



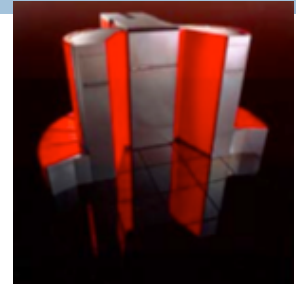
Improving HPC Software

Pete Beckman & Jack Dongarra

Looking at the Gordon Bell Prize

- 1 GFlop/s; 1988; Cray Y-MP; 8 Processors

- ▣ Static finite element analysis



- 1 TFlop/s; 1998; Cray T3E; 1024 Processors

- ▣ Modeling of metallic magnet atoms, using a variation of the locally self-consistent multiple scattering method.



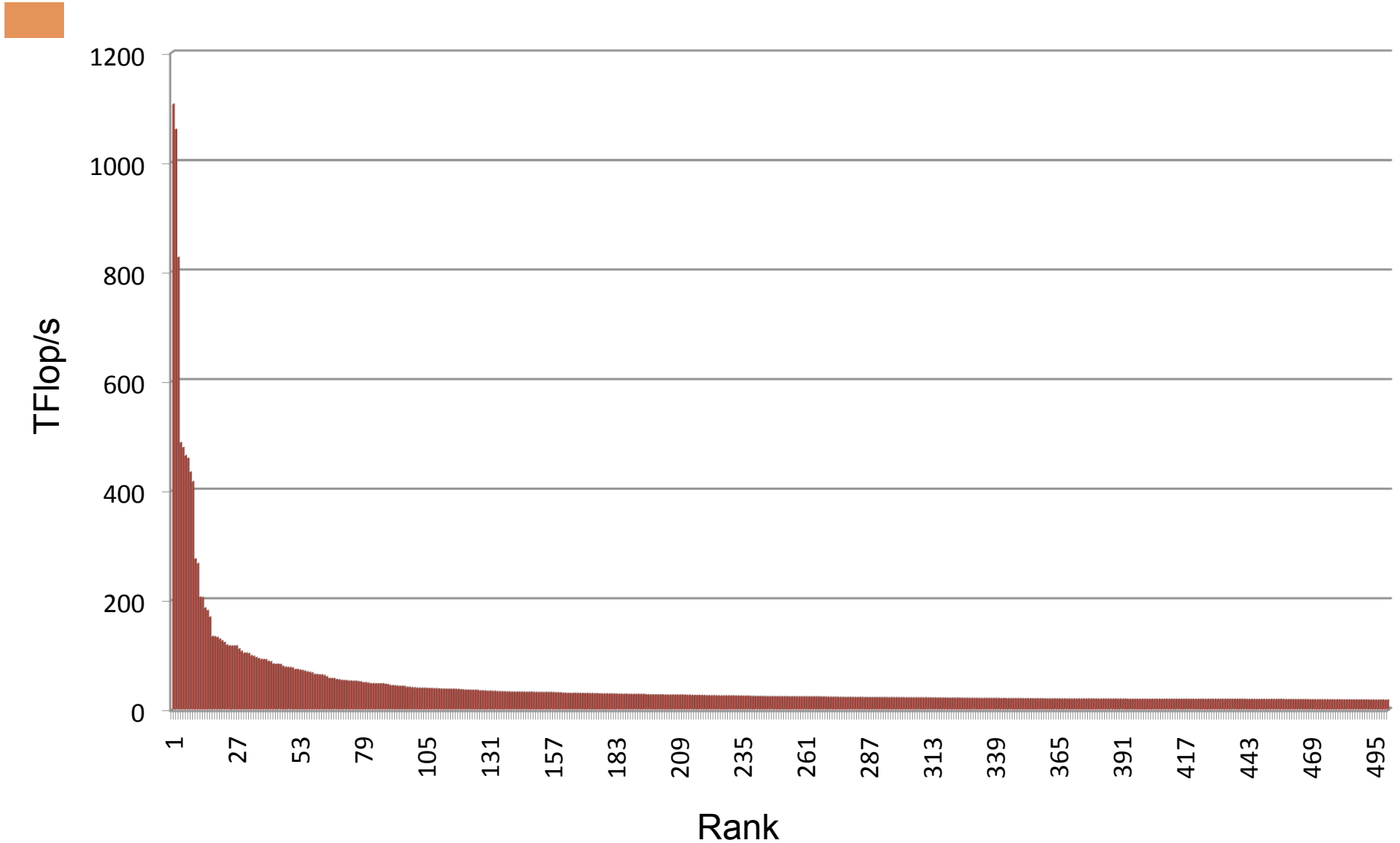
- 1 PFlop/s; 2008; Cray XT5; 1.5×10^5 Processors

