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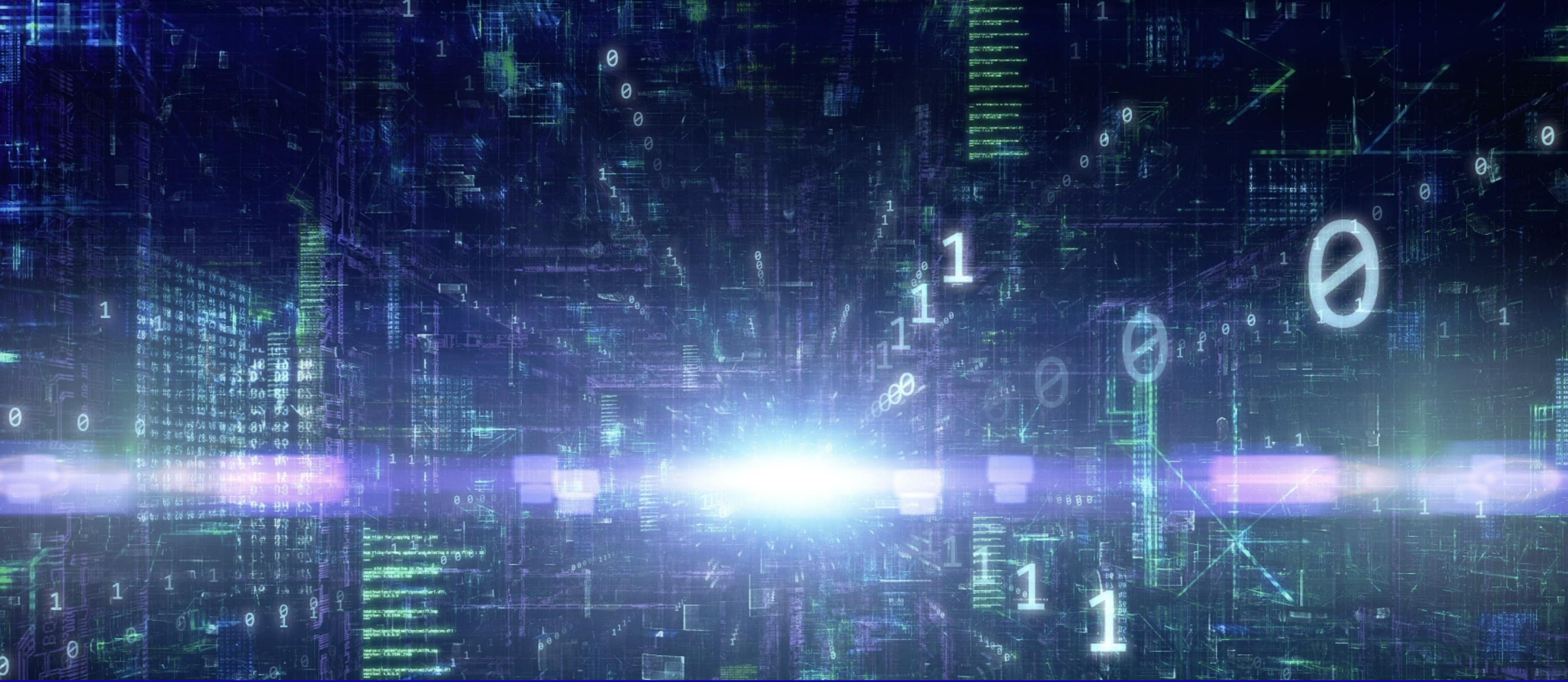
MACHING LEARNING FOR REMOTE SENSING BIG DATA POWERED BY SUPERCOMPUTING

UT-MESSAN – FEBRUARY 2ND – HARPA

Jon Atli Benediktsson & Gabriele Cavallaro



TOPICS AND OBJECTIVES OF THIS TALK

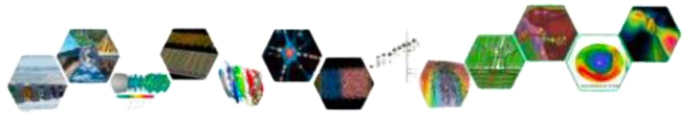
HOW TO USE ARTIFICIAL INTELLIGENCE FOR EARTH OBSERVATION AND EXTRACT INFORMATION IN A TIMELY MANNER WITH SUPERCOMPUTING?

ICELANDIC HPC COMMUNITY
SIMULATION AND DATA LAB REMOTE SENSING

ICELANDIC HIGH-PERFORMANCE COMPUTING (IHPC)

- Simulation and Data Lab Neuroscience
- Simulation and Data Lab Computational Chemistry
- Simulation and Data Lab Computational Fluid Dynamics
- Simulation and Data Lab Remote Sensing
- Simulation and Data Lab Electron, optical and transport properties of nanoscale systems – Computational Physics
- Natural Language Processing Lab
- Simulation and Data Lab Acoustic and Tactile Engineering
- Simulation and Data Lab Health and Medicine
- Algorithmic Mathematics Lab
- Simulation and Data Lab Software Engineering for HPC
- Statistical Weather Lab
- Quantum Simulation and Data Science Lab

EURO



– The members of IHPC established the Icelandic Simulation and Data Labs (SDLs)

– These labs incorporate academic and industrial partners who are involved in activities related to Artificial Intelligence, data analytics, and sciences.

– In a bottom-up approach, the SDLs collectively form the IHPC National Competence Center (NCC) for HPC & AI in Iceland

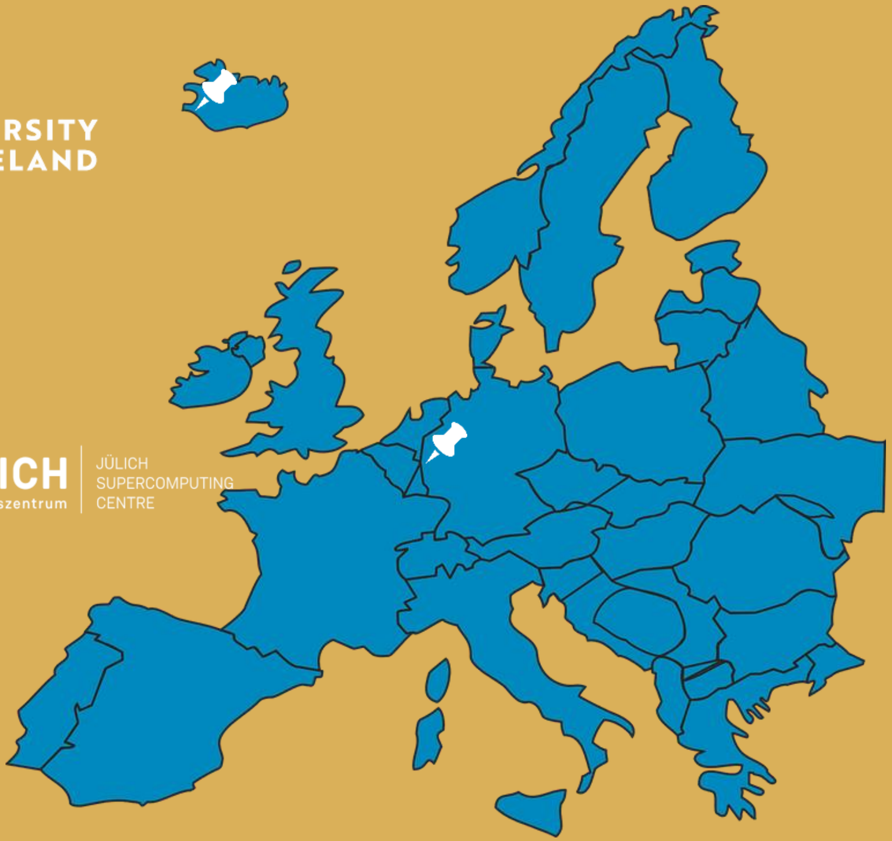
IHPC National Competence Center (NCC) for HPC & AI in Iceland, https://ihpc.is/

This work is co-financed by the EUROCC2 project funded by the European High-Performance Computing Joint Undertaking (JU) and EU/EEA states under grant agreement No 101101903.

