

UNIVERSITY  
OF TWENTE.

# Theatrical Technology Assessment

MODERATOR MATERIALS  
QUANTUM REVOLUTION

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Enschede 2022

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of Applied Sciences

We wish to thank all those involved in the project and the development of the cases.  
Special thanks go to: ECSens, QDNL, and the 4TU Plantenna project

These are the results of a project related to the NWA Route Quantum Nanorevolution  
funded by NWO.

Grant number: NWA.1418.20.002

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# Theatrical Technology Assessment - Moderator Material

## Quantum Revolution

In this document the key elements for moderation of the Theatrical Technology Assessment (TTA) case on “Quantum Revolution” are highlighted.

### What is TTA?

TTA is a learning activity designed by Klaasjan Visscher (2020) which “aims to enable engineering students to explore and anticipate the socio-technical dynamics of emerging technologies, and to find ways to integrate their insights in nuanced innovation plans” (2020, p.5). The method is based on the concept of Constructive Technology Assessment (CTA) (Rip et al., 1995), which is a research methodology to assess technological developments in society and enable real-world stakeholders to anticipate or influence this development and embedding (Te Kulve, 2011). In the educational setting, the focus is put on understanding new technologies in complex and uncertain situations while developing the competencies to deal with this. The roleplay simulation aspect of it allows the student to get an inside experience of stakeholder positions, including the conflicting and constructive relationships this stakeholder may have (Tjosvold, 2008). The materials of the case should facilitate sufficient information for the actor to play out the stakeholder in a realistic fashion. The method includes improvisational theatre to make actors more confident in their role while interactions are quicker and more interesting. It allows for the construction of the situation during the play because of its “yes-and” nature, which creates a certain path dependency and has room for alternative, new, or unexpected outcomes (Van Bilsen et al., 2013).

Goals of the TTA roleplay “Quantum Revolution”:

- Students learn about the positions of different stakeholders in the field of quantum technology, stakeholder dynamics, and tensions.
- Students experience uncertainties of this new and emerging research field, related to hypes, promises and expectations regarding the funding and development of quantum technology, as well as conflicts between political, economic and social aspects.
- Students learn about the socio-technical configuration and multi-level perspective of this niche technology with potentially disrupting character.
- Students become aware of the responsibilities of researchers with respect to research funding, and the alignment of research and societal values and needs.

### Setting and materials

Number of attendees: 5-25 (advisable to double role descriptions from 15 attendees onwards)

The complete set of material for this case can be found [online](#) and consists of the following:

- Moderator Material (this document)
- Moderator Cheat Sheet (Appendix 1 and separate .pdf)
- Technology description (Appendix 2 and separate .docx)
- Role descriptions (Appendix 3 and separate .docx)
- Observer instructions (Appendix 4 and separate .docx)

## Organisational aspects

This section covers the organisational aspects needed to execute a TTA roleplay. Make sure to read into the materials before implementing a specific case. We provide bullet points on what to address to make the introduction and moderation of the case easier.

### Materials to bring

It is important that the people who will act out as well as the ones who will observe the roleplay are well informed about the context of the play. This can be facilitated by bringing printed materials to class and allowing students a moment to read.

- Moderator Cheat Sheet
- Technology description (x number of persons present)
- Role descriptions (5 or 10, depending on choice to double roles)
- Observer instructions (x number of non-players)
- Blank sheet of sturdy paper for character names (1 for each role + yourself as moderator)
- Markers for writing the character names
- A watch for keeping time

To improve the readiness of those playing and to save time during the lecture, role descriptions can be shared with the actors before the play. This however requires the distribution and assigning of the roles prior to the meeting. Only share the role description with the persons who will play the roles and do so two days in advance latest. Do bring prints of the role descriptions to the lecture, this is often appreciated.

### Setting the room

Put all tables to the side to create a large open space. Put chairs in a semi-circle facing the front. At the end of the warming up, make a **V-formation** of two tables facing the audience. Put a chair for the moderator at the closed end and 5 chairs behind the tables. The tables only serve to put up the name of the character. This set-up gives the actors room to play, unobstructed by a table and allows the observers an unobstructed view of the goings-on.

No multimedia equipment is required for the roleplay, unless this is preferred during the introduction or reflection moments.

## Timeline of the play

Phase	Duration	Description
Introduction	5 min	·Introduce technology, aim of the meeting, and assign roles.
Preparation	10 min	·Give attendees time to read materials, think of a name, and write this on a paper card.
Warming up (extend in case of more time)	10 min	·Improvisational theatre exercise, make people enthusiastic, enter character.
Session 1 'CTA workshop'	20 min	·Introduction by the moderator, mention the setting, the reason for gathering, and goal of the session. Ask characters to introduce themselves and their perspective on the situation.
Reflection 1	15 min	·Analyse stakeholder dynamics, observed tensions, group formation, and applied strategy. Involve observers, ask about acting.
Break & Preparation of pressure cooker	15 min	·Prepare pressure cooker (5-10 year time jump). Involve observers.
Session 2 'Pressure cooker' (15min)	15 min	·Players are introduced to changed circumstance and presented with a challenge. Moderator can decide to step out and let actors discuss.
Reflection 2, Theory & Reflection assignment (extend in case of more time)	15 min	·In case of large group, involve students with digital platform of choice. Focus on discussion analysis, changes in the discussion compared to first session, and stakeholder influence on outcomes. If applicable, draw links to innovation and Safe-by-Design theories addressed in earlier lectures, link the outcome to the other assignments of the course (VSD).
<b>After the workshop [Suggested]</b>		
Reflection assignment		·Reflect on theory in relation to the role play experience ·Articulation of (new) insights

## Facilitating the Play

This section describes how to facilitate the play and provides important tips for the form and decisions during the session. It is good practice to lead the group with 2 persons, one to introduce the technology, stakeholders, and to play the moderator, and one to lead the warming up, pressure cooker, intermediate reflection sessions, and to keep track of the time. Make sure to guard the time well, often more can be discussed than time allows for.

### Starting the session

When introducing the session be as clear as possible on the origin of the concept, the outline of the session, and the goals. The introduction and goals can be found at the start of this document and the outline is included under “Timeline of the play”.

Then, briefly **introduce the technology**. This should provide an overarching frame for the students to put the technology description and potentially their role in. This overarching frame can be found under “Context of the play”. Address the following:

- Who works on the technology
- The aims of the project
- Main functional characteristics of the technology
- The reason for the stakeholder meeting
- The aim of the stakeholder meeting

Now, roles have to be assigned to the attendees (if not done before the roleplay). **Assign the roles** based on interest if you have not distributed this beforehand. Try to take into account the (first) impression you have of a person when assigning the roles to align these a little. This makes it easier for the person to play the character. Otherwise let students choose which role they want to play.

After the introduction, give people **time to read** their materials and prepare for their role. Invite actors and observers to read together and discuss a potential strategy of the stakeholder during the discussion, make sure of an even spread of observers among actors. Ask the actors to **think of a name** for their character, write this down on a sheet of paper, and put this in front of them. As a moderator you also think of a name and put this up (see Role description of moderator). Make sure to only refer to the actors by their fictive name during the session.

