TOP500 and Accidental Benchmarking

New Directions in Numerical Linear Algebra and High Performance Computing: Celebrating the 70th Birthday of Jack Dongarra, July 8, 2021

TOP 500
The List.

Erich Strohmaier

Confessions of an Accidental Benchmarker

- Appendix B of the Linpack Users' Guide
  - Designed to help users extrapolate execution Linpack software package
- First benchmark report from 1977;
  - Cray 1 to DEC PDP-10

"APPENDIX B"

UNIT = 10**6 TIME/(1/3 100**3 + 100**2)

$\frac{2}{3}n^3 \, 2n^2$ ops/time

| Facility	TIME N=100 secs.	UNIT micro- secs.	Computer	Type	Compiler
NCAR	.049	0.14	CRAY-1	S	CFT, Assembly BLAS
LASL	.148	0.43	CDC 7600	S	FTN, Assembly BLAS
NCAR	.192	0.56	CRAY-1	S	CFT
LASL	.210	0.61	CDC 7600	S	FTN
Argonne	.297	0.86	IBM 370/195	D	H
NCAR	.359	1.05	CDC 7600	S	Local
Argonne	.388	1.33	IBM 3033	D	H
NASA Langley	.489	1.42	CDC Cyber 175	S	FTN
U. Ill. Urbana	.506	1.47	CDC Cyber 175	S	Ext. 4.6
LLL	.554	1.61	CDC 7600	S	CHAT, No optimize
SLAC	.579	1.69	IBM 370/168	D	H Ext., Fast mult.
Michigan	.631	1.84	Amdahl 470/V6	D	H
Toronto	.890	2.59	IBM 370/165	D	H Ext., Fast mult.
Northwestern	1.44	4.20	CDC 6600	S	FTN
Texas	1.93*	5.63	CDC 6600	S	RUN
China Lake	1.95*	5.69	Univac 1110	S	V
Yale	2.59	7.53	DEC KL-20	S	F20
Bell Labs	3.46	10.1	Honeywell 6080	S	Y
Wisconsin	3.49	10.1	Univac 1110	S	V
Iowa State	3.54	10.2	Itel AS/5 mod3	D	H
U. Ill. Chicago	4.10	11.9	IBM 370/158	D	G1
Purdue	5.69	16.6	CDC 6500	S	FUN
U. C. San Diego	13.1	38.2	Burroughs 6700	S	H
Yale	17.1*	49.9	DEC KA-10	S	F40

* TIME(100) = (100/75)**3 SGEFA(75) + (100/75)**2 SGESL(75)

TOP500 – WHY HPL?

- Adaptive definition of 'Supercomputer' for collecting market statistics

- Simple metric and procedure (few rules)

- Based on measured performance (system has to function)

- Floating point benchmark ('scientific computing' in early 90s)

- High performing (optimizable) to encourage adoption

- Broad system coverage

➢ HPL (High Performance Linpack) had widest coverage by a factor 2-3 x at least

  ➢ In 1993 and still !

