Total Cost of Ownership in High Performance Computing

HPC data center cost considerations: investment, operation and maintenance.

SoSe 2014

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Why invest in HPC?

"Modern science needs growing computing power."

– Prof. Dr. Dieter Lenzen (25 Jahre Klimarechenzentrum)

Why invest in HPC?

- Research on a high level through experiments and simulation
- Benefits for society and industry

→ Mistakes in experiments and simulation are less costly than mistakes in reality

Why invest in HPC?

- PRACE (Partnership for Advanced Computing in Europe)
  - Enhances European competitiveness for benefit of society
  - Powers research in various scientific fields
  - Undertakes initiatives to prepare for changing technology
  - Interest in improving energy efficiency →Green Energy

- "High Performance Computing (HPC) is critical for industries that rely on precision and speed, such as automotive and aviation, and the health sector. Access to rapid simulations carried out by ever improving supercomputers can be the difference between new jobs and profits or bankruptcy."

Source: http://www.prace-ri.eu/IMG/pdf/prace_-_the_scientific_case_-_full_text_-.pdf

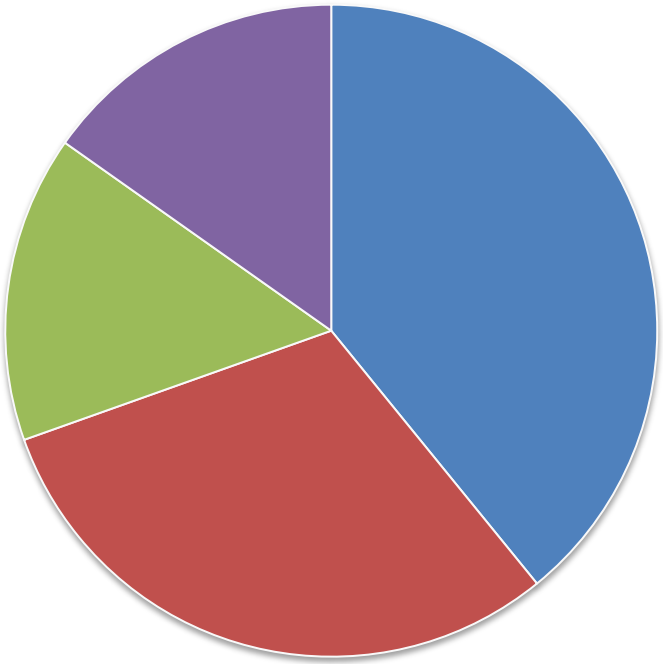
TCO – Total Cost of Ownership

- **Investment costs** (investments made upfront):
  - Hardware (servers, storage, network, cabling, generators, cooling systems, …)
  - Software
  - Data center construction costs

- **Operational costs** (recurring costs):
  - Energy costs
  - Human resources → "brainware" pays off
  - Maintenance / repairs

TCO – Total Cost of Ownership

- Investments in supercomputers worldwide:
  - 2011: $27 billion
  - 2016: $38 billion



Hardware	36 %
Power consumption	28 %
Staff	13 % - 14 %
Maintenance	13 % - 14 %

TCO – Total Cost of Ownership

- 2002: **Earth Simulator** (Yokohama): $600 million (6MW→ $5 million/year)
- 2010: **Tianhe-1A** (Tjanin): $88 million

  (4MW → $3.5 million/year)
- 2011: **K computer** (Kobe): around $1 billion (12MW → $10 million/year)
- 2012: **SuperMUC** (Munich): €135 million

  (3MW → €5 million/year)

Ecological footprint

- Supercomputer‘s lifelong energy costs almost equal the investment costs
- With increasing computational power the required energy rises as well
- TCO has to account for high reliability of power supply

- Green Energy
- Green500 list ranks Top500 by energy efficiency
  - #1 (Tianhe-2) of Top500 is #40 on Green500
  - #311 (Tsubame-KFC) of Top500 is #1 on Green500

