Supercomputing, quo Vadis?
Erfahrungen aus 15 Jahren TOP500 und 30 Listen

Hans Werner Meuer

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Universität Mannheim & Prometeus GmbH

Jahresabschluss-Kolloquium

Herzlichen Glückwunsch

TOP500 CERTIFICATE

JUGENE, an IBM System BlueGene/P Solution at the Forschungszentrum Juelich, Germany

is ranked

No. 2

among the World's TOP500 Supercomputers
with 167.3 TFlop/s Linpack Performance
on the TOP500 List published at the SC07 Conference, November 12, 2007

Congratulations from the TOP500 Editors

Hans Meuer
University of Mannheim

Erich Strohmaier
NERSC/Berkeley Lab

Jack Dongarra
University of Tennessee

Horst Simon
NERSC/Berkeley Lab

30th List: The TOP10

	Manufacturer	Computer	Rmax [TF/s]	Installation Site	Country	Year	#Cores
1	IBM	BlueGene/L eServer Blue Gene	478.2	DOE/NNSA/LLNL	USA	2007	212,992
2	IBM	JUGENE BlueGene/P Solution	167.3	Forschungszentrum Juelich	Germany	2007	65,536
3	SGI	SGI Altix ICE 8200	126.9	New Mexico Computing Applications Center	USA	2007	14,336
4	HP	Cluster Platform 3000 BL460c	117.9	Computational Research Laboratories, TATA SONS	India	2007	14,240
5	HP	Cluster Platform 3000 BL460c	102.8	Swedish Government Agency	Sweden	2007	13,728
6	Sandia/Cray	Red Storm Cray XT3	102.2	DOE/NNSA/Sandia	USA	2006	26,569
7	Cray	Jaguar Cray XT3/XT4	101.7	DOE/ORNL	USA	2007	23,016
8	IBM	BGW eServer Blue Gene	91.29	IBM Thomas Watson	USA	2005	40,960
9	Cray	Franklin Cray XT4	85.37	NERSC/LBNL	USA	2007	19,320
10	IBM	New York Blue eServer Blue Gene	82.16	Stony Brook/BNL	USA	2007	36,864

Outline

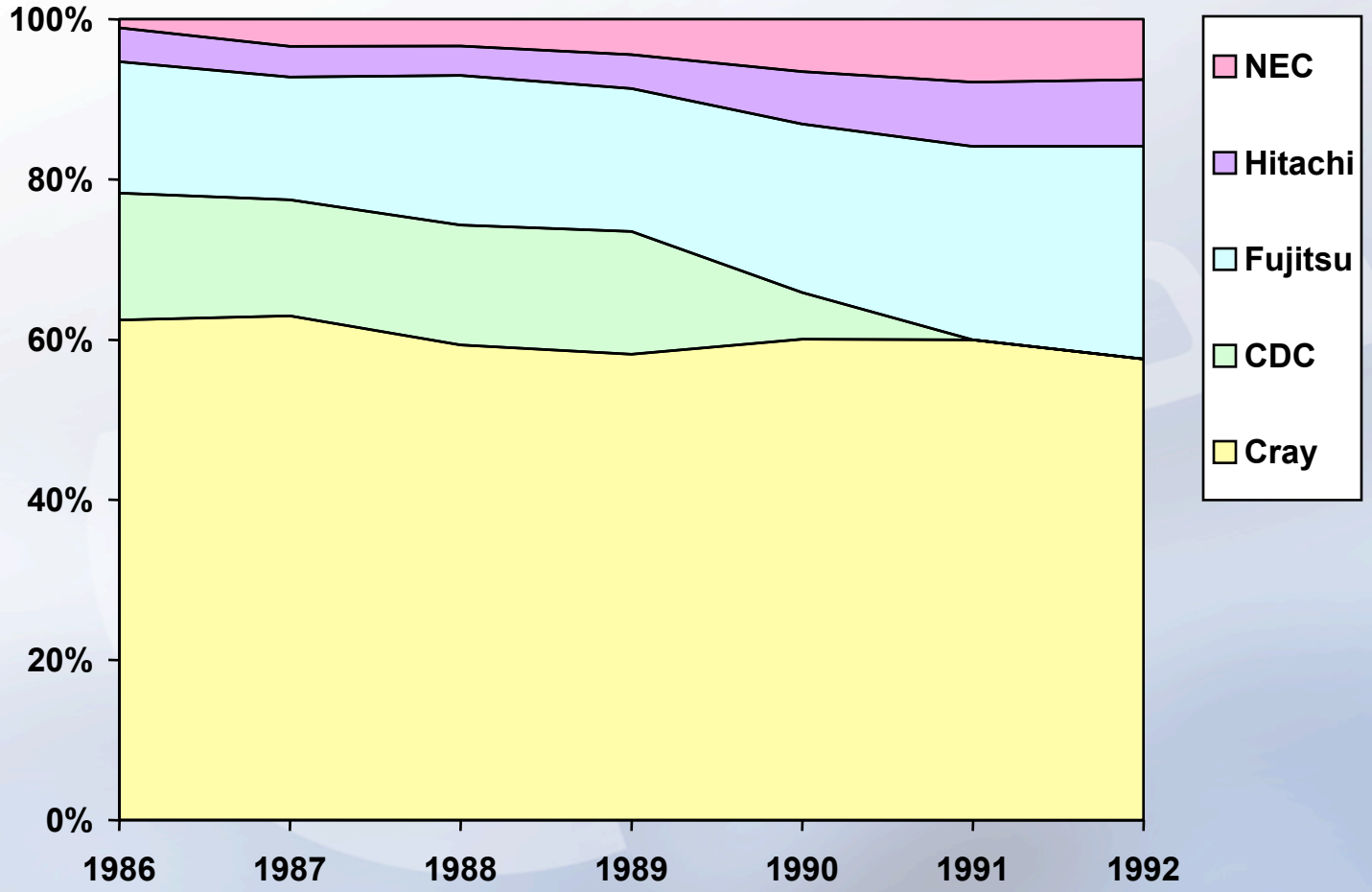
- Mannheim Supercomputer Statistics & Top500 Project Start in 1993
- Competition between Manufacturers, Countries and Sites
- My Supercomputer Favorite in the Top500 Lists
- The 30th List as of November 2007
- Performance Development and Projection
- Bell's Law
- Supercomputing, quo vadis?
  - in Jülich, Germany and Europe
  - in the Rest of the World
- Top500, quo vadis?

Mannheim Supercomputer Statistics 1986 – 1992

- Presented at ISC'86 – ISC'92/Mannheim Supercomputer Seminars
- Counting of Supercomputers in the World
- 530 systems in the year 1992

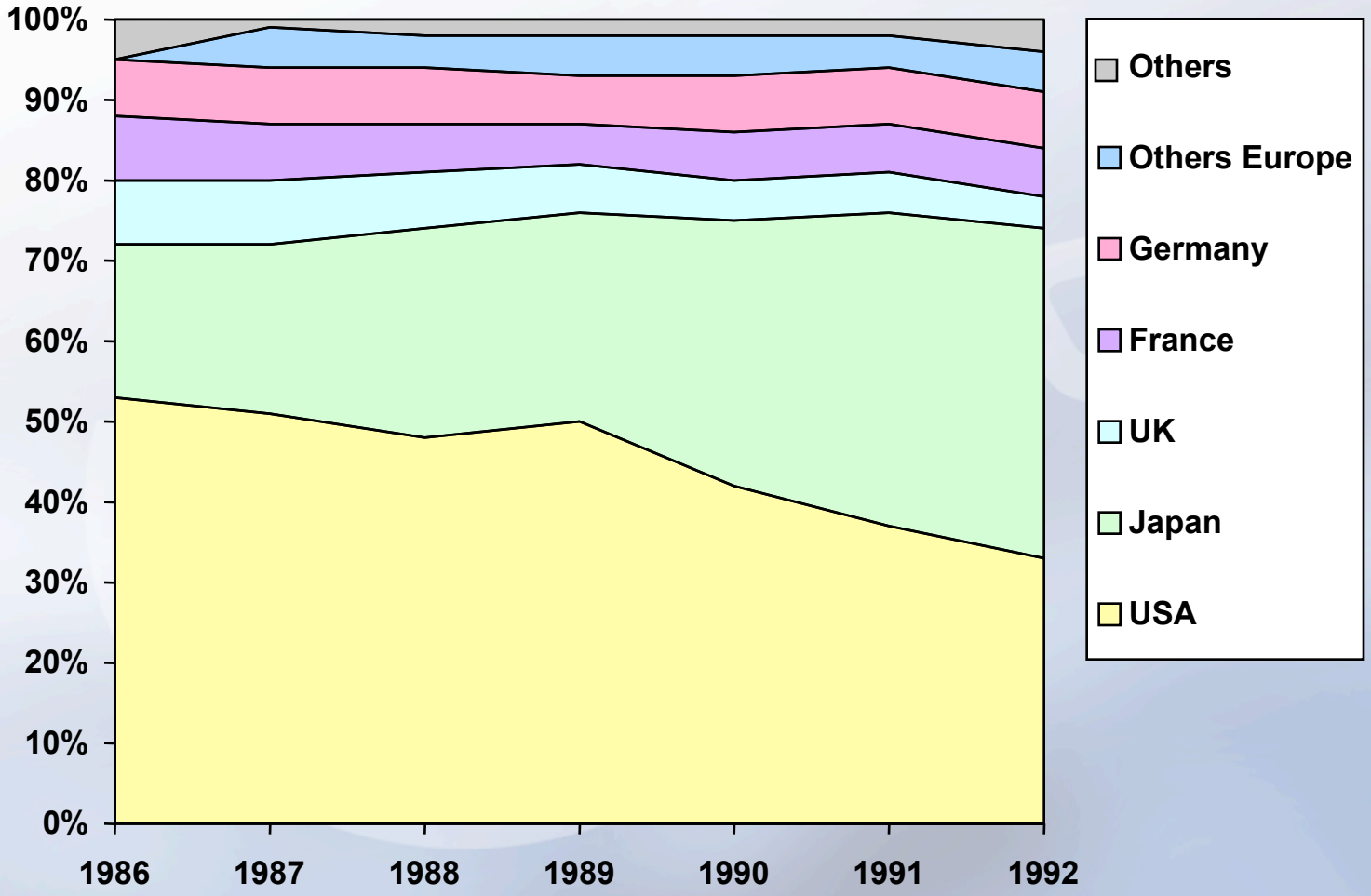
Mannheim Supercomputer Statistics & Top500 Project Start in 1993

Manufacturer Share



Mannheim Supercomputer Statistics & Top500 Project Start in 1993

Countries Share



Deficits of the Mannheim Supercomputer Statistics

- Not very reliable
- Vector Supercomputers only – „numerical“/ mainly „scientific and engineering“ applications
- Definition of „Supercomputer“ necessary

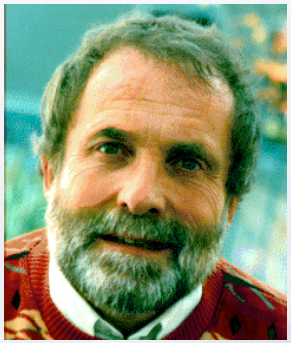
Top500 Procedure

- Listing the 500 most powerful computers in the world
- Yardstick: Rmax of Linpack

  Solve Ax=b, dense problem, matrix is random
- Update twice a year:
  - ISC'xy in June in Germany
  - SC'xy in November in the U.S.
- All information available from the TOP500 webserver at: www.top500.org

Top500 Authors

Project was started in spring 1993 by:



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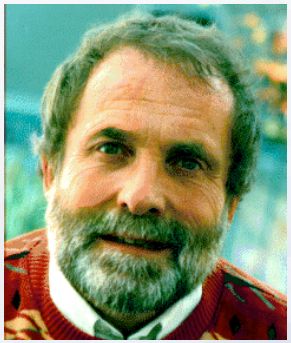

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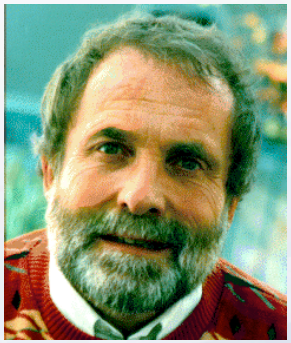

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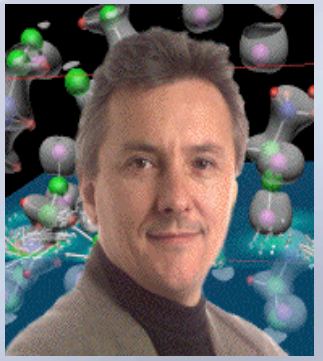

11/2000
Horst Simon

Dongarra's TOP500 List of World's Fastest Supercomputers Released at Mannheim Conference

„CRPC researcher Jack Dongarra of the University of Tennessee and Oak Ridge National Laboratory is one of three renowned computer scientists who assemble the legendary TOP500 List of the world's fastest supercomputers. Released twice a year since 1993, the list features sites with the most powerful computer systems, determined with information from a questionnaire sent to high-performance computer (HPC) experts, computational scientists, manufacturers, and the Internet community at large. Dongarra, Hans Meuer of the University of Mannheim, and Erich Strohmaier of the University of Tennessee released their June 1999 TOP500 List at the 14th Mannheim Supercomputing Conference and Seminar, held June 10-12 in Mannheim, Germany.“

Source: http://www.crpc.rice.edu/WhatsNew/top500.html
The Center for Research on Parallel Computation at Rice University

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Top500 Status

- 1st Top500 List in June 1993 at ISC'93 in Mannheim
- .
- .
- .
- .
- 29th Top500 List on June 27, 2007 at ISC'07 in Dresden
- 30th Top500 List on November 13, 2007 at SC07 in Reno

- 31st Top500 List on June 18, 2008 at ISC'08 in Dresden
- 32nd Top500 List on November 18, 2008 at SC08 in Austin
- 33rd Top500 List on June 24, 2009 at ISC'09 in Hamburg

- Acknowledged by HPC-users, manufacturers and media

Competition between Manufacturers,

1st List as of 06/1993

Countries	Count	Share %
USA	225	45.00%
Japan	111	22.20%
Germany	59	11.80%
France	26	5.20%
United Kingdom	25	5.00%
Australia	9	1.80%
Italy	6	1.20%
Netherlands	6	1.20%
Switzerland	4	0.80%
Canada	3	0.60%
Denmark	3	0.60%
Korea	3	0.60%
Others	20	4.00%
Totals	500	100%

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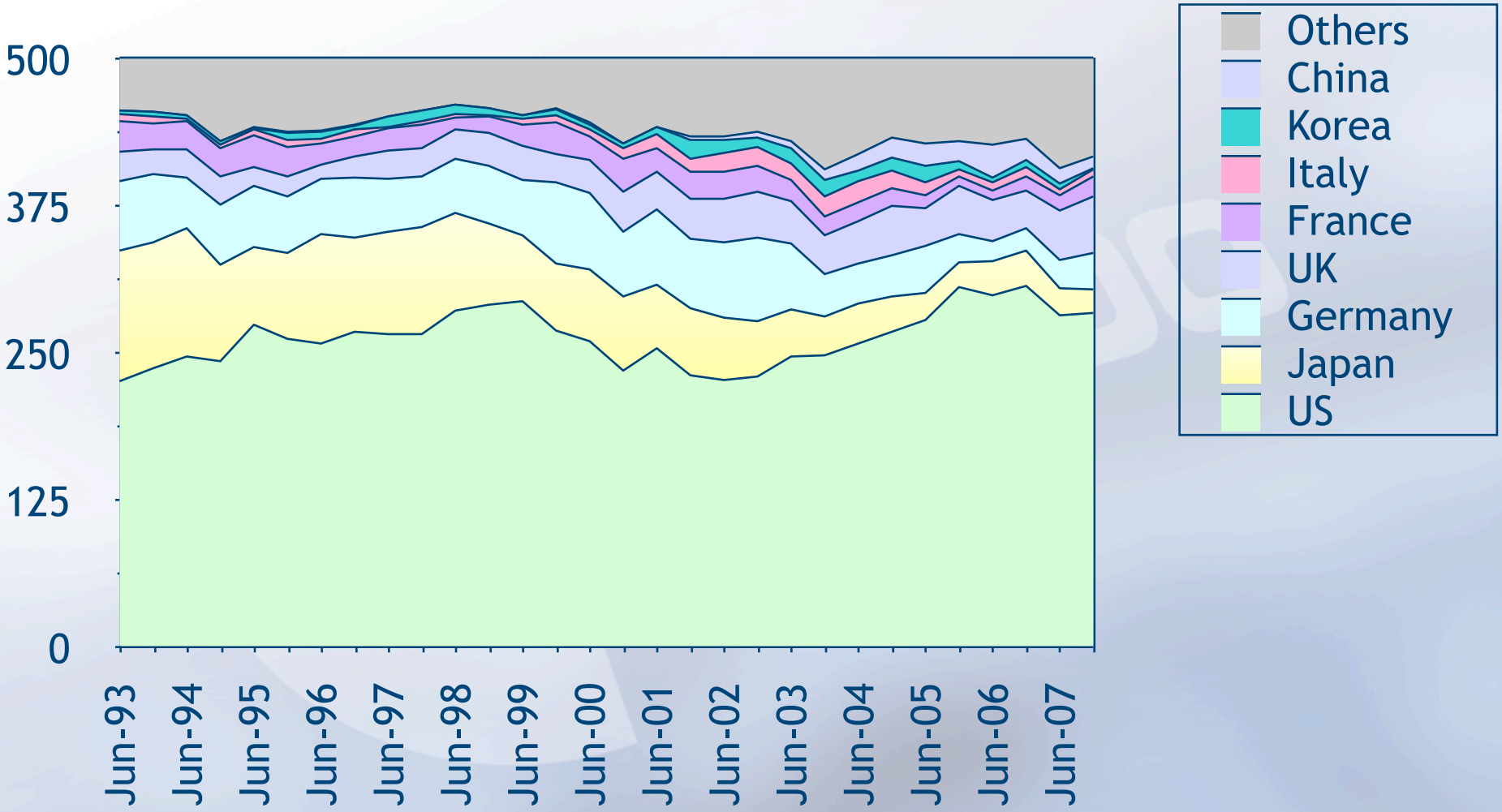
Korea	3	0.60%
Others	20	4.00%
Totals	500	100%

30th List as of 11/2007

Countries	Count	Share %
USA	283	56.60%
Japan	20	4.00 %
Germany	31	6.20 %
France	17	3.40 %
United Kingdom	48	9.60 %
Australia	1	0.20 %
Italy	6	1.20 %
Netherlands	6	1.20 %
Switzerland	7	1.40 %
Canada	5	1.00 %
Denmark	1	0.20 %
Korea	1	0.20 %
China	10	2.00 %
India	9	1.80 %
Others	55	11.00 %
Totals	500	100 %

Competition between Manufacturers,

Countries/Systems



Competition between Manufacturers,

1st List as of 06/1993

Manufacturers	Count	Share %
Cray Research	205	41.00%
Fujitsu	69	13.80%
Thinking Machines	54	10.80%
Intel	44	8.80%
Convex	36	7.20%
NEC	32	6.40%
Kendall Square Research	21	4.20%
MasPar	18	3.60%
Meiko	9	1.80%
Hitachi	6	1.20%
Parsytec	3	0.60%
nCube	3	0.60%
Totals	500	100%

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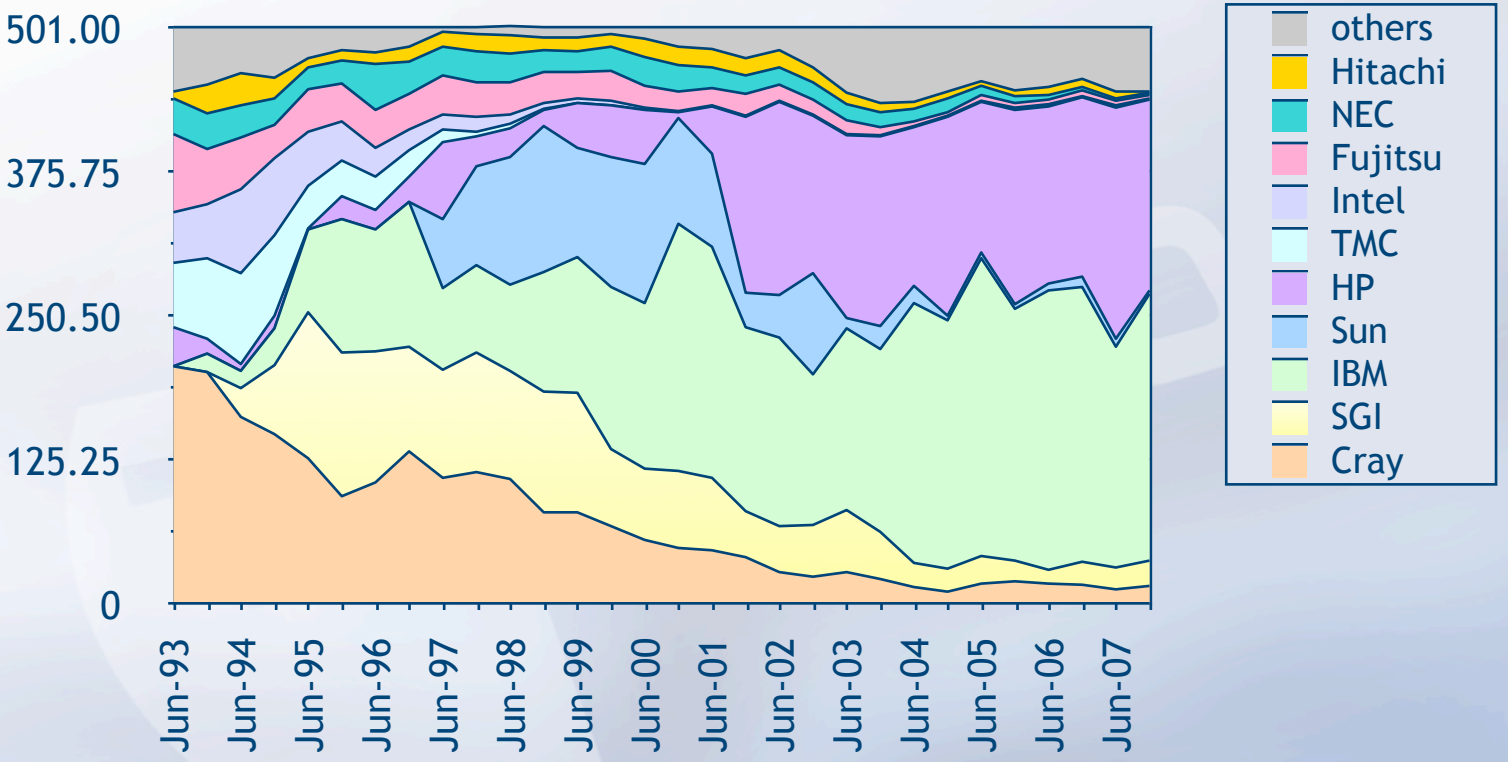
nCube	3	0.60%
Totals	500	100%

30th List as of 11/2007

Manufacturers	Count	Share %
Cray Inc.	14	2.80 %
Fujitsu	3	0.60 %
Thinking Machines	—	—
Intel	1	0.20 %
Hewlett-Packard	166	33.20 %
NEC	2	0.40 %
Kendall Square Research	—	—
MasPar	—	—
Meiko	—	—
Hitachi/Fujitsu	1	0.20 %
Parsytec	—	—
nCube	—	—
IBM	232	46.40 %
SGI	22	4.40 %
Dell	24	4.80 %
Others	35	7.00 %
Totals	500	100 %

Competition between Manufacturers,

Manufacturer/Systems



Competition between Manufacturers,

Top Sites through 30 Lists

Rank	Site	Country	% over time
1	Lawrence Livermore National Laboratory	United States	5.39
2	Sandia National Laboratories	United States	3.70
3	Los Alamos National Laboratory	United States	3.41
4	Government	United States	3.34
5	The Earth Simulator Center	Japan	1.99
6	National Aerospace Laboratory of Japan	Japan	1.70
7	Oak Ridge National Laboratory	United States	1.39
8	NCSA	United States	1.31
9	NASA/Ames Research Center/NAS	United States	1.25
10	University of Tokyo	Japan	1.21
11	NERSC/LBNL	United States	1.19
12	Pittsburgh Supercomputing Center	United States	1.15
13	Semiconductor Company (C)	United States	1.11
14	Naval Oceanographic Office (NAVOCEANO)	United States	1.08
15	ECMWF	United Kingdom	1.02
16	ERDC MSRC	United States	0.91
17	IBM Thomas J. Watson Research Center	United States	0.86
18	Forschungszentrum Juelich (FZJ)	Germany	0.84
19	Japan Atomic Energy Research Institute	Japan	0.83
20	Minnesota Supercomputer Center	United States	0.74

