Practical and ethical implications of quantum technology

Eline de Jong (e.l.dejong@uva.nl)

Universiteit van Amsterdam (ILLC, IOP, QuSoft)

Stanford Center for Responsible Quantum Technology

OQIxGiga: Quantum for Connectivity

19 October 2024

Practical implications

Ethical implications

i. Five general challenges

ii. Responsible QT

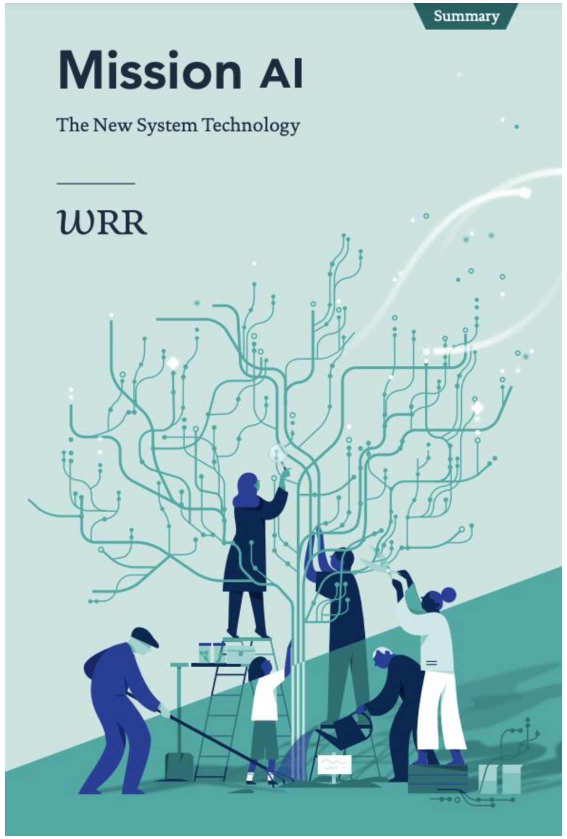
iii. Understanding

iv. Keeping it real

Practical implications

i. Five general challenges

Practical implications
i. Structural challenges of embedding QT within society



Mission AI: The New System Technology
The Netherlands Scientific Council for Government Policy

"Embedding system technologies within society involves five structural challenges." (WRR, 2021)

Practical implications
i. Structural challenges of embedding QT within society

Quantum technology is a ‘system technology in the making’ (de Jong, 2022)

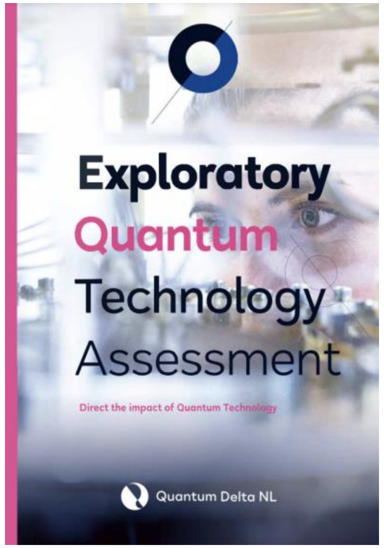
By anticipating five challenges, we can prepare society for quantum technology

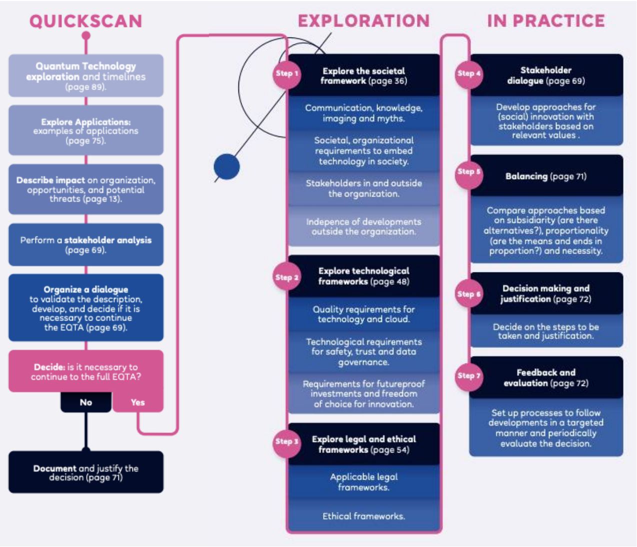
Perception	→ **Demystification** *(what are we talking about?)*
Socio-technical context	→ **Contextualisation** *(how will this work in practice?)*
Societal context	→ **Engagement** *(who should be involved?)*
Rules	→ **Regulation** *(what frameworks do we need?)*
International context	→ **Positioning** *(how do we relate to others?)*

