The Future Begins Here
intel labs
Labs Day 2020 | December 3

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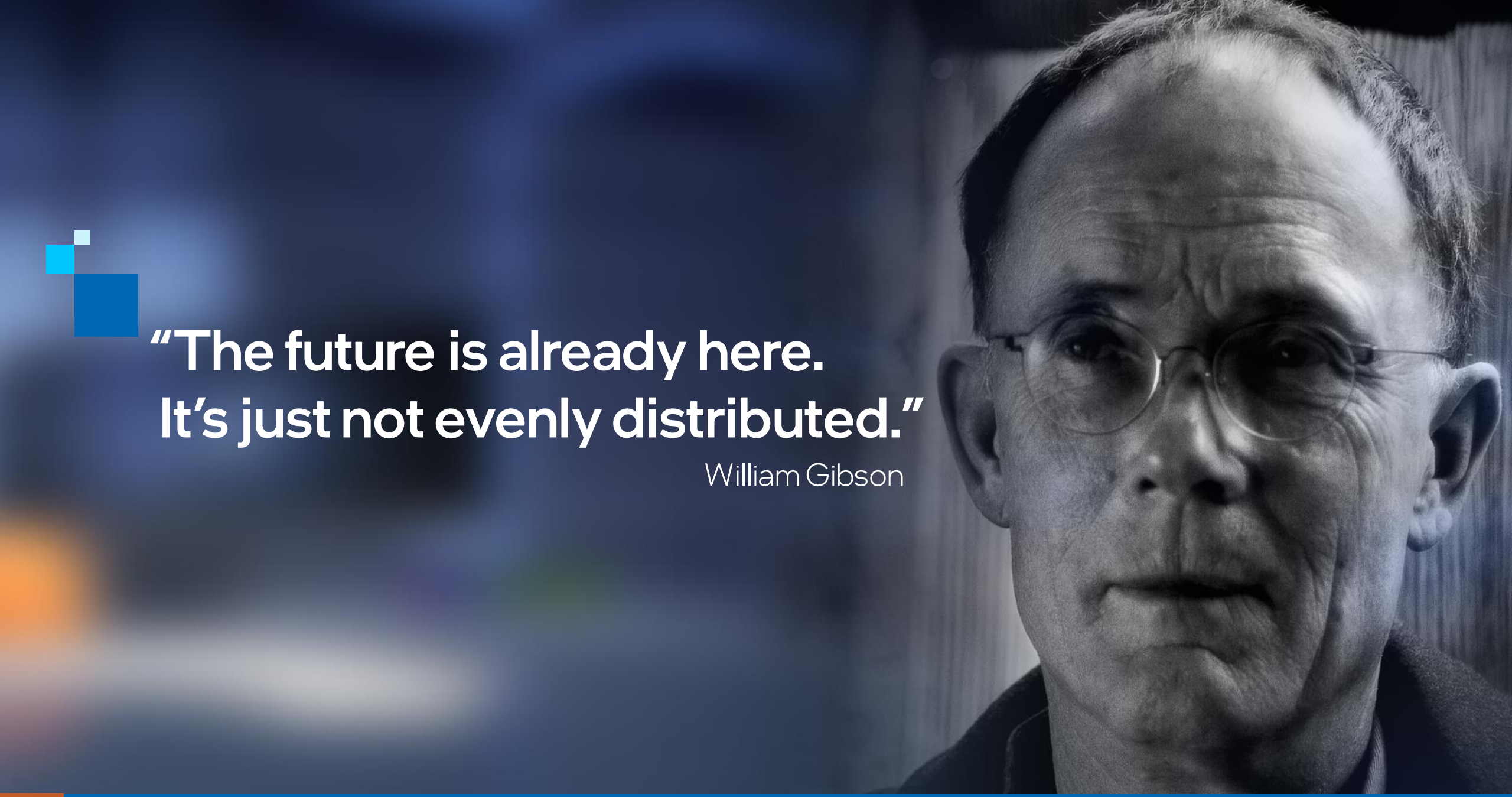
In Pursuit of 1000X:
Disruptive Research for the Next Decade of Computing
Rich Uhlig
Intel Sr. Fellow, VP, & Director of Intel Labs
Labs Day 2020


“The future is already here.
It’s just not evenly distributed.”
William Gibson

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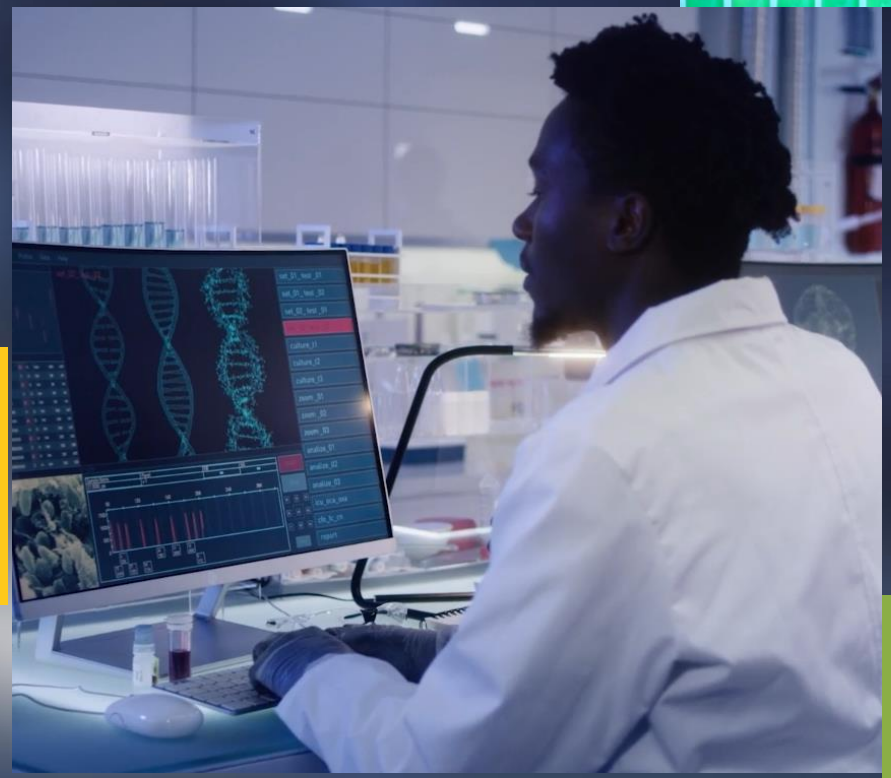

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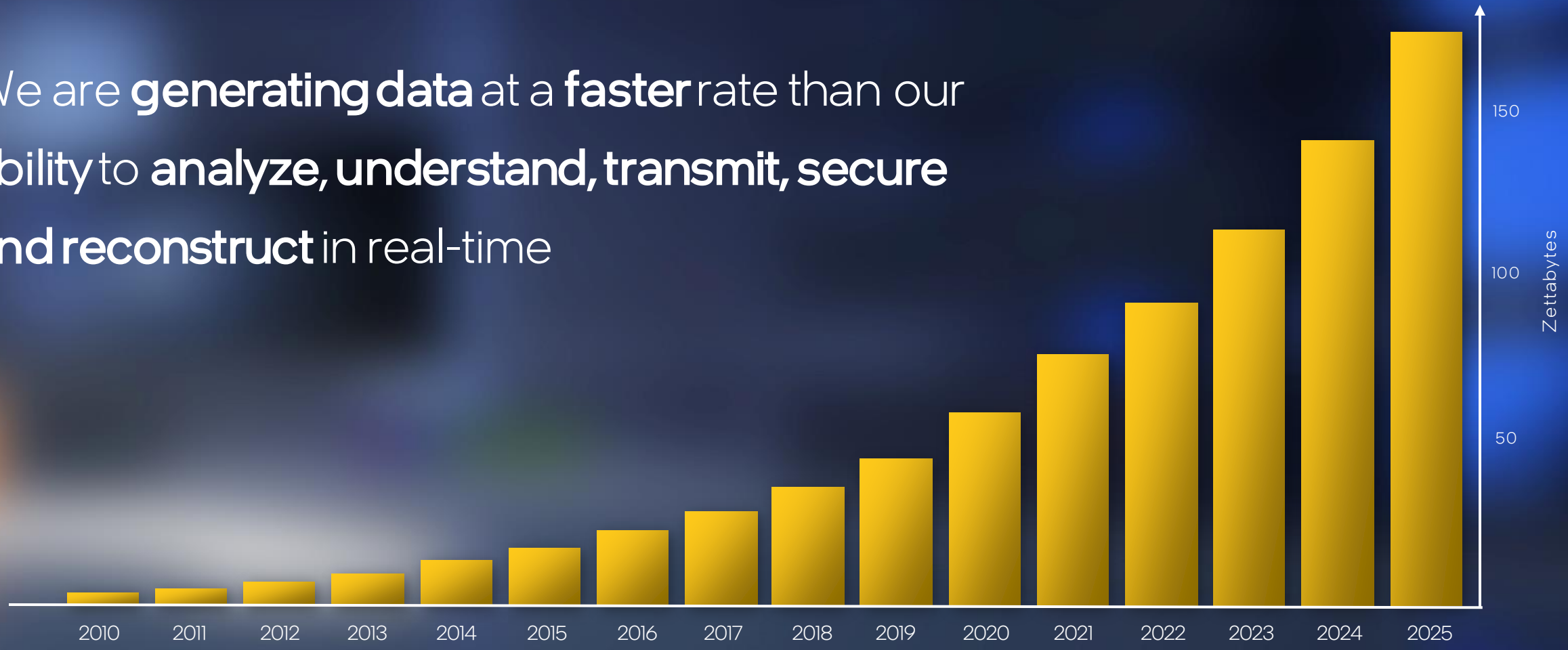
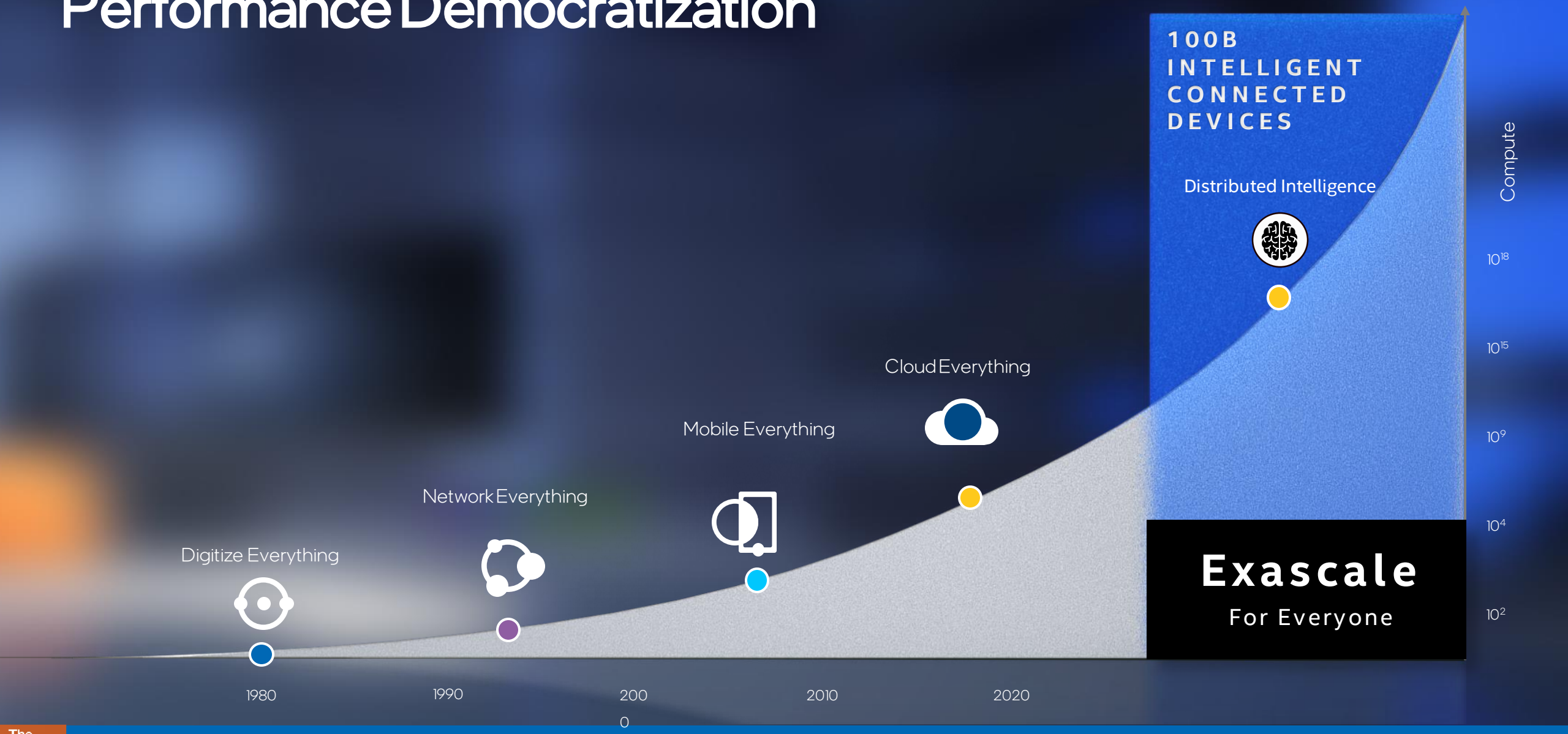
The Data Problem

175ZB

We are **generating data** at a **faster** rate than our ability to **analyze, understand, transmit, secure and reconstruct** in real-time



Performance Democratization



We create world-changing technology that enriches the lives of every person on earth

