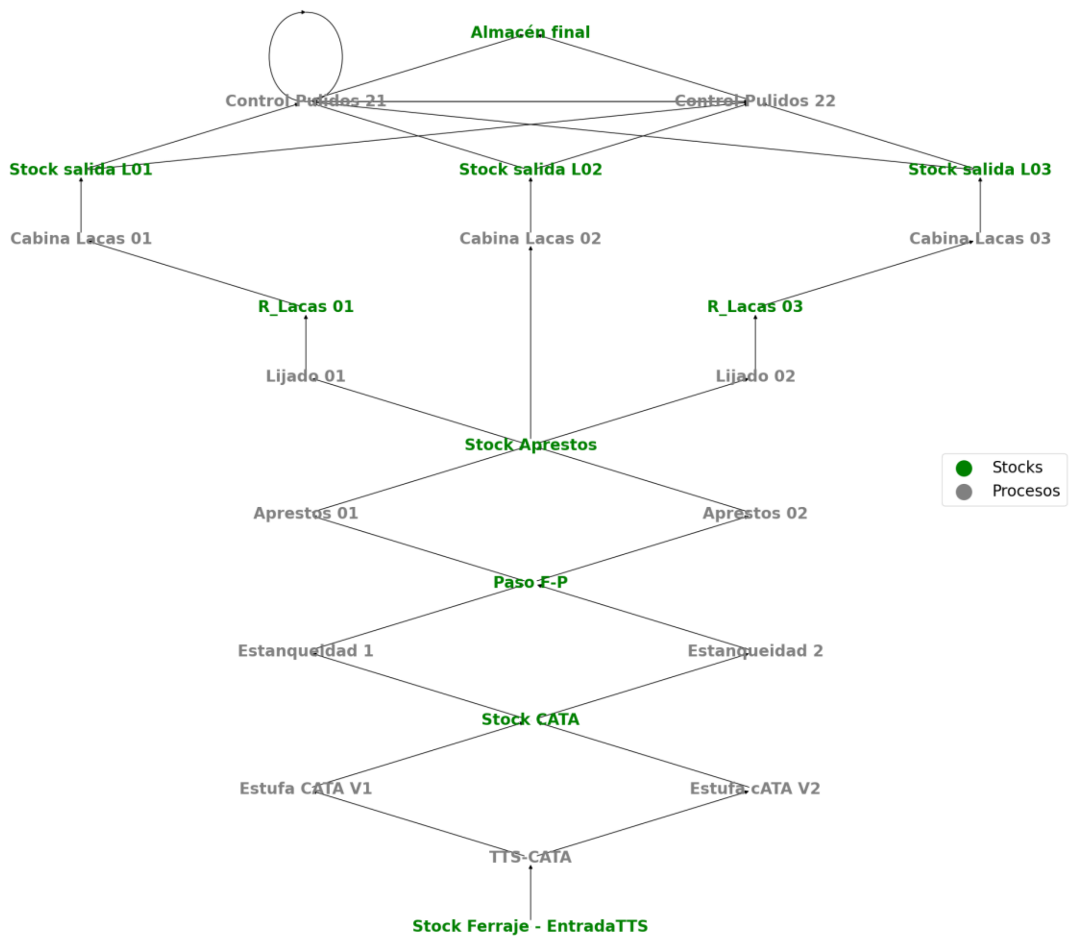
Real production info

- Production goal: 2177 cars
- Time on per stand:
  - 23h12min (**Model 1**)
  - 22h28min (**Model 2**)

Simulated production info

- Set a production of 2177 cars
- Compare with real time each stand is on:
  - Stock occupation over time
  - Cost (tiempo de encendidos)
  - Stock degradation

