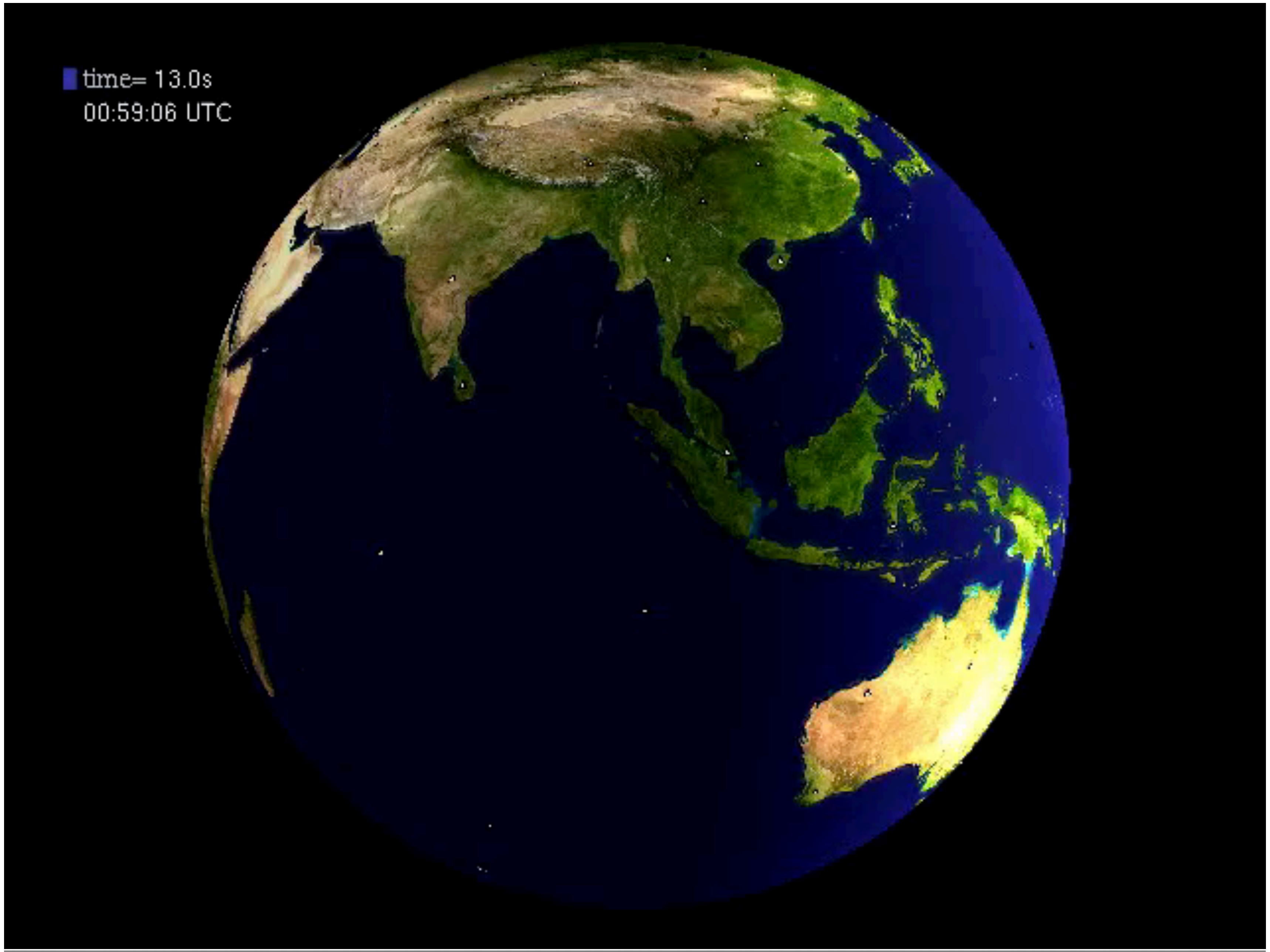
Computational Geophysics
ErSE 326



Introduction:

- computational trends

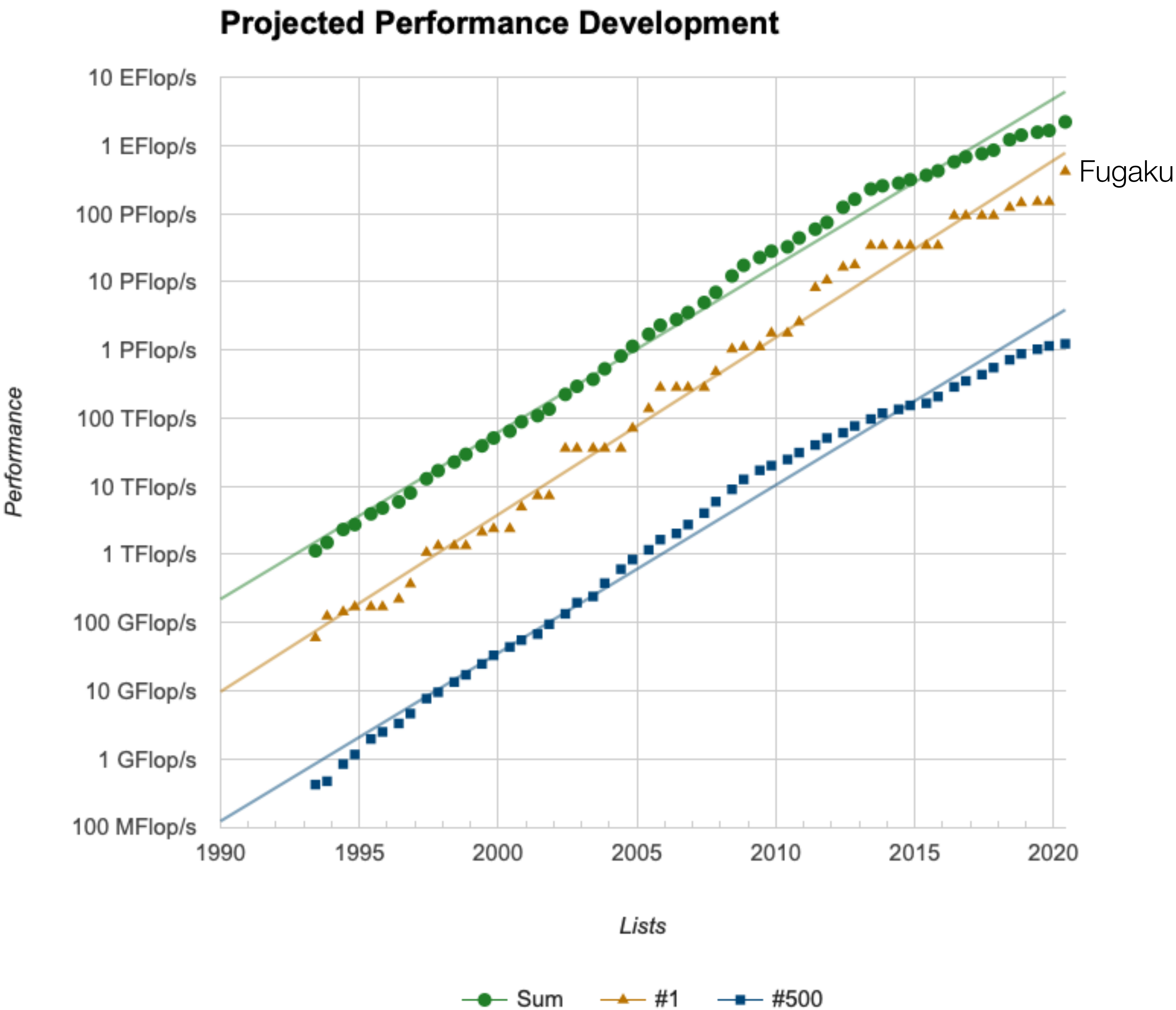
Geophysics:

- Heat Flow
- Wave propagation

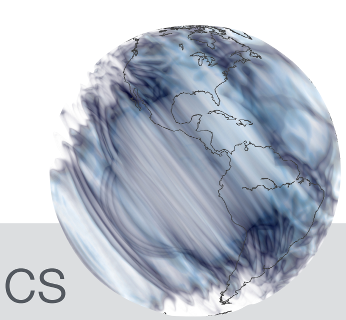
Numerical methods:

- finite-differences (FD)
- pseudo-spectral (PS)
- finite-element method (FEM)
- spectral-element method (SEM)