Ecological footprint

- 2.26 million MWh in 2010
- Google‘s data centers are particularly energy efficient
- ~34 % clean energy
- Invests more than $1 billion in renewable energy projects

Source: http://www.google.com/green/energy/

Google‘s data centers –an example

- Hamina (Finland)

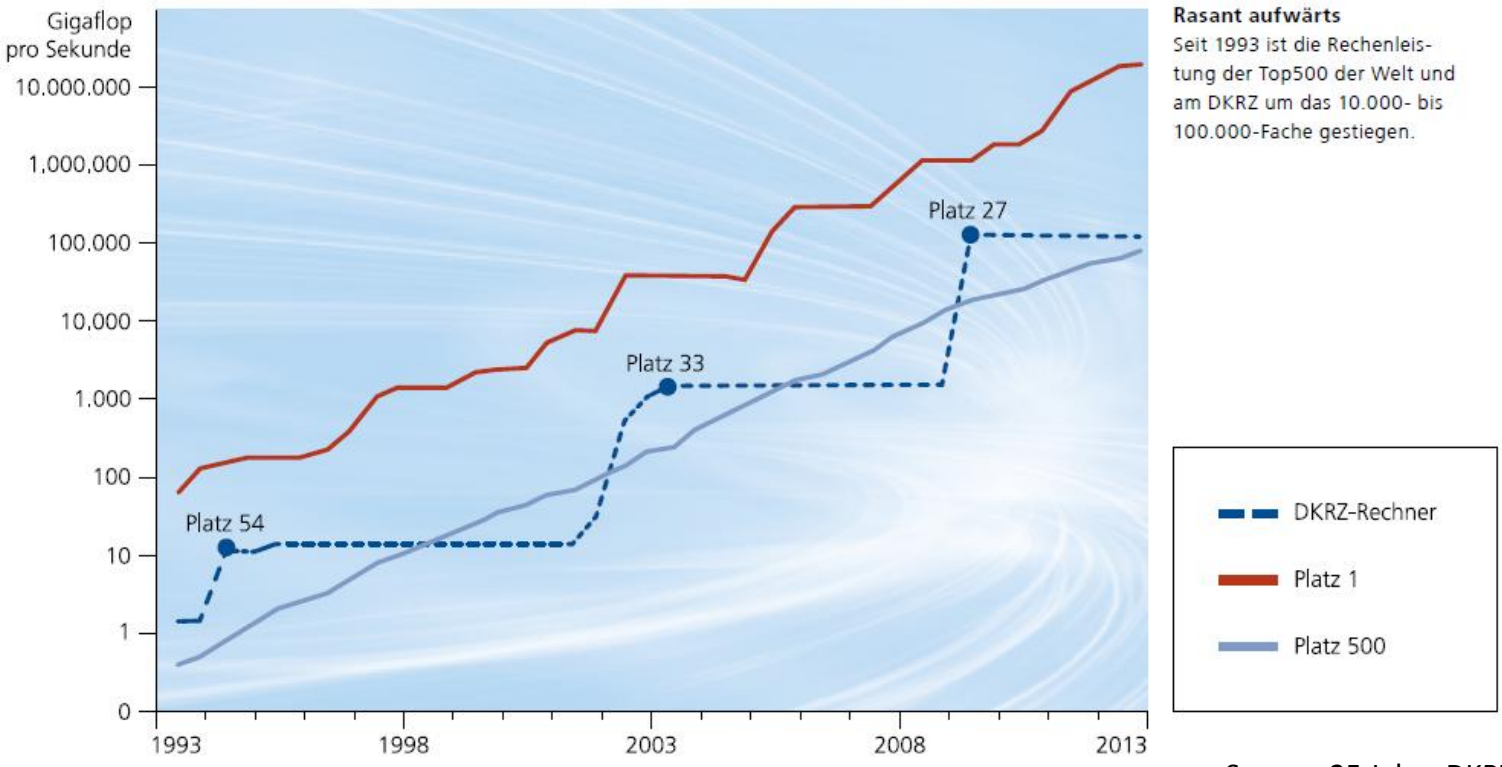
- Rising investment:
  Phase 1 (2009-2011): €200 million
  Phase 2 (2012-2013): + €150 million
  Phase 3 (2013): + €450 million
  → keeps on expanding

