

# Overview of Supercomputers



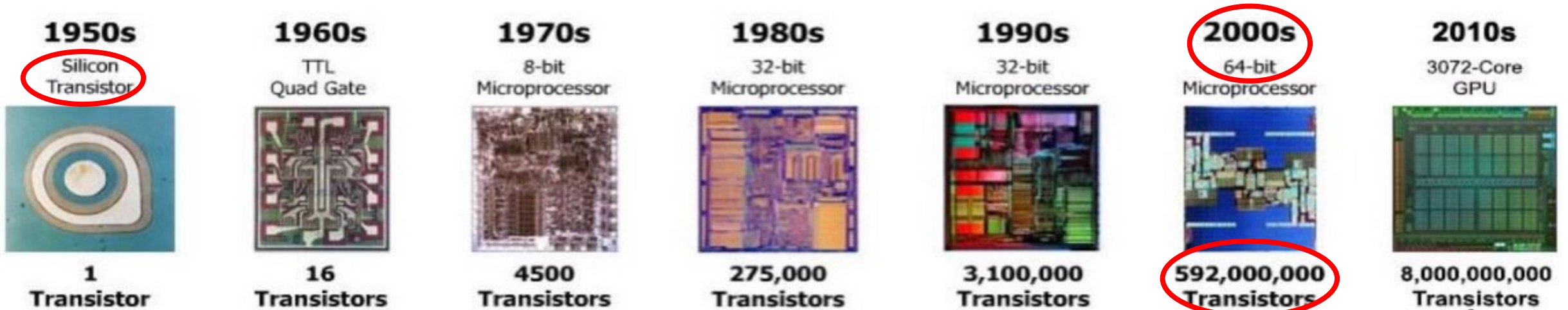
Norwegian research infrastructure services

Hicham Agueny, PhD  
Scientific Computing Group  
IT-department, UiB

# Overview

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

# Evolution of Processors: last 70 years



- 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**



**Mohamed Attala**

Invented  
in 1959 &  
In production  
Until 2018



**Dawon Kahng**



# Evolution of transistors in processor

Moore's Law: The number of transistors on microchips doubles every two years

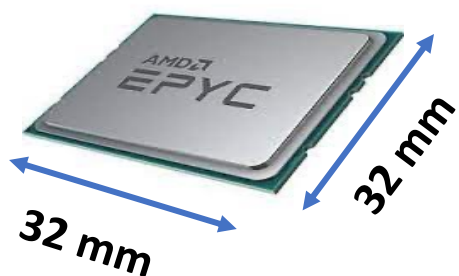
Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important for other aspects of technological progress in computing – such as processing speed or the price of computers.