In Pursuit of
1000X
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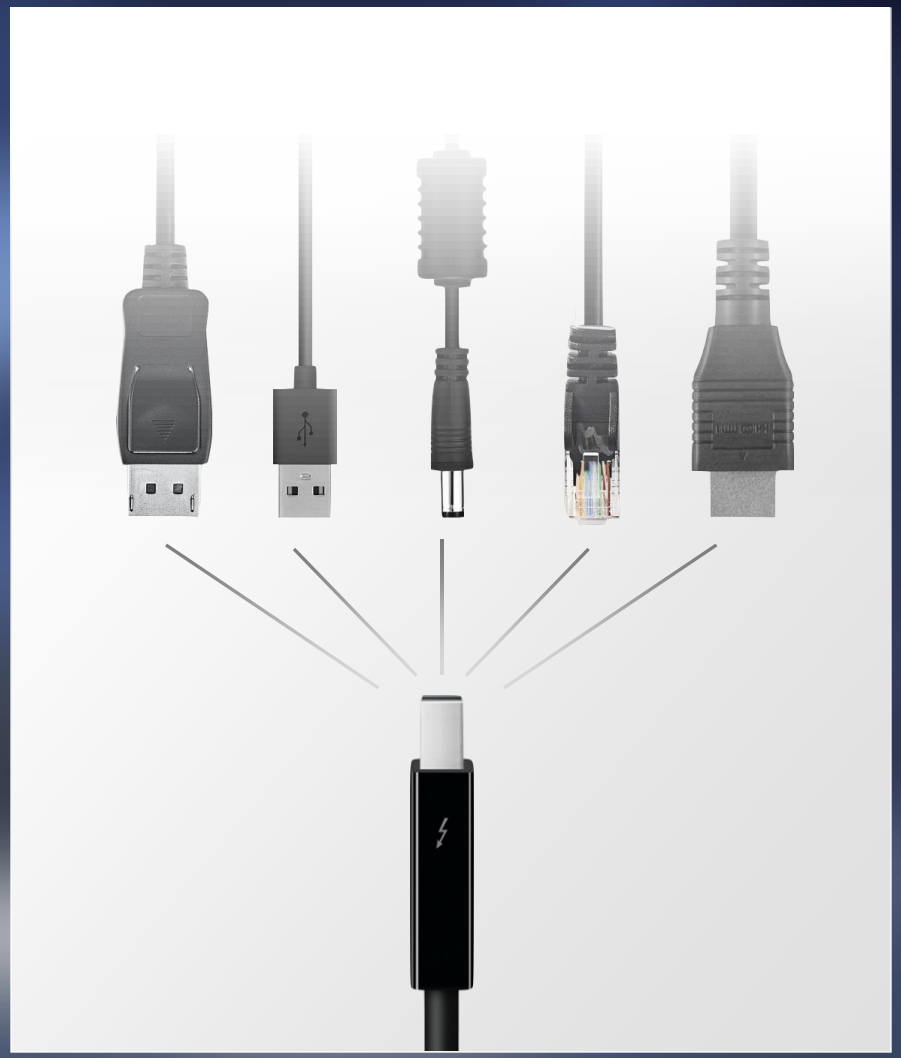
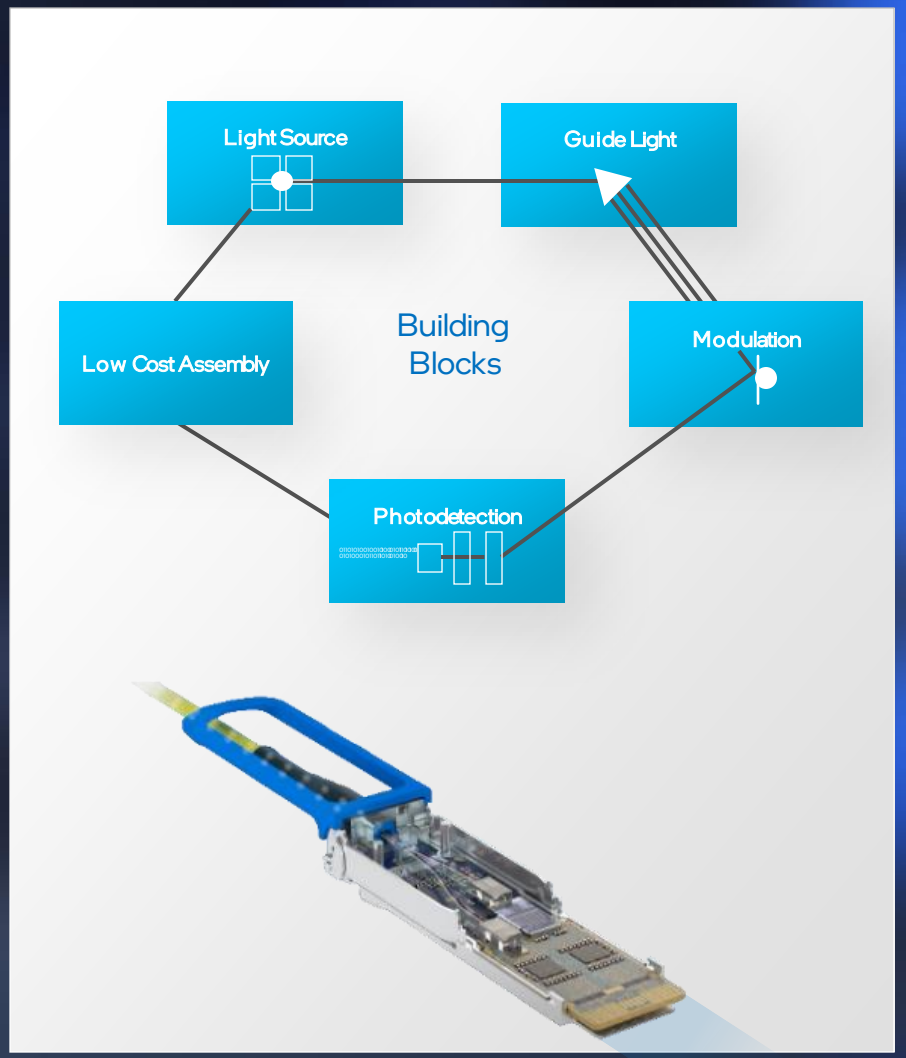
USB & Thunderbolt



Silicon Photonics



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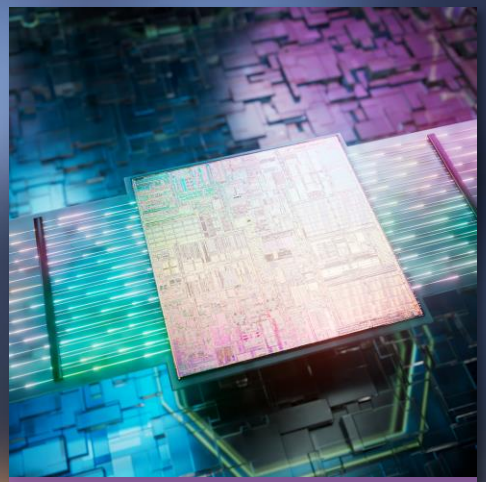
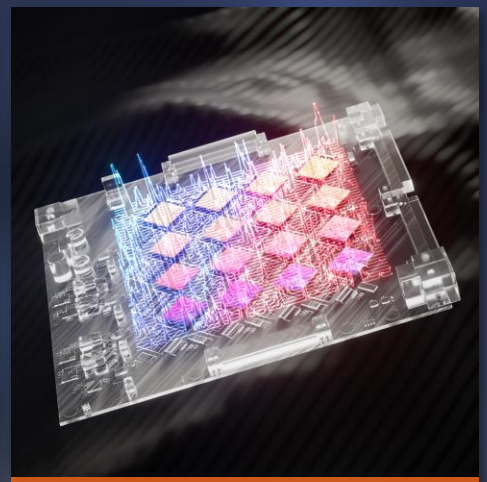
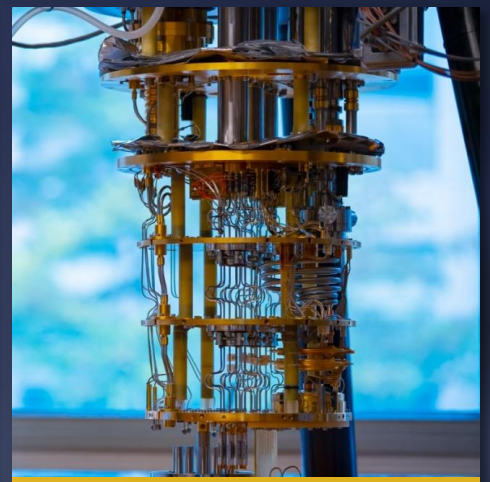
Today's Tracks



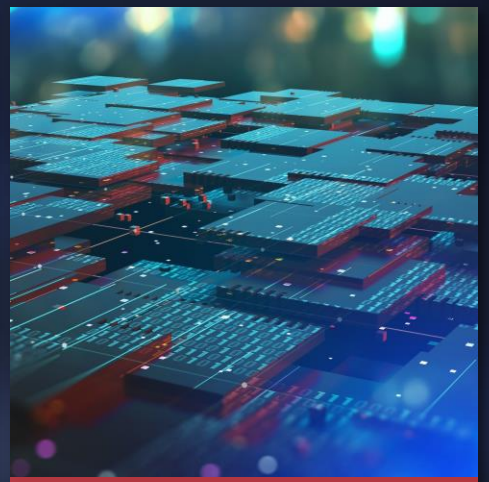
Integrated Photonics



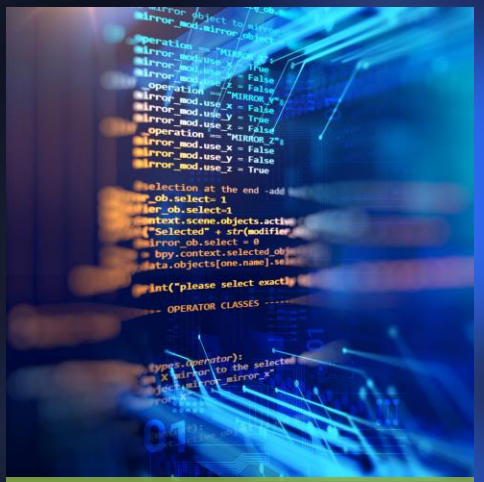
Neuromorphic Computing



Quantum Computing



Confidential Computing



Machine Programming

Integrated Photonics
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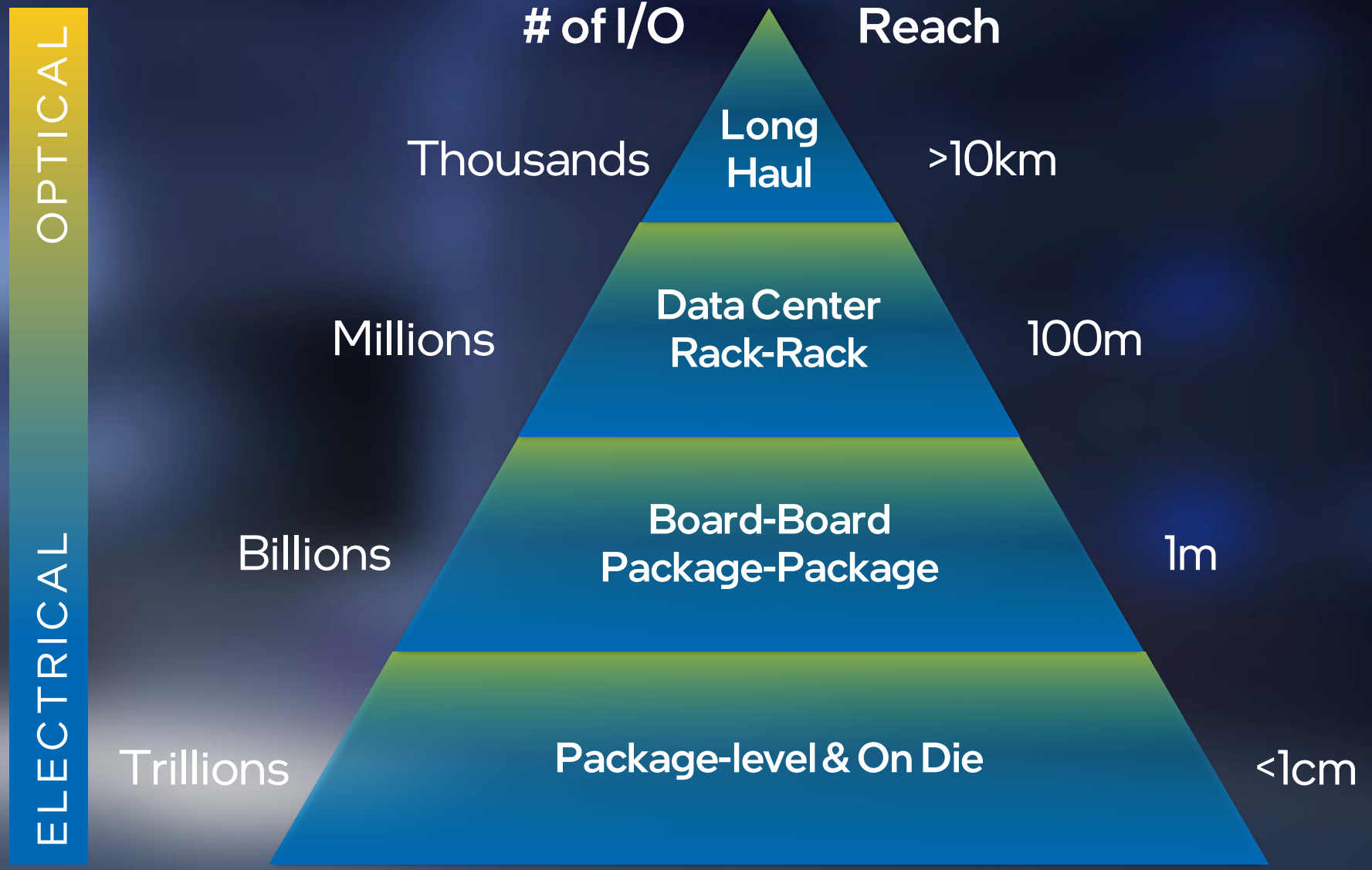
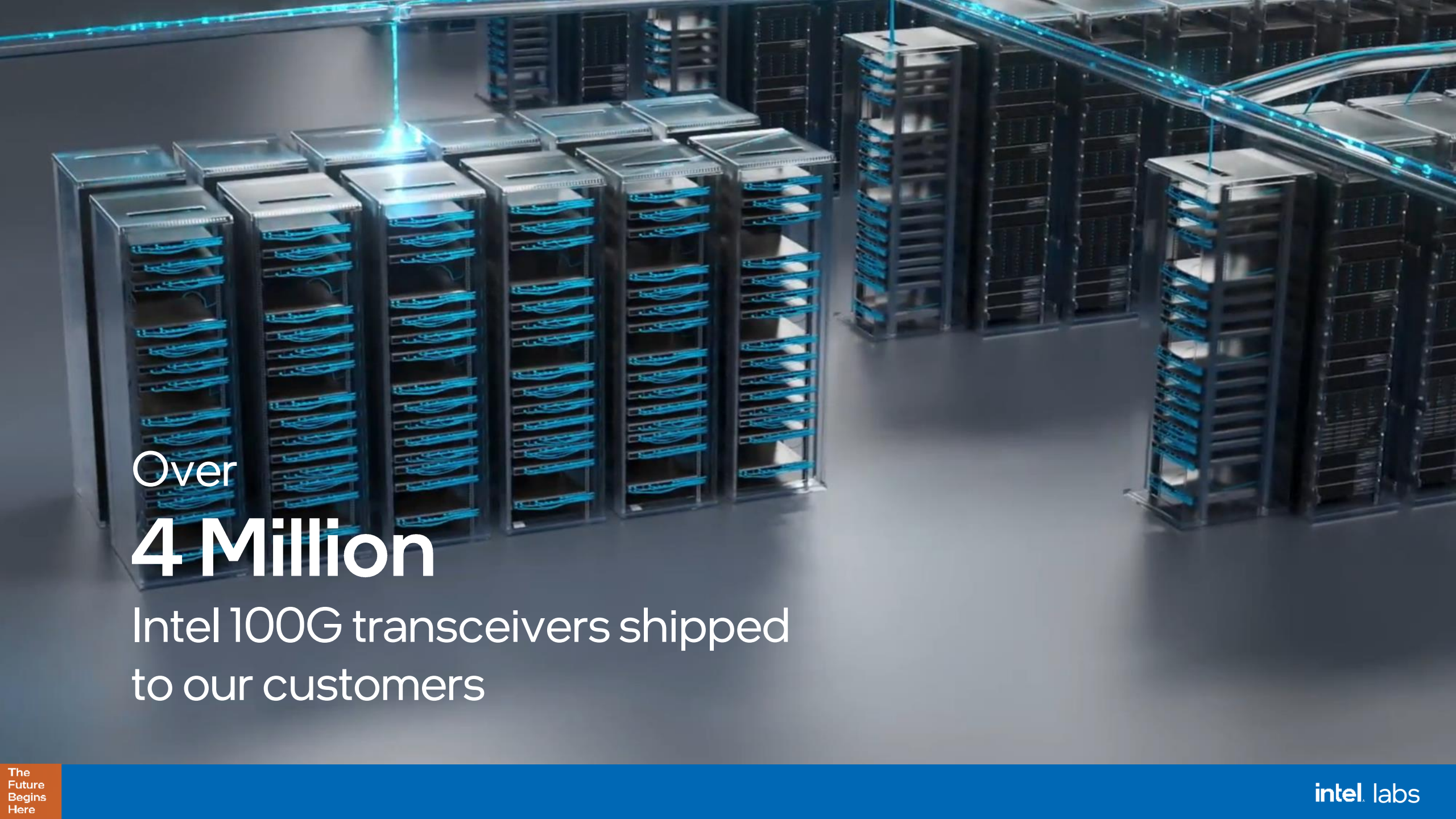
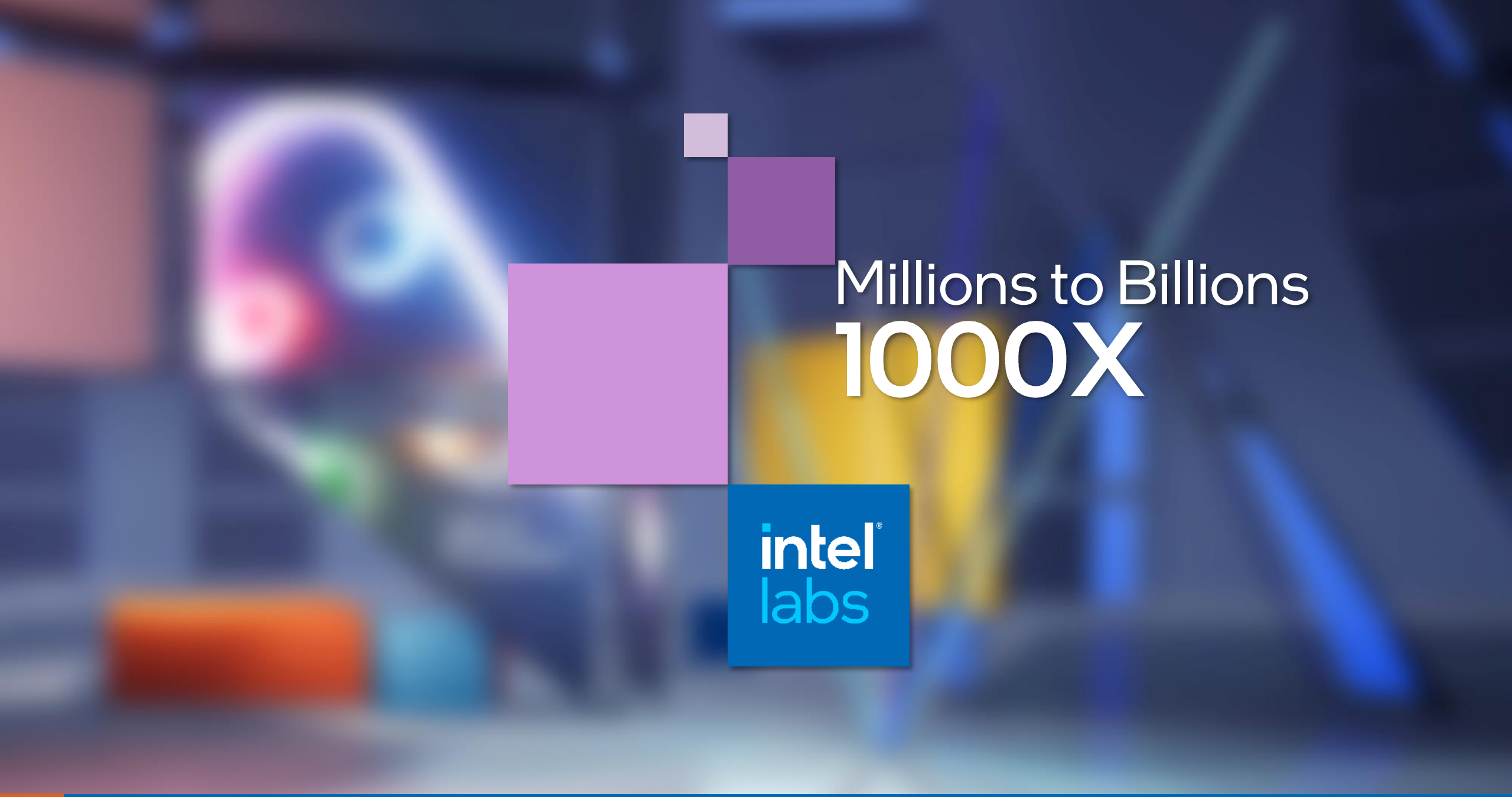
Attacking the I/O Power Wall
James Jaussi
Senior Principal Engineer and
Director of PHY Research Lab
Labs Day 2020