PERFORMANCE DEVELOPMENT
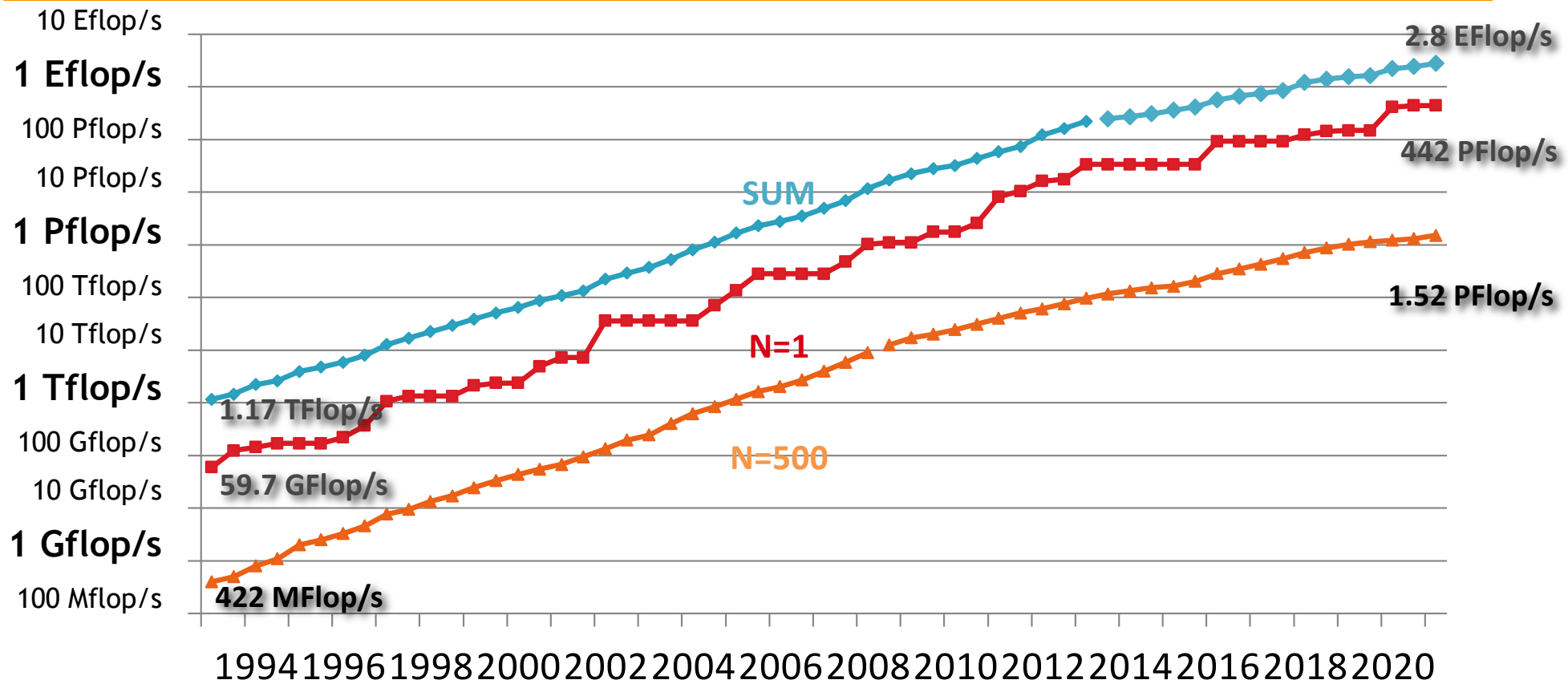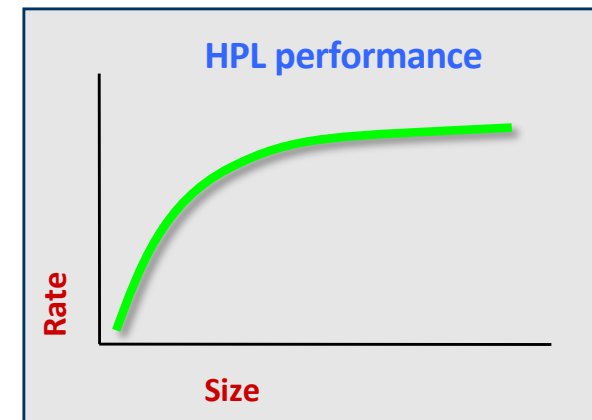
WHY DID LINPACK WORK SO WELL?

Many reasons, here are 2 essentials for the *TOP500*:

1) Easy and continuous scalable problem size

    – Simplicity

2) Asymptotically best performance

    – For both **system size** and **problem size**

    – Brings out correct long-term trends
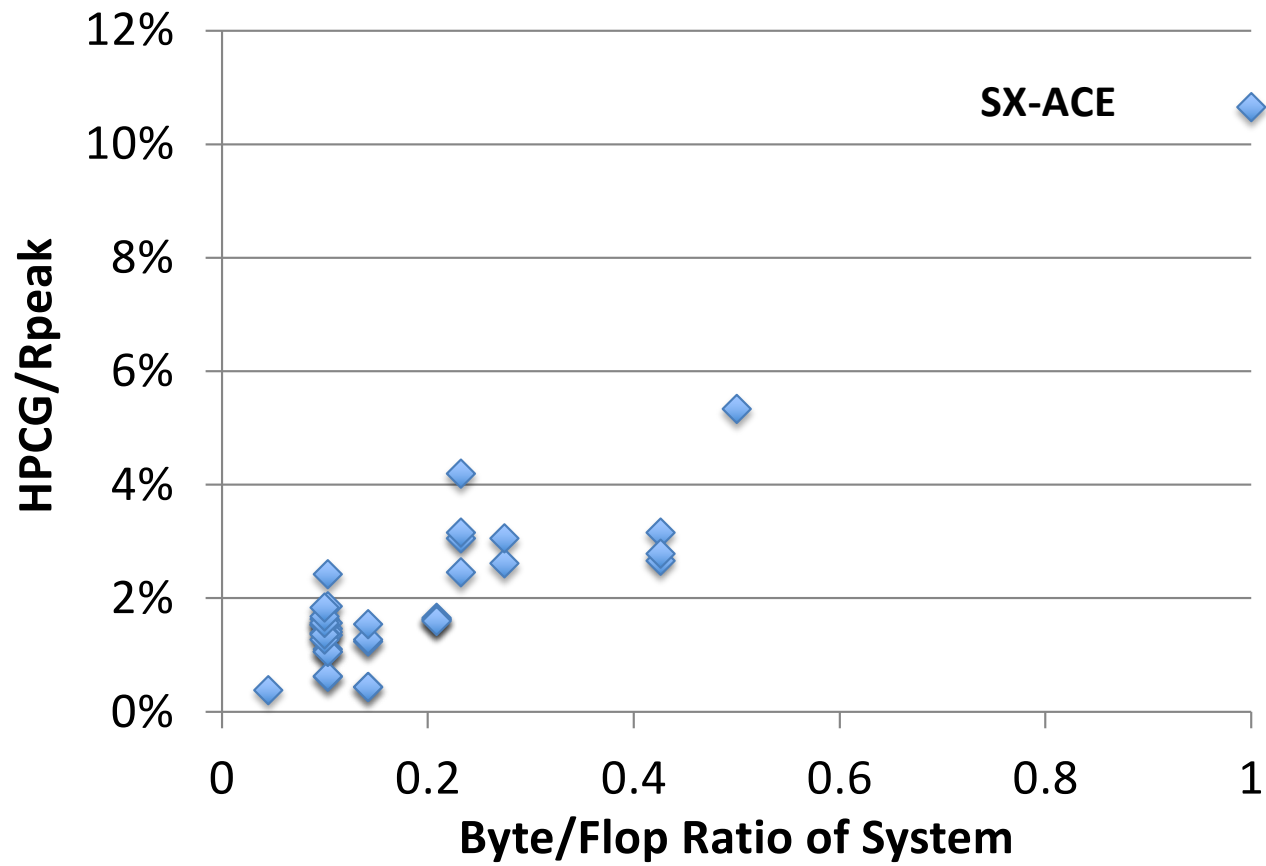
CRITERIA FOR ADDITIONAL BENCHMARKS

- **All the good things from HPL plus**:
    - **Arithmetic Intensity: Flop/Bytes ~ O(1)**
    - Main features all scale with O(n)