The **warming up** is next. Depending on the group size this can be done with the complete group, only the actors, or with the group of observers as ‘one’ role. There are several activities you can choose from:

- *Circle of emotions*: Everyone stands in a circle. You request a regular sentence that an attendee has said during the day (“I want coffee” or “What a beautiful morning” or the like). Additionally, you request an emotion. This makes a pair. One person starts by saying the sentence with the accompanying emotion. This is passed on through the circle and with each repetition, the emotion has to be stronger. After completing the round ask for a new sentence-emotion-pair and repeat. Make sure you have had a positive and a negative emotion. If at the end of the second round the emotion can still grow stronger, surprise them by announcing another round of the same prompt, while continuing to enlarge the emotion.
- *Walk around*: In the open space, ask everyone (observers pick a role) to walk as their character in silence. Begin this session by showing examples yourself, it is all about body language. During the session, prompts like “Does this person walk around like they are the top dog or more shy”, “Are they comfortable looking others in the eye”, and “Is this

person intimidating towards others or not? [remember no shoving or pushing, can be laughed at].”

- *1 min introductions*: Ask the actors to introduce themselves to the observers in their group as the character they will be playing.
- *Cheerleading*: Ask the actors and observers to psych each other up in groups (already formed), as if they were in a way too enthusiastic start-up environment. Sentences like “You/we can do this!” and “Go get ‘em!” are well suited. Ask them to do this in a circle of emotions style, several rounds of repeating the sentence each time with more hype. Mention that this can be completely over the top.
- *Clapping*: Go round the circle clapping with eye contact, amp up the game by the possibility of going back with double clap. Pointing a clap to someone skips the circle. You can also try make two claps go around the circle.
- *Cluedo*: Have all but one participant leave the room, the location and murder weapon are told to the first person. One by one come in, location is portrayed without words, just sounds until the person knows and shakes their hand, then the weapon is portrayed, hand is given and then this person acts it out to the next one.

People will be nervous about playing, so make sure to **exert enthusiasm** towards the group from the introduction onwards. In the end, you are also playing a role and enthusiasm is contagious.

After the warming up, request the actors to enter the stage as their character (think of the way they walk, talk or sit), introduce themselves to each other, and make some small talk (the journey, building, lunch, etc.). As a moderator you play along with this. This enables the actors to step into the character role and activate the improvisational aspect of the play.

### Starting the play

When everyone is seated at the table the moderator starts the play with a welcome and short introduction. The following points can guide this introduction

- Name the setting (The Hague, Ministry or City Hall), introduce yourself in character
- Mention who initiated the meeting and the reason for meeting
- Mention the goal of the meeting
- Mention some of the clear tensions present, for example:
  - Open source research vs. research of confidential nature
  - Focus on encryption vs. focus on fundamental research
  - Justification of large investments to the public
- Give the word to the actors at the table
- “I believe not everyone knows each other at the table, so let’s start with a round of introductions, and please elaborate on what you think of the technology”
- [After introductions] As soon as the discussion picks up, leave it to the actors. If this does not happen, ask one stakeholder to elaborate their perspective on the situation.
- [In the second half of the first round] Help the discussion to work towards the intended outcome

### How to design the pressure cooker

During the break, you as a moderator will have to design the prompt for the pressure cooker. The design has to **build forth** on the outcomes and decisions made in the first CTA session. **Imagine** a situation that is five to ten years into the future. Try to centre the design on two considerations:

- Have tensions remained unaddressed that would be interesting to highlight?
- Have stakeholders been in the background, formed strong alliances, or any other consolidated position that should be shaken up?

Involve the observers in this process. Make use of the designed tensions and underlying theoretical concepts described further on in this document. These might help when you have to design a pressure cooker in a limited time span. Make sure to write down the key points of the pressure cooker prompt before starting the second session to increase the clarity of your story. Ensure to create a sense of **urgency** in the pressure cooker.

### Starting the pressure cooker

After the break and designing the pressure cooker, the stakeholders will come back to the table. In the case that 2 actors are assigned to each role, make sure the other person is at the table. As a moderator you can choose to do another brief warming up exercise in character, like meeting the others in a hotel lobby. Make sure to address this in the introduction.

- Start the pressure cooker by introducing the time setting (5 years later) and the reason to convene (often the request of a relevant Minister)
- [When having new actors] Make sure everyone introduces themselves again
- Make sure any papers with information are withdrawn (such as role description) are removed from the table. This will help the actors act more freely.
- An overview of what has happened, the pressure cooker prompt
- An element to create a sense of urgency
- The request for a timely response
- [Depending on how comfortable actors are playing] Moderator leaves upon the prompt of another important meeting or call
- [Three quarters into pressure cooker] Moderator drops in to push for concrete outcomes, can decide to keep moderating

### Intermissions and ending of the session

During the session there are two moments of reflection with the actors and observers on the roleplay and a break, one after the first discussion round and one after the pressure cooker. The moderator, or preferably a well-informed colleague, leads the reflection. During the break, the moderator is responsible for deciding on the prompt for the pressure cooker, together with the observers of the session.

### How to reflect during session

Begin the reflection on what happened between the stakeholders during the play. Allow all people present to contribute to this. When possible, already make a link between underlying theories and observations. Some examples:

- Which tensions or conflicts did you observe during the discussion?
- How were the stakeholder positions distributed (dominant vs weak stakeholder positions, neutral vs engaged)? Who formed alliances, who were opponents?
- [To the actors] Why did you follow this particular strategy to defend your position during the discussion? Are you satisfied with the result of the discussion? How can you feed it back to your peers / colleagues?

Do not start off with the question of how it was to play, while it may be natural to do so. The discussion on the contents of the play will be difficult to start up afterwards. Also, this is a question that can be best left for the second reflection or feedback in a digital survey after the session.

During the **second reflection** round, try to **draw out contrasts with the first session** and reasons why this may have occurred. Especially a reflection on what the group of the first session could have done differently in the first session can be of interest.

## Reflection assignment

The stakeholder roleplay can be combined with a reflection assignment to deepen the experience, e.g.:

- Describe the stakeholder dynamics you observed during the discussion. How did these change during the pressure cooker and why?
- Which Safe-by-Design elements did you observe in the roleplay? How could these elements impact the development of the technology?
- Which aspects could have been taken into account already in the first round of the discussion to overcome challenges and tensions present in the pressure cooker?
- Which conclusions do you draw from the roleplay for developing technologies in general?
- What other underlying theoretical concepts regarding stakeholder discussions are applicable to the roleplay?

## The Play

This section provides an introduction to the play, your own role during the roleplay, an overview of the actors present, and the designed tensions in the discussion.

### Context of the play

The meeting takes place at top floor of the Education, Culture, and Science Ministry in The Hague, in a building nicknamed the “Fountain pen”. China has recently communicated about reaching quantum advantage with a photon-based quantum computer. This is a significant breakthrough in their development of a quantum computer. An operable, fully programmable quantum computer is expected within a decade. This puts high pressure on the European Union to ramp up their research efforts and make progress quickly. Otherwise, the EU is worried that the digital security of member states, and their citizens, will be compromised soon. Now, Minister Vos of Education, Culture, and Science has called a stakeholder meeting to discuss how the Netherlands should respond to this increased pressure. The aim of the meeting is to decide on where to focus investments in the field of quantum technologies, on encryption to secure communications, or on fundamental quantum research and the development of a quantum computer itself. Many questions on how this research should be done remain unanswered.

### Role description of moderator

As a civil servant to the Ministry of Education, Culture, and Science, you work closely with the responsible Minister Vos. They have asked you to chair the stakeholder meeting because of your extensive experience with chairing meetings and stakeholder discussions.

Your aim is to enable all stakeholders present to put forward their perspective in full. In the beginning of the discussion, you love to solely intervene when the discussion comes to a halt. When this happens, you do not shy away from pointing out conflicting opinion or topics that are brushed over and giving this person the word. While each stakeholder obviously has their own stake in specific outcomes, you try to ensure that the discussion satisfies its overall goal towards the end of the discussion.

