NSTF
National Science & Technology Forum

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Quantum science and technology

An NSTF Discussion Forum

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Concept document

In recognition of the International Year of Quantum Science and Technology (IQY2025), the National Science and Technology Forum (NSTF) adopted its organisational theme for 2025 as 'Quantum science and technology'.

Background:

Quantum science is a field that's been around for more than 100 years. It led to major inventions like lasers, used in everything from manufacturing to communication and transistors, which are the building blocks of the computers and electronics we use every day.

In recent years, new discoveries in a part of quantum science called **quantum entanglement** have sparked what's being called the **"second quantum revolution."** This breakthrough was so important it earned Alain Aspect, John Clauser and Anton Zeilinger the 2022 Nobel Prize in Physics, exactly 100 years after Niels Bohr was awarded his Nobel Prize for his work on the atomic structure and quantum theory. These new developments could lead to powerful new technologies that affect many areas of life. They could help us tackle big global challenges like climate change, energy shortages, food security, healthcare, and access to clean water, issues highlighted in the United Nations (UN) Sustainable Development Goals (SDGs).

In the coming decades, we could see big improvements in things like:

- Medical scans and imaging
- Better batteries and solar panels for clean energy
- Ultra-secure communication systems
- Super-fast quantum computers to solve complex problems like climate modeling

Additionally, quantum technology is built on the unique principles of quantum science, enabling the development of tools and machines that go beyond the capabilities of conventional technology. Breakthroughs driving the second quantum revolution are now making exciting new technologies possible, such as:

- **Quantum computers** – super-powerful computers that can solve certain problems much faster than today's computers.
- **Quantum communication** – a new way to send information that is extremely secure.
- **Quantum sensors and measurement tools** – devices that can measure things with incredible accuracy, helping in areas like medicine, navigation, and tracking environmental changes.

Themes:

1. Quantum biosensing: Quantum biosensors (QB) are a new type of medical tool that combines physics and biology to improve how we detect and monitor diseases. They use powerful effects from quantum science to make medical tests faster, more accurate, and more sensitive than traditional methods. These sensors work by linking biological elements like DNA, proteins, or enzymes with quantum devices. When these sensors encounter certain molecules in a sample (like blood or saliva), they produce small changes in light that can be measured. This helps doctors detect early signs of diseases like Alzheimer's or cancer. Quantum biosensors can also track how patients respond to treatments in real time, giving doctors more information to personalise their care. However, there are still challenges, including making the sensors stable and reliable, and understanding the complex quantum effects involved. It's also not yet easy to fit them into existing medical systems. Quantum biosensors are still developing, but they hold great promise to change the future of medical diagnostics, as well as environmental monitoring.
2. Application and commercialisation of quantum technologies: Modern computers are extremely fast at arithmetic, but they struggle with combinatorics problems, tasks that involve calculating all possible combinations of items. These problems grow too complex too quickly, limiting what classical computers can solve. Quantum computers are being developed to handle these challenges. Though still in the early stages, they offer new ways to solve problems in areas like:
    - Cybersecurity
    - Drug and materials development
    - Finance
    - Manufacturing

    Even now, quantum-inspired algorithms are improving how classical computers solve complex problems. Quantum computers may help simulate complex molecules, which could speed up discoveries in medicine and materials. While we don't yet know which technology will dominate, quantum computing is already driving innovation and opening new possibilities.

3. Quantum dots: A quantum dot is an extremely tiny crystal—just a few nanometers wide—made from a semiconductor material. Because it's so small, the electrons inside are trapped in place and can only have specific, fixed energy levels, much like electrons in individual atoms. That's why quantum dots are often called "artificial atoms."

When energy is added to a quantum dot, an electron inside it moves to a higher energy level. As it drops back down, it releases light of a specific colour, depending on the dot's size and material. This controlled light emission makes quantum dots useful for technologies like displays, solar cells, and medical imaging.

4. Quantum Computing: Quantum computing is a new area of computer science that uses the principles of quantum mechanics to solve problems too complex or time-consuming for today's most powerful computers. It involves developing both quantum hardware and quantum algorithms. By exploiting quantum effects, future quantum computers could perform certain calculations millions of times faster than classical computers—solving in minutes problems that might otherwise take thousands of years.

   In short, quantum computing harnesses the strange behaviour of particles at the quantum level to unlock entirely new ways of processing information.
5. Cybersecurity in the quantum era: The rise of quantum computing marks a major shift in cybersecurity and infrastructure protection. Its immense computing power threatens traditional encryption methods like RSA, Diffie-Hellman, and elliptic curve cryptography (ECC), the foundations of today's data security.

6. As quantum computers advance, they could break current encryption, allowing attackers to intercept data, steal passwords or money, forge digital identities, and access sensitive systems. This poses risks not only to individuals and organisations but also to national security. To prepare, the world must transition to quantum-safe cryptography, which resists attacks from quantum computers. However, even after adopting these new methods, systems may still face other types of cyber threats not based on encryption breaking.

Objectives:

This discussion forum has these objectives, among others:

- Raise awareness of quantum science and technology and its potential societal impact
- Explore the promise of the second quantum revolution
- Showcase SA's quantum technology progress
- Facilitate collaboration among stakeholders
- Identify skills development and workforce needs
- Explore how quantum science and technology could contribute towards the attainment of the UN SDGs

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