High Performance Computing Systems

- Benchmarks

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What is High Performance?

- Based on performance, of course
  - Many possible interpretations of performance....
- What can we use as indicators of performance?
- How do we go about measuring performance?
- Can we distinguish between HPC systems and non-HPC systems?

Benchmarks

- Used to assess performance of a machine
- Useful because they are "platform agnostic"
  - Or are they?
- Drawbacks?

Types of Benchmarks

- Real program
- Kernel
- Synthetic
- I/O
- Database
- Parallel

Whetstone

- First benchmark to gain wide usage
- Remove compiler optimization from the picture
- Results reported in MWIPS

Supplier or System	CPU and Precision	Clock MHz	MWIPS	MFLOPS	VAX MIPS	MWIPS DP	Lang	Opt	Cost $K	Intr Date
Cray										
Cray 1A	P4 Scalar	80	12.4			1.30	For		7000	1978
Cray 1A	P4 Scalar	80	16.2			1.30	For	later	7000	1978
Cray 1S	P4 Scalar	80	16.1				For			1980
Cray 1S	Vector	80	98.0				For			1980
X-MP1	P4 Scalar	118	30.3	11.0	34.7	2.70	For		5000	1982
X-MP1	Vector	118	313	151	175		For		5000	1982
X-MP1	90% Vector	118	162	66.4	125		For		5000	1982
Y-MP1	P4 Scalar	154	31.0	12.0	32.6	2.8	For		5000	1987
Y-MP1	Vector	154	449	195	314		For		5000	1987

- Doug's Laptop: guesses?

Dhrystone

- Only uses integer programming
  - Why?
- Design tries to mimic "real programs"
- Still in use today

Machine	RESULT	INDEX
Itanium2 "Madison" (1.5ghz, 6mb L3, 10gb ddr2100, Ubuntu 8.04 LTS, icc -s -static -O3 -fast -ipo -mcpu=itanium2)	31848427.3	1423.9
Xeon L5506 2.1ghz (Dell Poweredge R410, 8gb, gcc4.4,3 -O3 -m64)	22614633.6	1011.1
Q6600 (Gigabyte P35-DQ6, 3.6ghz, 2gb ddr2-800mhz, Ubuntu 64bit)	19240141.3	860.2
Athlon 64 3500+ (Gigabyte ga-k8u-939, pc2700, gcc4.0.2 -O3 -m64, overclocked to 2475Mhz)	16949343.0	757.8
i7 920 (Asus P6T Deluxe, overclocked 3.06ghz, 3x1GB DDR3, Ubuntu 8.10, gcc4.3 -m64)	16876489.8	754.5
Athlon 64 3800+ (MSI K8N NEO2 Platinum-54G, pc3200 corsair, Mandriva 2006.0, gcc4.0.1 -O6 -m64)	16633090.0	743.7

- Doug's Laptop: Guesses?

NAS Parallel Benchmarks

- Developed by NASA in 1991
- Test suite – 8 different benchmarks
  - Kernel (5)
  - Computational Fluid Dynamics applications (3)
  - More have been added since
- Designed for highly parallel systems (supercomputers)

NAS

- Kernel
  - Integer sort
  - Embarassingly Parallel
  - Multi-grid
  - Conjugate Gradient
  - Fast Fourier Transform



NAS – CFD Benchmarks

- All three solve a system of non-linear PDEs, only difference is the method used:
  - Block Tridiagonal
  - Scalar Pentadiagonal
  - Successive over-relaxation (Gauss-Sidel)

- These were included because the field of CFD is an area of particular interest to NASA (and others)

NAS – Problems

- Two major issues:
  - "Pencil and paper"
  - Problem size
- Successive releases fixed these problems

LINPACK

- Perhaps the most important benchmark today
  - Not originally intended for benchmarking...
- Became increasingly successful because of its scalability
- Relies on LU decomposition:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} u_{11} & u_{12} & u_{13} \\ 0 & u_{22} & u_{23} \\ 0 & 0 & u_{33} \end{bmatrix}.$$

LINPACK - Details

- Sucessful due to its fairly simple procedure
  - Gaussian elimination
  - How many operations?
- Has been shown to provide performance at or near a computer's limits
- HPLinpack allows for this benchmark to be executed on parallel systems

LINPACK

- Pros:
  - Provides a single metric
  - Highly scalable
  - (relatively) Simple Algorithm
- Cons?