### Overview of actors

#### Director Ecosystem Development, Quantum Delta NL

*Enactor*

The Director Ecosystem Development of Quantum Delta NL (QDNL) is responsible for establishing a leading quantum research environment in the Netherlands.

The QDNL director wants to develop the Netherlands into a quantum-driven economy involving all relevant stakeholders. To realise this, she vouches for the general accessibility of quantum computing capacity for researchers and entrepreneurs. An open science approach is preferred.

QDNL expects to realise a fully programmable quantum computer in the mid 2030's, Google's expectation is to reach it by 2029, and China's expectation is unknown.

#### Professor in Quantum optics, University of Twente

*Enactor*

The professor is held in high regard and has an excellent track record. In the meeting he is focused on the fundamental research in quantum optics and pushes for additional investments in this field.

The professor holds the position that fundamental research is required to develop truly secure communication. The professor is critical of overly optimistic expectations of progress in quantum computing. Additionally, the professor vouches for an open science approach.

## Director of Internet Freedom 4 All

### *Selector*

The director of Internet Freedom 4 All (IF4A) aims to protect citizen's internet freedom based on the civil right to privacy and on the freedom of communication. Both foreign governments and the national government are scrutinised by the director of IF4A.

A focus of investments on the wide-spread implementation of quantum-proof encryption is preferred by the director of IF4A and the research should be publicly available and collaboratively developed.

## Director of the Netherlands National Communications Security Agency

### *Selector*

The director of the Netherlands National Communications Security Agency (AIVD) is mostly concerned with the protection of state secrets and state communication. On the short-term, this means a focus on quantum-proof encryption, on the long-term, expertise in quantum computing is required.

To limit risks involved in the research, the AIVD vouches for confidential development of the technology and limited access to its outputs.

## Executive Vice President Strategy, Research and Technology at Thales Group

### *Enactor*

The executive vice president strategy of Thales Group is focused on realising strategic business opportunities for Thales Group. Quantum encryption and research is of interest because of its promising economic forecasts.

The VP is very optimistic about the research prospects of quantum and aims to establish private patents on the developed technology. Thales Group holds significant resources to invest in the research activities.

## Designed Tensions

Via the role descriptions of the characters, several tensions are implemented in the roleplay. Use this during the session to bring out topics and controversies that have to be discussed. Additionally, you can use this when designing the pressure cooker to identify tensions that have not been addressed but you would like to see emphasized.

## Research Approach

Research can be conducted in different collaborations and degrees of openness. Several actors, like IF4A and QDNL, wish to research openly and collaboratively based on the idea of using the "knowledge of the crowd". Citizens can be involved and international collaboration with other researchers can be a great benefit to the research progress. Parties like the AIVD and Thales Group vouch for confidential research and development based on safety or economic reasons respectively. In light of safety, the AIVD wishes to keep the researchers national, not international.

## Research Focus

This relates to where investments and research efforts should be geared towards. There is disagreement on whether to invest more to realise a quantum computer or to focus investment now on the safety of encryption.

## Coordinating actor

The research has to be conducted by a specific party. Leading the research efforts has significant gains economically and with regard to status, which is why the interest is high. However, there are consequences to this choice because of the different motives of the actors involved.

## (Future) Use

Who gets to reap the benefit of the quantum research efforts? A future quantum computer harbours great potential, those who have access to it will be at a great advantage, security-wise, power-wise, academically, and/or professionally, compared to others. This establishes tensions.

This introduces the discussion of whether quantum computing technologies should be a public or private good. In case public funds are used, the significant spending on quantum technologies has to be justified to citizens. A sketch for (future) use plays an essential role therein.

## Technological Optimism

Research success cannot be guaranteed. Word goes around that quantum computing is expected to grow exponentially faster than conventional computing (Neven's law). This has implications for the feasibility of fundamental quantum computing research under the existing time pressure, but is disputed by key players, like the Professor. Fundamental hurdles in research seem to be neglected.

## Pressure cooker examples

### Decisiveness lacks

The first meeting lacks decisive action on crucial decisions. Other countries have successfully developed a fully programmable quantum computer. The Netherlands has made progress in research, but does not yet equip of a quantum computer, nor has successfully implemented a quantum-proof encryption. Both national and citizen communications are compromised.

### Encryption

The first meeting places all bets on quantum-proof encryption. In the meantime, other countries develop a fully programmable quantum computer. Quantum-proof encryption turns out to not be resistant against the computing power of quantum computers, and is thus not quantum-proof. Sensitive citizen data has been stolen by a malicious foreign hacker group.

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## Appendix 1: Moderator Cheat Sheet

See next page

# Quantum Moderator Cheat Sheet: Preparation

Duration (1h 45m)	Subject	Setting the scene		Warming up	 <b>Checklist To bring</b>
5 min	Introduction	<p><b>Introduction</b></p> <ul style="list-style-type: none"> <li>• Method origin (TTA)</li> <li>• Outline of today</li> <li>• Goals of the session</li> <li>• The technology</li> <li>• Aim of stakeholder meeting</li> <li>• Introduce roles and impersonate briefly</li> <li>• Distribute roles</li> </ul> <p><b>Goal of Meeting:</b> Decide on the goal and prerequisites put to investment in Quantum</p> <p><b>Stakeholders:</b> <b>QDNL   Professor   IF4A   Secret Service (NBV)   Horizon   Ministry</b></p>	<ul style="list-style-type: none"> <li>• Circle of emotions, sentence + emotion</li> <li>• Silent walk around in character</li> <li>• 1 min introduction as character</li> <li>• Cheerleading, hype each other up</li> <li>• Clapping, pass a clap around the circle</li> </ul>	<ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Moderator Cheat Sheet <b>1x</b></li> <li><input checked="" type="checkbox"/> Technology Description <b>X</b> number of attendees</li> <li><input checked="" type="checkbox"/> Role Descriptions <b>5 or 10</b> (double roles)</li> <li>Observer Instructions</li> <li><input checked="" type="checkbox"/> <b>X</b> number of non-players</li> <li><input checked="" type="checkbox"/> Sturdy sheets of paper <b>6 or 11</b> (double roles)</li> <li><input checked="" type="checkbox"/> Markers for writing the character names</li> <li><input checked="" type="checkbox"/> Watch to keep time</li> </ul>	
10 min	Reading time				
10 min	Warming up				
20 min	Session 1 "CTA"				
15 min	Reflection 1		<p><b>Tips</b></p> <ul style="list-style-type: none"> <li>• Be enthusiastic</li> <li>• Provide implicit assurance by acting</li> <li>• Play your own role</li> <li>• Fun and laughing allowed!</li> </ul>		
15 min	Break and Prep pressure cooker				
15 min	Session 2 "Pressure Cooker"				
15 min	Reflection 2, Theory, & Reflection assignment				