OPTICAL
ELECTRICAL
# of I/O
Reach
Long Haul
Thousands
>10km
Data Center Rack-Rack
Millions
100m
Board-Board Package-Package
Billions
1m
Package-level & On Die
Trillions
<1cm


Over
4 Million
Intel 100G transceivers shipped
to our customers

Integrated Photonics

Bringing optical I/O directly into our servers and onto our packages


Millions to Billions
1000X
intel
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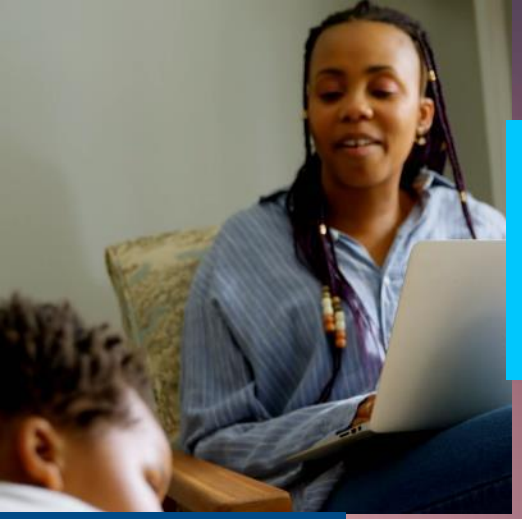

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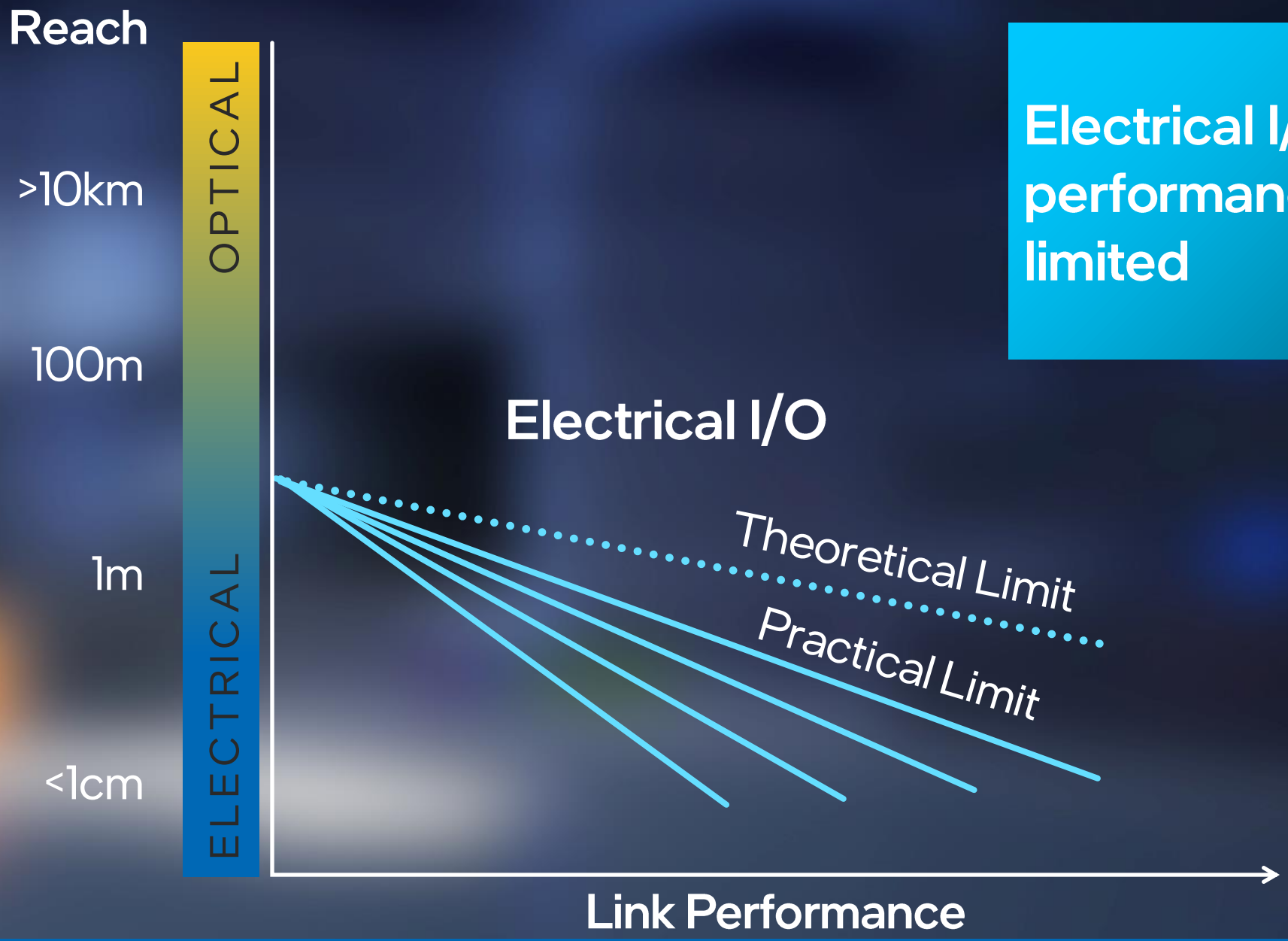
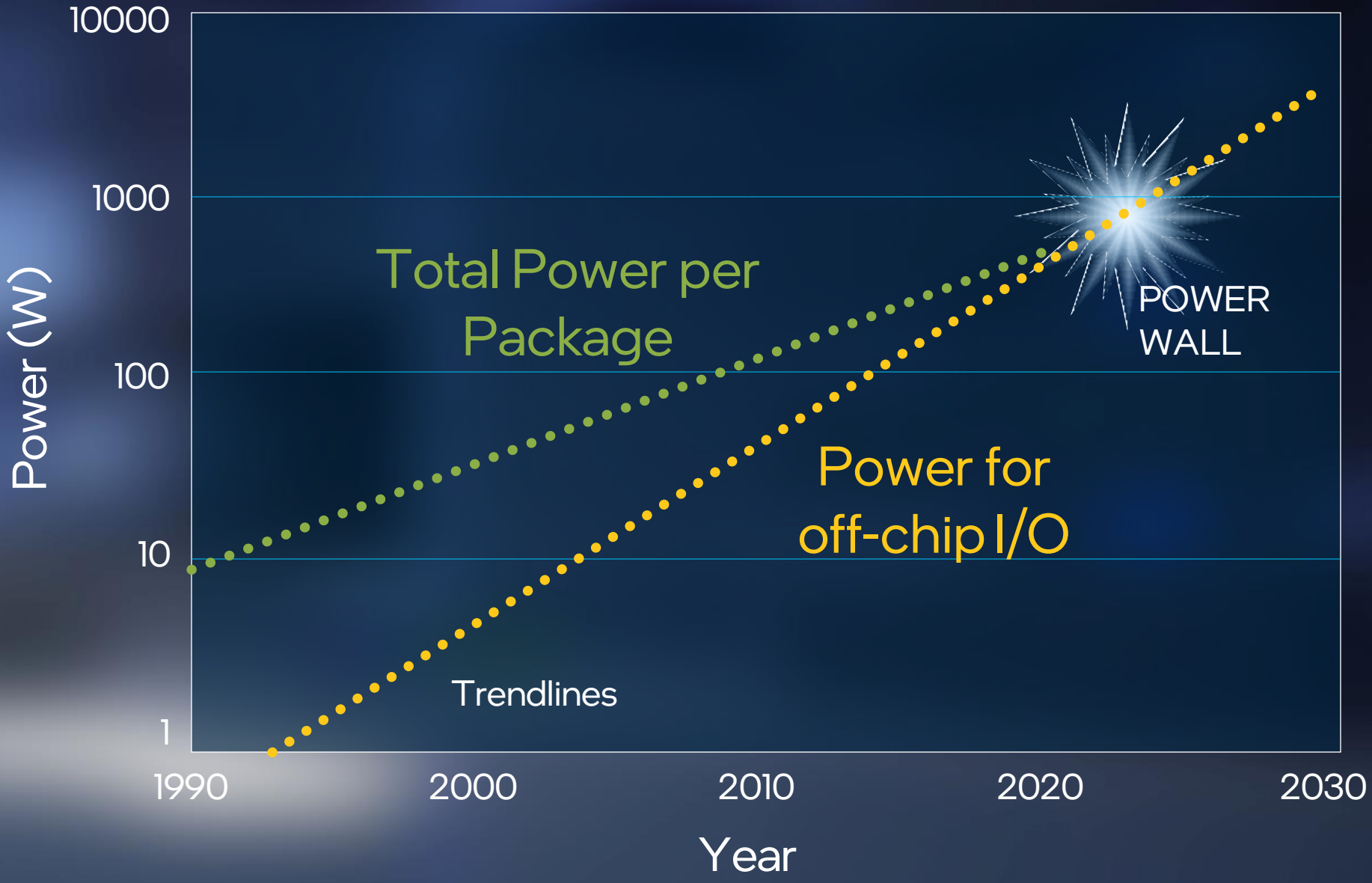


Electrical I/O is performance-distance limited



Credit: DARPA for trendlines

Integrated Photonics will fundamentally change compute I/O.

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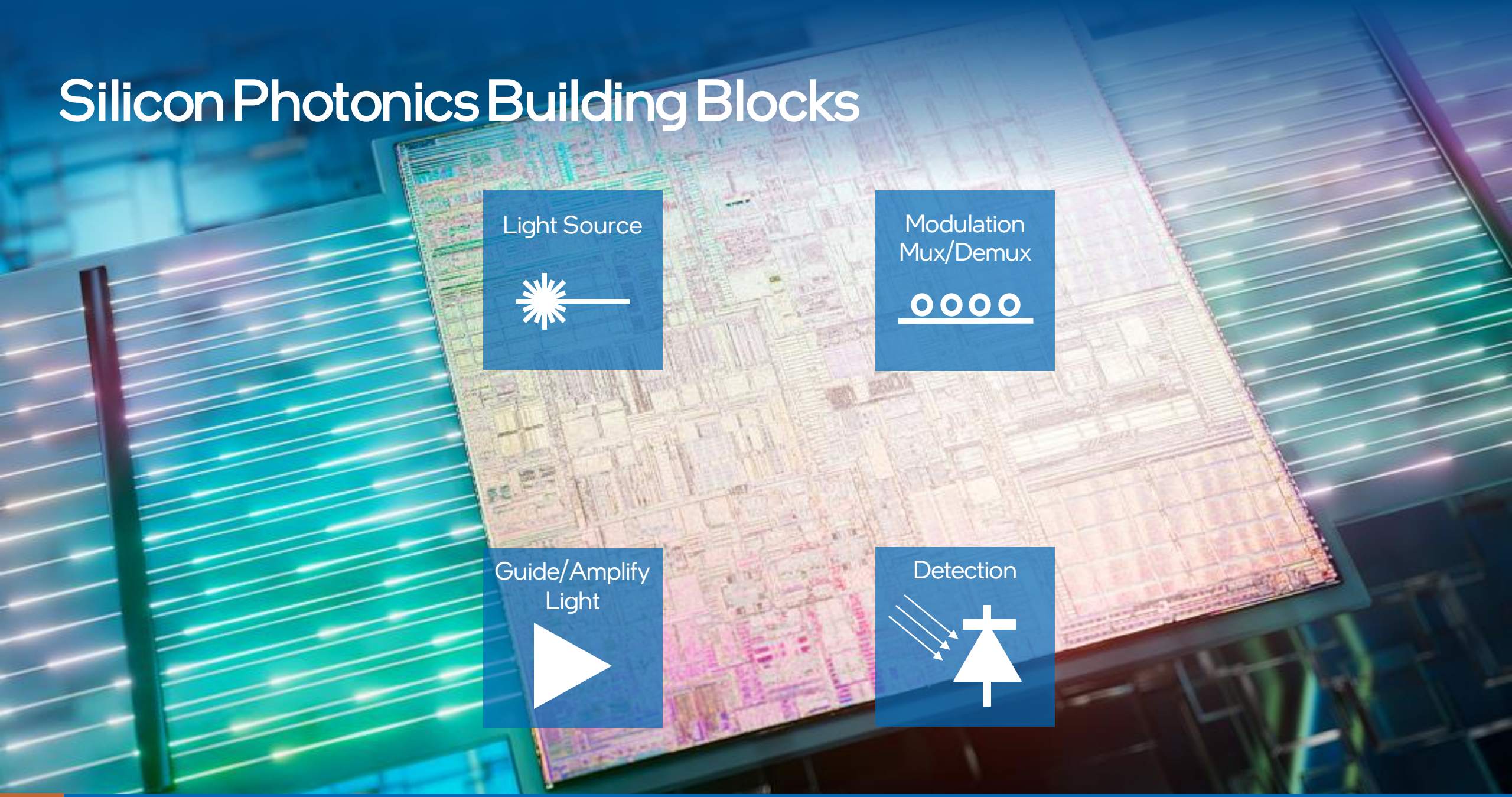
Silicon Photonics Building Blocks