Esquema del módulo de pintura



Stellantis Sucess Story

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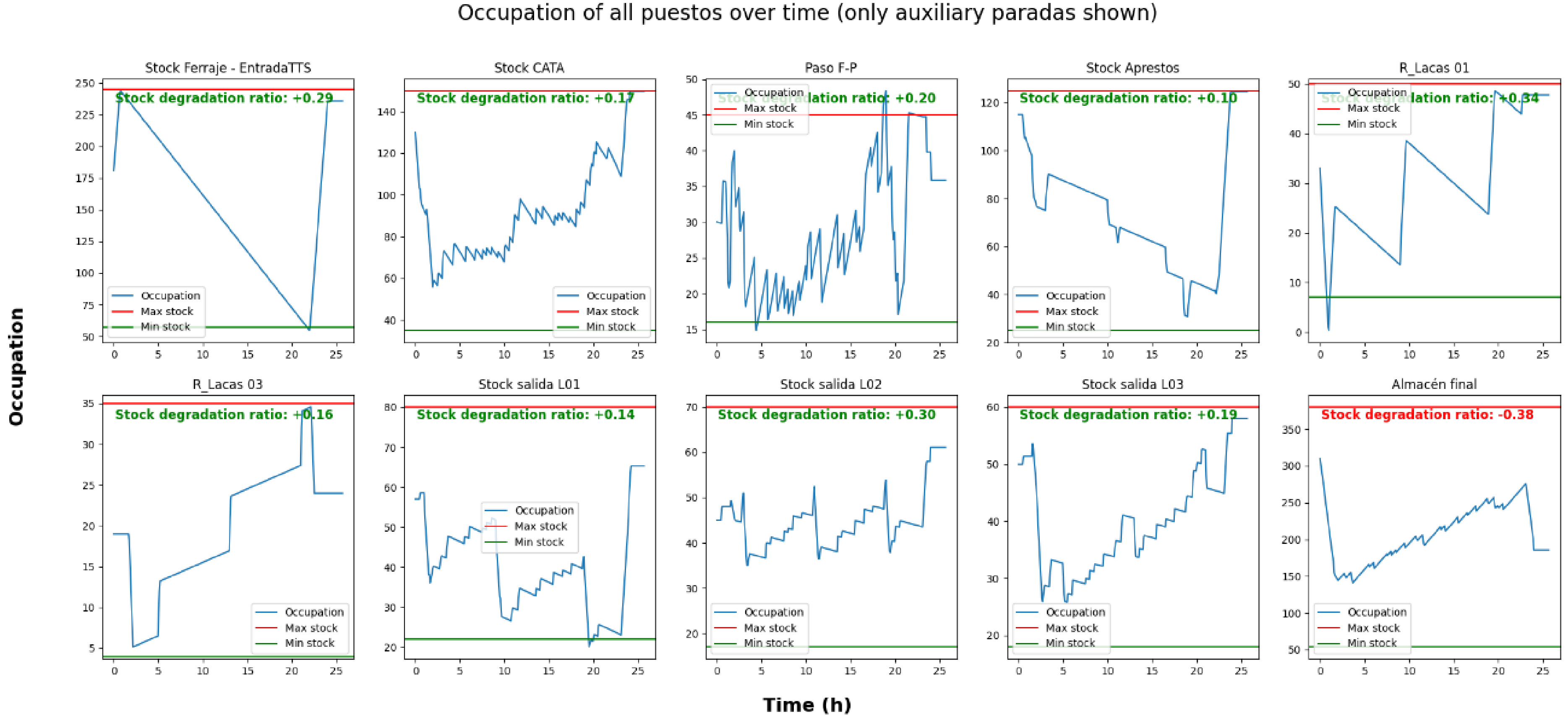
Simulated stock level over time