# Quantum Moderator Cheat Sheet: The Play

 <b>Tensions</b> In discussion	<b>Kick off Session 1</b> Bring up in introduction	<b>Pressure cooker design</b>	<b>Duration</b> (1h 45m)	<b>Subject</b>
<p><b>Research approach,</b> Open source, engaging non- or international professionals, vs. confidential national research</p> <p><b>Research focus,</b> Encryption vs. fundamental research (time-pressure)</p> <p><b>Coordinating actor,</b> The stakeholder who will lead the research efforts</p> <p><b>(Future) Use,</b> Desirable use(rs) of quantum technologies</p> <p><b>Technological optimism,</b> Whether it is likely for quantum technologies to deliver on its promise</p>	<p><b>The setting:</b> Ministry of Education - The Hague</p> <p><b>Reason for meeting:</b> Recent breakthroughs in quantum technologies and increased international pressure</p> <p><b>Goal of the meeting:</b> Decide on the goal and prerequisites put to investment in Quantum</p> <p><b>Initial risks:</b> How to respond to international pressure   Safety of internal communications   Paradox of security, stolen now, decrypted later   What group has access and partakes in quantum research</p>	<p><b>Start</b> with the outcome of the first session</p> <p><b>Imagine</b> a situation 5 to 10 years in the future</p> <p><b>Base the scenario</b> on</p> <ul style="list-style-type: none"> <li>Desired changes in stakeholder dynamics</li> <li>Tensions that have remained unaddressed</li> </ul> <p><b>Make it urgent</b></p> <p>Examples:</p> <p><b>Decisiveness lacks,</b> Other countries successfully develop quantum computers, nation-wide communication is compromised</p> <p><b>Encryption</b> efforts insufficient against actual quantum computer, sensitive data leaks</p>	<p>5 min</p> <p>10 min</p> <p>10 min</p> <p>20 min</p> <p>15 min</p> <p>15 min</p> <p>15 min</p> <p>15 min</p>	<p>Introduction</p> <p>Reading time</p> <p>Warming up</p> <p>Session 1 "CTA"</p> <p>Reflection 1</p> <p>Break and Prep pressure cooker</p> <p>Session 2 "Pressure Cooker"</p> <p>Reflection 2, Theory, &amp; Reflection assignment</p>

Monday,  
7 March 2022

# Daily Wire

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Jennifer Robinson

## China Reaches Quantum Advantage

### What now?

Last week, Chinese researchers have publicly presented their latest developments of the quantum computer Jiuzhang 2.0. In this demonstration, Jiuzhang 2.0 and the state-of-the-art supercomputer had to solve a computational challenge specifically designed for this test. The result: the quantum computer reached a conclusion, while the supercomputer did not. The Chinese researchers claim that their photon-based quantum computer Jiuzhang 2.0, which works at room temperature, computed the specific challenge 1 septillion (a thousand, raised to the seventh power) times faster than the supercomputer. In other words, they have demonstrated quantum advantage.

Three years ago, Google and NASA reported the achievement of quantum advantage for the first time, in their case with the superconducting quantum computer Sycamore, operable at very low temperatures. Since then, development of quantum computers has skyrocketed. While Sycamore was equipped with 53 qubits, the photon-based quantum computer Jiuzhang 2.0 reaches 113 qubits. This may remind one of the well-known Moore's law of conventional computing, the doubling of transistor numbers in an integrated circuit every two

years - yet this is not optimistic enough. Based on in-house observations at Google, Neven's law has been proposed as a Moore's law for quantum computers, stating that the computational capacity of quantum computers grows doubly exponentially relative to conventional capacity. This implies a growth by the powers of powers of two (i.e.  $2^2$  (4),  $2^4$  (16),  $2^8$  (256),  $2^{16}$  (65.536), etc.), meaning that quantum computing is expected to grow exponentially faster than conventional computing. For comparison, if this would apply to conventional computing methods, we would have had today's laptops and computers in 1975.

To say that the developments by the Chinese towards a quantum computer is an endpoint, is a mistake. Jiuzhang 2.0 has demonstrated that it can do this specific challenge faster, but this does not extend to any computational challenge. To deliver on its potential and become fully programmable like a conventional computer, quantum computers must be developed further. Yet, considering Neven's law and the fast-paced development of quantum computers in the past three years, useable quantum computers are expected within a decade.

Quantum computers promise to be a gamechanger in scientific research involving highly complex simulations, in the pharmaceutical industry to find compounds used as medicine, for financial modelling to predict market trends or for the

entertainment sector to develop more exciting experiences. Another sector which quantum computers are expected to impact is the communication sector, especially with a focus on secure communication. By applying quantum mechanical principles to data encryption and transmission it will be possible to create high encryption standards to secure digital communication from hackers and eavesdroppers.

*The Chinese quantum computer Jiuzhang 2.0 based on a photonic processor. Chao-Yang Lu, Chinese University of Science and Technology.*



### COLUMN

## The Unfinished Race

The Netherlands is being outrun by China and the US

Anyone with a little foresight could have seen this situation coming, China has outrun Western countries in the race towards quantum computing. This race has started in 1980 and only received considerable investment from the Dutch government when it launched Quantum Delta NL in 2020. Now we can see that this is too little, but maybe it is not too late.

This demonstration of Chinese researchers is impressive and is an important milestone in the race of building a quantum computer. However, this potential computational capacity poses a threat to our communication networks, since our current encryption standards can easily be cracked by such superior computing power. It is only a matter of time until the superior quantum computing power can be utilised for large-scale intervention in networks relying on conventional computing and establishing a communication network of far superior encryption. This is a threat not only to governmental sensitive information, but also will impact the privacy of all citizens.

The European Union has expressed its concern about the sovereignty of member states in the context of the increasing technological capacity of the US and China, rightly so. Investments that have been made earlier are not enough, the Dutch government is faced with the need to respond now. Faced with the same decision, Japan put priority on effective encryption of their communications and independence of other countries by prioritising domestic development of the necessary technology, vastly increasing its commitment once again.

This shows that the race is not yet finished. Now, it is up to the Dutch government and its EU partners to increase investment quickly and ride out this challenging competition in quantum computing and (post-quantum) cryptography or abandon the race and brace themselves for what is to come. I would say: catch up, the potential of this technology and the looming insecurities are too great to not act now. The Dutch government must prove its worth.



*Rosalie Primm, International relations and quantum technology expert*

Alexander Preston

## Quantum-what?

Quantum computers, quantum advantage and post-quantum cryptography spelled out

A quantum computer is a new and powerful computer which can analyse large amounts of data and run detailed simulations - tasks a conventional computer is not capable of. Conventionally, a computer encodes information in bits as '0's or '1's. A quantum computer encodes information in qubits which, based on the principles of quantum theory, can have the states of 0 and 1 at the same time. This is called superposition. Qubits have the property that they cannot be copied, which makes it possible to keep the stored data private.

Quantum advantage describes the scientific goal to demonstrate that a

quantum computer can solve a specific problem a conventional computer cannot solve - regardless of whether the problem is useful or not. Since quantum advantage is mainly an intermediate, scientific goal towards the creation of a powerful quantum computer, the clear application or societal relevance of this research field is not yet clear.

Post-quantum cryptography refers to algorithms used for the encryption of information which cannot be cracked by a quantum computer. Currently, research efforts focus on the development of post-quantum cryptographic standards to improve existing encryption standards and secure today's data against a quantum computer attack decades in the future.

## Time to bundle forces

Minister Vos invites stakeholders to discuss next steps

Mirjam Nilsson

In response to the recent advances in the field of quantum technology and the resulting opportunities and challenges regarding quantum encryption, the minister of Education, Culture and Science, Peter Vos, has invited various stakeholders to discuss next steps. National and international pressure for more funding requires a decision on how to invest in quantum communication technologies. Should we invest in quantum computing to develop quantum encryption standards for secure future communication or should we focus on the safety of our current encryption? "In the Netherlands, we have a vivid quantum environment with great potential. It is time now, that we bundle our forces and resources to increase our competitive capacity and to contribute to an economic, inclusive and societally desirable development of quantum communication technologies.", Vos said. The meeting will be held in The Hague on April 14<sup>th</sup>.

