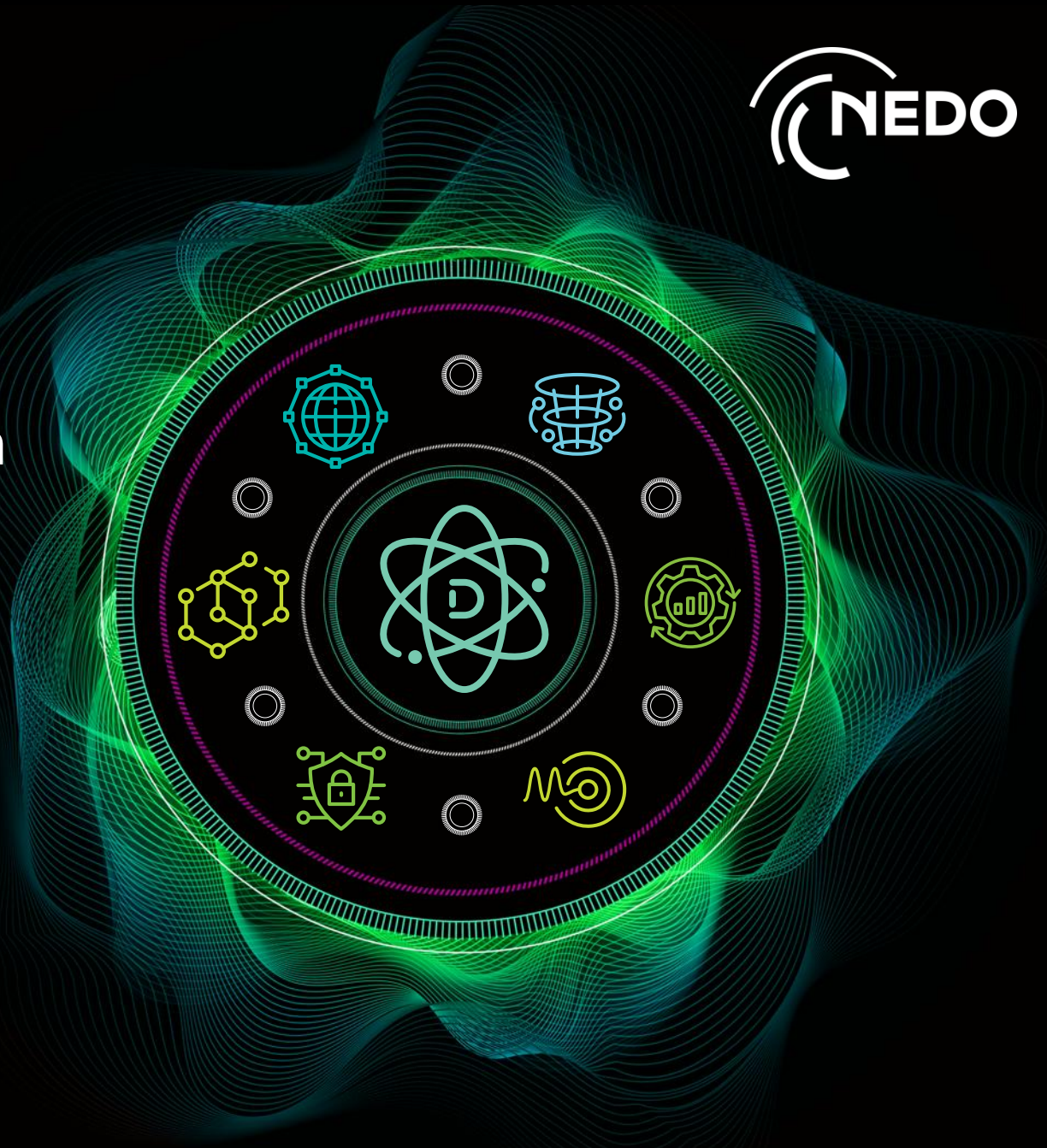
Quantum Computing Use Cases

Air Cargo Placement Optimization

Airbus



New Energy and Industrial Technology Development Organization (NEDO)

Airbus: Air Cargo Placement Optimization [2022/8] 1/2

Validation

Industry	Discrete Manufacturing Transportation
Process/Means	Procurement/air transport
Method	combinatorial optimization
Category	Gate*

Background

- Airbus expects the global air cargo market to grow 50% by 2042, further exacerbating the emerging supply chain crisis
- Airlines are **seeking to maximize the payload capacity of the aircraft and optimize parameters that affect performance to reduce operating costs (fuel burn)** in order to deliver more efficiently, maximize profits and reduce fuel consumption.
- However, optimization is limited by the range of aircraft operations that need to be complied with.
  - ✓ **The most important limitations are the maximum payload of the aircraft on a particular mission, the position of the centre of gravity of the aircraft on board and the shear limit of the aircraft**
- The roadmaster responsible for the safe loading, transportation, etc. of air cargo is responsible for accurately planning fuel combustion, reducing overall operating costs, and loads (roadsheets) to meet all operational and safety requirements
  - ✓ Traditionally, optimization tasks have been performed manually or through “drag and drop ” applications, but the complexity of parameter combinations has limited their use.

Issues and motivation to be solved

- **Optimization problems of cargo placement with an exponential number of combinations are classified as NP-hard problems (exponentially complex problems) and are difficult to solve in a realistic time using classical computers.**
- In 2022, **Airbus partnered with IonQ on a 12-month Quantum Cargo Placement Optimization/Quantum Machine Learning project** to develop prototypes of onboard quantum applications to reduce costs and CO2 emissions.

