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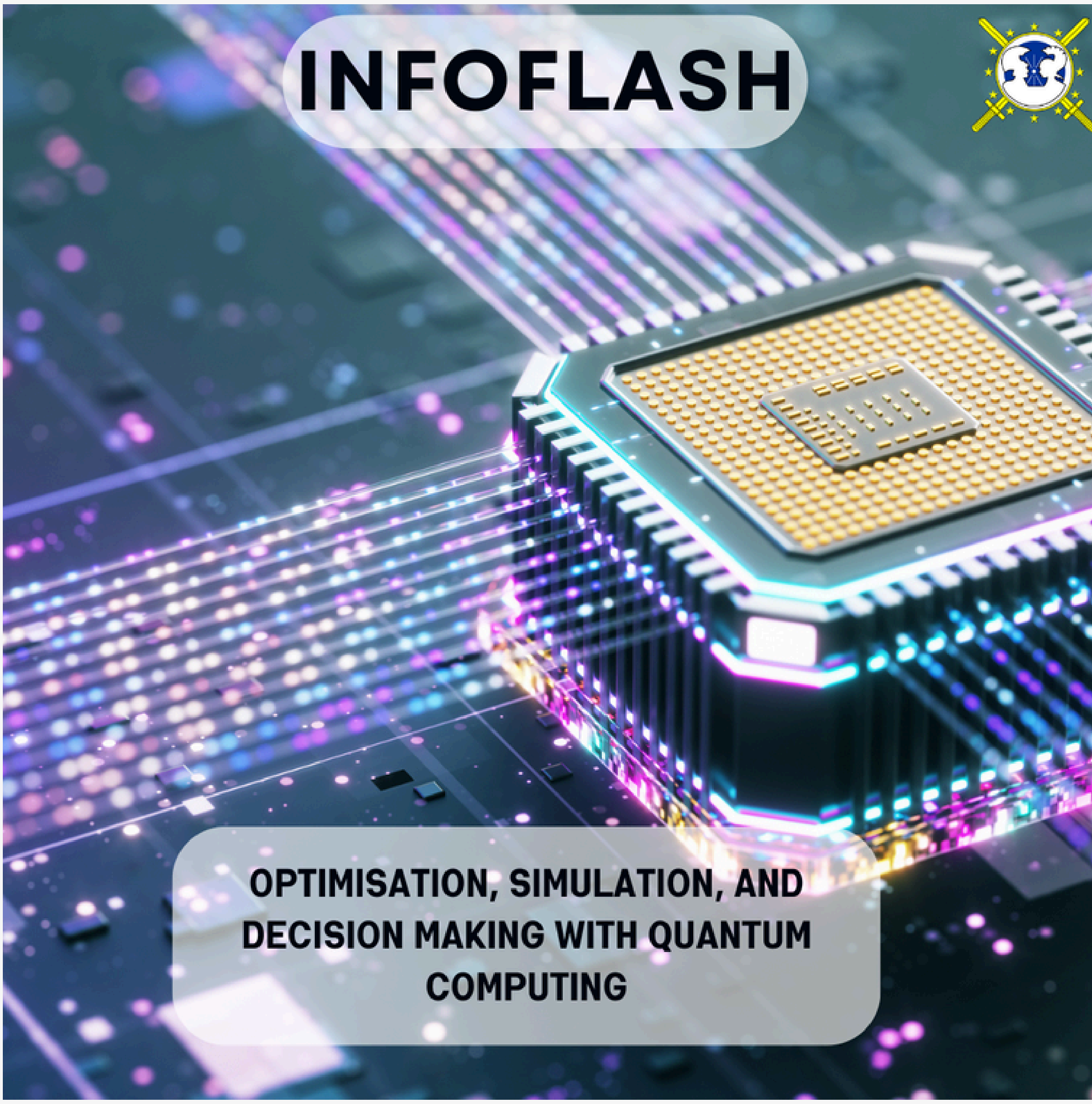

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Optimisation, Simulation, and Decision Making with Quantum Computing

"Not only is the Universe stranger than we think, it is stranger than we can think." – Werner Heisenberg