- Energy efficient, high tech-cooling system uses nearby seawater

Source:
http://www.google.com/about/datacenters/inside/locations/hamina/index.html

DKRZ

- A new supercomputer every 5 years
- Increase in processing power and data by factor 100,000 within 25 years
- Uses certified renewable energy



Rasant aufwärts
Seit 1993 ist die Rechenleistung der Top500 der Welt und am DKRZ um das 10.000- bis 100.000-Fache gestiegen.

Source: 25 Jahre DKRZ, S.17

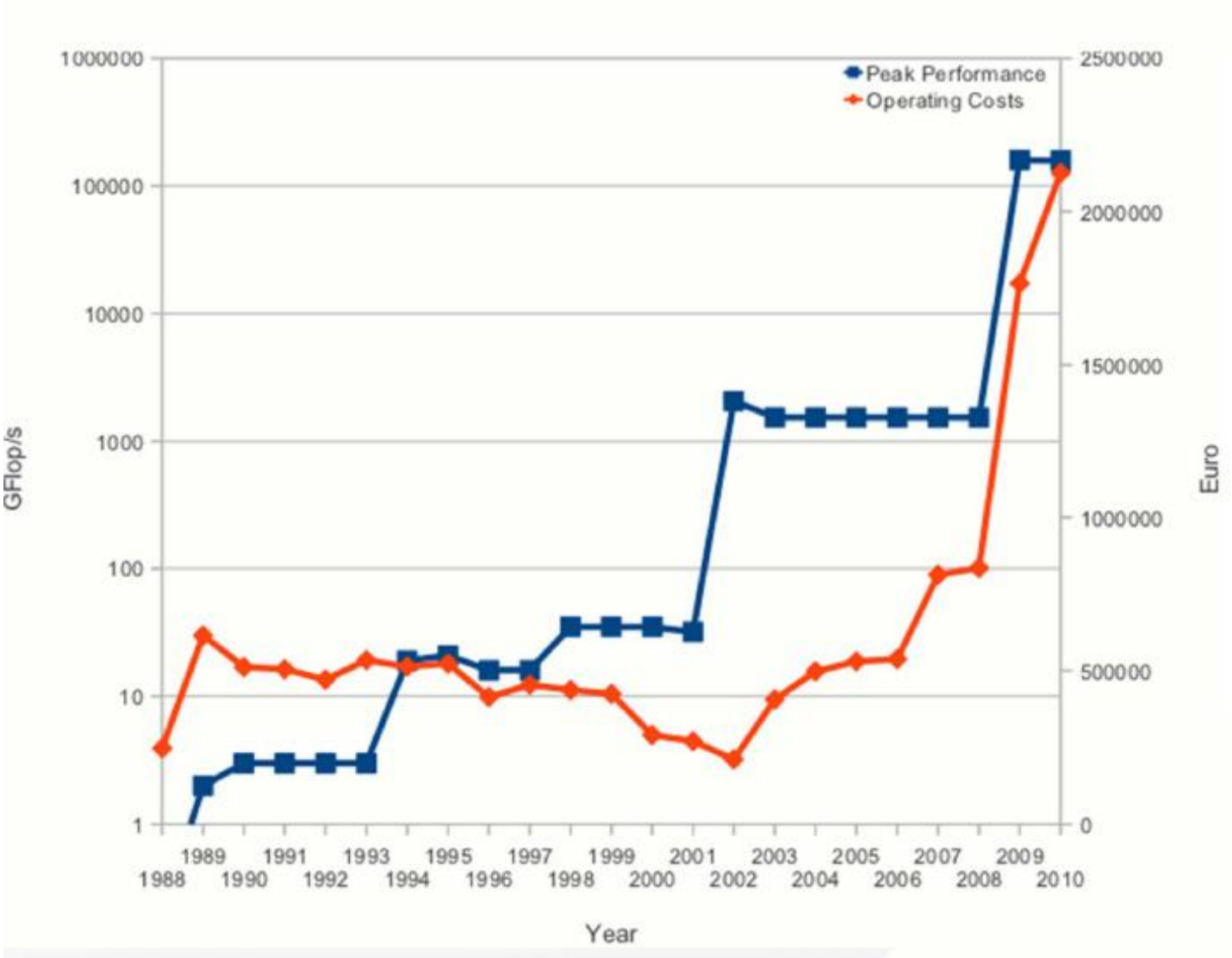
DKRZ

- Blizzard:
  - €35 million (Blizzard + new data archive)
  - 8,500 cores
  - 158 TFlops/s
  - 250m² room, 35t
  - 2MW
  - >€2 million/year for electricity