Trends - fastest supercomputers



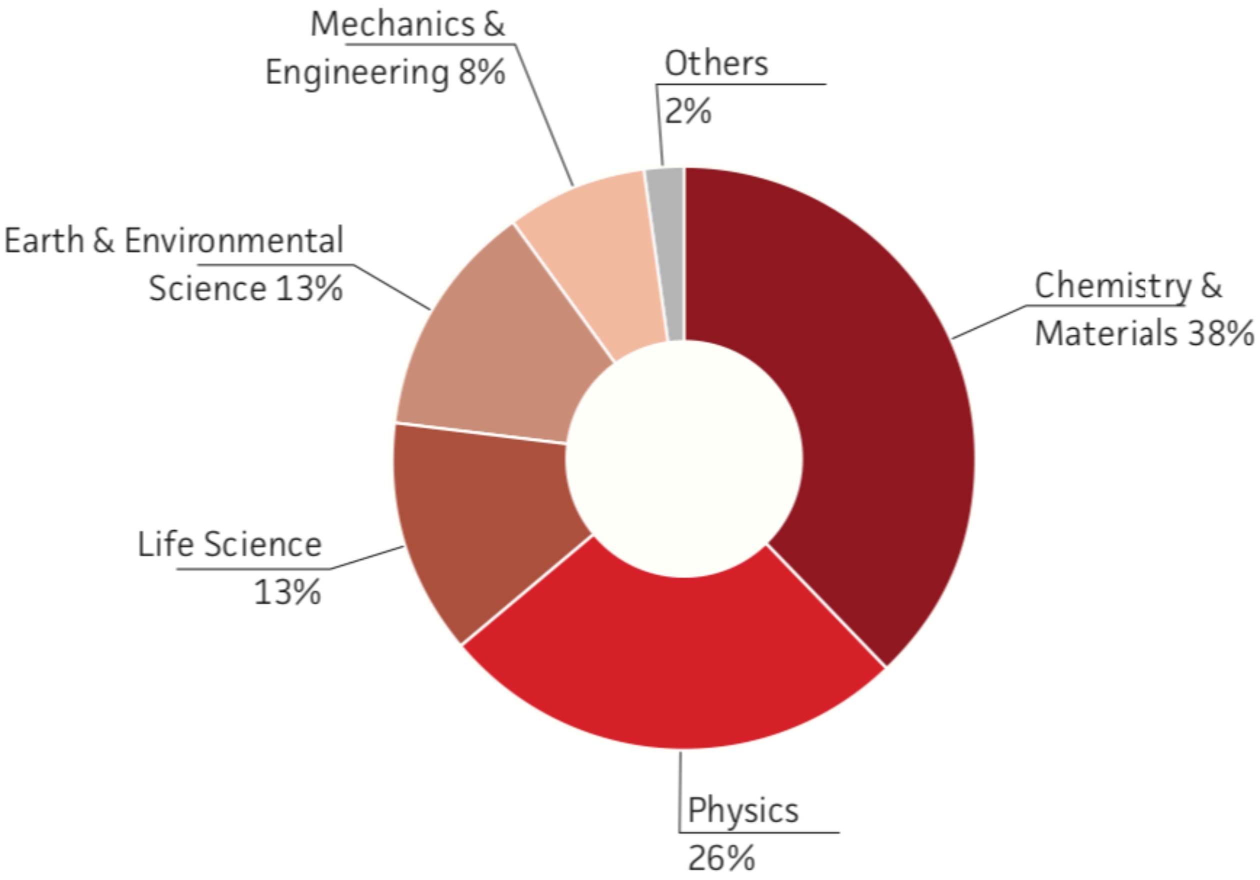
1. exa-scale (half-precision) system year 2020



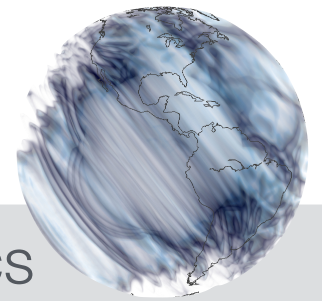
Trends - Usage by Research Field

User Lab Usage by Research Field

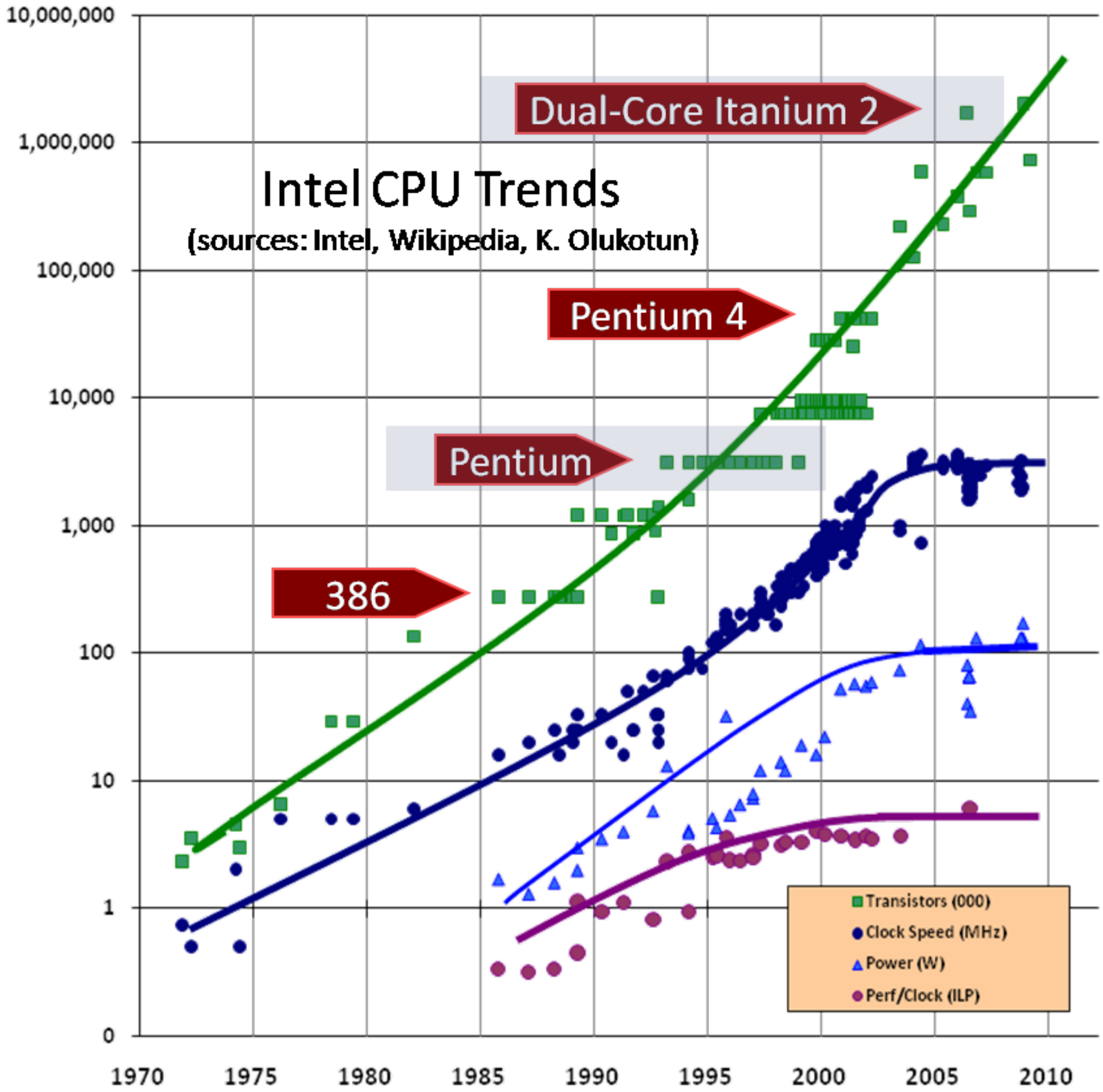
Research Field	Node h	%
Chemistry & Materials	14986864	38
Physics	10315970	26
Life Science	5320871	13
Earth & Environmental Science	5058587	13
Mechanics & Engineering	3196088	8
Others	979962	2
Total Usage	**39 858 342**	**100**



Swiss National Supercomputing Center CSCS (2019)