## Appendix 3: Role descriptions

### Director Ecosystem Development, Quantum Delta NL

As part of the executive board of the national program Quantum Delta NL (QDNL) you are responsible to position the Netherlands as a leading ecosystem in quantum technologies. This entails the coordination of all quantum technology initiatives in the Netherlands, setting up innovation hubs, fostering the economic growth in the field of quantum technologies and facilitating technology transfer and start-ups. In 2021, QDNL received a subsidy of €615 million until 2027 to achieve these goals. Programmes of QDNL cover the whole spectrum of quantum technologies, including quantum computing, quantum networks and quantum sensors.<sup>1</sup>

With great interest you have followed the societal and political discussions around the investment in specific quantum technology applications, especially in the communication sector. You believe that quantum computing has the potential to revolutionize our current communication system. You have seen many promising start-ups and **want to develop the Netherlands into a quantum-driven economy involving all relevant stakeholders. Therefore, the general accessibility of quantum computing capacity for researchers and entrepreneurs is an important goal for you.**

You are at this meeting to think along and ensure connection with the existing efforts in the QDNL program. Your facilities support any research and experimental activity in this field which aligns well with the QDNL goal to develop a collaborative national innovation ecosystem.

*Interests:* Real world applications of quantum computing; multi-stakeholder investments.

*Irritated by:* Delayed investments; lack of ambition; Negative International comparison.

*Habits:* Visionary; easily makes promises about technological futures; tends to boast about the Dutch position in quantum.

#### Factsheet

You have created a 1<sup>st</sup> version of Quantum Inspire (QI) - the first European Quantum Computer available in the cloud. The website contains a knowledge base with relevant information on quantum computing and a simulator with enough qubits to solve quantum problems in 5 years.<sup>2</sup>

QDNL website: “If you are looking for the best spot to launch or grow your quantum business, rest assured: the Netherlands offers an excellent ecosystem where your company can flourish. For years, the Netherlands has been the largest receiver of European funding in the field of quantum technology, and now the Dutch national government is providing a solid foundation for structural support in the decades to come, by launching Quantum Delta NL.”<sup>3</sup>

Boston Consulting Group estimates that quantum computing will create a value of 450 - 850 billion euros in the upcoming 15 to 30 years.<sup>4</sup>

Considering the current pace of development and the time needed to educate skilled researchers in this field, you expect to reach a functional quantum computer in the mid 2030's. Google plans to reach it in 2029, the expectancies of China are unknown.

<sup>1</sup> The Dutch Quantum Ecosystem - Birch / University of Utrecht ([Download PDF](#))

<sup>2</sup> [www.quantuminspire.com](http://www.quantuminspire.com)

<sup>3</sup> [Quantum Delta NL - Quantum Delta NL](#)

<sup>4</sup> <https://www.bcg.com/publications/2021/building-quantum-advantage>

## Professor in Quantum optics, University of Twente

As a professor in quantum optics and head of a research group at the University of Twente, you lead a small team of talented and ambitious scientists who are as dedicated and fascinated about the fundamental principles of quantum technology as you are. Together with your team you have made considerable contributions to photonic processors for quantum computing. Your achievements are published in many well-cited journals and are rewarded by numerous prestigious grants. In the field of quantum optics, you are a well-known and respected authority.

Over the last decades, you have applied for grants to finance fundamental research. However, your success of these applications has been decreasing. Currently, the focus lies on application driven research, and **you are searching for opportunities to finance your fundamental research in this application-driven environment - ideally you choose a funding program with a long perspective.** This increases your chances of receiving funding which is crucial to maintain your research group and live up to the expectations of the university. This lack of freedom to pursue fundamental research frustrates you.

You believe that the ongoing developments of photonic processors are a game-changer in quantum communication and computing in the coming 15 years. Together with your international collaborations, especially with research groups in China, you have contributed to this development: parts of the chip used in the Chinese quantum computer featured in the newspaper have been developed in your lab! Although it remains uncertain whether quantum computing will be able to deliver on its potential, you believe that quantum technologies should be pursued for their inherent value to humankind. To use one of your own quotes: “I want to give mankind a tool to realise their imagination. Putting such a tool to good use is a strength of people.” In this sense, you vouch for the installation of an openly accessible cloud-quantum-computing platform. **Regarding safety of our communication, you see this going hand in hand with fundamental research into quantum encryption.** Fundamental research eventually leads to the development of fully functional and stable quantum computers and to post-quantum encryption methods – the best way to protect our communication infrastructure.

*Interests:* Reputation and recognition; (fundamental) science, a quantum computer.

*Irritated by:* Irrationality; procrastination; lack of scientific insight and ambition.

*Habits:* Enthusiastic speaker; can be derogative when others show ignorance; plays with pen or glasses when irritated.

### Factsheet

Quantum computing is based on Qubits. Often, Qubits are created by using electrons, for example in superconductor-based quantum computers. Photonic processors on the other hand use light particles, or photons, instead of electrons to store information. Photons and electrons allow to store information in more ways than the bit. The advantage of using photons lies in the operability of the system at room temperature, whereas electron-based computations must be kept at extremely low temperatures making the system bulky and expensive.

It is important for your career to maintain international collaborations.

Neven's law was coined in 2019 and is overly optimistic. It bases itself on principles of quantum computing, like the exponential increase of information processing when adding a single qubit. However, it overlooks fundamental challenges quantum computing faces. Most importantly the challenge is to establish a multipurpose, programmable quantum computer.

## Director of Internet Freedom 4 All

As director of *Internet Freedom 4 All* (IF4A) you are responsible for the strategy, daily operations, and public outings of the foundation. The goal of your foundation is to protect internet freedom based on the civil right to privacy and on the freedom of communication.

The recent news of quantum breakthroughs in China have concerned you and your organisation. **You are afraid that the privacy and freedom of communication of Dutch citizens may be attacked.** You are especially concerned that governments, national as well as foreign, would use an unsecure communication infrastructure to their advantage at the costs of citizen's privacy. You are strongly against the utilisation of technological superiority for offensive purposes. The governments and citizens of all countries must be protected from malicious infringement on their privacy and communications. **In your opinion, efforts should be focused on implementation of the encryption methods that are already available.** You demand the government to take actions immediately on this topic before it is too late.

Internet Freedom 4 All also advocates to make quantum technologies available to the public via cloud-based platforms and open source patents. **You believe that transparency and open availability of knowledge will trump secretive development because of its ability to use the knowledge of the crowd and move quickly.** This way the technology can be used to solve societal problems and funding is not wasted in fundamental research which is not benefitting society directly.

*Interests:* A safe and reliable communication system; internet safety and freedom for all citizens; having a say in decision making.

*Irritated by:* Plans that disregard the public interest mainly related to privacy and internet freedom; wasting taxpayers' money; being marginalized by powerful actors.

*Habits:* Activist attitude; not afraid to speak up; can be constructive but gets agitated when being marginalized.

### Factsheet

Post-quantum cryptography standards which are fully secure are still under development and are expected around 2024. Until then, hybrid forms of encryptions can be established, based on currently used methods and the existing post-quantum cryptography methods.

Citizen privacy is regularly attacked by secret services. The Dutch Secret service for example collects enormous amounts of data from citizens in order to not miss out on relevant information. However, because the Secret Service does not have the capacity and time to analyse all collected data, the information is stored for a much longer period than regulated by law – at the expense of our privacy!<sup>5</sup>

The unique digital infrastructure in the Netherlands must be secured – the development of secure encryption is a key to maintain a trustworthy and confidential network.<sup>6</sup>

You have prepared a demonstration in front of the Dutch parliament to show your discontent with the outcome of the meeting, in case this is necessary.