TOP500 – Supercomputer Rankings

- Since HPC is a constantly developing field, what is considered the "best" HPC changes frequently
  - This has implications over time....

- Enter TOP500:
  - Started in 1993
  - Also provides information about theoretical performance, power consumption, number of cores, etc.
  - List is recompiled twice a year

TOP500 – The top 5 (Nov. 2016)

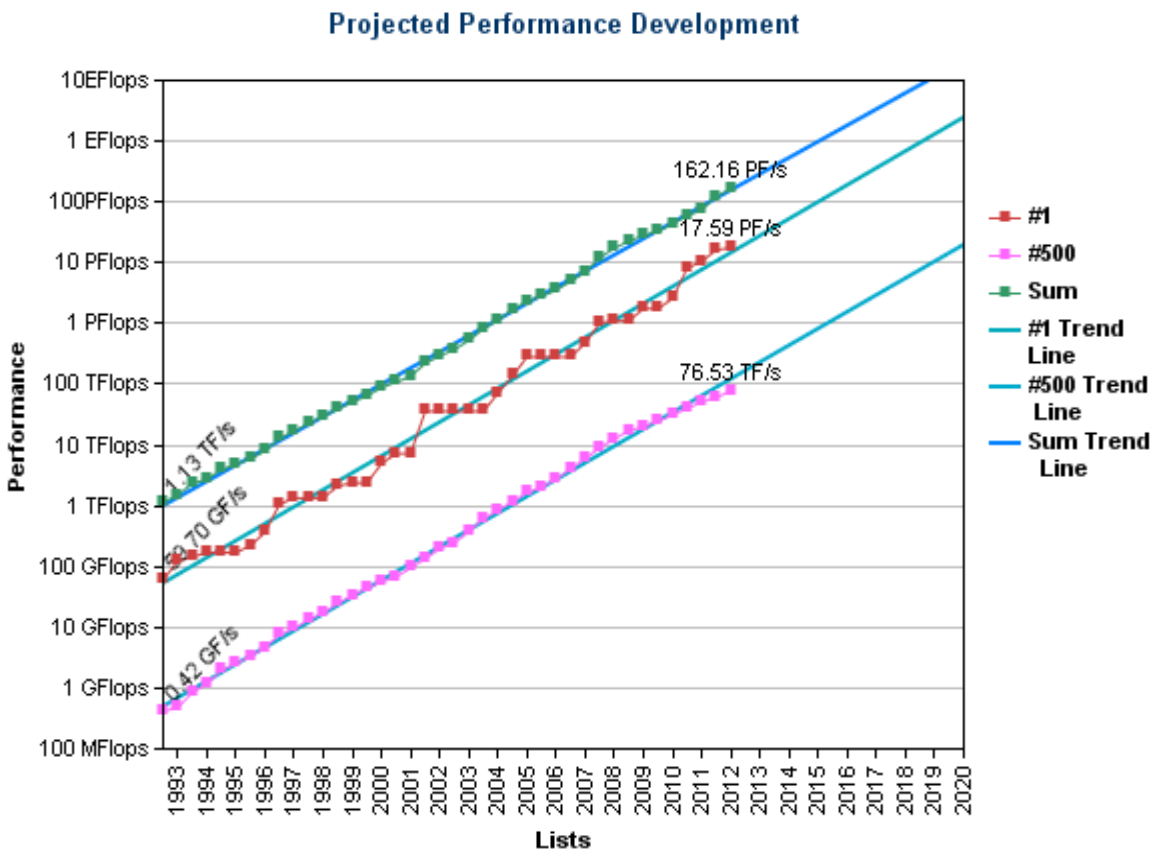
Rank	Site	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	National Supercomputing Center in Wuxi China	**Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway NRCPC	10,649,600	93,014.6	125,435.9	15,371
2	National Super Computer Center in Guangzhou China	**Tianhe-2 (MilkyWay-2)** - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P NUDT	3,120,000	33,862.7	54,902.4	17,808
3	DOE/SC/Oak Ridge National Laboratory United States	**Titan** - Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x Cray Inc.	560,640	17,590.0	27,112.5	8,209
4	DOE/NNSA/LLNL United States	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM	1,572,864	17,173.2	20,132.7	7,890
5	DOE/SC/LBNL/NERSC United States	**Cori** - Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect Cray Inc.	622,336	14,014.7	27,880.7	3,939