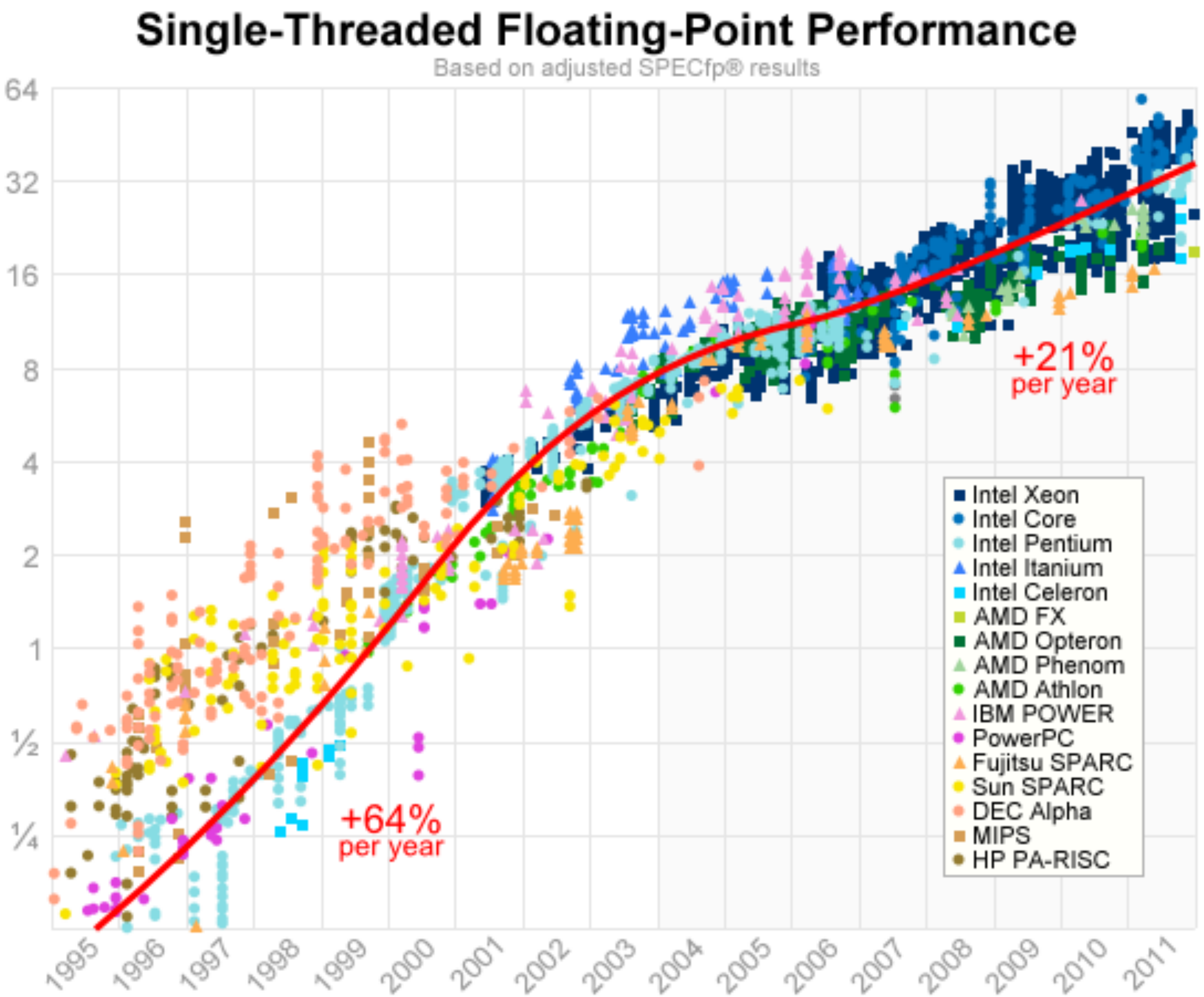


Trends - CPU



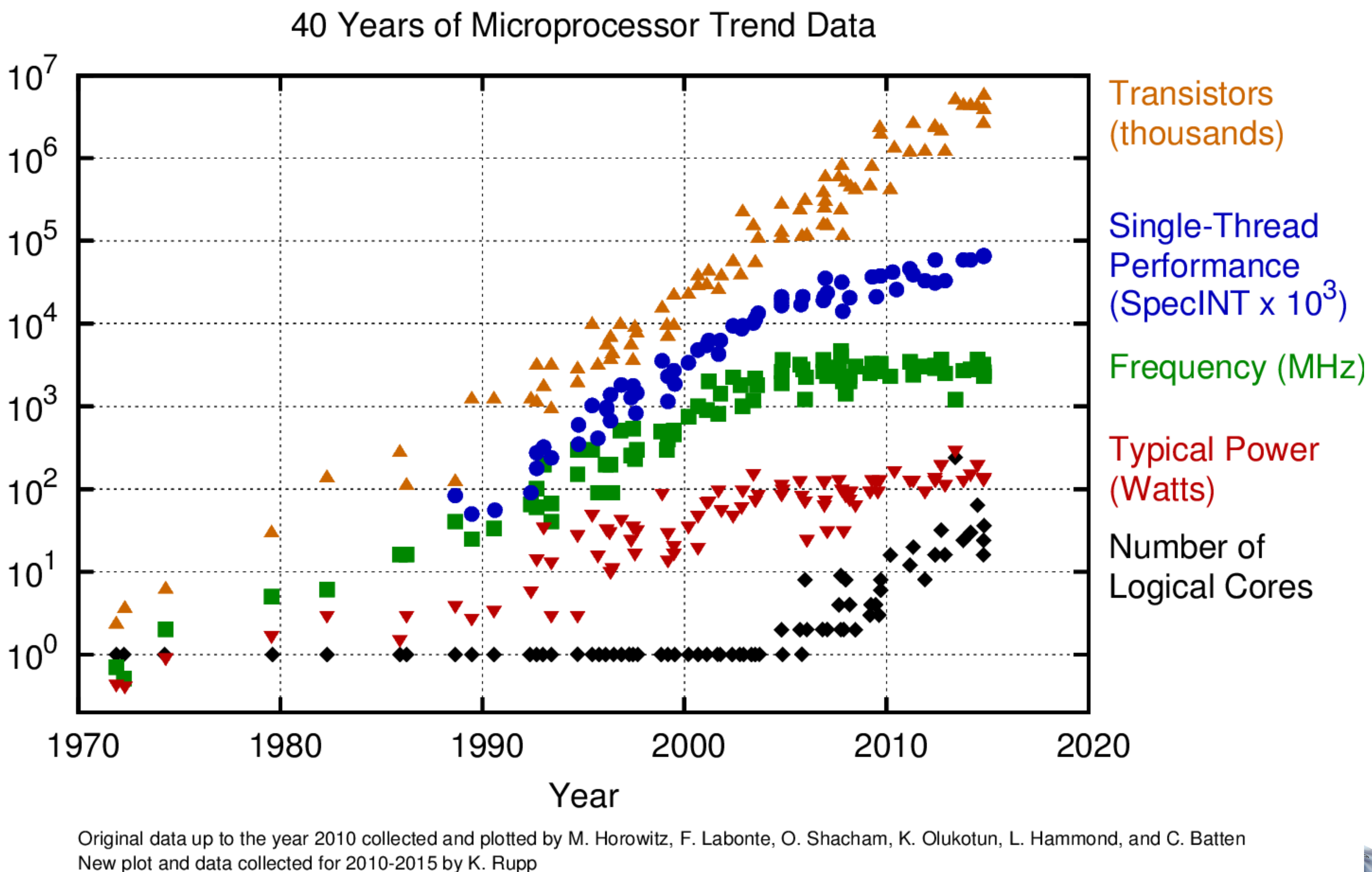
multi-core CPUs since ~2006

Trends - CPU



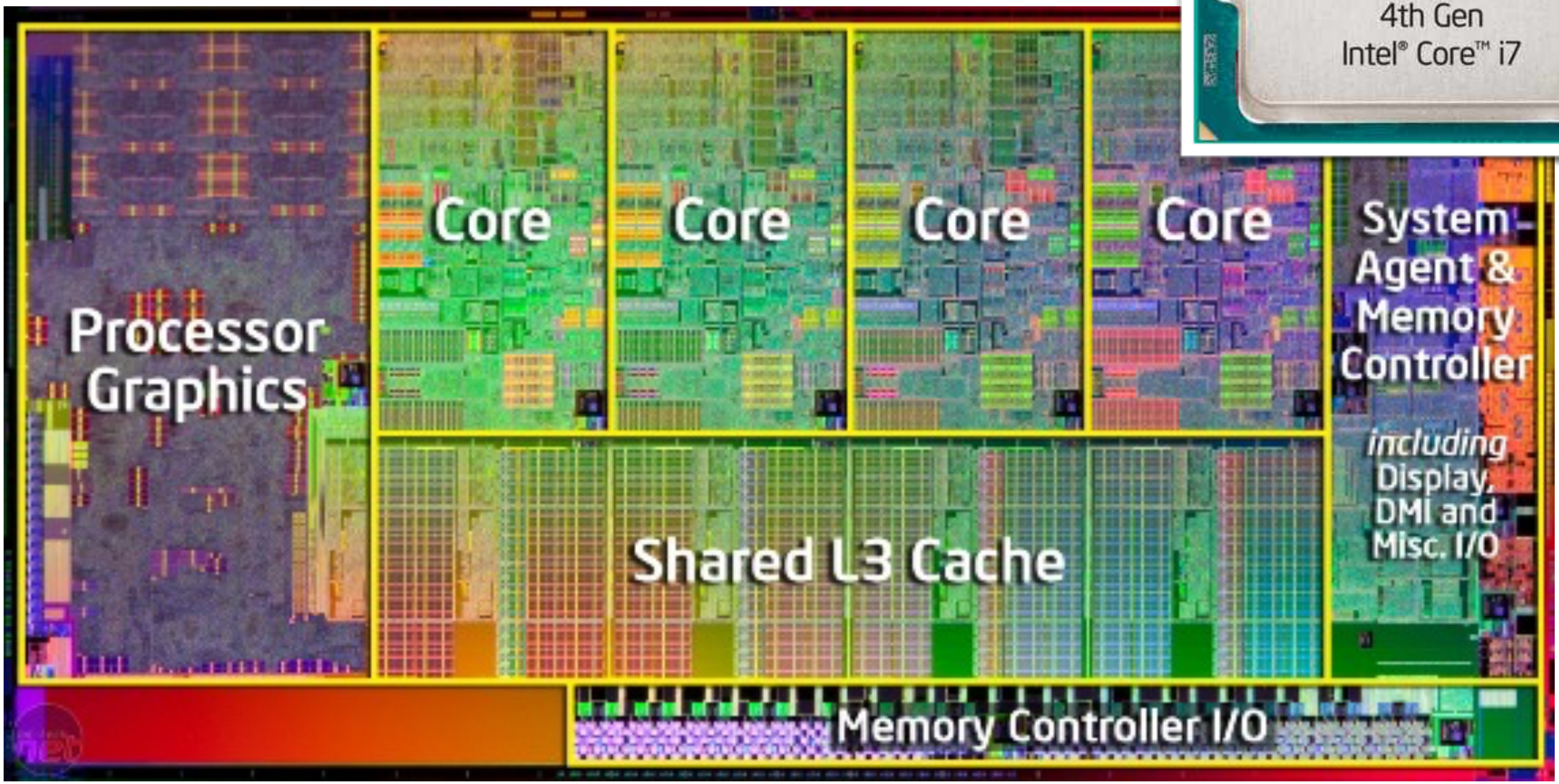
slow-down since ~2003

Trends - CPU



40 Years of Microprocessor Trend Data
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
1970
1980
1990
2000
2010
2020
Year
Transistors (thousands)
Single-Thread Performance (SpecINT x 10^3)
Frequency (MHz)
Typical Power (Watts)
Number of Logical Cores
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 2010-2015 by K. Rupp

Trends - CPU


Processor Graphics
Core
Core
Core