- **Does not correlate overly well with established BMs**
- **Changes relative rankings compared to TOP500**
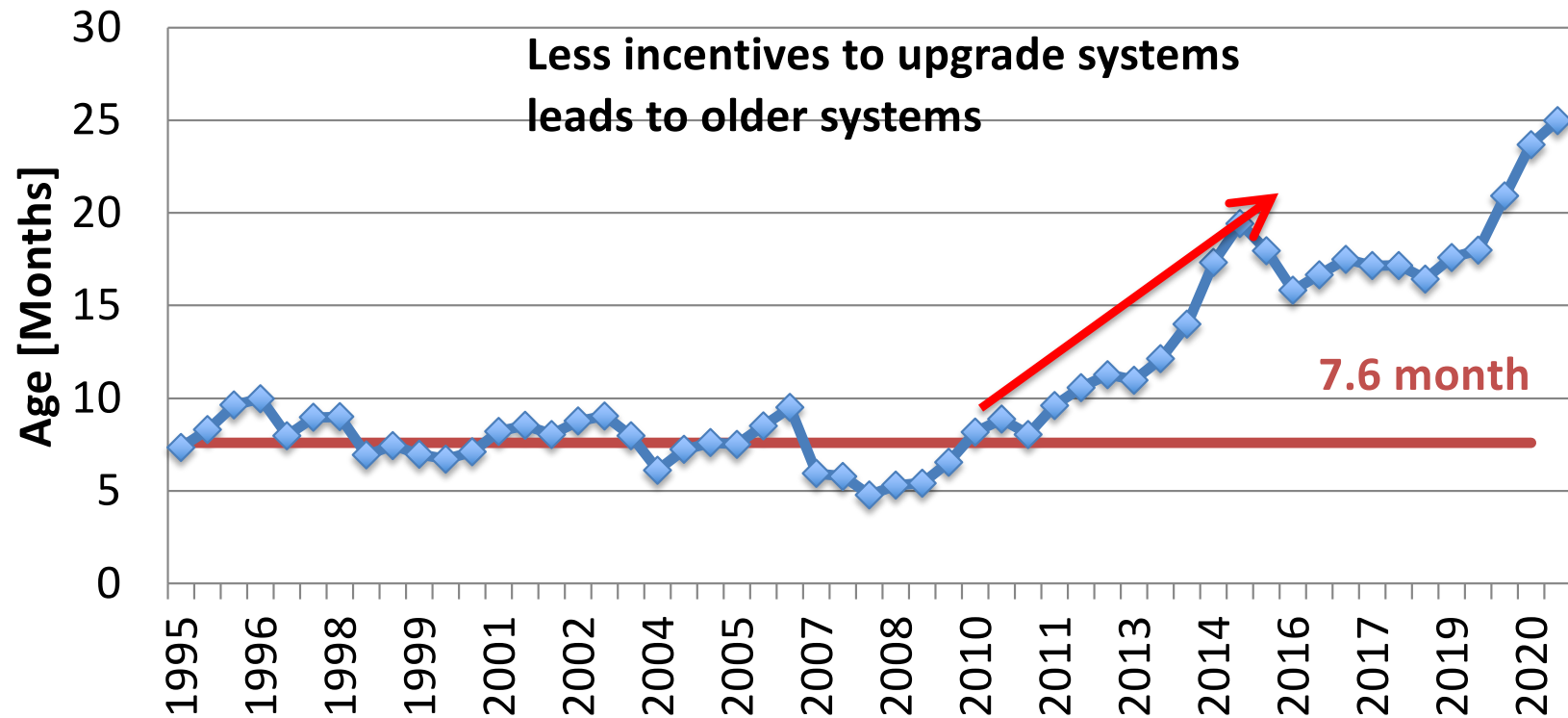
HPCG - BYTES/FLOPS