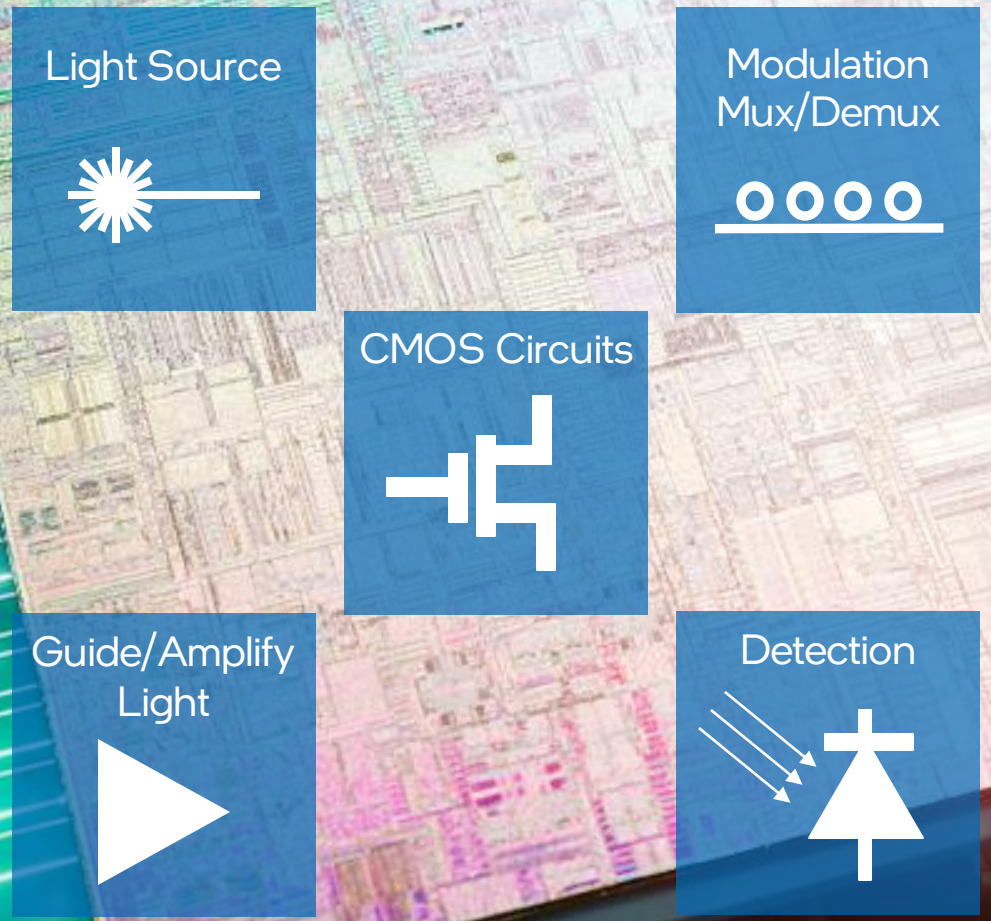


Integrated Photonics

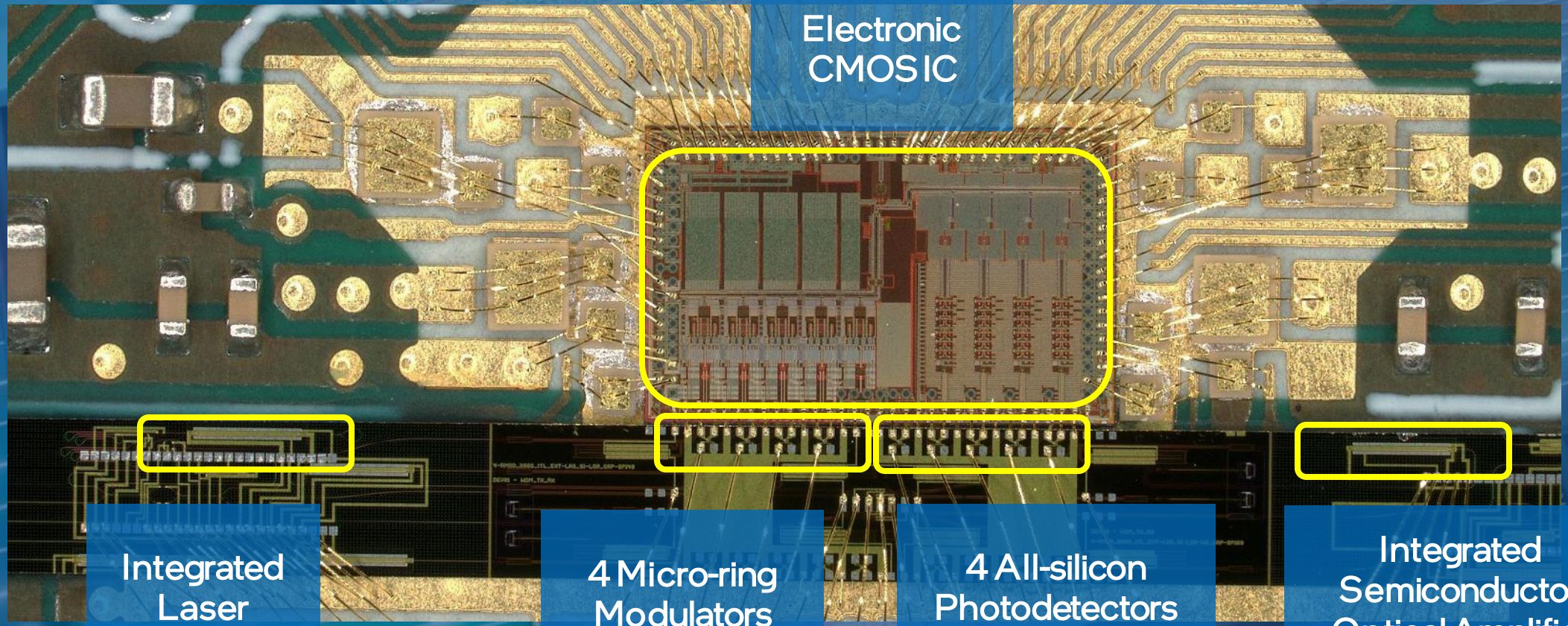
Silicon Photonics

CMOS Electronics

Package Integration



Integrated Photonics Prototype



Industry-leading Prototype with Key Technology Building Blocks

Neuromorphic Computing

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Synapses to Silicon: Brain-inspired Microarchitecture

Mike Davies
Director Of Neuromorphic Computing Research

Labs Day 2020

2018 IROS Drone Racing Competition

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Brains are Unrivaled Computing Devices

COCKATIEL PARROT

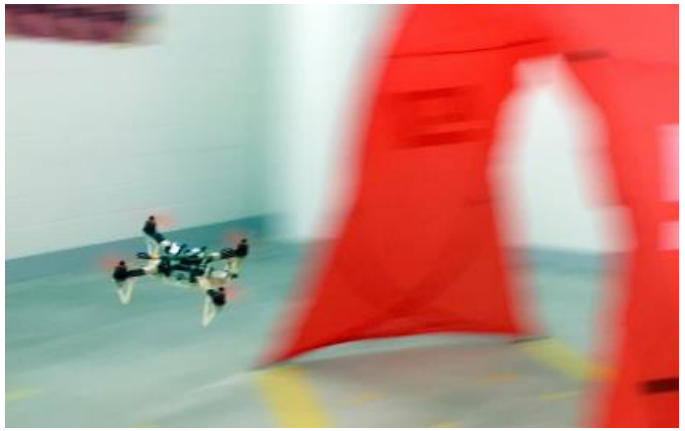
Brain
Power: 50 mW
Mass: 2.2 grams

Navigates and learns unknown environments at 22 mph

Can learn to speak English words

Can learn to manipulate cups for drinking

AUTONOMOUS DRONE



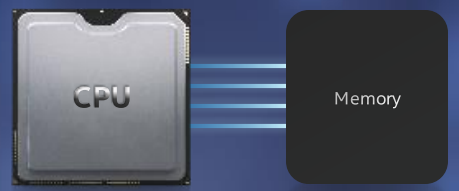
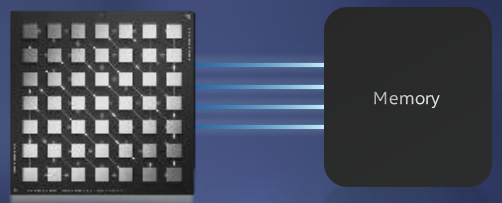
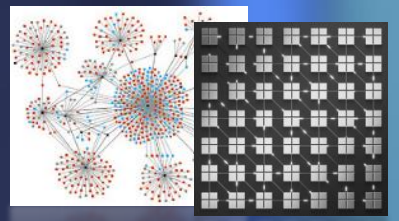
CPU/GPU controller
Power: 18,000 mW
Mass: ~40 grams

Pre-trained to fly between known gates at 5.6 mph

Can't learn anything online

Sources: PNAS, June 13, 2016; https://link.springer.com/article/10.1007/s00360-011-0603-1; Davide Scaramuzza, ETH Zurich and A. Loquercio et al, "Deep Drone Racing: From Simulation to Reality with Domain Randomization," IEEE Trans. Robotics, 2020.

A New Kind of Computer Architecture

Standard Computing	Parallel Computing	Neuromorphic Computing
		
PROGRAMMING BY ENCODING ALGORITHMS	OFFLINE TRAINING USING LABELED DATASETS	LEARN ON THE FLY THROUGH NEURON FIRING RULES
SYNCHRONOUS CLOCKING	SYNCHRONOUS CLOCKING	ASYNCHRONOUS EVENT-BASED SPIKES
SEQUENTIAL THREADS OF CONTROL	PARALLEL DENSE COMPUTE	PARALLEL SPARSE COMPUTE

Loihi

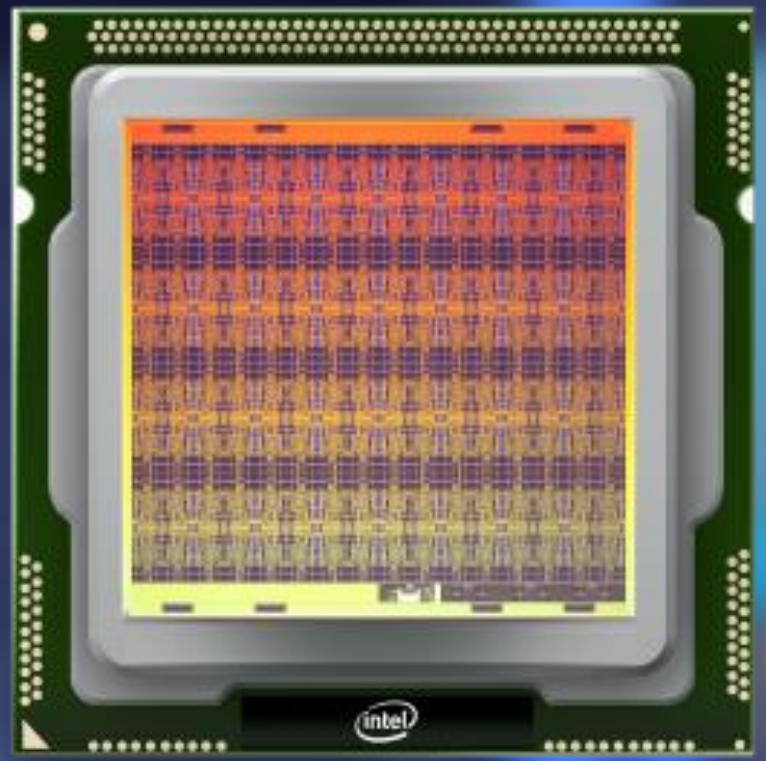
KEY PROPERTIES

- 128k neurons and 128 million synapses
- Compute-memory integrated architecture
- Fully digital in standard 14nm process
- Asynchronous design enables scalability
- Versatile on-chip learning – a first for the field

Yet,

- No floating point numbers!
- No multiply-accumulators!

Fundamental to deep learning hardware



Loihi

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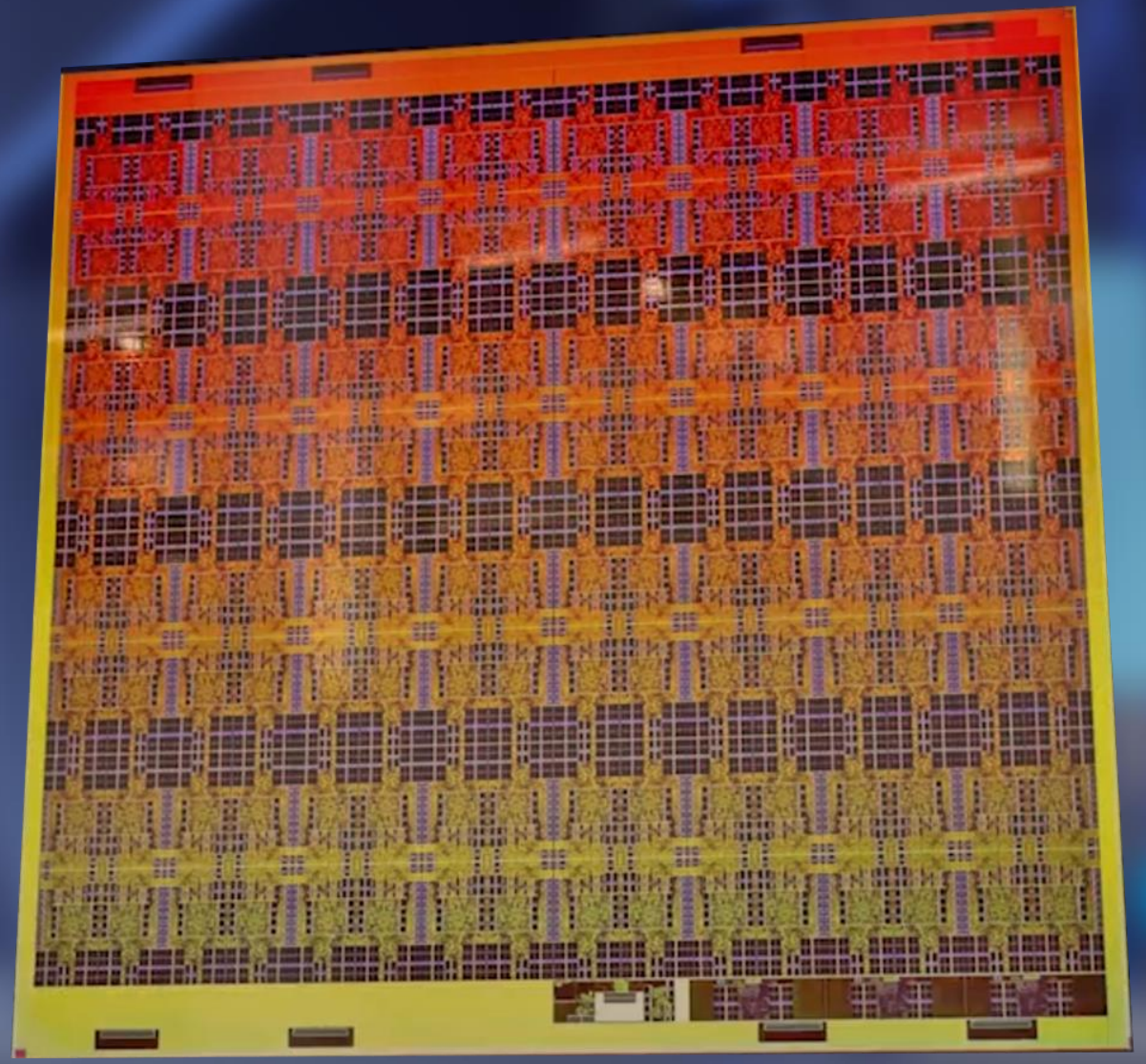
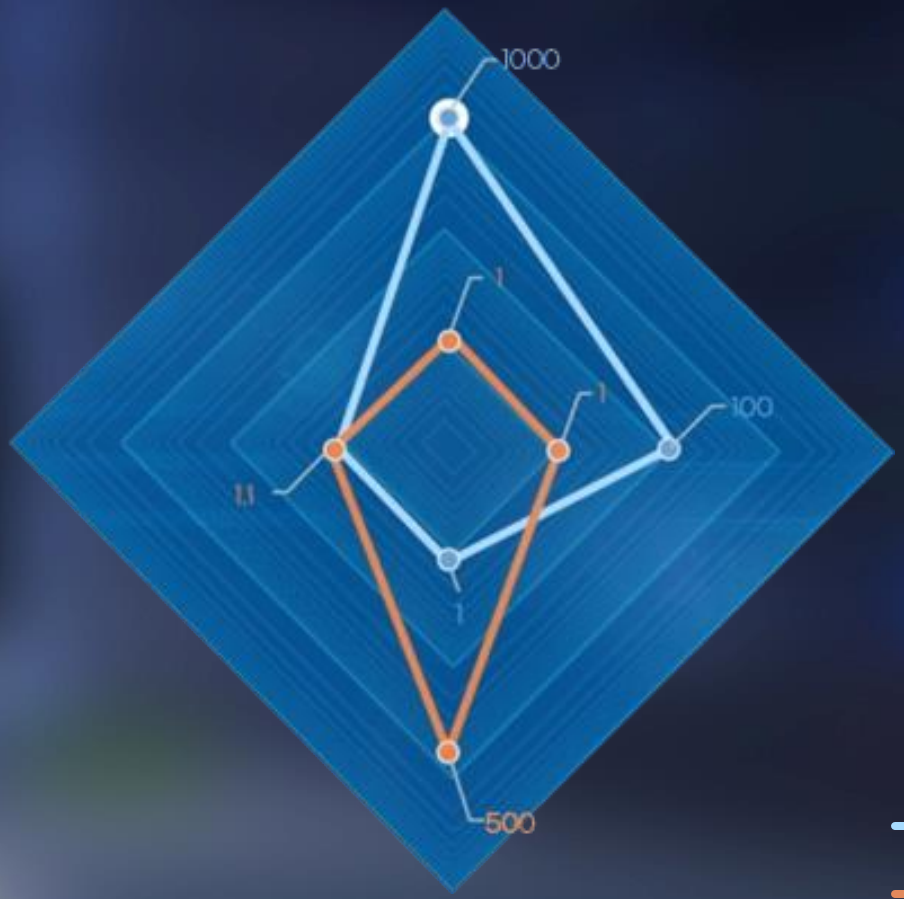