Expected business benefits

- In the demonstration, **the optimum arrangement with the maximum loadable weight satisfying the operational constraint including three types of virtual containers was extracted**
  - ✓ **Leverages IonQForte (28 qubits) to perform 250,000 iterations of variational optimization algorithm to** run the math correctly
- This demonstration is the largest optimization algorithm performed on gated quantum systems as of 2023.

Reference: Airbus AIRBUS QUANTUM COMPUTING CHALLENGE (https://www.airbus.com/sites/g/files/jlcbta136/files/2021-10/Airbus-Quantum-Computing-Challenge-PS5.pdf), M e mCoputing Inc "Aircraft Cargo Loading Optimization Case Study" (https://www.memcpu.com/media/2019/04/AirCargo-UseCase-V2.pdf), IonQ"IonQ, Airbus Sign Agreement to Collaborate on Aircraft Loading Project using Quantum Computing" (https://ionq.com/news/august-18-2022-ionq-2022-airbus)
*Gate（gate-based）: A computing approach in which operations are applied sequentially to qubits to perform calculations. Similar in concept to logic circuits in classical computers, it can address a wide range of problems.

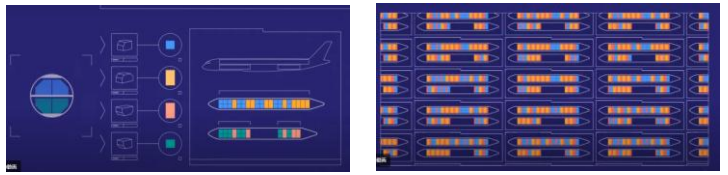
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Validation

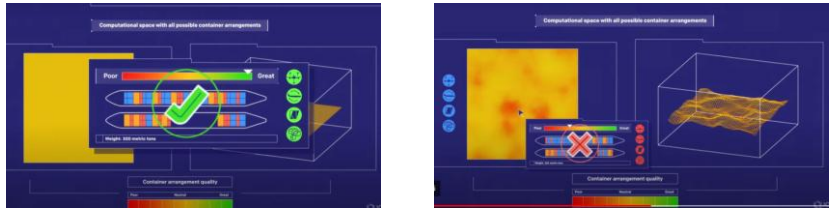
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Problem setting as a quantum computer

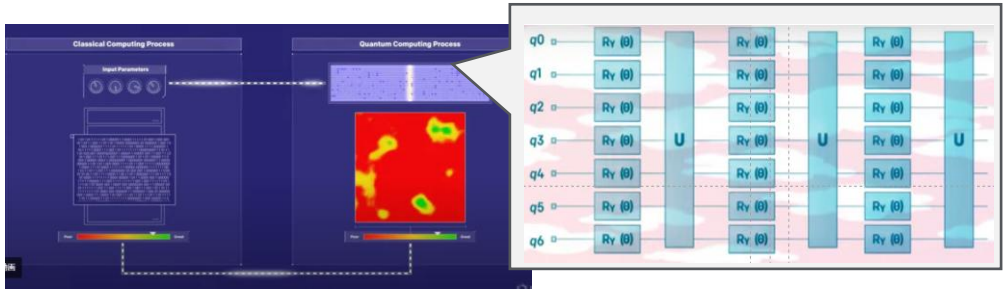
- The **Optimal Placement of Aircraft Cargo** in which there are various slots to hold multiple types of containers becomes a constrained combinatorial optimization problem.
  - ✓ **As constraints, cargo capacity, centre of gravity at maximum cargo mass, shear limits of the aircraft, and virtual containers** are considered**.**
- In quantum computer optimization problems, all combinations of containers and slots can be processed simultaneously in a superposition of qubits.
- Quantum computer calculations search for quantum states that describe the arrangement of containers capable of carrying the heaviest cargo without violating the operational constraints of the aircraft
  - ✓ Variational optimization algorithm identifies container and slot combinations that satisfy constraints and those that do not
- The computation is performed by a combination of the classical computer, which processes input and output data, and the **quantum computer (gated IonQ Forte)** which amplifies the optimum arrangement.
  - ✓ the classical computer selects input parameters that affect the quantum circuit, quantum circuit amplifies the configuration that satisfies the constraints, and sends the result back to the classical computer for evaluation
  - ✓ The above sequence of processes is iterated and finally the operational configuration is extracted as the state of maximum amplitude



Container arrangement in slots of aircraft (left) and combination example (right)



Container placement satisfying constraints extracted by a quantum computer (left) and unsatisfied (right)



Hardware configuration (left) and algorithm (right)
Iteration of input processing by classical computer and large-scale computations by quantum computer

: IonQ"Learn Quantum: Cargo Loading Optimization" (https://ionq.com/resources/learn-quantum-cargo-loading-optimization)
*Gate（gate-based）: A computing approach in which operations are applied sequentially to qubits to perform calculations. Similar in concept to logic circuits in classical computers, it can address a wide range of problems.

More use cases are available on our website. We invite you to explore them.
https://www.quantum-computing-use-cases.nedo.go.jp/english/

More Use Cases

New Energy and Industrial Technology Development Organization (NEDO)
AI and Robotics Department (e-mail: quantum_ai@ml.nedo.go.jp)

This collection of use cases was obtained as a result of the work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) "Cyber-Physical Development Business of Quantum/Classical Hybrid Technology/Study of Use Case of Quantum Technology" and the "Post-5G Information and Communications System Infrastructure Reinforcement R & D Project (Quantum Industrialization)/Comprehensive Study for Promoting the Industrialization of Quantum Computers".