  - 75 % water-cooling, 25 % air-cooling

  - TCO/year: €16 million (€8M hardware + €8M operational costs)

Source: https://www.dkrz.de/about/kontakt/presse/aktuell/archiv-2013/energieeffizienz/image

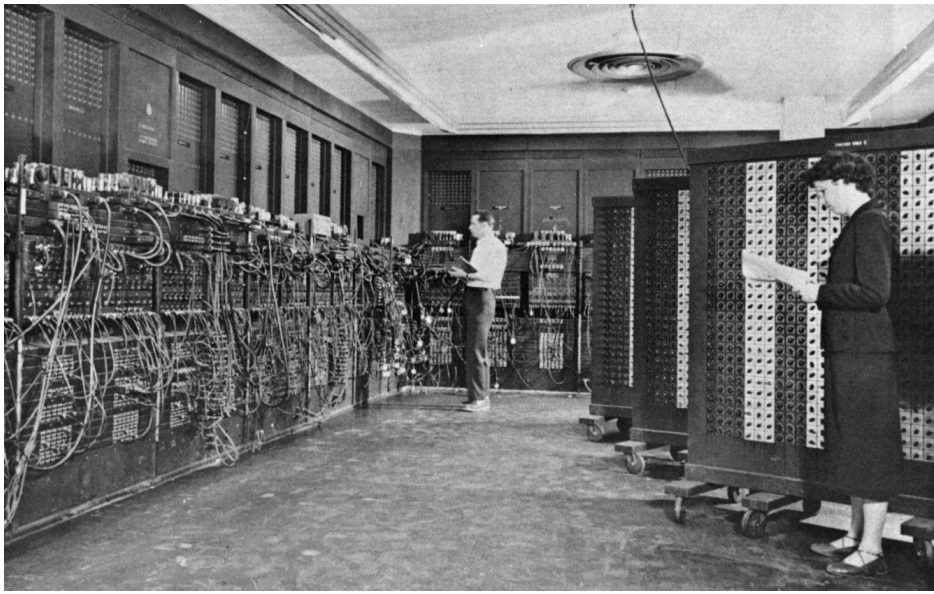
DKRZ



Source: The Costs of HPC-based science in the exascale era

Eniac – the first electronic general-purpose computer

- In operation from 1947 to 1955
- $500,000 (~ $6 million today)
- 27 tons, 167m² room, 150 kW



- Vacuum tubes burned out almost every day → nonfunctional about half the time
- Could calculate numbers 50,000 times faster than a human, 20,000 times faster than a calculator