Loihi Efficiency



Pohoiki Springs

Neuromorphic Computing

Beyond Today's AI

New algorithmic approaches emulate the human brain's interactions with the world.

The emergent capabilities in artificial intelligence being driven by Intel Labs have more in common with human cognition than with conventional computer logic.

HIGHLIGHTS

- Neuromorphic computing research emulates the neural structure of the human brain.
- The Loihi research chip includes 130,000 neurons optimized for spiking neural networks.
- Intel Labs is making Loihi-based systems available to the global research community.
- Probabilistic computing addresses the fundamental uncertainty and noise of natural data.
- Collaborations on next-generation AI extend to worldwide industry and academic researchers.

What Is Neuromorphic Computing

The first generation of AI was rules-based and emulated classical logic to draw reasoned conclusions within a specific, narrowly defined problem domain. It was well suited to monitoring processes and improving efficiency, for example. The second, current generation is largely concerned with sensing and perception, such as using deep-learning networks to analyze the contents of a video frame.

A coming next generation will extend AI into areas that correspond to human cognition, such as interpretation and autonomous adaptation. This is critical to overcoming the so-called "brittleness" of AI solutions based on neural network training and inference, which depend on literal, deterministic views of events that lack context and commonsense understanding. Next-generation AI must be able to address novel situations and abstraction to automate ordinary human activities.

Intel Labs is driving computer-science research that contributes to this third generation of AI. Key focus areas include neuromorphic computing, which is concerned with emulating the neural structure and operation of the human brain, as well as probabilistic computing, which creates algorithmic approaches to dealing with the uncertainty, ambiguity, and contradiction in the natural world.

Neuromorphic Computing Research Focus

The key challenges in neuromorphic research are matching a human's flexibility, and ability to learn from unstructured stimuli with the energy efficiency of the human brain. The computational building blocks within neuromorphic computing systems are logically analogous to neurons. Spiking neural networks (SNNs) are a novel model for arranging those elements to emulate natural neural networks that exist in biological brains.

News Byte

November 18, 2019

Contact Intel PR

Accenture, Airbus, GE and Hitachi Join Intel Neuromorphic Research Community

What's New: Today, Intel announced the first corporate members – Accenture, Airbus, GE and Hitachi – to join the fast-growing Intel Neuromorphic Research Community (INRC). The INRC has tripled in size over the past year and now has more than 75 organizations, spanning leading

Latest News: Artificial Intelligence

October 29, 2020
Intel to Acquire SigOpt to Scale AI Productivity and Performance

October 29, 2020
Artificial Intelligence

October 20, 2020
Intel Powers First Satellite with AI on Board

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INRC includes over 100 groups

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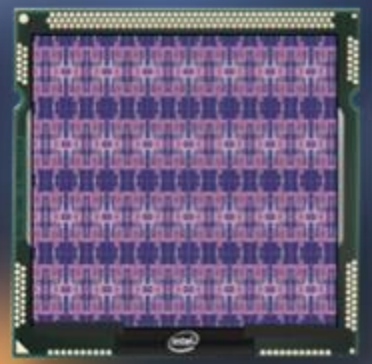
Opportunity at All Scales

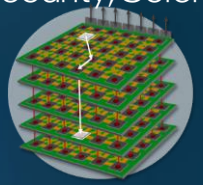
Future Neuromorphic Technology



Visual Intelligence

Personalized Computing
(Real-time speech, speaker ID, localization, denoising)

At-Scale Problem Solving
Data Analytics, Security, Scientific Computing

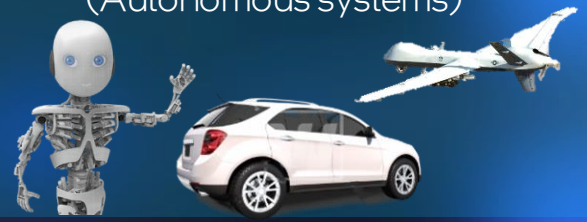


Intelligent Sensors
(Low latency, event-based, anomaly detection)

IoT

Robotic Sensing + Control

SWaP-constrained AI
(Autonomous systems)



Human-Computer Interfacing
(EEG, neuroprosthetics)

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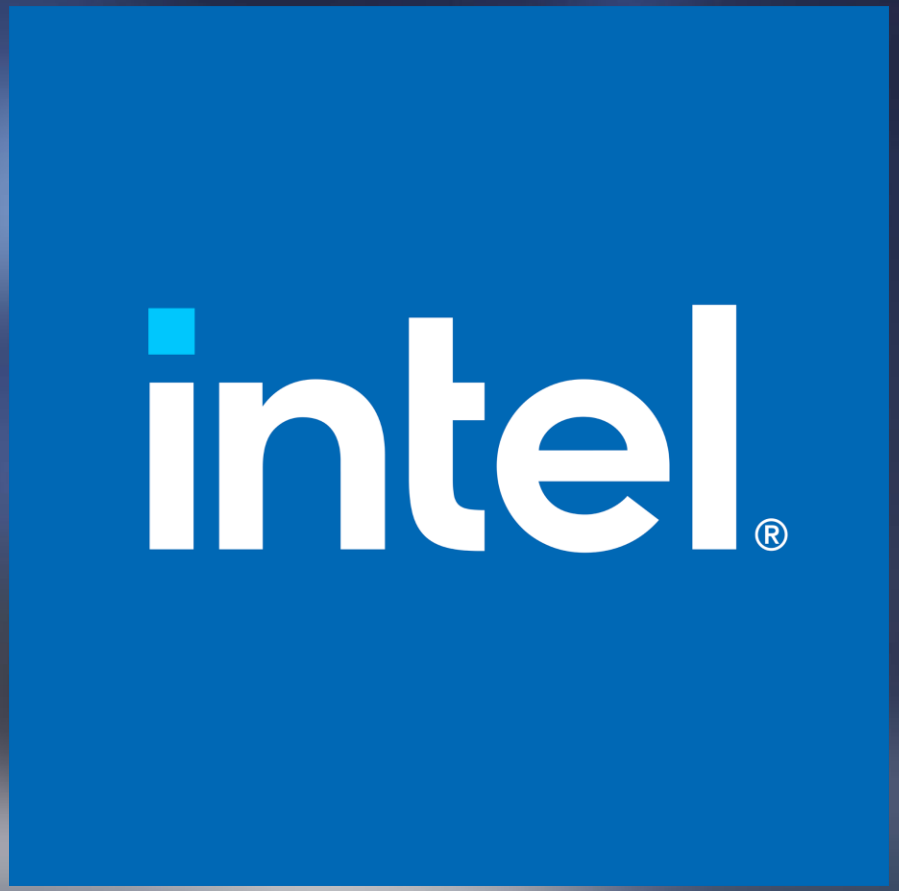

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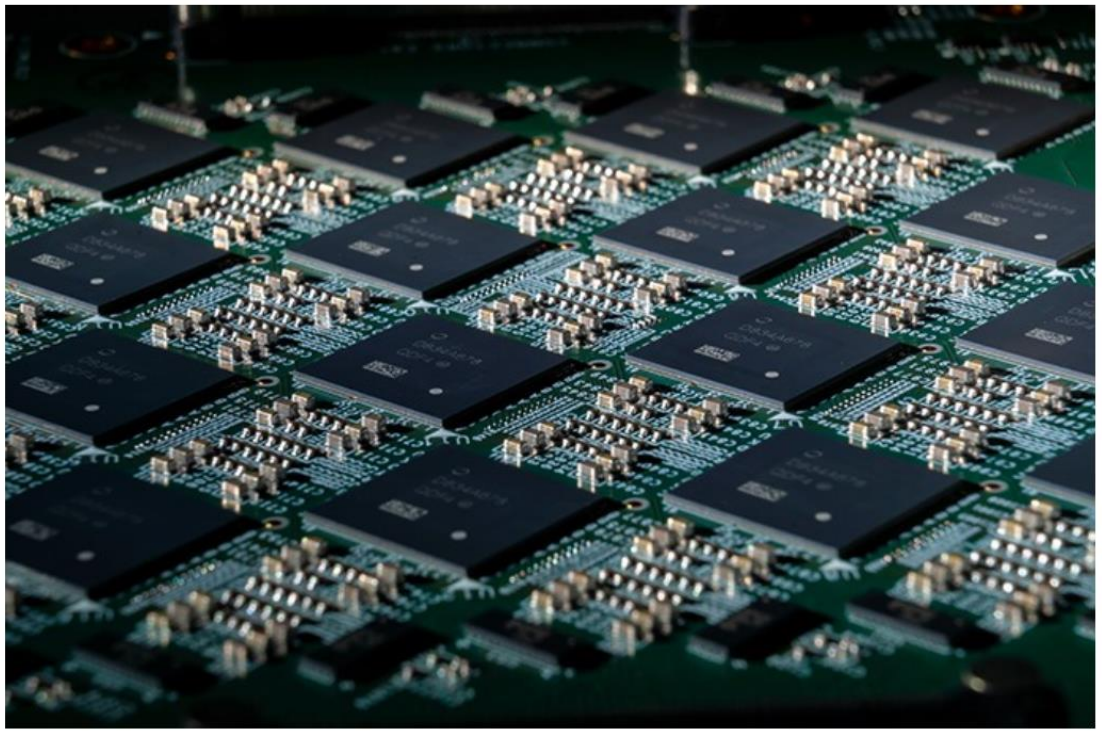
News Byte

October 2, 2020

Contact Intel PR

Intel and Sandia National Labs Collaborate on Neuromorphic Computing



A close-up shot of an Intel Nahuku board, each of which contains 8 to 32 Intel Loihi neuromorphic chips. Intel's latest neuromorphic system, Pohoiki Beach, is made up of multiple Nahuku boards and contains 64 Loihi chips. Pohoiki Beach was introduced in July 2019. (Credit: Tim Herman/Intel Corporation)

Latest News: Artificial Intelligence

November 18, 2020
Survey Shows Next Era of Healthcare Will Be Powered by AI

November 17, 2020
First Intel Structured ASIC for 5G, AI, Cloud and Edge Announced

SIGOPT

October 29, 2020
Intel to Acquire SigOpt to Scale AI Productivity and Performance

Read More

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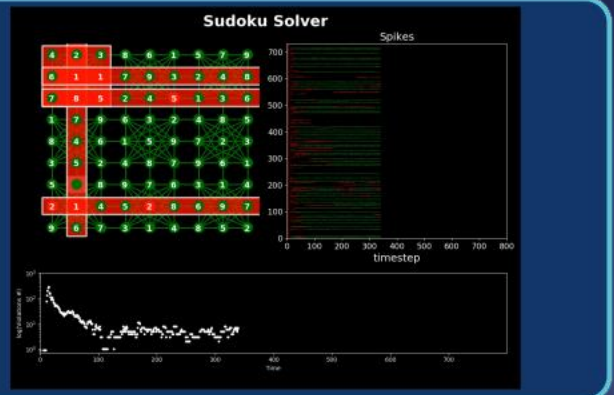
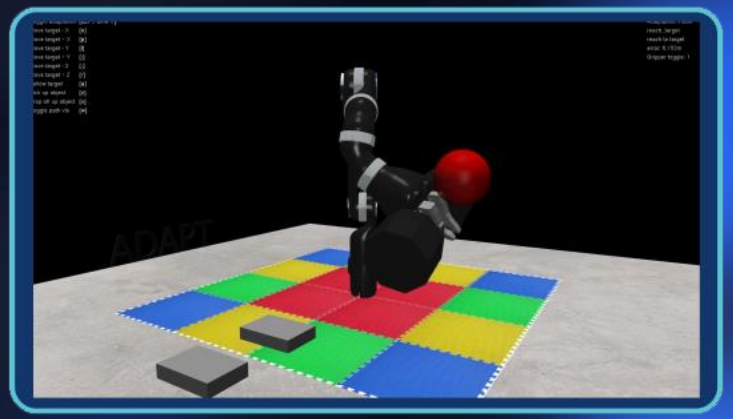
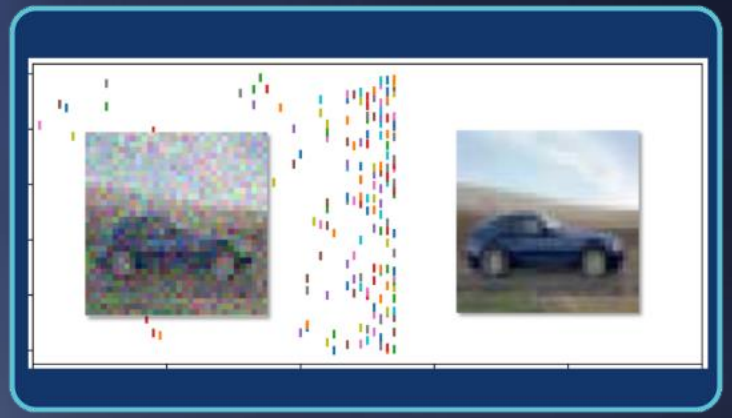


Constrained optimization problems
(e.g. Sudoku)
1000x lower energy
100x faster

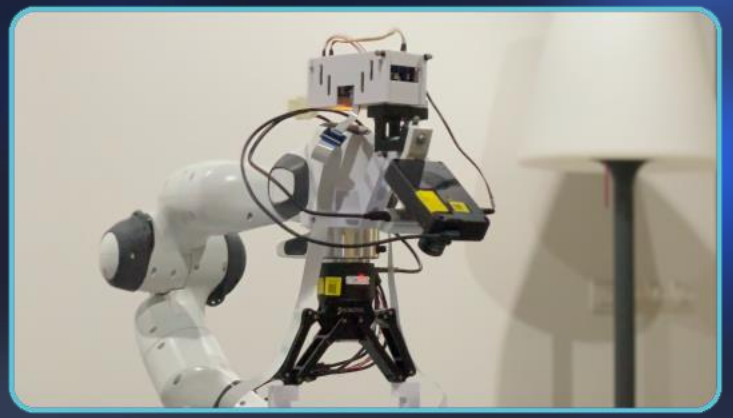


Adaptive robotic arm control 40x lower power , 50% faster (vs GPU)