Stellantis Sucess Story

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Savings per stand

Total savings:
5.94

Stand	Start time	Finish time	Projected time on (h)	Real time on(h)	Savings (h)	Savings (normalized costs*)
TTS-CATA	0,00	22,50	23,10	23,20	0,10	0,06
Estufa CATA v1	1,50	22,50	21,64	23,20	1,56	0,58
Estufa CATA v2	1,50	22,50	21,64	22,50	0,86	0,38
Estanqueidad 1	1,50	22,50	21,00	23,20	2,20	1,17
Estanqueidad 2	0,68	23,03	22,35	22,50	0,15	0,15
Aprestos 01	1,50	22,50	22,02	23,20	1,18	0,33
Aprestos 02	0,45	22,65	22,88	22,50	-0,38	-0,18
Lijado 01	1,43	23,25	22,04	23,20	1,16	0,00
Lijado 02	1,43	22,58	21,30	22,50	1,20	0,00
Cabina Lacas 01	0,00	23,25	24,85	23,20	-1,65	-0,80
Cabina Lacas 02	0,68	22,50	23,125	22,50	-0,63	-0,34
Cabina Lacas 03	0,83	22,95	23,07	23,20	0,13	0,07
Control Pulidos 21	1,43	23,40	21,98	23,20	1,23	0,82
Control Pulidos 22	1,43	23,78	22,35	22,50	0,15	0,10

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Quantum Computing in the Energy Sector

Quantum Computing in the Energy Sector

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GRAVITEQA

European Commission | HORIZON EUROPE 2021-2027

Load-Side Management for Flexibility Provisioning: The problem focuses on smartly reducing electricity use to prevent grid overload. Devices such as heaters or air conditioners can lower their consumption at predefined levels, each with an associated cost. The grid is modeled as a graph where congestion at one point can affect others. The goal is to coordinate these reductions to relieve stress on the system while minimizing overall impact.

Optimization of Renewable Energy Facility Location: This project tackles the Facility Location Assignment (FLA) problem for deploying renewable energy infrastructure (solar farms, wind turbines, hydro plants). It aims to maximize energy efficiency, minimize infrastructure costs, and meet regional energy demands. Constraints include resource availability, proximity to existing infrastructure, and environmental impact. The problem is solved using quantum-inspired and quantum optimization techniques.

EoliQ

ITER

ARQUIMEA

Optimized Battery Management in Hybrid Wind Farms: This use case focuses on optimizing battery charging and discharging in hybrid wind farms. By complementing the basic Battery Management System (BMS), it aims to improve energy storage use, increase profitability, and enhance supply stability under variable wind conditions.

Load-side Management for flexibility provisioning

Load-side Management for flexibility provisioning

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- Electric grid operation is becoming more challenging
- **Electricity demand** is steadily **increasing**.
- **Renewables**, **EVs** and **storage** are rapidly connecting to the grid.
- Most flexibility is now distributed at the distribution level.
- **Grid reinforcement** alone is **slow** and **costly**.

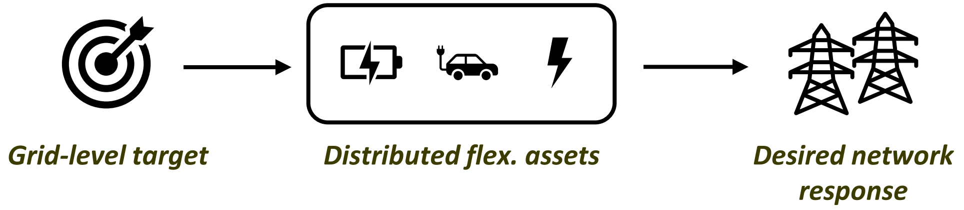
- There are several mechanisms in place
- **Network reinforcement** and long-term planning.
- **Curtailment** of generation in critical situations.
- **Demand response** and load shedding programmes.
- Aggregator providing **balancing** and ancillary **services**.

Flexible assets	Adjustable loads and storage connected to the grid
How are they used	Demand response and aggregation mechanisms
Why they matter	They provide fast, local support for grid operation
Current challenge	Scaling asset coordination in real time

1. ***Event-based demand response, not grid-aware operation***
2. ***There is limited real-time coordination***
3. ***They are treated as aggregated resources***

The use case addresses how distributed flexible loads are managed to meet a grid-level power requirement.