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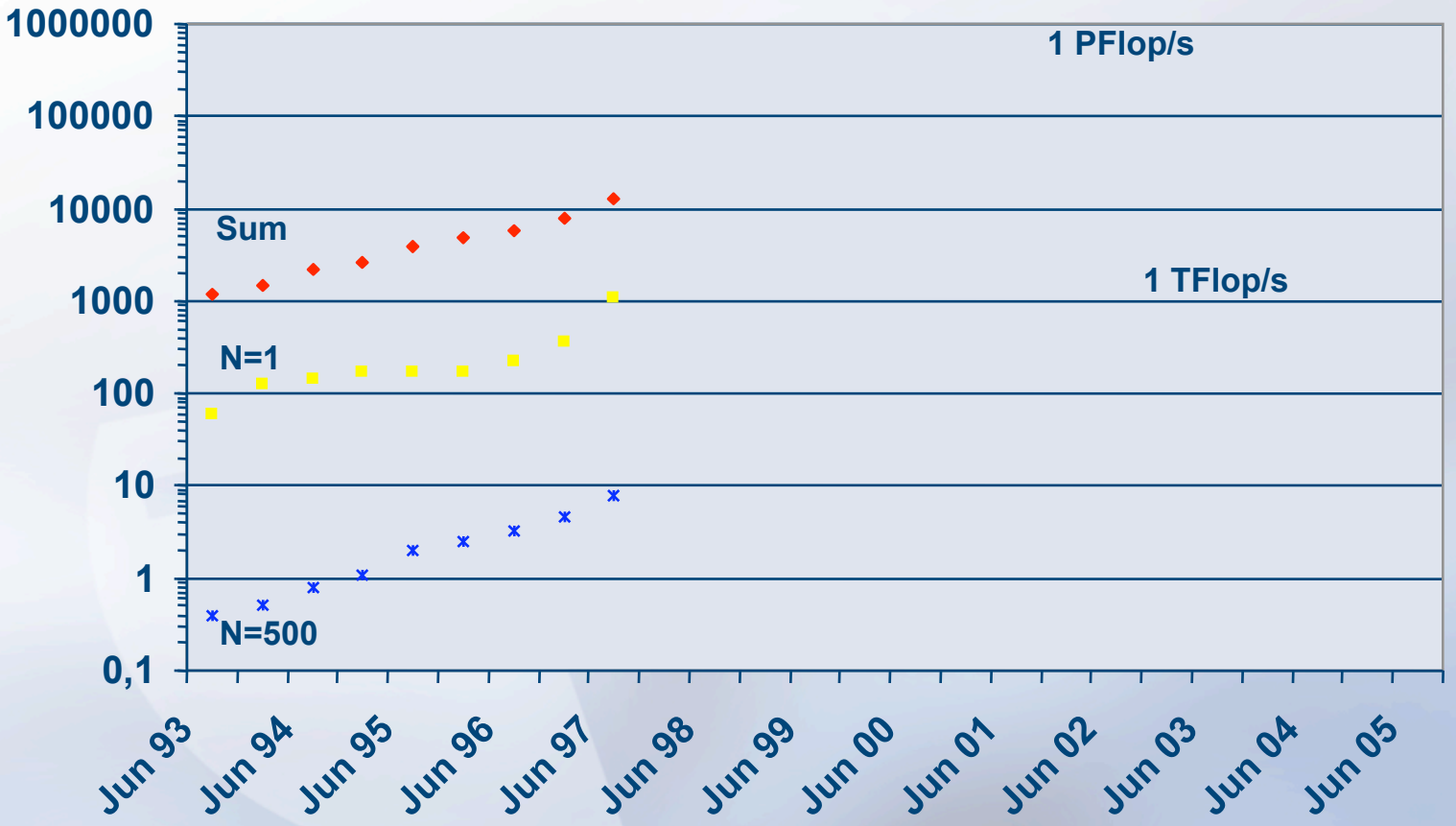
My Supercomputer Favorite in the Top500 Lists

Top10 in the 06/1997 list

	Manufacturer	Computer	Rmax [GF/s]	Installation Site	Country	Year	#Proc
1	Intel	ASCI Red	1068	Sandia National Laboratories	USA	1996	7264
2	Hitachi	CP-PACS/2048	368.2	Center for Computational Science	Japan	1996	2048
3	Fujitsu	Numerical Wind Tunnel	229	National Aerospace Laboratory	Japan	1996	167
4	Hitachi	SR2201/1024	220.4	University of Tokyo	Japan	1996	1024
5	Cray	T3E	176	Forschungszentrum Jülich	Germany	1996	512
6	Cray	T3E	176	Government	USA	1997	512
7	Cray	T3E	176	Max-Planck-Gesell. MPI/IPP	Germany	1997	512
8	Cray	T3E	176	NASA/Goddard Space Flight Center	USA	1996	512
9	Cray	T3E	176	Pittsburgh Supercomp. Center	USA	1996	512
10	Cray	T3E	176	University Stuttgart	Germany	1996	512

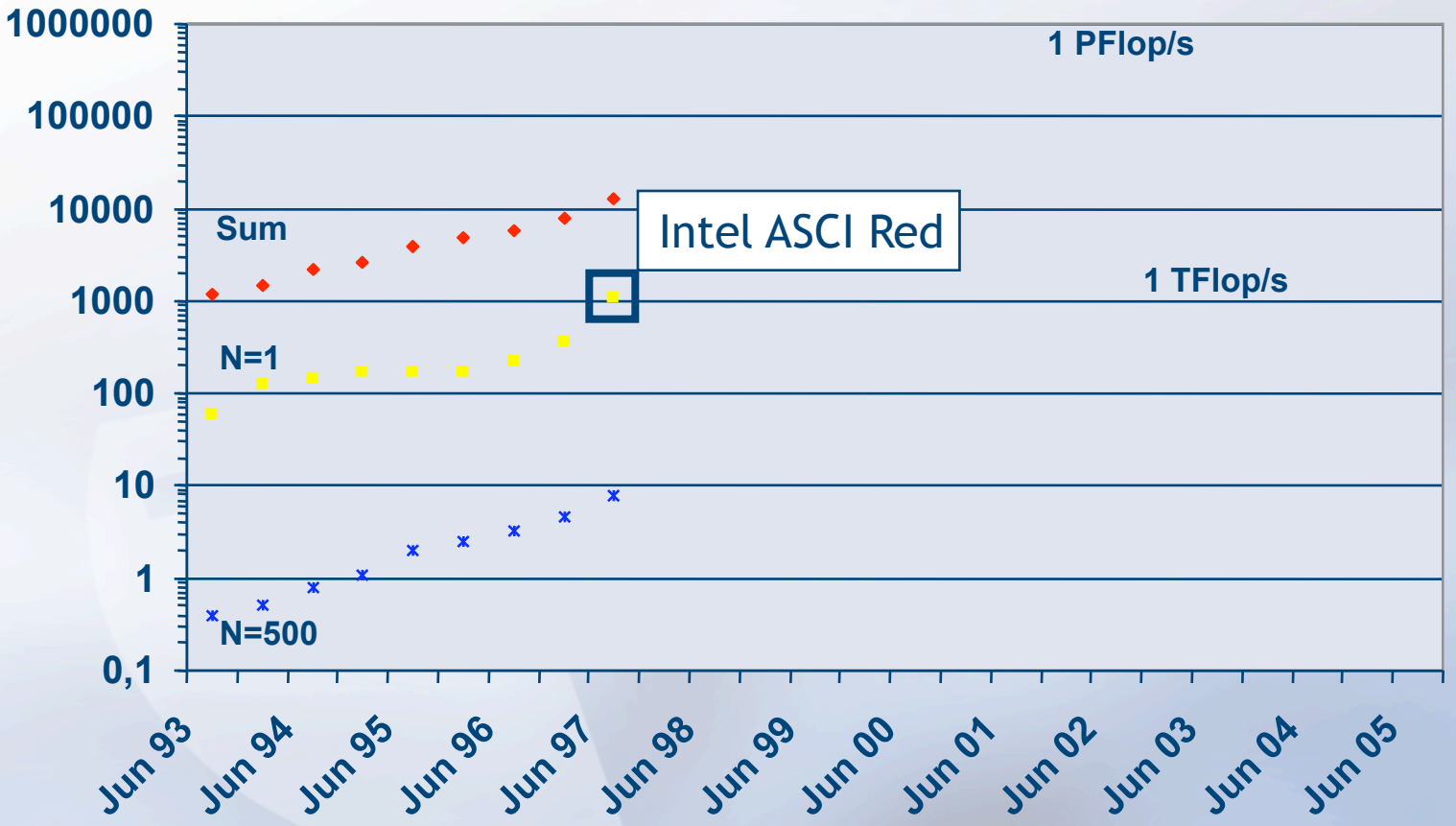
My Supercomputer Favorite in the Top500 Lists

Performance [GFlop/s]



My Supercomputer Favorite in the Top500 Lists

Performance [GFlop/s]



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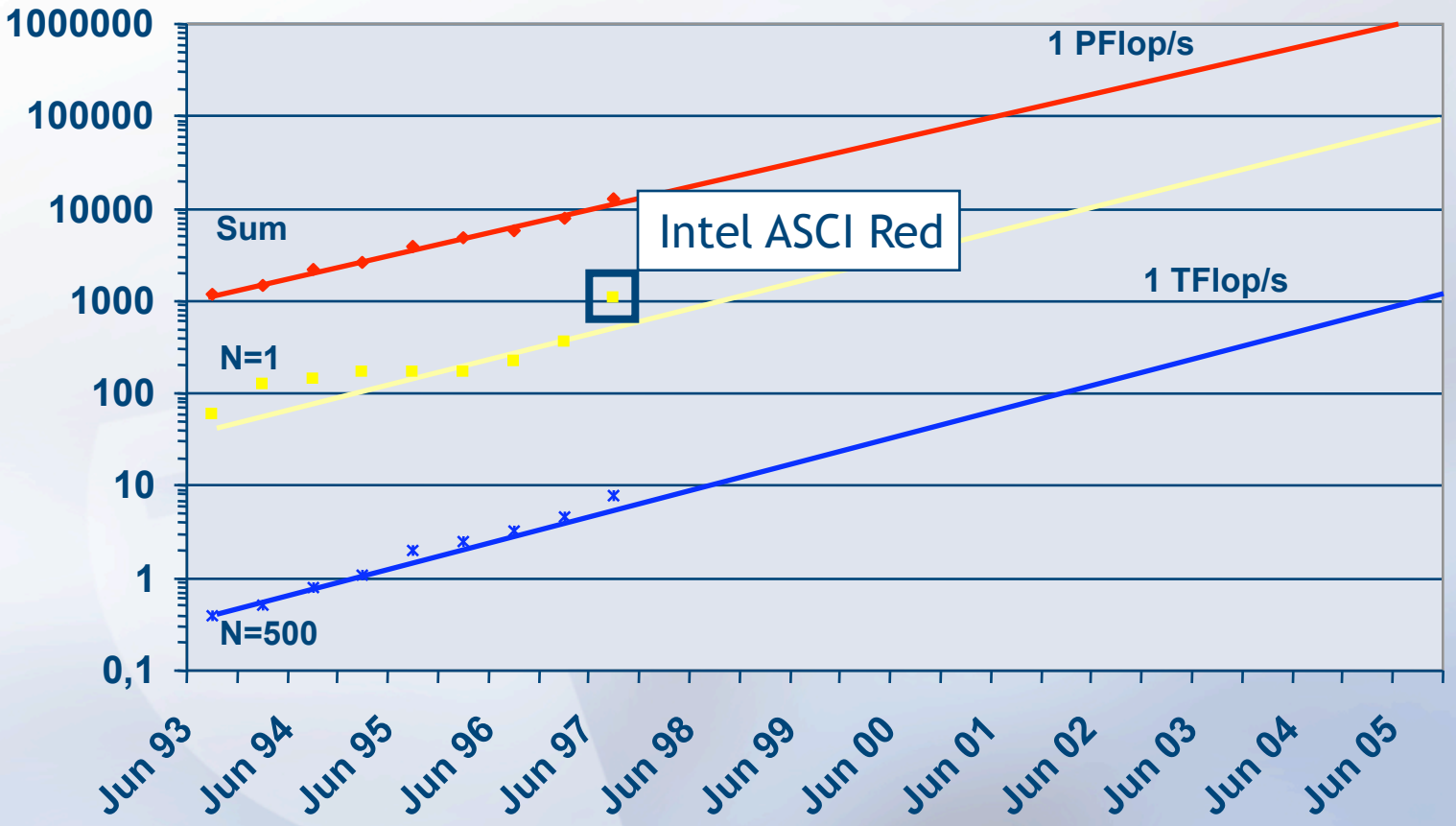

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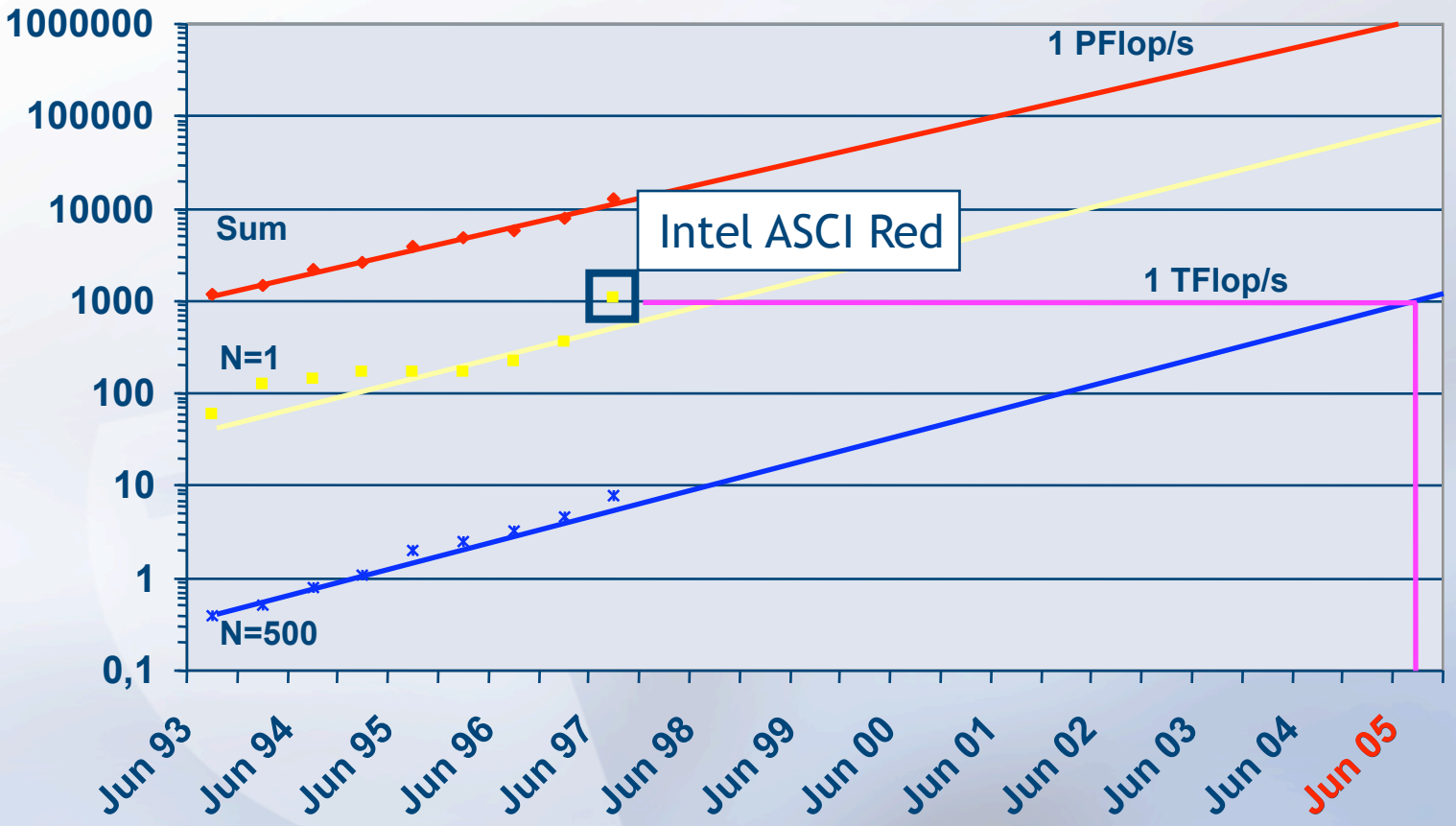
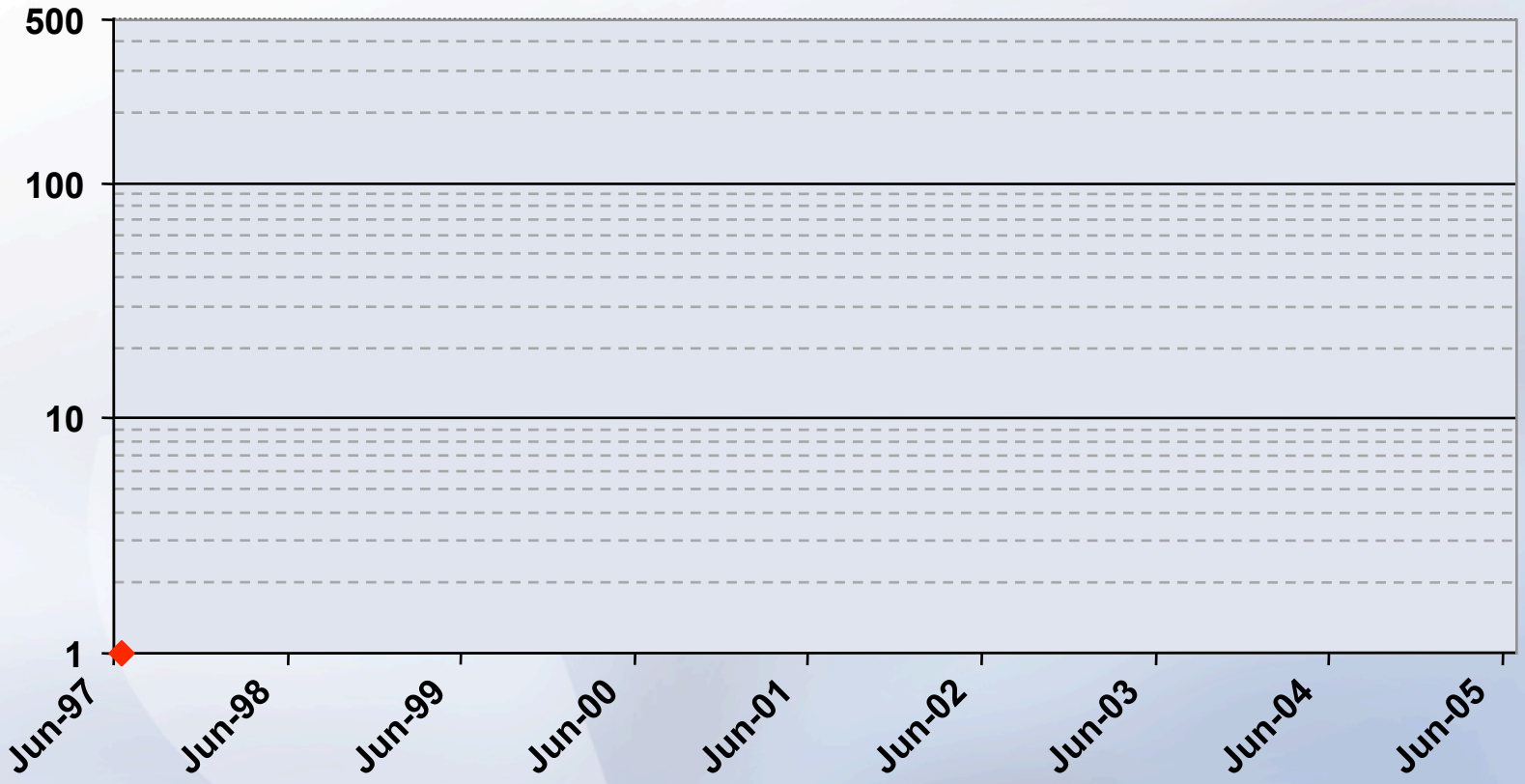


My Supercomputer Favorite in the Top500 Lists

Number of Teraflop/s Systems in the Top500



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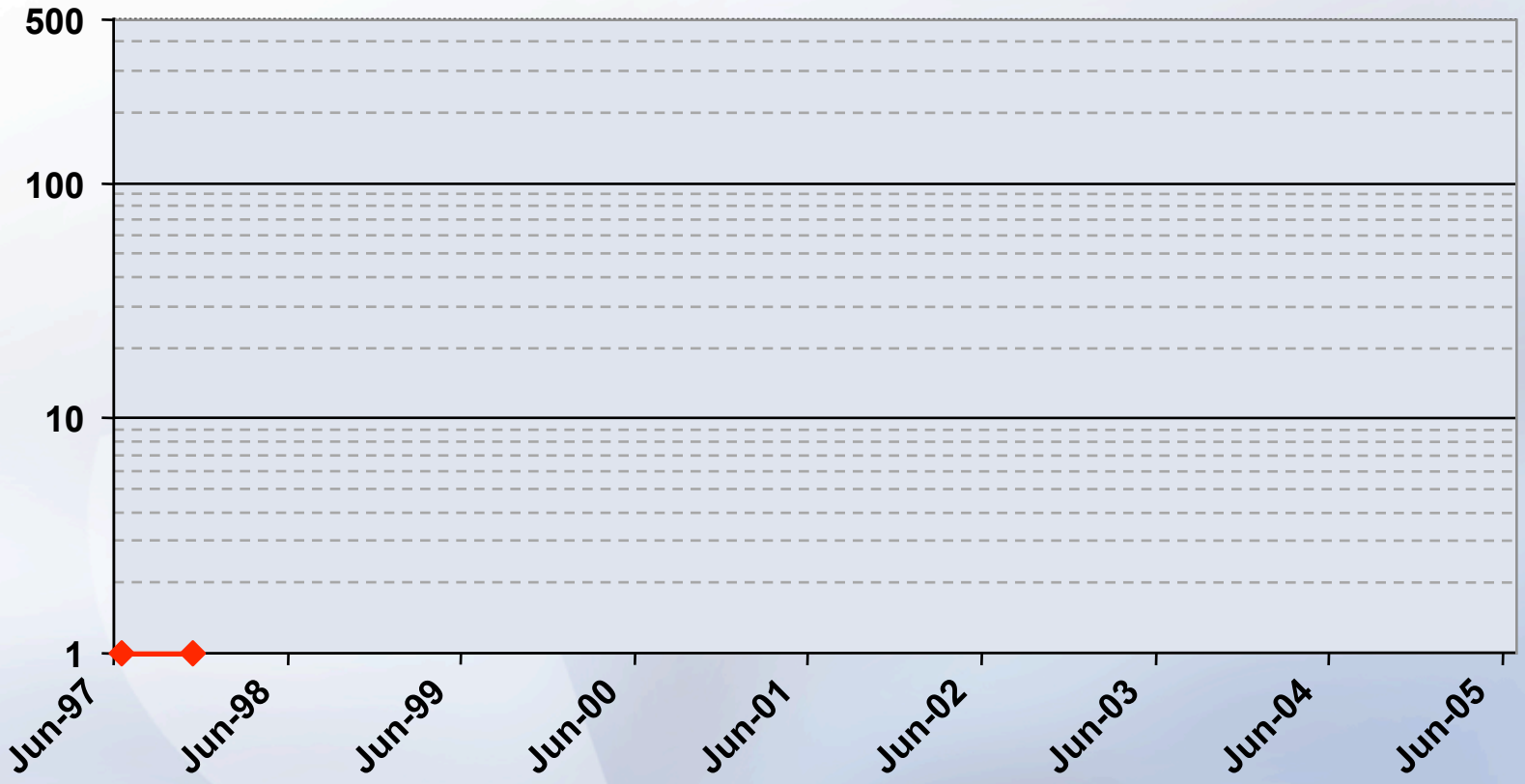

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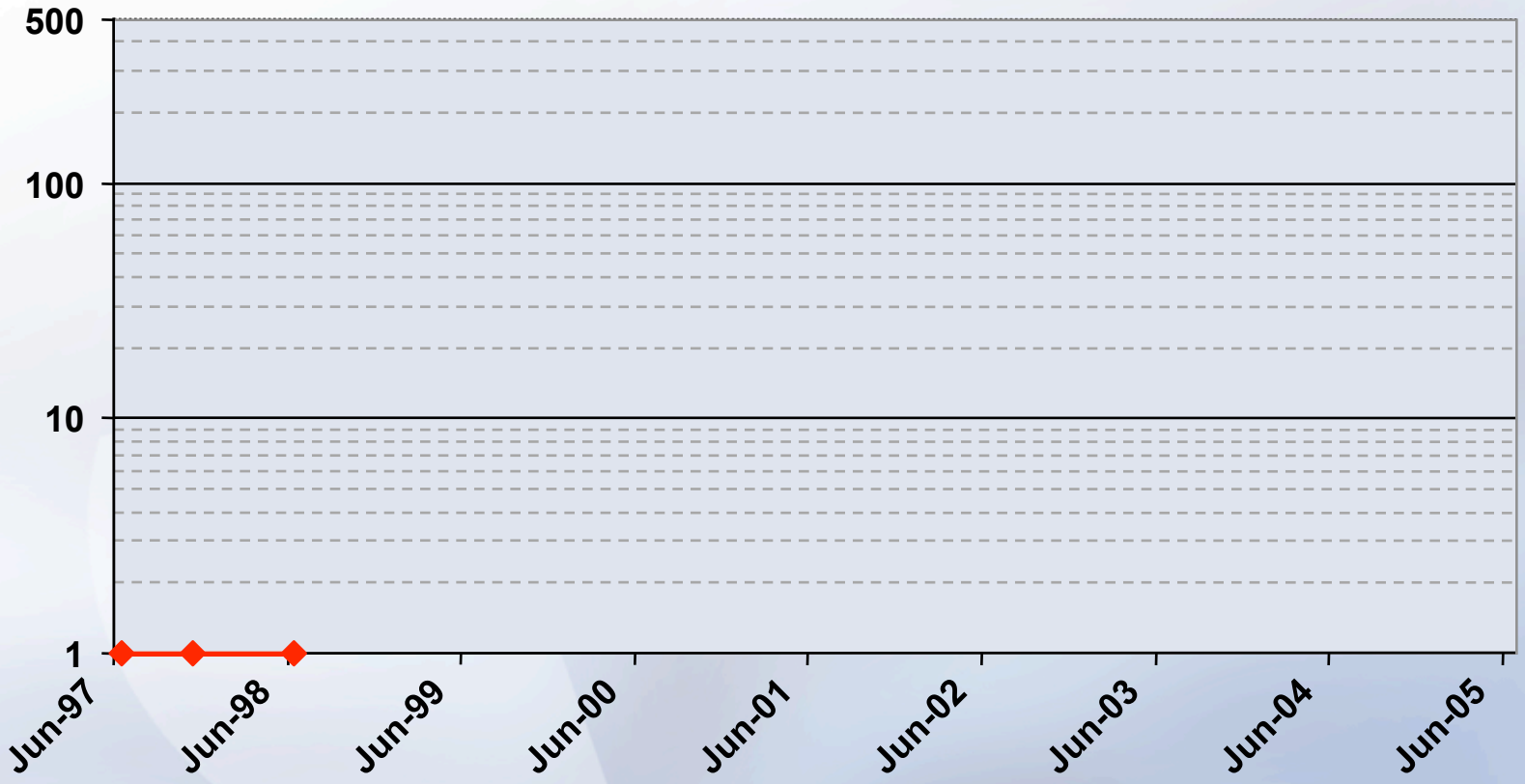