Practical implications
i. Structural challenges of embedding QT within society

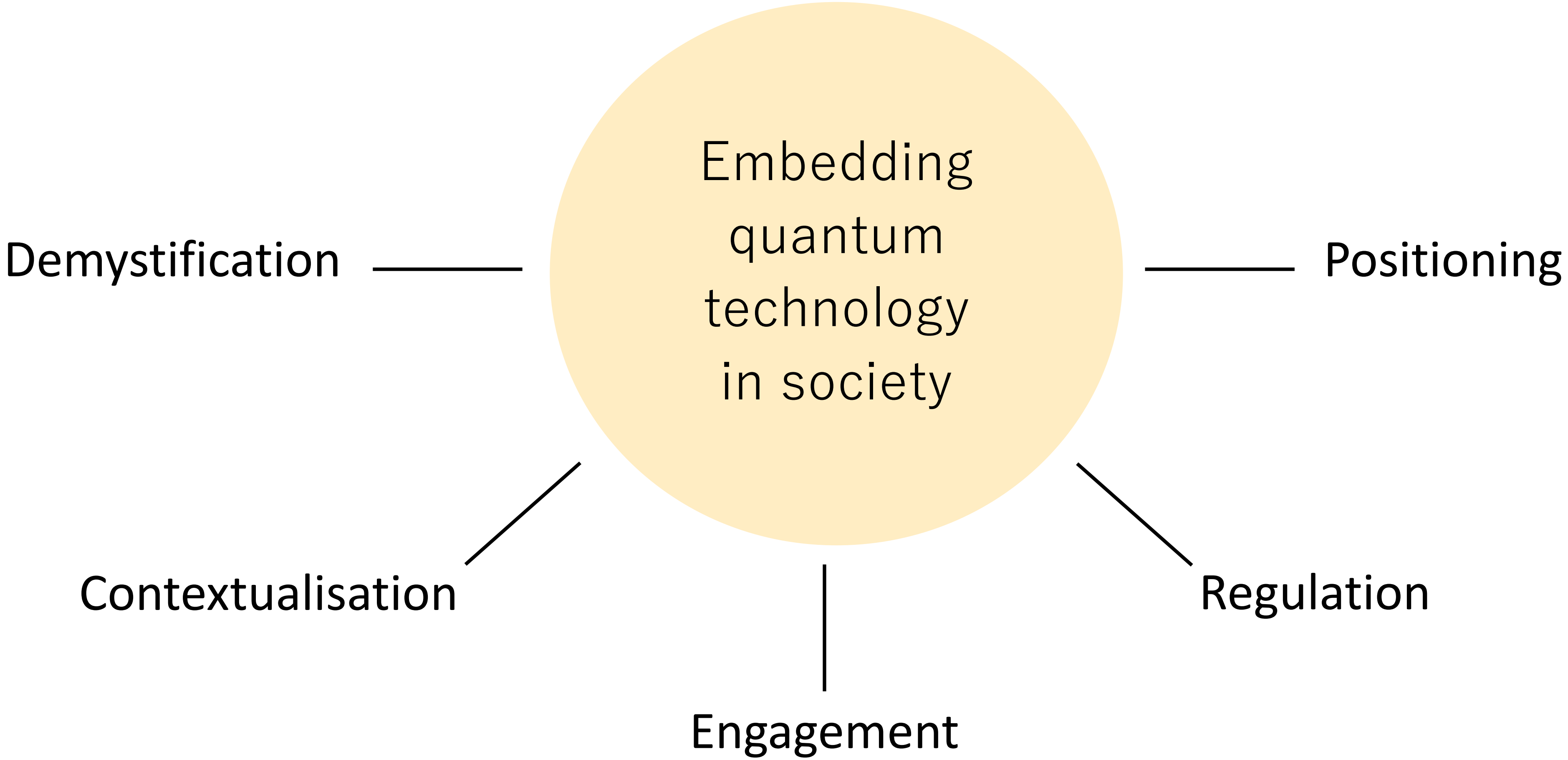
Each challenge can be translated into questions for individual organisations

Exploratory Quantum Technology Assessment (QDNL, 2022)





Practical implications
i. Structural challenges of embedding QT within society



How do we define success?