- A **power exchange target** is defined at the grid level.
- Flexible load-side assets (**FPUs**) are individually adjusted to meet this target.
- The goal is to **adapt demand locally** to support stable grid operation.



Load-side Management for flexibility provisioning

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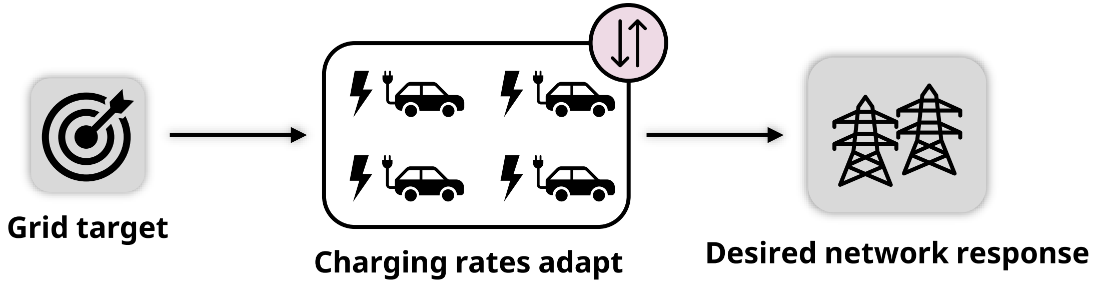
EV Charging Hub

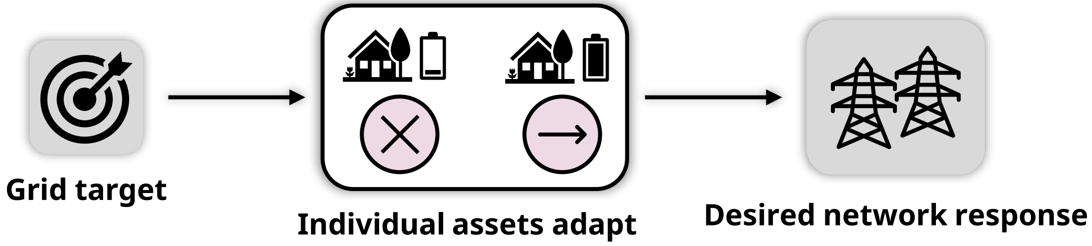


A large EV charging hub can act as a flexible load by adjusting the charging power of connected vehicles.

- **Charging rates are modulated** according to grid needs.
- **Flexibility** is offered to the network operator **as a service**.
- The grid uses this flexibility to **manage** peak **demand and** local **constraints**.

Flexibility can come from consumption, not only from generation.

Distributed Energy Community



A local energy community with renewable generation and storage provides flexibility to the grid.

- **Individual assets adapt** their behaviour based on **grid requirements**.
- **Excess** generation or storage **can be injected into the network** when needed.
- Community members receive **compensation for** providing **flexibility**.

Flexibility is managed at the asset level, not as a single aggregated resource.