SIAM PP 2018

HPL-AI Benchmark Top 5 List, June 2021

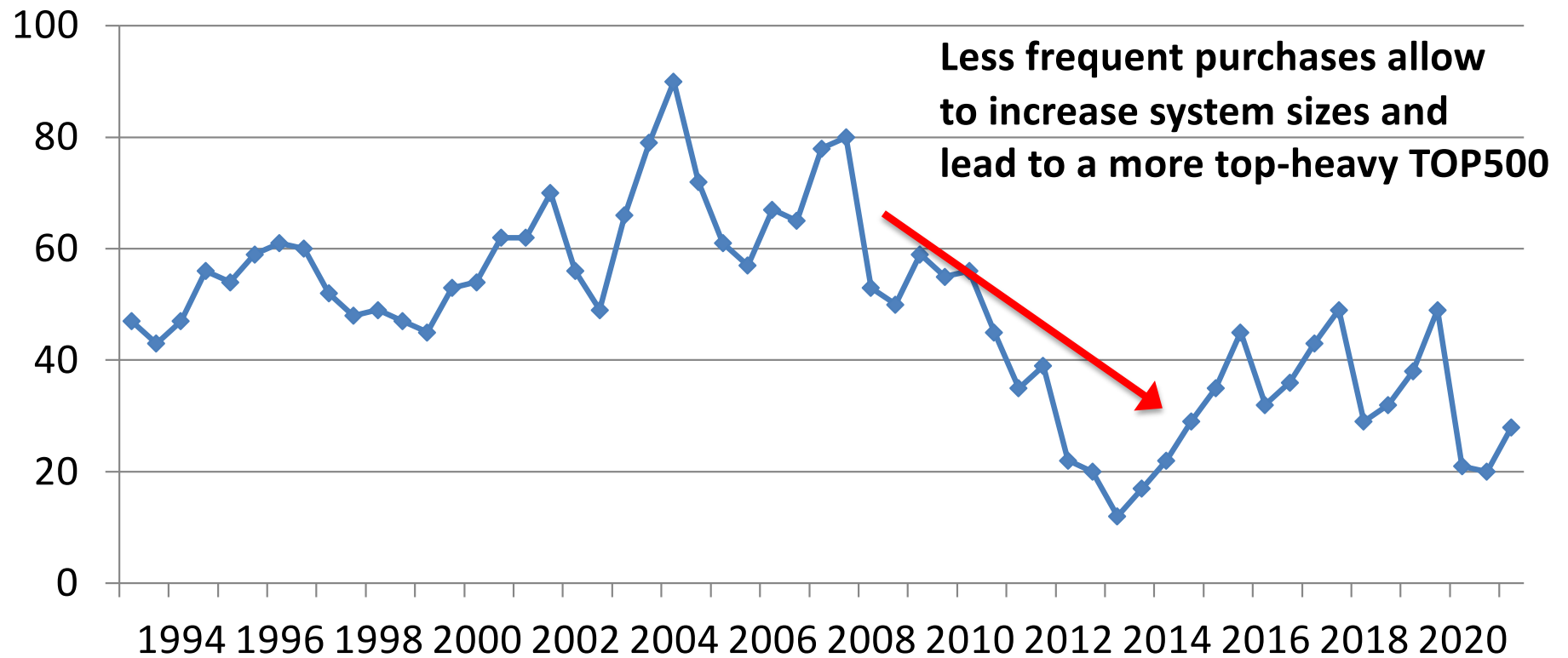| Rank	Site	Computer	Cores	HPL Rmax (Eflop/s)	TOP500 Rank	HPL-AI (Eflop/s)	Speedup
1	RIKEN Center for Computational Science Japan	**Fugaku**, Fujitsu A64FX, Tofu D	7,630,848	0.442	1	2.0	4.5x
2	DOE/SC/ORNL USA	**Summit**, AC922 IBM POWER9, IB Dual-rail FDR, NVIDIA Volta V100	2,414,592	0.149	2	1.15	7.7x
