



Quantum
Delta NL

QDNL'S CATALYST PROGRAMMES

Quantum computing and simulation

Quantum communication and quantum secured internet

Quantum Sensing Applications Programmes

CAT-1: Quantum computing and simulation

The CAT 1 ambition for phase 3 is to reach the NISQ application era (stage 3 in our four stages of quantum computing) and thereby deliver advantages over classical computer on real-world problem and economic end user value. The NISQ Application era hinges on the capabilities of beyond-classical quantum computing. It encompasses computational methods that function in the absence of error correction. In other words, these methods operate using noisy qubits and gates at the logical level.

It is anticipated that NISQ applications will heavily rely on emerging techniques such as error mitigation and hybrid quantum computing. These approaches also involve transferring the maximal portion of computation to classical devices as possible, thereby minimizing the quantum requirements. Error mitigation enables us to extrapolate noise-free outcomes by leveraging multiple iterations on the noisy quantum device. Hybrid methods allow us to overcome limitations of size (enabling simulations exceeding hardware sizes), bypass connectivity and architectural constraints (e.g., through variational methods), and fundamentally compute only what is necessary on the quantum hardware. Estimates for error thresholds can be gleaned by studying concrete methodologies like UCCSD-ansatz-based chemistry, where the demand for depths approaches thousands, assuming computations on beyond-classical qubit numbers (>100). This leads to error-level requirements close to what is needed for fault tolerance. To optimize the potential of error mitigation and hybrid methodologies, the incorporation of rapid gate execution, fast readouts and exceptionally stable (drift-free) systems becomes pivotal. Establishing seamless connectivity to high-performance classical hardware via high-throughput channels also takes the central stage.

More concretely we have set the main requirements for the quantum compute resources at systems with at least 100 qubits and single- and two-qubit error rates better than 10^{-3} . The path to this goal will already provide economic value to The Netherlands, by creating a strong value chain for quantum computing.

Activities executed within CAT 1 shall contribute to the following goals:

- Engineering quantum computers with at least 100 qubits and single- and two-qubit error rates better than 10^{-3} and operating at clock speeds above 1 MHz.
- Strengthening the Dutch supply chain for quantum computing components and modules
- Development & application of quantum algorithms and procedures/methods to optimize the execution of such algorithms for NISQ quantum computers
- Standardization (of interfaces) and definition PLUS implementation of benchmarks for quantum computing
- Creation of synergy between CAT 1 and European projects aimed at the above goals, such as from EuroHPC JU, H2020, etc

CAT-2: Quantum communication and quantum secured internet

CAT-2 distinguishes two Quantum Communication stages:

- First Generation Quantum Networks (QKD Networks)
- Next Generation Quantum Networks (Entanglement and Quantum Internet)

Hardware in scope of the First Generation Quantum Networks is generally available with medium TRL levels and QKD research is widely executed throughout Europe. Our focus is therefore to widen and deepen the industry adoption.

The full potential of the quantum communication technology, however, lies within the next-generation entangled and quantum internet. This technology still requires major effort in research and development. We therefore focus on the acceleration of the research in this field, aimed to apply the technology as soon as it is ready.

Therefore CAT-2 has set the following goals:

1. Build the national quantum network

We will roll-out a nation-wide quantum network, based on first-generation quantum key distribution (QKD) technology. By actively governing and expanding this network, the number of end-users will increase over time. This network will build upon local networks that are either deployed or are in progress at strategic locations throughout the Netherlands (e.g. Utrecht, Rotterdam, Amsterdam, Delft/The Hague and Eindhoven). The end-goal is to connect this network cross-border in EU, leveraging the nodes available in these locations. This requires a cross-border network design, hardware and software like a domain controller, KMS and orchestration layer.

2. Accelerate next-generation technology developments

We will accelerate the development of next-generation quantum technology (the so-called full entanglement and/or quantum internet technology) such as quantum repeaters, memories and a quantum internet domain controller, as well as the overall miniaturization of hardware components through, for example, integrated photonics. Rolling out Quantum Internet throughout the EU is the final goal of CAT-2 hence all efforts to accelerate these developments are key.

3. Commercialize quantum communication technology

We will foster a sustainable market for quantum communication technology by productizing hardware and software components and increasing industry adoption. CAT-2 is interested in adding more industry parties to implement QKD or to support research, focused at the next-generation quantum communication technology.

Showcasing a quantum network with multiple end-user applications (e.g. interconnected quantum sensors) to solve real-world problems would be a great achievement and will attract the interest of a wider industry.

CAT-3: Quantum Sensing Applications Programmes

We live in a world of sensors constantly translating stimuli into electric signals. Whether it's the thermometers in our homes, the high-performance sensors in our smartphones, or the myriad sensors within the machinery fabricating such devices, their ubiquity is undeniable. In other words, better sensors can have a disruptive impact on our societies.

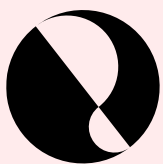
Quantum sensors are a particular type of sensor where a coherent transformation of quantum systems mediates the sensing process. Typically fragile due to susceptibility to environmental influence, quantum systems are nonetheless ideal for developing highly sensitive sensors. And beyond sensitivity, quantum sensors can offer more accurate, thorough, efficient, and productive measurements.

Despite the promise of quantum sensor technology, realising its full potential requires extensive research and development. Fundamental research into quantum physics is essential for creating new sensors and enhancing existing ones. Collaboration among academia, industry, and other sectors is crucial to identifying and developing applications with the most significant impact.

Within this context, CAT-3's main goal is accelerating the industrialisation of Quantum Sensing Applications while strengthening the QDNL ecosystem to ensure that these technologies substantially benefit Dutch society and economy.

During Phase 3 of QDNL, CAT-3 will support initiatives aligned with this goal, which might include those aimed to

- Contributing to the advancement of Quantum Sensing technologies in the Netherlands, with a focus on core technologies such as Cold Atoms, Optomechanical systems, and NV Centers.
- Proposing, developing, and testing tangible industrial Quantum Sensing use cases across sectors such as the Semiconductor Market, Space, Energy Transition, Defense, and Security.
- Strengthening the Dutch proposition on Quantum Sensing within the Dutch and European quantum ecosystem.



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