Load-side Management for flexibility provisioning

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- Main system components

BUS

*Electrical **node of the network** where power is injected or withdrawn.*

LINE

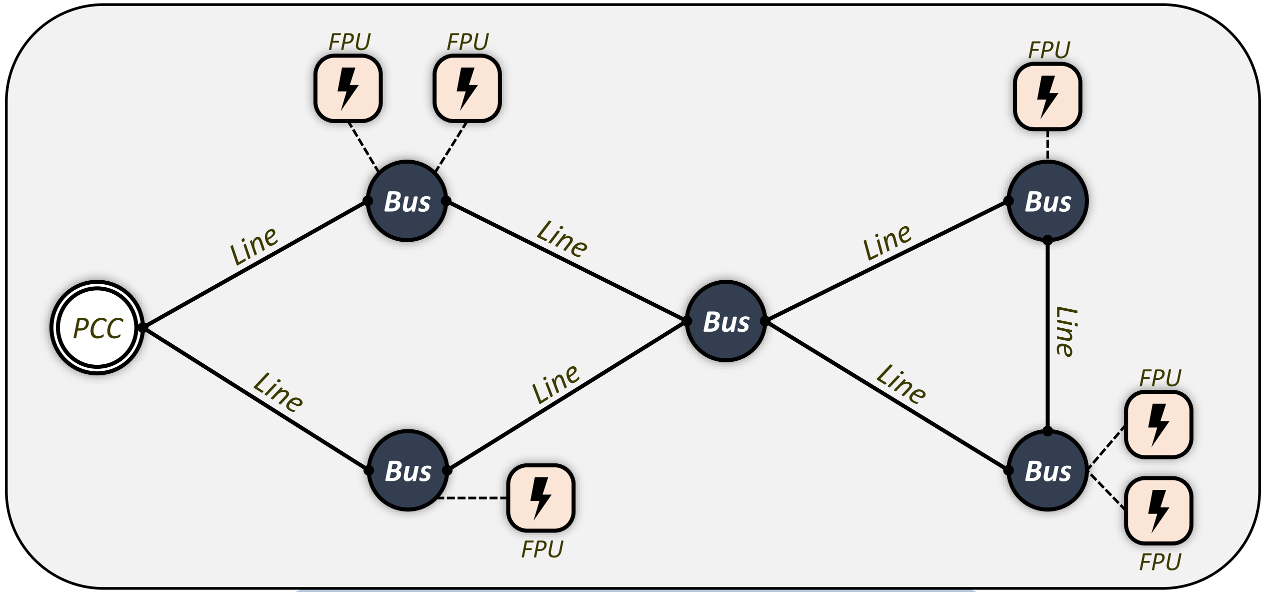
*Physical **connection between buses**, defining how effects propagate through the network.*

FPU (Flex. Power Unit)

***Controllable resource connected to a bus**, whose operation can be adjusted to support the grid.*

PCC

*A **designated bus** where grid-level **requirements** are **evaluated** and **enforced**.*



Flexible Power Units may include:

- *Batteries*
- *Thermal storage systems*
- *Flexible loads*
- *Distributed generation*
- *HVAC systems*
- *EV charging points*

Load-side Management for flexibility provisioning

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To ensure safe and efficient grid operation, the LMFP problem must simultaneously address the following optimisation goals:

1. **PCC tracking** → Ensure that active and reactive **power requirements are met *at the PCC***.
2. **Cost of flexibility activation** → **Minimise** the **economic cost** associated with **activating and modulating *FPUs***.
3. **Voltage security** → Maintain ***bus* voltages** within **safe operating limits** across the network.
4. **Thermal limits** → Ensure that **power flows** in **all *lines*** remain within their **thermal** capacity **limits**.

These objectives must be jointly balanced to obtain a safe and economically viable response to network demand changes.

Feeding strategies optimization with DA

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The Nueva Pescanova group's commitment to aquaculture is growing. Aquaculture accounts for **50% of the company's production** approximately. There is an **ongoing commitment to innovation** within the company, with technologies such as 5G, IoT and AI

Feeding strategies are the key factor shaping aquaculture outcomes

- ✓ In aquaculture, feed is the single largest cost, both economically and in terms of carbon footprint.
- ✓ Even minor improvements in feed efficiency can have a substantial economic and environmental impact.

Our approach: AI + Quantum Inspired

1. **AI** based module for estimation of expected growth based on feed and conditions

+

2. **Quantum Inspired optimization** module for finding the most profitable & sustainable strategy over all the production period

Results

Fase I: PoV

- ✓ MVP development
- ✓ Result comparison with historical data

Cost -20%

Phase II: Pilot on a real farm

- ✓ Pilot testing at Nueva Pescanova's shrimp farm in Ecuador

Cost -18%

Accelerating beer recipes

Estrella Galicia

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- ✓ Searching for new prescriptions is an expensive process because of the large number of lab tests needed. It is possible to speed up and reduce the cost of this process by reducing the number of potential candidates using computational techniques.
- ✓ With Quantum Inspired technology we were able to improve HPC results for freshnesh problem.