- ▣ Superconductive materials

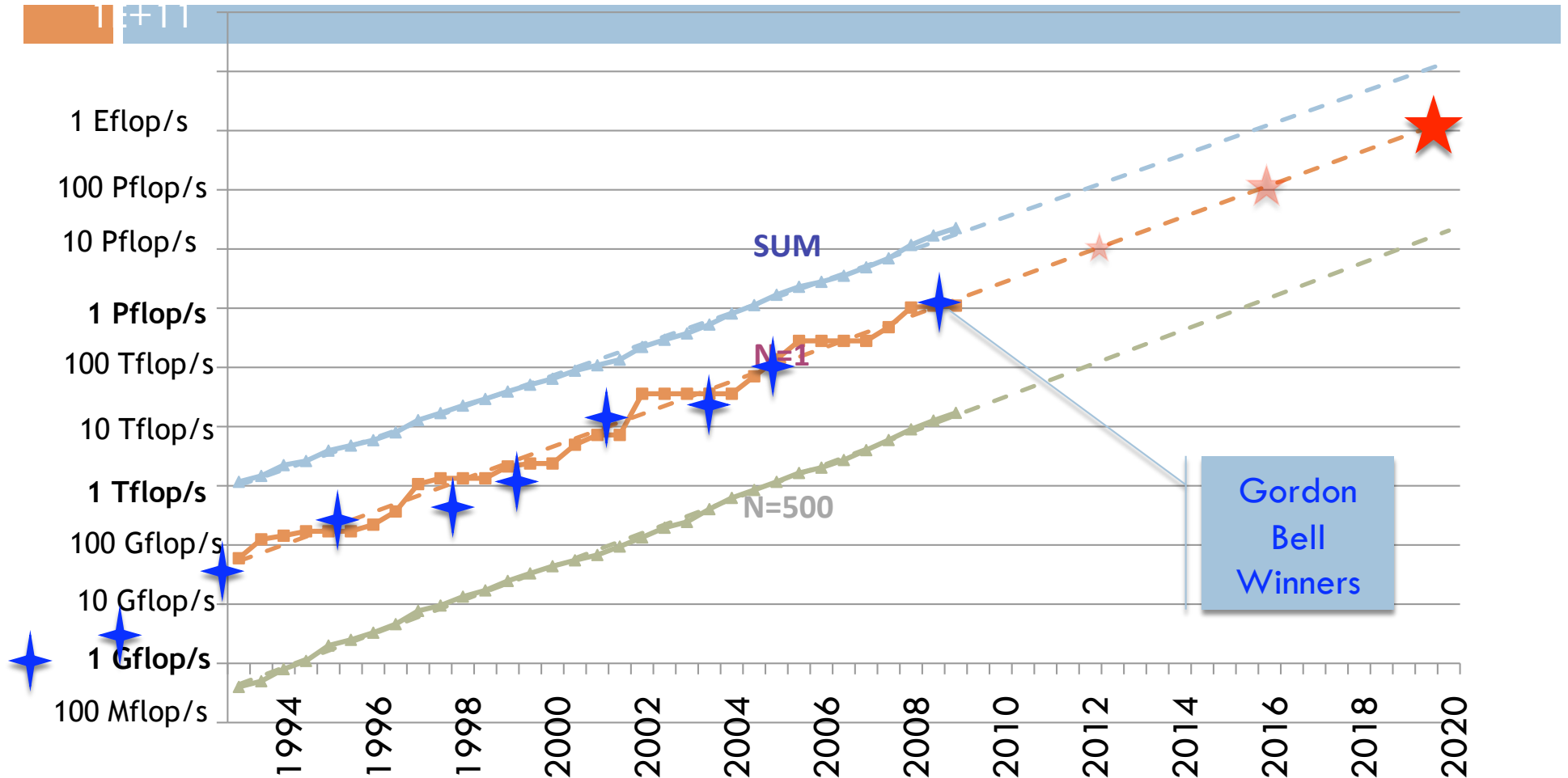


- 1 EFlop/s; ~ 2018 ; ?; 1×10^7 Processors (10^9 threads)

