State-of-the-art Supercomputers

NRIS

Norwegian research infrastructure services

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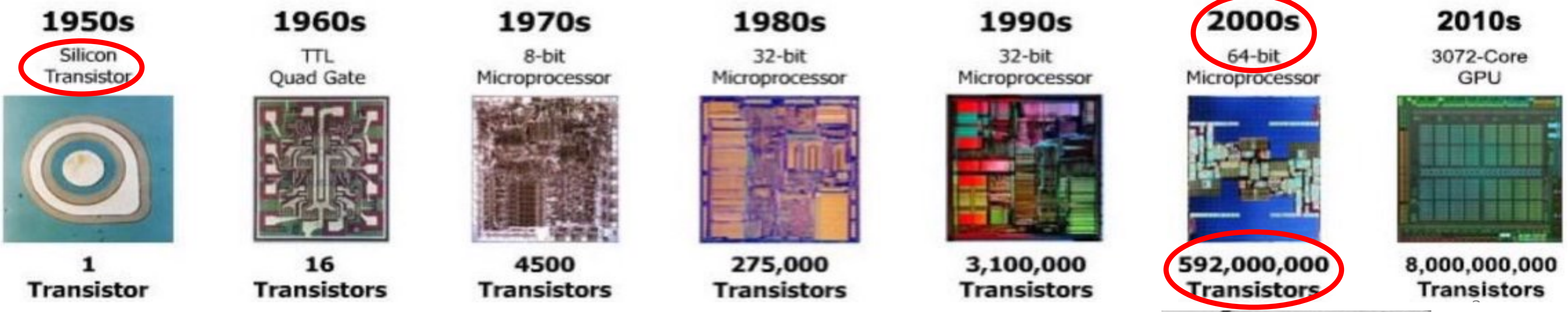
Overview

- **Evolution of Processors & transistors**
- **Evolution of Supercomputers**
- **What Supercomputers can be used for?**

Evolution of Processors: last 70 years



Mohamed Attala

Invented in 1959 & In production Until 2018

Dawon Kahng

- Transistors are the **building block of a processor.**
- **Transistors** are fabricated using a concept based on **metal-oxide-silicon**.
- **Clock rate**: Transistors can switch on/off (one-cycle) from million times per second (MHz) up to billion times per second (GHz).
- The performance of a processor depends on how fast transistors can switch on/off.

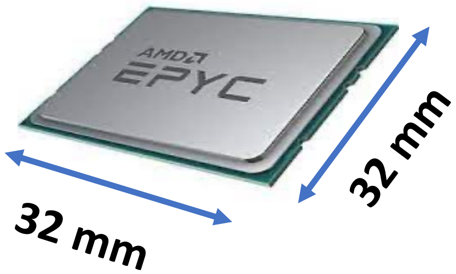
64-bit in 2000s was a big step in performing precise calculations