1. Introduction

On 23 September 2025, Europe inaugurated its second quantum computer in Ostrava, Czechia, as part of the European High Performance Computing Joint Undertaking (EuroHPC JU). The computer is expected to integrate with classical supercomputers and provide classical-quantum hybrid services. (European Commission, 2025c) Europe is not the only region that is part of the quantum race. Microsoft's Majorana 1, Amazon Web Services' Ocelot, Google's Willow, and IBM's Heron 2 (Ivezic, 2025) are new entrants to the market as well. The inauguration of quantum computers and the release of quantum chips show increasing interest in quantum computing, which is not misplaced, as its implications are far-reaching. Hence, it is timely to analyse the impact of quantum computing – in this case, what a computer powered by quantum chips and qubits, as opposed to central processing units (CPU) or graphics processing units (GPU) can do – on security and defence.

Quantum computing can revolutionise defence logistics, R&D, and command and control. Quantum computers can rely on quantum annealing, Grover's algorithm, and quantum phase estimation, among other algorithms, to efficiently find solutions to multivariate problems and find specific entries in a large database. Hardware, alongside these algorithms can facilitate the efficient deployment of units and assets, a better understanding of novel materials to facilitate military R&D, and enable better decision-making.

Europe has embarked on several projects to provide policy guidance and funding for quantum initiatives, including quantum computing. To this end, two initiatives stand out: the EuroHPC JU and the Quantum Flagship. Unfortunately, several challenges remain: fragmentation, the lack of expertise, and the supply chain continue to be thorns in Europe's side as it seeks to burnish itself as a continued leader in the quantum field.

2. Current issues with computing

Several processes across militaries are suboptimal because of computing limitations. Examples include logistics and sustenance, simulation in R&D and Artificial Intelligence (AI) and Machine Learning (ML) integrations.

Firstly, militaries are often engaged in the movement of people and materiel, whether it be for training exercises or operations. These movement operations are complex, as each asset may only be able to travel at certain speeds and along certain routes. For instance, certain platforms may require specific bridges to cross, given that anything with less strength may collapse. To add more complexity, specific units and materiel may need to arrive at their destination by a specific date and time, which has implications for their departure time and ttravelling speed. These conditions create so many possible outcomes that classical computers find the optimal transportation solution intractable (Q-CTRL, 2024). As a result, militaries are settling for suboptimal solutions in logistics movements due to processing power limitations.

Secondly, militaries are limited in their R&D because of computing issues. Some R&D is focused on modelling the behaviour of biological agents or chemicals in the production of armour, improved uniforms, or advanced materials (National Research Council, 2011; NSCC, 2021). However, classical computers are unable to simulate the behaviours of every sub-particle in given atoms because of processing power limitations (Belaloui et al., 2025; Department of Defense, n.d.). Hence, some guesswork and simplification are involved in every simulation, creating uncertainty and longer R&D timelines as researchers attempt to validate the simulations (Giselle Fernández-Godino, 2023). Our militaries, once again, must rely on estimates and longer timelines because of limitations in processing power.

Finally, the advent of AI and ML in combat is hindered by processing power. First, while AI can perform some sensor fusion, it is plagued by several issues (Gao et al., 2023) due to processing power constraints. These issues prevent accurate predictive analytics and intelligence. Second, adversaries may also attack neural networks capable of deep learning, introducing "perturbations" that alter the functioning of the model (Akhtar and Mian, 2018). These perturbations could be as simple as a discolouration of a pixel. This may cause the AI to generate junk information that negatively affects exercises or operations. Perturbations could even spoof image recognition algorithms in unmanned aerial systems, causing misrecognition at best and fratricide at worst (Li et al., 2021). Hence, a lack of processing power opens new AI and ML integrations to generating junk information.

3. Some Quantum Principles and Algorithms

The basics of superposition, entanglement, interference, and decoherence are covered in the first article of this series, "The End of State Secrets with Quantum Cryptography". This section covers some algorithms applicable to quantum computing.