Core
System Agent & Memory Controller
including Display, DMI and Misc. I/O
Shared L3 Cache
Memory Controller I/O


intel
4th Gen
Intel® Core™ i7

Trends - CPU

6 cores
12 threads (hyperthreading)
base frequency 2.9 GHz
lithography 14nm
average power **45 W**

(2018)

Trends - CPU

8 cores
16 threads (hyperthreading)
base frequency 2.4 GHz
lithography 14nm
average power **45 W**

(2020)

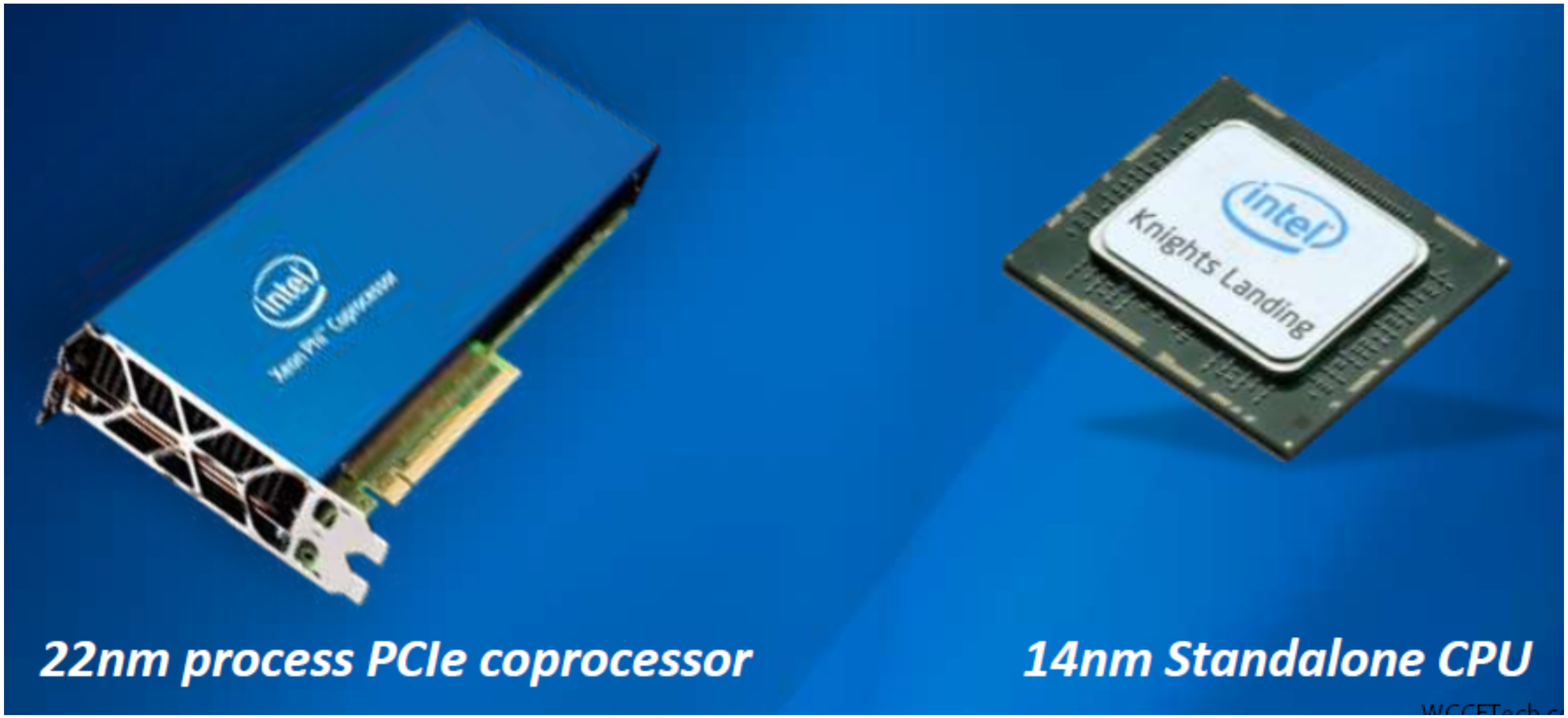
Trends - CPU

Arm v8-architecture
48+4 cores
512-bit SIMD
base frequency 2.2 GHz
lithography 7nm

average power ~160 W
-> 16 GF/W

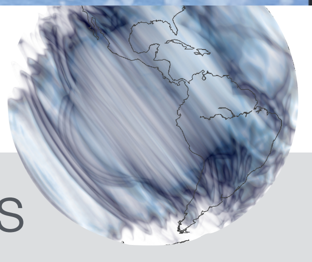
(2020)