Ethical implications

ii. Responsible QT

iii. Understanding

iv. Keeping it real

Ethical implications

ii. A call for responsible quantum technology

Comment

https://doi.org/10.1038/s41567-024-02462-8

A call for responsible quantum technology

Urs Gasser, Eline De Jong & Mauritz Kop

Check for updates

The time has come to consider appropriate guardrails to ensure quantum technology benefits humanity and the planet. With quantum development still in flux, the science community shares a responsibility in defining principles and practices.

A new generation of quantum applications has begun to transform research practices in chemistry, material sciences, and optimization, often combined with machine learning and data science[1]. In parallel, research into quantum–classical hybrid approaches are beginning to proliferate in healthcare, finance, defence, and beyond. At a time when policymakers from Washington DC to Beijing are grappling with the question of how to deal with the potentially existential risks emerging from applied, generative and interactive artificial intelligence (AI), advancements in quantum technology (QT) may mark the next – and likely even murkier – frontier of global governance.

From a policy and societal perspective, QT shares some of the characteristics of AI innovation. Like AI, the application areas of QT will be diverse and its impact broad, perhaps disruptive: quantum sensing will transform how we map the physical world, quantum computers promise to significantly expand computing abilities[2], and quantum communication potentially introduces a new paradigm in how we communicate securely. While quantum sensors are already available, quantum computers and quantum communication are at a relatively low level of technological readiness. What all QT research areas have in common is an accelerating pace of innovation.

The dawning of the quantum age hints at a list of opportunities that resemble nirvana from the vantage point of a troubled societies confronted with a variety of crises, ranging from public health and climate to social injustice. Put positively, QT comes with the promise of pursuing a broad range of desirable societal outcomes, including those laid out in the context of United Nations Sustainable Development Goals. Quantum computing, sensing and metrology, for instance, could contribute to better healthcare by boosting drug discovery, advancing personalized medicine, and monitoring patient health in real-time. Quantum simulation could play an important role in dealing with climate change by enabling innovation in battery design and clean energies.

Not surprisingly and like any other complex socio-technological phenomenon, QT also comes with substantial challenges. Several of them exacerbate risks already familiar from current debates in the domain of AI. Among them are threats to civil rights and liberties with regard to the powerful surveillance capabilities of near-field and long-distance quantum sensing applications; questions of equitable access amidst unequal global distribution of quantum computing and networking capabilities; or the problem of dual use, which suggests that the same technology can be used for socially beneficial but also for harmful purposes[3]. For example, quantum simulation could be used for the development of new drugs or chemical weapons.

Some risks associated with the latest wave of QT software and hardware structures might even be entirely new. Quantum algorithms, for instance, display the potential to break current cryptographic protocols, posing a systemic threat to data, privacy, and cybersecurity with unforeseen ramifications for societal trust and democratic cohesion. A technological arms race could result in a Sputnik moment for quantum and diminish interest in guardrails. As with QT's promises, the list of challenges and risks is long, with many unknown unknowns lurking off-stage given its nascent – or more accurately, uneven – state of development and deployment.

Some argue that it is premature to consider QT guardrails seriously. Indeed, we currently lack a full understanding of the overall potential of QT, nor do we have a final grasp of the array of specific risks associated with it. Although some applications in the field of quantum sensing or hybrid computing have already entered the market, today's limited availability of large-scale quantum applications such as networked universal quantum computers constrains our evidence base about risks and opportunities. Nonetheless, the history of technology – from nuclear energy to present-day AI – offers a cautionary tale by teaching us that ethical, legal, social, and policy implications of powerful new technologies too often are only an afterthought once the genie is already out of the bottle – typically ignoring occasional voices calling for safeguards early in the process.

Given the high stakes of QTs and considering the wisdom that we tend to overestimate a technology's short-term effect while underestimating its long-term impact, we suggest that we must avoid repeating the same mistake this time around. What is needed in our view is a proactive approach towards responsible QT innovation at a time when it is still malleable – exactly because the future is uncertain and the speed of development accelerating[4]. Granted, crafting guardrails for a technology environment that is in flux is neither an easy task nor a quick win.