Quantum computers can find the most optimal solutions to complex problems through quantum annealing. It helps to visualise the field of solutions to optimisation problems as a varied landscape of valleys and mountains. The lowest point in the landscape is the lowest energy state and the optimal solution (Jaiswal, 2023).[1] A tracker must find the lowest point

1. The lowest point of any function is its lowest energy state. Physically, all things tend towards its lowest energy state (for example, a pen resting on a table) and at its most optimum. Hence, functions at its lowest energy state are optimised.

but might get stuck in a low valley that is not the lowest point in the landscape ("a local minima"). Trackers in classical computers do not have the energy to climb out of this valley, even if there is a lower point in the landscape (Quinton et al., 2025). Quantum computers, however, can power trackers to tunnel through landscapes – technically, energy barriers – rather than climb them to arrive at a lower energy solution, or the "global minima" (He, 2024, p. 1). This way, quantum computers are better able to find the optimal solution to a problem with several variables.

The first quantum algorithm is Quantum Phase Estimation, a tool used to estimate the ground state of specific elements. The QPE is a method for estimating the ground state of organic, chemical, or biological compounds, providing crucial information about the compound's behaviour (Belaloui et al., 2025). First, one group of qubits are set into superposition and initialised, creating an "estimation register". Another group of qubits, which will be manipulated, is called a "system register". Then, an operation reflecting information on the target compound is systematically applied to the system register, which imprints the results of the operation to the estimation register through a "phase kick back". Thirdly, the Inverse Quantum Fourier Transform re-expresses these manipulations in binary terms, the measurement of which provides an approximate ground energy reading of the target compound. (Nielsen and Chung, 2010) The lowest energy solution reveals an immense amount about chemical and biological substances and is useful for military R&D.

The final quantum algorithm is a quantum variational classifier (QVC). It is a type of Variational Quantum Algorithm (VQA) that encodes data into a superposition, is run through a set of quantum gates, and then recoded back into binary for a probability measurement. These steps are repeated until the probability is high. (Macaluso et al., 2020) The strength of the method lies in quantum particles' ability to understand an image in superposition and pixels' links to each other, which makes it harder to spoof.

4. How does quantum computing facilitate military operations?

First, quantum computers can optimise military logistics (Krelina, 2025). For example, Q-CTRL, an Australian quantum computing company, was tasked with efficiently and effectively moving 60 convoys of approximately 5000 vehicles from Brisbane and Townsville to the Shoalwater Bay Training Area in preparation for Exercise Talisman Sabre, a bilateral training exercise between the Australian Defence Forces and the US military (Q-CTRL, 2025). Q-CTRL used a hybrid quantum-classical algorithm and its proprietary quantum infrastructure hardware to reduce noise and improve error correction. Where it took a month to optimally route 120 convoys, the total runtime for Q-CTRL's algorithm was six times faster than the normal classical algorithm (Q-CTRL, 2024). The result also saved time for the ADF. While a benchmark solver presented a solution that took 21 hours and 19 minutes for the full move, Q-CTRL's systems generated a solution that only took 19 hours and 17 minutes. While this

2-hour reduction may seem insignificant, it meant that platforms would not have had to spend excessive hours on the road in the dark and at late hours, reducing the risk of accidents (Q-CTRL, 2025). Error-corrected quantum computers were able to save time as well as increase efficiency and effectiveness in aiding the Australian Army with a large and complex administrative move. Hence, quantum computers can optimise military logistics.

Quantum computers can also use quantum annealing to find the most efficient distribution of items. For example, D-wave, a quantum computing company, uses quantum annealing to resolve Multi-Echelon Inventory Optimisation problems that are formulated as a Quadratic Unconstrained Binary Optimisation problem (D-Wave, 2022). The problem enables users to include both intended benefits and constraints, such as warehouse capacity limits and budget constraints, while ensuring equipment availability when required (Harikrishnakumar et al., 2020). Militaries could use this software to understand how and where to position particular materiel, such as spare parts. This might be useful for NATO militaries, given that they must coordinate the production and delivery of different types of materiel across their theatres (Ti and Kinsey, 2023). While such a solution has not been commercialised, available technology and use cases in other sectors suggest that a military application is technically possible (D-Wave, n.d.).