Similarity search
24x faster and 30x lower energy (vs CPU)

Head direction localization and learning
v00x lower power vs CPU
1000x lower energy
100x faster



Visual-tactile sensing
45x lower power
20% faster (vs GPU)

+

PROPHESEE
METAVISION FOR MACHINES

Mercedes-Benz

logitech

Lenovo

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Quantum Computing
intel
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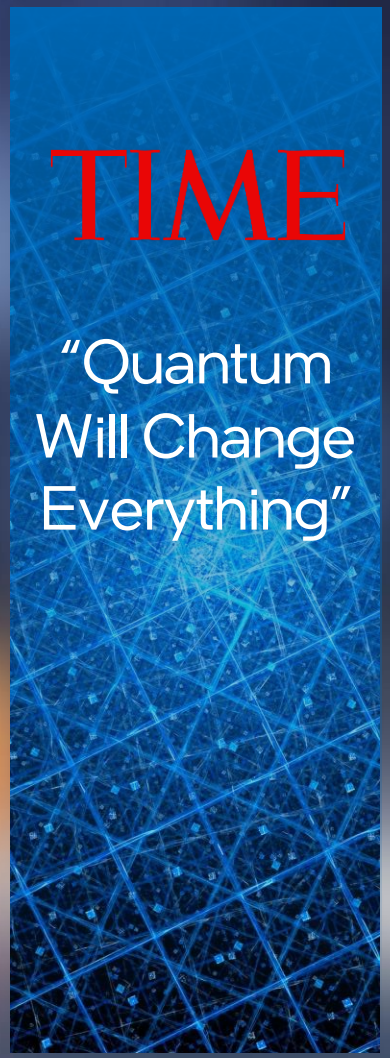
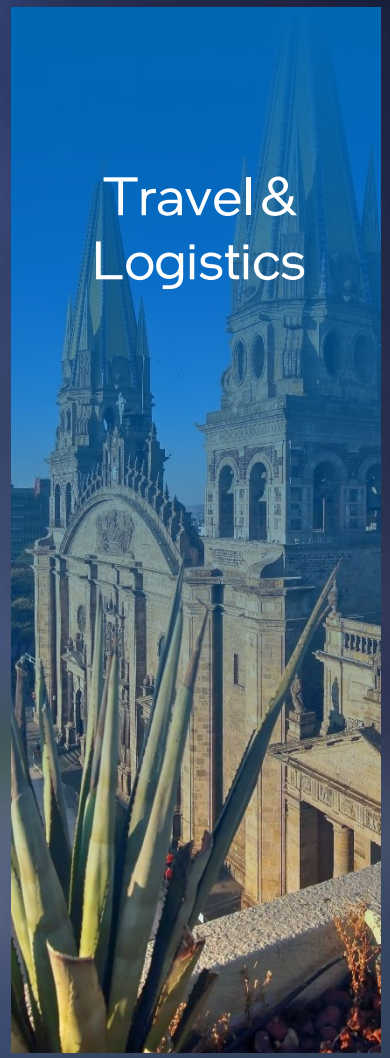
Four biggest challenges to Quantum Practicality & How We Might Solve Them

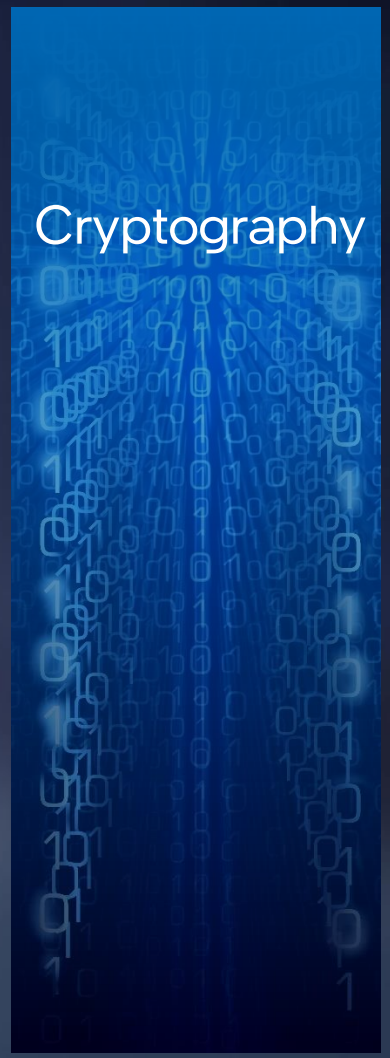
Anne Matsuura
Director of Quantum Computing Architecture

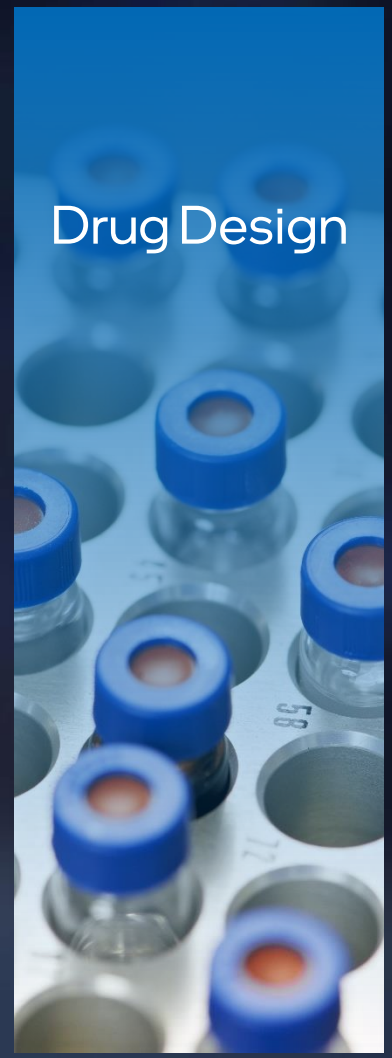
Labs Day 2020

Changing the World









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Quantum Computing: Key Concepts

Superposition

Classical Physics

Heads OR Tails

Quantum Physics

Heads AND Tails

Entanglement

1)

2)

3)

4)

N Quantum Bits or **Qubits** = 2^N States

Fragility

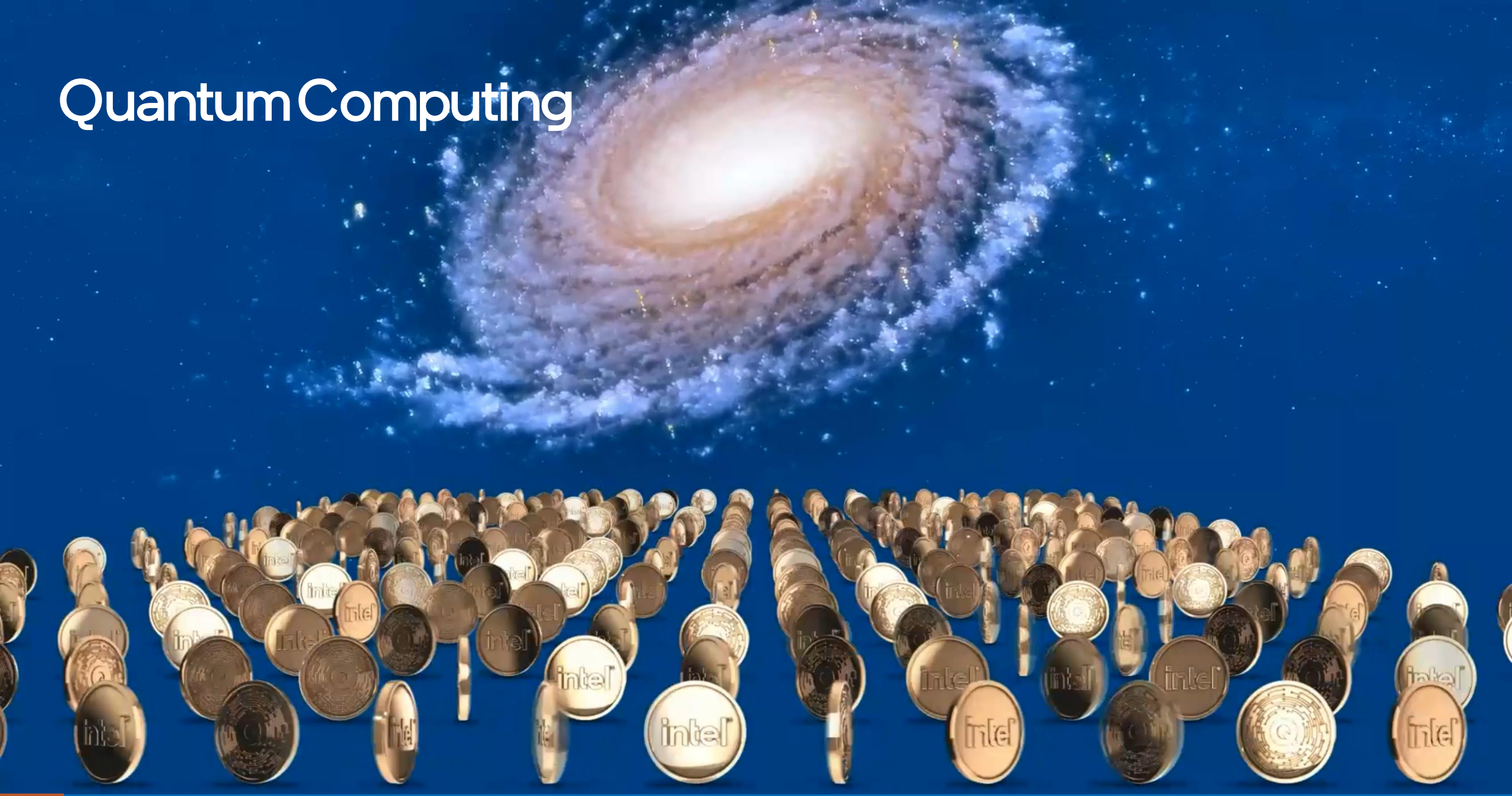
Observation or noise
causes loss of information