3	NVIDIA USA	**Selene**, DGX SuperPOD, AMD EPYC 7742 64C 2.25 GHz, Mellanox HDR, NVIDIA A100	555,520	0.063	6	0.63	9.9x
4	DOE/SC/LBNL/NERSC USA	**Perlmutter**, HPE Cray EX235n, AMD EPYC 7763 64C 2.45 GHz, Slingshot-10, NVIDIA A100	761,856	0.065	5	0.59	9.1x
5	Forschungszentrum Juelich (FZJ) Germany	**JUWELS Booster Module**, Bull Sequana XH2000 , AMD EPYC 7402 24C 2.8GHz, Mellanox HDR InfiniBand, NVIDIA Ampere A100, Atos	449,280	0.044	8	0.47	10x
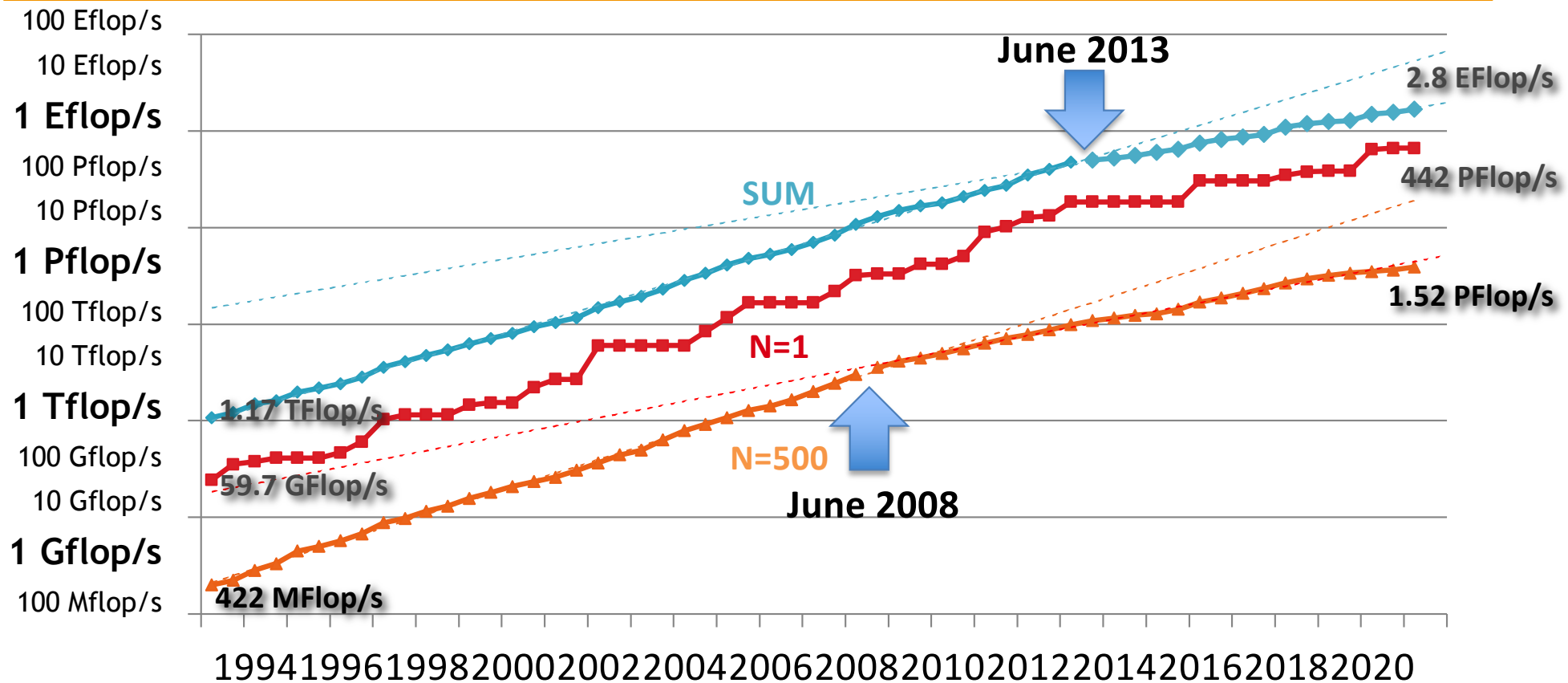
AVERAGE SYSTEM AGE
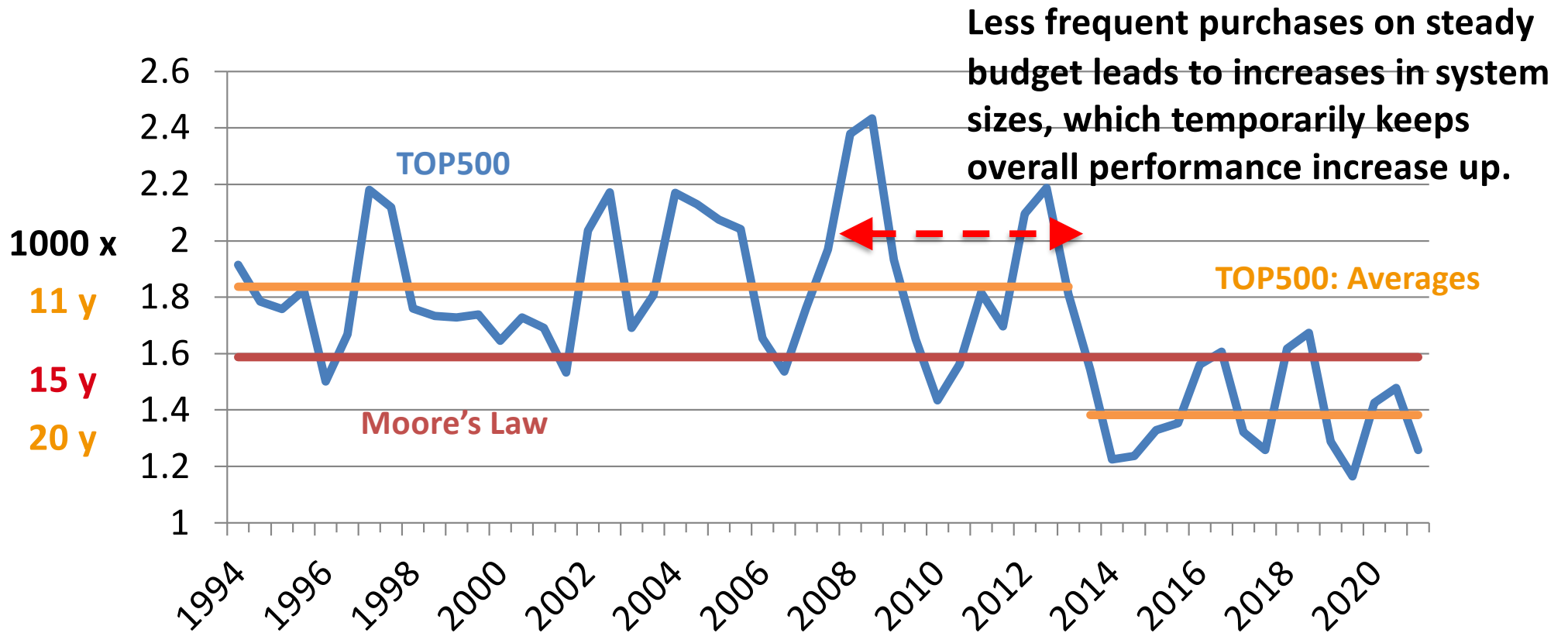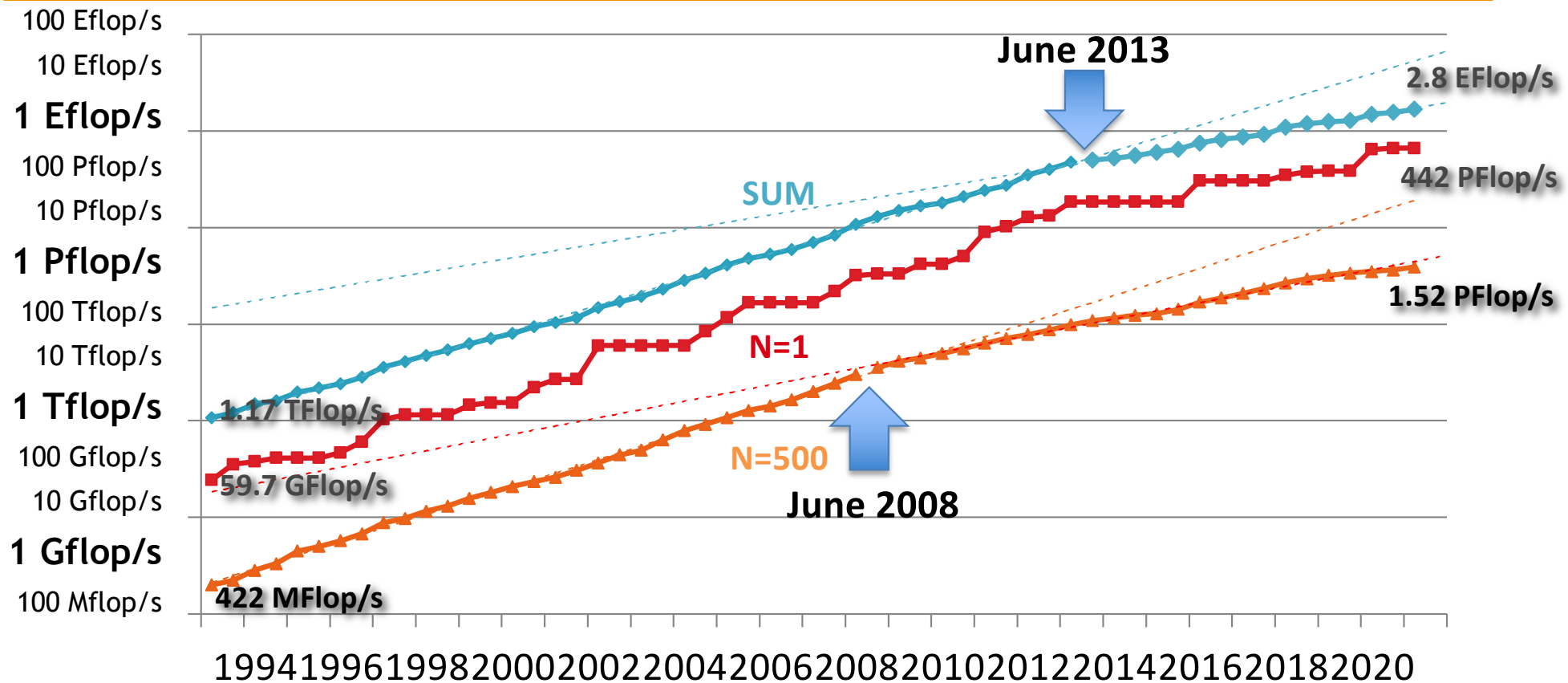
RANK AT WHICH HALF OF
TOTAL PERFORMANCE IS ACCUMULATED