SIMULATION AND DATA LAB. IN REMOTE SENSING

UNIVERSITY OF ICELAND

JÜLICH Forschungszentrum | JÜLICH SUPERCOMPUTING CENTRE



Jón Atli Benediktsson

Gabriele Cavallaro

Morris Riedel

(plus 6 PhD students and 1 Postdoc)

- International cooperation with the Jülich Supercomputing Centre (Forschungszentrum Jülich, Germany)
- Joint activities that include research projects, teaching courses, community support and supervision of students at different academic levels

Jülich Supercomputing Centre, Forschungszentrum Jülich, https://www.fz-juelich.de/en/ias/jsc

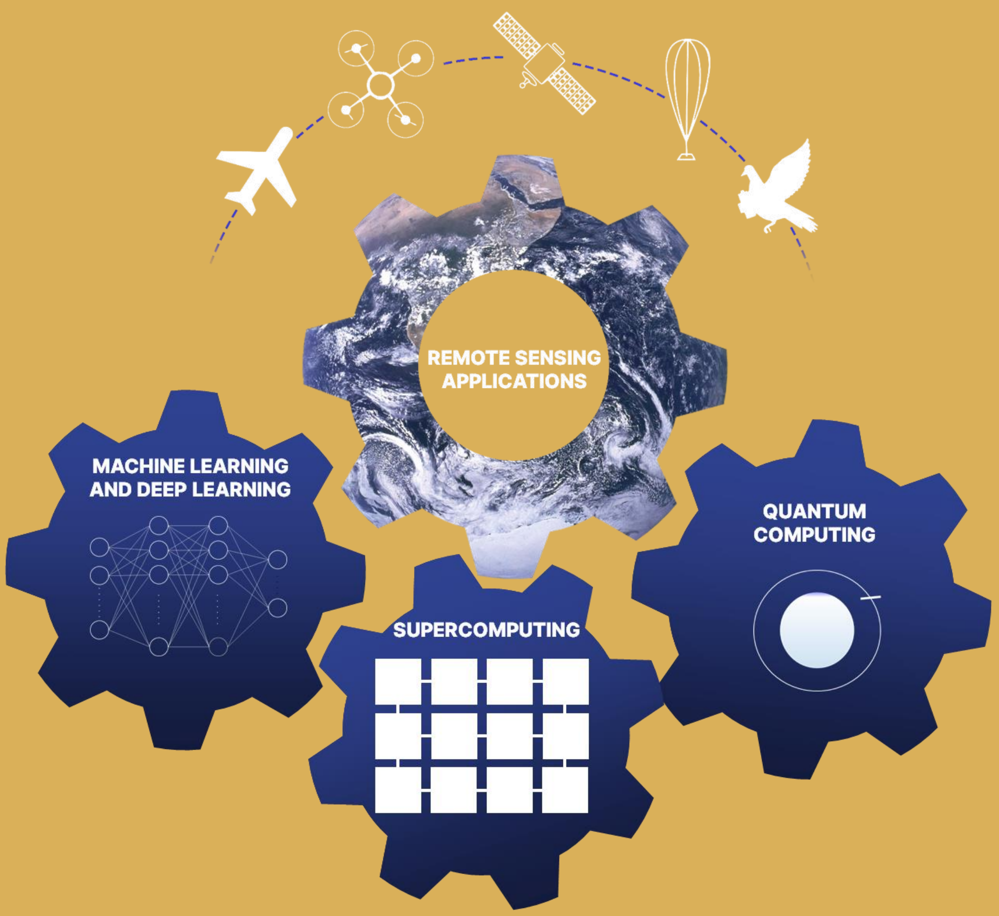
School of Engineering and Natural Sciences, University of Iceland, https://english.hi.is/school_of_engineering_and_natural_sciences

SDL AI and ML for Remote Sensing, https://www.fz-juelich.de/en/ias/jsc/about-us/structure/simulation-and-data-labs/sdl-ai-ml-remote-sensing

Simulation and Data Lab Remote Sensing, https://ihpc.is/simulation-and-data-lab-remote-sensing/

INTERDISCIPLINARY WORK AND RESEARCH ACTIVITIES

https://ihpc.is/simulation-and-data-lab-remote-sensing/



https://eo4society.esa.int/projects/qc4eo-study/

https://www.grss-ieee.org/technical-committees/earth-science-informatics/

https://www.coe-raise.eu/

https://www.admire-eurohpc.eu/

https://eupex.eu/

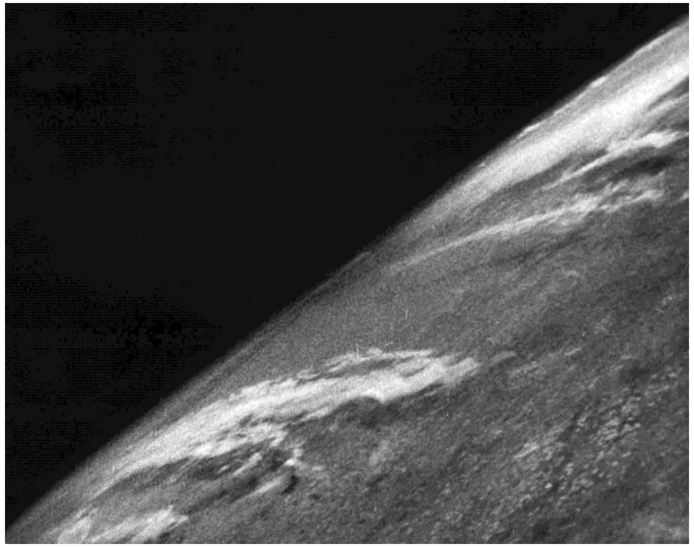
https://www.euspa.europa.eu/embed2scale-earth-observation-weather-data-federation-ai-embeddings

https://www.fz-juelich.de/en/ias/jsc/about-us/structure/simulation-and-data-labs/sdl-ai-ml-remote-sensing

REMOTE SENSING

FIRST IMAGE FROM SPACE

The first satellite image was taken on August 14, 1959, by the U.S. satellite Explorer 6



V-2 rocket (sub-orbital) - 1946

Explorer 6 (orbital, 27,000 Km) - 1959

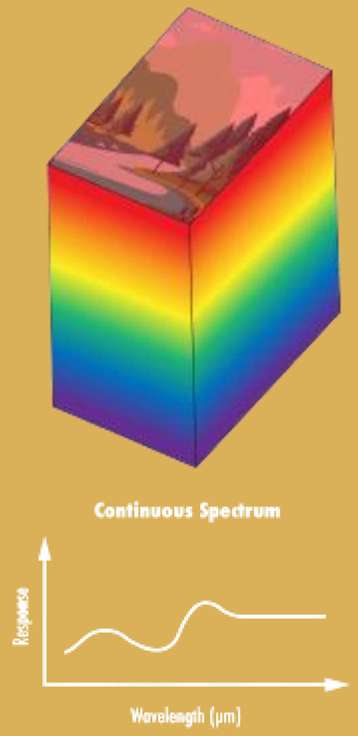
Satellite imagery, https://en.wikipedia.org/wiki/Satellite_imagery#History

- The actual first images from space were taken during sub-orbital flights in 1946 by V-2 rockets
- Taken from a height five times greater than the previous record of 22 km, which was set by the Explorer II balloon mission in 1935
- The first satellite (orbital) photos, taken by Explorer 6, show a sunlit area of the Central Pacific Ocean and its cloud cover

MULTISPECTRAL VS. HYPERSPECTRAL

Multispectral

Hyperspectral



Spectral capabilities of multispectral and hyperspectral sensors (Edmund Optics 2019), https://www.edmundoptics.eu/knowledge-center/application-notes/imaging/hyperspectral-and-multispectral-imaging/

APPLICATIONS OF REMOTE SENSING

Observing objects and phenomena from a distance without physical contact allows for numerous applications

PLANETARY EXPLORATION | URBAN PLANNING | … | METEREOLOGY | BIOMEDICAL | DAMAGE ASSESMENT

… | … | …

CLIMATE CHANGE | EARTH OBSERVATION | AIR TRAFFIC CONTROL | … | SMART CITIES | CIVIL PROTECTION

- Non-invasive method in contrast to in situ or on-site observation
- Efficient and continuous observation of the Earth and its changes
- Satellite platforms provide repetitive and consistent view