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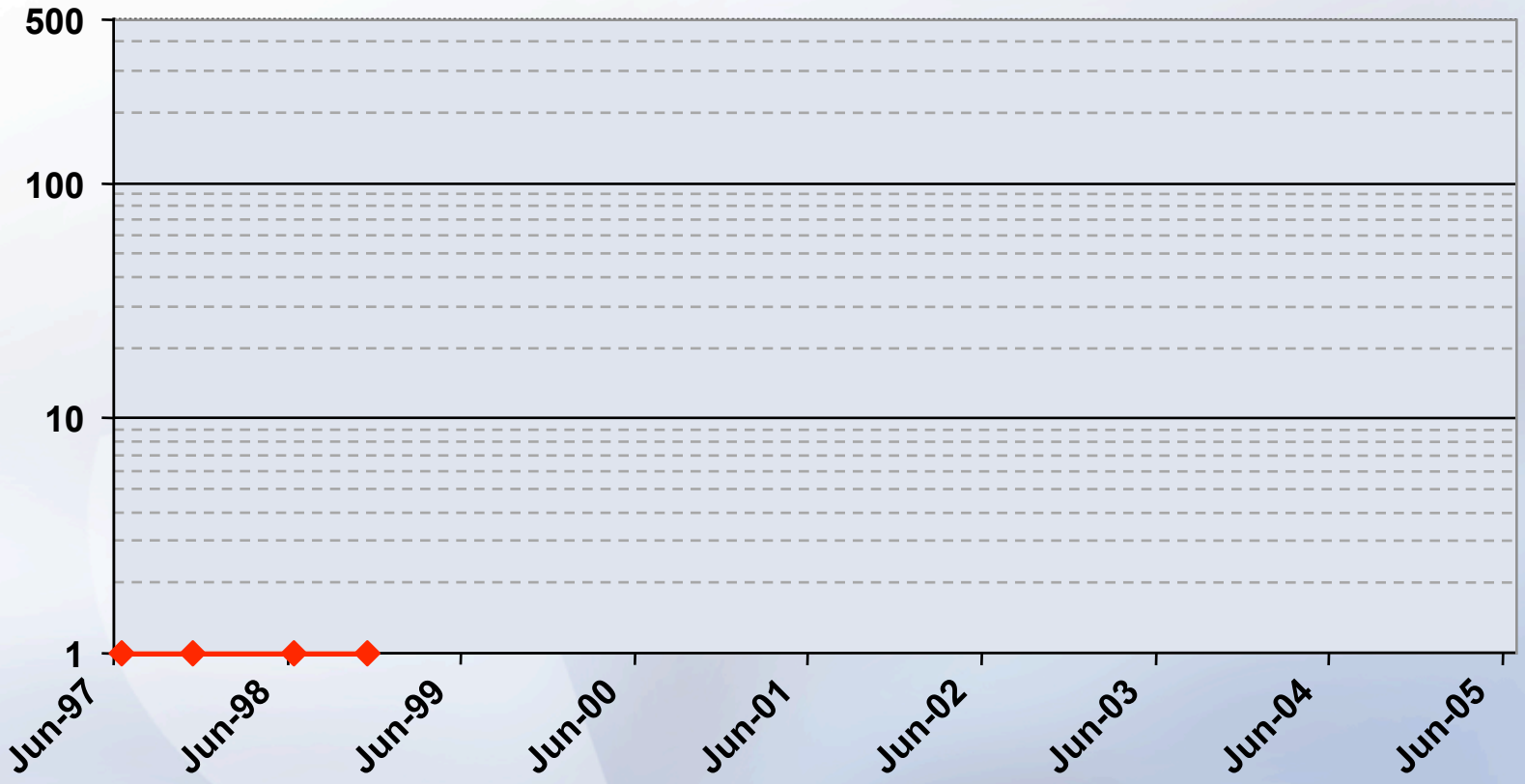

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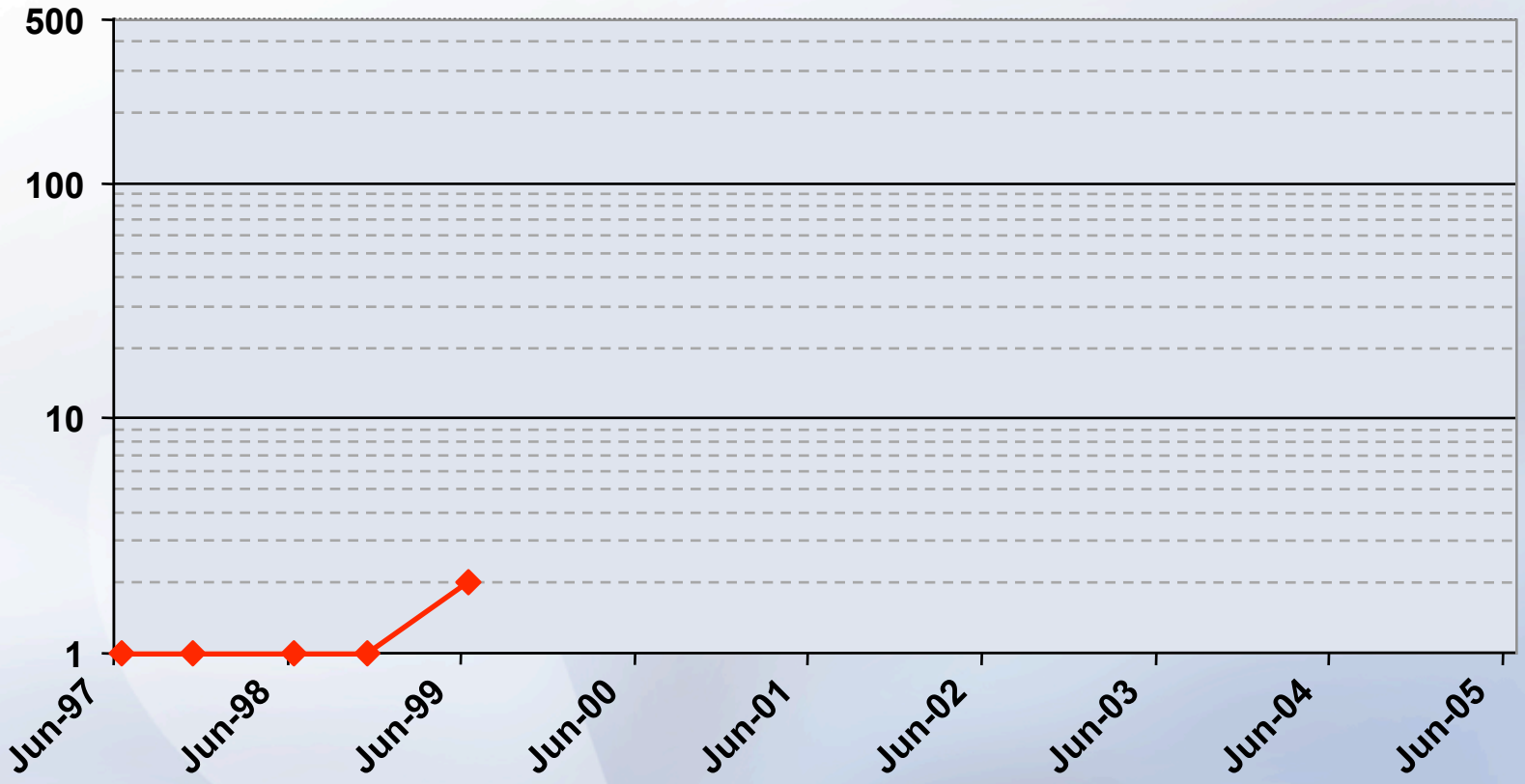

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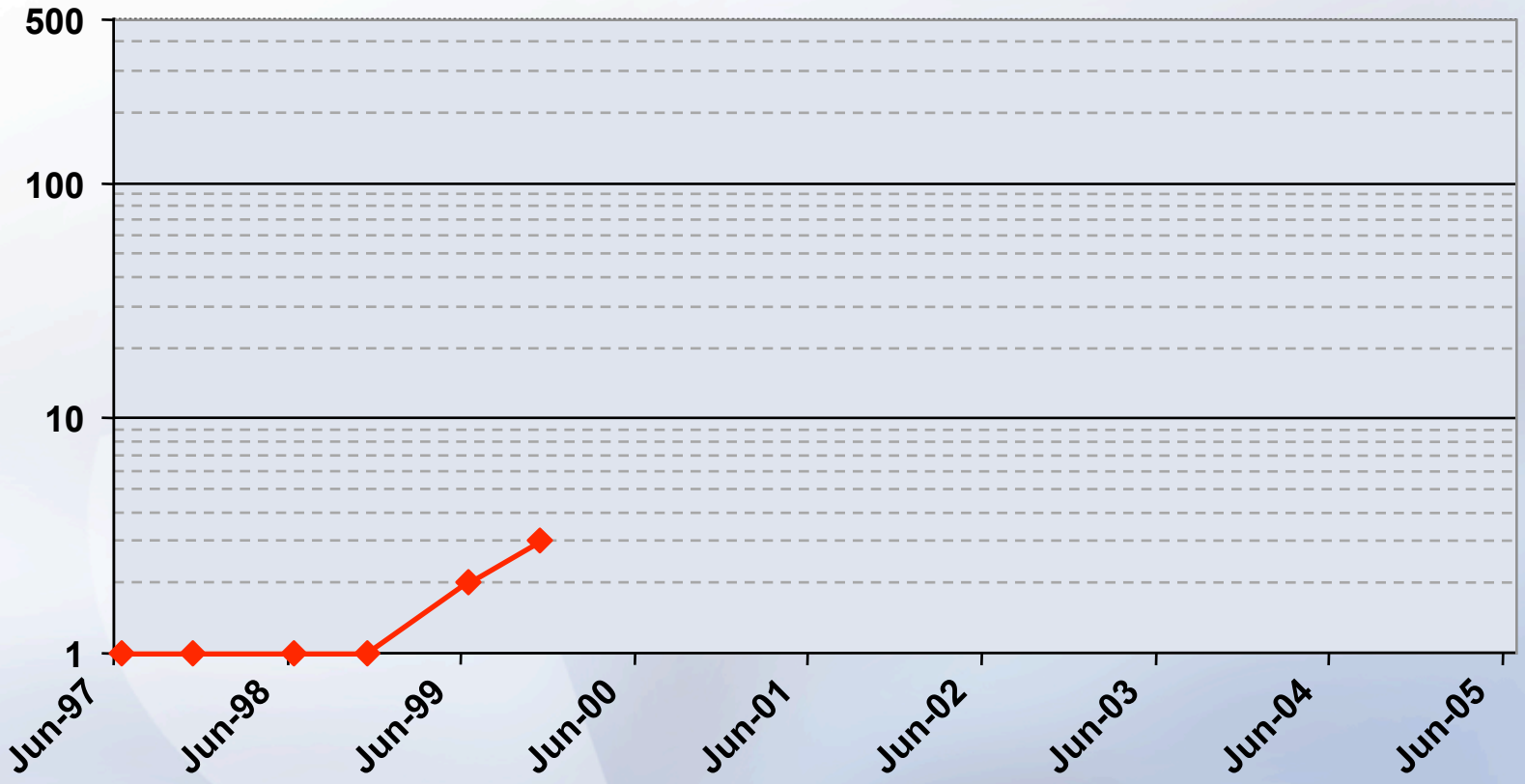

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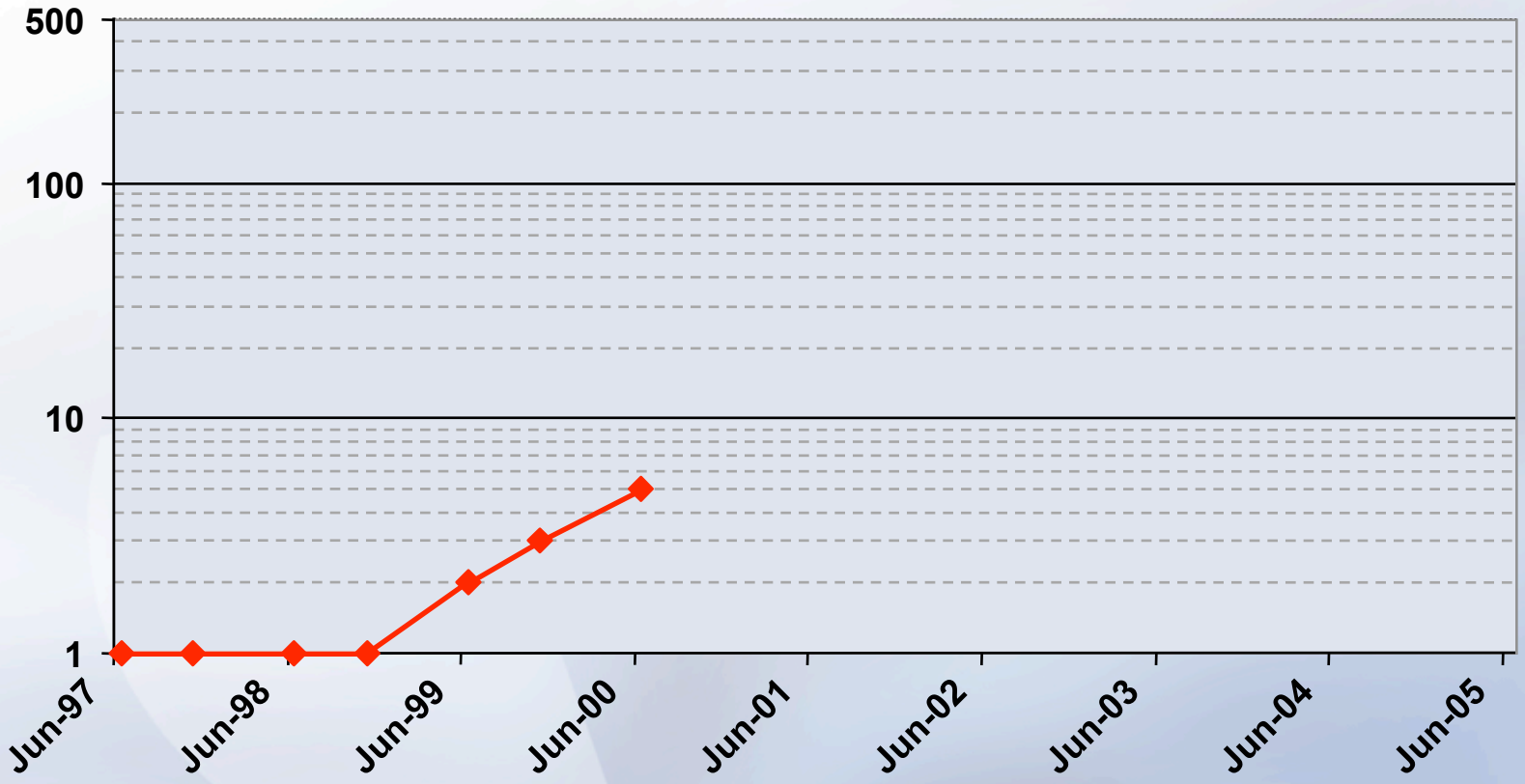

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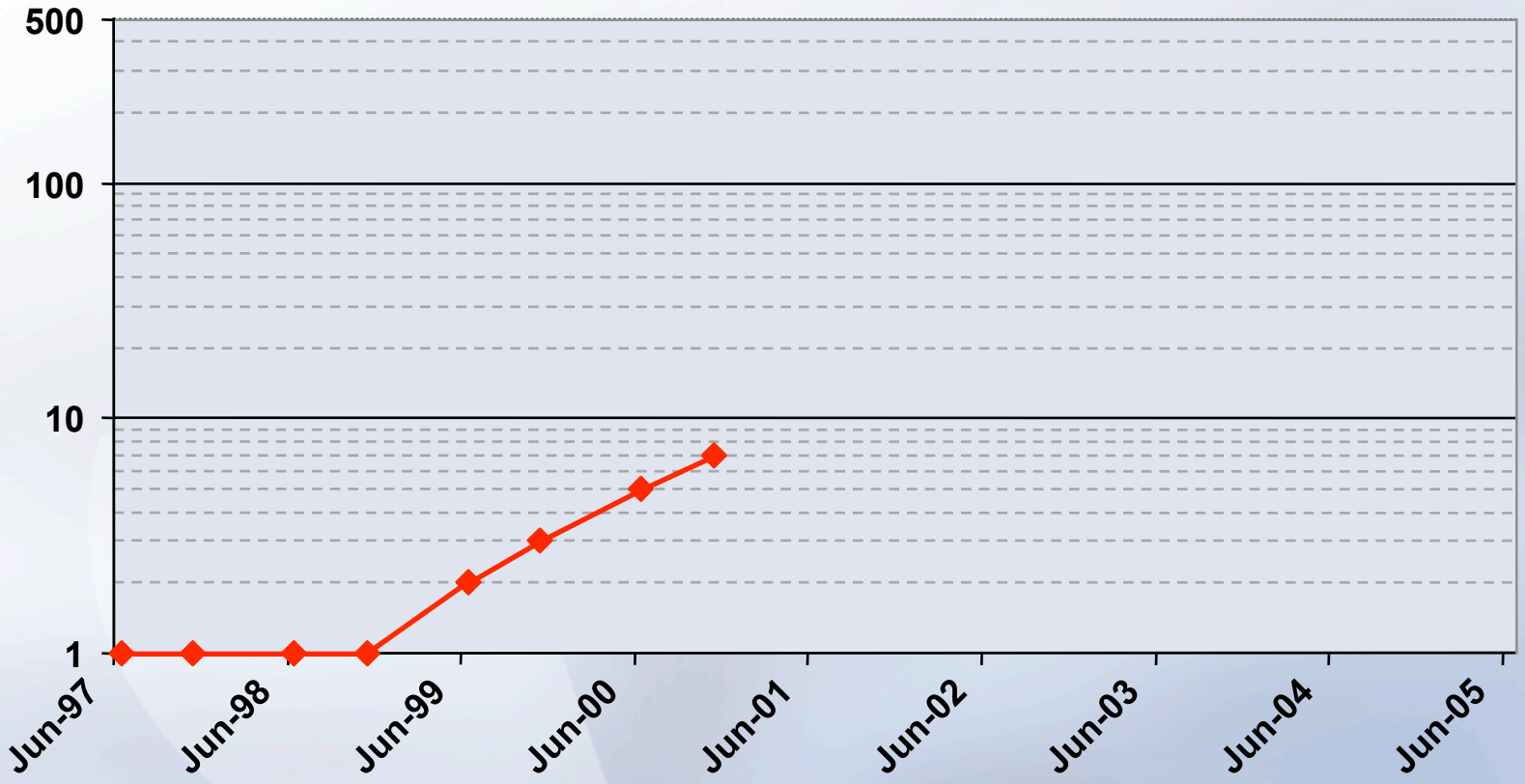

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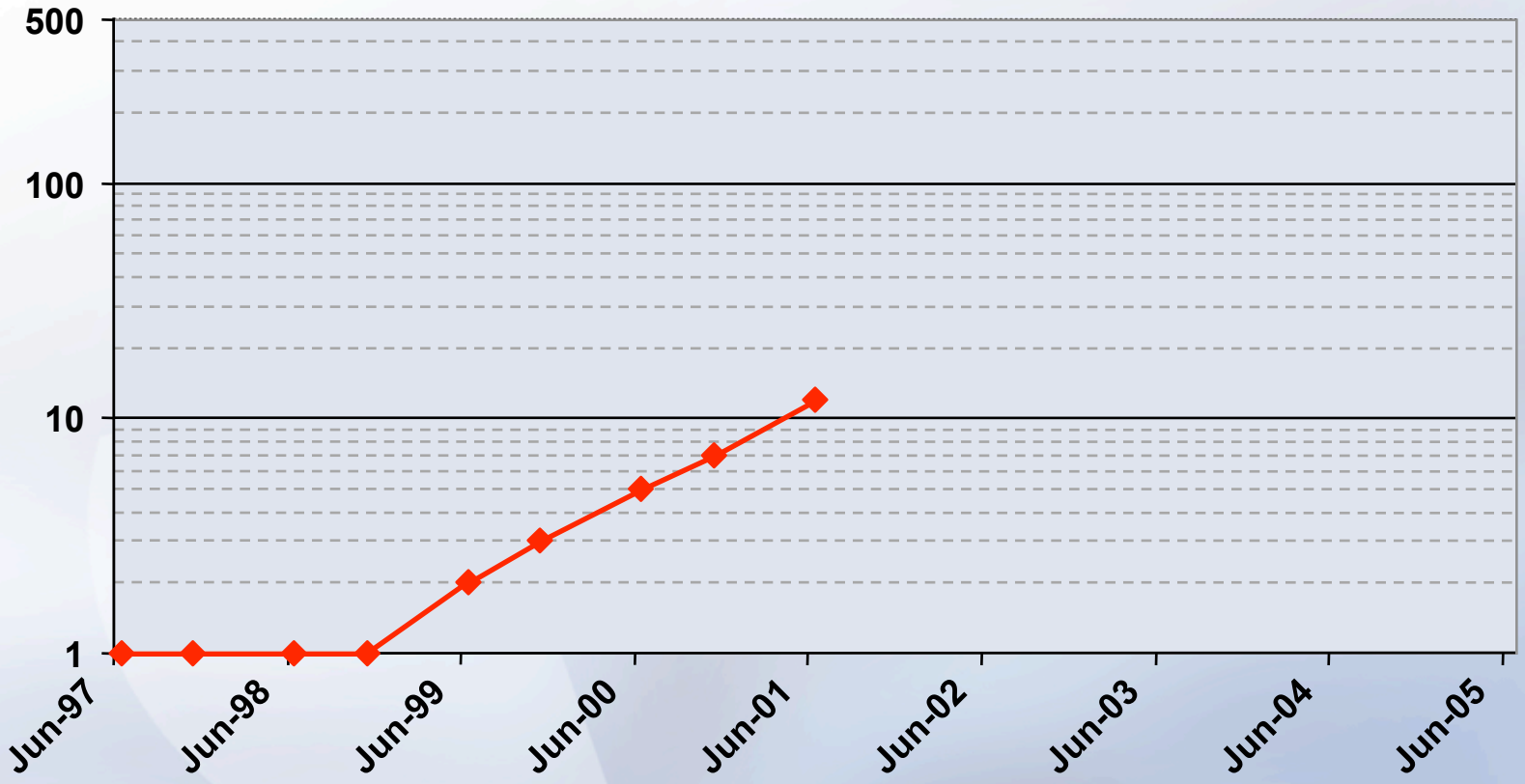

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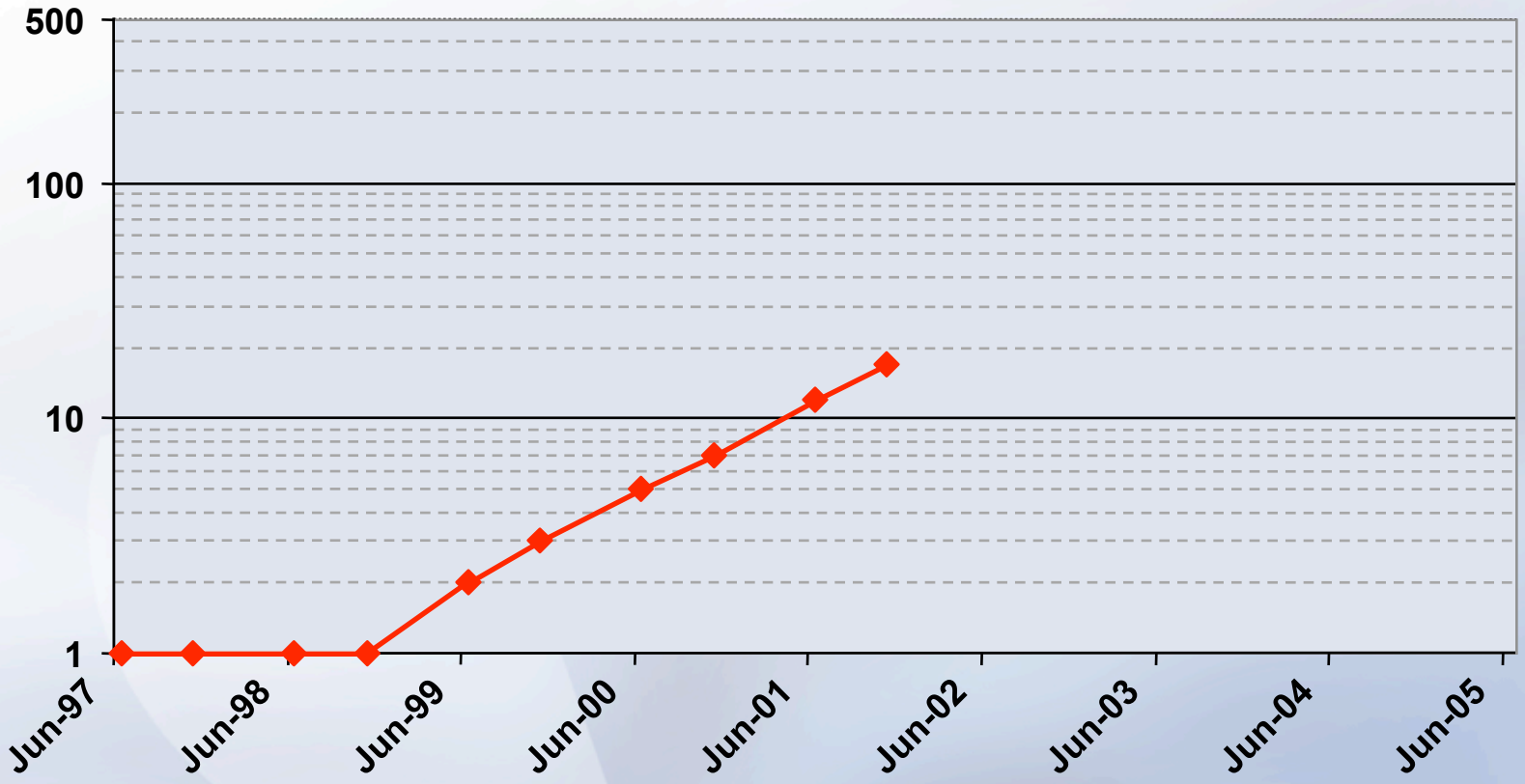