Quantum computers can carry out accurate simulations and depict the behaviour of chemical and organic compounds. Using QPE, researchers can determine the lowest-energy state of a given substance and gain a deeper understanding of its properties, including its thermodynamics and stability when exposed to specific substances. Researchers have demonstrated the ability of quantum error-corrected computers using QPE algorithms to determine the lowest-energy state of hydrogen (Yamamoto et al., 2025). Applying this to the military realm could shorten timelines for R&D into the behaviour of chemical and biological agents (Krelina, 2021), in particular explosive agents or advanced materials for armour (NSCC, 2021).

Finally, quantum computers can integrate with AI and ML to turbocharge sensing and protect against neural network attacks. Militaries deploy many sensors across several domains to provide information. Quantum computers have the processing power required not only to integrate information from these sensors (Krelina, 2025), but also to integrate them to provide predictive analytics. For example, BQP's quantum algorithms facilitate predictive maintenance of US Armoured Fighting Vehicles and increase their lifespan (BQP, n.d.). Other Quantum enabled AI software can also aid in intelligence, surveillance, and reconnaissance, such as Artificial Brain's Plank Hyperspectral Intelligence, which can analyse not only single band wavelengths, but hyperspectral information, including that from the electromagnetic spectrum (Artificial Brain, 2025). Quantum computers are also able to better defend against adversary attempts to perturb neural networks and interfere with pattern recognition. QVC patterns were found to have been resistant to adversarial attacks attempting to manipulate foundational data as quantum algorithms learned a wholly different, and meaningful, set of information that enabled them to function better than classical computers (West et al., 2022). Hence, quantum computing can integrate with AI and ML to turbocharge sensor fusion, predictive analytics, and guard against neural network attacks.

5. What is Europe doing?

Europe has embarked on a comprehensive strategy to build several Noisy Intermediate-Scale Quantum (NISQ) computers[2] while working towards a Fault-Tolerant Quantum Computer (FTQC), or one that can function accurately even in the presence of errors (Davis et al., 2025).

The strategy is already showing results. The EuroHPC JU, which benefits from €7 billion in funding from the European Commission, aims to federate supercomputing and quantum computer capabilities (European Commission, n.d.). Two quantum computers have already been inaugurated in Poland (European Commission, 2025a) and Czechia (European Commission, 2025c). More inaugurations are likely on the way as the Polish and Czech computers are the first two in a series of six planned inaugurations. Under the auspices of the EuroHPC JU, states signed a Memorandum of Understanding committing to integrate quantum capabilities into existing supercomputers in Czechia, France, Italy, Germany, Poland, and Spain (EuroHPC Joint Undertaking, 2023). NATO has similarly released a Quantum Strategy and called for member states to "accelerate" the development of quantum technologies, because of its security implications (NATO, 2024). Hence, it is likely that Europe will only deepen its quantum computer capabilities.

Europe is also funding and working with consortia to develop quantum capabilities in sensor fusion and simulation. The EuroHPC JU also works with Pasquans 2, a consortium of researchers and private sector players, to operationalise a simulator capable of simulating 1000 atoms. The specific goal of the mission is to bring such a simulator "from research labs to real world applications" (European Commission, 2023). The European Commission has also funded this project with €27.3 million. There are also efforts at enabling sensor fusion. Initiatives like ADEQUADE, which enjoys a €27.5 million funding from the European Defence Fund (EDF), are working towards building sensor fusion capabilities that allow commanders to receive a quick and accurate picture of the battlefield (European Commission, 2021).

Europe is also going to implement policies that force integration and usher talent into the sector. For example, the European Commission is currently drafting a European Quantum Act, which is expected in 2026. (Cyber Risk GmbH, n.d.) The act is expected to establish

2. NISQ computers are not error-corrected and have a limited number of qubits.

regulations and legal protection for the Quantum Europe Strategy, including a framework for targeted investments, a quantum design facility for domestic quantum chip production, and strengthened coordination (Gleiss Lutz, 2025). On the talent front, initiatives like the European Quantum Skills Academy, an online platform offering graduate degrees and PhDs to those interested in developing quantum expertise (Misheva, 2025). It is also implementing mobility programs allowing foreign expertise to complement local talent (European Commission, 2025b).