SATELLITES ORBITING THE EARTH IN 2023

Individual satellites orbiting the Earth: 7389 (2021), 8261 (2022), 11330 (2023)

- Communications: 4823 satellites
- Earth observation: 1167 satellites
- Technology development/demonstration: 414 satellites
- Navigation/positioning: 155 satellites
- Space science/observation: 109 satellites
- Earth science: 25 satellites
- Other purposes – 25 satellites

https://physicsworld.com/a/space-debris-threat-to-geosynchronous-satellites-has-been-drastically-underestimated/

https://www.pixalytics.com/satellites-orbiting-earth-2023/

ESA-DEVELOPED EARTH OBSERVATION MISSIONS

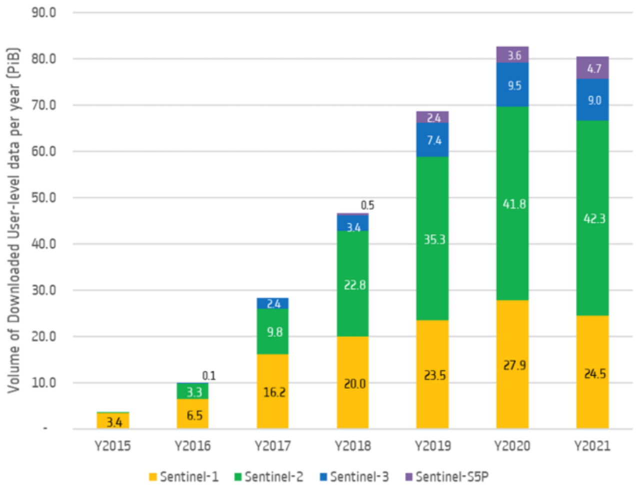
ESA dedicated to observing Earth from space ever since the launch of its first Meteosat weather satellite back in 1977

https://www.esa.int/ESA_Multimedia/Images/2019/05/ESA-developed_Earth_observation_missions

- ESA launched a range of different types of satellites over the last 40 years,
- The objective is to understand the complexities of our planet, particularly with respect to global change
- Applications: weather forecasting, Earth-science research, enhancing agriculture and maritime safety, aiding disaster response, etc.

COPERNICUS SENTINEL DATA

Sentinel data available for retrieval in 2021 was 41.86 PB, with a total download volume of 80.5 PB

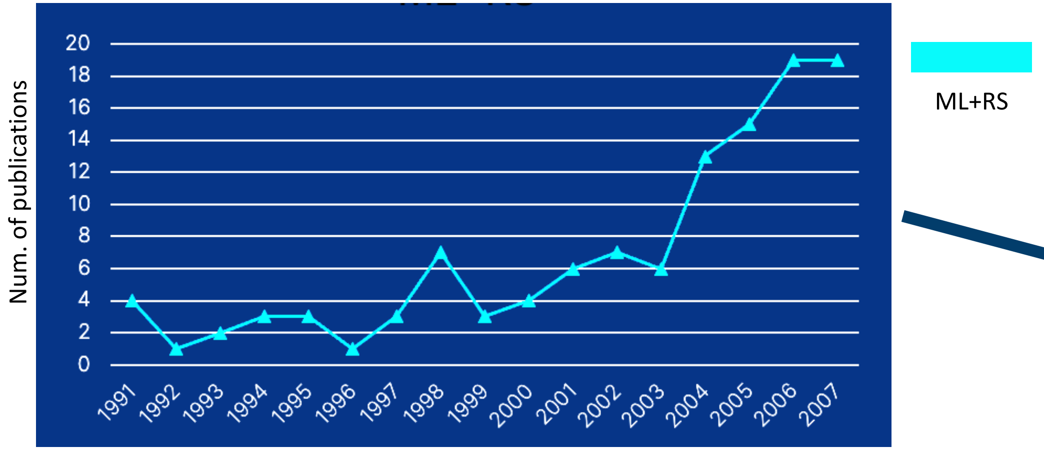


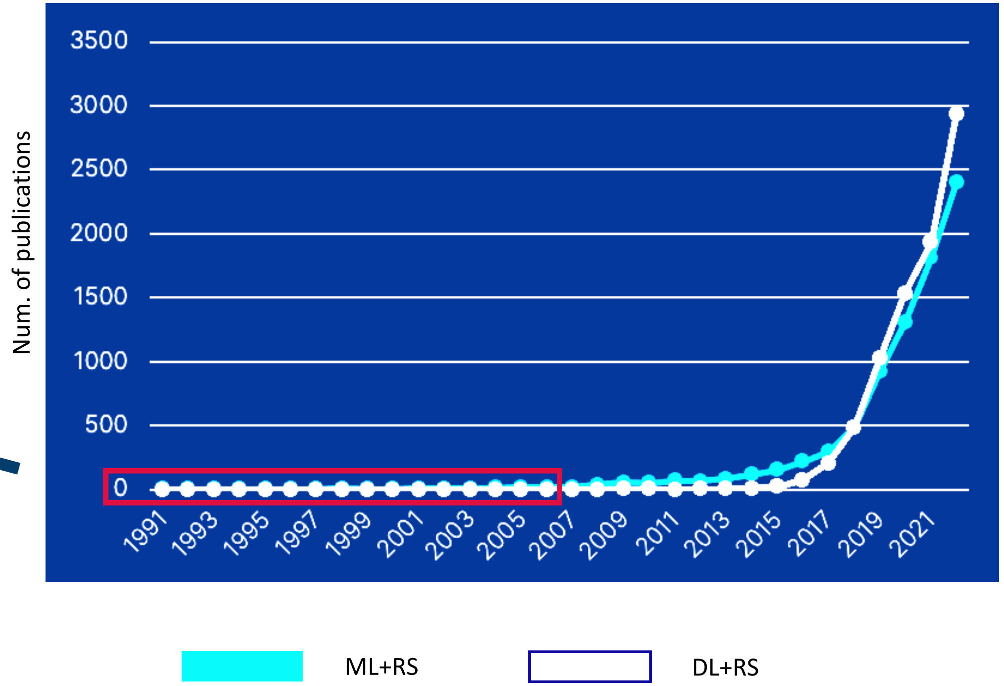
https://scihub.copernicus.eu/twiki/do/view/SciHubWebPortal/AnnualReport2021

- The Copernicus Open Access Hub provides complete, free and open access to Sentinel data
- Platforms: Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products
- 490,000 registered users with an average daily download volume of 203 TiB

MACHINE LEARNING AND DEEP LEARNING IN REMOTE SENSING

- Classical ML such as Support Vector Machine (SVM) and Random Forest (RF) since the '90s





- DL unleashed advances in the last decade

- Figures may differ depending on the source, but the overall trend remains consistent

https://www.scopus.com

COMPUTING TECHNOLOGIES HAVE EVOLVED IN RECENT DECADES

MICROPROCESSOR TREND DATA

Moore's Law

Drove the semiconductor industry to cram more and more transistors and logic into the same volume

End of Dennard's Scaling

Limits in how much it is possible to shrink voltage and current without losing predictability