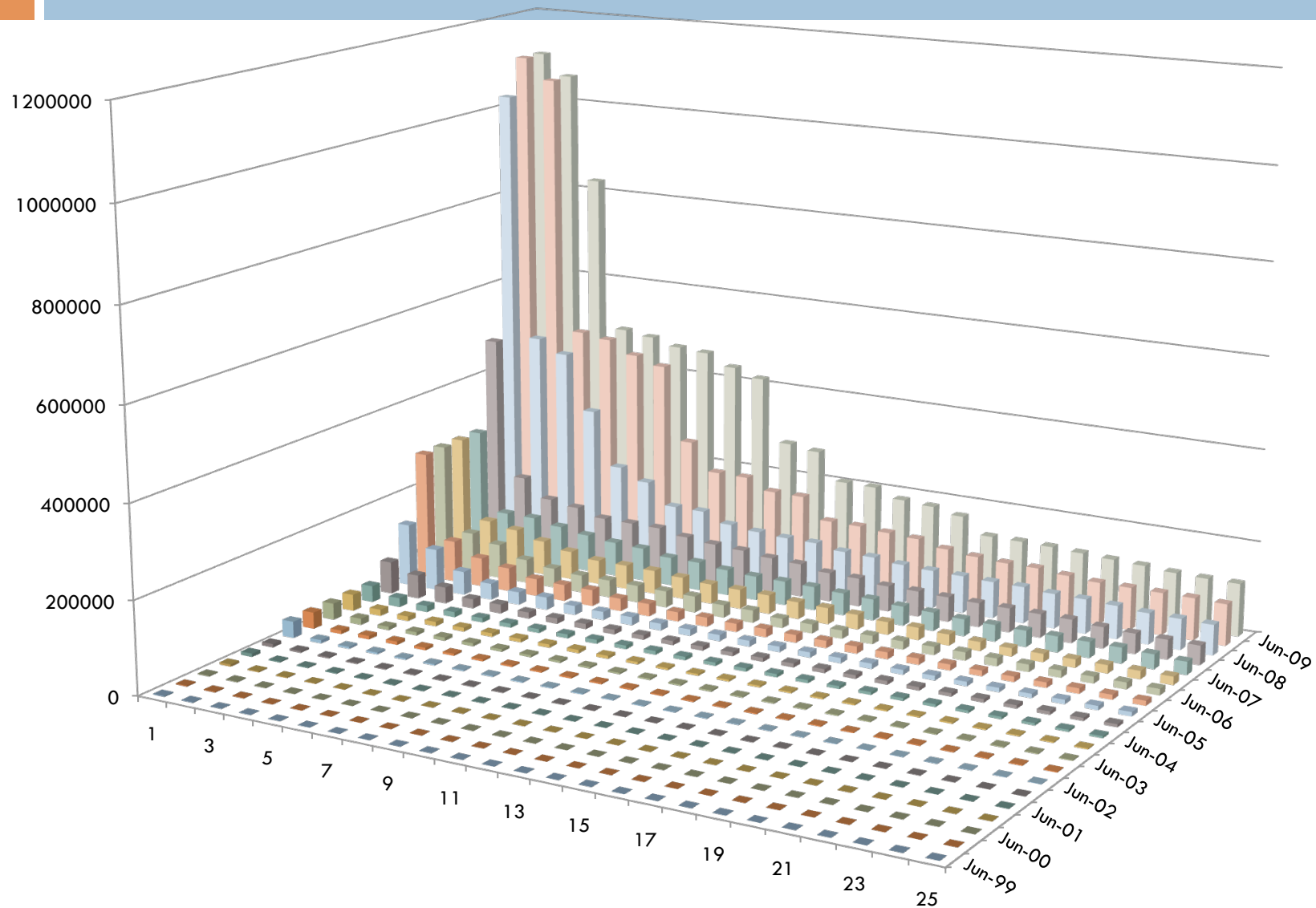
Distribution of the TOP 500



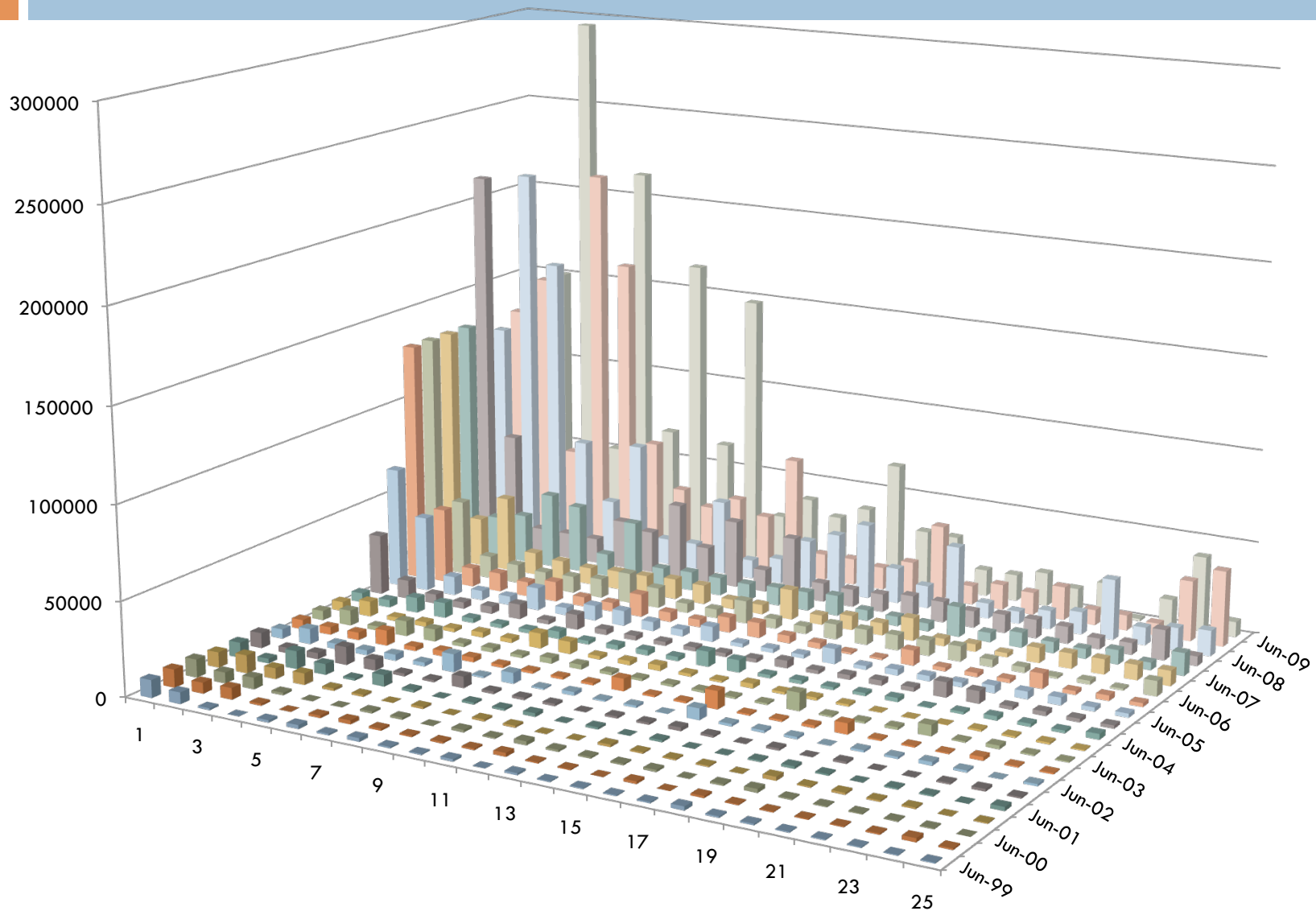
Performance Development in Top500



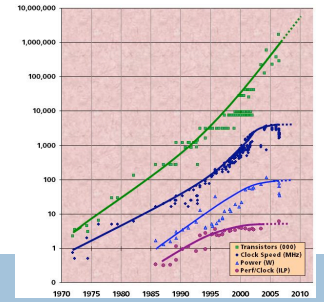
Performance of Top25 Over 10 Years



Cores in the Top25 Over Last 10 Years



A Call to Action



- ❑ Hardware has changed dramatically while software ecosystem has remained stagnant
- ❑ Previous approaches have not looked at co-design of multiple levels in the system software stack (OS, runtime, compiler, libraries, application frameworks)
- ❑ Need to exploit new hardware trends (e.g., manycore, heterogeneity) that cannot be handled by existing software stack, memory per socket trends
- ❑ Emerging software technologies exist, but have not been fully integrated with system software, e.g., UPC, Cilk, CUDA, HPCS
- ❑ Community codes unprepared for sea change in architectures
- ❑ No global evaluation of key missing components