Trends - Intel Phi



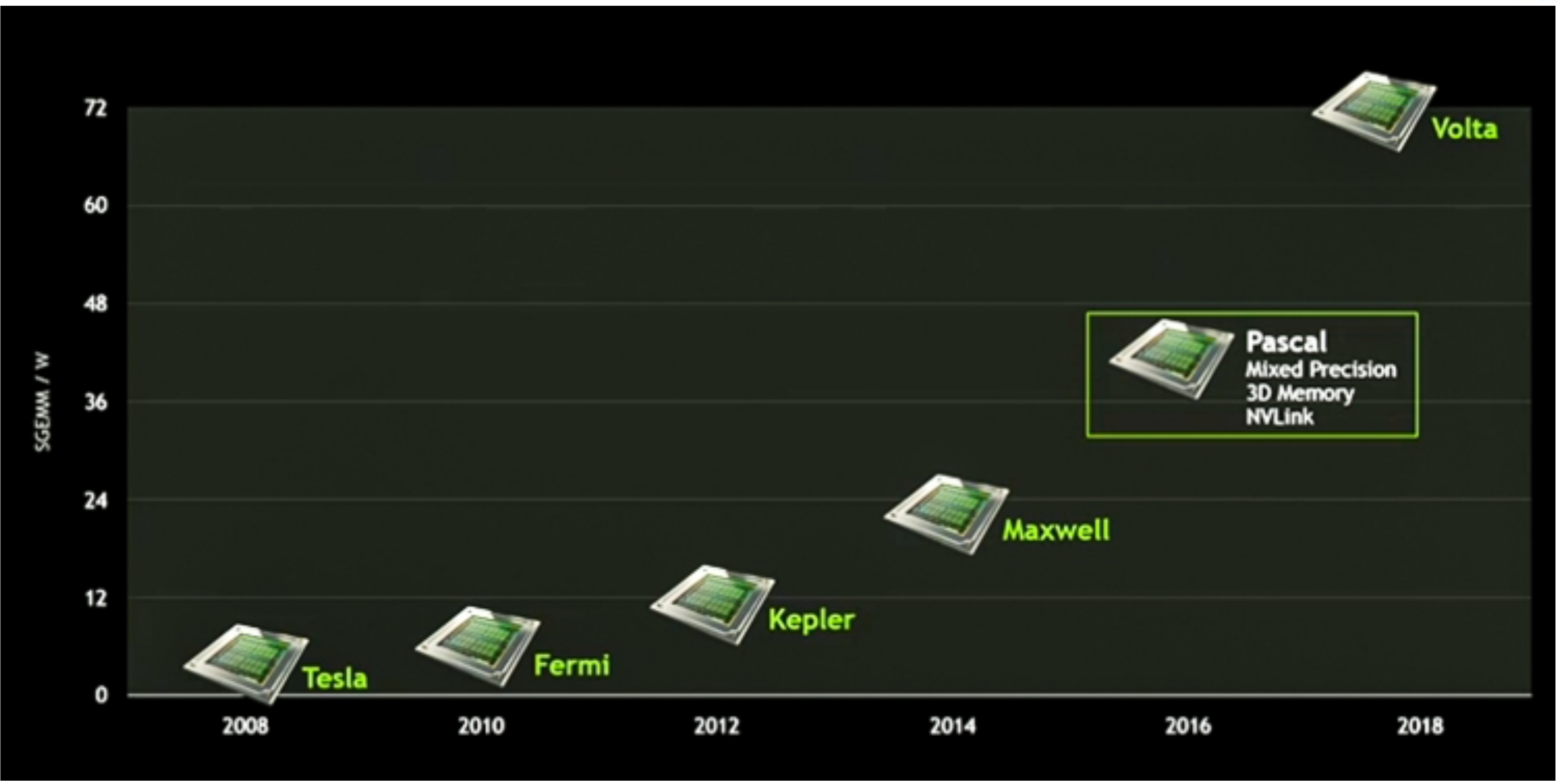
hardware accelerators
(discontinued 2020)