Multi-Core Era

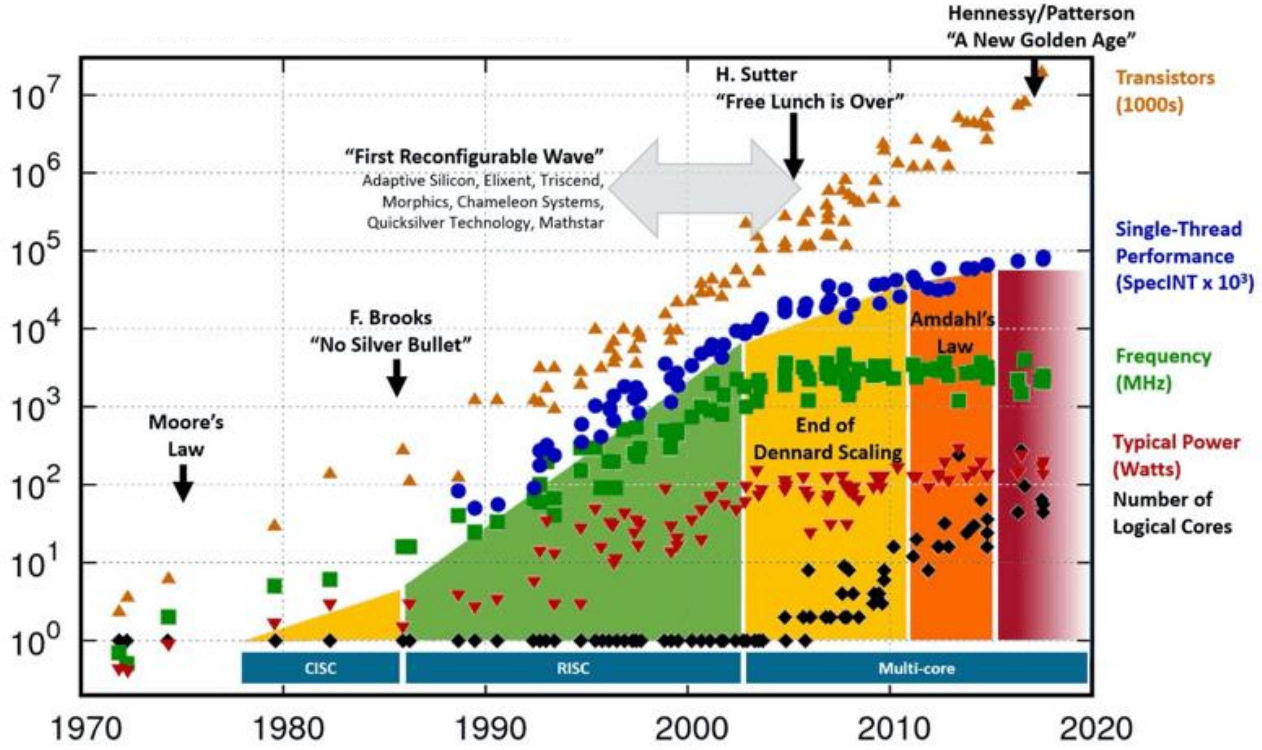
Triggered by the Instruction Level Parallelism (ILP) wall

Amdahl's Law

Challenges in terms of energy efficiency, thermal management and parallelizability

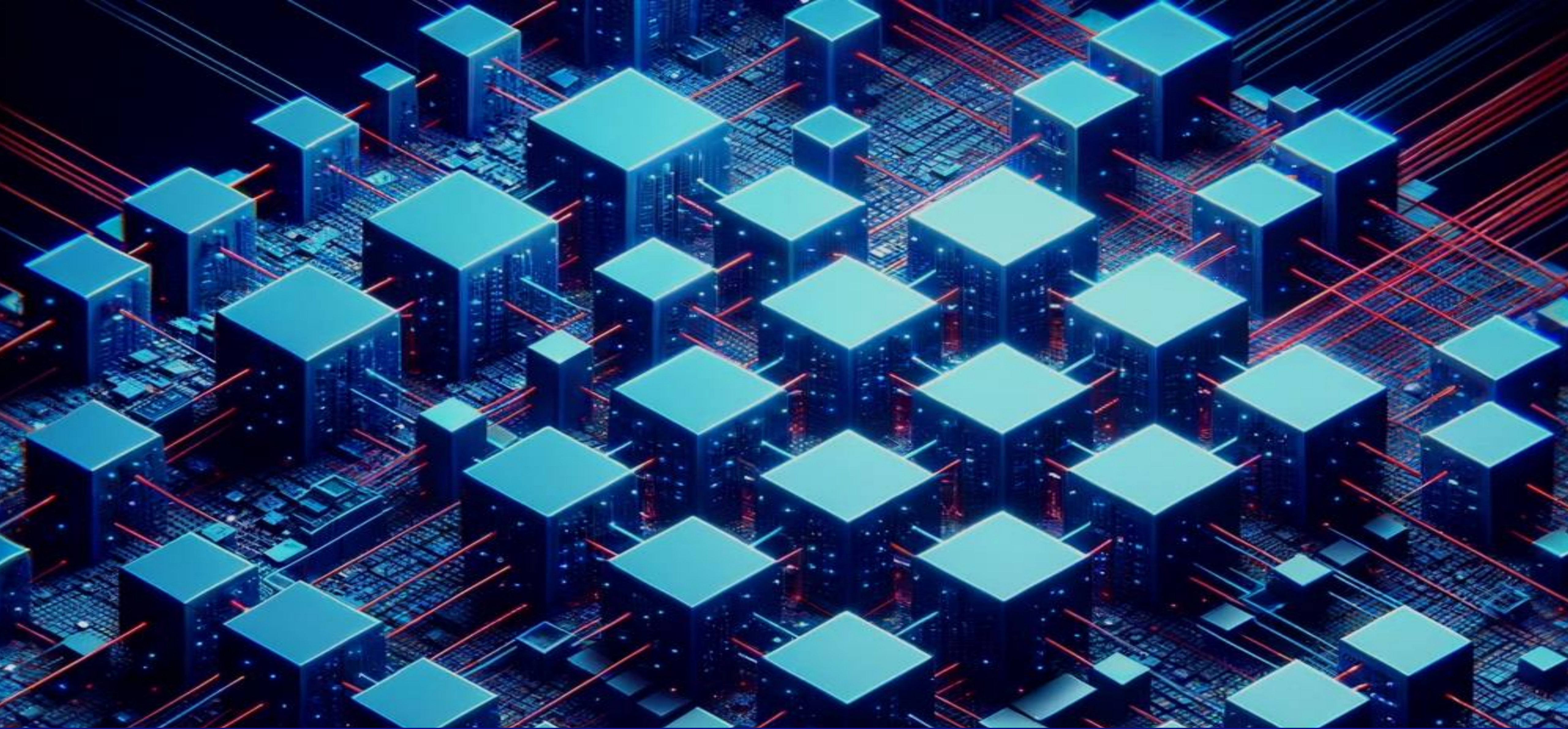
New Trends

To obtain the best performance-cost-energy tradeoffs for defined tasks



J. L. Hennessy, D. A. Patterson, "A New Golden Age for Computer Architecture", in Communications of the ACM, vol. 62 no. 2, pp. 48-60, 2019, https://doi.org/10.1145/3282307

Hennessy and Patterson, Turing Lecture 2018, overlaid over "42 Years of Processors Data" https://www.karirupp.net/2018/02/42-years-of-microprocessor-trend-data/; "First Wave" added by Les Wilson, Frank Schirrmeister Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten New plot and data collected for 2010-2017 by K. Rupp