IESP Goal



Improve the world's simulation and modeling capability by improving the coordination and development of the HPC software environment

Workshops:

Build an international plan for developing the next generation open source software for scientific high-performance computing

Impact of Exascale

OAK RIDGE
NATIONAL LABORATORY
MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2007/238

Scientific Application Requirements for Leadership Computing at the Exascale

National Center for Computational Science
December 2007

Modeling and Simulation at the Exascale for Energy and the Environment

Co-Chairs:

Broad consensus
necessitate the
redesign and
replacement of many
of the algorithms and
software
infrastructure that
HPC has built on for
more than a decade.

OAK RIDGE
NATIONAL LABORATORY
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FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2007/232

Science Prospects and Benefits with Exascale Computing

December 2007

Prepared by
Douglas B. Kothe
Director of Science
National Center for Computational Science



ExaScale Computing Study: Technology Challenges in Achieving Exascale Systems

Peter Kogge, Editor & Study Lead

Keren Bergman
Shekhar Borkar
Dan Campbell
William Carlson
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William Harrod
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Jon Hiller
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Allan Snively
Thomas Sterling
R. Stanley Williams
Katherine Yelick

September 28, 2008

This work was sponsored by DARPA IPTO in the ExaScale Study
Program Manager, AFRL contract number FA8650-07-C-7724. 1
of scientific and technical information exchange and its publication
Government's approval or disapproval of its ideas or findings

NOTICE

Using Government drawings, specifications, or other data include
purpose other than Government procurement does not in any way



Developing a high performance computing / numerical analysis roadmap

Prof. A. P. Tiedeman, University of Oxford
Prof. N. J. Higham, University of Manchester



Prof. I. S. Duff, Rutherford Appleton Laboratory
Prof. P. V. Coveney, University College London

Applications/Algorithms Roadmapping Activity

Roadmap Version 1.0

January 2009

Strong science
case for the
continued
escalation of
high-end
computing.

Factors that Necessitate Redesign

- **Steepness of the ascent from terascale to petascale to exascale**
- Extreme parallelism and hybrid design
 - Preparing for million/billion way parallelism
- Tightening memory/bandwidth bottleneck
 - Limits on power/clock speed implication on multicore
 - Reducing communication will become much more intense
 - Memory per core changes, byte-to-flop ratio will change
- Necessary Fault Tolerance
 - MTTF will drop
 - Checkpoint/restart has limitations
- **Software infrastructure does not exist today**

International Community Effort



- We believe this needs to be an international collaboration for various reasons including:
 - ▣ The scale of investment
 - ▣ The need for international input on requirements
 - ▣ US, Europeans, Asians, and others are working on their own software that should be part of a larger vision for HPC.
 - ▣ No global evaluation of key missing components
 - ▣ Hardware features are uncoordinated with software development

Where We Are Today:

- SC08 (Austin TX) meeting to generate interest
- DOE's Office of Science funding
- US meeting April 6-8, 2009
 - 65 people
- NSF's Office of Cyberinfrastructure funding
- European meeting June 28-29, 2009
 - 70 people
 - Draft Roadmap
 - Outline Report
- Asian meeting (Tsukuba Japan) October 18-20, 2009
 - Refine roadmap
 - Refine Report
- SC09 (Portland OR) BOF to inform others
 - Public Comment
 - Draft Report presented

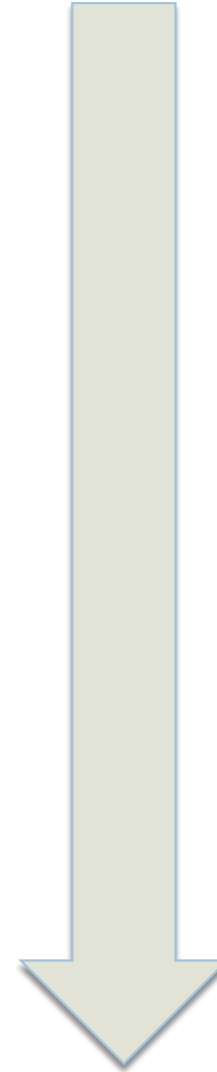
Nov 2008

Apr 2009

Jun 2009

Oct 2009

Nov 2009



Follow on Workshops



- Spring of 2010
 - Continued coordination
 - Refine Roadmap
 - Implementing the plan