Evolution of transistors in processor

AMD CPU

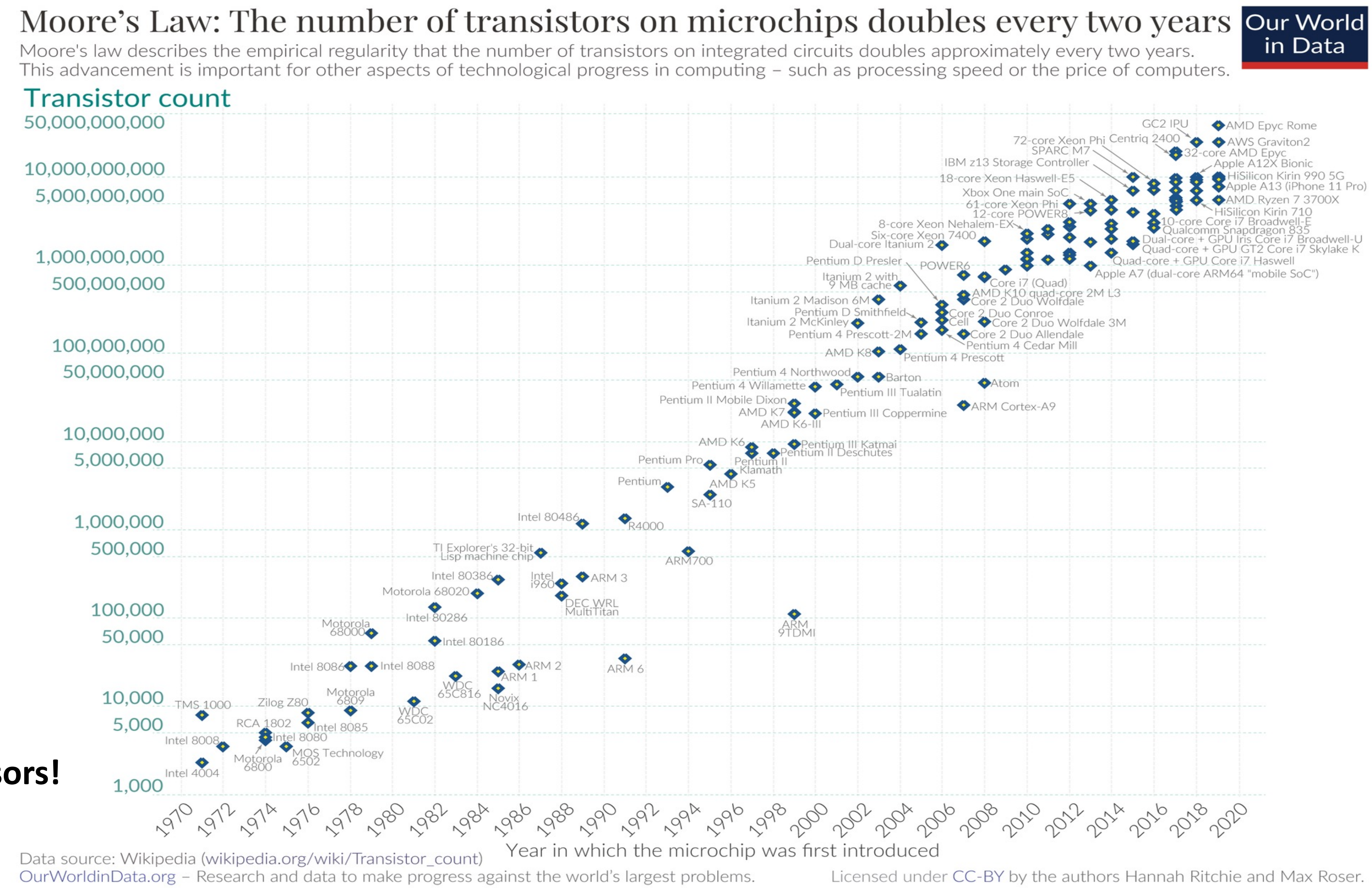
~40 billion transistors

1008 mm^2



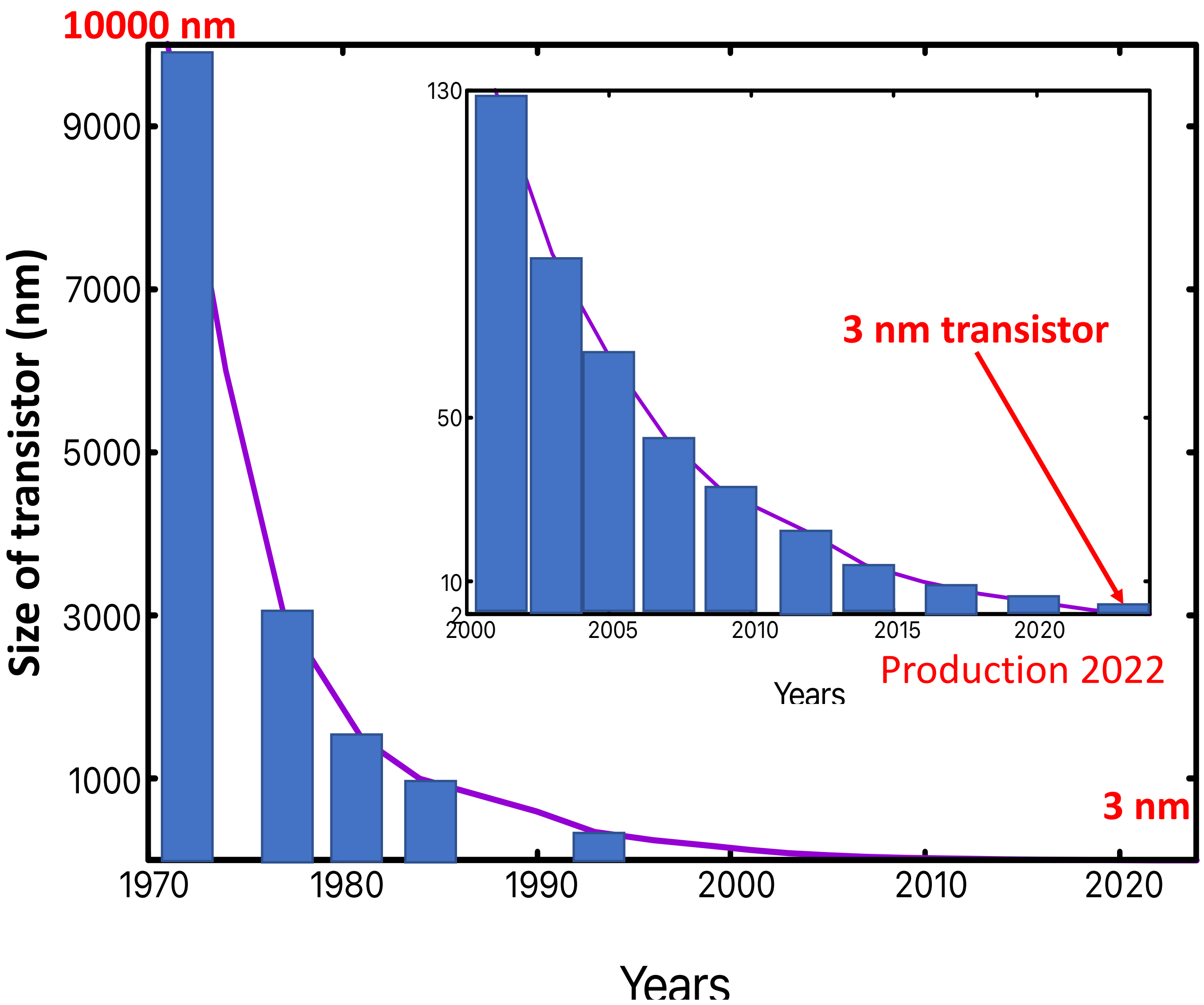
4-5 nm sized-transistor

This is a big step....in modern processors!



https://en.wikipedia.org/wiki/Moore%27s_law#cite_note-153

Evolution of transistors: last 50 years



About 3334 times smaller

BUT is it possible to go below nm....??

https://en.wikipedia.org/wiki/Moore%27s_law#cite_note-153

Perspective:

Towards PetaHz(10^6 GHz)-CPU with pico-m (10^-3 nm) sized-transistors

Atomic engineering

LETTERS

PUBLISHED ONLINE: 19 FEBRUARY 2012 | DOI: 10.1038/NNANO.2012.21

nature nanotechnology

A single-atom transistor

Martin Fuechsle[1], Jill A. Miwa[1], Suddhasatta Mahapatra[1], Hoon Ryu[2], Sunhee Lee[3], Oliver Warschkow[4], Lloyd C. L. Hollenberg[5], Gerhard Klimeck[3] and Michelle Y. Simmons[1]*

Fabrication of working devices such as transistors with extremely short gate lengths **requires** the ability to **position individual atoms** in materials with atomic precision. Ultimatly to make **atomic-scale logic circuits** that operate at the **picometer (10^-3 nm)-length scale**.