6. A Reality Check

The technologies covered in this paper are still in their infancy. Quantum computers are notorious for being unstable, given qubits' sensitivity to their environment (Krelina, 2025). It is difficult to keep quantum computers running for extended periods of time (Pattinson, 2025). Hence, NISQs, which are more prone to errors, cannot sustain the consistent processing required by AI/ML integrations or simulations. Further research is needed before the futuristic scenarios described in this paper can become a reality.

The scope and extent of this research, and the consequent ability to scale findings, depend on several factors, such as continued funding and talent retention. However, that seems to be a problem: Europe does not enjoy the same private sector investment that the US does, explaining why large US MNCs are releasing quantum chips regularly while Europe must overcome continent-state fragmentation, work with EU funding, and produce demonstrators and proof-of-concepts rather than minimum viable products themselves. Indeed, while the private sector accounts for 44% of all quantum funding in the US, the European private sector makes up only a paltry 12% (Erixon et al., 2025). Talent retention schemes may work when training a new corps of quantum specialists; however, insufficient pay and a lack of industrial-scale adoption will lead to a loss in patent registrations and brain drain. Indeed, a fifth of Harvard's Quantum Initiative Facility are Europeans, due to its high pay, facilities, private funding, and commercialisation support outclassing a prestigious apex position at France's Centre National de la Recherche Scientifique (Crane, 2025). The European Commission's schemes must be complemented with a more welcoming investment regime that encourages private sector companies to work with researchers for innovations to exit the lab.

Finally, fragmentation, by the European Commission's own admission (European Commission, 2025c), is a persistent issue. Many nations have their own quantum computing strategies, some of which may be at odds with the European Quantum Strategy. France has funded a domestic quantum masterplan to the tune of €1.8 billion, while Germany has done the same for €2 billion (Kelly, 2021). Countries are also coming together in trilateral or multilateral formats to issue investment calls to the private sector. For example, France, Germany, and the Netherlands launched a €30 million call for projects in scalable quantum computing, quantum networks, and quantum sensing technologies in May 2025 (Choucair, 2025). The multiple calls for projects might put a significant amount of public money behind quantum technology. It is unclear, however, what the effect of multiple grant calls is, especially if different grants eventually award the same applicant, increasing redundancies.

7. Series Conclusion: A Tempering

Quantum cryptography, sensing, and computing, taken to their full potential, upends the world we are used to. Encryption, radio frequency sensing, and computing itself seem to be at risk, with quantum futures predicting breakdowns of standard encryption and the publication of state secrets (see first article), more accurate sensing that is resistant to GPS denial or degradation efforts (see second article), and computers that can generate kill lists faster than any other.

This future is decently distant. Quantum technology itself is unstable and undeployable. We are still in the NISQ era, where quantum computers are yet to run for extended periods of time (Pattinson, 2025). Quantum sensors like cold atom interferometers are yet to be miniaturised to be deployed on platforms that operate in harsh environments. Hence, its potential for solving optimisation problems, running complicated simulations, and augmenting AI/ML is muted in the short-term. However, if quantum technology's future is fully realised, quantum cryptography, sensing, and computing could change the way that societies defend themselves, with huge implications for data security, privacy, sensing, navigation, optimisation, simulation, and strategy.

This dream is fuelled by a comprehensive policy framework that is likely to be institutionalised under the EU Quantum Act next year. The goal of being a Quantum power by 2030, alongside a comprehensive quantum strategy, is putting Europe on the right path. Several billion dollars in public funding have been mobilised for companies and researchers to perform further R&D and build working quantum tools that societies can use for advancement and defence.

However, quantum R&D is plagued with technological difficulties, fragmentation, the availability of expertise, and supply chain constraints. These problems can be resolved through centralising funding, encouraging private sector investment, prioritising operationalisation and, if appropriate, commercialisation. These, in turn, would encourage talent retention (Clara, 2025). Finally, supply chain constraints – especially in rare earth materials required for quantum sensors and computers – must play a key role in research, to ensure that Europe can maintain sovereignty over its quantum infrastructure.

The future is squarely in the quantum realm. It resolves problems that we cannot even think of yet. While Europe is headed in the right direction, it can do more to make the quantum future bright for Europe and its militaries.

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