Trends - GPU



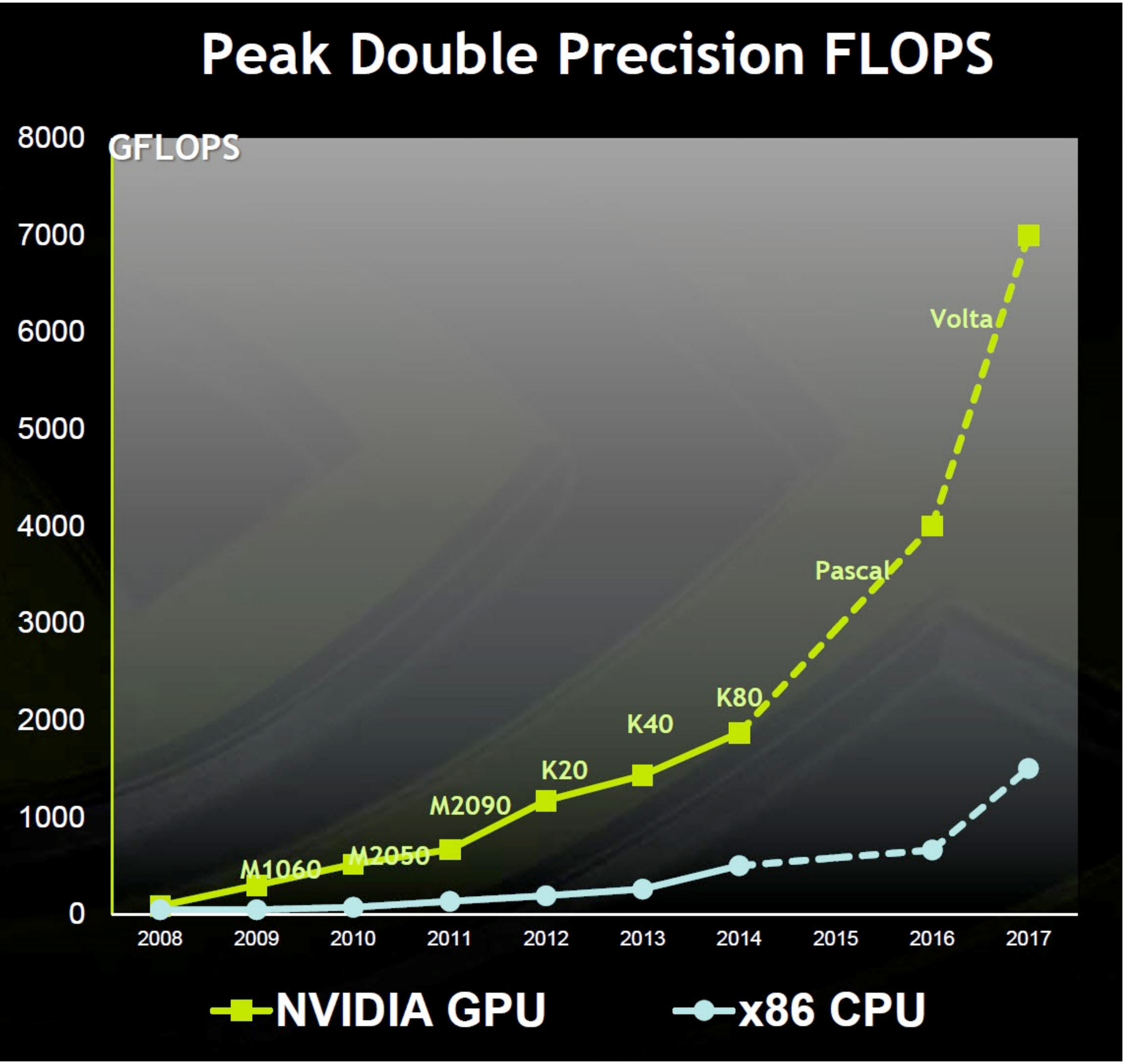
Trends - GPU

Nvidia - graphic cards



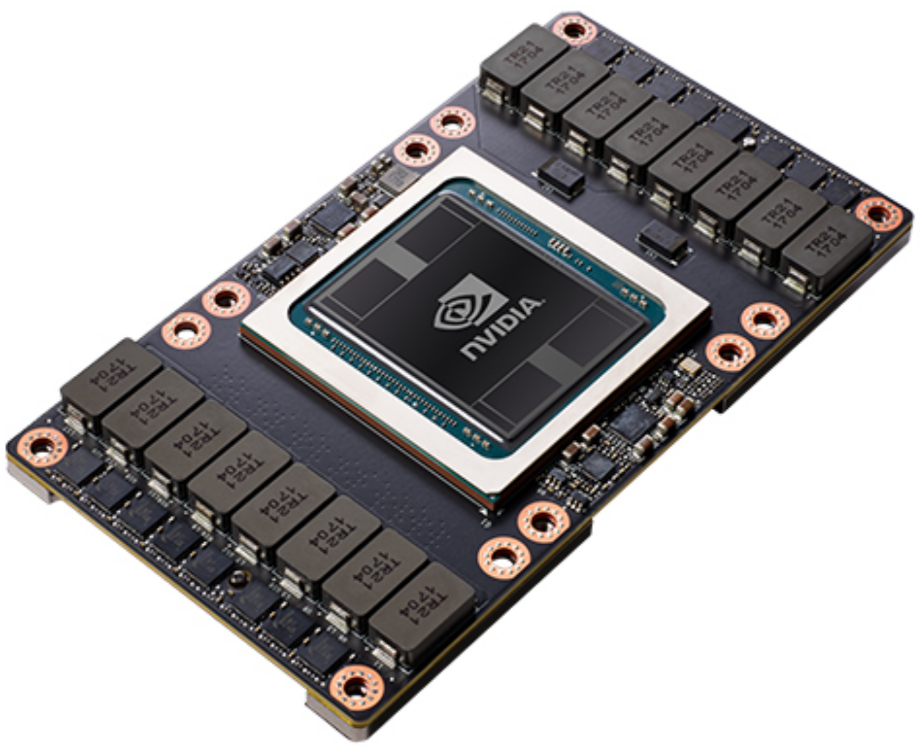
hardware accelerators

Trends - GPU



hardware
accelerators

Trends - GPU

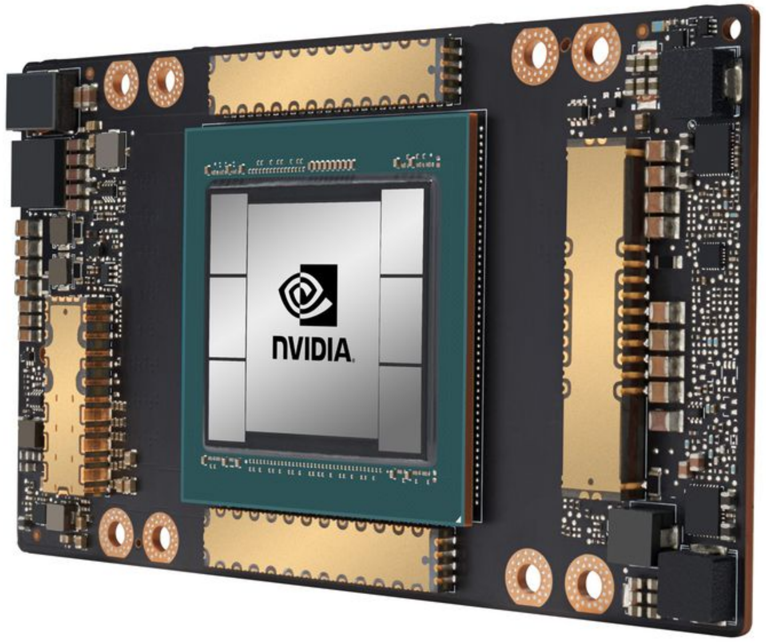


Nvidia Volta V100
32 * 80 double-precision cores

base frequency 1.5 GHz
lithography 12nm

power ~300 W
-> peak 26 GF/W (FP64)
(2018)

Trends - GPU

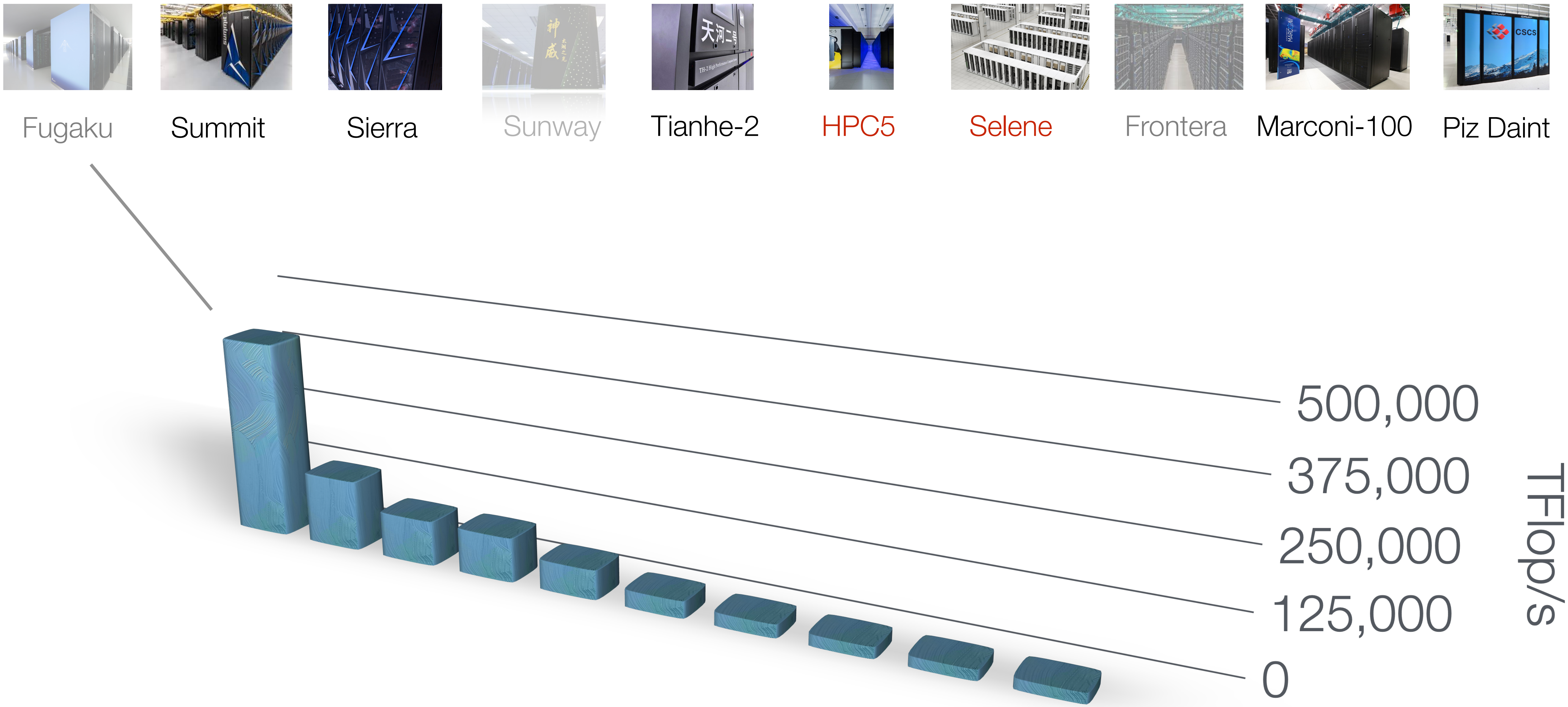


Nvidia Ampere A100
32 * 108 double-precision cores

base frequency 1.4 GHz
lithography 7nm

power ~400 W
-> peak 24 GF/W (FP64)
(2020)

Trends - Supercomputers w/ hardware accelerators



(Top500.org - June 2020)

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Numerical methods:

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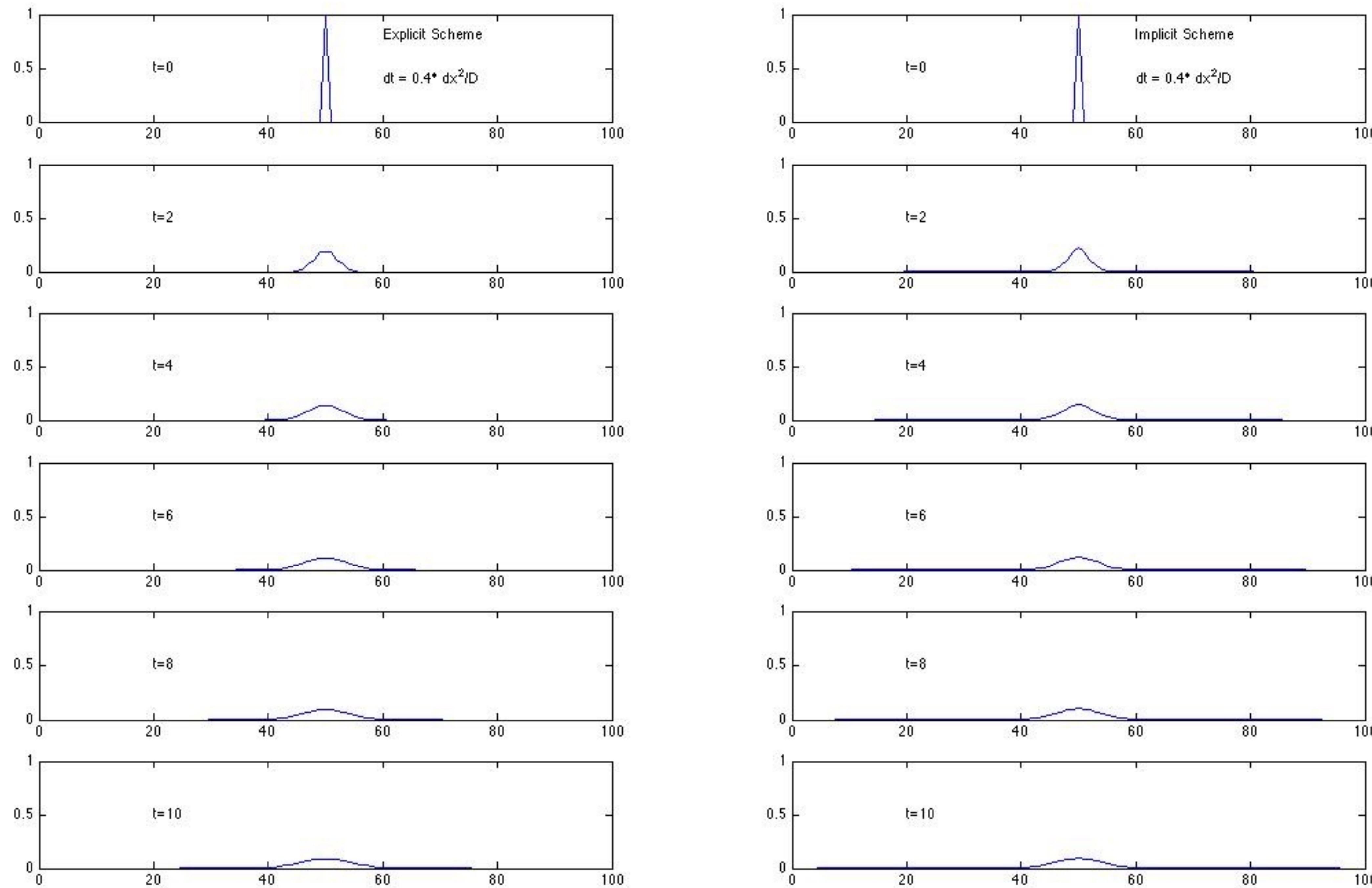
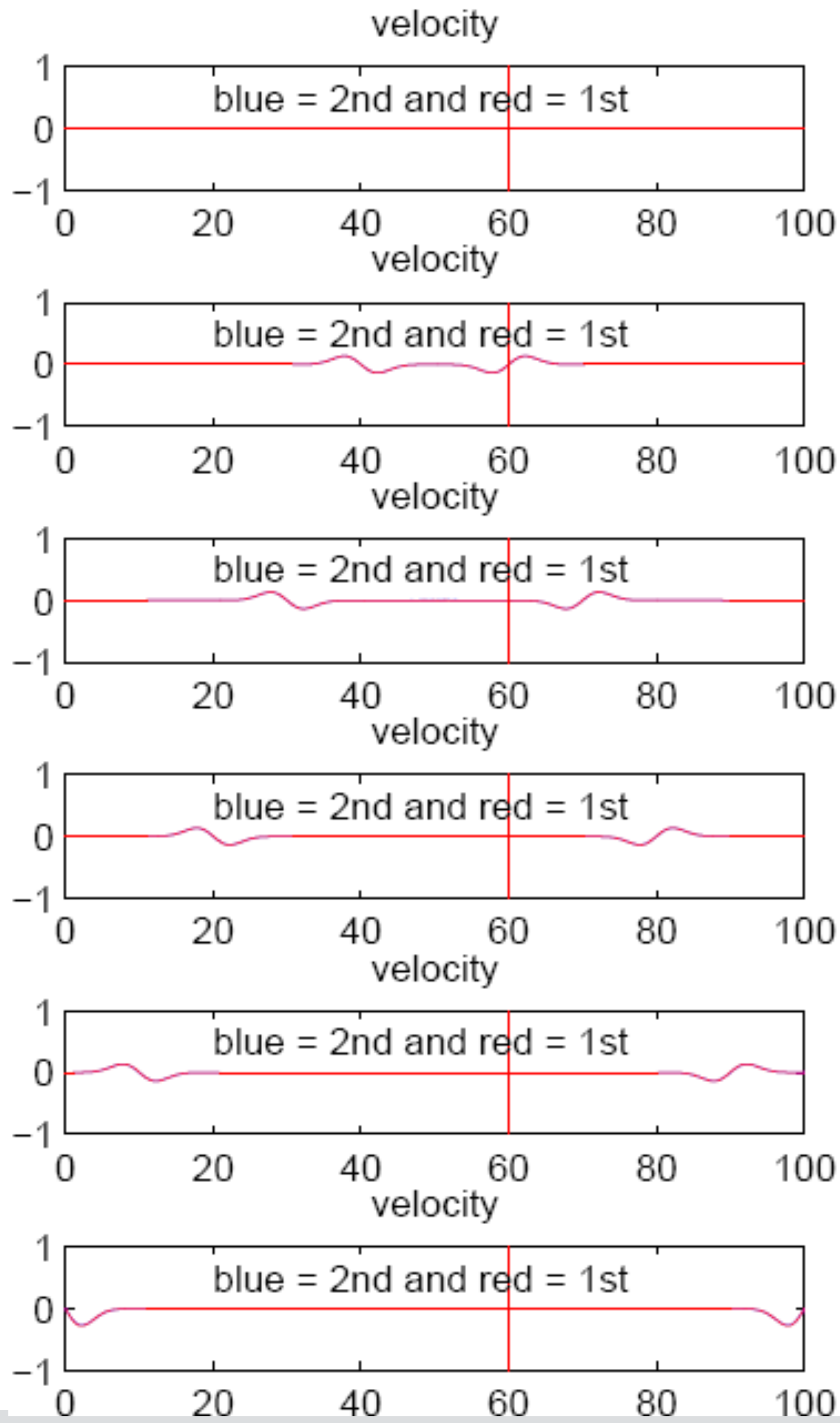
Numerical methods - **Finite-Differences**