One sensible approach – an initial step, really – in this early stage of the tech innovation cycle is the creation of what in the field of science and technology policy is called a responsible research and innovation framework. It offers a systematic approach to anticipate and manage societal risks and opportunities that may arise when a new technology is developed. In the context of QT, and building upon past experiences in domains like biotechnology or nanotechnology research, this type of framework can offer guidance to researchers in labs, but also to funding agencies and regulators when it comes to its ethical, legal, social, and policy implications and ways to address emerging issues throughout the QT lifecycle.

The building blocks of such frameworks have been proposed recently, including work that focuses on responsible QT in defence and national security. Probably the most comprehensive effort to date aimed at developing normative guidance is an interdisciplinary initiative anchored at Stanford University, which has brought together a transatlantic team of experts – among them the authors of this Comment – representing different disciplines, including quantum

nature physics

A call for responsible quantum technology, ensuring it "benefits humanity and the planet."
(Gasser, Kop & de Jong, 2024)

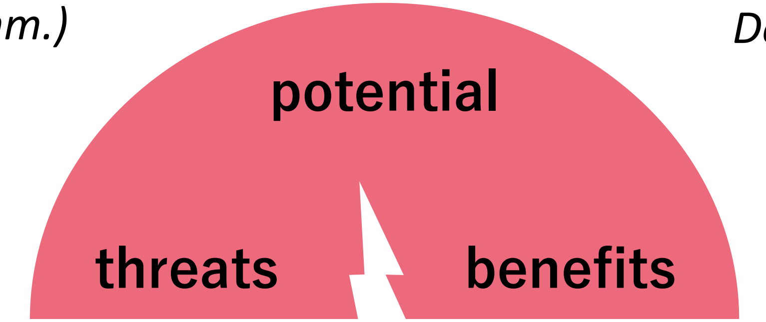
Ethical implications

ii. A call for responsible quantum technology

Given the vast potential of quantum technologies, the stakes are high

…undermining cybersecurity (Q computing)
…facilitating criminal networks (Q comm.)
…compromising privacy (Q sensing)

…contributing to the UN Sustainable Development Goals



Given these high stakes, we share a responsibility to ensure ethical development and deployment of quantum technologies

With great technology
comes great responsibility

Ethical implications
ii. A call for responsible quantum technology

Responsible quantum innovation, guided by three objectives:

1. **Safeguarding society**: proactively identifying and mitigating risks
2. **Advancing society**: leveraging new capabilities for societal goals
3. **Engaging society**: involving society in development, implementation, evaluation

… sure, but how?

How can we enable a meaningful and inclusive discussion about the ethical implications of quantum technologies?

Ethical implications
iii. The necessity of understanding quantum technology

Sufficient understanding of quantum technology is a key condition for a meaningful debate about its ethical implications.

Source: ANP

Ethical implications
iii. The necessity of understanding quantum technology

Sufficient understanding of quantum technology is a key condition for a meaningful debate about its ethical implications.

→ What kind of understanding is required to consider the societal and ethical aspects of quantum technology?

Ethical implications
iii. The necessity of understanding quantum technology

Technological understanding (de Jong & De Haro, forthcoming)

= the ability to realise a practical aim (e.g. solving a problem, meeting a need) by using a technology