TOP500 – The top 5 (Jun. 1993)

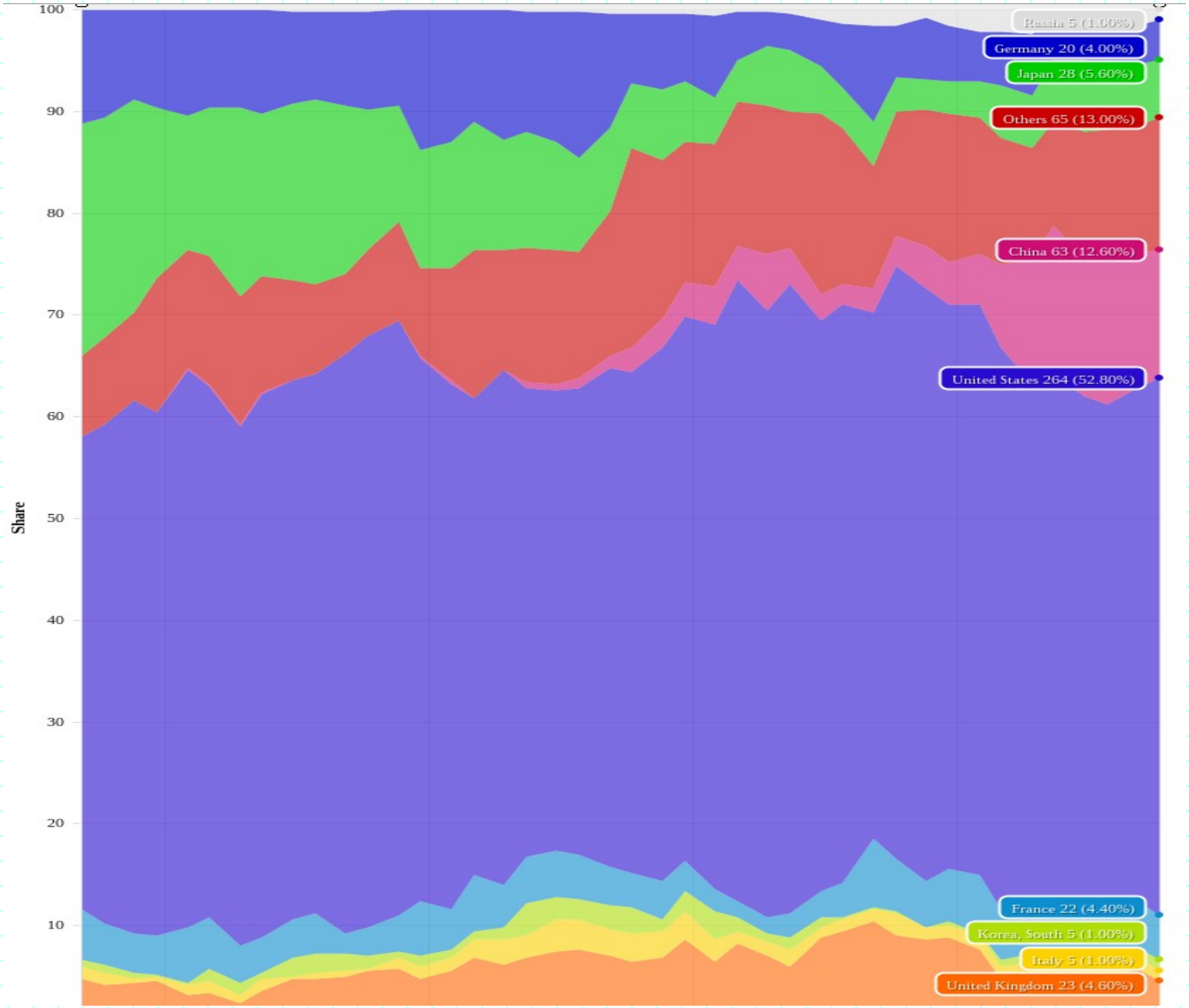
Rank	Site	System	Cores	Rmax (GFlop/s)	Rpeak (GFlop/s)
1	Los Alamos National Laboratory United States	CM-5/1024 Thinking Machines Corporation	1024	59.7	131.0
2	Minnesota Supercomputer Center United States	CM-5/544 Thinking Machines Corporation	544	30.4	69.6
3	National Security Agency United States	CM-5/512 Thinking Machines Corporation	512	30.4	65.5
4	NCSA United States	CM-5/512 Thinking Machines Corporation	512	30.4	65.5
5	NEC Japan	SX-3/44R NEC	4	23.2	25.6