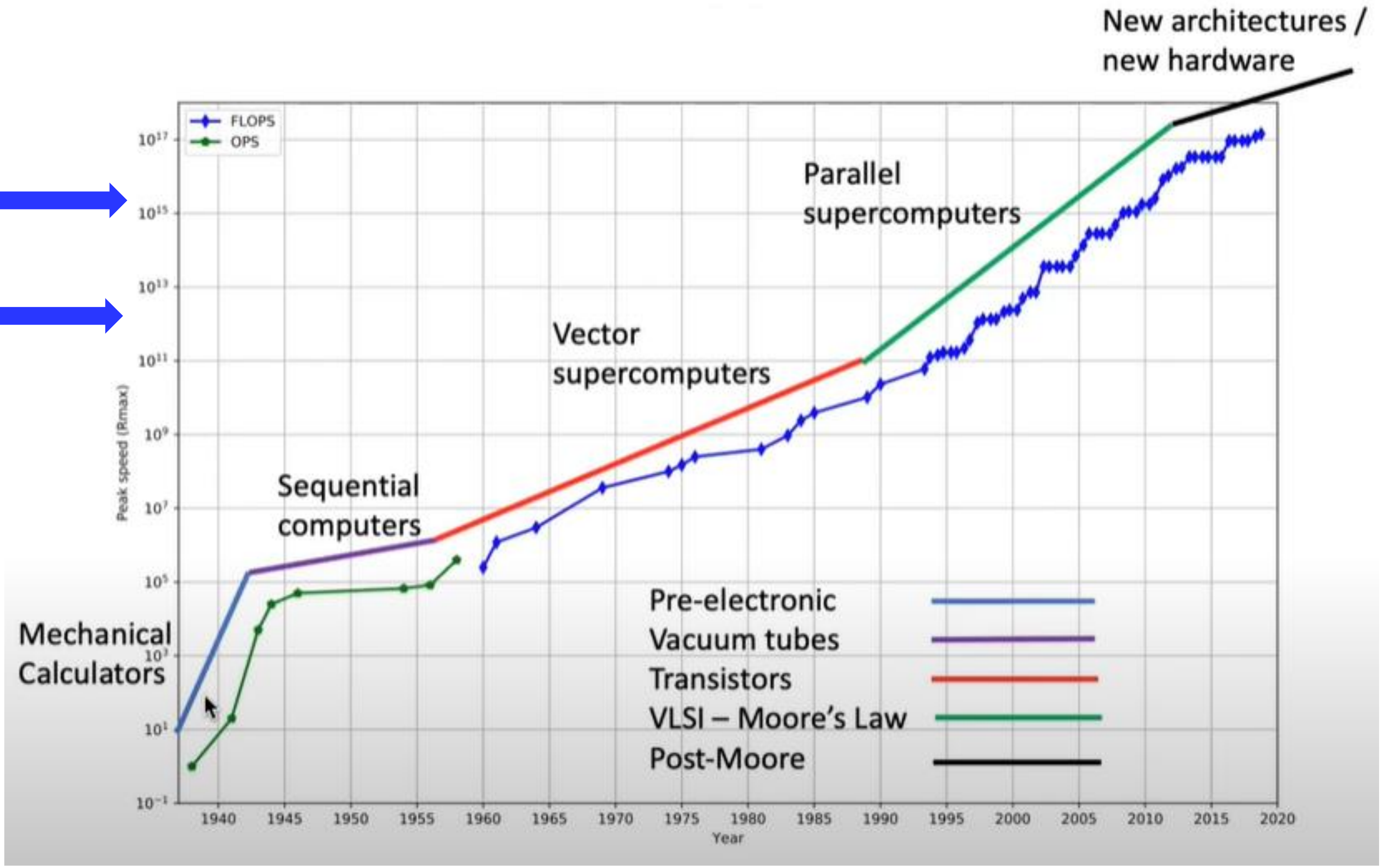


SUPERCOMPUTING

PERFORMANCE OF THE WORLD'S FASTEST SUPERCOMPUTERS

2008
First 1 PFLOP/s computer
(Roadrunner)

1997
First 1 TFLOP/s computer
(Intel ASCI Read/9152)

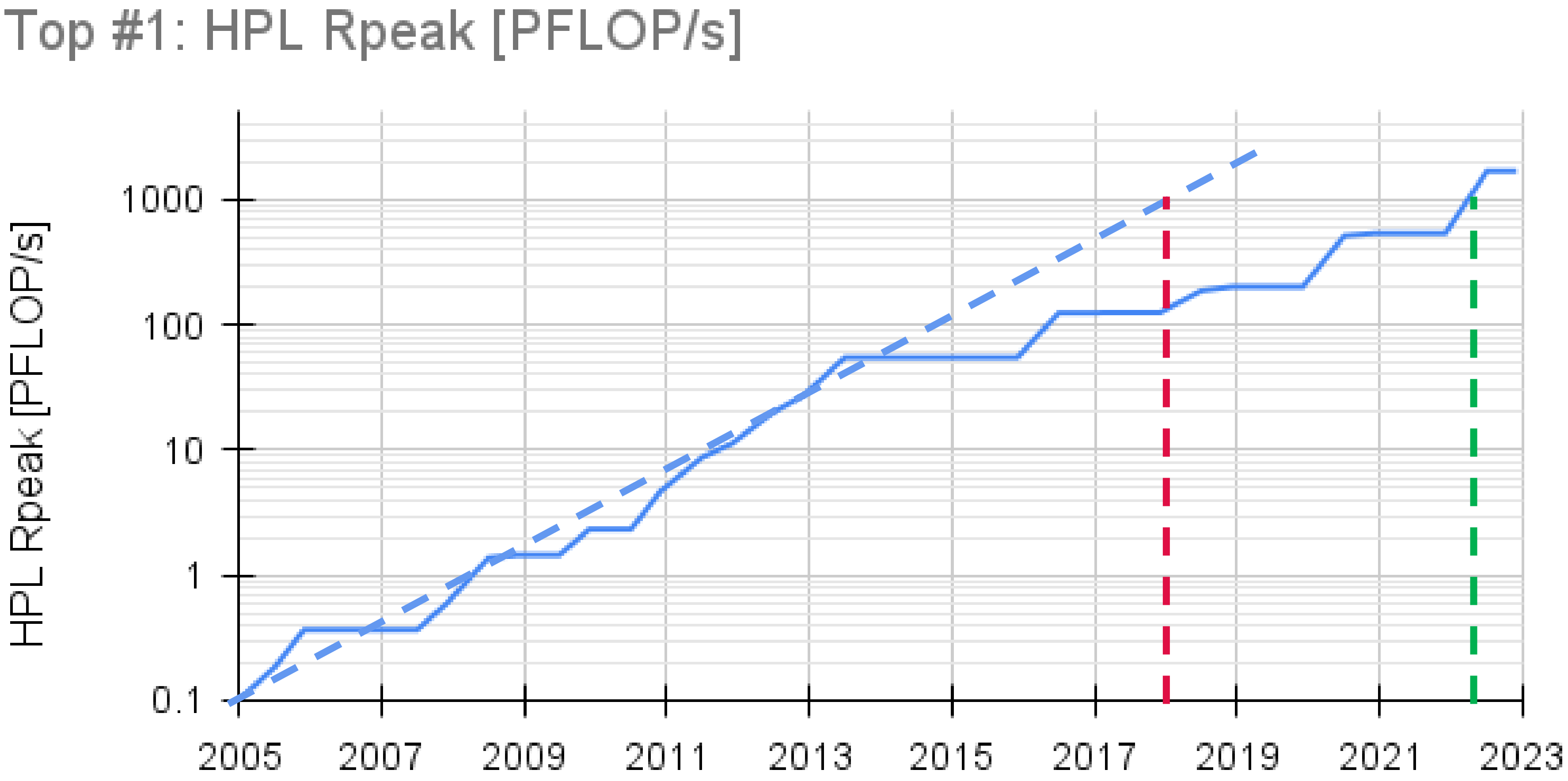


*floating point operations per second
(FLOPS, flops or flop/s)

Rob Schreiber, High Performance Computing: Beyond Moore's Law https://www.youtube.com/watch?v=LOf57fdxln4&t=258s