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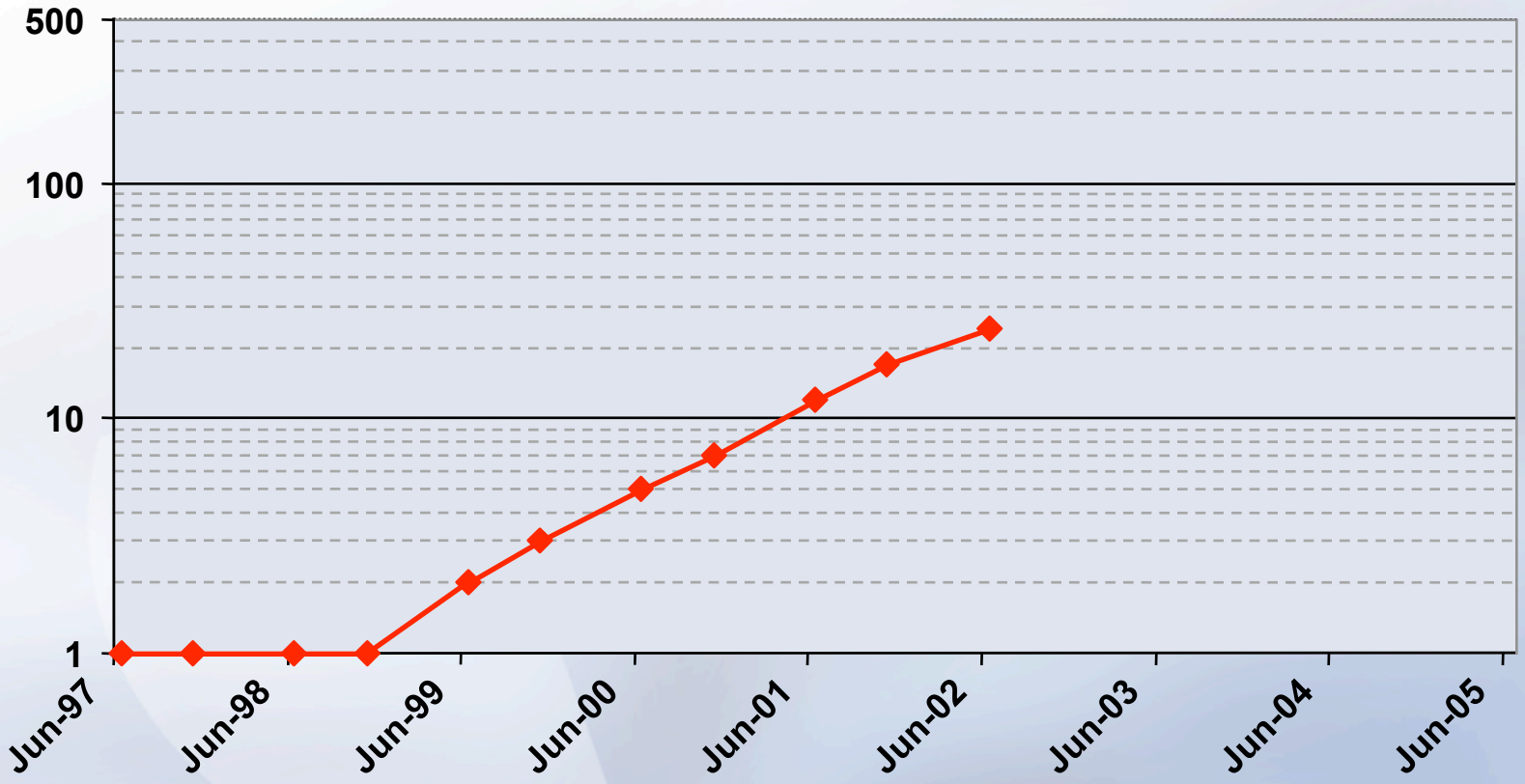

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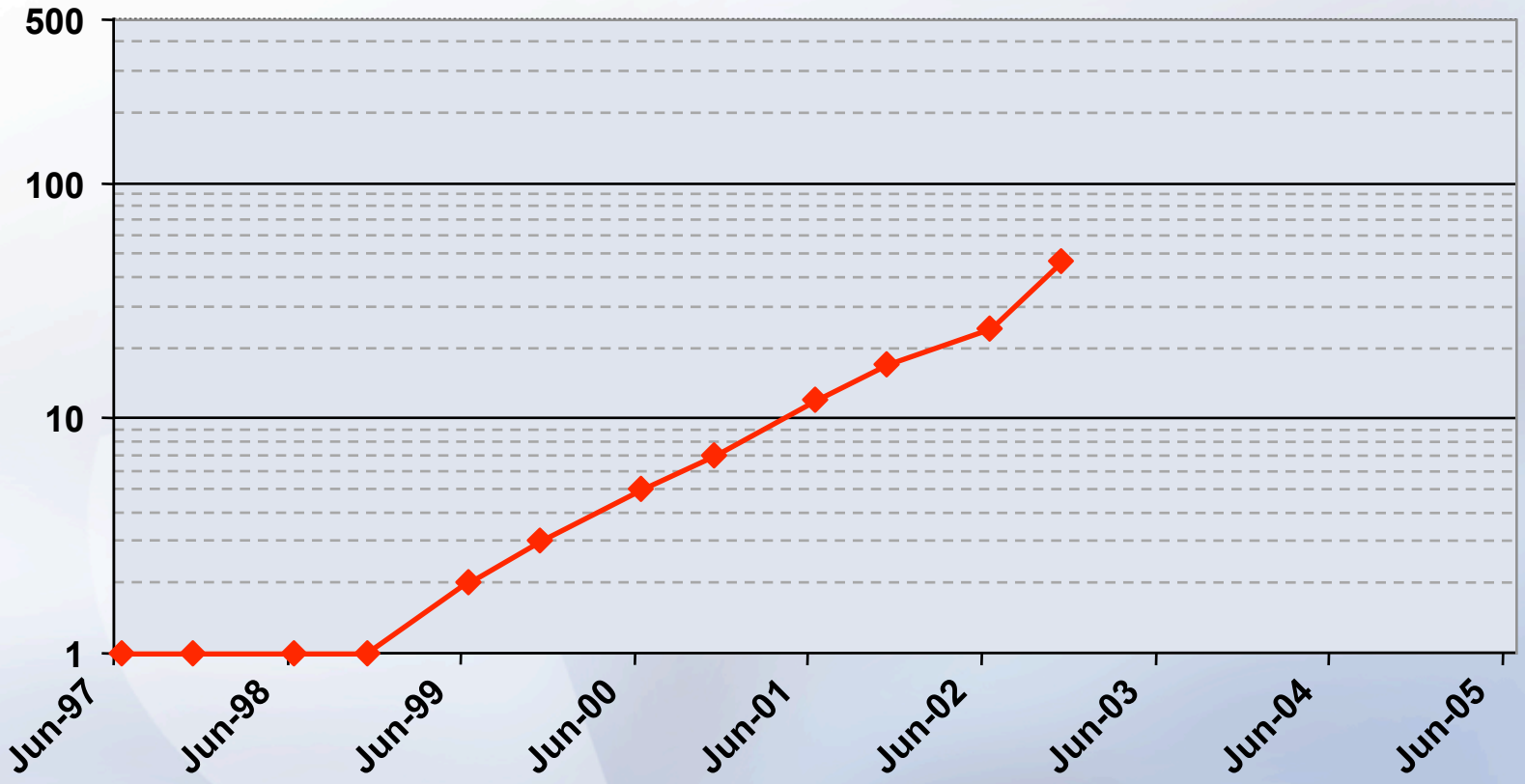

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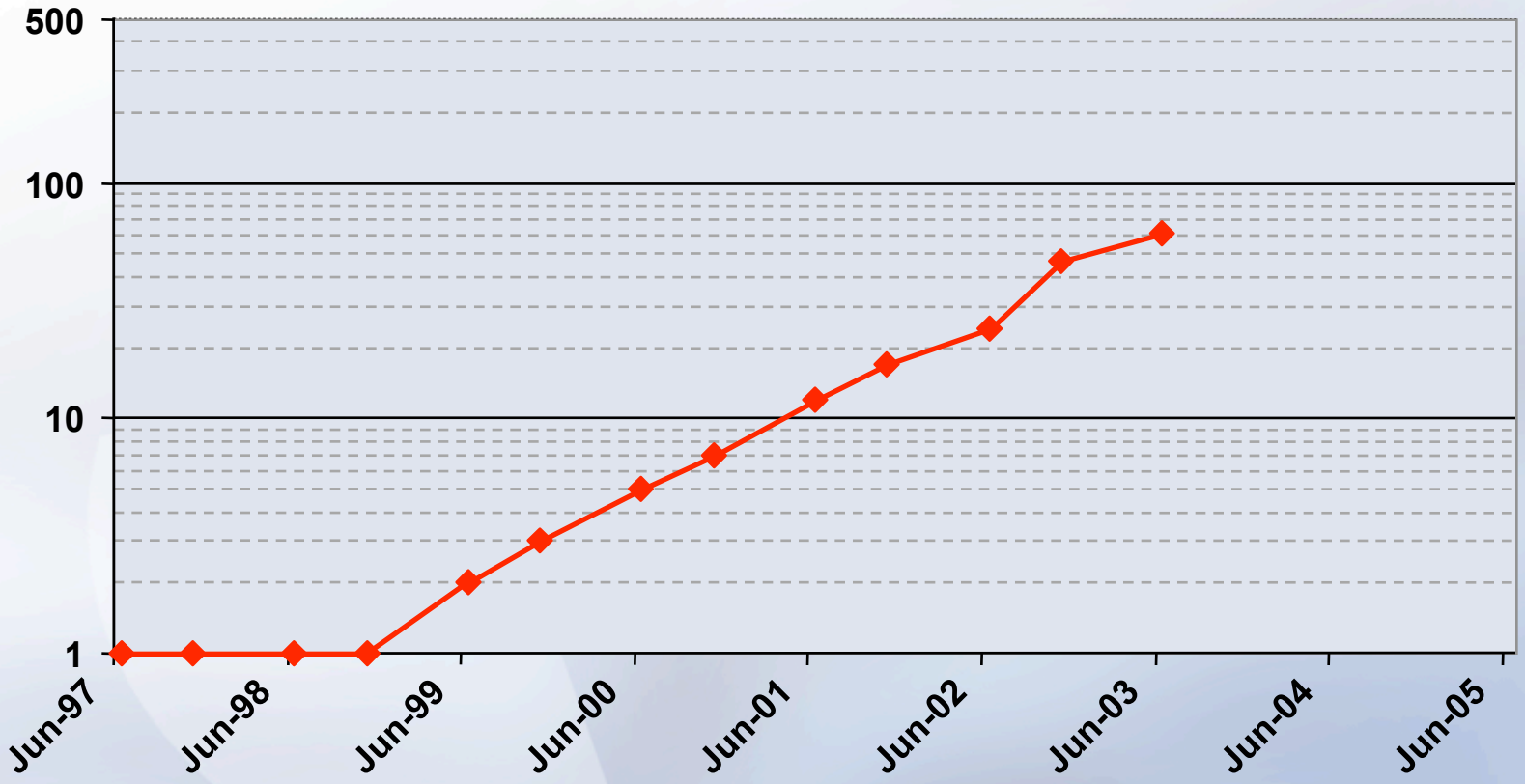

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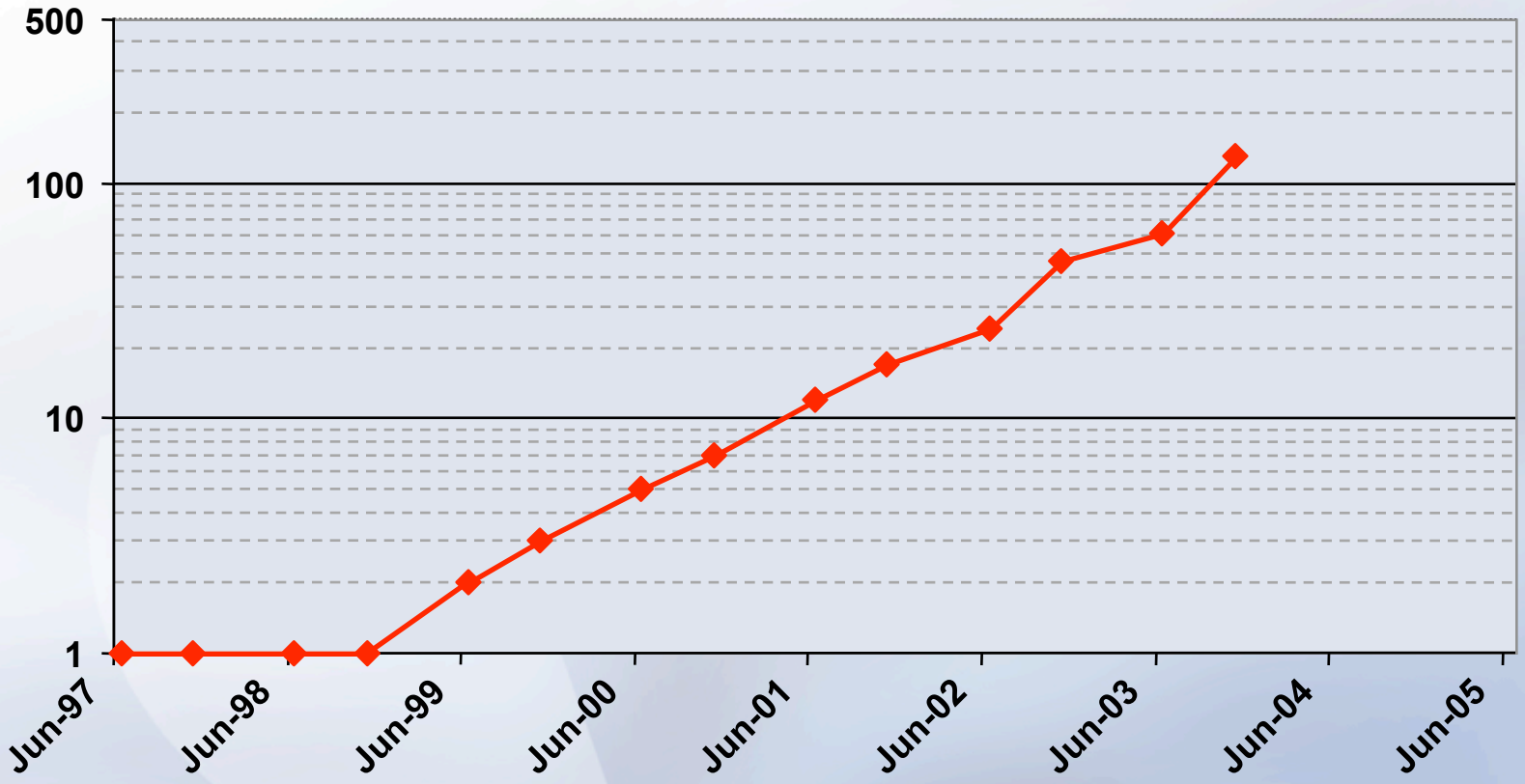

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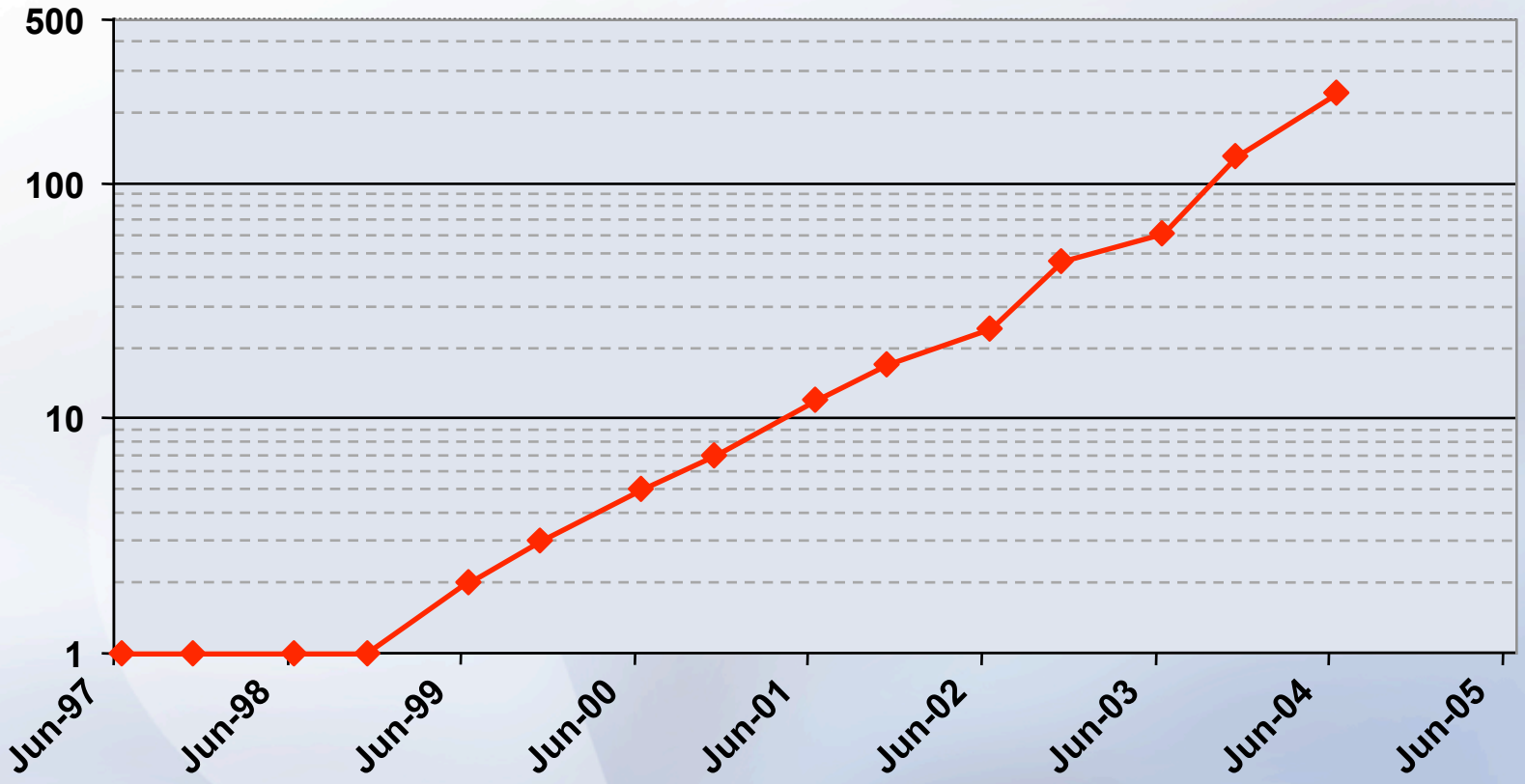

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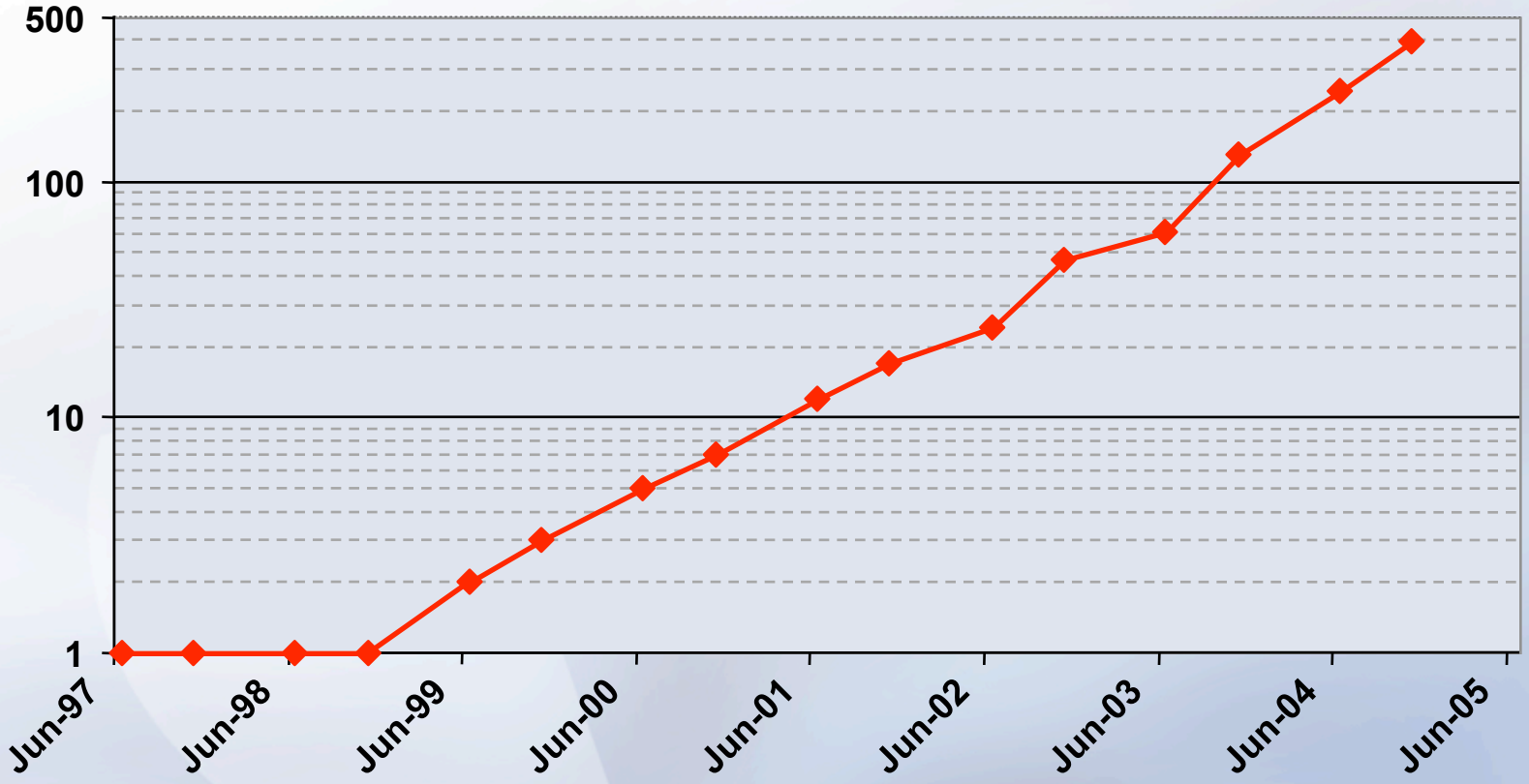

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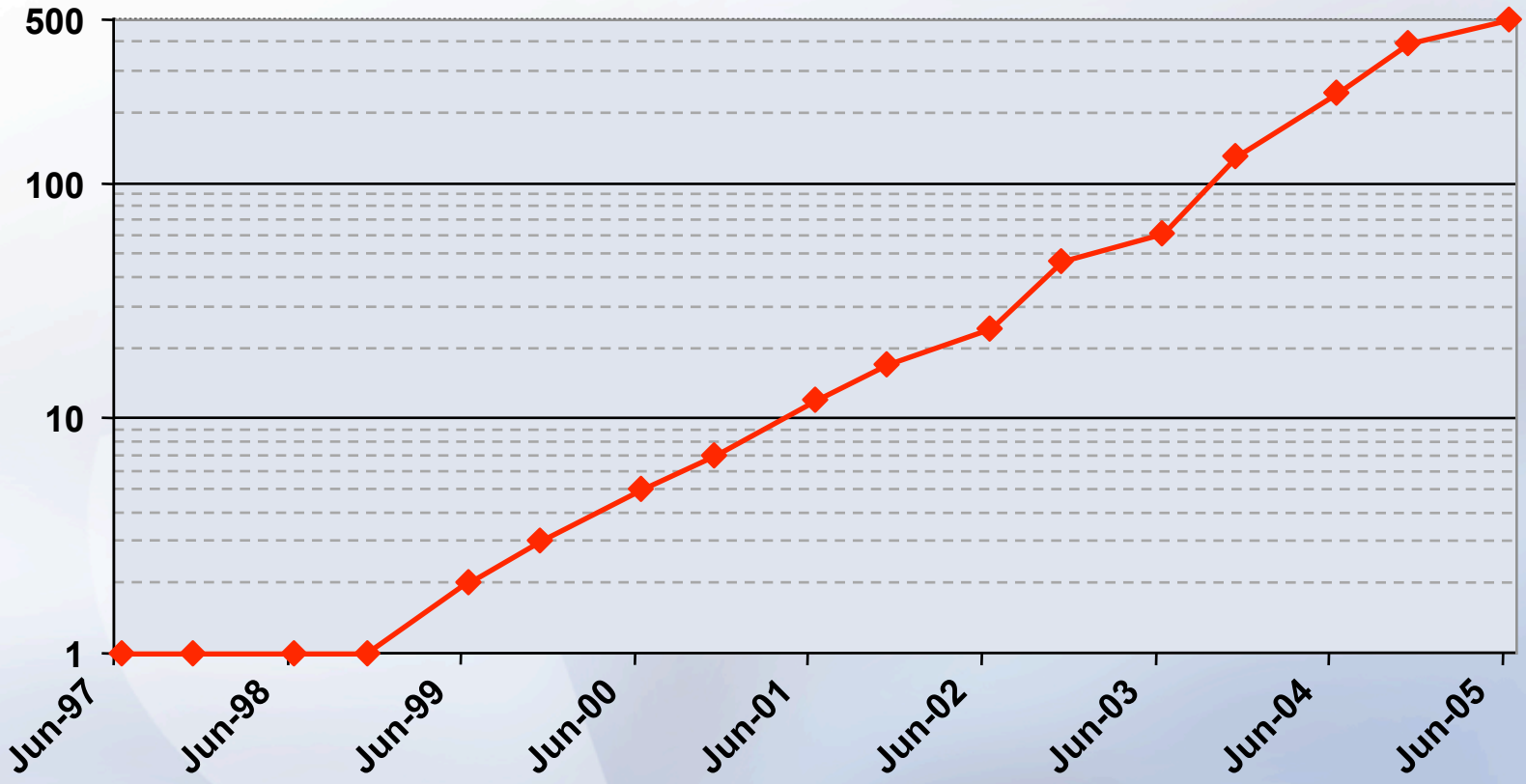