This is a breakthrough in physical sciences!

Perspective:

Towards PetaHz(10^6 GHz)-CPU with pico-m (10^-3 nm) sized-transistors

LETTER

RESEARCH LETTER

doi:10.1038/nature19821

Multi-petahertz electronic metrology

M. Garg[1], M. Zhan[1], T. T. Luu[1], H. Lakhotia[1], T. Klostermann[1], A. Guggenmos[1] & E. Goulielmakis[1]

The speed limit of electronics (signal processing) is determined by the frequency of electric current.
The use of light to drive electrons promises to access to vastly higher frequencies.
(increase the bandwidth of electronics).

Improving the performance by 6 order of magnitude.
From GHz (clock rate) towards PHz-based processors.

This is a breakthrough in physical sciences!

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Performance of a computer

- **The performance of a processor is measured by the quantity:**

FLOPS (**F**loiting-**P**oint of **O**pertaions **P**er **S**econd).

- It is a measure of the speed of a computer to perform arithmetic operations.

- **For a single processor**:

  FLOPS = (Clock speed)x(cores)x(FLOPs/cycle)=Peak performance

  FLOP is a way of encoding real numbers (i.e. DB 64bit or SP 32bit…)

- 1 GigaFLOPS: processor can handel **billion floating-point (64 bit) operations every second**.
- **For matching: 1GigaFLOPS ~performing one calculation every second for 31.69 years**.
- 1 TeraFLOPS = 10^12 calculations per second.
- 1 PetaFLOPS = 10^15 calculations per second.

Supercomputer

Cluster

Computer

(or node/server)

IBM Supercomputing timeline

1950 · 1960 · 1970 · 1990 · 2000 · 2010 · 2020

1954 NORC

1961 IBM 7030

1966 IBM 360

1997 Deep Blue

2004 Blue Gene

2008 Roadrunner

2011 Watson

2012 Sequoia

2018 Summit and Sierra

2019 Pangea III

2020 High Performance Computing Consortium

1954

The Naval Ordnance Research Calculator helped forecast weather and performed other complex calculations.

1961

The **IBM 7030** was capable of 2 million operations per second.

1966

The **IBM 360** and its successors helped power NASA's Apollo program.

1997

Deep Blue wins its match with chess grandmaster Garry Kasparov.

2004

Blue Gene ushers in a new era of high-performance computing as it helps biologists explore gene development.

2008

Built for Los Alamos National Laboratory, **Roadrunner** is the first super-computer in the world to reach petaflop speed.

2011

Watson beats human competitors on Jeopardy!, earning a million-dollar jackpot for charity.

2012

Sequoia, the third-generation **Blue Gene** system, reaches speeds of 16.32 petaflops.

2018

Summit begins work at Oak Ridge National Laboratory; a sister machine, **Sierra,** launches at Lawrence Livermore National Laboratory.

2019

IBM builds **Pangea III,** the world's most powerful commercial super-computer, for Total to accurately locate new energy resources.

2020

IBM helps launch the COVID-19 **High Performance Computing Consortium** to research the COVID-19 virus and its potential cures.