<sup>5</sup> [Unfriendly reminder: De geheime diensten stelen nog steeds onze gegevens – Bits of Freedom](#)

<sup>6</sup> [Stimuleer encryptie en koester tegenspraak: ons advies aan de commissie voor Digitale Zaken – Bits of Freedom](#)

## Director of the Netherlands National Communications Security Agency

As director of the Netherlands National Communications Security Agency (NBV), you are part of the Dutch General Intelligence and Security Service (AIVD) and responsible for the protection and management of crucial government information and state secrets. The expertise of your department lies in the technical measures to ensure the best protection of sensitive government information. Your department also ensures the protection of classified NATO and EU information in the Netherlands.

Personally, you live for this work. You hold a key position in the security of the country. You have been part of the Dutch Commando Troops as an information specialist. You consider yourself a very dutiful, disciplined, and competent individual.

The rise of quantum computing is of high significance for your work in securing information. Your current protection standards are well-equipped to hold off targeted attacks by current state-of-the-art (super)computers. However, the computational power of a quantum computer is set to become so large, that your current encryption methods are in no way up for the challenge. This would compromise classified information of the Dutch government, NATO, and the EU, leading towards a national and international security disaster.

**Therefore, it is crucial to catch up with quantum computing research of countries such as China and the US. Establishing a post-quantum cryptography standard is of the utmost importance to secure sensitive data.** On the short term, this can be achieved by developing encryption methods that are difficult for quantum hardware to compute. On the long-term, you believe expertise in quantum computing and a quantum computer are required to maintain the security of government information.

Preferably, you want to get an edge on other countries by developing the technology first to be able to use it to your advantage. Therefore, the confidentiality of technological advances in developing quantum computers and quantum encryption is of utmost importance. **You do not want other countries or mal-intended citizens to get ahead in the development of quantum computers because the information they needed was handed to them.** In the best case, you want to gain insight into the classified information of other non-friendly governments. This would benefit state safety and the protection of the Dutch citizens.

*Interests:* Security of the country; getting an edge on other countries; putting the brightest minds to use for the safety of the country.

*Irritated by:* Lack of discipline; others acting without knowing; neglection of national security; negative stance towards government involvement.

*Habits:* Hard to convince; gets stand-offish when irritated.

### Factsheet

Most problematic is the possibility for mal-intended groups or countries to harvest encrypted data now and decode it later using quantum computing.

Post-quantum encryption is already offered by certain large companies and standardisation efforts are made by the US-based National Institute of Standards and Technologies. Organising a shift towards these systems is a huge undertaking and requires adaptation of currently existing infrastructure but should have a focus now. Post-quantum encryption standards are expected to be established by 2024.

## Executive Vice President Strategy, Research and Technology at Thales Group

As the Executive Vice President of Strategy, Research, and Technology at Thales Group you are responsible for the identification and exploitation of strategic opportunities for Thales. As a Dutch company, Thales is a global leader in private technology research with 80.000 employees spread over every continent in the world with great importance in the field of communications security. Thales facilitates complex, secure communication networks and engineering solutions in ground transportation, aviation, and space.

Your company has started to make sizable investments in quantum computing. At the moment you offer one of the first post-quantum cryptography methods. You have the potential to become an established actor in quantum technologies because of your vast experience in the field of engineering and communications security. **Economic growth is a central value to the justification of your research directions and to the existence of your company.**

You hold the strong belief that quantum technologies must be developed with an application in mind, which should be serving economic growth. Post-quantum cryptography is required to ensure the security of critical and sensitive information in various sectors such as governmental and military data, bank details and medical records. **Your department vouches for developing quantum computing technologies for the purpose of advancing post-quantum cryptography to secure current communication, and to maintain digital sovereignty.** Additionally, you see quantum computing as a great opportunity to enable more complex simulations that are central to the development of your engineering solutions, especially in space.

*Interests:* Stronger market position, short-term opportunities, mid- to long-term profits, advanced encryption and complex simulations to increase economic position.

*Irritated by:* Lack of clarity, indecisiveness, having to pay for other people's hobby horses.

*Habits:* No-nonsense attitude, tough negotiator, visibly annoyed when irritated by others

### Factsheet

Post-quantum cryptography is based on the fundamental computational properties of a quantum computer and is therefore expected to be resistant against quantum computers.

Implementing post-quantum cryptography requires large efforts from all organisations involved. As a leader in the market, you see the opportunity to establish a coalition of large private companies to make a sizeable investment in this transformation, on the prerequisite that you can establish patents on this technology and market it to other parties. Publicly open research results and freely accessible computing power is a thorn in your side. A governmental standard for secure communication enables you to widely disseminate your technology.

Boston Consulting Group estimates that quantum computing will create a value of 450 - 850 billion euros in the upcoming 15 to 30 years.<sup>7</sup>

When a person collects encrypted data at this point in time he/she can likely decipher this data 20 to 30 years from now using a quantum computer. This makes implementation of post-quantum cryptography urgent for data which is still sensitive 20 years from now.

<sup>7</sup> <https://www.bcg.com/publications/2021/building-quantum-advantage>

## Appendix 4: Doubled roles

### Chairman Science and Technology, Quantum Delta NL

As part of the executive board of the national program Quantum Delta NL (QDNL) you are responsible to position the Netherlands as a leading ecosystem in quantum technologies. This entails the coordination of all quantum technology initiatives in the Netherlands, setting up innovation hubs, fostering the economic growth in the field of quantum technologies and facilitating technology transfer and start-ups. In 2021, QDNL received a subsidy of €615 million until 2027 to achieve these goals. Programmes of QDNL cover the whole spectrum of quantum technologies, including quantum computing, quantum networks and quantum sensors.

With great interest you have followed the societal and political discussions around the investment in specific quantum technology applications, especially in the communication sector. You believe that quantum computing has the potential to revolutionize our current communication system. You have seen many promising start-ups and **want to develop the Netherlands into a quantum-driven economy involving all relevant stakeholders. Therefore, the general accessibility of quantum computing capacity for researchers and entrepreneurs is an important goal for you and your network.**

You are at this meeting to think along and ensure connection with the existing efforts in the QDNL program. Your facilities support any research and experimental activity in this field which aligns well with the QDNL goal to develop a collaborative national innovation ecosystem.

*Interests:* Finding real world applications for quantum computing; multi-stakeholder investments.

*Irritated by:* Delayed investments; lack of ambition; Negative International comparison.

*Habits:* Creative thinker; proud on innovative potential within QDNL; tends to boast about the Dutch position in quantum.

#### Factsheet

You have created a 1<sup>st</sup> version of Quantum Inspire (QI) - the first European Quantum Computer available in the cloud. The website contains a knowledge base with relevant information on quantum computing and a simulator with ample qubits to solve quantum problems in 5 years.<sup>8</sup>

QDNL website: “If you are looking for the best spot to launch or grow your quantum business, rest assured: the Netherlands offers an excellent ecosystem where your company can flourish. For years, the Netherlands has been the largest receiver of European funding in the field of quantum technology, and now the Dutch national government is providing a solid foundation for structural support in the decades to come, by launching Quantum Delta NL.”<sup>9</sup>

Boston Consulting Group estimates that quantum computing will create a value of 450 - 850 billion euros in the upcoming 15 to 30 years.<sup>10</sup>

Considering the current pace of development and the time needed to educate skilled researchers in this field, you expect to reach a functional quantum computer in the mid 2030's. Google plans to reach it in 2029, the expectancies of China are unknown.