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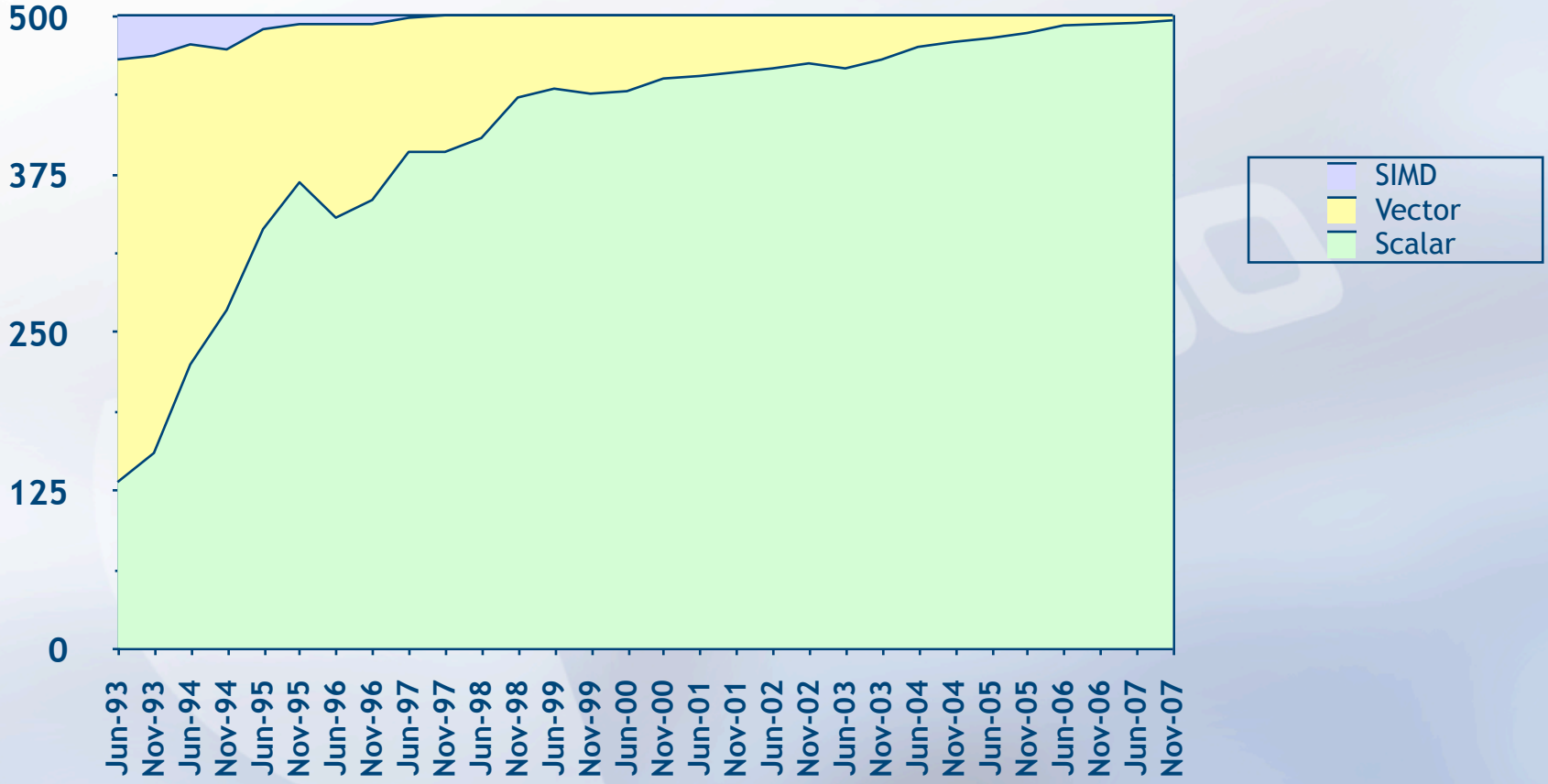
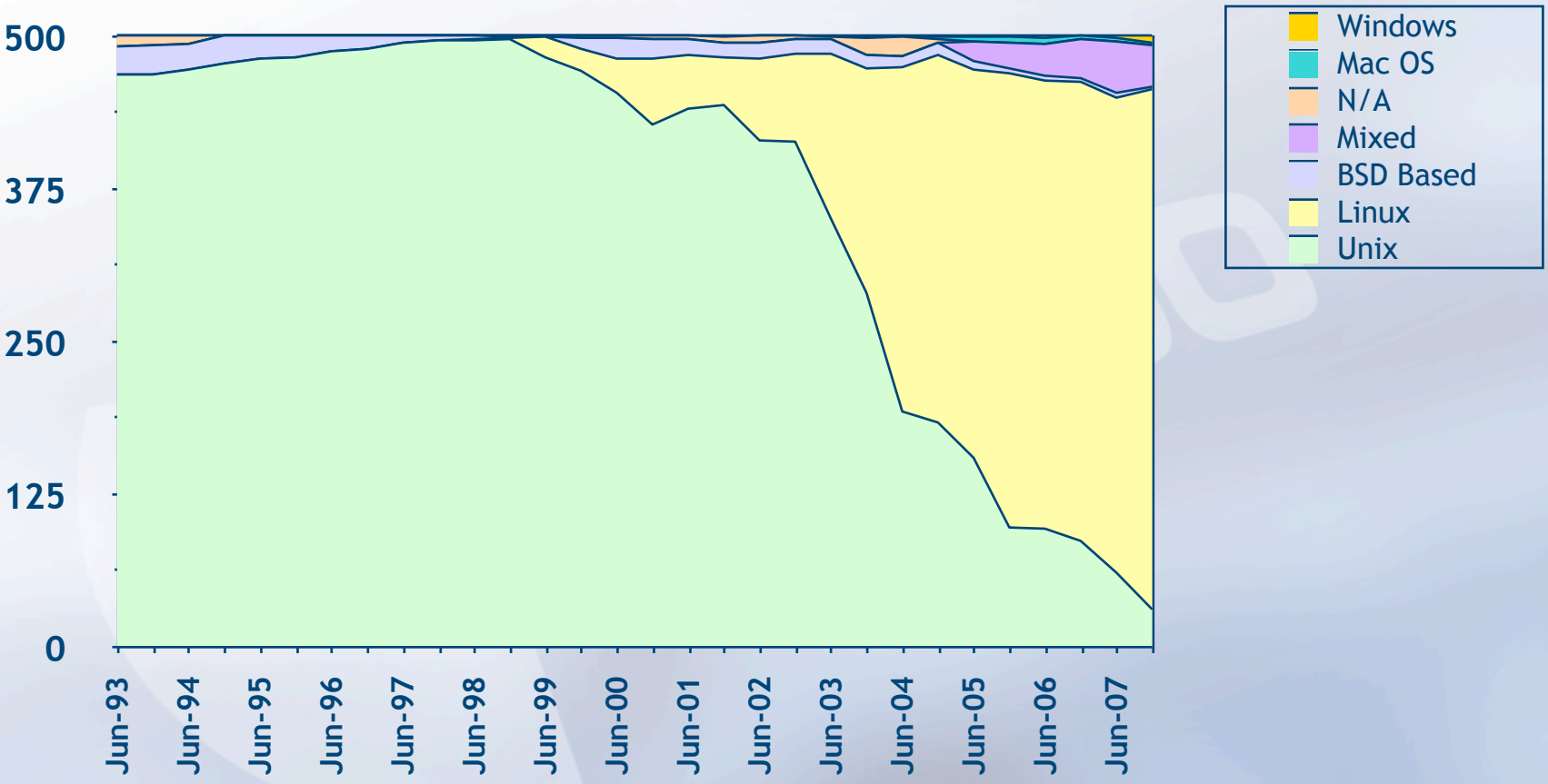
The 30th List as of November 2007

Processor Architecture/Systems



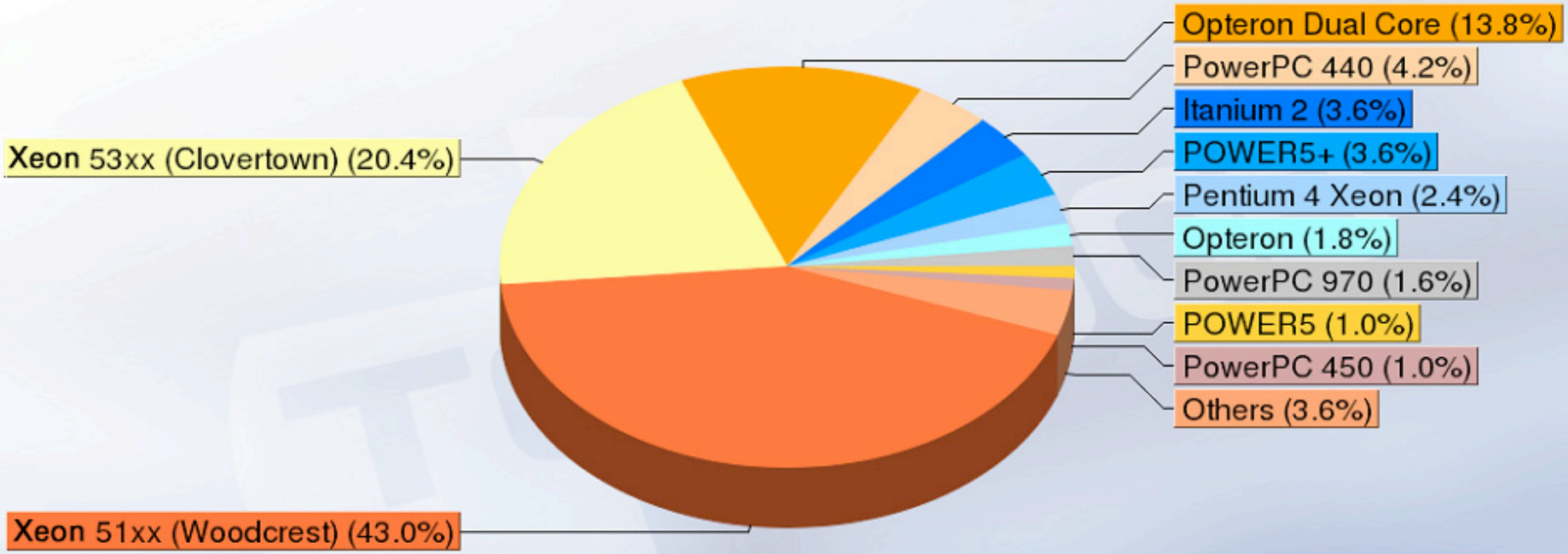
The 30th List as of November 2007

Operating Systems/Systems



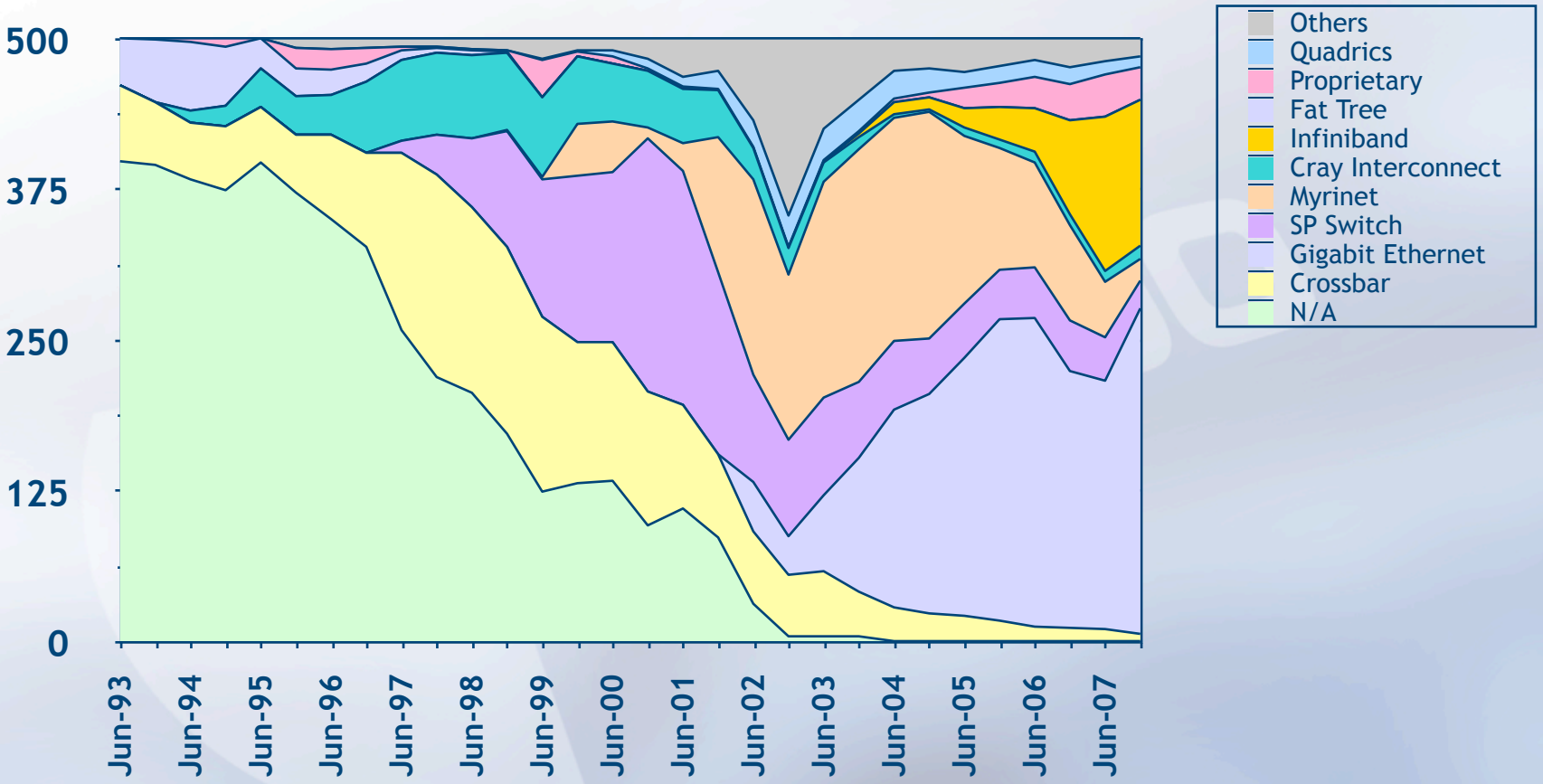
The 30th List as of November 2007

Processor Generation/Systems (November 2007)



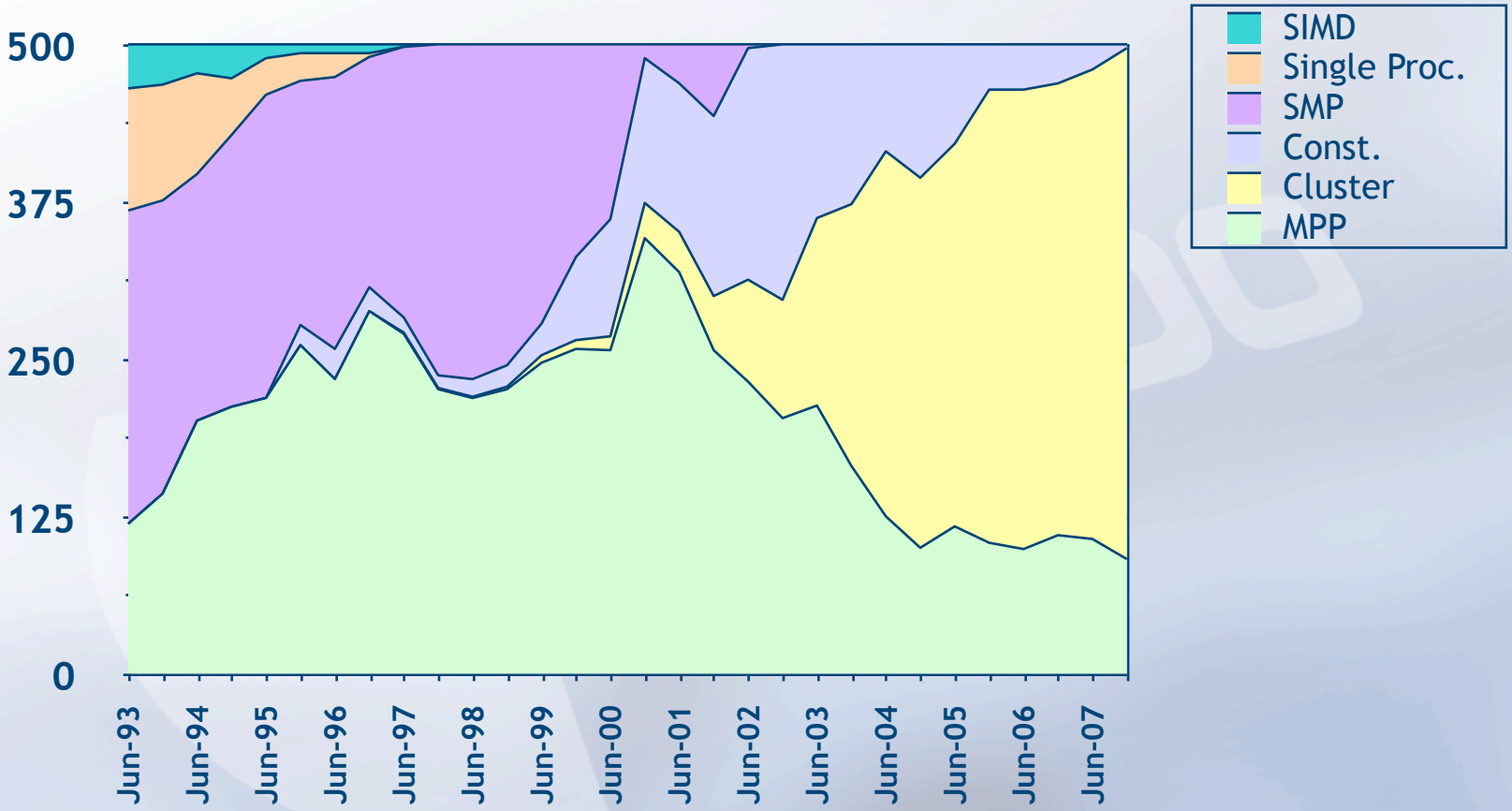
The 30th List as of November 2007

Interconnect Family/Systems



The 30th List as of November 2007

Architectures / Systems



Outline

- Mannheim Supercomputer Statistics & Top500 Project Start in 1993
- Competition between Manufacturers, Countries and Sites
- My Supercomputer Favorite in the Top500 Lists
- The 30th List as of November 2007
- → Performance Development and Projection
- Bell's Law
- Supercomputing, quo vadis?
  - in Jülich, Germany and Europe
  - in the Rest of the World
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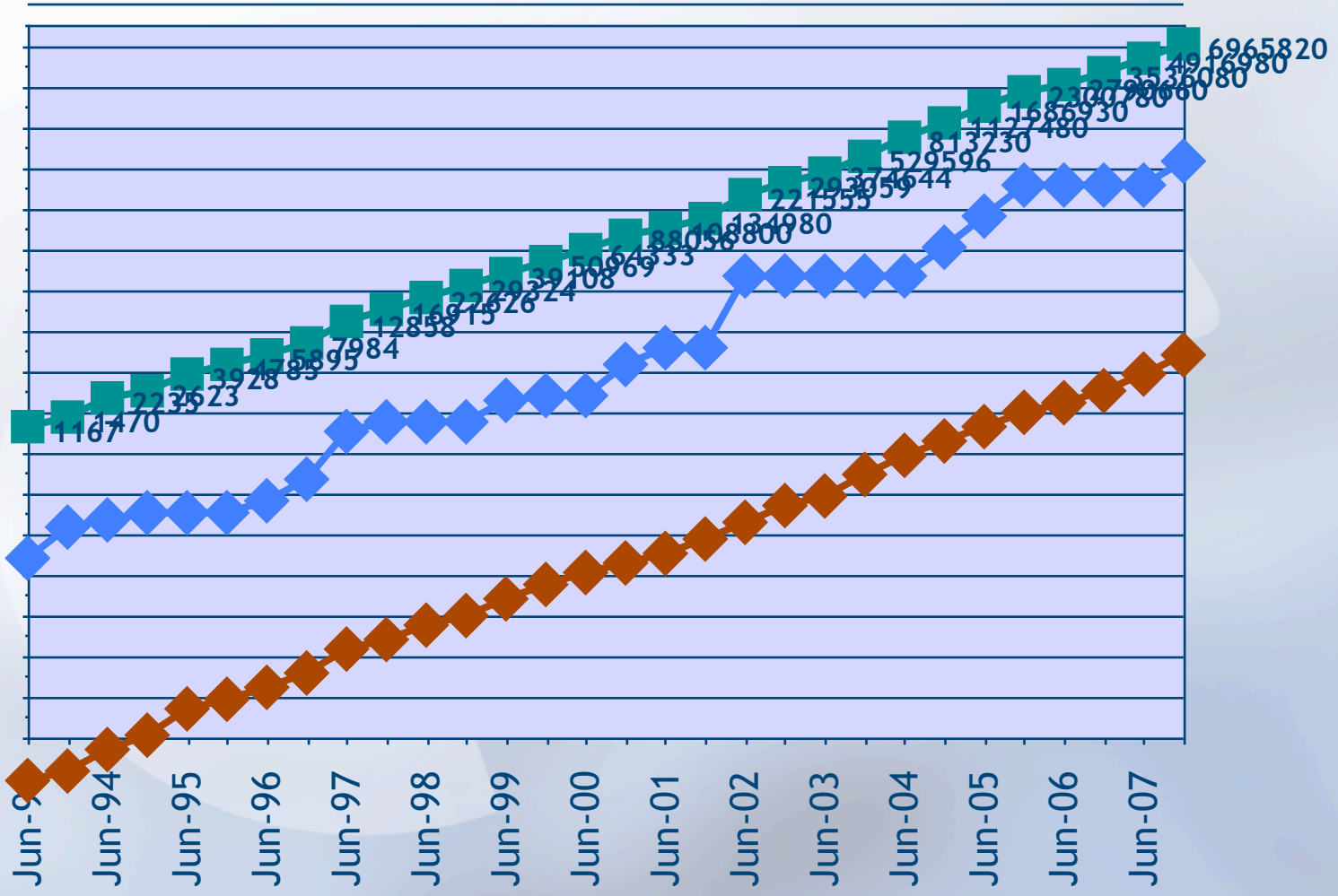
Performance Development

Performance Development



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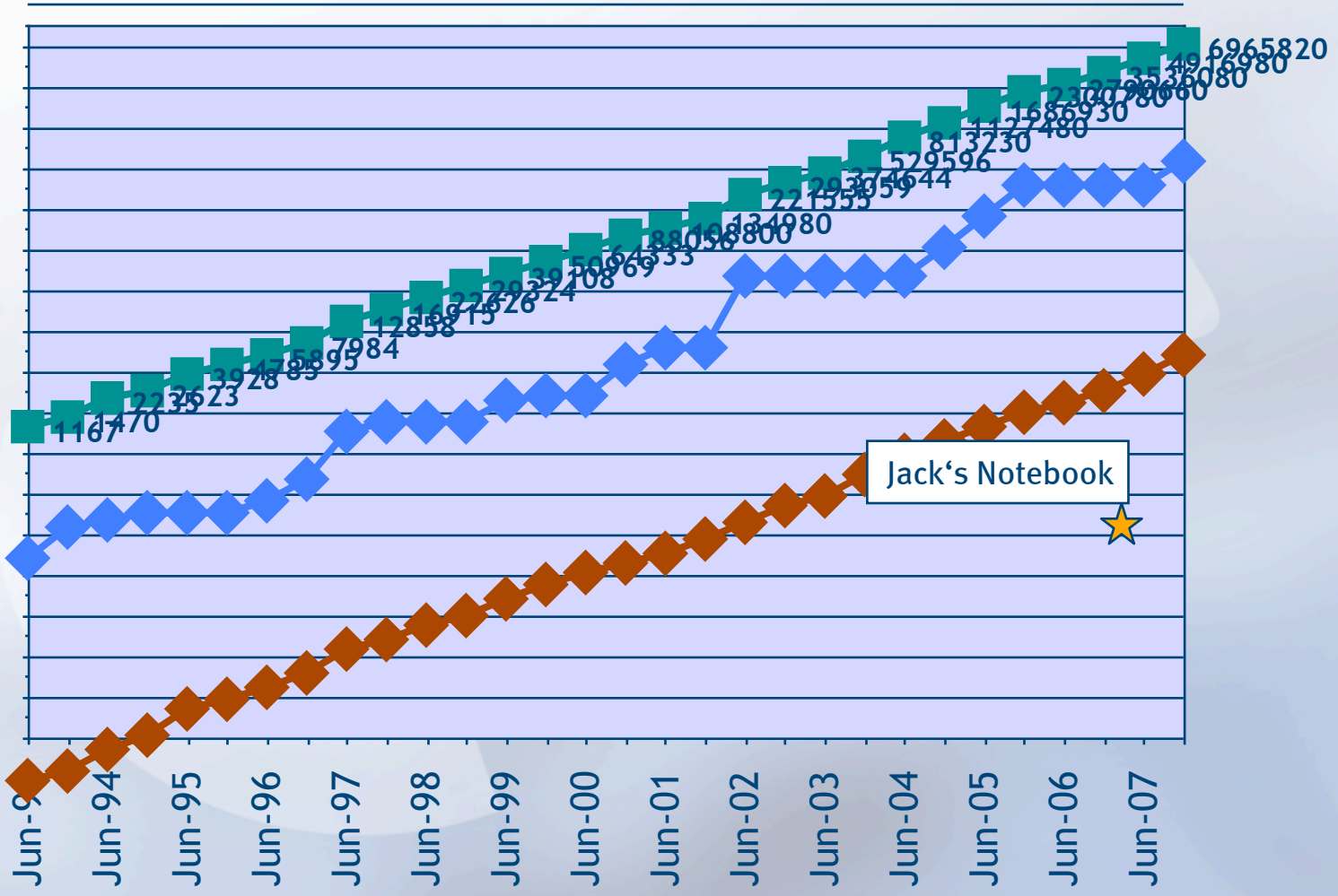