heat flow



Numerical methods - **Finite-Differences**

wave propagation

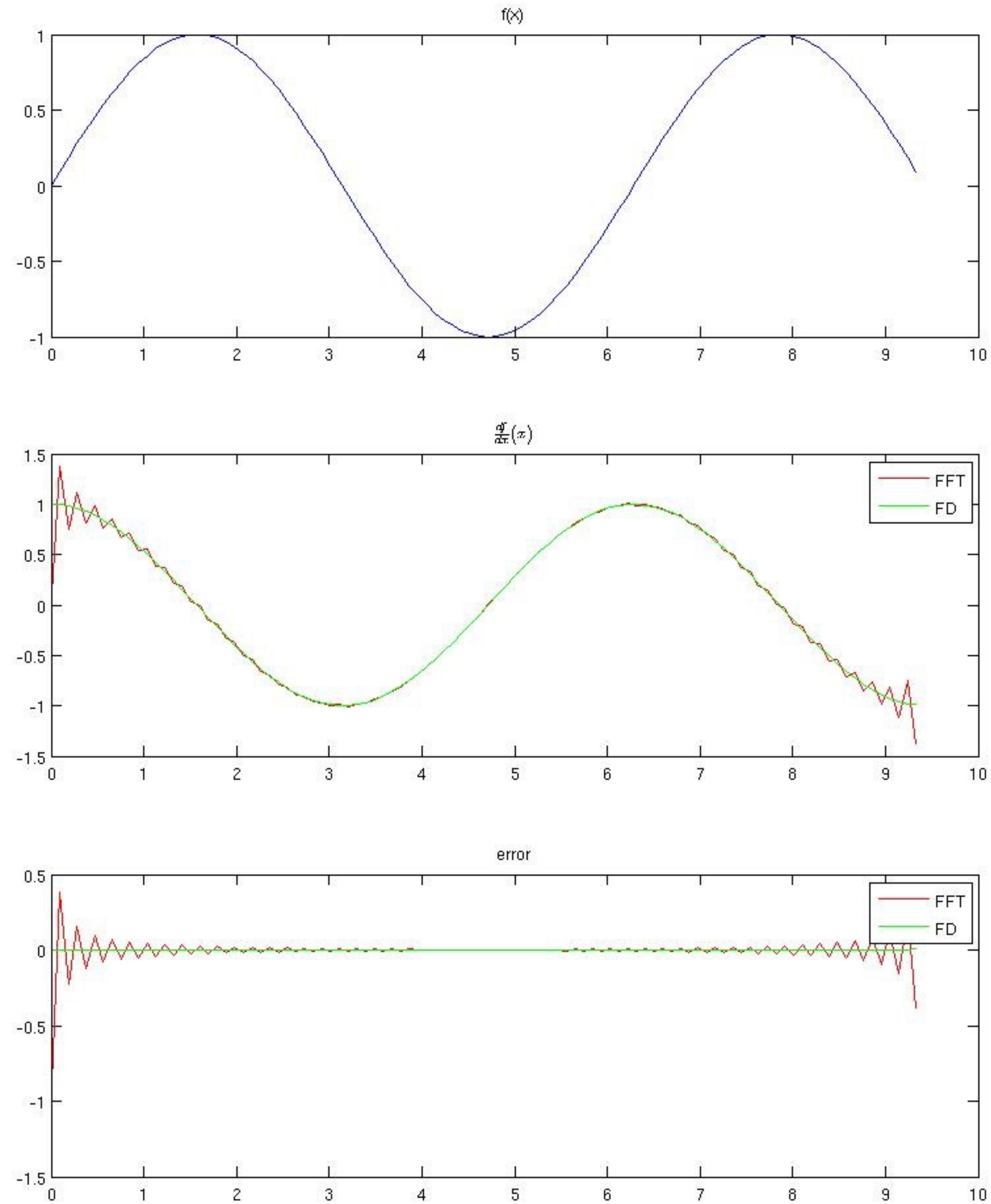


Numerical methods - **Finite-Differences**

tsunami waves

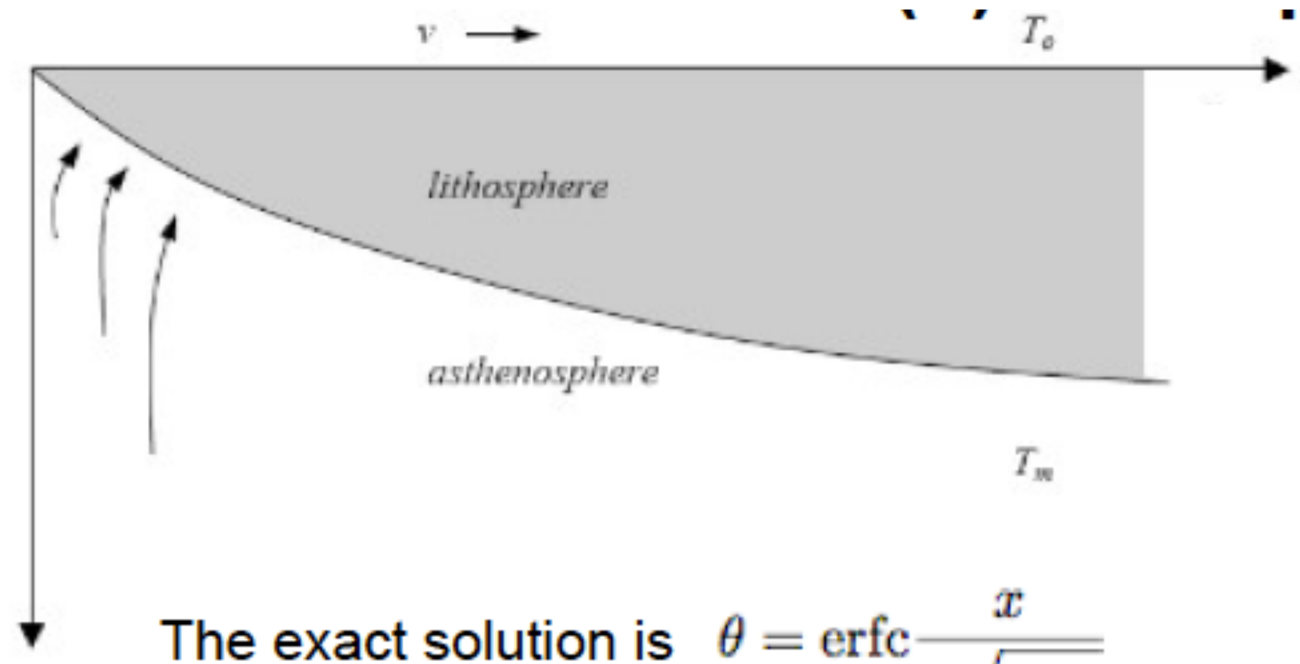
Numerical methods - **Pseudo-Spectral**

wave propagation

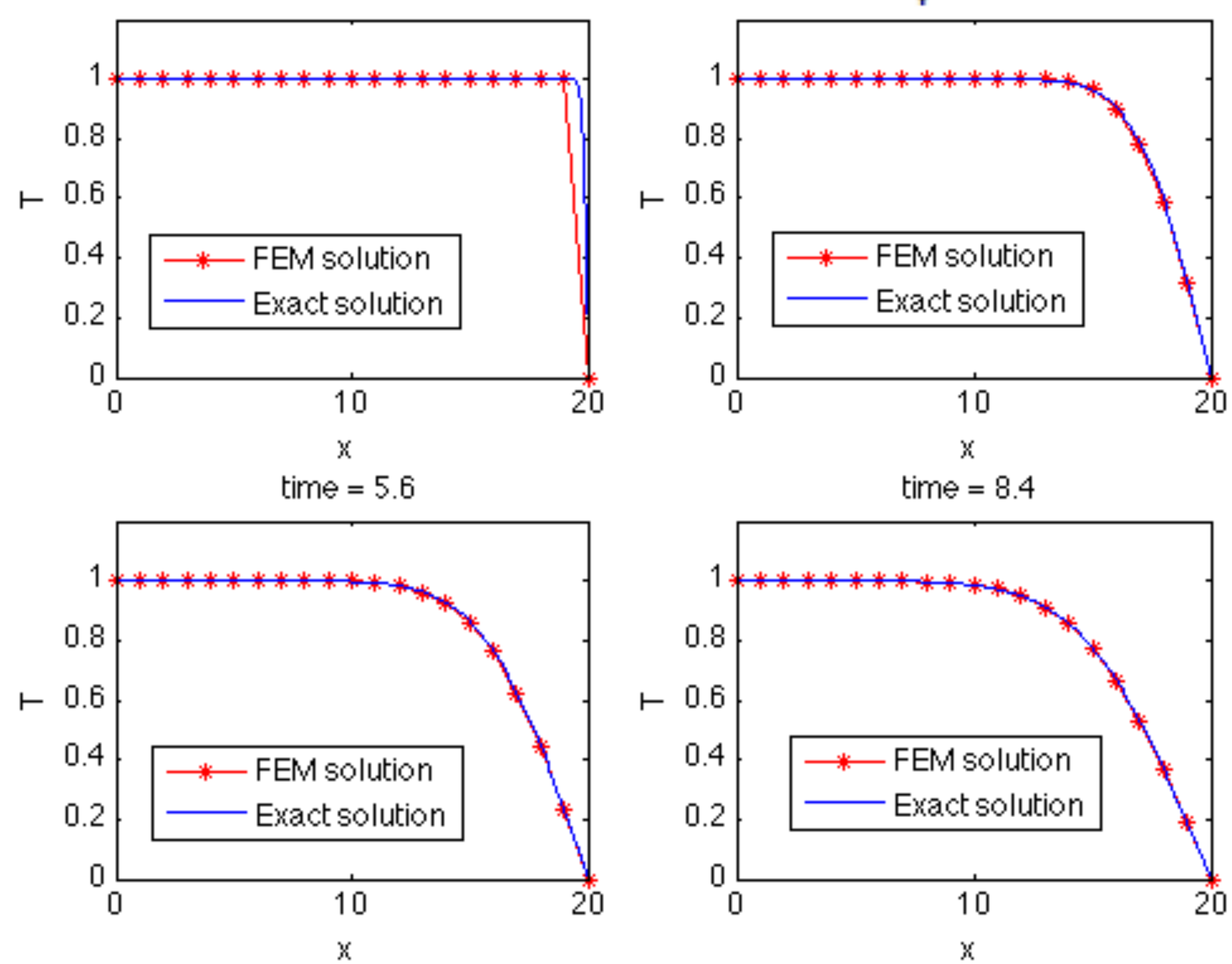


Numerical methods - **Finite-element method**

half-space cooling



The exact solution is $\theta = \operatorname{erfc}\dfrac{x}{2\sqrt{\frac{\kappa}{\rho c_p}t}}$



Numerical methods - **Spectral-element method**

wave propagation - anywhere

Computational Geophysics
-> in a nutshell