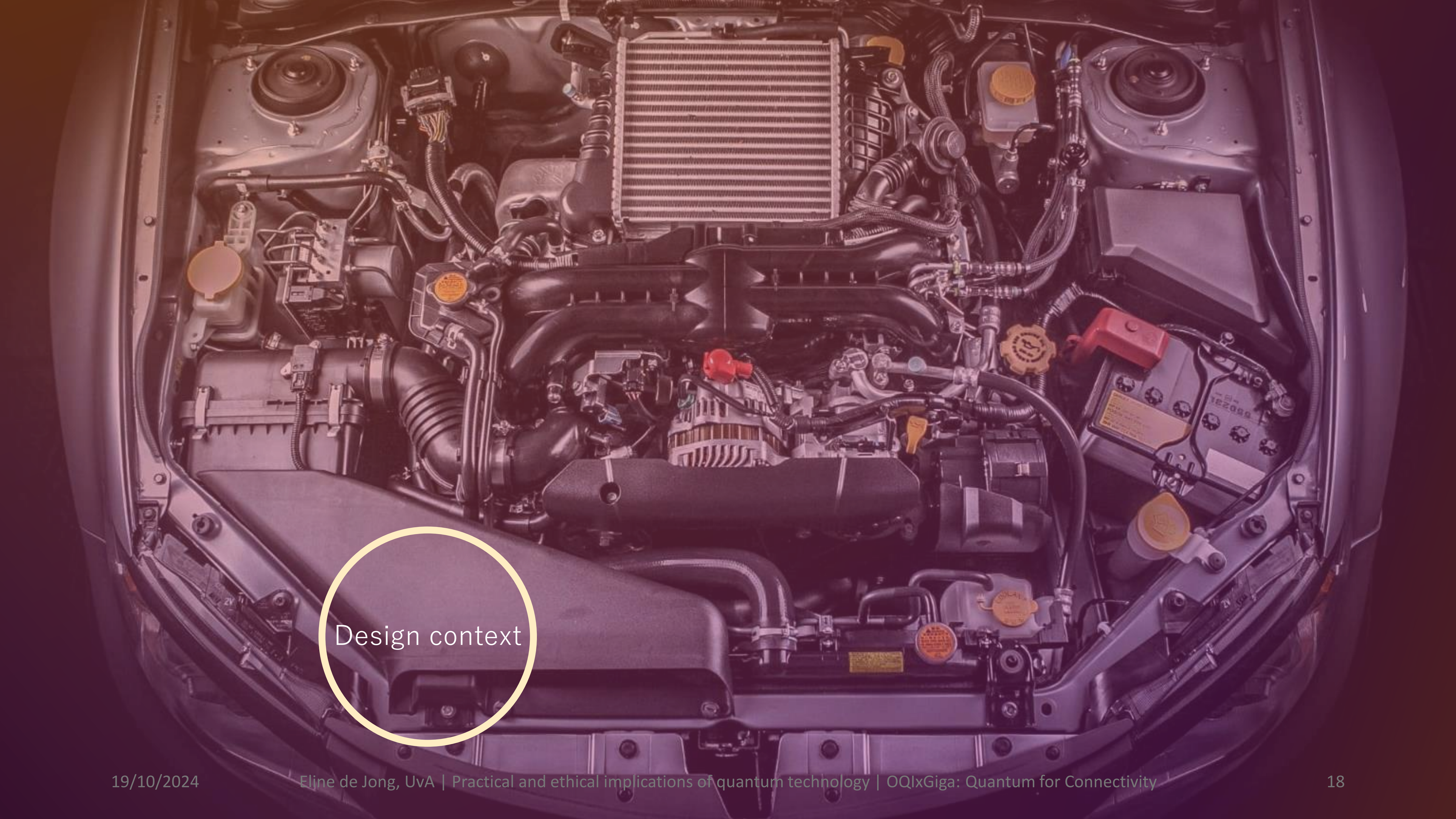
This requires some degree of insight into how the technology works