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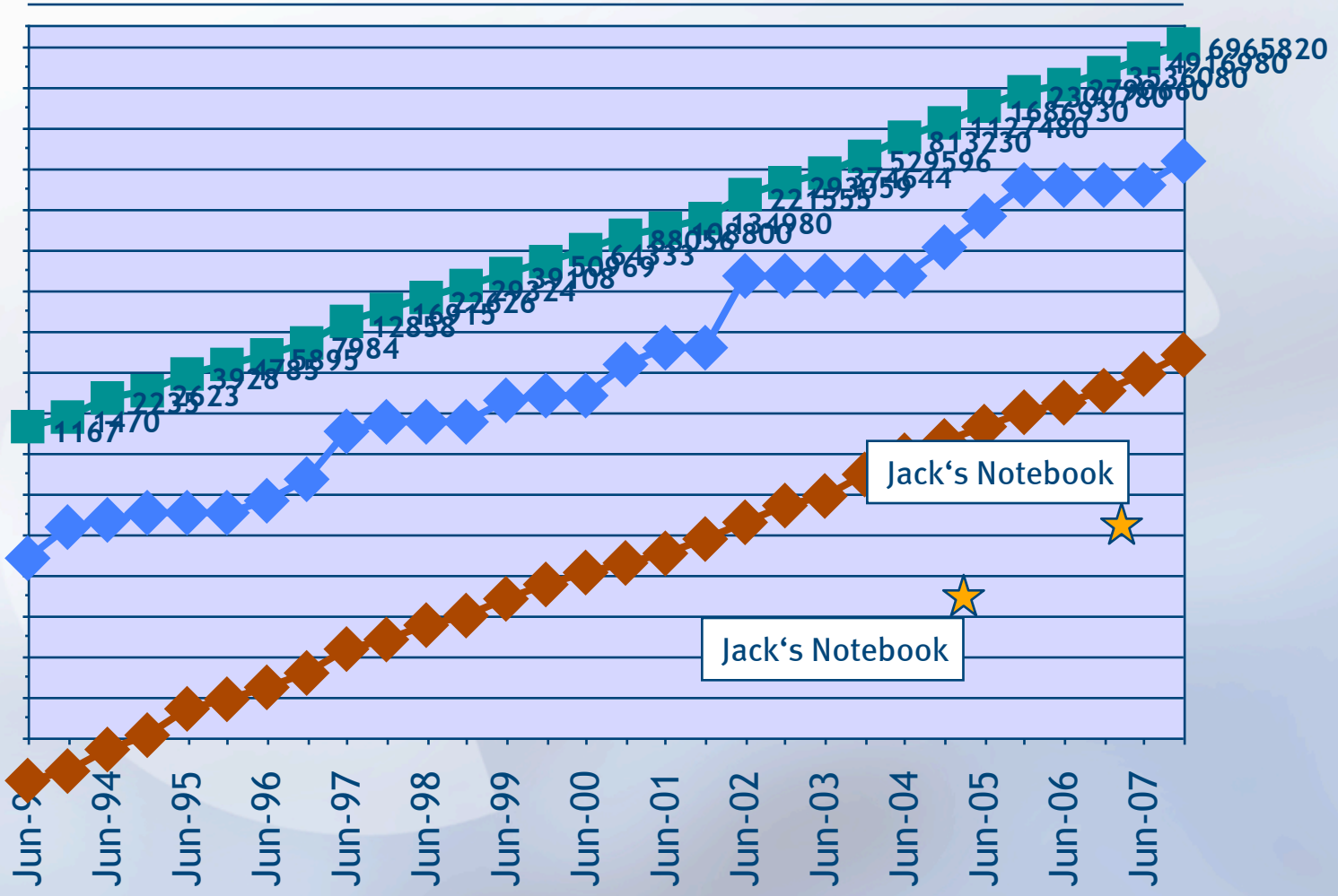
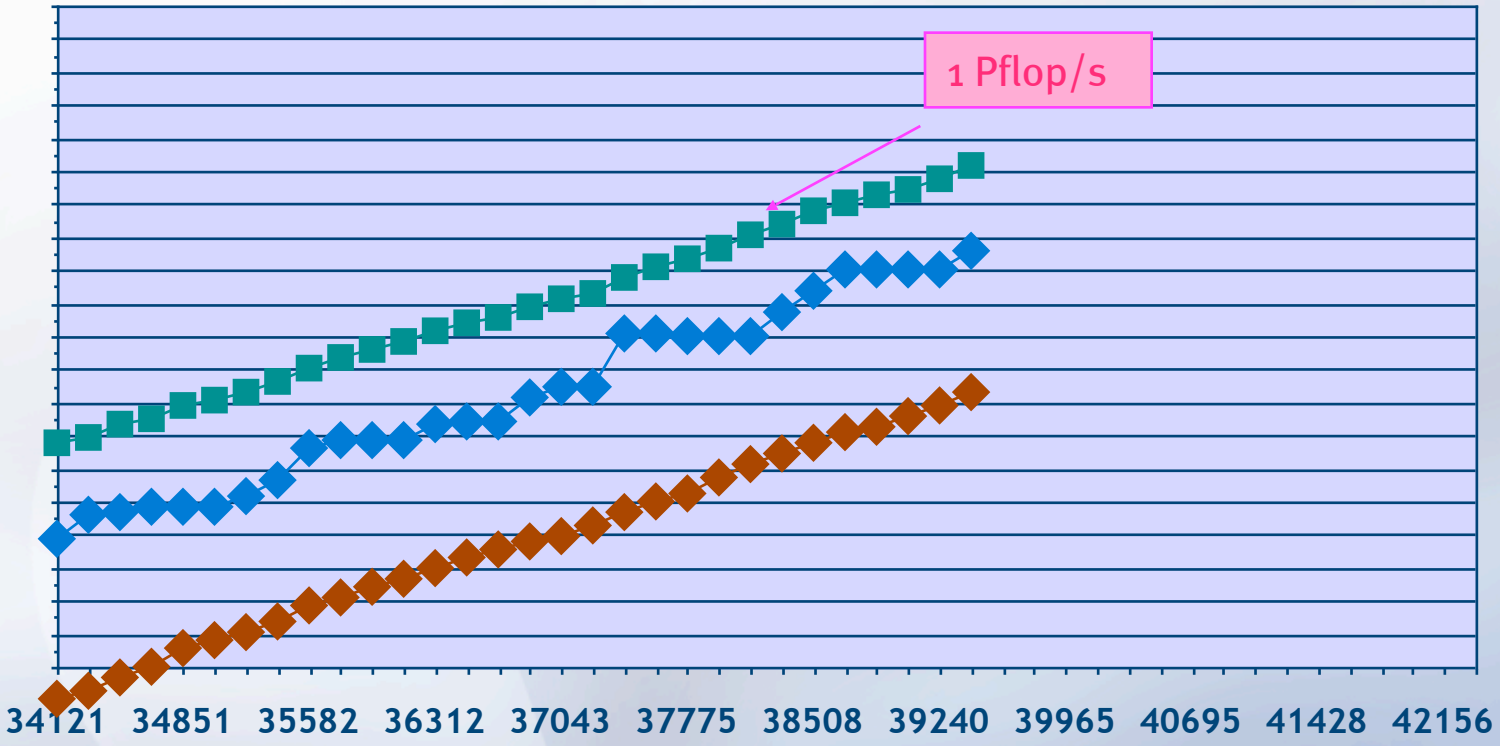


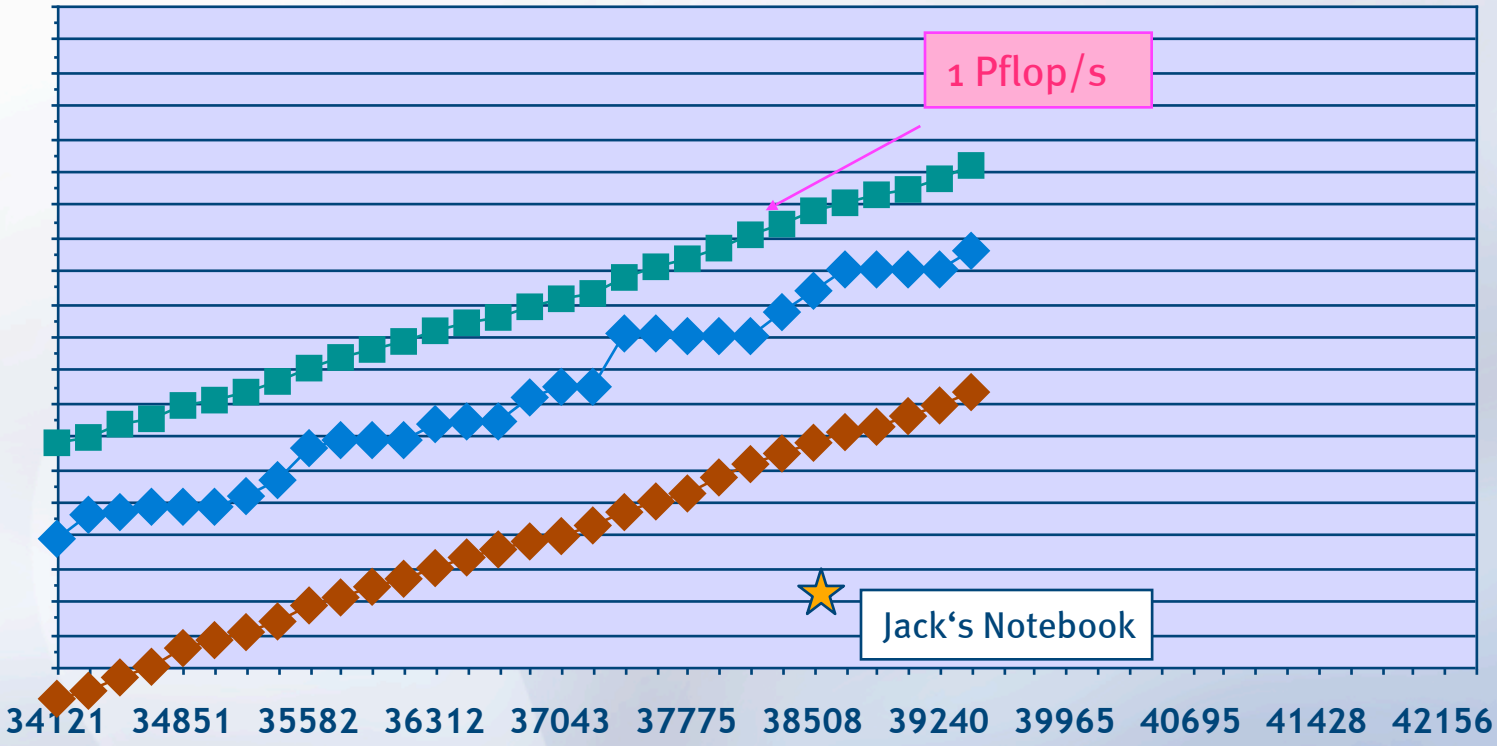
Performance Development

Performance Projection



Performance Development

Performance Projection



Performance Development

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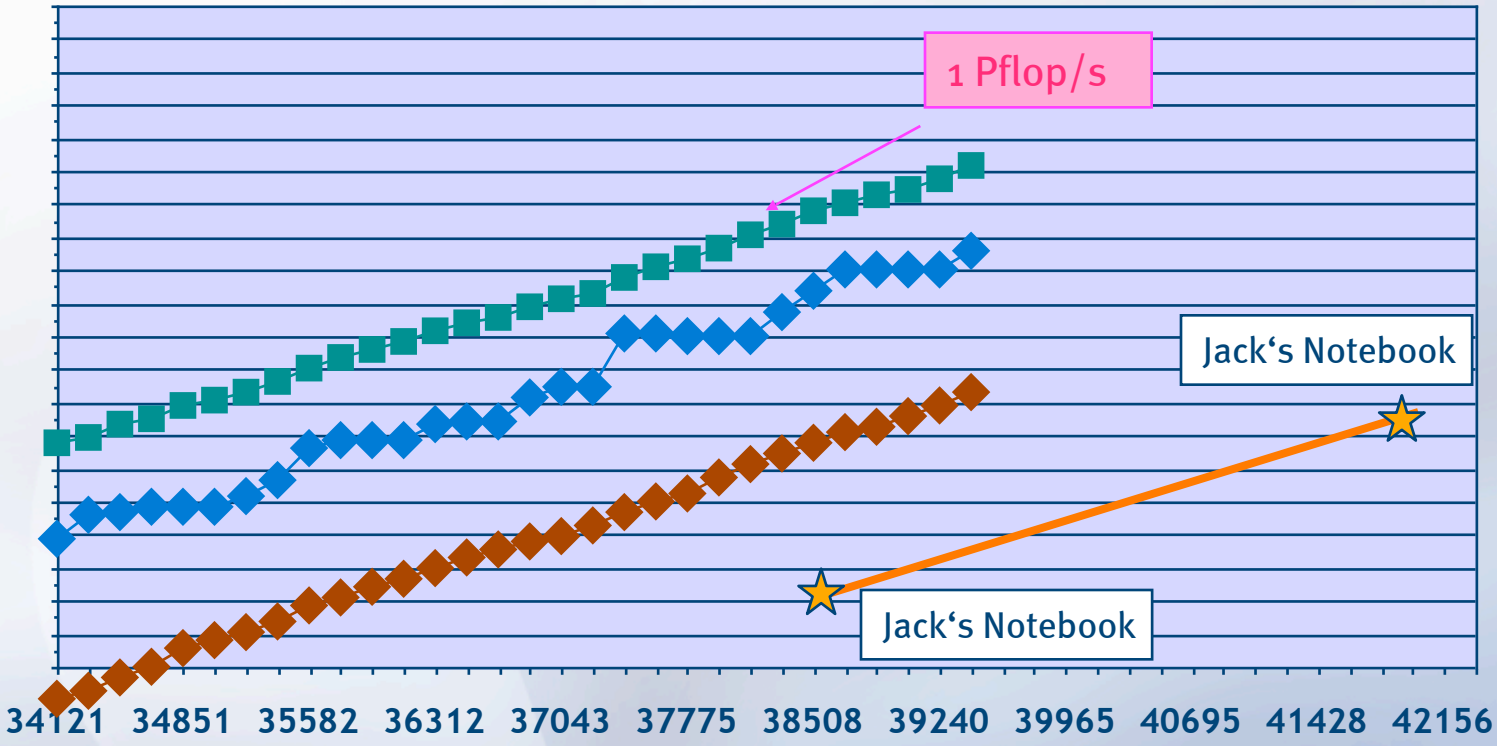
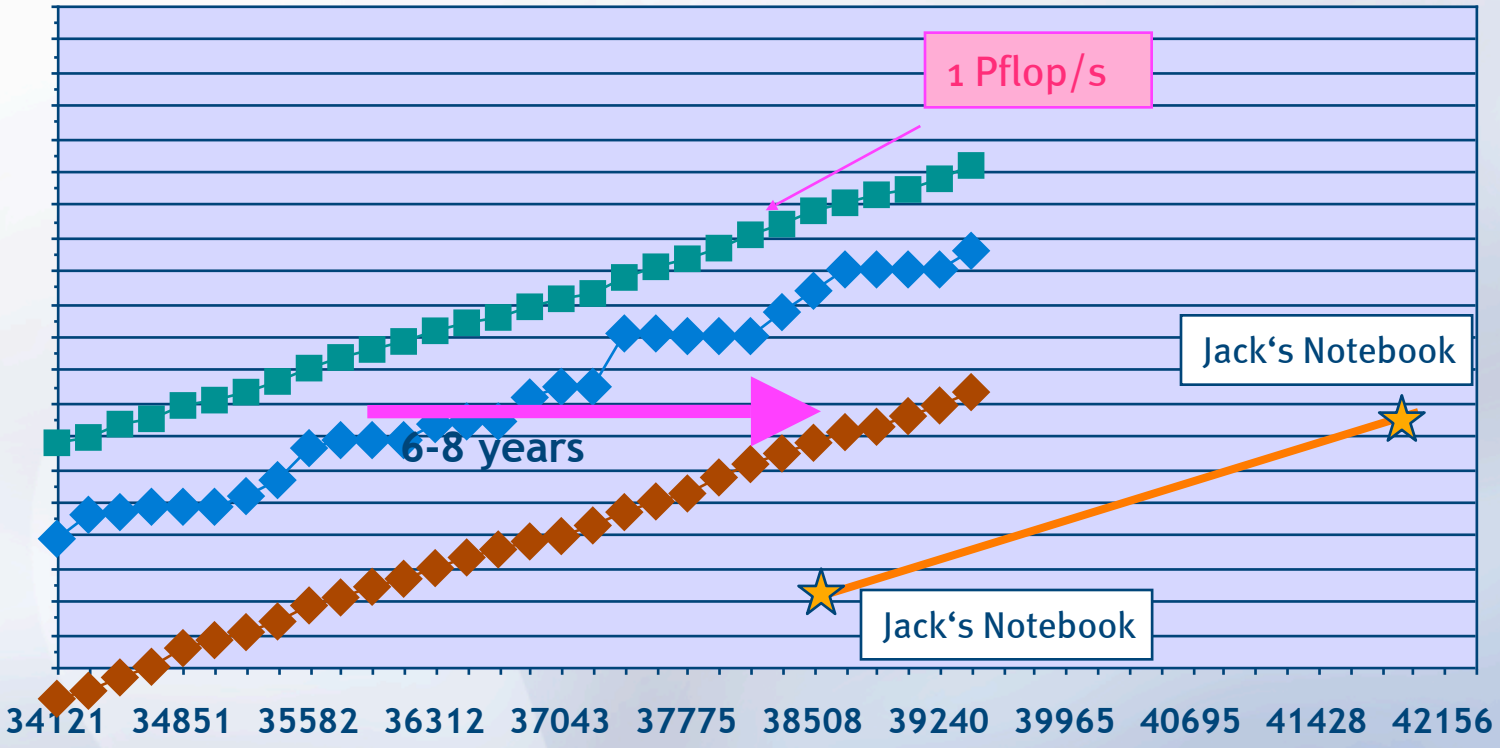


Performance Development

Performance Projection



Performance Development

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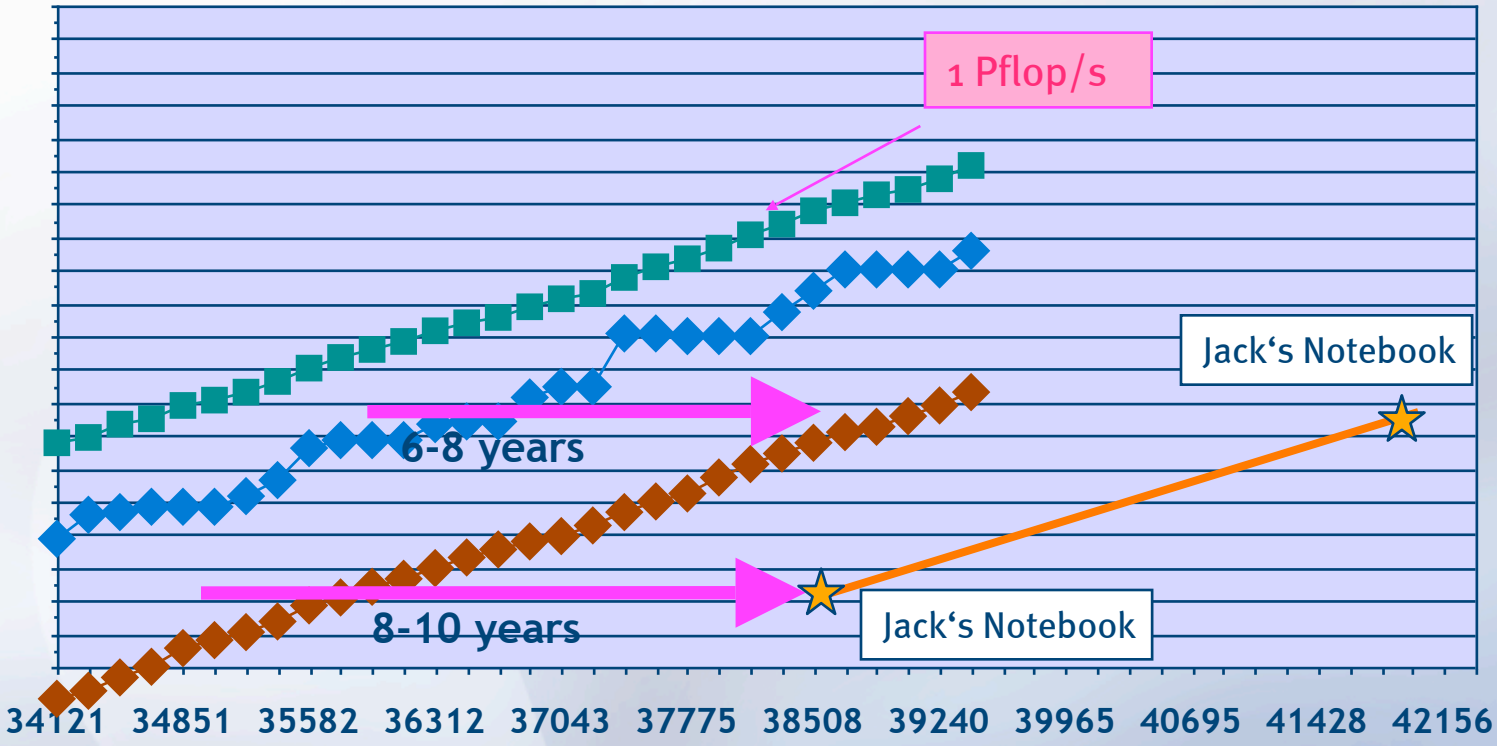

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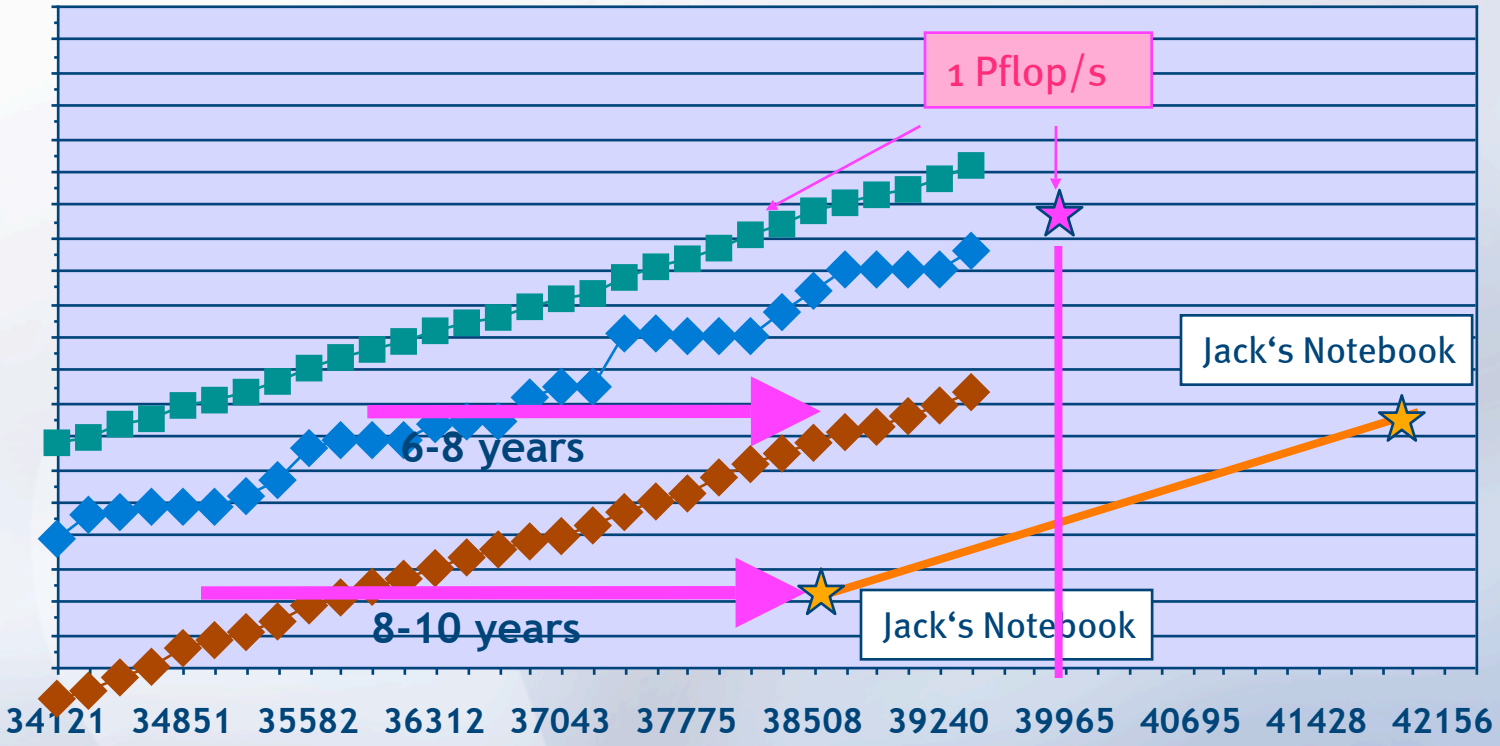
Performance Projection



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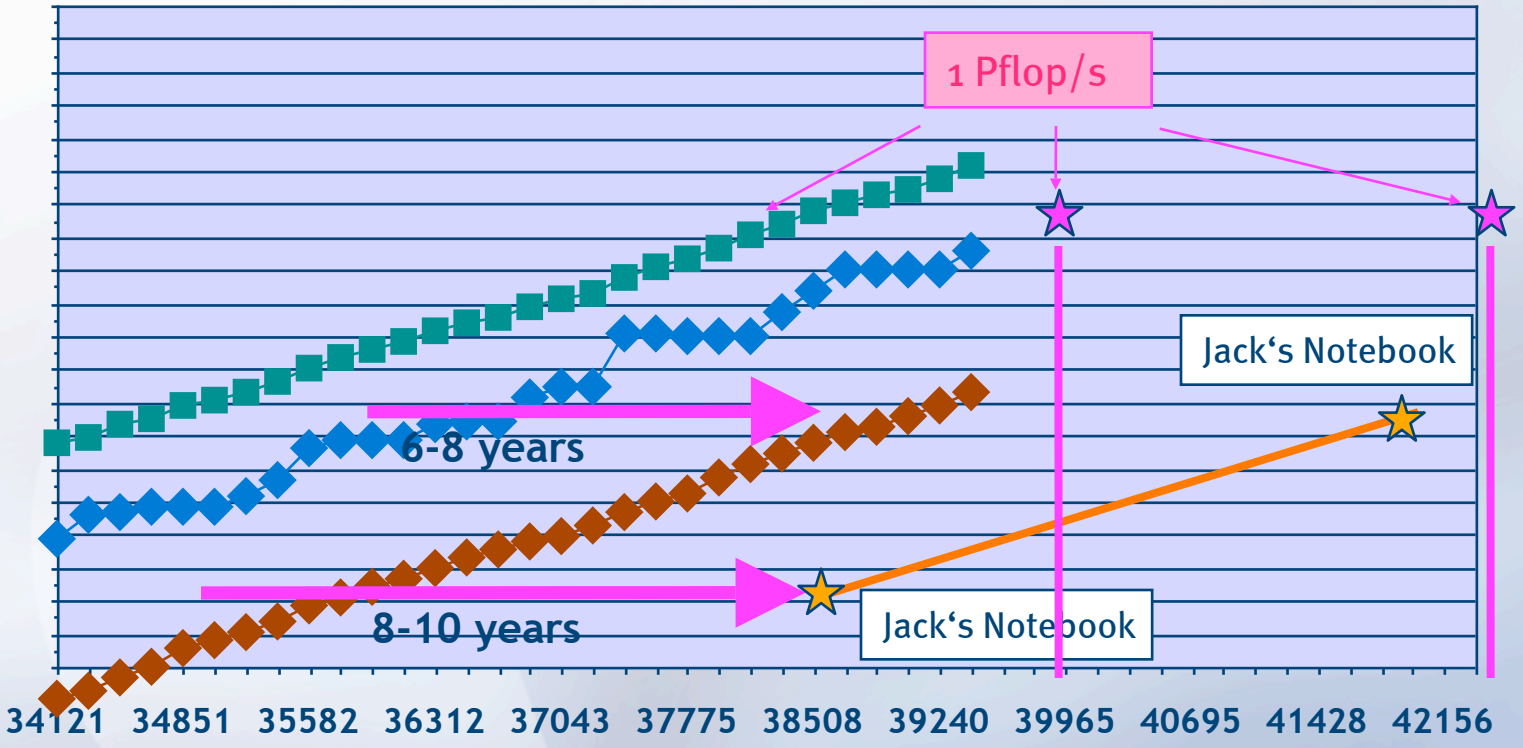

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Bell‘s Law

Bell's Law of Computer Class formation
was discovered about 1972. It states that technology advances in semiconductors, storage, user interface and networking advance every decade enable a new, usually lower priced computing platform to form. Once formed, each class is maintained as a quite independent industry structure. This explains mainframes, minicomputers, workstations and Personal computers, the web, emerging web services, palm and mobile devices, and ubiquitous interconnected networks. We can expect home and body area networks to follow this path.