<sup>8</sup> [www.quantuminspire.com](http://www.quantuminspire.com)

<sup>9</sup> [Quantum Delta NL - Quantum Delta NL](#)

<sup>10</sup> <https://www.bcg.com/publications/2021/building-quantum-advantage>

## Associate Professor in Quantum Information, University of Twente

As an associate professor in quantum optics and part of a research group at the University of Twente, you lead a small team of talented and ambitious scientists who are as dedicated and fascinated about the fundamental principles of quantum technology as you are. Together with your team you have made considerable contributions to photonic processors for quantum computing. Your achievements are published in various well-cited journals and are rewarded by prestigious grants. You have a large international network in the quantum optics community.

Over the last decades, you have applied for grants to finance fundamental research. However, your success of these applications has been decreasing. Currently, the focus lies on application driven research, and **you are searching for opportunities to finance your fundamental research in this application-driven environment - ideally you choose a funding program with a long perspective.** This increases your chances of receiving funding which is crucial to maintain your reputation and increase your chances towards a full professorship position at the university. This lack of freedom to pursue fundamental research frustrates you.

You believe that the ongoing developments of photonic processors are a game-changer in quantum communication and computing in the coming 15 years. Together with your international collaborations, especially with research groups in China, you have contributed to this development: parts of the chip used in the Chinese quantum computer featured in the newspaper have been developed in your lab! Although it remains uncertain whether quantum computing will be able to deliver on its potential, you believe that quantum technologies should be pursued for their inherent value to humankind. In this sense, you vouch for the installation of an openly accessible cloud-quantum-computing platform. **Regarding safety of our communication, you see this going hand in hand with fundamental research into quantum encryption.** Fundamental research eventually leads to the development of fully functional and stable quantum computers and to post-quantum encryption methods – the best way to protect our communication infrastructure.

*Interests:* Reputation and recognition; (fundamental) science, a quantum computer.

*Irritated by:* Irrationality; procrastination; lack of scientific insight and ambition.

*Habits:* Gets excited when talking about science; annoyed by other's ignorance; plays with pen when irritated.

### Factsheet

Quantum computing is based on Qubits. Often, Qubits are created by using electrons, for example in superconductor-based quantum computers. Photonic processors on the other hand use light particles, or photons, instead of electrons to store information. Photons and electrons allow to store information in more ways than the bit. The advantage of using photons lies in the operability of the system at room temperature, whereas electron-based computations must be kept at extremely low temperatures making the system bulky and expensive.

It is important for your career to maintain international collaborations.

Neven's law was coined in 2019 and is overly optimistic. It bases itself on principles of quantum computing, like the exponential increase of information processing when adding a single qubit. However, it overlooks fundamental challenges quantum computing faces. Most importantly the challenge is to establish a multipurpose, programmable quantum computer.

## Policy advisor of Internet Freedom 4 All

As policy advisor of *Internet Freedom 4 All* (IF4A) you are mainly concerned about the power relationship between the state and the citizens. The goal of your foundation is to protect internet freedom based on the civil right to privacy and on the freedom of communication.

The recent news of quantum breakthroughs in China have concerned you and your organisation. **You are afraid that the privacy and freedom of communication of Dutch citizens may be attacked.** You are especially concerned that governments, national as well as foreign, would use an unsecure communication infrastructure to their advantage at the costs of citizen's privacy. You are strongly against the utilisation of technological superiority for offensive purposes. The governments and citizens of all countries must be protected from malicious infringement on their privacy and communications. **In your opinion, efforts should be focused on implementation of the encryption methods that are already available.** You demand the government to take actions immediately on this topic before it is too late.

Internet Freedom 4 All also advocates to make quantum technologies available to the public via cloud-based platforms and open source patents. **You believe that transparency and open availability of knowledge will trump secretive development because of its ability to use the knowledge of the crowd and move quickly.** This way the technology can be used to solve societal problems and funding is not wasted in fundamental research which is not benefitting society directly.

*Interests:* A safe and reliable communication system; internet safety and freedom for all citizens; having a say in decision making.

*Irritated by:* Plans that disregard the public interest mainly related to privacy and internet freedom; wasting taxpayers' money; being marginalized by powerful actors.

*Habits:* Activist attitude; engaged when it comes to citizen rights; can be constructive but gets agitated when being marginalized.

### Factsheet

Post-quantum cryptography standards which are fully secure are still under development and are expected around 2024. Until then, hybrid forms of encryptions can be established, based on currently used methods and the existing post-quantum cryptography methods.

Citizen privacy is regularly attacked by secret services. The Dutch Secret service for example collects enormous amounts of data from citizens in order to not miss out on relevant information. However, because the Secret Service does not have the capacity and time to analyse all collected data, the information is stored for a much longer period than regulated by law – at the expense of our privacy!<sup>11</sup>

The unique digital infrastructure in the Netherlands must be secured – the development of secure encryption is a key to maintain a trustworthy and confidential network.<sup>12</sup>

You have prepared a demonstration in front of the Dutch parliament to show your discontent with the outcome of the meeting, in case this is necessary.

<sup>11</sup> [Unfriendly reminder: De geheime diensten stelen nog steeds onze gegevens – Bits of Freedom](#)

<sup>12</sup> [Stimuleer encryptie en koester tegenspraak: ons advies aan de commissie voor Digitale Zaken – Bits of Freedom](#)

## Executive director of the Netherlands National Communications Security Agency

As executive director of the Netherlands National Communications Security Agency (NBV), you are part of the Dutch General Intelligence and Security Service (AIVD) and responsible for the protection and management of crucial government information and state secrets. The expertise of your department lies in the technical measures to ensure the best protection of sensitive government information. Your department also ensures the protection of classified NATO and EU information in the Netherlands.

Personally, you live for this work. You hold a key position in the security of the country. You have been part of the Dutch Commando Troops as an information specialist. You consider yourself a very dutiful, disciplined, and competent individual.

The rise of quantum computing is of high significance for your work in securing information. Your current protection standards are well-equipped to hold off targeted attacks by current state-of-the-art (super)computers. However, the computational power of a quantum computer is set to become so large, that your current encryption methods are in no way up for the challenge. This would compromise classified information of the Dutch government, NATO, and the EU, leading towards a national and international security disaster.

**Therefore, it is crucial to catch up with quantum computing research of countries such as China and the US. Establishing a post-quantum cryptography standard is of the utmost importance to secure sensitive data.** On the short term, this can be achieved by developing encryption methods that are difficult for quantum hardware to compute. On the long-term, you believe expertise in quantum computing and a quantum computer are required to maintain the security of government information.

Preferably, you want to get an edge on other countries by developing the technology first to be able to use it to your advantage. Therefore, the confidentiality of technological advances in developing quantum computers and quantum encryption is of utmost importance. **You do not want other countries or mal-intended citizens to get ahead in the development of quantum computers because the information they needed was handed to them.** In the best case, you want to gain insight into the classified information of other non-friendly governments. This would benefit state safety and the protection of the Dutch citizens.

*Interests:* Security of the country; getting an edge on other countries; putting the brightest minds to use for the safety of the country.

*Irritated by:* Lack of discipline; others acting without knowing; neglection of national security; negative stance towards government involvement.

*Habits:* Stubborn; gets unfriendly when irritated.

### Factsheet

Most problematic is the possibility for mal-intended groups or countries to harvest encrypted data now and decode it later using quantum computing. This is something we have to anticipate and prepare for.