FROM PETASCALE TO EXASCALE COMPUTING

EXASCALE ERA



https://www.top500.org/

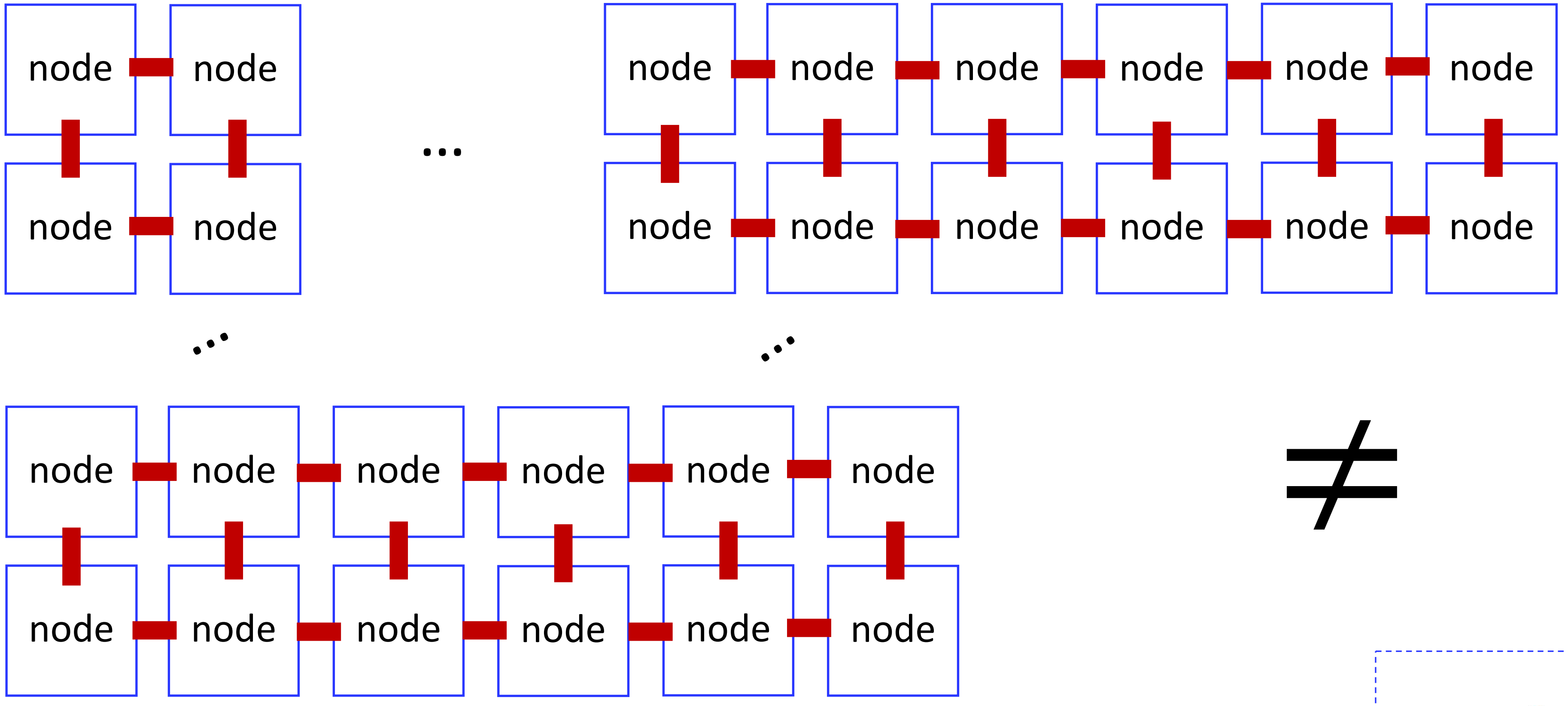
- **1997:** First **1 TFLOP/s** computer: (*Intel ASCI Read/9152)*
- **2008:** First **1 PFLOP/s** computer: (*Roadrunner*)
- So…. First **1 EFLOP/s** computer: **2018 !!**
  - Well… not really
- It took 4 more years… **2022**

FRONTIER
First Exascale System

https://www.ornl.gov/news/ornl-celebrates-launch-frontier-worlds-fastest-supercomputer

WHAT ACTUALLY IS A SUPERCOMPUTER?

HIGH-PERFORMANCE COMPUTING SYSTEMS



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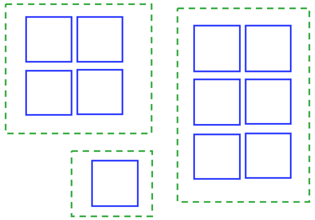
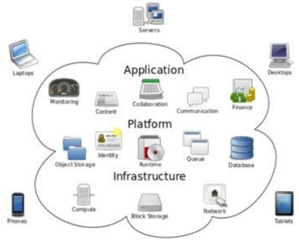
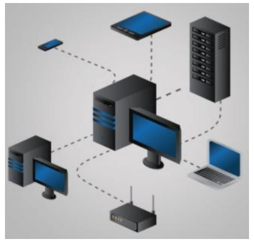


Many independent computations



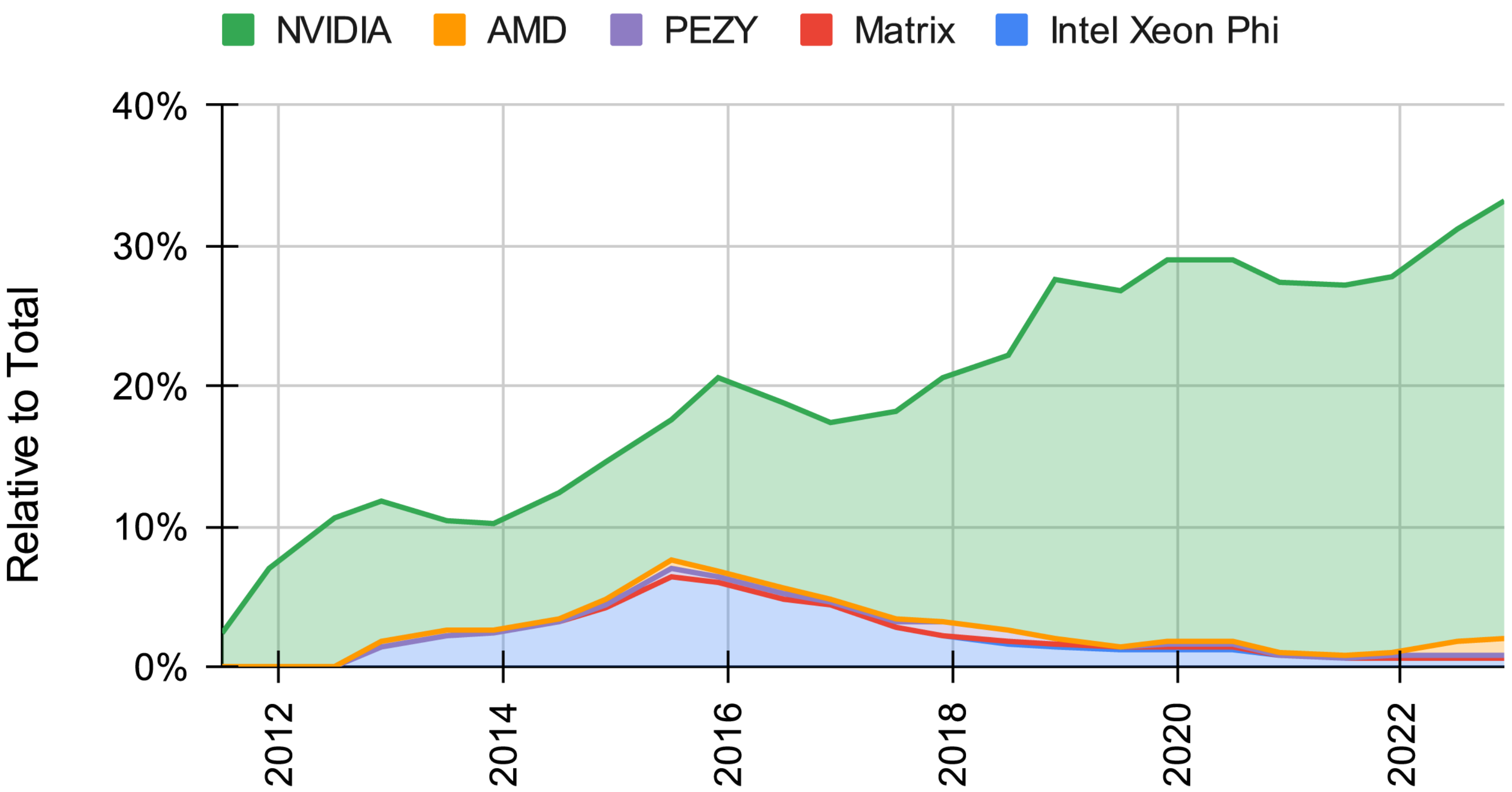
Virtual machines in compute center(s)

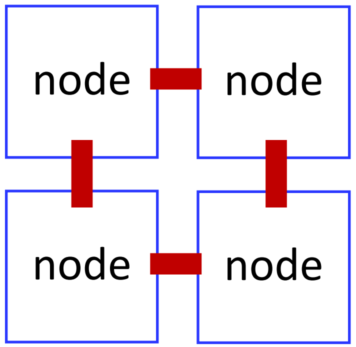


Many computers bound together locally

- High number of **compute nodes**
- Vast amounts of memory
- **High-speed interconnects**