From Gordon Bell (2007), http://research.microsoft.com/~GBell/Pubs.htm

Bell's Law

Bell's Law states, that:

- Important classes of computer architectures come in cycles of about 10 years.
- It takes about a decade for each phase :
  - Early research
  - Early adoption and maturation
  - Prime usage
  - Phase out past its prime
- Can we use Bell's Law to classify computer architectures in the TOP500?

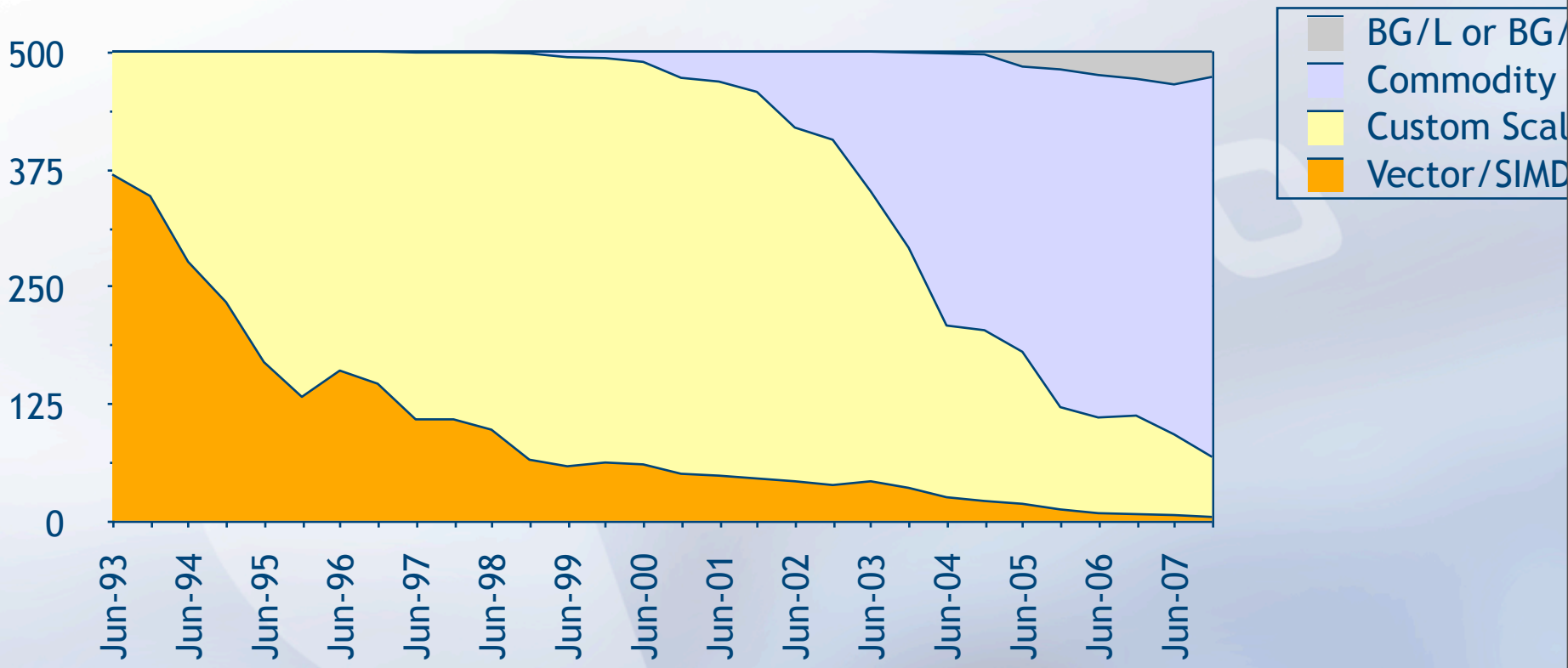
Bell's Law

Gordon Bell (1972): 10 year cycles for computer classes
Computer classes in HPC based on the TOP500:

- Data Parallel Systems:
  - Vector (Cray Y-MP and X1, NEC SX, ...)
  - SIMD (CM-2, ...)
- Custom Scalar Systems:
  - MPP (Cray T3E and XT3, IBM SP, ...)
  - Scalar SMPs and Constellations (Cluster of big SMPs)
- Commodity Cluster: NOW, PC cluster, Blades, ...
- Power-Efficient Systems (BG/L or BG/P as first example of low-power / embedded systems = potential new class ?)
  - Tsubame with Clearspeed, Roadrunner with Cell ?

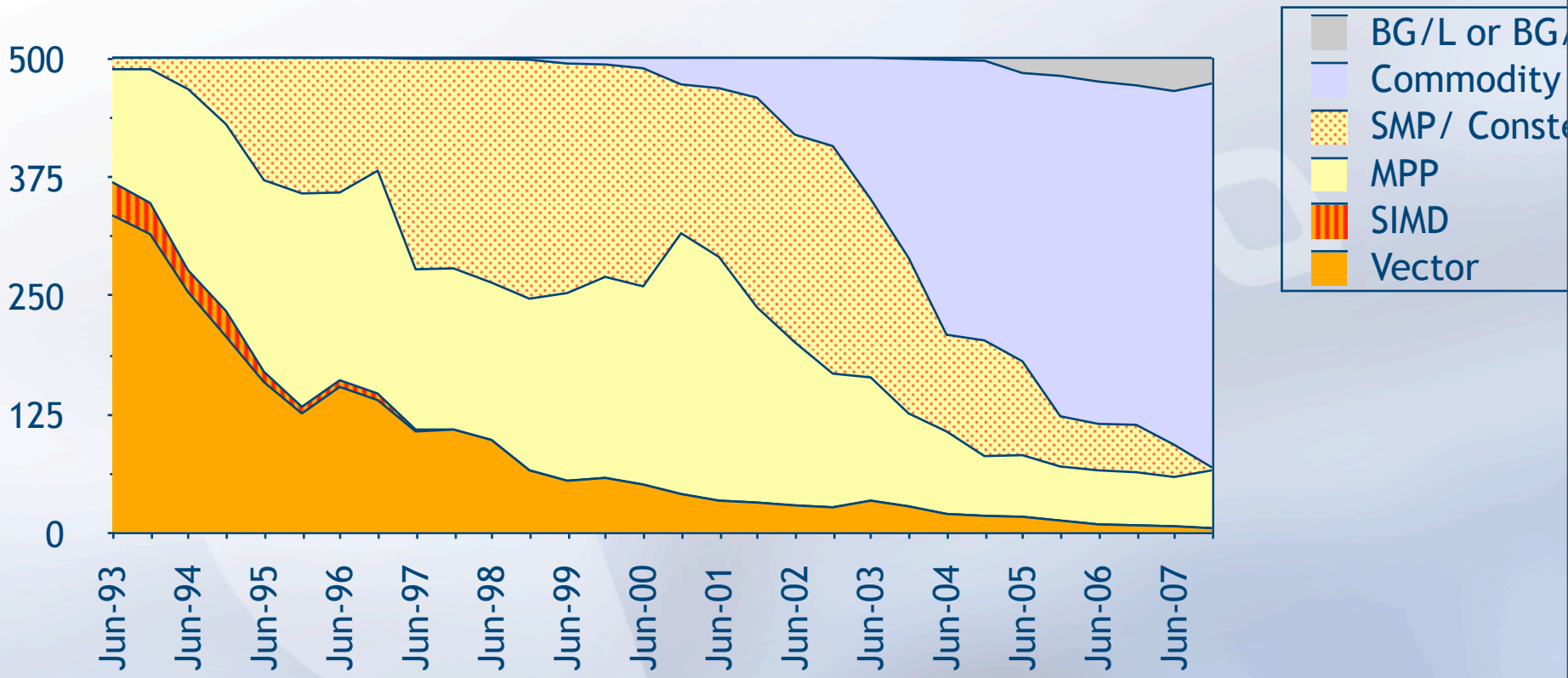
Bell's Law

Computer Classes / Systems



Bell's Law

Computer Classes - refined / Systems



Bell's Law

HPC Computer Classes

Class	Early Adoption starts:	Prime Use starts:	Past Prime Usage starts:
Data Parallel Systems	Mid 70's	Mid 80's	Mid 90's
Custom Scalar Systems	Mid 80's	Mid 90's	Mid 2000's
Commodity Cluster	Mid 90's	Mid 2000's	Mid 2010's ???
BG/L or BG/P	Mid 2000's	Mid 2010's ???	Mid 2020's ???

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Supercomputing in Jülich und dem Rest der Welt

Hans Werner Meuer
ehem. Mitarbeiter des ZAM von 1962-73

Kolloquium zur Verabschiedung von
Prof. Dr. Friedel Hoßfeld

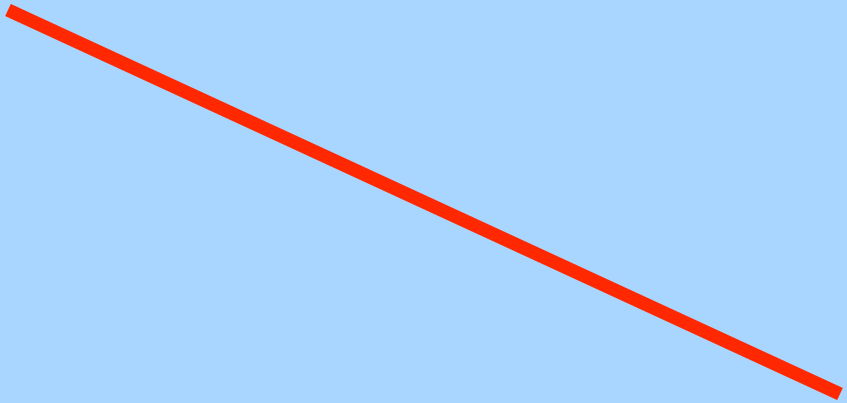
Forschungszentrum Jülich, 11. Juli 2002

1997

$0.18 * 10^{12}$ Flop/s

- Cray T3E im FZJ
- 512 Prozessoren
- # 5 in TOP500 Liste 06/97

1997-2002

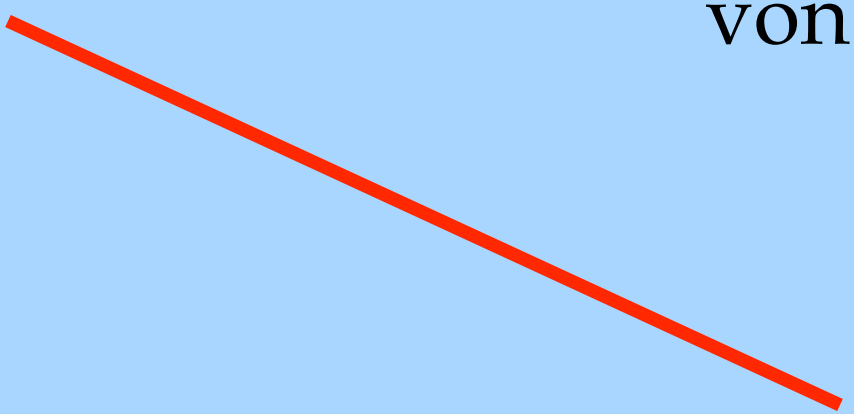


$35.86 * 10^{12}$ Flop/s

- Earth Simulator Japan
- 5120 NEC Vektor-Prozessoren

1997-2002

von da an ging‘s bergab…



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von da an ging‘s bergab…

…mit dem Standing
des FZJ in den TOP500!

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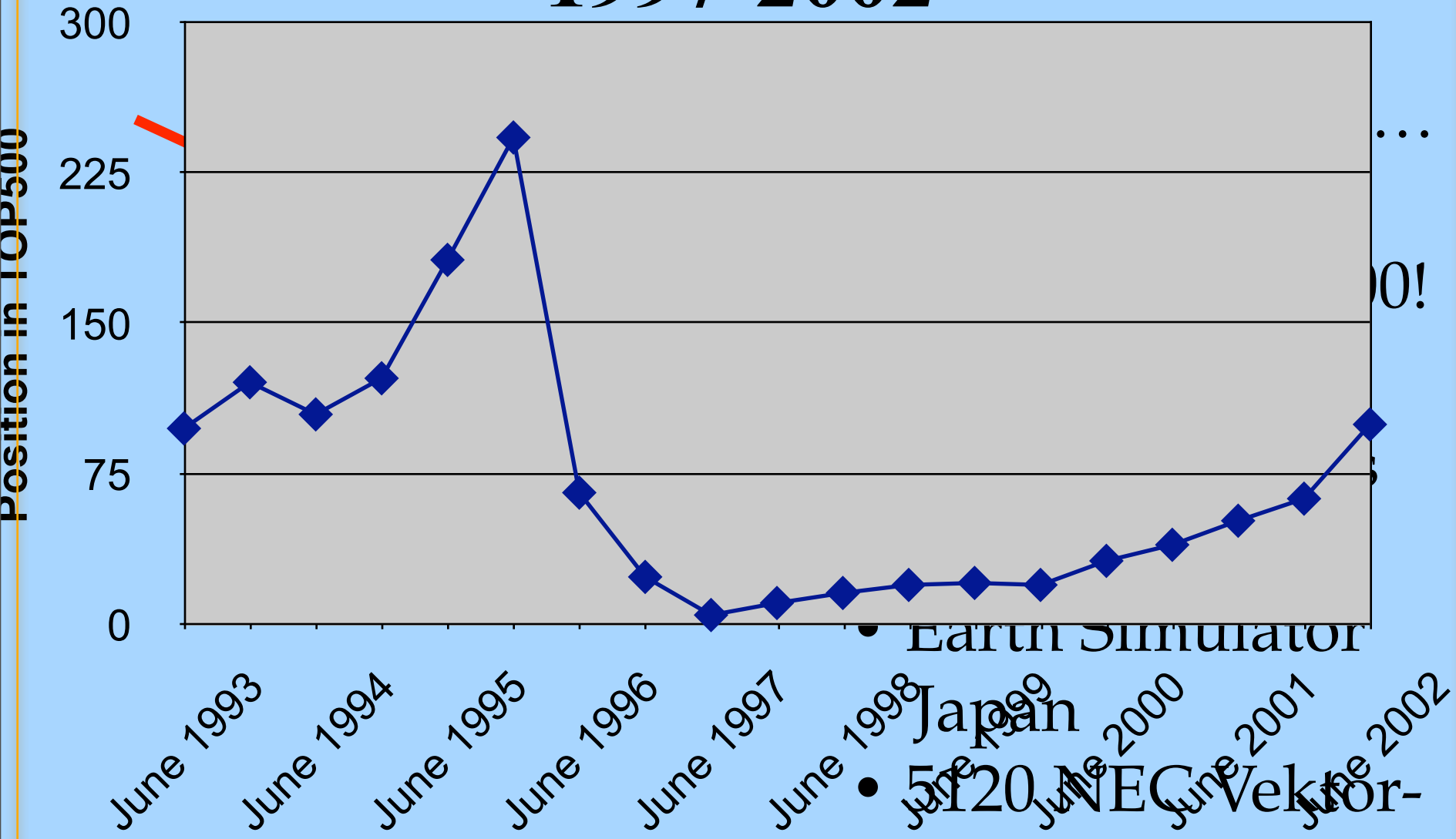

...

0!

- Earth Simulator Japan
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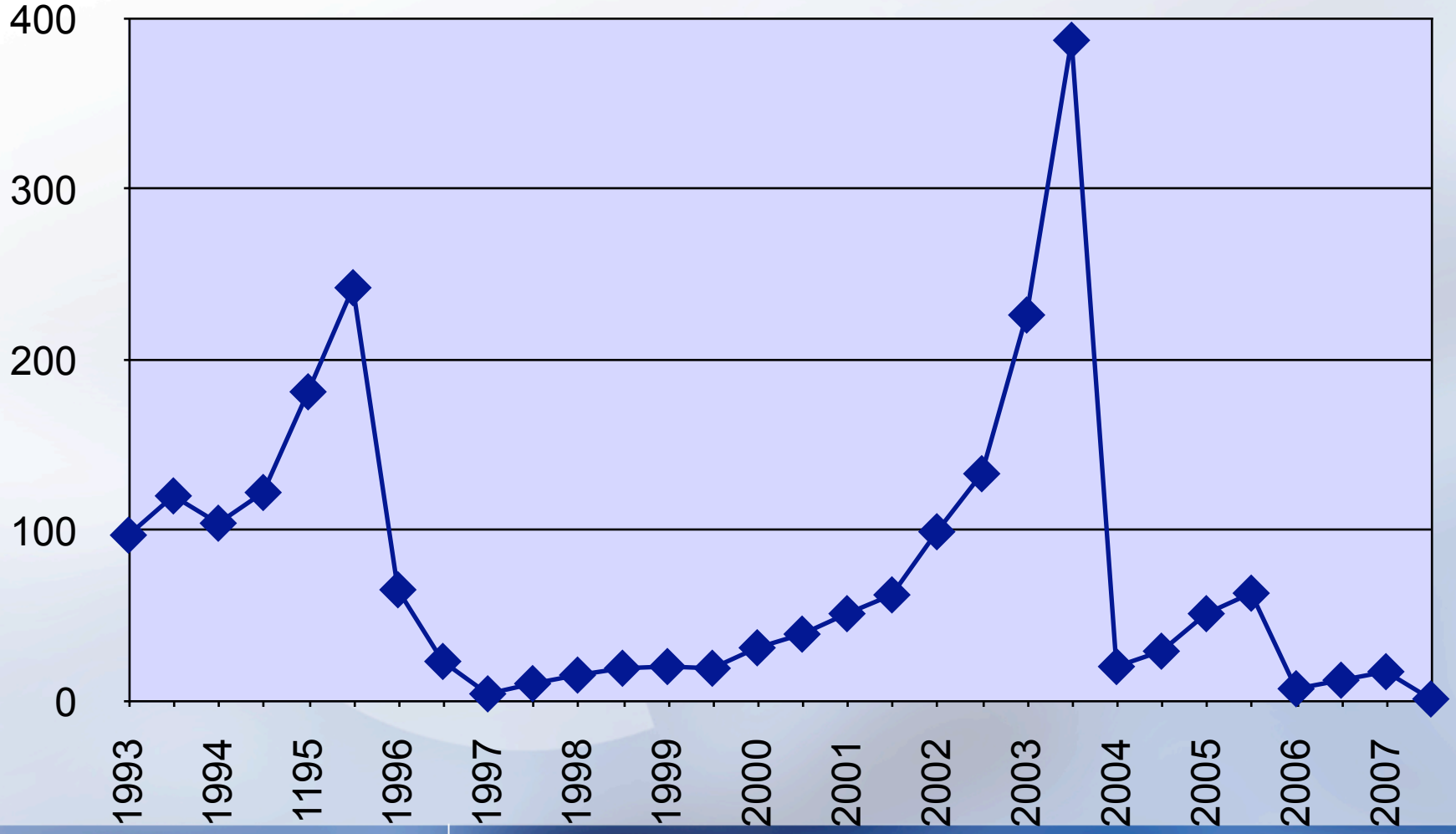
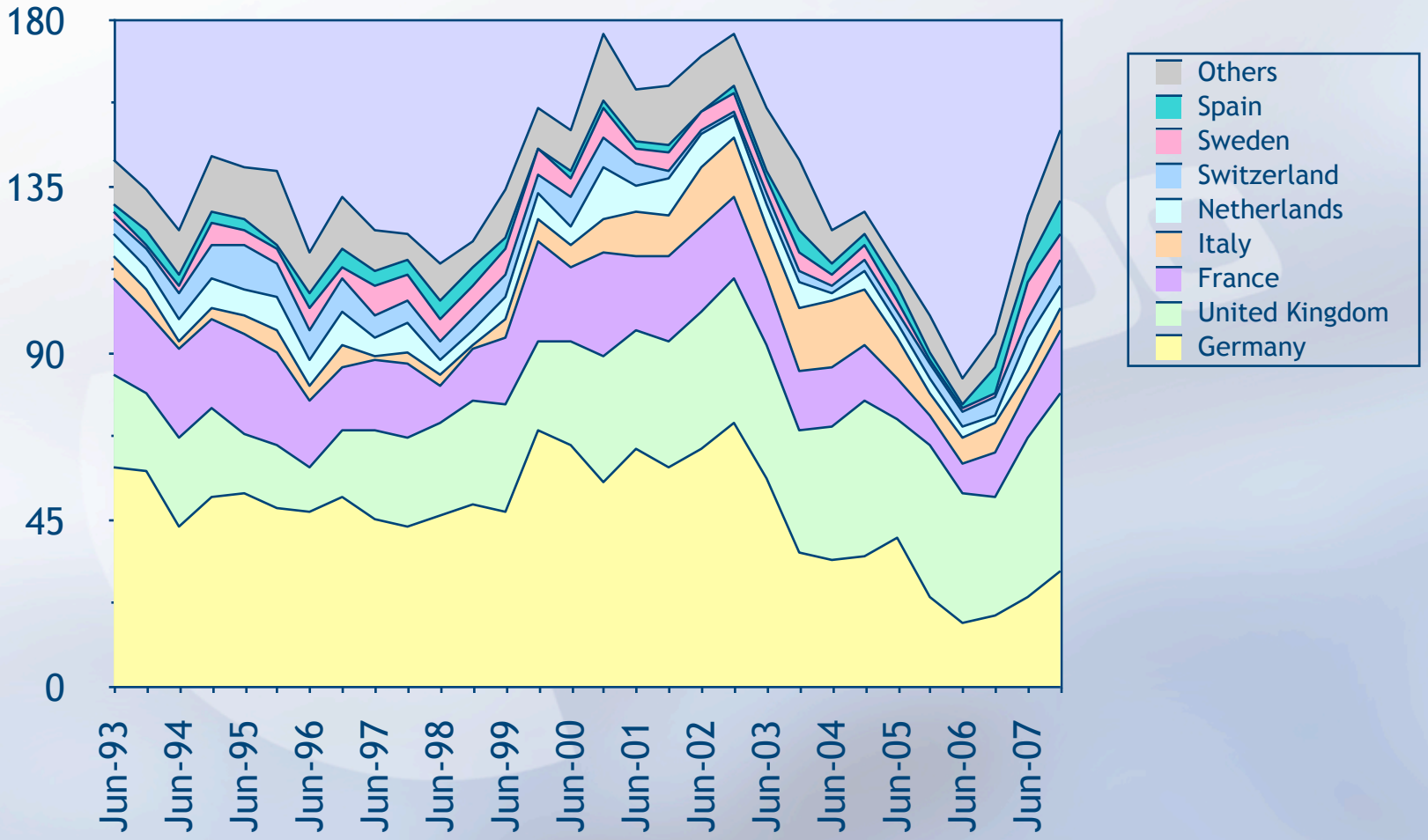
Supercomputing, quo vadis?

FZ Jülich Position in Top500



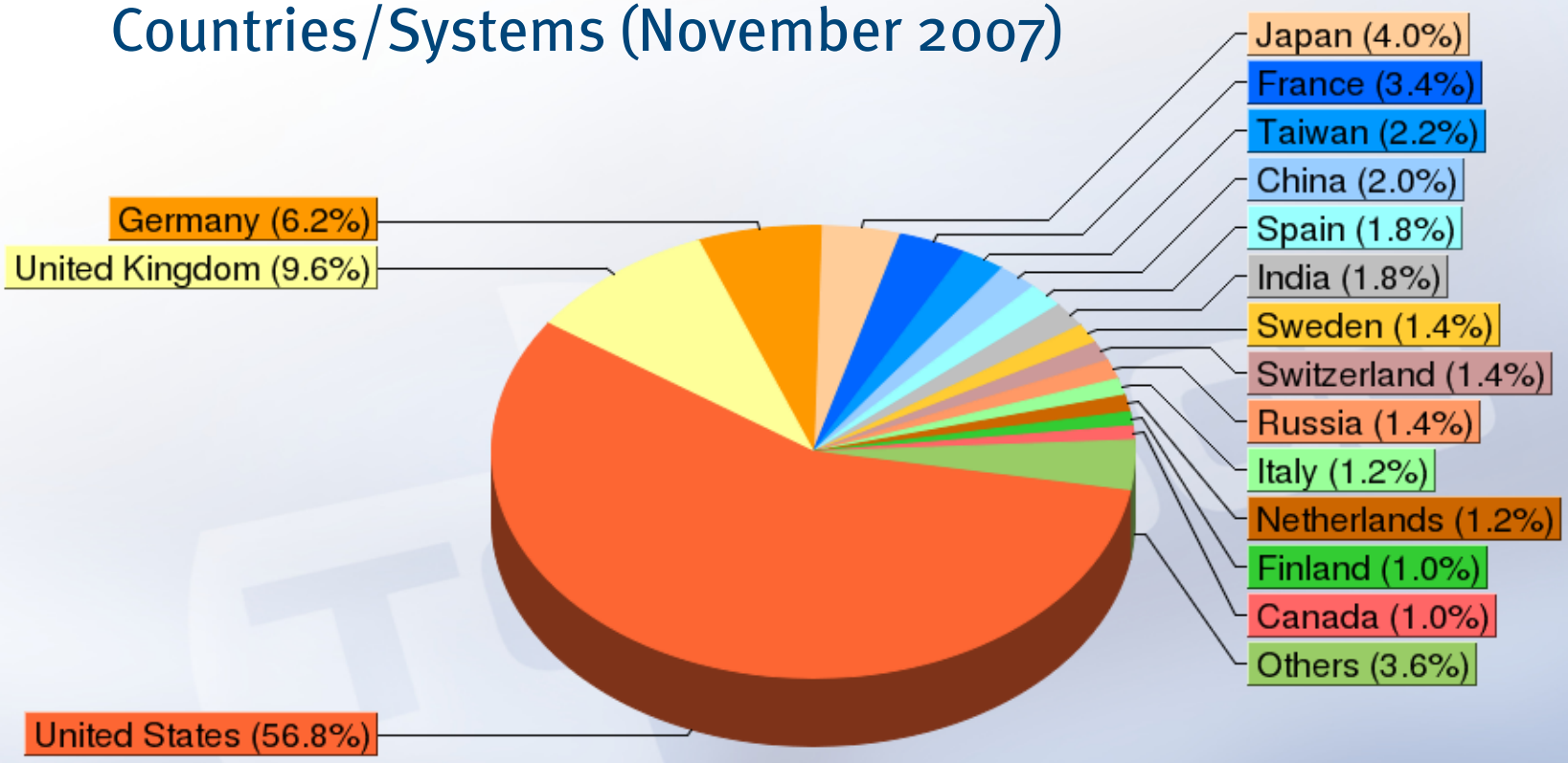
Supercomputing, quo vadis?

