Application Areas: Astrophysics, financial markets (portfolio management), scientific research (computational modelling, biology, chemistry, physics, mathematics, geometry, graphics, signal processing, etc.), . . . Will be covered again in detail

Rank	Site	System	Cores	TFLOPs	Power (kWh)
1	Guangzhou, China	Tianhe-2: Intel Xeon	3,120,000	54,902	17,808
2	Oak Ridge Lab, USA	Titan: Cray Opteron, NVIDIA K20	560,640	27,112	8,209
3	DoE, USA	Sequoaia:, IBM BlueGene/Q	1,572,864	20,132	7,890
4	RIKEN Ins., Japan	K-Computer: Fujitsu SPARC64	705,024	11,280	12,660
5	DoE, USA	Mira: IBM BlueGene/Q	786,432	10,066.3	3,945
6	Swiss S.Comp., Switzerland	Cray, Intel Xeon, NVIDIA K20	115,984	7,788	2,325
7	Univ. Texas, USA	Stampede: Intel Xeon	462,462	8,520	4510
8	Forschchung Juelich, Germany	JUQUEEN: IBM BlueGene/Q	458,752	5,872	2,301
9	DoE, USA	Vulcan: IBM BlueGene	393,216	5,033	1,972
10	US Govt	Cray, Intel Xeon, NVIDIA K40	72,800	6,131	1,499
-	Your Home	Intel Core-i7	4	.026	0.3
-	Your Home	NVIDIA K40	2,880	4.29	0.3

Table 1: Top 10 Supercomputers: February 2015, top500.org

Premise: Top 10 Supercomputers (cont.)

Figure 4: China's Tianhe-2 . . . The Heaven River, The Milky Way, developed and operated by 1,300 scientists and engineers. Plans to double the computing power were stopped by the US government when they rejected Intel's application of granting an export license for selling CPU's and motherboards to the chinese government. Total of 3.12 Million Cores, and 1,375 TB RAM, runs Kylin Linux, and Slurm job management

Premise: Top 10 Supercomputers (cont.)

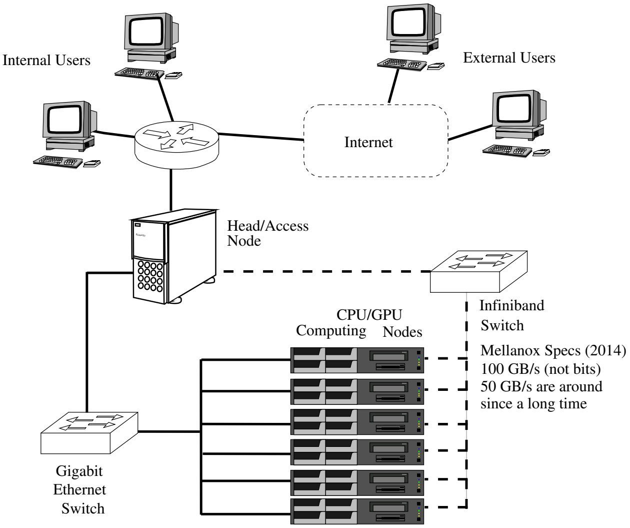


Figure 5: Setup of a typical HPC facility

Top 10 Supercomputers over Time

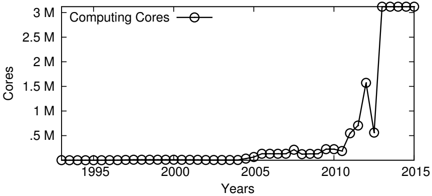
Year	Cores	FLOPs
2006	131,072	367,000,000,000,000 (367 TFLOP)
2007	212,992	596,000,000,000,000 (596 TFLOP)
2008	129,600	1,456,700,000,000,000 (1.4 PFLOP)
2009	224,162	2,331,000,000,000,000 (2.3 PFLOP)
2010	224,162	4,701,000,000,000,000 (4.7 PFLOP)
2011	705,024	11,280,400,000,000,000 (11.2 PFLOP)
2012	1,572,864	27,112,500,000,000,000 (27.1 PFLOP)
2013	3,120,000	54,902,400,000,000,000 (54.9 PFLOP)
2014	3,120,000	54,902,400,000,000,000 (54.9 PFLOP)
2015	3,120,000	54,902,400,000,000,000 (54.9 PFLOP)

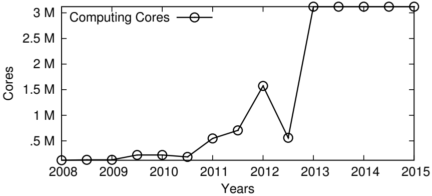
Table 2: Timeline Table of the Top Super-Computer, top500.org