Required depth of insight varies per context

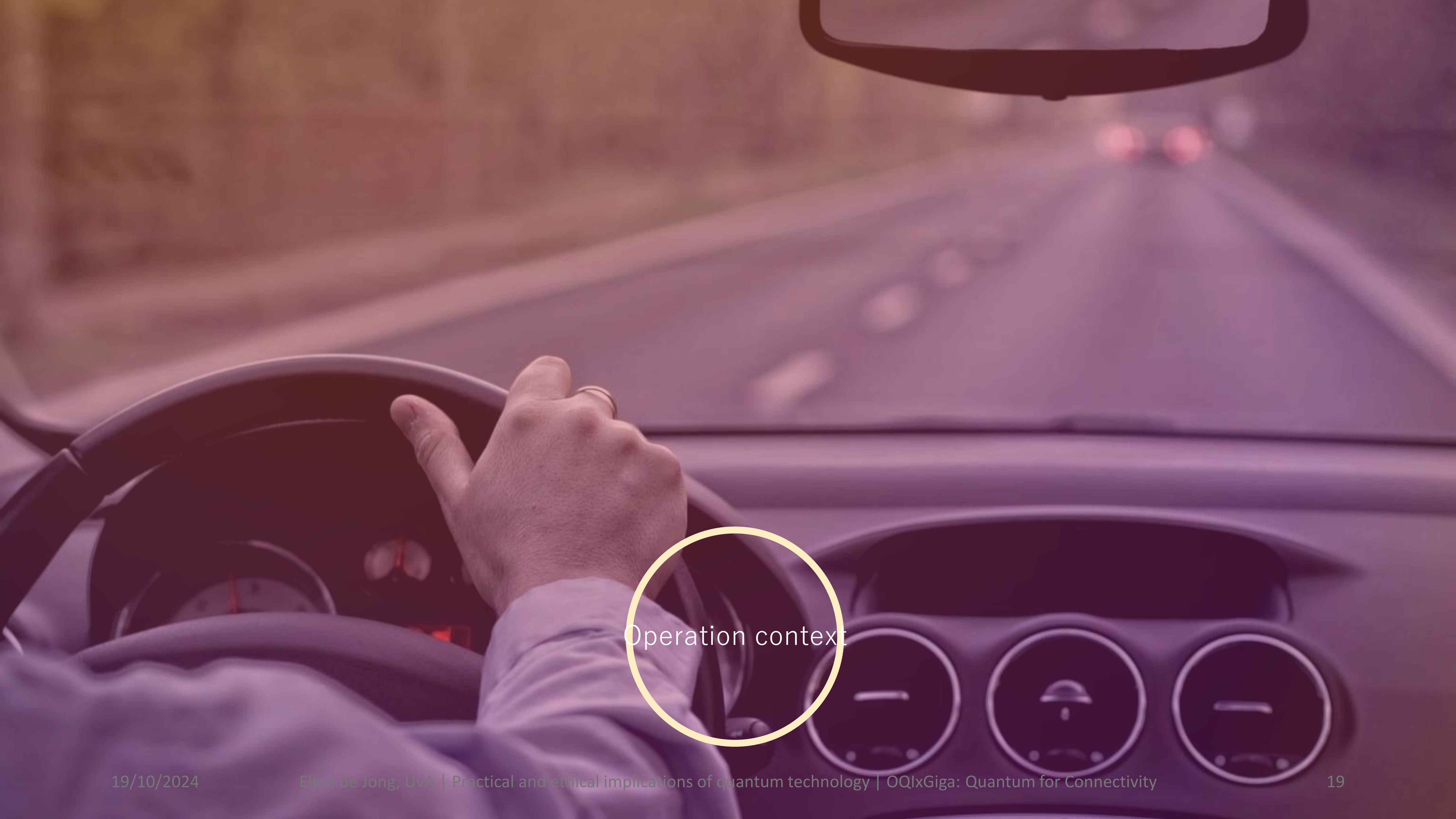
Design context

Operation context

Innovation context



Design context



Operation context

Innovation context

Ethical implications
iii. The necessity of understanding quantum technology

What it means to have (enough) techn. understanding, depends on the context:

→ 1. **Design**: understanding at level of inner workings
2. **Operation**: understanding at level of direct consequences
3. **Innovation**: understanding at level of functional capabilities

Introductions to quantum technology often focus on explaining inner workings

Ethical implications
iii. The necessity of understanding quantum technology

What it means to have (enough) techn. understanding, depends on the context

1. **Design**: understanding at level of inner workings
2. **Operation**: understanding at level of direct consequences
3. → **Innovation**: understanding at level of functional capabilities

Introductions to quantum technology often focus on explaining inner workings

For considering the societal and ethical implications of QT, we first and foremost need an understanding of their functional capabilities

Ethical implications
iv. Keeping it real

New and emerging technologies like quantum, raise the dilemma between early-stage uncertainty and late-stage entrenchment

Quantum technology — knowledge problem — versus — power problem

Ethical implications
iv. Keeping it real

Speculative ethics ("if-then") can distract attention from more urgent issues

"upstream stage of technology development"

"downstream ethics" (focused on specific outcomes)

A low Technology Readiness Level = a low Ethics Readiness Level

Ethical implications
iv. Keeping it real

The risk of "thinking ahead too much" also applies to quantum technology

It is important to foster ethical discussions that are grounded in the present

(Shelley-Egan & de Jong, forthcoming)

We need to find the right mode of doing "upstream ethics" ⟵

Ethical implications
iv. Keeping it real

Possible strategy: Shifting the focus from consequences to visions

What do visions communicate? ("why") ⟵ **Visions** ⟶ Whose visions are they? ("by whom", "for whom")

Thank you!

Eline de Jong (e.l.dejong@uva.nl)

Universiteit van Amsterdam (ILLC, IOP, QuSoft)

Stanford Center for Responsible Quantum Technology

OQIxGiga: Quantum for Connectivity

19 October 2024