TOP500

- In the last 20 years the fastest super computer has increased by an astonishing factor
- More astonishing: this growth conforms to expectations

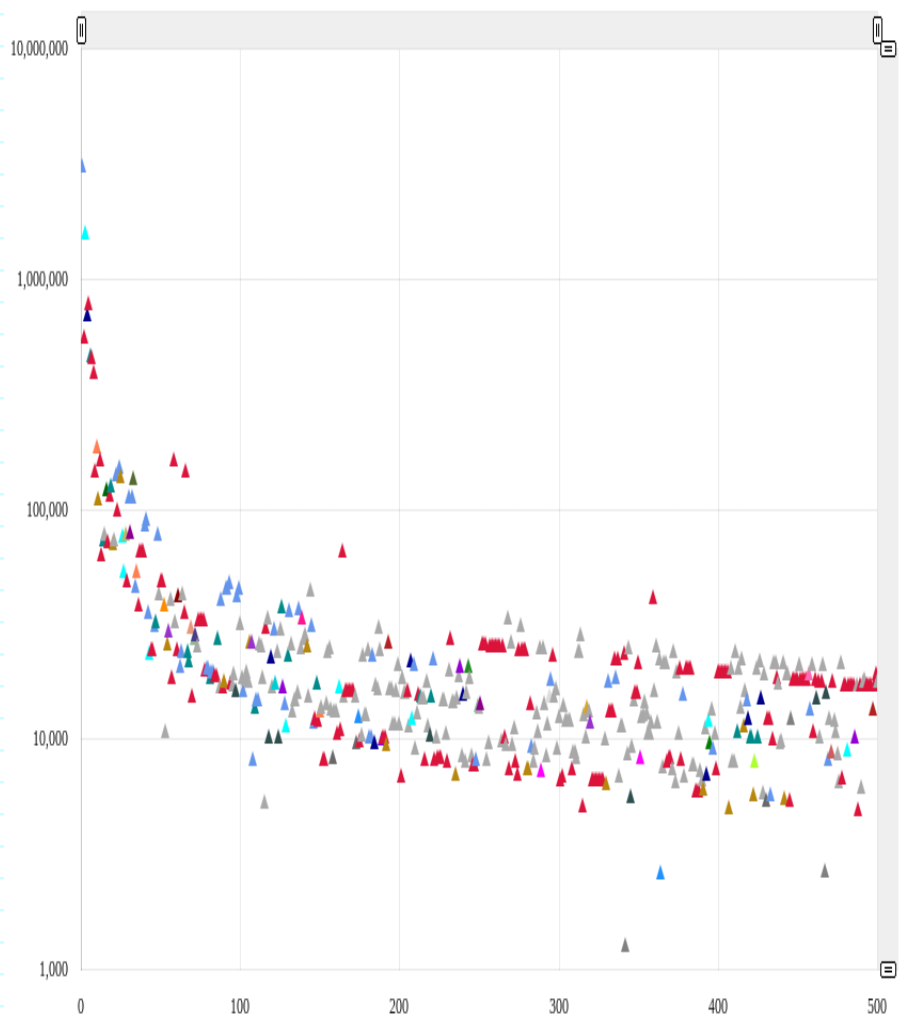


TOP500 – Country Breakdown



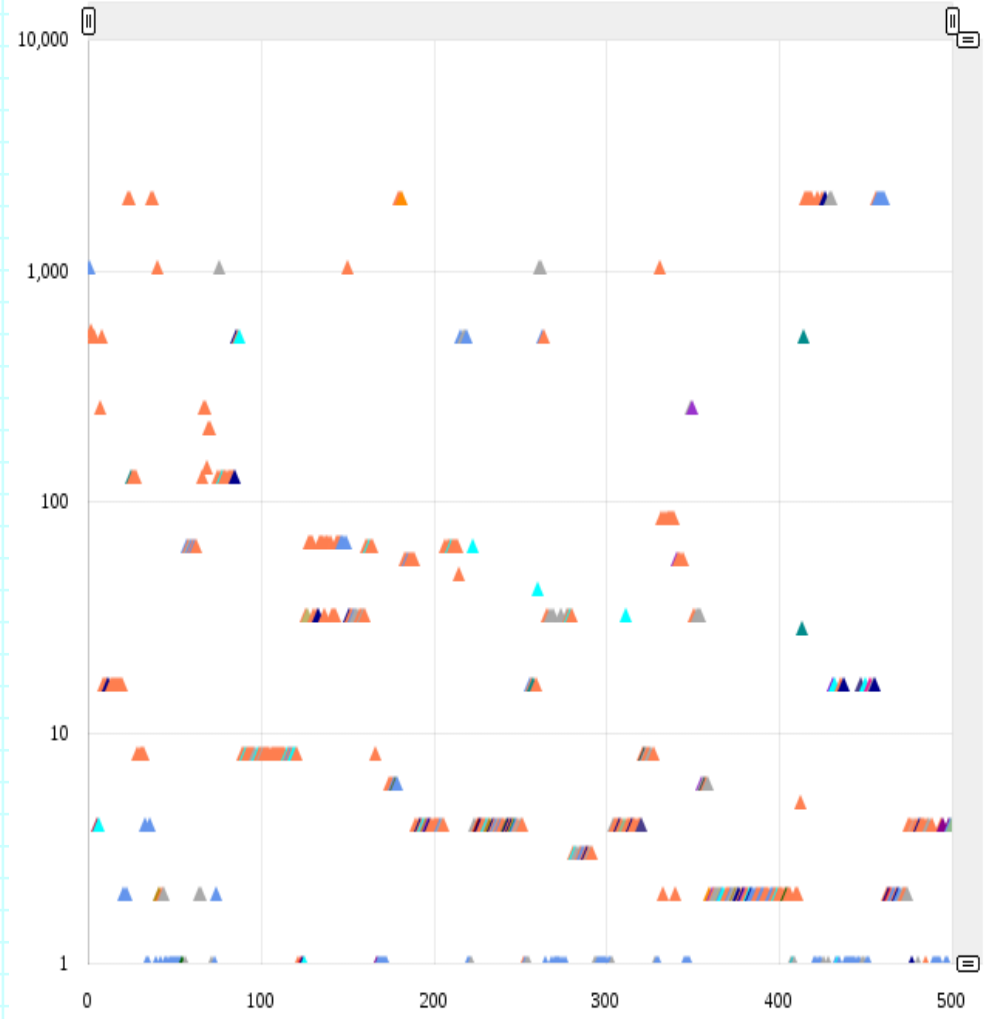
TOP500 – Number of cores

2013



TOP500 Ranking

1993



TOP500 Ranking

The Future of Benchmarking

- LINPACK is becoming less adequate
- Traversed edges per second (TEPS)
  - Edge refers to....
  - Traversal refers to....
  - Tracked by Graph500
    - Results?

GRAPH 500

No.	Rank	Machine	Installation Site	Number of nodes	Number of cores	Problem scale	GTEPS
1	1	K computer (Fujitsu - Custom)	RIKEN Advanced Institute for Computational Science (AICS)	82944	663552	40	38621.4
2	2	Sunway TaihuLight (NRCPC - Sunway MPP)	National Supercomputing Center in Wuxi	40768	10599680	40	23755.7
3	3	DOE/NNSA/LLNL Sequoia (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)	Lawrence Livermore National Laboratory	98304	1572864	41	23751
4	4	DOE/SC/Argonne National Laboratory Mira (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)	Argonne National Laboratory	49152	786432	40	14982
5	5	JUQUEEN (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)	Forschungszentrum Juelich (FZJ)	16384	262144	38	5848

What is High Performance?

- Answer: It depends
  - Generically...
  - Specifically...
-
- Many factors go into performance
- Performance is constantly being measured (benchmarks)
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- So what do you think?