Our World  
in Data

## AMD CPU

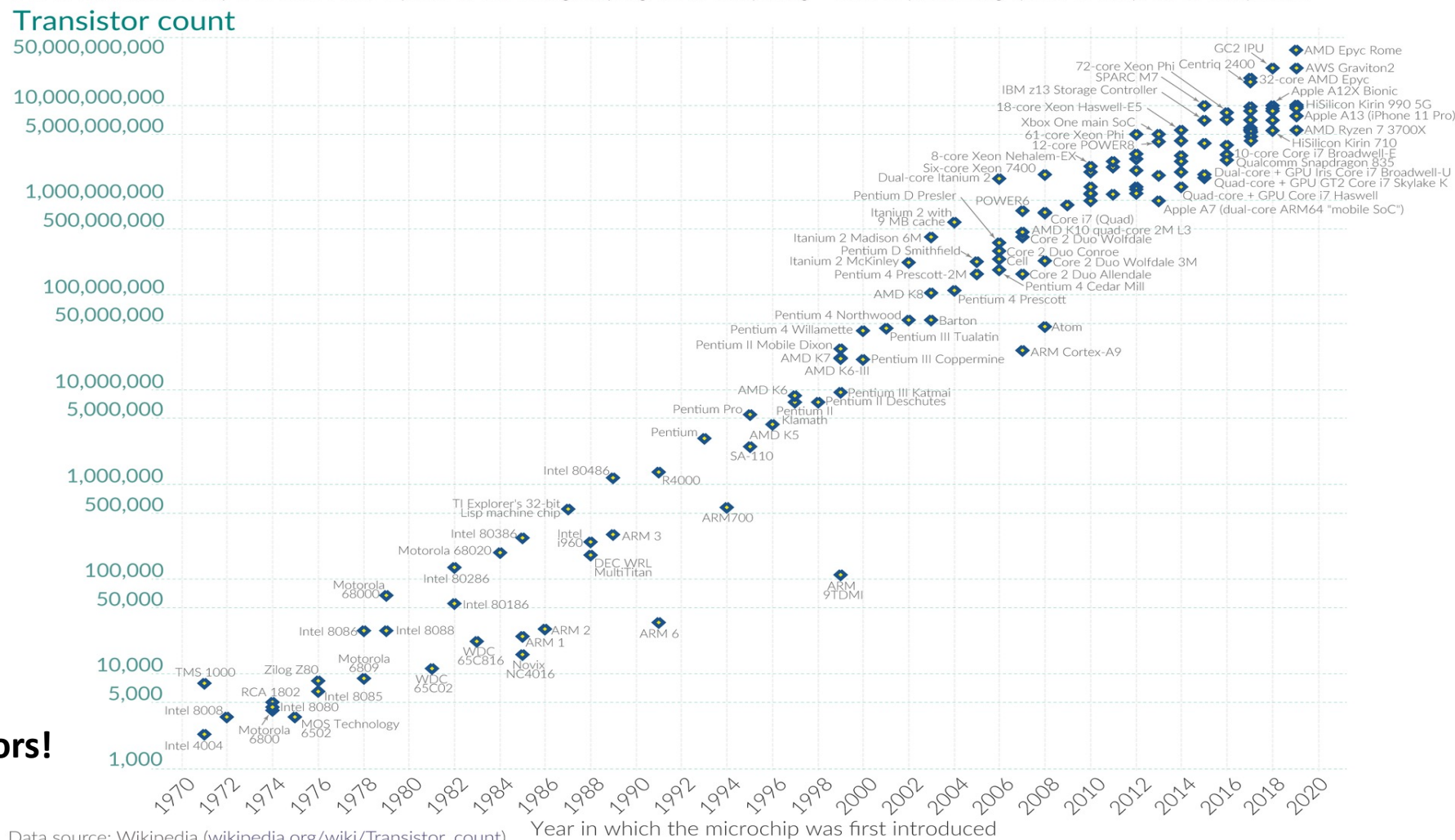
**~40 billion transistors**

**1008 mm<sup>2</sup>**



## 4-5 nm sized-transistor

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

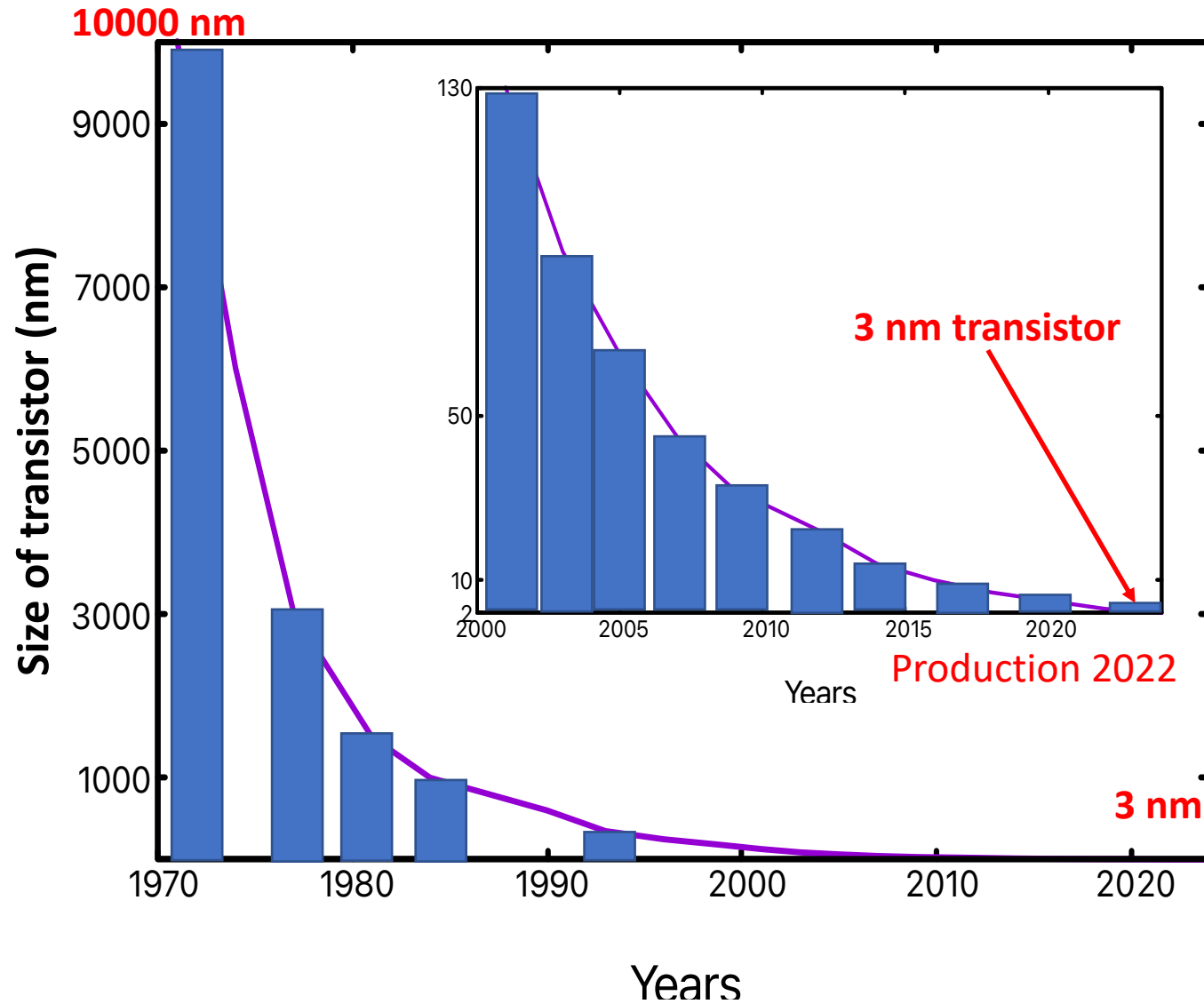


Data source: Wikipedia ([wikipedia.org/wiki/Transistor\\_count](https://wikipedia.org/wiki/Transistor_count))

OurWorldinData.org – Research and data to make progress against the world's largest problems.

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# Evolution of transistors: last 50 years



About 3334 times smaller

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

# 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<sup>1</sup>, Jill A. Miwa<sup>1</sup>, Suddhasatta Mahapatra<sup>1</sup>, Hoon Ryu<sup>2</sup>, Sunhee Lee<sup>3</sup>,  
Oliver Warschkow<sup>4</sup>, Lloyd C. L. Hollenberg<sup>5</sup>, Gerhard Klimeck<sup>3</sup> and Michelle Y. Simmons<sup>1\*</sup>

**Fabrication of working devices such as transistors with extremely short gate lengths requires the ability to position individual atoms** in materials with atomic precision.

Ultimately 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<sup>1</sup>, M. Zhan<sup>1</sup>, T. T. Luu<sup>1</sup>, H. Lakhotia<sup>1</sup>, T. Klostermann<sup>1</sup>, A. Guggenmos<sup>1</sup> & E. Goulielmakis<sup>1</sup>

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

# Performance of a computer

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

**FLOPS (Floiting-Point of Opertaions Per Second).**

- 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



**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 supercomputer 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 supercomputer, 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

