Innovation briefing

Future of computing

The new commercial horizon

From prosthetics control to hyperscale datacentres, from DNA storage to supply chain optimisation… discover just some of the coming use cases that will change industry forever

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CC in three your key notes to take away

1. Novel computing technologies will ultimately make the seemingly impossible possible – achieving step changes in performance, cost and power consumption along the way.

2. Future technologies will serve specific applications and classical computing will not be replaced. Instead, a hybrid future will emerge, blending novel silicon architectures and neuromorphic, photonic, biological and quantum computing.

3. If you identify the capabilities that match your business goals, you'll be able to unlock huge value by exploiting the new technology's benefits for your organisation – in terms of both their technical performance and business value.

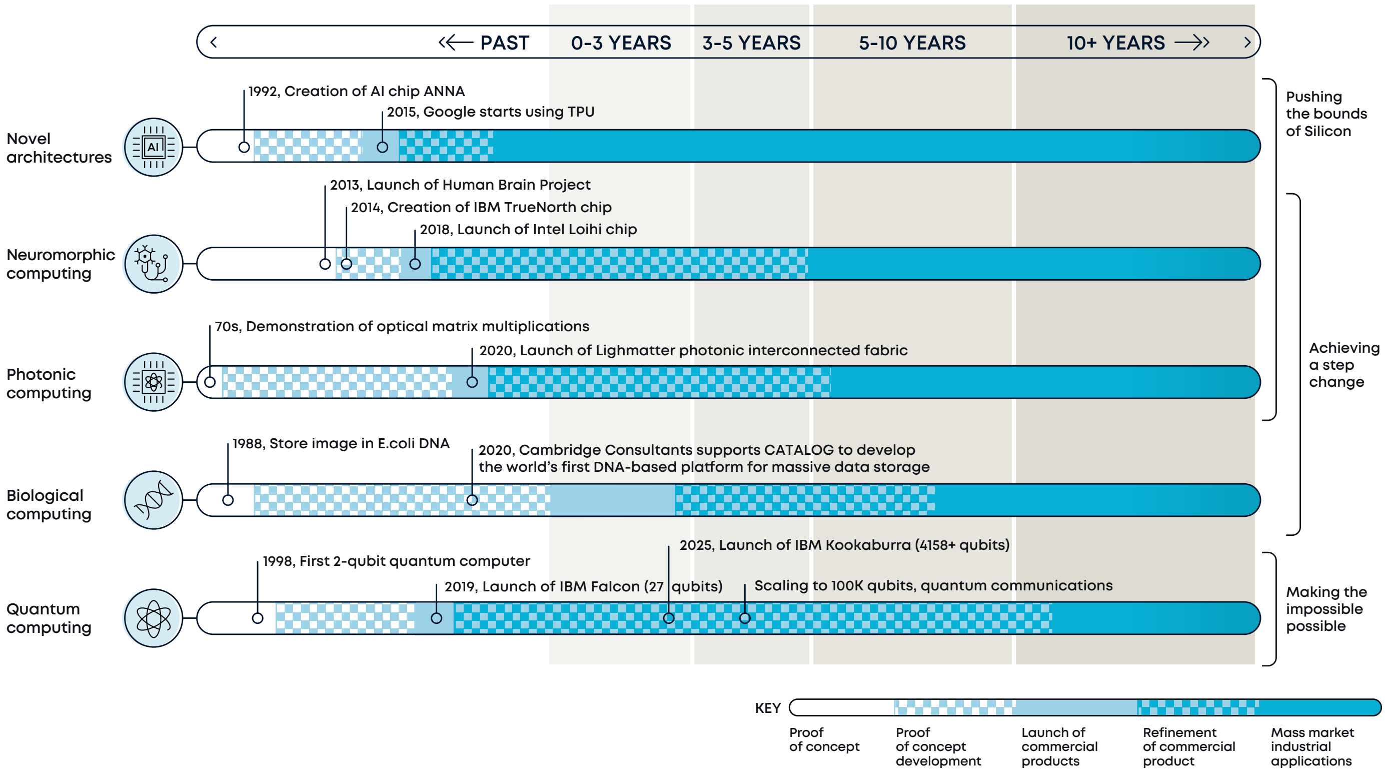
Introduction

Computing has changed the story of all of our lives, but humanity is poised to begin a new chapter. Silicon is being stretched to its limits. Many computational problems remain intractable. And the sustainability imperative is changing everything. The future of computing is near – and now is the time to get to grips with it. In this Innovation Briefing, our multidisciplinary team unpacks the technologies, evaluates potential use cases, and throws light on the new commercial horizon.

What does the future of computing mean for you?

A good question, and we certainly don't have a glib answer. But what we plan to do here is put the potential of the emerging opportunities into perspective to help you and your organisation prepare for change. We believe that timing is everything – and you may have already explored on our Future of Computing webpage, the timeline (reproduced below) that scans future horizons. It's been prepared by experts in these technologies and is founded on CC's decades of experience developing world-first computing technologies for our clients.

