Advanced Research + Invention Agency ARIA

Nature computes better – let's catch up

Opportunity space

v1.0

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CONTEXT

This document describes an opportunity space - an area that we believe is likely to yield breakthroughs, from which one or more funding programmes will emerge. You can sign up for updates about funding opportunities emerging from this space and provide us with feedback **here**.

In tandem, our first emerging programme hypothesis related to this opportunity space has now been published. You can read this document and register for updates about programme funding opportunities **here**.

An ARIA opportunity space should be

+ important if true (i.e. could lead to a significant new capability for society),
+ under-explored relative to its potential impact, and
+ ripe for new talent, perspectives, or resources to change what's possible.

We can redefine the way computers process information by exploiting principles found ubiquitously in nature. In doing so, we can better understand how the natural world around us performs computation and build dramatically more efficient computers.

BELIEFS

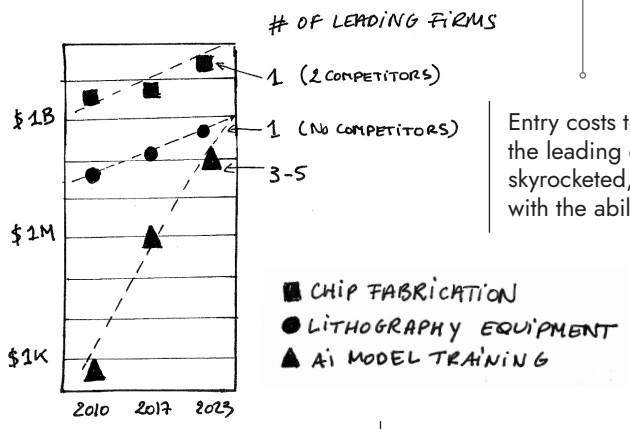
The core beliefs that underpin/bound this area of opportunity.

1. The growth of AI exacerbates an already unsustainable demand for compute $\longrightarrow$ **we need alternative scaling pathways.**
2. Natural systems are orders of magnitude more efficient than silicon microprocessors at a wide range of computational tasks, and we barely even understand how living systems compute $\longrightarrow$ **hardware modalities which use statistical physics to augment AI represent a significantly underexplored opportunity.**
3. Modern AI has massive and broad applicability but is underpinned by a narrow set of mathematical kernels $\longrightarrow$ **this presents a unique opportunity to focus the creative energies of the R&D community.**

OBSERVATIONS

Some signposts as to why we see this area as important, underserved, and ripe.

For the first time in computing history, increasing performance requires exponentially increasing costs. The economics of Moore's Law are fundamentally broken.



Entry costs to innovate at the leading edge have skyrocketed, leaving few firms with the ability to participate.

Vibrant communities have developed around quantum computing and neuromorphic computing, but far less attention has been paid to energy-minimisation in physical systems as an extremely efficient computational mechanism.

These features are wastefully recreated within a paradigm designed specifically to avoid them

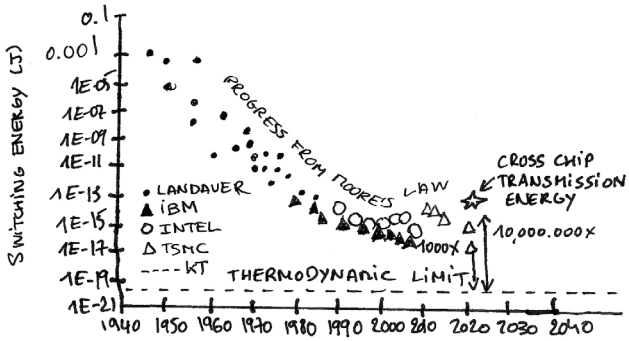
Recent popular demonstrations (e.g. Stable Diffusion, ChatGPT) are increasingly showing impressive new capabilities by incorporating phenomena found in nature (stochasticity/probability) as core features.

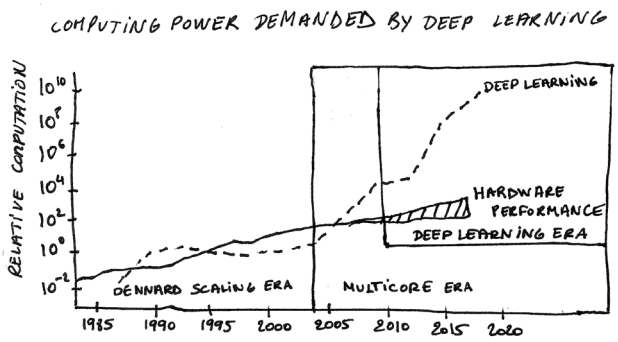
Algorithmic advances are plentiful (and being investigated exhaustively), but rarely change the fundamental dynamics of the industry. Alternative hardware paradigms present a riskier alternative but can ultimately lead to much larger performance improvements.

Access and governance of this critical technology has become a major geopolitical issue.

The energy required to flip a bit in the digital domain has plateaued at about 1000x the fundamental limit. Sending that bit across a chip requires yet another 10,000x more energy. A single user's session with chatGPT requires ~150x more power than a human brain consumes performing ALL functions.

There is ample room for improvment





AI is now the primary economic driver of computational power, and its capabilities are primarily derived from well-known mathematical primitives.

It provides a unique combination of specificity and impact

Scalability, manufacturability, and true economic advantage have historically limited the adoption of new computing technologies. These commercial constraints can serve as an opportunity to galvanise creative approaches and improve the chances for new technologies to break through.

SOURCES

A compiled, but not exhaustive list of works helping to shape our view and frame the opportunity space (for those who want to dig deeper).

The End of Moore's Law

Compute Demand in the AI Era (Figure 3)

The Geopolitics of AI and Semiconductors (1,2,3,4,5)

The Role of Probabilities in ChatGPT

Energy-Based AI Algorithms

Energy-Minimization in Hardware

Thermodynamic Linear Algebra

Computing with Biology

A Burgeoning Community

Computing with Light

AI & Novel Electronic Memories

The Evolution of Transistor Switching Energy (Figure 2)

ENGAGE

We invite you to shape our efforts by providing feedback and surfacing breakthrough ideas related to this opportunity space. Our next step will be to formulate a programme that directs funding across research disciplines or institutions toward a focused objective. We also plan to open up seed funding for researchers whose bold aspirations are unlikely to be funded elsewhere.

Sign up for updates and share your feedback **here**. You can upload a short pdf – we will read anything you send.

If you require an accessible version of this document and/or form, please contact us at info@aria.org.uk.