MegaFLOPS
Million operation/s

1st supercomputer

A new era of HPC

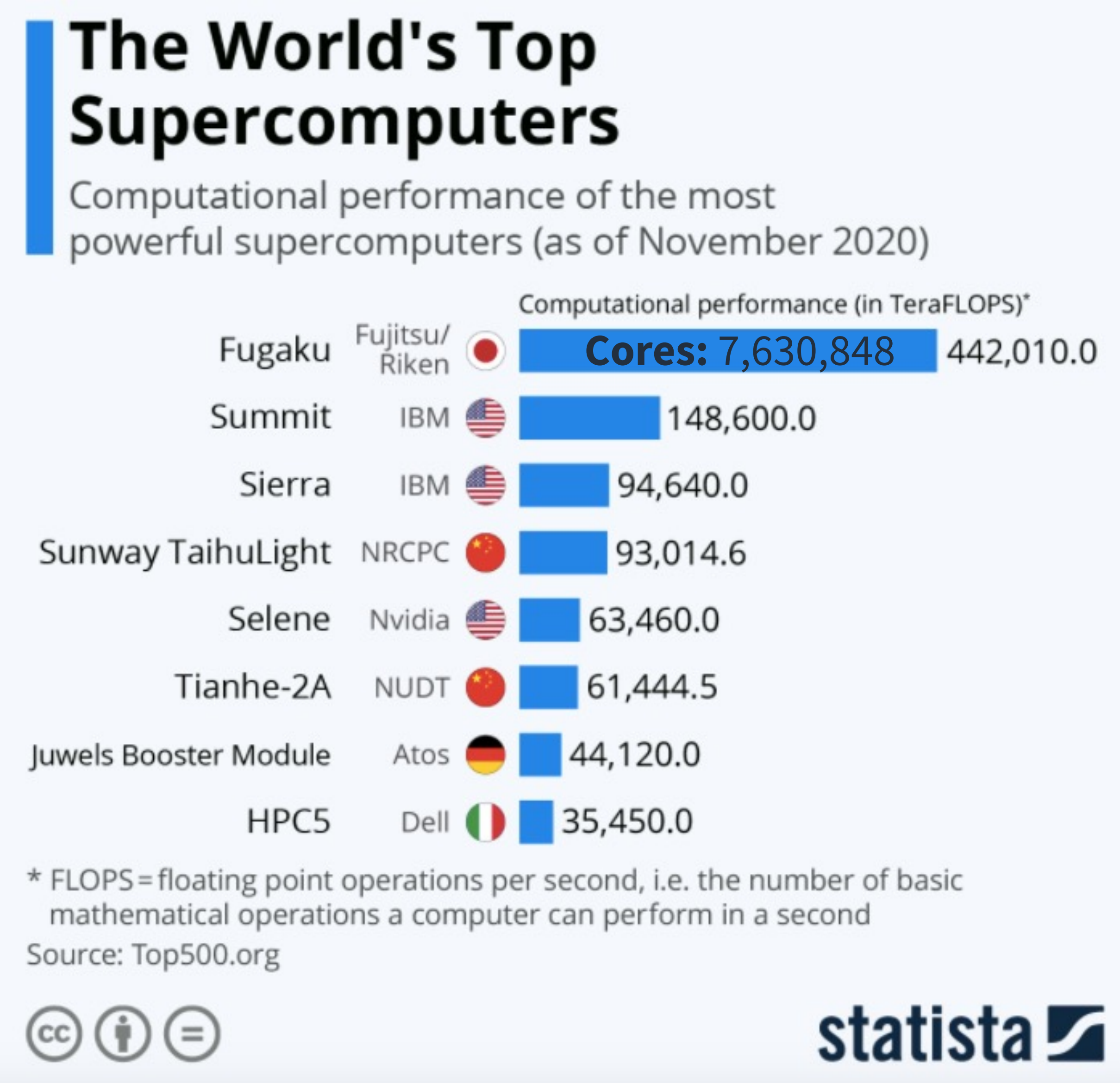
PetaFLOPS
Quadrillion

1st P-FLOPS supercomputer

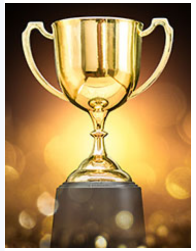
16 PetaFLOPS

~500 PetaFLOPS

IBM



https://www.fujitsu.com/



The Fugaku (**158,976 nodes**) compute system was designed and built by Fujitsu and RIKEN. They take the first place worldwide in TOP500.