Source: http://upload.wikimedia.org/wikipedia/commons/4/4e/Eniac.jpg

System /360

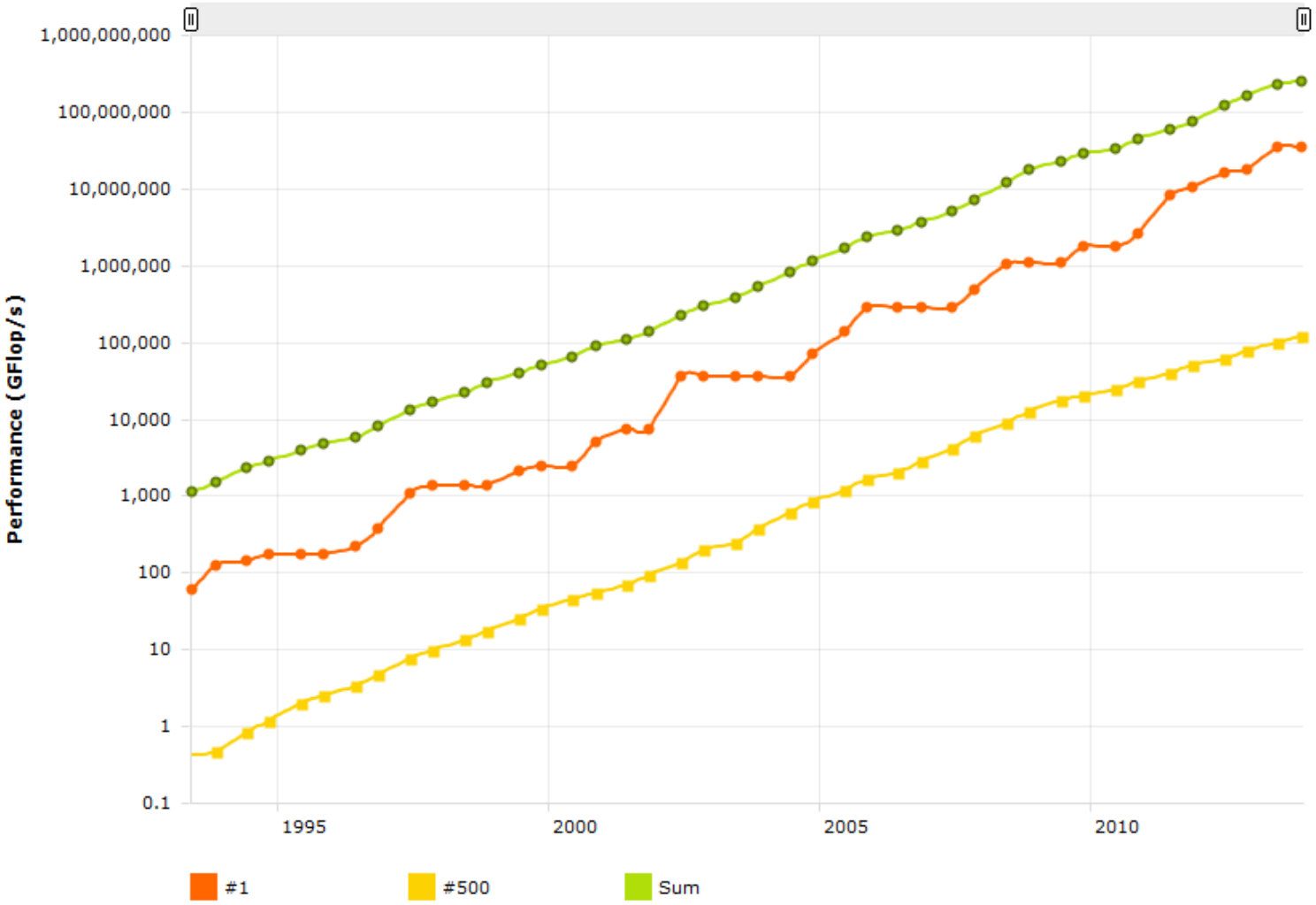
- Announced April 7, 1964
- IBM invested $5.5 billion (~ $40 billion today)
- Between 33,000 and 750,000 additions
- Beginning of an era of computer compatibility
  → Computer <u>systems</u>
- A new industry with
  plug-compatible products was born
- Clones of System /360
  spawned the PC industry in the 80s

Source: http://www-03.ibm.com/ibm/history/ibm100/images/icp/C713286B04220T42/us__en_us__ibm100__system_360__woman_at_360__800x593.jpg