Timeline for computing types



Our innovation projection spans silicon boundary pushing, step changes in performance and the prospect of making the seemingly impossible possible. It's no wonder then, that organisations are keen to embrace future computing technologies. Goldman Sachs, for instance, has been busy exploring quantum computing[1]. But for many organisations, the plethora of technologies and the uncertainty about their maturity makes the decision to invest much less clearcut. Many are still evolving and could have a large price tag, so present risk in terms of future return. So where to start?

It's important to realise that most, if not all, of these technologies are being developed for a specific application or capability; that is, to overcome a particular limitation of existing CPU silicon chips. The objective is not a wholesale replacement of classical compute. It is common today for specialty chips, say for AI acceleration, to be combined with CPU, and we expect a similar hybrid approach even for the most exotic of the future technologies, like quantum computers.

Viewing future computing technologies as a means to achieve better capabilities helps get to grips with the plethora of choices. By identifying the capabilities that you will need to reach your goals and aspirations, it is possible to evaluate the fit of new technologies to your organisation, both in terms of their technical performance and their business value.

What new use cases will be enabled?

Novel silicon architectures for cycling training

It is crucial for professional cyclists to maintain a healthy level of physical effort during training. To do so, they are equipped with sensors to individually monitor different biological variables and receive feedback from a wearable device. But physical effort can't be measured just by assuring that all the variables are within their predefined range. They need a deeper analysis and correlation, done by AI algorithms, to provide accurate, precise and real-time information.

Currently, AI algorithms are run in general processors which are neither fast nor small enough for this type of application. Simply increasing the processing speed of current wearables would require incorporating more processing hardware into the device, making them larger and heavier. Further, the use of AI for this analysis requires data to be sent to external devices, which increases latency and prevents cyclists from receiving feedback in real-time.

Novel silicon architectures have supported the development of novel processors especially designed to support AI computing, known as AI accelerators. They are small and light enough to be integrated in a wearable device and consume less energy than general processors, making them economically competitive in the wearable devices market.

Novel silicon architectures can deliver powerful insights to professional cyclists during races by monitoring a combined set of signals measured. This real-time information, potentially combined with previous information like sleep patterns and past training performances, will allow them to adjust their physical effort during training, identify the best time to take a break or drink. A notification could be sent to the trainer or the closest hospital under special or extreme circumstances.

Neuromorphic computing for myoelectric prosthetics control

We all tend to gradually lose mobility as we age, leaving us increasingly dependent on others to help with physical tasks. Myoelectric prosthetics can provide an alternative by assisting people with reduced mobility while allowing them to retain their autonomy. Currently, myoelectric prosthetics are based on the ability to sense and process muscle spikes. Electromyography (EMG), a neurophysiological technique for recording muscle movements, is used. Although wearable solutions exist, some inefficiencies must be improved for an enhanced user experience, such as increasing the granularity of movement classification or reducing computational resources to decrease energy consumption.

Neuromorphic computing can solve more complex AI problems faster due its parallel processing capabilities using spike neural networks (SNNs). Muscles are naturally activated through spikes that could be directly processed through neuromorphic computing. This would decrease the processing time and the latency from sensing to action, making this technology ideal for real-time performances and enhancing the user's experience.

Neuromorphic computing's small size and low energy requirements make wearable devices an excellent application to enlarge an autonomous life. When connected to an external robotic device, such systems could mimic physical movements and help humans with their daily routines. Different external devices could be used for various purposes, such us getting out of bed, cooking or moving things around.

Photonic computing for hyperscale data centres

Standard microelectronic components can't satisfy the computational requirements of growing data traffic. In data centres across the world today, the majority of computing is done using traditional electronic components within servers. But in an effort to reduce computational latency and handle growing data traffic, data is sent between servers using optical technology. Optoelectronic devices convert the information stored digitally within servers into light. These light-based system-to-system connections leverage the benefits of optical data transfer but are currently only economically viable over large distances due to the relatively large size and weight of optoelectronic converters. If data capacity increases, individual pluggable photonic transceivers with separate microelectronic switches will not work.

Photonic computing will significantly reduce latency, increase efficiency, and deliver higher bandwidth. According to the International Energy Administration (IEA), data centres account for 1.4% of global energy consumption, following an increase of up to 60% over the last six years[2]. While the current state-of-the-art data transfer speed in data centres is approximately 100 Gb/s, industry is looking to deploy 400 Gb/s to handle fast growing data traffic. This growth is driving the need for high-speed connectivity between servers and switches themselves. Large industry players, such as Intel, are betting on photonic-based data centre interconnects (DCI) to help make this transition, given the numerous benefits they offer. These photonic interconnects offer a theoretical minimum latency – since nothing can exceed the speed of light – so could provide 10 times the energy efficiency and 50 times bandwidth improvement over standard electronic DCIs[3].

In the longer term, global data traffic is increasing exponentially to enable a vast number of internet applications for consumers and businesses alike, so new forms of data centres must emerge. Hyperscale data centres (HDC) are massive business-critical facilities that contain thousands of servers and handle massive volumes of data to satisfy the networking needs of tech giants such as Google, Amazon, and Microsoft. Furthermore, hyperscale computing refers to an architecture that expands and contracts based on the current needs of the business – this makes HDC exceptionally agile and efficient.