INSIDE MODERN SUPERCOMPUTERS

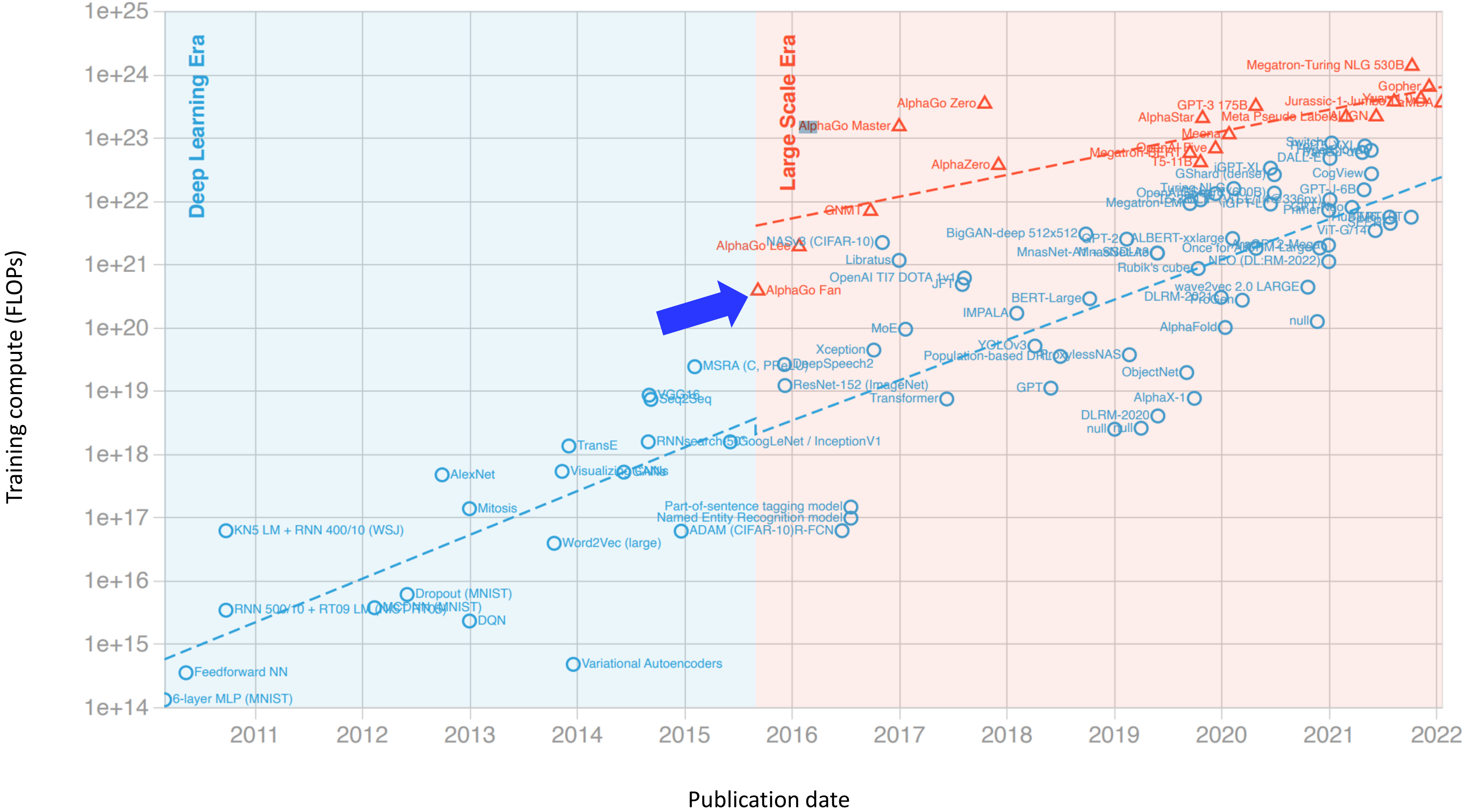




Share of Top500 systems using some kind of accelerator (top500.org)

ARTIFICIAL INTELLIGENCE
A DRIVER OF COMPUTE TRENDS

THE ERA OF LARGE-SCALE DEEP LEARNING



J. Sevilla, L. Heim, A. Ho, T. Besiroglu, M. Hobbhahn and P. Villalobos, "Compute Trends Across Three Eras of Machine Learning," 2022 International Joint Conference on Neural Networks (IJCNN), pp. 1-8, 2022, https://doi.org/10.1109/IJCNN55064.2022.9891914

LARGE LANGUAGE MODELS (LLM)

Chat GTP-4 Could Pass the Bar Exam

How Our Technology Evolves FAST

Brian Lamacraft · Follow
Published in ILLUMINATION · 2 min read · Jan 5

AI chatbot's MBA exam pass poses test for business schools

ChatGPT earned a solid grade and outperformed some humans on a Wharton course

ChatGPT Passes Google Coding Interview for Level 3 Engineer With $183K Salary

'Amazingly, ChatGPT gets hired at L3 when interviewed for a coding position,' reads a Google document, but ChatGPT itself says it can't replicate human creativity and problem-solving skills.

By Emily Dreibelbis February 1, 2023

AI Passes U.S. Medical Licensing Exam

— Two papers show that large language models, including ChatGPT, can pass the USMLE

by Michael DePeau-Wilson, Enterprise & Investigative Writer, MedPage Today January 19, 2023

CURRENT POPULARITY OF AI SUPERCOMPUTERS

TPU v4: An Optically Reconfigurable Supercomputer for Machine Learning with Hardware Support for Embeddings
Industrial Product*

Norman P. Jouppi, George Kurian, Sheng Li, Peter Ma, Rahul Nagarajan, Lifeng Nai, Nishant Patil, Suvinay Subramanian, Andy Swing, Brian Towles, Cliff Young, Xiang Zhou, Zongwei Zhou, and David Patterson
Google, Mountain View, CA

Tech > Science

BABY STEPS Google artificial intelligence supercomputer creates its own 'AI child' that can outperform its human-made rivals

The NASNet system was created by a neural network called AutoML earlier this year

Mark Hodge
Published: 15:22, 5 Dec 2017 | **Updated:** 11:27, 6 Dec 2017

FORBES > INNOVATION > SUSTAINABILITY

Tesla's Biggest News At AI Day Was The Dojo Supercomputer, Not The Optimus Robot

James Morris Contributor
I write about the rapidly growing world of electric vehicles

Follow

0 Oct 6, 2022, 07:23am EDT

BUSINESS

Microsoft invests $1 billion in OpenAI to pursue artificial intelligence that's smarter than we are

By Taylor Telford
July 22, 2019 at 3:25 p.m. EDT

RESEARCH

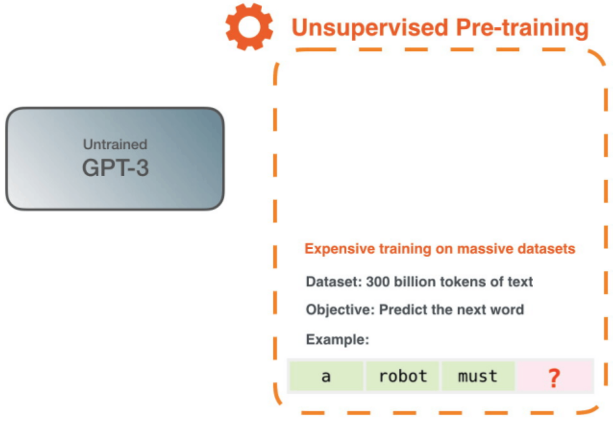
Introducing the AI Research SuperCluster — Meta's cutting-edge AI supercomputer for AI research