The Top500 list

- Since 1993, updated twice a year
- Lists supercomputers ranked by their performance on the numeric LINPACK Benchmark
- American supercomputers are dominating the list (264 entries in November 2013)
- A rank on the list comes with financial benefits

The Top500 list



Source: Top500, Performance development: http://www.top500.org/statistics/perfdevel/#.U3IUTihri8A

CM-5

- **CM-5/1024** in Los Alamos National Laboratory (United States)
- 1,024 cores
- 59.7 GFlops/s

FROSTBURG (CM-5 supercomputer):

- Used by NSA, 1991-1997
- $25 million
- Peak performance of 65.5 GFlops/s

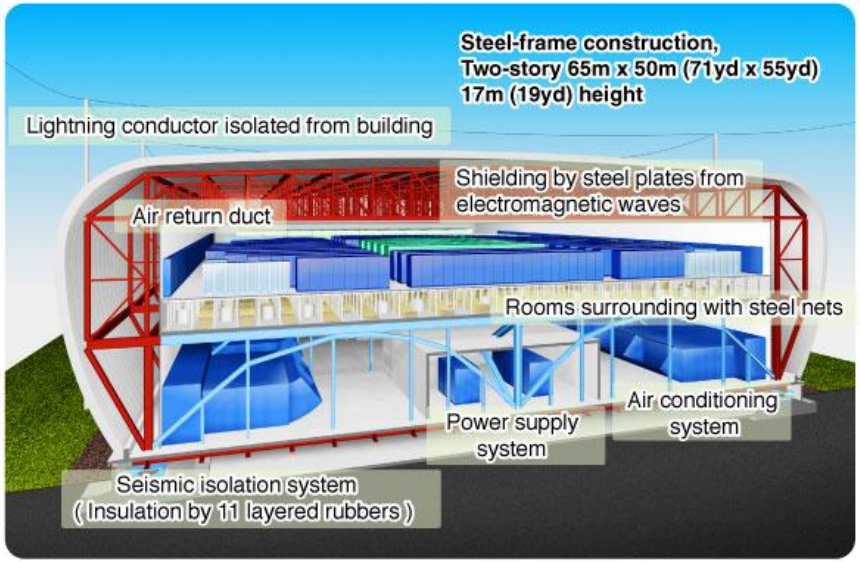
Source: http://www.top500.org/featured/systems/cm-5-los-alamos-national-lab/#.U3I9kyhri8B