Post-quantum encryption is already offered by certain large companies and standardisation efforts are made by the US-based National Institute of Standards and Technologies. Organising a shift towards these systems is a huge undertaking and requires adaptation of currently existing infrastructure but should have a focus now. Post-quantum encryption standards are expected to be established by 2024.

## Executive Vice President Secure Communications & Information Systems at Thales Group

As the Executive Vice President of Secure Communications & Information Systems at Thales Group you are responsible for the identification and exploitation of strategic opportunities for Thales. As a Dutch company, Thales is a global leader in private technology research with 80.000 employees spread over every continent in the world with great importance in the field of communications security. Thales facilitates complex, secure communication networks and engineering solutions in ground transportation, aviation, and space.

Your company has started to make sizable investments in quantum computing. At the moment you offer one of the first post-quantum cryptography methods. You have the potential to become an established actor in quantum technologies because of your vast experience in the field of engineering and communications security. **Economic growth is a central value to the justification of your research directions and to the existence of your company.**

You hold the strong belief that quantum technologies must be developed with an application in mind, which should be serving economic growth. Post-quantum cryptography is required to ensure the security of critical and sensitive information in various sectors such as governmental and military data, bank details and medical records. **Your department vouches for developing quantum computing technologies for the purpose of advancing post-quantum cryptography to secure current communication, and to maintain digital sovereignty.** Additionally, you see quantum computing as a great opportunity to enable more complex simulations that are central to the development of your engineering solutions, especially in space.

*Interests:* Stronger market position, short-term opportunities, mid- to long-term profits, advanced encryption and complex simulations to increase economic position.

*Irritated by:* Lack of clarity, indecisiveness, having to pay for other people's hobby horses.

*Habits:* business-like appearance, tough negotiator, tips his nose when irritated by others

### Factsheet

Post-quantum cryptography is based on the fundamental computational properties of a quantum computer and is therefore expected to be resistant against quantum computers.

Implementing post-quantum cryptography requires large efforts from all organisations involved. As a leader in the market, you see the opportunity to establish a coalition of large private companies to make a sizeable investment in this transformation, on the prerequisite that you can establish patents on this technology and market it to other parties. Publicly open research results and freely accessible computing power is a thorn in your side. A governmental standard for secure communication enables you to widely disseminate your technology.

Boston Consulting Group estimates that quantum computing will create a value of 450 - 850 billion euros in the upcoming 15 to 30 years.<sup>13</sup>

When a person collects encrypted data at this point in time he/she can likely decipher this data 20 to 30 years from now using a quantum computer. This makes implementation of post-quantum cryptography urgent for data which is still sensitive 20 years from now.

<sup>13</sup> <https://www.bcg.com/publications/2021/building-quantum-advantage>

## Appendix 5: Observer description

Your task is to carefully observe the discussion, identify the dynamics and conflicts between the different stakeholders, and find important tensions relevant for the development of the technology. You can take notes during the discussion of interesting behavior you see. The following questions might help you during your observation:

- Which stakeholder is dominant in the discussion and who is rather weak?
- Which conflicts and tensions come up during the discussion? How do the stakeholders react upon these issues?
- Who formed alliances? Who oppose each other?
- Which tensions, concerns or risks of the technology become visible during the discussion? How do the stakeholders react to this?

After the first discussion round we move to the ‘pressure cooker’ – a scene in the future in which the same stakeholders need to discuss action points for the technology. To help design this focus on these questions:

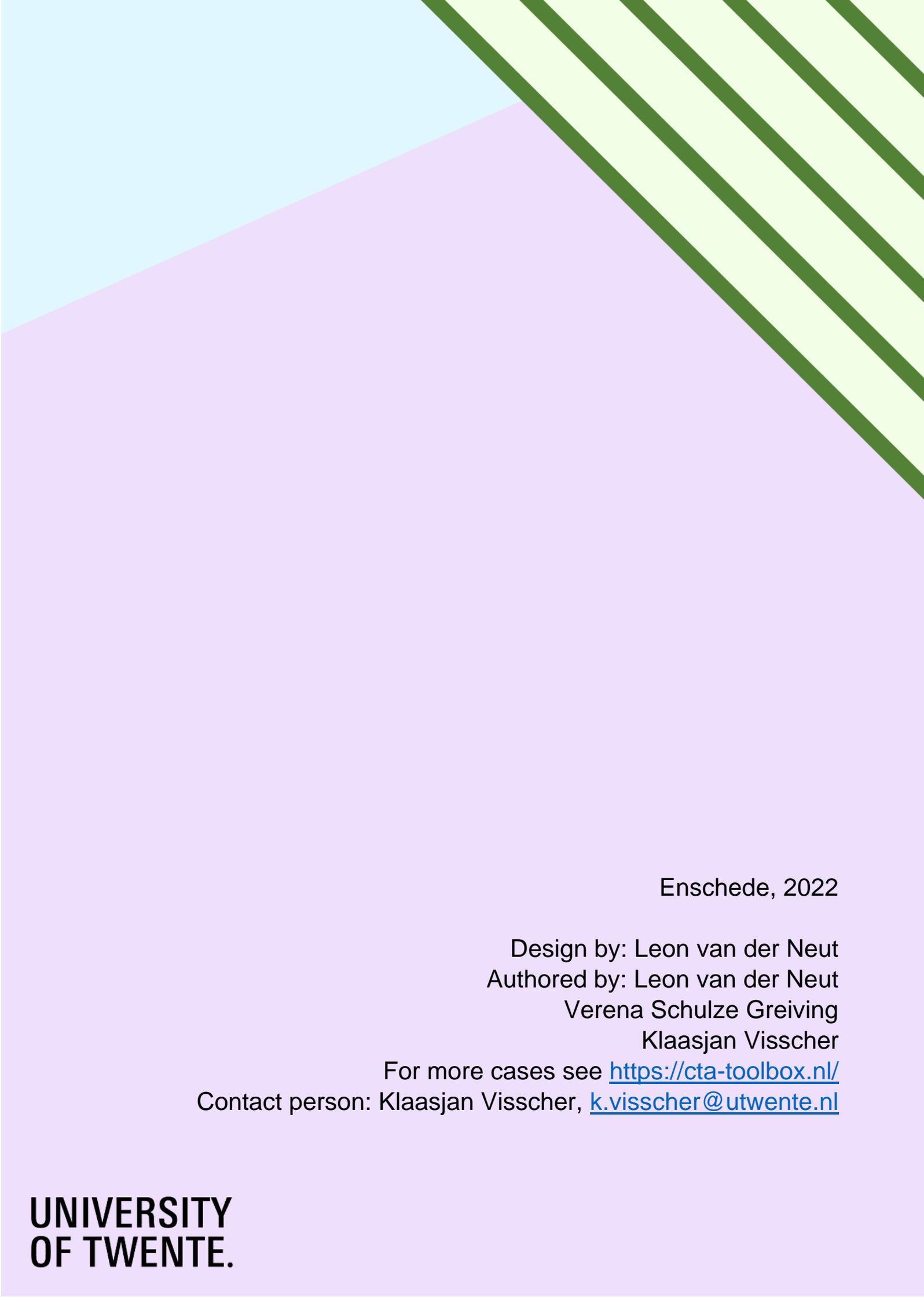
- From the earlier discussion, which points would be interesting to follow up on?
- Where do you see tensions in the future?
- Which event could be a gamechanger for the technology or for the stakeholders involved?

During the second discussion round you focus on these questions:

- What does the outcome of the discussion mean for the development of the technology?
- Which design adaptations could be made in the technology / implementation in order to prevent some of the discussed problems?
- How do the proceedings of the first session affect the current discussion?







Enschede, 2022

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