January 24, 2022

AI FOUNDATION MODELS FOR EARTH OBSERVATION

TRAINING AI FOUNDATION MODELS

GPT-3

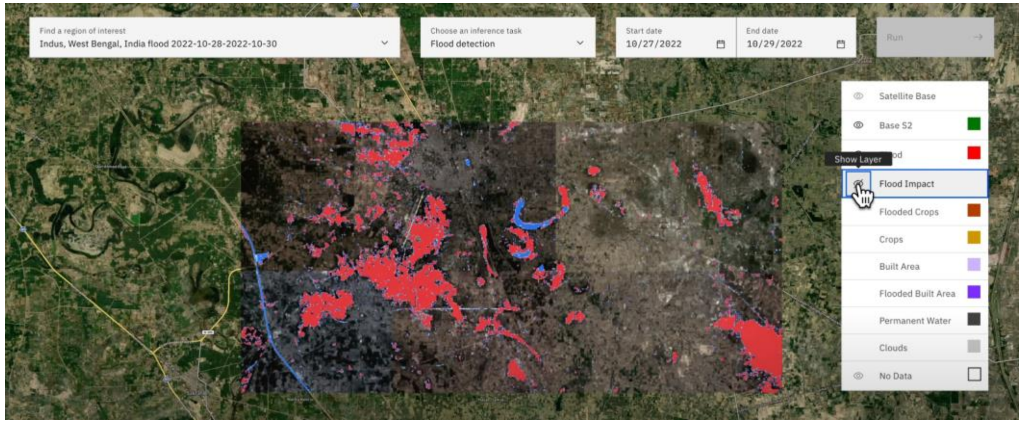


- Model size: 175B parameters
- Time: 100 years (one Nvidia A100 GPU)
- Cost*: >1M€
- Power consumption= ~385 $[MWh]$
  CO2 footprint: >100 $[tCO_2eq]$ = lifecycle of ~5 cars

https://openai.com/blog/gpt-3-apps

Jay Alammar, How GPT3 Works - Visualizations and Animations, http://jalammar.github.io/how-gpt3-works-visualizations-animations/

NASA/IBM Prithvi



- Model size: 100M parameters
- Time: 1 year (one Nvidia A100 GPU)
- Cost*: >10,000€
- Power Consumption= ~3,85 $[MWh]$

https://www.earthdata.nasa.gov/news/impact-ibm-hls-foundation-model

IBM Research, IBM geospatial foundation model, https://youtu.be/9bU9eJxFwWc?si=0by1WdkFT23o0vY5

*Cost for 8x A100 = 12 $/hour on AWS (membership with best deal)

Stefan Kesselheim, "Large Language Models Training in Practice", Helmholtz AI, 2023

H. Touvron, et al, "LLaMA: Open and Efficient Foundation Language Models", 2023, https://doi.org/10.48550/arXiv.2302.13971

TRENDS TO PUSH COMPUTING BEYOND CURRENT LIMITS

Heterogeneous HPC

Energy Efficient Hardware

Exascale and beyond

Rise of non-x86 Architectures and Custom Chips

Lower Process Nodes

Energy-Aware Software

Cross Layer Energy Efficiency, Standards

Domain-Specific Stacks

Sub-threshold voltage designs

Neuromorphic Computing and other non-Von Neumann Systems

Quantum Computing

Thermodynamic Computing

R. Muralidhar, R. Borovica-Gajic, and R. Buyya, “Energy Efficient Computing Systems: Architectures, Abstractions and Modeling to Techniques and Standards”, in ACM Computing Surveys, vol. 54, no. 11s, 2022, https://dl.acm.org/doi/10.1145/3511094

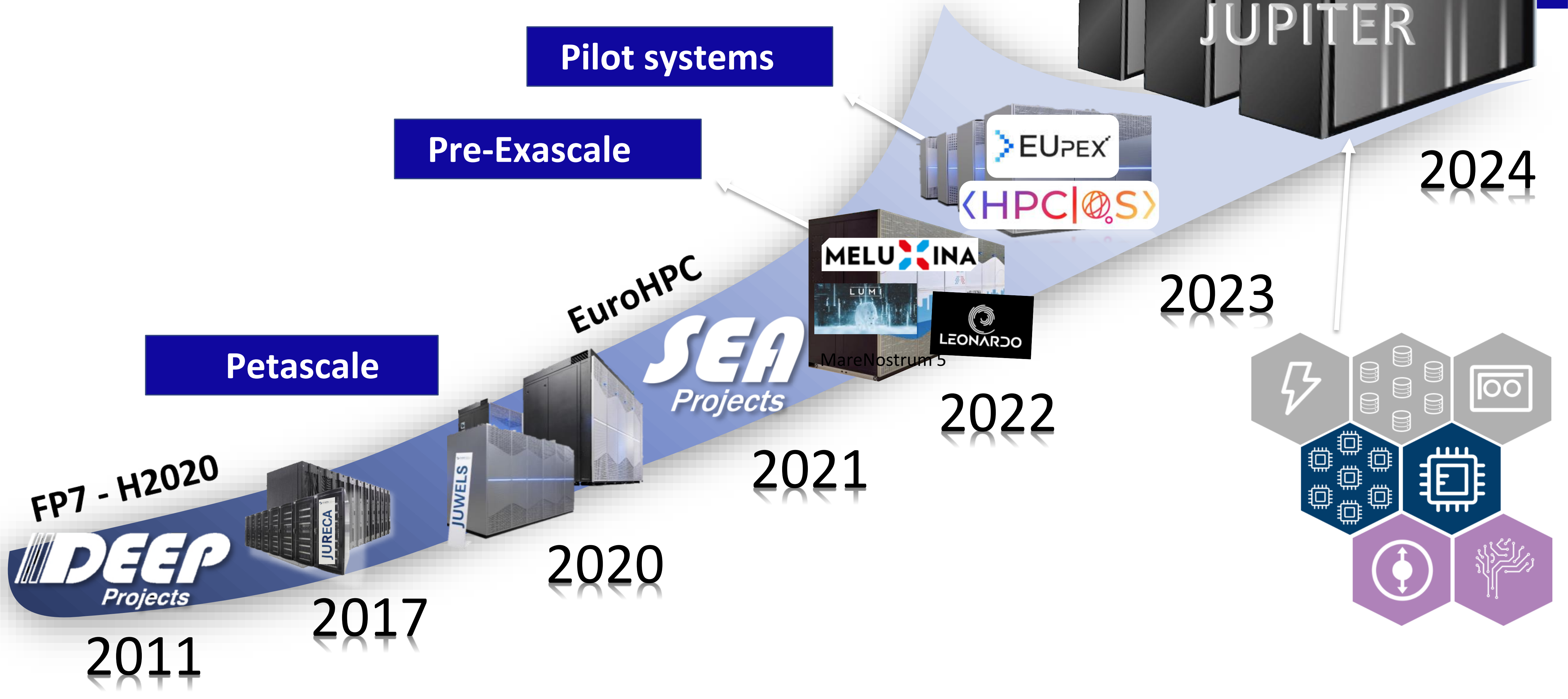
HETEROGENEOUS HPC

NON-X86 ARCHITECTURES

QUANTUM COMPUTING

EXASCALE COMPUTING IN EUROPE

Perspective of JSC



CONCLUSIONS

- Earth Observation (EO) serves as a key tool for scrutinizing land and ocean processes, understanding dynamic phenomena, and assessing the health of our planet
- EO has immensely benefited from a wealth of multi-source remote sensing (RS) data. Today, an expansive array of sensor data, including active, passive, and of various resolutions, is accessible not only to researchers and agencies but also to the general public
- The application of Deep Learning (DL) and other Machine Learning (ML) techniques has significantly shaped EO and RS. These techniques have been employed throughout data processing chains, from compression and transmission to image recognition and environmental predictions

- High-Performance Computing (HPC) systems can power large-scale DL models. This accelerates the extraction of critical information from complex RS data and reduces the time needed for model deployment and development
- The aim of these efforts is to increase the availability of useful data and enhance our understanding of complex relationships, leading to significant impacts. This includes everything from predicting and issuing timely warnings of potential natural disasters to forecasting the effects of human activities and natural processes on our environment and society

Remote Sensing for Climate Change Studies in the Arctic

Jón Atli Benediktsson and Gabriele Cavallaro

2023 Arctic Circle Assembly

Meet in Reykjavík
Iceland Convention Bureau

UNIVERSITY OF ICELAND

IGARSS 2027 - International Geoscience and Remote Sensing Symposium

Reykjavik, Iceland
4-9 July 2027

THANK YOU FOR YOUR ATTENTION

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