1 Initial Candidates

Reference

2 Ligand Structural Comparison

Filtering the most likely candidates without taking into account the recipient

100%
90%
70%
65%
50%
10%

3 Ligand and receptor compatibility analysis

4 Dynamic simulation of ligand and receptor interaction

Molecular Dynamics Analysis

5 Laboratory Tests

Tasting process with the final candidates

Success cases *on going – R&D projects* - ***health***

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Qcare

In genomics, the project applies quantum computing to **reconstruct phylogenetic trees**, improving the understanding of mutation evolution. Fsas-IQC, collaborating with the University of A Coruña and Qilimanjaro, employs quantum algorithms such as N-Cut and encoding methods like Pauli Correlation Encoding to generate more accurate phylogenetic representations, facilitating the tracking of variants and their impact on public health.

The project explores the use of quantum computing and quantum-inspired technologies to **accelerate drug discovery**. By leveraging quantum optimization algorithms, large compound libraries are screened to identify promising candidates. Fsas-IQC, in partnership with the University of Santiago and Qilimanjaro, implements hybrid approaches that combine classical and quantum models for efficient molecule selection.

In healthcare assistance, the project uses quantum-inspired technologies to **optimize the allocation of medical resources**. A key case focuses on improving diagnostic and treatment planning for COPD patients, reducing waiting times and maximizing hospital efficiency.

Quantum4Health

Quantum4Health will apply quantum machine learning algorithms to accelerate and improve the **detection of genetic variants in large-scale sequencing data**, enhancing precision in identifying mutations and supporting faster, more personalized genomic diagnostics.

Quantum Machine Learning will **analyze medical images to detect complex patterns** that are difficult to capture with classical methods, enabling more accurate and timely diagnoses and supporting clinicians in decision-making.

Quantum optimization techniques will help **assign shifts and resources efficiently in hospitals and clinics**, reducing workload stress, ensuring adequate coverage, and providing flexible staffing solutions in response to unpredictable patient demand.

Quantum algorithms will **optimize drone routes and operations for delivering and collecting medical supplies in sparsely populated areas**, minimizing transport times and costs while improving access to critical resources in remote regions.