**1<sup>st</sup> supercomputer**

**A new era of HPC**

**PetaFLOPS**  
Quadrillion

**1<sup>st</sup> P-FLOPS supercomputer**

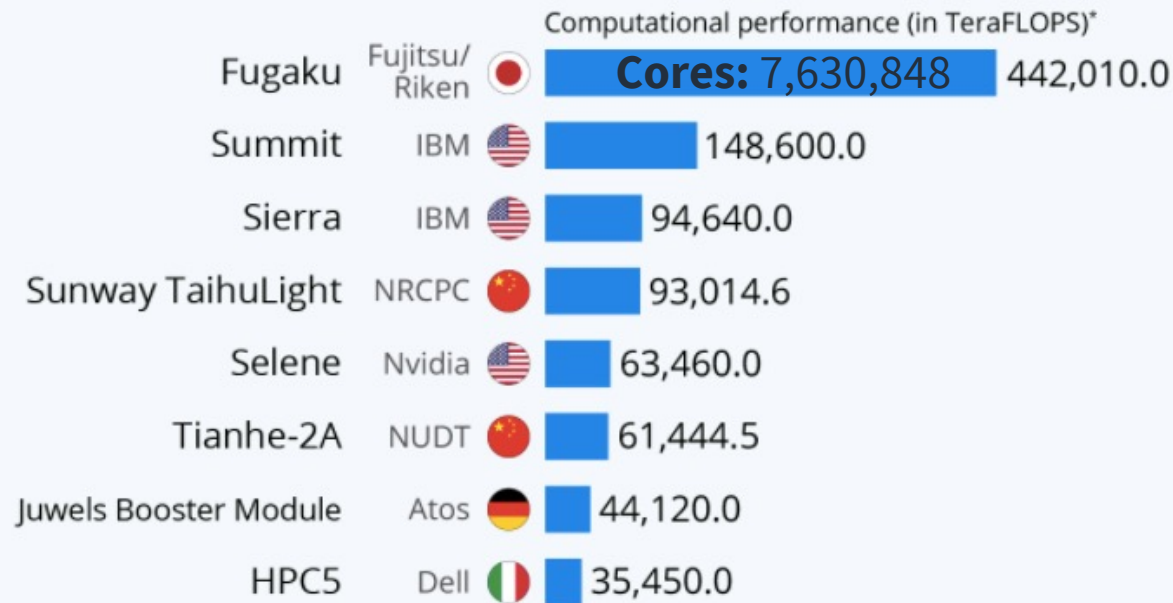
**16 PetaFLOPS**

**~500 PetaFLOPS**



# The World's Top Supercomputers

Computational performance of the most powerful supercomputers (as of November 2020)



\* FLOPS = floating point operations per second, i.e. the number of basic mathematical operations a computer can perform in a second

Source: Top500.org



statista



<https://www.fujitsu.com/>

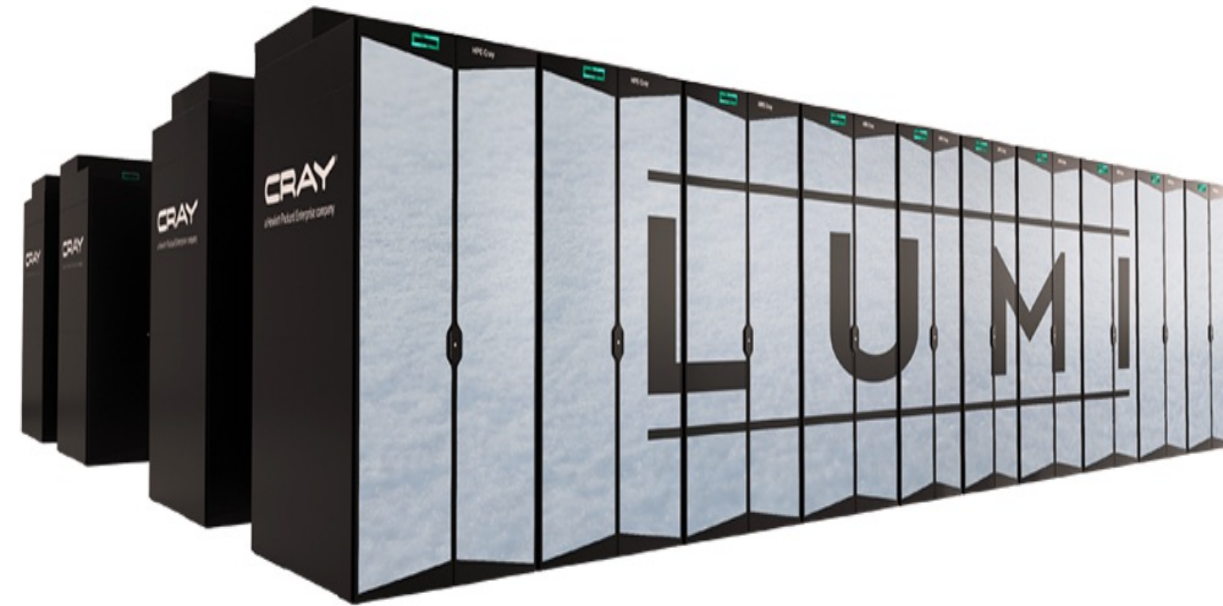
The Fugaku (158,976 nodes) compute system was designed and built by Fujitsu and RIKEN. They take the first place worldwide in TOP500.

**Peak performance**

**537 PetaFLOPS**

=537 (quadrillion)  $10^{15}$  (64 bit) operations/s  
Exceeding Summit by more 3x.

# 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 tennis court**



**Weight around 150 000 Kg**

## 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)**





# What Supercomputers can be used for ?

To solve majore challenges in the world.



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.**
- Designing new molecules 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**.