Peak performance
537 PetaFLOPS
=537 (quadrillion) 10^15 (64 bit) operations/s
Exceeding Summit by more 3x.

https://www.top500.org/

LUMI is one of the fastest supercomputers in the world

Taken from https://www.lumi-supercomputer.eu/

- **LUMI** (Large Unified Modern Infrastructure):
- **LUMI** is located in a data center in Kajaanni, **Finland**.
- Funded by the **EuroHPC JU** (50%) and a **consortium of 10 countries.**
- **LUMI consortium**: Finland, Belgium, The Czech republic, Denmark, Estonia, **Norway**, Poland, Sweden, Switzerland and Iceland.

Peak Performance

550 Petaflop/s
~550 quadrillion calculations per second

Computing power equivalent to

1 500 000

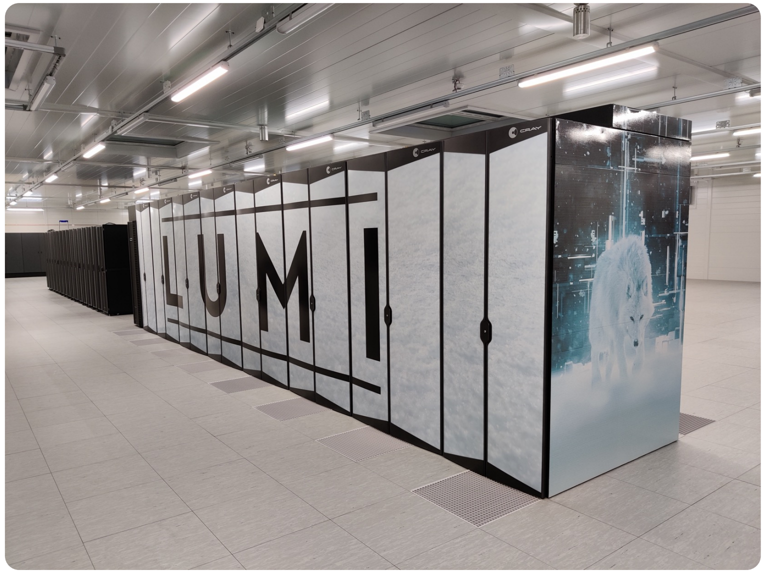
Modern laptop computers

About the size of a tenis court

Weight around 150 000 Kg

LUMI

Phase 1: CPU Partition (LUMI-C)



- **1536 compute nodes** with 2x AMD EPYC 7763 (Milan)
- 128 cores per node, **196 608 cores** total
- 256 GiB of memory per node
- Some nodes with 512 GiB and 1 TiB

Phase 2: GPU Partition (LUMI-G)

- Next generation AMD Instinct GPUs (**2560 nodes** each with **8 GPUs** (MI250X))
- 550 Pflops peak performance
- The fastest supercomputer in Europe
- Available summer (August-September) 2022

Norway's share (2 %: ~ 4000 cores on LUMI-C, ~ 200 GPUs on LUMI-G)

EuroHPC JU's share (50 %: ~ 100k cores on LUMI-C, ~ 5000 GPUs on LUMI-G)

Adapted from Orian Louant, LUMI User Support Team

What Supercomputers can be used for ?

To solve majore challenges in the world.

Supercomputer platfrom

High-Performance Computing (HPC)

Artificial Intelligence (AI)

To solve complicated problems in physical sciences engineering such that:

- Exploring the boundaries of quantum chemistry (first project LUMI).
- Predicting the structure of proteins using data-driven methodologies (ML, DL).
- Understanding the functionality **of COVID-19 virus** & potential cures.
- Desiging new molecues with unique functionality for modern technology.
- Delivering reliable weather and climate predictions.

Conclusion

- The **lifetime** of high-performance **hardware** is less than **five years**, while **software can be used for decades**.
- **Software investments** should therefore provide more **flexibility to new and fast evolving technology**.