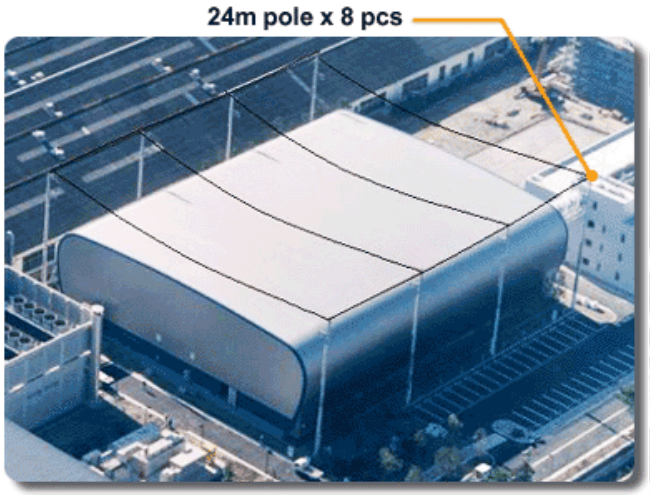
Earth Simulator 地球シミュレータ

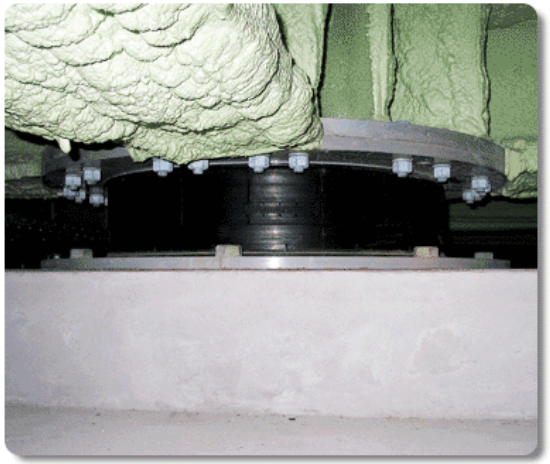
- In operation since 2002 (#1 from 2002 to 2004)
- Runs global climate models
- $600 million
  incl. $200 million (facility (3,250 m^2)
  and power plant) + $200 million for the system
- Earth Simulation center is
  protected from natural disasters
- 35.86 TFlops/s
- 6MW
- ES2 in 2009
  (#23 in 2009, #472 in 2013)
- 122.4 TFlops/s

Source: http://upload.wikimedia.org/wikipedia/commons/1/18/EarthSimulator.jpg

Earth Simulator 地球シミュレータ





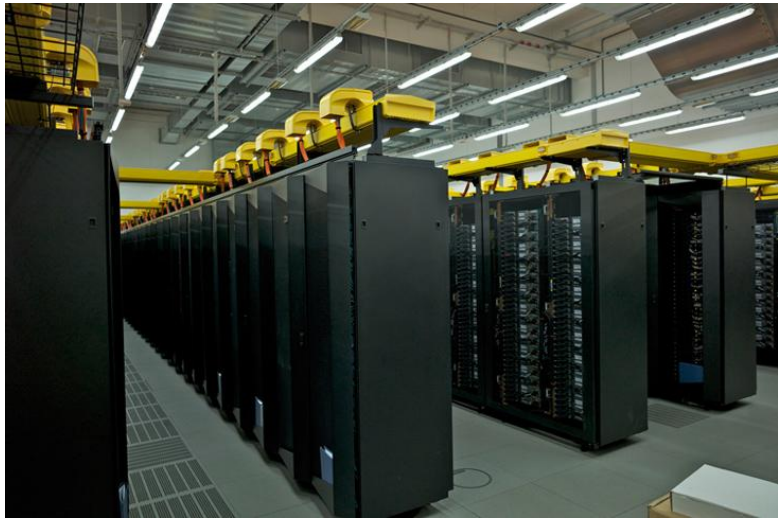


Source: http://www.jamstec.go.jp/es/en/es1/system/facility.html

SuperMuc

- #10 in the current Top500
- In operation since 2011/2012
- €50 million for data center + €50 million for system + €30 million for electricity costs
- 2.8 PFlop/s
- 147,456 cores
- 3MW
- Cooling through warm water

  → saves energy costs



Source: http://www.research.ibm.com/software/IBMResearch/image/7176787740_e3e063c90f_h.jpg

Tianhe-2 天河二号 (*MilkyWay-2*)

- Current #1
- $390 million
- 34 PFlops/s
- 3,120,000 cores
- 18MW + 6.4MW cooling
- 720m² room

Source: http://www.top500.org/system/177999#.U3IcjShri8A

Advent of the Exascale Era

- EFlops-computer by 2020
- Shall be 50 to 100 times more powerful than today‘s supercomputers
- $500 million to $1.5 billion
- Energy costs will be higher:

  20MW → $20 million/year for electricity

Quantum Computing

- Uses Quantum mechanics
- Can solve more complex problems
- Qubit: can be either 1 or 0 or both at the same time→ calculates faster
- Quantum tunneling → less energy
- Manufacturing company D-Wave in Canada:
  - Since 2013 in the shared AI lab of Google and NASA
  - Not yet faster than a normal supercomputer

"Virtually every sector of society-manufacturing, financial services, education, science, government, the military, entertainment, and so on-has become dependent on continued growth in computing performance to drive industrial productivity, increase efficiency, and enable innovation."

Source:
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