European Countries / Systems



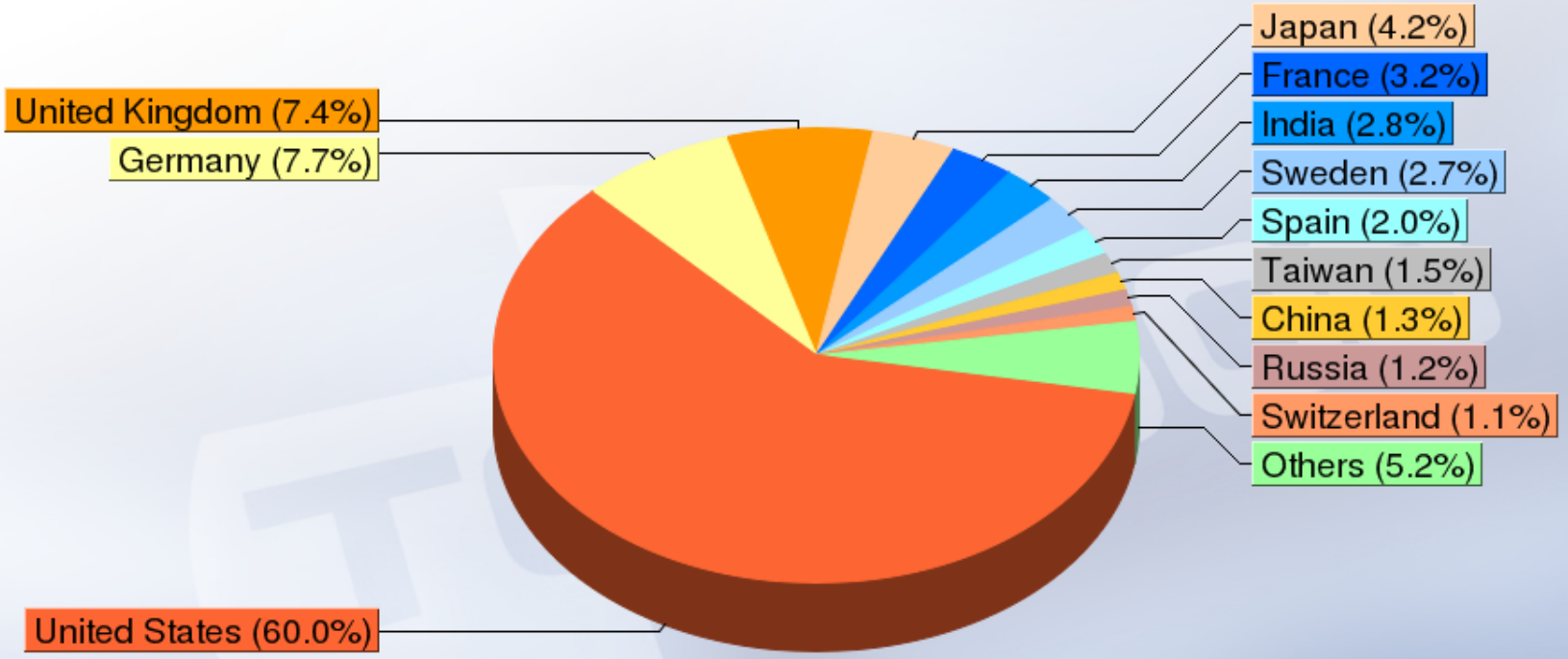
Supercomputing, quo vadis?

Countries/Systems (November 2007)



Supercomputing, quo vadis?

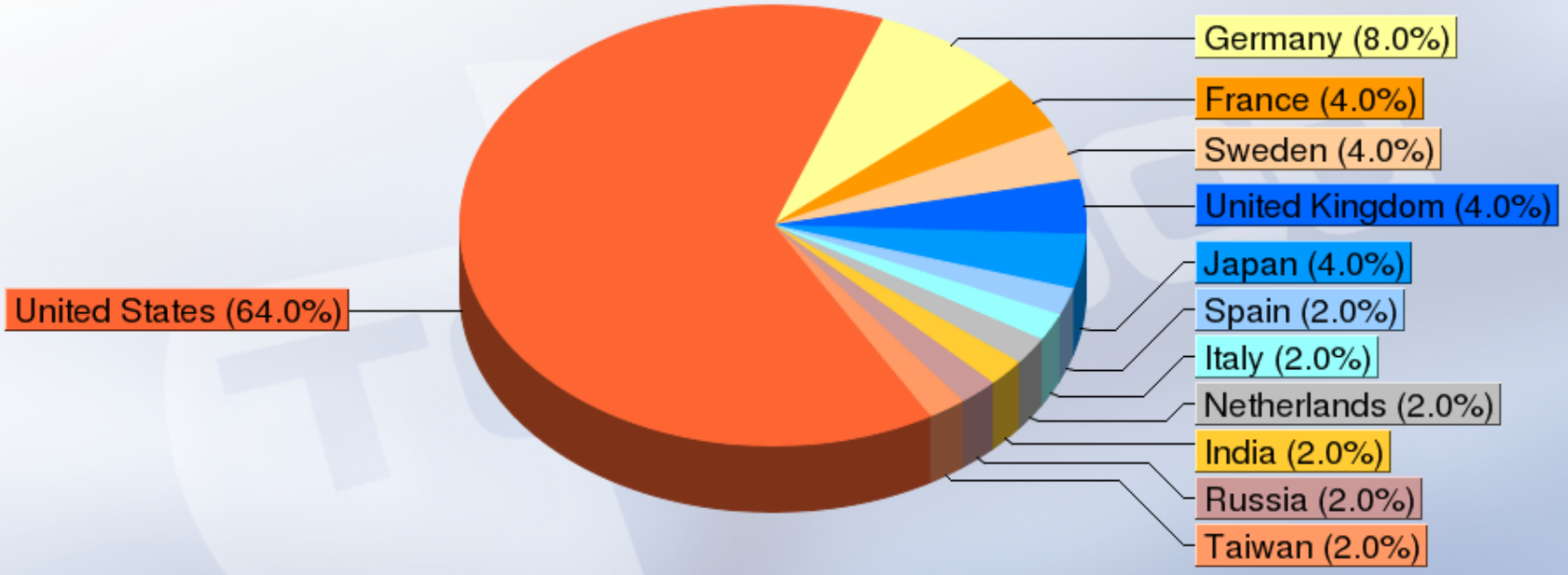
Countries/Performance (November 2007)



Supercomputing, quo vadis?

Countries/Systems (November 2007)

TOP50



Conference Program – Thursday, June 19, 2008

IV. European High End Activities

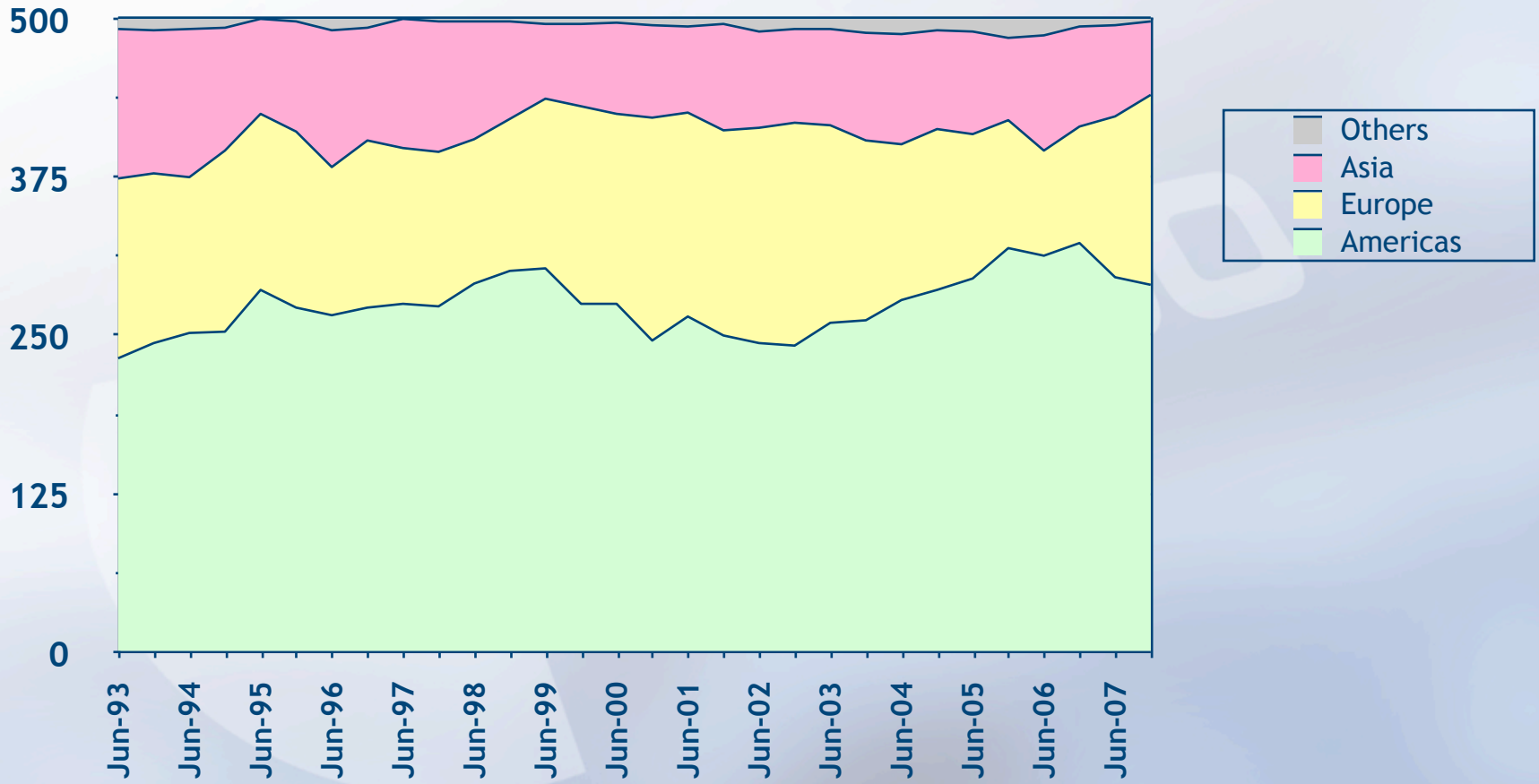
9:00 am – 10:30 am

Chair: *Dr. Francesc Subirada, Barcelona Supercomputing Center, Spain*

- **PRACE – Partnership for Advanced Computing in Europe**
  Prof. Dr. Achim Bachem, Research Centre Jülich, Germany
- **The European PROSPECT Project**
  Prof. Dr. Dr. Thomas Lippert, Jülich Supercomputing Centre (JSC), Germany
  Giovanni Trezza, Quadrics, Italy
- **The European TALOS Project**
  Claude Camozzi, Bull, France
  Pierre Leca, CEA, France

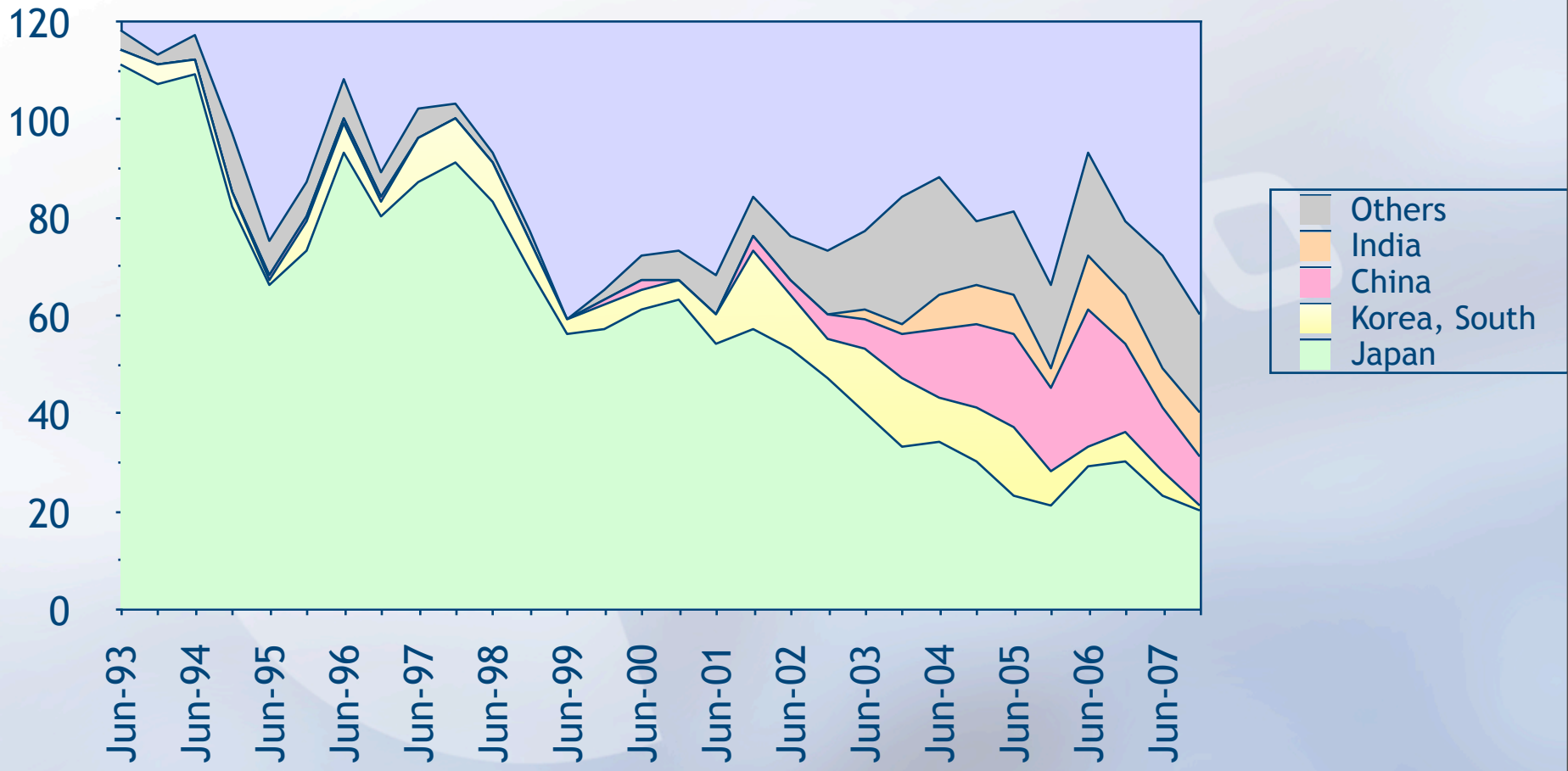
Supercomputing, quo vadis?

Continents/Systems



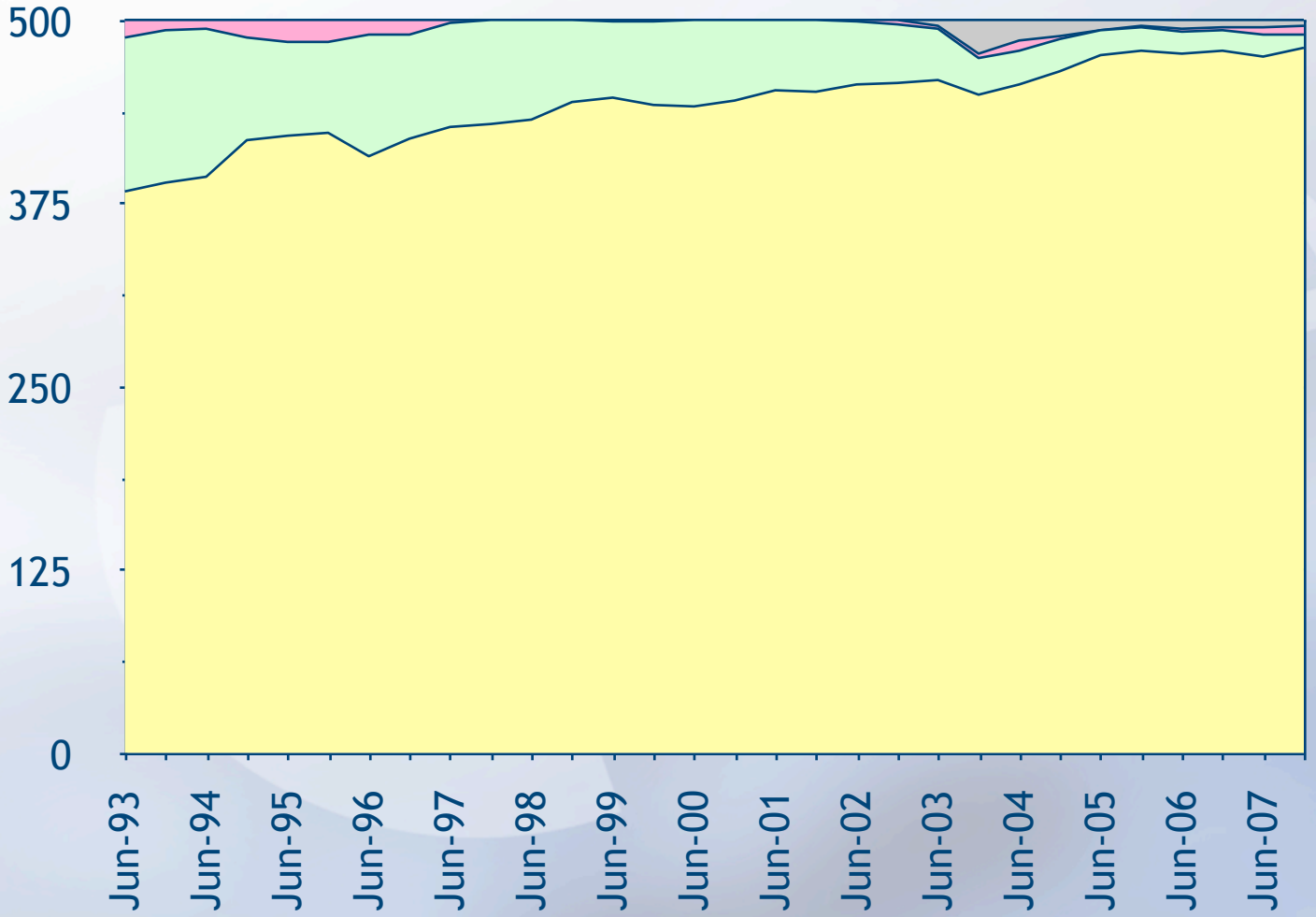
Supercomputing, quo vadis?

Asian Countries / Systems



Supercomputing, quo vadis?

Producing Regions / Systems



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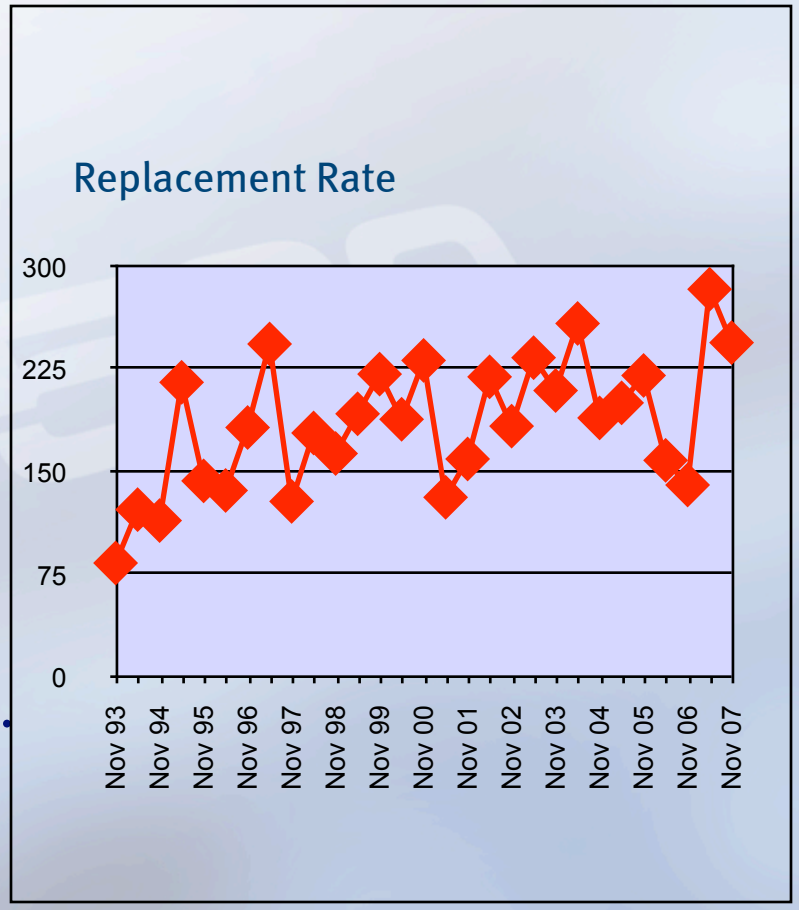
Top500, quo vadis?

www.top500.org

Top500, quo vadis?

Summary after Fifteen Years of Experience

- TOP500 proofed itself by correcting the Mannheim Supercomputer Statistics.
- It is simplistic, but (or because of it) it gets trends right.
- It does not easily allow to track market size
- It's inventory based.
  - This smoothes seasonal fluctuation.
  - Turn-over very high, so it still reflects recent developments.



Top500, quo vadis?

Motivation for Additional Benchmarks

Linpack Benchmark

Top500, quo vadis?

Motivation for Additional Benchmarks

Linpack Benchmark

- Pros
  - One number
  - Simple to define and rank
  - Allows problem size to change with machine and over time
  - Allowing Competitions

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- Cons
  - Emphasizes only “peak” CPU speed and number of CPUs
  - Does not stress local bandwidth
  - Does not stress the network
  - No single number can reflect overall performance

Top500, quo vadis?

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- Clearly need something more than Linpack

Top500, quo vadis?

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Top500, quo vadis?

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- Clearly need something more than Linpack
- HPC Challenge Benchmark and others

Top500, quo vadis?

HPC Challenge Benchmarks and the TOP500

Jack Dongarra (UTK/ORNL)

Presented at ISC'06
June 27-30 2006

1

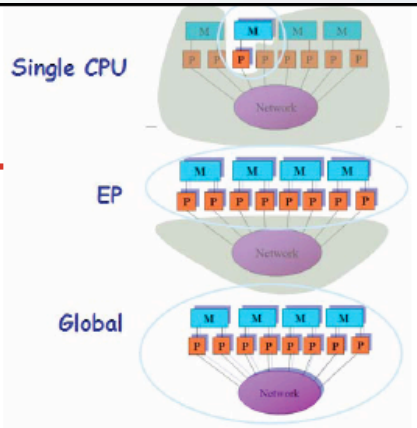
Top500, quo vadis?

HPC Challenge Benchmark

Consists of basically 7 benchmarks;

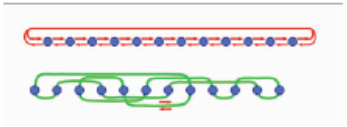
- Think of it as a framework or harness for adding benchmarks of interest.

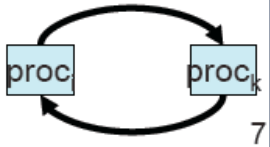
1. HPL (LINPACK) — MPI Global (Ax = b)
2. STREAM — Local; single CPU
   *STREAM — Embarrassingly parallel
3. PTRANS ($A \leftarrow A + B^T$) — MPI Global
4. RandomAccess — Local; single CPU
   *RandomAccess — Embarrassingly parallel
   RandomAccess — MPI Global
5. BW and Latency – MPI
6. FFT - Global, single CPU, and EP
7. Matrix Multiply – single CPU and EP



name	kernel	bytes/iter	FLOPS/iter
COPY:	a(i) = b(i)	16	0
SCALE:	a(i) = q*b(i)	16	1
SUM:	a(i) = b(i) + c(i)	24	1
TRIAD:	a(i) = b(i) + q*c(i)	24	2

Random integer read; update; & write





7

Top500, quo vadis?

Green500 Rank	MFLOPS/W	Site	Computer	Total Power (kW)	TOP500 Rank
1	357.23	Science and Technology Facilities Council - Daresbury Laboratory	Blue Gene/P Solution	31.10	121
2	352.25	Max-Planck-Gesellschaft MPI/ IPP	Blue Gene/P Solution	62.20	40
3	346.95	IBM - Rochester	Blue Gene/P Solution	124.40	24
4	336.21	Forschungszentrum Juelich (FZJ)	Blue Gene/P Solution	497.60	2
5	310.93	Oak Ridge National Laboratory	Blue Gene/P Solution	70.47	41
6	210.56	Harvard University	eServer Blue Gene Solution	44.80	170
7	210.56	High Energy Accelerator Research Organization /KEK	eServer Blue Gene Solution	44.80	171
8	210.56	IBM - Almaden Research Center	eServer Blue Gene Solution	44.80	172
9	210.56	IBM Research	eServer Blue Gene Solution	44.80	173
10	210.56	IBM Thomas J. Watson Research	eServer Blue	44.80	174

Top500, quo vadis?

http://www.green500.org

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6	210.56	Harvard University	eServer Blue Gene Solution	44.80	170
7	210.56	High Energy Accelerator Research Organization /KEK	eServer Blue Gene Solution	44.80	171
8	210.56	IBM - Almaden Research Center	eServer Blue Gene Solution	44.80	172
9	210.56	IBM Research	eServer Blue Gene Solution	44.80	173
10	210.56	IBM Thomas J. Watson Research	eServer Blue	44.80	174

Vielen Dank für Ihr Aufmerksamkeit!

Die Folien sind hier erhältlich:

http://www.top500.org/slides/meuer