Market leaders in this industry expect silicon nanophotonics to play a large role in delivering the much needed capacity for technology giants. In fact, the global silicon photonics optical receiver market is projected to grow rapidly from $455m in 2018 to a staggering $4bn in 2024. Instead of microelectronic receivers used today, small photonic chips ('chiplets' or 'photonic engines') will be placed next to the electrical networking chip to integrate photonics and electronics in a single multichip package, according to Intel.

Biological computing for DNA storage

Current information storage technologies have serious flaws that must be addressed. Traditional methods have enabled the revolutionary automation and digitisation inventions of the 20th century. But the world is currently dealing with the three main limitations they present: a relatively high volume, inevitable decay, and unsustainable reliance on certain materials. These drawbacks, paired with the exponential increase in global digital data production, are driving the development of novel data storage technologies.

Using biological computing to store data in DNA material would overcome these limitations. Much research has been conducted in storing information in specific orders of the four bases (adenine, cytosine, guanine, thymine) that make up DNA material in living organisms. Through DNA synthesis, DNA sequencing and encoding and decoding algorithms, information can be represented in DNA with remarkable stability, extreme durability to harsh conditions and environmental sustainability. It is also at a much higher density when compared to conventional systems.

In the long term, encoding and storing information in biological cells could bring forward far more sustainable and reliable computing. As the cost of DNA synthesis is restricting the commercialisation of DNA storage, current applications have focused on 'cold' archival data storage, i.e., for inactive data. In particular, CATALOG developed a DNA storage machine in partnership with Cambridge Consultants. The 'terabit machine' achieved a landmark moment when it encoded the whole of the English-language Wikipedia into DNA, demonstrating success in terms of speed, scale and accuracy.

Looking ahead, many research labs such as IARPA (through the MIST programme) will foster the development of new technologies that support DNA data storage. For example, operating software that is purpose-built to use data stored as DNA, and random access retrieval methods that scan DNA sequences will emerge as the field of synthetic biology expands.

Future applications could include devices that use information encapsulated in DNA molecules to authenticate and verify items along supply chains as they can withstand high temperatures and dangerous chemicals. Another use case could be the storing of electronic health records inside implants, leveraging the massive savings in information density and biocompatibility of DNA storage.

Quantum computing for supply chain routes optimisation

Supply chains are complex interconnected and interdependent systems that have to deal with very large amounts of information to be able to deliver goods when and where they are needed. To fulfil a delivery, there can be millions of discrete decisions that need to be made just in terms of transportation – and that is just accounting for a single delivery.

The reality is even more complex when managing a fleet of ships, trucks or last mile vans, especially when unforeseen events occur, such as weather and traffic disruptions. The complexity and fragility of global supply chains has become evident in the past few years in the wake of COVID-19 pandemic restrictions.

Currently, there is no supercomputer able to monitor, predict and optimise the delivery routes due to the large number of variables that needs to be considered. Quantum computing can open the door for these problems to be solved, by taking advantage of the quantum properties of particles to solve greater problems with bigger amounts of variables, all the while reducing the processing time. This makes quantum computing ideal to increase supply chains' reliability and resilience. The ongoing development of quantum computing will unlock the potential of machine learning and its application to these currently unsolvable issues.

Conclusion

Cambridge Consultants is actively developing future computing technologies for clients in our research and development facilities in Cambridge, UK. We have deep technical expertise in the current state of the art and how it might evolve. We work across numerous disciplines including semiconductors, photonics, AI, quantum technologies, and bioengineering as well as diverse markets including aerospace, communications, consumer, digital services, energy, healthcare and manufacturing.

We excel at demystifying technology and pride ourselves on providing independent, balanced commercial and strategic advice about how new technologies could be used to meet your goals. Get in touch if you'd like to discuss how we could help propel your ambitions.

References

1 Salton et al,. (2022) Goldman Sachs and AWS examine efficient ways to load data into quantum computers, AWS Quantum Technologies Blog. Available at: https://go.aws/3yCZU8k (Accessed February 2023).

2 International Energy Administration (IEA), (2021) Data Centres and Data Transmission Networks. Available at: https://bit.ly/3ZNe9TR (Accessed February 2023).

3 Ayar Labs, (2021) Technical Brief: Optical I/O Chiplets Eliminate Bottlenecks to Unleash Innovation. Available at: https://bit.ly/3YIffyV (Accessed February 2023).

Why CC?

Cambridge Consultants (CC), part of Capgemini Invent, is a global team of 800 bright, talented people – united by the ambition to turn brilliant and radical ideas into technologies, products and services that are new to the world. We expand the boundaries of technology innovation by tackling the tough, high-risk challenges that bring sustained competitive advantage and market leadership for clients. We are trusted by some of the world's biggest brands and most ambitious start-ups to realise their critical technology-based aspirations – and we've been doing it for 60 years.

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