Less frequent purchases allow
to increase system sizes and
lead to a more top-heavy TOP500

ANNUAL PERFORMANCE INCREASE
OF THE TOP500

TOP 500

Less frequent purchases on steady budget leads to increases in system sizes, which temporarily keeps overall performance increase up.

1000 x

11 y

15 y

20 y

TOP500

TOP500: Averages

Moore's Law

2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1

1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020

PERFORMANCE DEVELOPMENT

RESEARCH / COMMERCIAL MARKETS

- Markets for scientific computing and for commercial data processing are very different.

- Extract proper sub-samples for these markets from the full TOP500 list
  - TOP100 Research and Academic installations
  - TOP100 Industry (and Vendor) installations
    - Could try to separate out Industry installations but difficult to do
  - Ignore "Government, Classified, Others" for now
  - 100 works reasonably well, more is difficult

ENTRY LEVEL SYSTEM SIZE
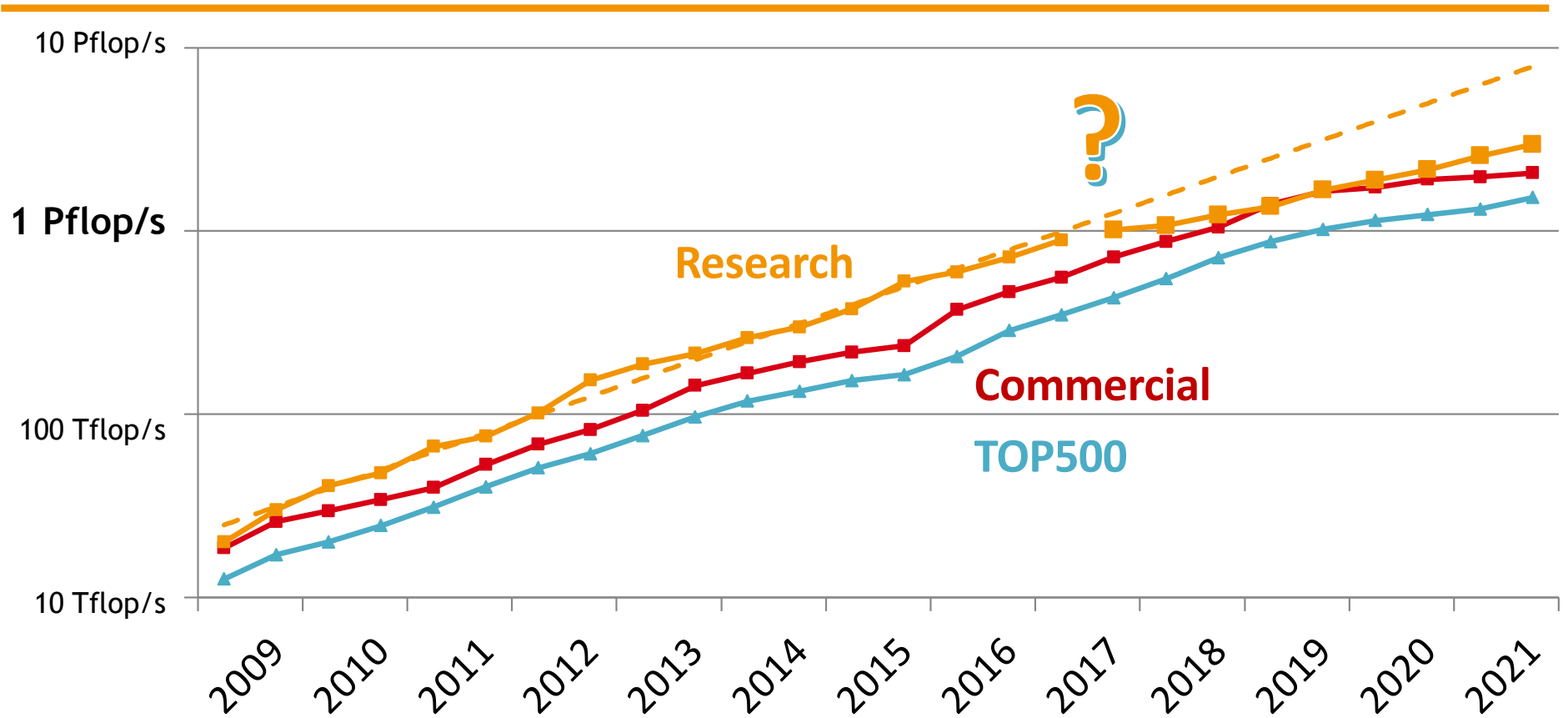
"SUMMARY"

- HPL might have been an afterthought, but it does not look like an accident!

- Linear Algebra seems to be everything we need to measure HPC performance ...

- HPL served us well to analyze performance trends in the TOP500 - and continues to do so!