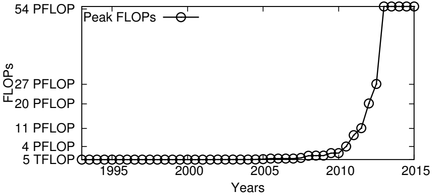
atto	10^{-18}		exa	10^{18}
femto	10^{-15}		peta	10^{15}
pico	10^{-12}		tera	10^{12}
nano	10^{-9}		giga	10^{9}
micro	10^{-6}		mega	10^{6}
milli	10^{-3}		kilo	10^{3}

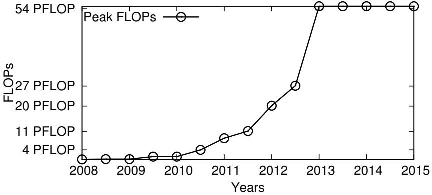
Table 3: Scales

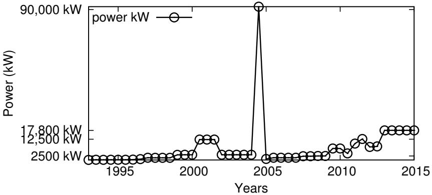
Top 10 Supercomputers over Time (cont.)

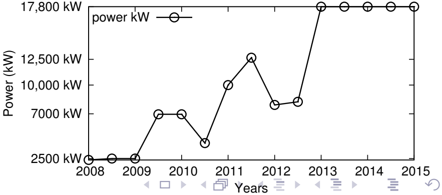












Moore's Law, 1965

A prediction that would define the pace of digital revolution.
Many interpretations:

- Computing would increase in **power** exponentially
- Computing would decrease in relative **cost** exponentially
- **Transistory density** will double every year (revised to double every 18 months)

Cramming more components onto integrated circuits

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore

Director, Research and Development Laboratories, Fairchild division of Fairchild Camera and Instrument Corp.

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

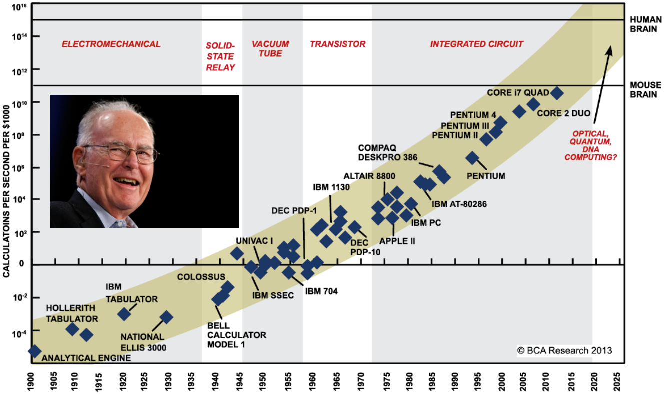
But the biggest potential lies in the production of large systems. In telephone communications, integrated circuits in digital filters will separate channels on multiplex equipment. Integrated circuits will also switch telephone circuits and perform data processing.

Computers will be more powerful, and will be organized in completely different ways. For example, memories built of integrated electronics may be distributed throughout the

The author

Dr. Gordon E. Moore is one of the new breed of electronic engineers, schooled in the physical sciences rather than in electronics. He earned a B.S. degree in chemistry from the University of California and a Ph.D. degree in physical chemistry from the California Institute of Technology. He was one of the founders of Fairchild Semiconductor and has been director of the research and development laboratories since 1959.

Electronics, Volume 38, Number 8, April 19, 1965



SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

Serial vs Parallel vs Distributed

Serial Computing Systems

- Single control mechanism, determines the next instruction to be executed.
- All data operations are fetched from memory one at a time.
- Speedup can be introduced using:
  - Instruction Caching (large caches with low latency)
  - Pipelining (super-scalar architectures)
  - Overclocking
  - Overlapping of I/O and computation using Direct Memory Access (DMA)
- **Note: Two serial programs can execute concurrently (multi-taskng)**.

- **Multi-Processing**: Multiple CPU cores executing more than 1 program at a given time
- **Multi-Tasking**: A single CPU core "appearing" to be executing more than 1 program at a given time
- **Multi-Threading**: The presence of more than 1 "threads" in a single program.

Serial vs Parallel vs Distributed (cont.)

Parallel Computing Systems

- Several processors that are located within a small distance of each other
- Their main purpose is to perform a computation task jointly
- Communication between processors, if required, is reliable, fast, and predictable.

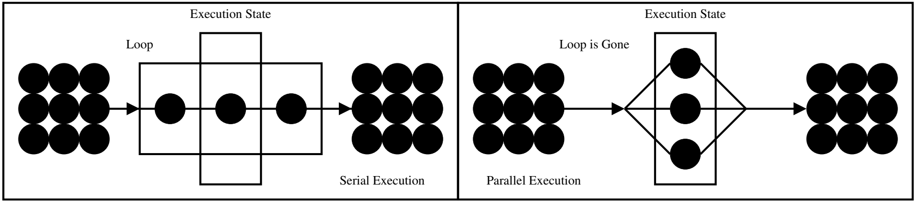


Figure 6: Difference between serial and parallel execution