Quantum Computing

1
2
3
4
5
6
7
8

Quantum Computing

Quantum Computing



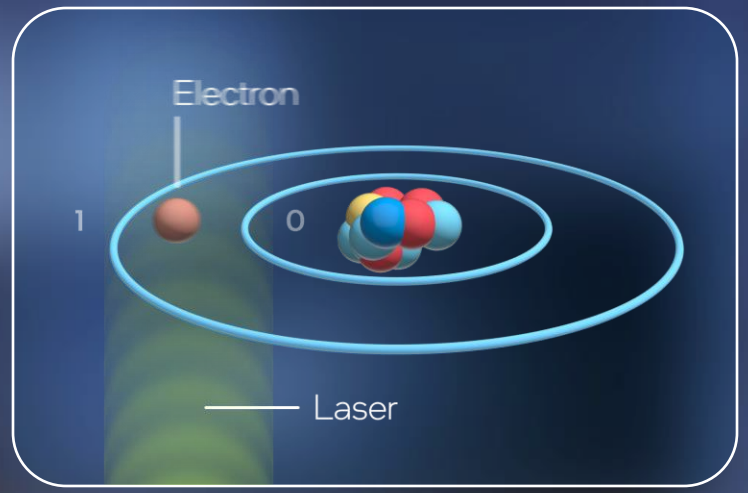
Quantum Computing

Spin Qbit technology

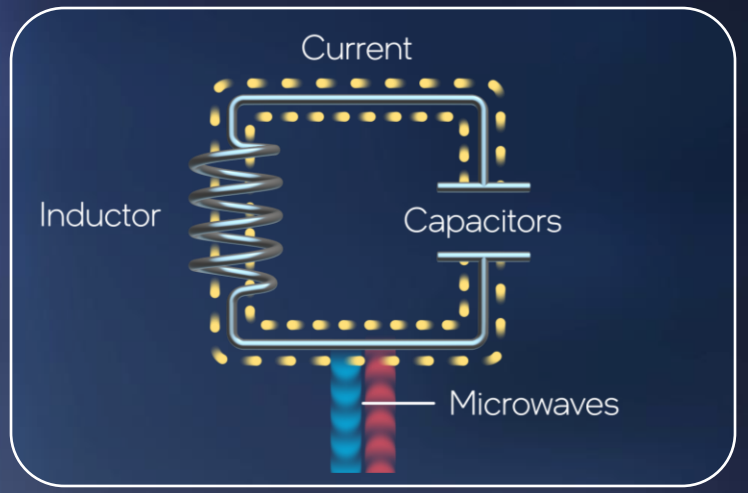
Cryogenic control technology

Full stack innovation

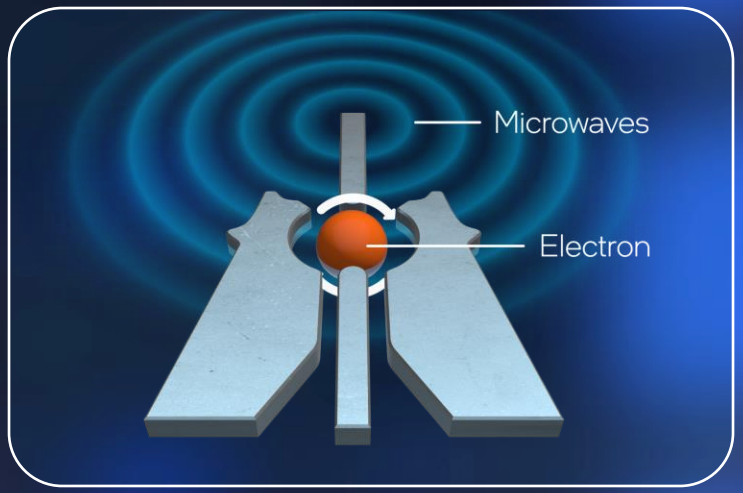
A Quantum Bit



Honeywell,
IonQ



Intel Corporation,
HRL



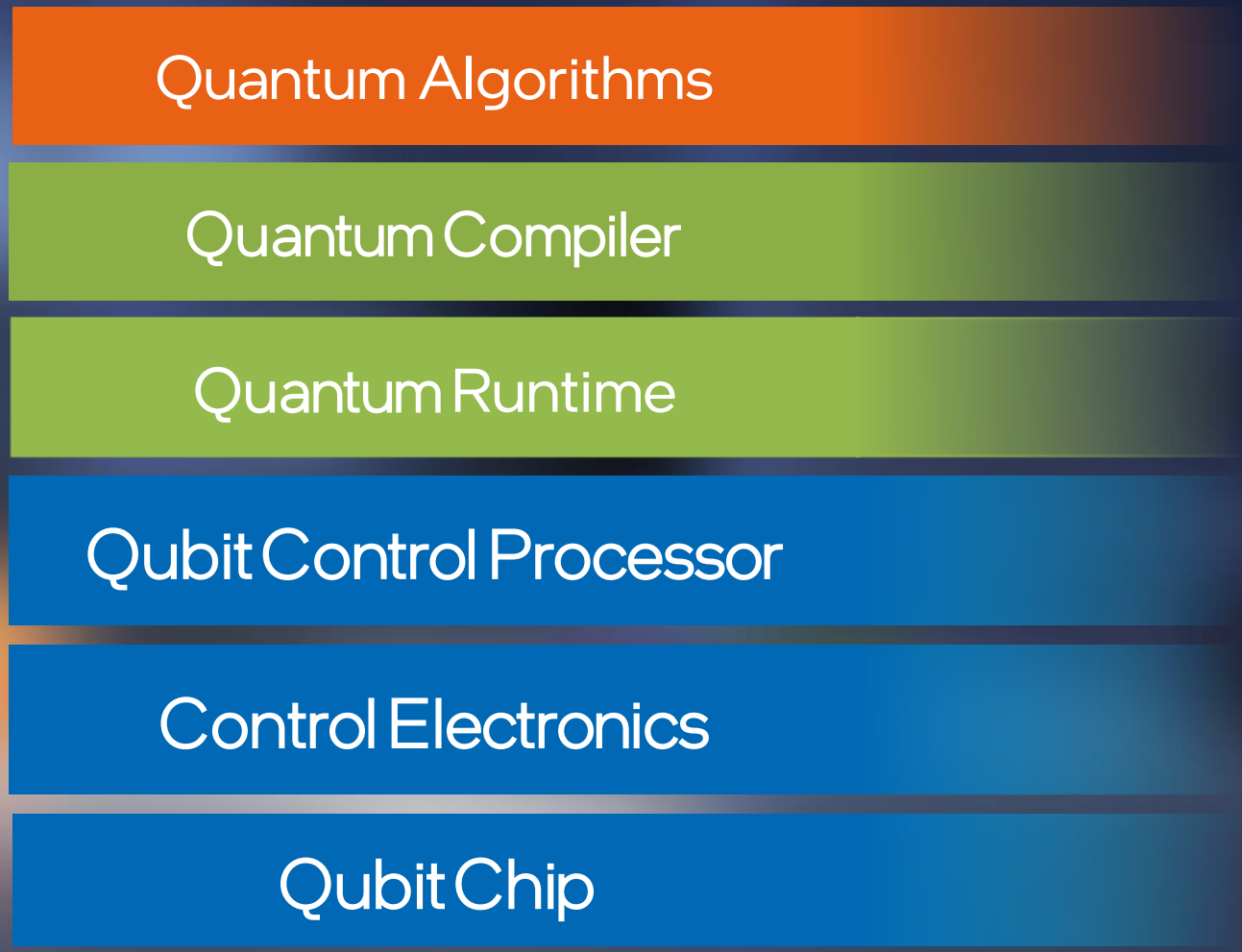
Google, IBM,
Rigetti, DWave

Only one of these Qubits is built on the technology of transistors

Other names and brands may be claimed as the property of others

Other names and brands may be claimed as the property of others

Architecture: Completely New Kind of Compute

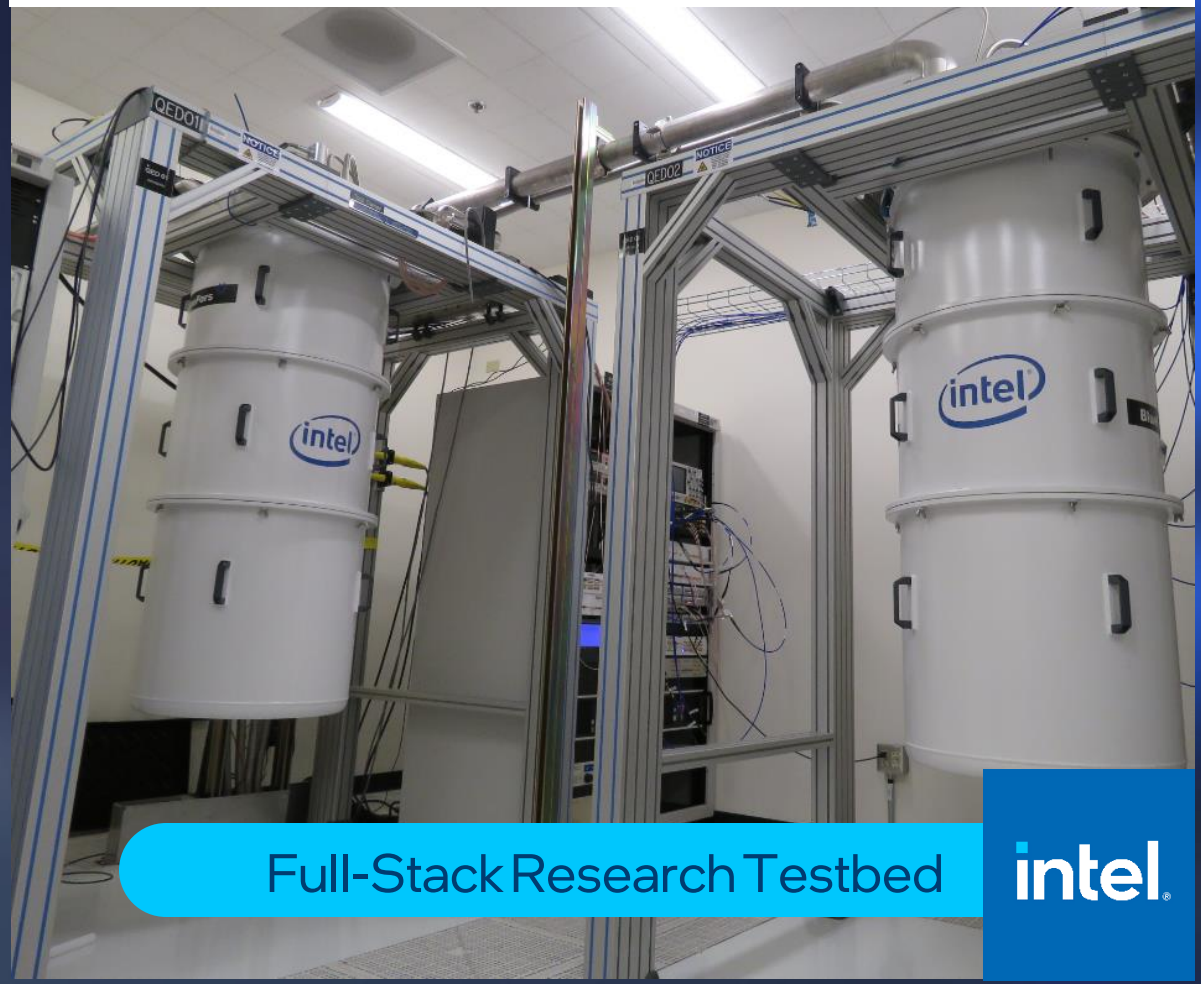


Key system challenges for Quantum Practicality

- New execution model
- Error mitigation & resilience
- Scalability
- Interconnect complexity
- Qubit device design

Putting it All Together

- Quantum Algorithms
- Quantum Compiler
- Quantum Runtime
- Qubit Control Processor
- Control Electronics
- Qubit Chip



*Q-NEXT brings together nearly 100 world-class researchers from three national laboratories, 10 universities and 10 leading U.S. technology companies with the single goal of developing the science and technology to control and distribute quantum information.

Confidential Computing
intel
labs

The Data Silo Problem

- Privacy / Legality
- Data too valuable
- Data too large to transmit

intel labs

Confidential Computing Edge to Cloud

Jason Martin
Principal Engineer, Security and Privacy Research

Labs Day 2020

Confidential Computing

Data Confidentiality

Execution Integrity

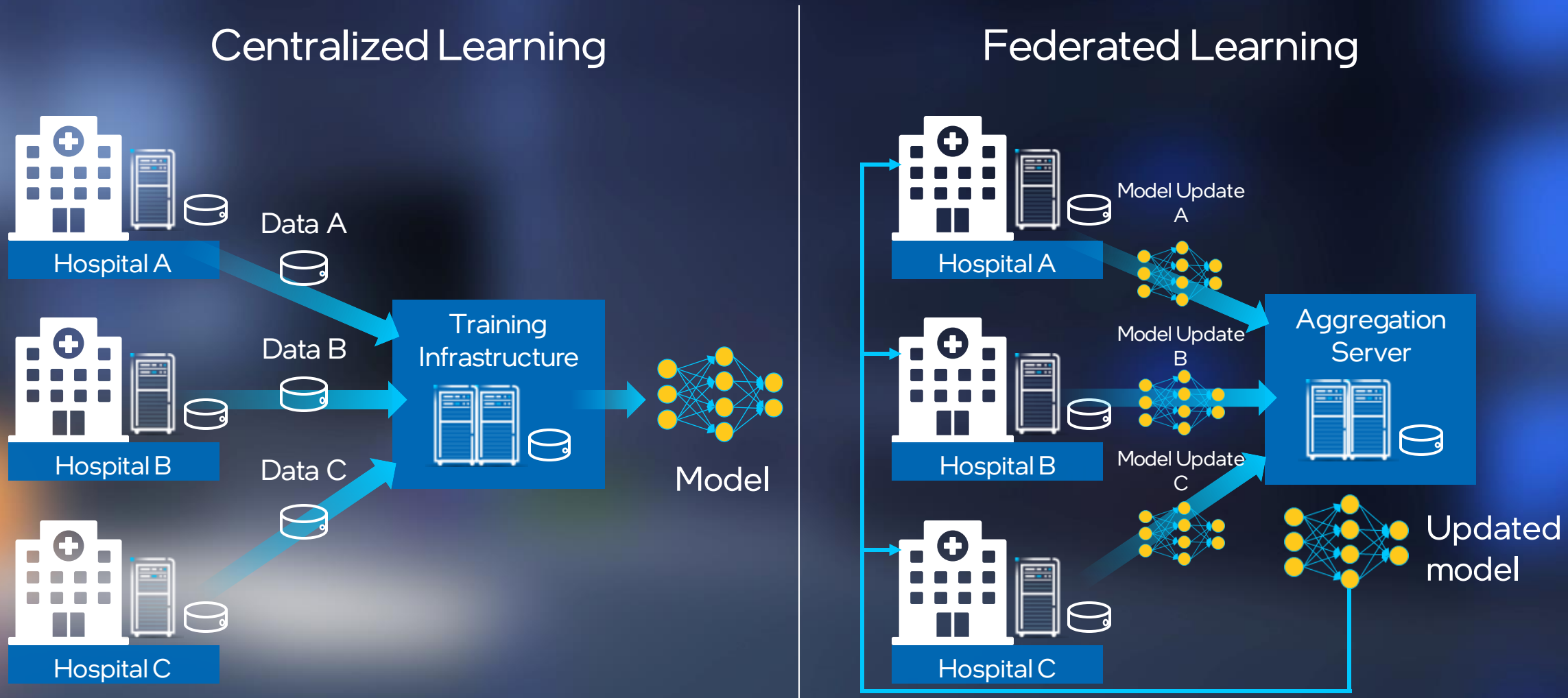
Attestation

Confidential Computing

Hardware Control Access

Encryption

Federated Learning – Move Compute to Data



Intel-UPenn Collaboration

nature research | SCIENTIFIC REPORTS

nature research

Check for updates

OPEN

Federated learning in medicine: facilitating multi-institutional collaborations without sharing patient data

Micah J. Sheller[1], Brandon Edwards[1], G. Anthony Reina[1], Jason Martin[1], Sarthak Pati[2,3], Aikaterini Kotrotsou[4,5], Mikhail Milchenko[6], Weilin Xu[1], Daniel Marcus[6], Rivka R. Colen[4,5,7,8] & Spyridon Bakas[2,3,9]

How much better does each institution do when training on the full data vs. just their own data?

17% BETTER on the hold-out BraTS data

2.6% BETTER on their own validation data

Brain tumor segmentation finds tumors from MRIs

Other names and brands may be claimed as the property of others

Sheller, M.J., Edwards, B., Reina, G.A. *et al.* Federated learning in medicine: facilitating multi-institutional collaborations without sharing patient data. *Sci Rep* **10,** 12598 (2020).

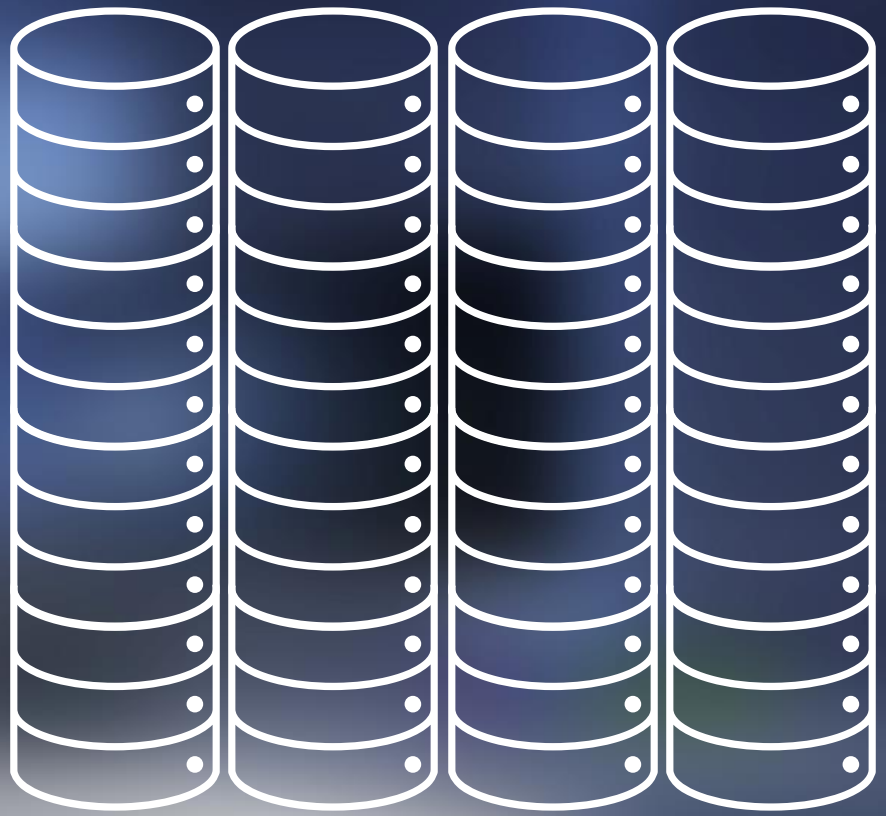
Fully Homomorphic Encryption

Traditional Encryption

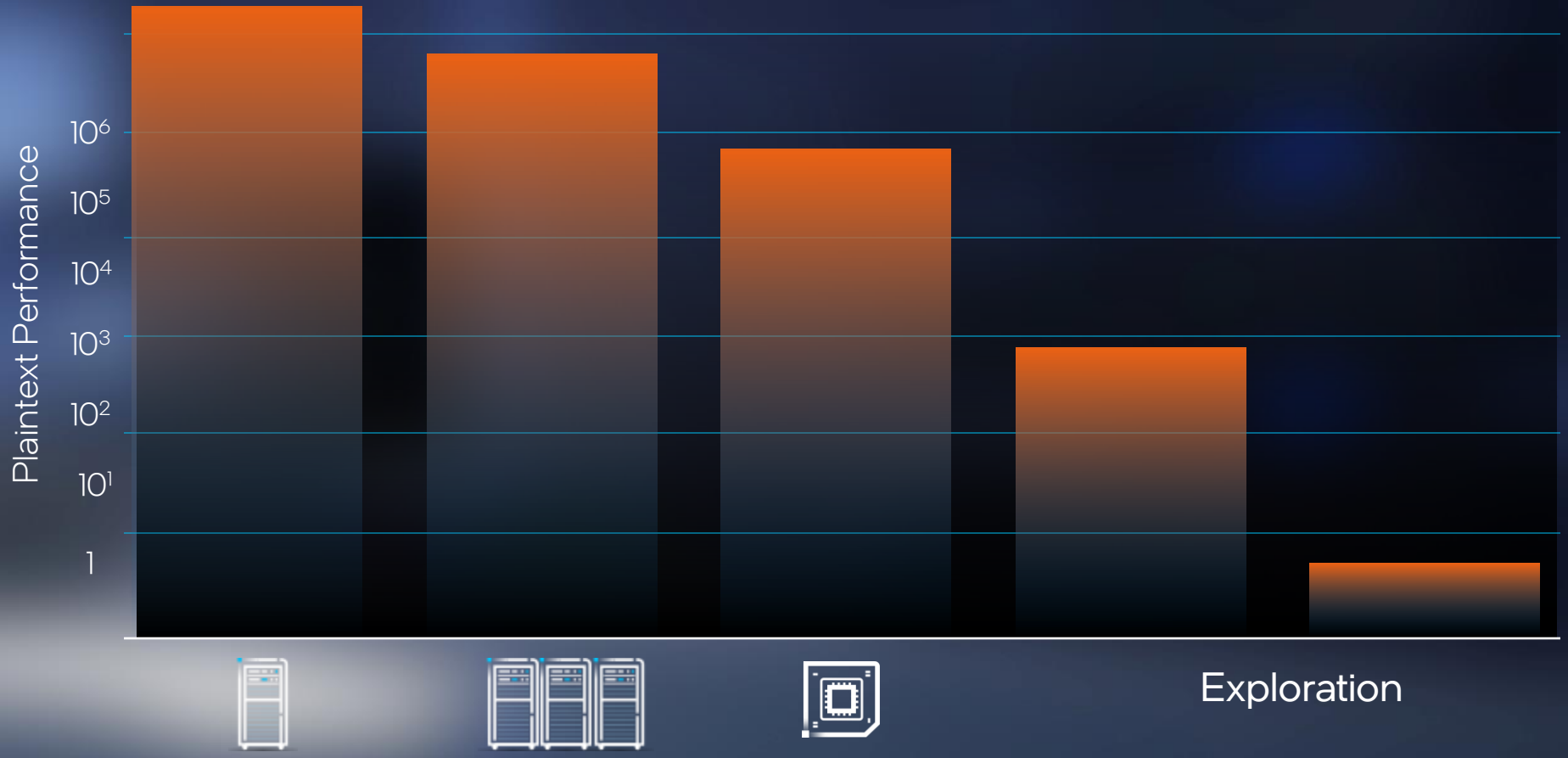
Fully Homomorphic Encryption

10,000X

Larger



FHE Performance Explorations



See cited sources for workloads and configurations. Results may vary.
Jung et al. HEANN Demystified. arXiv:2003.04510, March 2020
Riazi et al. HEAX. ASPLOS 2020