A Running Start - White Papers:

www.exascale.org

- *Musings on the Path Toward Exascale*, Robert Lucas – ISI/USC
- *BSC Vision Towards Exascale*, Mateo Valero, BSC
- *Software Challenges of Extreme Scale Computing*, Michael Heroux – Sandia National Laboratory
- *Software and Exascale Computing*, Bill Camp – Intel Corporation
- *Application Analysis and Porting in the PRACE Project*, Michielse – Netherlands National Computing Facility (NCF)
- *The Application Perspective – Seeking Productivity Performance*, David Barkai – Intel Corporation
- *EDF white paper*, J.Y. Berthou and J.F. Hamelin – EDF
- *The Biggest Need: A New Model of Computation*, Tom R. Shiple – Louisiana State University
- *NSF IESP Whitepaper*, Abani Patra, Rob Pennington, Office of Cyberinfrastructure, National Science Foundation
- *A Proposal for a Capability Centers Consortium*, Bill Snir – NCSA and the University of Illinois at Urbana-Champaign
- *Slouching Towards Exascale*, Rusty Lusk, Argonne National Laboratory
- *A Collaboration and Commercialization Model for Software Research*, Mark Seager and Brent Gorda, Lawrence Livermore National Laboratory
- *The Case for A Hierarchical System Model for Linux*, Mark Seager and Brent Gorda, Lawrence Livermore National Laboratory
- *IESP Whitepaper: PDE-based applications and solving at exascale*, David Keyes, Columbia University & SciDAC Task 1
- *Developing a high performance computing/numerical roadmap*, Ann Trefethen, Nick Higham, Ian Duff, and Alan Coveney

Whitpapers and notes on crosscutting issues for Paris Meeting

- *Performance at Exascale*, Bernd Mohr (Jülich Supercomputing Centre) and Matthias S. Mueller (Wolfgang E. Nagel Center for Information Services and HPC)
- *Resource Management*, Barney McCabe (ORNL) and Hugo Falter (ParTec)
- *Programmability Issues*, Vivek Sarkar (Rice U.), Jesus Labarta (UPC), Mitsuhiro Sato (U. of Tsukuba), Barbara Chapman (U. of Houston)
- *Models of Computation – Enabling Exascale*, Thomas Sterling, Louisiana State University.
- *Major Computer Science Challenges at Exascale*, Al Geist (ORNL) and Robert Lucas (ISI)
- *Towards Exascale File I/O*, Yutaka Ishikawa, University of Tokyo
- *Co-design of Architectures and Algorithms*, Al Geist (ORNL) and Sudip Dosanjh (SNL)
- *IESP Exascale Challenge: Resilience and Fault Tolerance*, Al Geist (ORNL) and Franck Cappello (INRIA)

Workshops and Report

- 3 workshops
 1. Santa Fe, April 7-8
 2. Paris, June 28-29
 3. Tsukuba, October 18-20
- Broad engagement by the community
- Initial reports in fall 2009
- Draft report presented at SC09
- Planning for *IMMEDIATE* payoff
 - ▣ Could begin initial components of plan in FY10



June 28, Sun

8:00 – 9:00 am	Bus from Novotel to Teratec
9:00 am	Welcome - Catherine Riviere & Christian Saguez
9:15 am	General objectives of IESP - Jack Dongarra
9:45 am	Objectives and organization of the meeting – Franck Cappello & Christian Saguez
10:00 am	Main results of the Santa Fe Meeting - Pete Beckman
10:30 am	Break
11:00 am	Lessons and feedback of the Santa Fe Meeting – Jean-Yves Berthou
11:30 am	Synthesis of the white papers - Thomas Lippert
12:00	Report on DOE Exascale studies - Paul Messina
12:30 – 2:00 pm	Lunch
2:00 pm	Organize to split into subgroups
2:15 – 4:00 pm	Breakout groups
4:00 pm	Break
4:30 – 6:00 pm	Reports from subgroups
Dinner	In Paris on the Seine