From research to business value

THALES

CASE STUDY

Applying quantum algorithms to satellite mission planning, unlocking new revenue potential

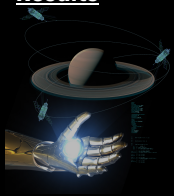
Earth imaging satellites are a crucial part of our everyday lives, impacting services such as connectivity, navigation, and media. Therefore, it is critical that satellites are employed efficiently and reliably. As they receive dynamic instructions on how to execute their mission in orbit, optimally planning the exact sequence of tasks is a complex endeavour, known as the satellite mission planning problem, which may be computationally prohibitive to solve at scale. While close-to-optimal algorithms such as greedy reinforcement learning and optimization algorithms can be used to address this problem, through our work with Thales Group, we introduced a quantum-enhanced approach to satellite mission planning optimisation using hybrid quantum algorithms in the areas of machine learning and optimisation, demonstrating their superior performance and potential for unlocking significant additional revenue.

Key takeaway: **A hybridized quantum-enhanced reinforcement learning approach achieves a completion rate of 98.5% over high-priority tasks, significantly outperforming the baseline greedy methods. These results pave the way to quantum-enabled solutions in the space industry and, more generally, future mission planning problems across industries.**

The Problem

The satellite mission planning problem consists of maximising the number of images captured by satellites based on a list of task requests and available time. Each task is chosen at the expense of others and has long-term effects on the orientation of the satellite as it must point its camera in the appropriate direction within its data take opportunity window for the entire acquisition period. The goal is to optimize the order of task requests, maximising the number of completed requests, given numerous constraints, related to the characteristics of the satellites and the tasks to be performed.

Results



98.5% **Task completion rate, using quantum-enhanced methods**

1% **Improvement in solution optimality**

2x **Faster calculation using optimization methods**

Access our publication for more: Quantum algorithms applied to satellite mission planning for Earth observation

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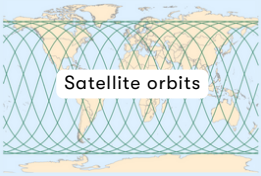
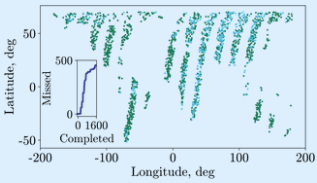
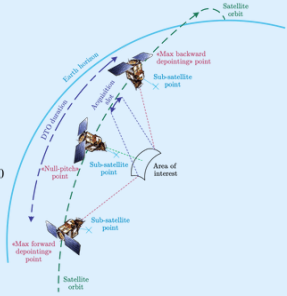
The Approach

To solve the challenge, the satellite motion (including orbit number, time stamp, and satellite position and velocity) and task request information are collected and formatted for analysis. Then, to handle the increasing complexity of the problem, clustering was used to stratify the data and reduce the number of calculations.







This novel approach involves a combination of

- Hybrid optimisation methods
- Quantum-enhanced reinforcement learning

Hybrid Optimisation

Various hybrid optimization methods were explored, including a few different formulations derived from the quadratic unconstrained binary optimization (QUBO) model. These methods leverage quantum computing techniques to accelerate the optimisation process and find the best course of action for maximizing task completion.

Reinforcement Learning

We introduced a novel quantum-enhanced reinforcement learning approach, inspired by the AlphaZero model, consisting of:

- Monte Carlo tree search
- Encoding network
- Quantum policy network
- Value network

Conclusion

Our algorithm achieves a completion rate of 98.5% on high-priority requests in a multi-satellite system, demonstrating significant improvement over the baseline greedy methods and unlocking new revenue potential for the optimisation of each satellite.

These results show that Terra Quantum's hybrid quantum algorithms outperform classical approaches in satellite mission planning, overcoming the increasing complexity of scheduling high-priority tasks and demonstrating that through solution-chaining and clustering, quantum-enhanced optimisation and machine learning algorithms offer the greatest potential for optimal solutions in satellite mission planning.

> The prototype enables a more cost and energy-efficient use of satellites, contributing to the sustainable commercialization of space.
> - David Sadek, VP, Research, Technology & Innovation of Thales Group.