Government
Office for Science

FUTURE COMPUTING

CONTEXT

Computers underpin all modern economies, the internet, and a huge range of goods and services. For over 60 years computing power has roughly doubled every two years, as transistor density has increased in accordance with Moore's Law. However, evidence suggests we are reaching fundamental physical limits, with effects like quantum tunnelling impacting performance.

TECHNOLOGY

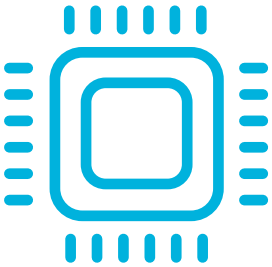
To meet ever-increasing performance demands, scientists and engineers are innovating chip design, software, and exploring new materials. Wholly new forms of computing such as quantum and neuromorphic offer potentially substantial performance and efficiency gains, or solutions to currently intractable problems.

FUTURE THINKING

New computing paradigms are unlikely to wholly replace classical computing, but will likely be increasingly integrated into hybrid systems to augment performance in specific applications. For example, optical components can improve communication speed between chips, while neuromorphic chips can enable efficient processing of analogue signals.

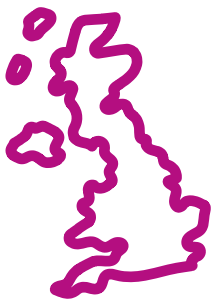
UK POSITION

The UK produces highly impactful research in a range of computing technologies, but performs less well in the latter stages of research and innovation, such as intellectual property, private investment, and exports.



£13-17BN
revenue expected by 2030 for the UK semiconductor market.

Source: DSIT Semiconductor Sector Study



1ST
The UK ranks 1st globally for research impact.

Source: Dimensions

KEY DRIVERS

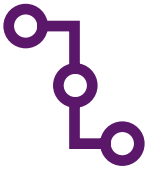
Sustainability

Big Data

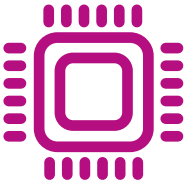
New Frontiers

Artificial Intelligence (AI)

Performance Bottlenecks



Supply Chains



Industrial Competition

Optical

Advantages: Faster communication speed, energy efficiency.

Applications: AI inference, rapid communication between chips, servers and data centres.

Challenges: Lack of access to alternative materials, inefficiency in optical-electrical conversion.

Optical components may increase neuromorphic speed and efficiency.

Neuromorphic

Advantages: Low power, colocalization of memory and processing, highly scalable.

Applications: Large scale AI computing, edge AI and sensing, autonomous vehicles, robotics.

Challenges: Complex software requirements, loss of talents to other domains, coordination of multidisciplinary expertise.

Photonic components are key to quantum computing.

Classical

Hybrid Systems

Computing

Neuromorphic computing may enable computer interfaces.

Quantum

Advantages: Fast processing, simultaneous multi-input computation.

Applications: Drug and materials discovery, advanced modelling, logistics optimisation, cryptography and encryption.

Challenges: Error prone, scaling increases error rates, expensive to manufacture and operate.

Biological

Advantages: Low power, low training data requirements, simultaneous computation.

Applications: AI training, neurotechnology, neurological research, DNA data storage.

Challenges: Limited understanding of use cases.

OPPORTUNITIES

- **Continued performance gains:** Innovations in classical computing and new computing paradigms promise continued performance gains to meet the ever increasing demand for computing power and efficiency.
- **Sustainable deployment of AI:** Paradigms such as neuromorphic and optical computing could offer large efficiency improvements. These technologies could help enable AI in edge devices and make data centres more sustainable to help meet Net Zero targets.
- **Breaking barriers:** Quantum computing offers the potential to solve problems which are not practical for classical computing, for example rapid simulation of molecule interactions for drug and material discovery.
- **Strong UK Research Base:** The UK has a strong R&D ecosystem that produces very high-impact and influential research, ranking 1st for field citation ratio in quantum, optical and biological computing, and 2nd for neuromorphic computing.

CHALLENGES

- **Technical challenges:** New paradigms require new software to maximise their benefits and, without the algorithms to support them, otherwise promising hardware may fail. Interoperability is a key challenge to overcome to make sure new and current technologies can work together.
- **An Established Market:** The global compute market is large, and several stages of the supply chain are dominated by a small number of players with substantial market share. New technologies must present clear advantages for industry to adapt costly manufacturing processes and change complex supply chains.
- **International Competition:** The US and China are clear global leaders and increasingly competing with both economic benefit and national security in mind. This has prompted countries to onshore production and diversify supply chains to mitigate against risks.
- **Securing UK Benefit:** The UK performs less well in patenting and commercialisation of new computing technologies compared to leading countries. Experts highlighted limited manufacturing infrastructure and difficulties in retaining UK intellectual property and talent, making it difficult for the UK to compete.

Please share your views.
Email us at **emtech@go-science.gov.uk**