El caso de uso, en detalle

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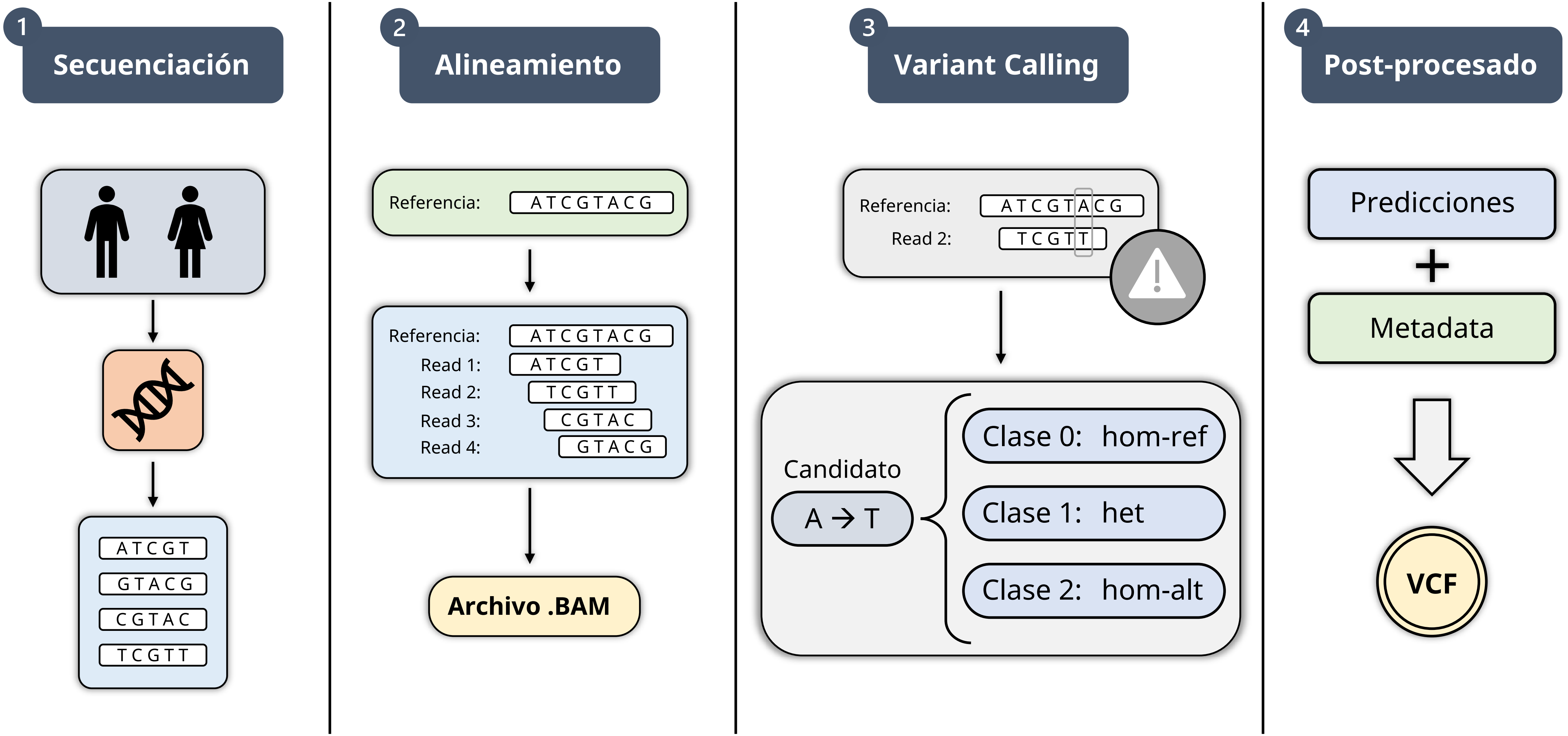

Aspectos que afectan al calling

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Regiones de baja cobertura (low-coverage)

<u>Cobertura</u> = número de **reads** disponibles para una **base**

Caso 1: Cobertura suficiente

Ref: A T C G T A C G
R1: A T C G A
R2: T C G T A
R3: C G T A C
R4: G T A C G

$$\mathit{Cobertura}\ (\mathit{Depth}) = 4$$

Se dispone de <u>suficientes lecturas</u> para determinar si existe variante.

Caso 2: Cobertura insuficiente

Ref: A T C G T A C G
A T C G A

$$\mathit{Cobertura}\ (\mathit{Depth}) = 1$$

Determinar la variante es <u>muy complejo</u> por falta de datos.

Regiones difíciles de clasificar (hard-to-call)

Algunas regiones del genoma pueden ser **<u>muy complicadas</u>** para el calling

Caso 1: Zona simple

Ref: A T C G T A C G
R1: A T C G A
R2: T C G T A
R3: C G T A C
R4: G T A C G

Las <u>lecturas</u> son muy <u>limpias</u> y la posible variante clara.

Caso 2: Zona complicada

Ref: A T C G T A C G
R1: A C C T T
R2: T C C A A
R3: A A T A C
R4: G T G T G

Hay <u>muchos cambios</u> frente a la <u>referencia</u> y <u>entre</u> las diferentes <u>lecturas</u>.

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Thank you!

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