Intel Launches Private AI Collaborative Research Institute

Advancing technologies in privacy and trust for decentralized AI

Carnegie Mellon University
National University of Singapore
Université Catholique de Louvain
University of California, San Diego
University of Louvain
University of Southern California
University of Toronto
University of Waterloo
Technische Universität Darmstadt

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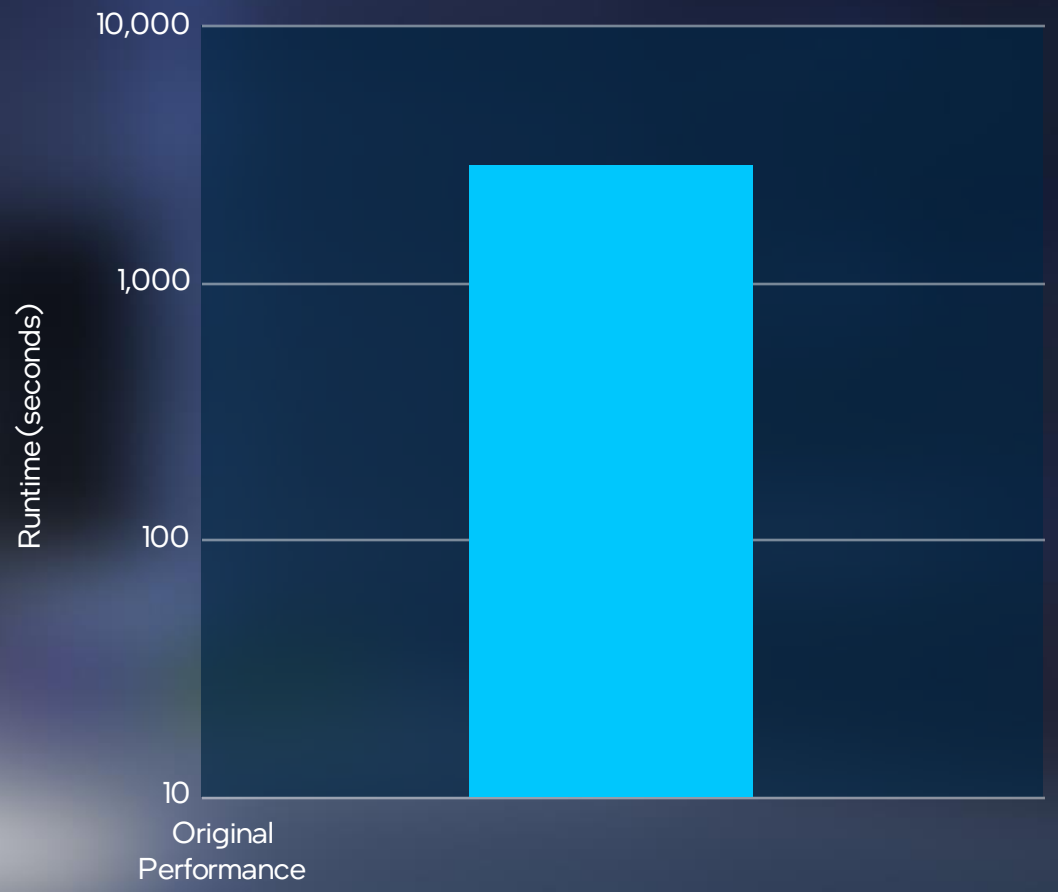
Machine Programming

Programming Challenges

Programming in the XPU Era



A cosmology application from the Stephen Hawking Institute

Source: Intel Labs

Ninja – an expert in SW development generally requiring a deep understanding of HW

Programming Challenges

Programming in the XPU Era

A cosmology application from the Stephen Hawking Institute

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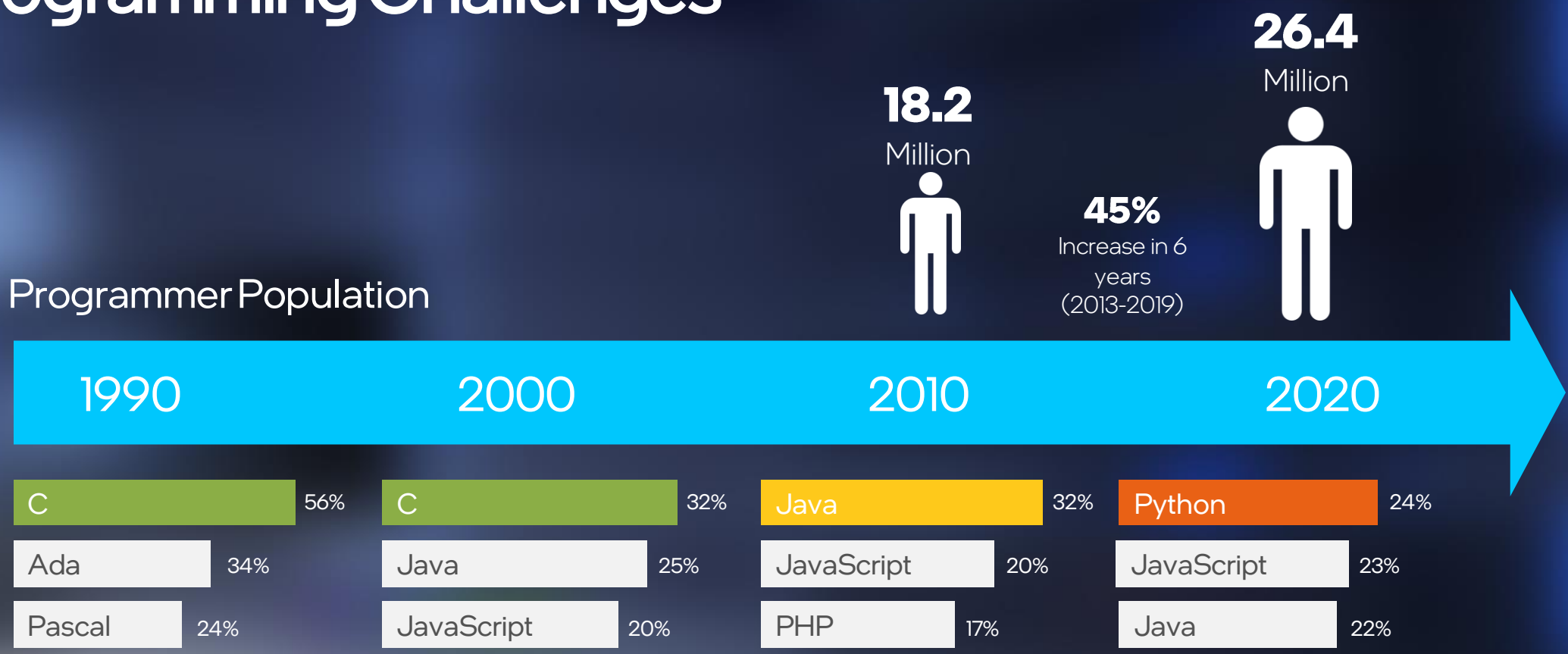
Programming Challenges



Other names and brands may be claimed as the property of others
Source – Programming Languages: https://youtu.be/Og847HVwRSI, http://pypl.github.io/PYPL.html
Source – Programmer Population size: http://www.computersciencezone.org/developers

intel labs

Reimagining the Future of AI-assisted Software Design

Justin Gottschlich
Principal Engineer, Machine Programming Research

Labs Day 2020

How do you develop software to fully exercise the capabilities of these novel types of hardware?

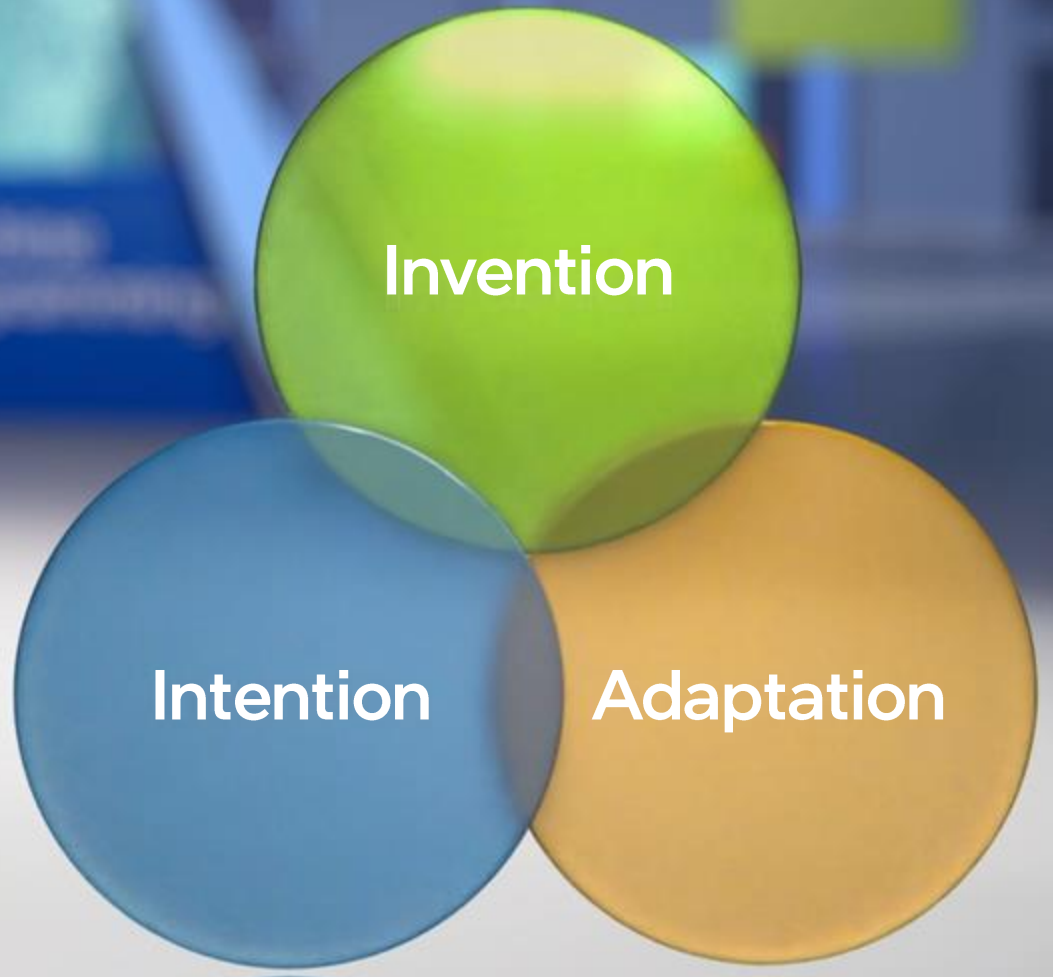
Machine Programming

- Any technique that automates software development

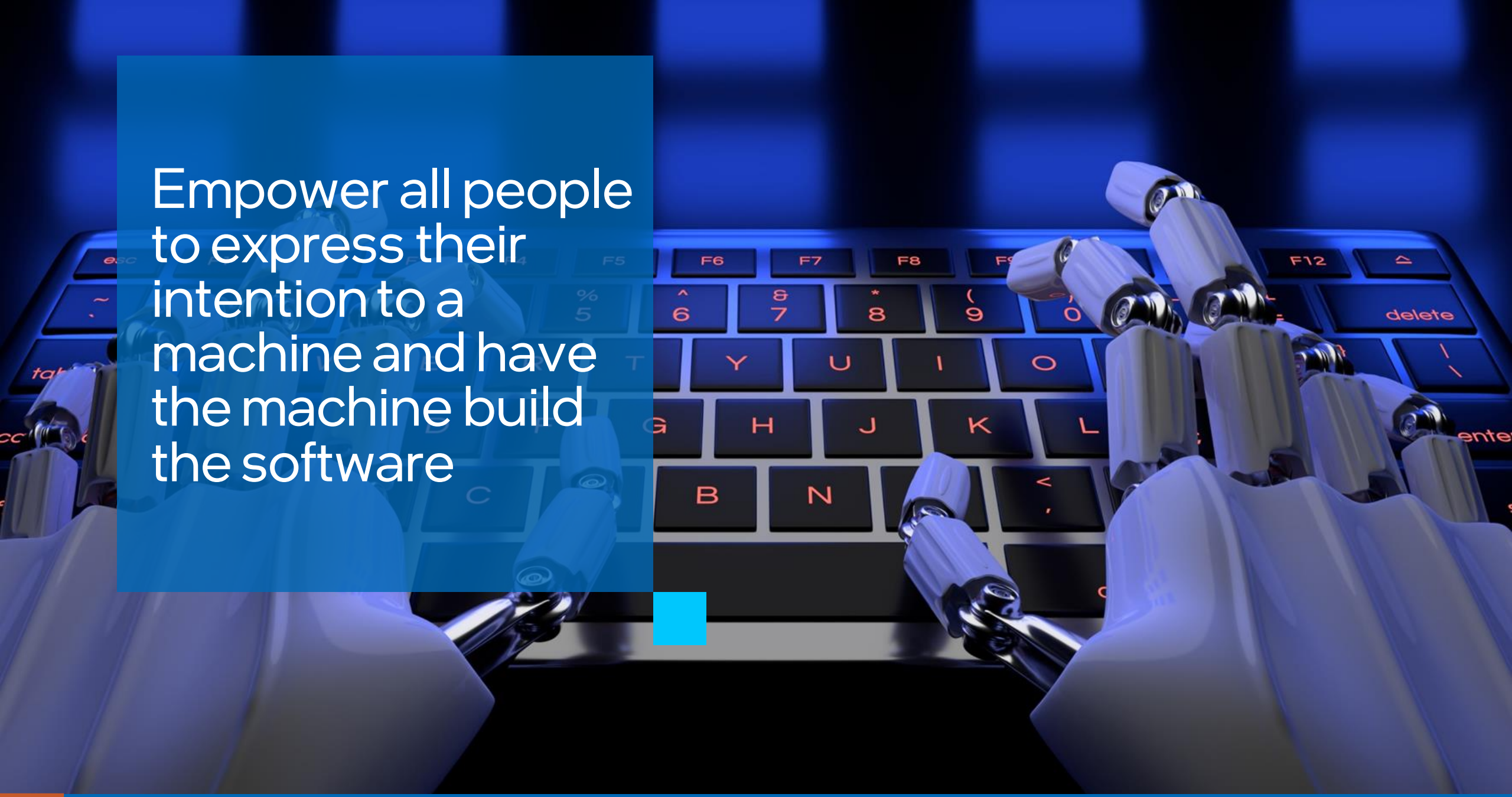
Intel's goal with MP

- Democratize and accelerate the creation of quality software

The Three Pillars of Machine Programming



Less than 1% of the global
population can code.


Empower all people to express their intention to a machine and have the machine build the software

Programmers spend
50% of their time debugging
Can we do better?

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The Future Begins Here
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Labs Day 2020 | December 3