TOP500 Report 1996

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Preface

The Aims

This report is a snapshot of the state of supercomputer installations in the world. It is based on the TOP500 list that was published in November 1996 and includes trends from the previous lists from June 1993 till November 1996.

Statistics on high-performance computers are of major interest to manufacturers, users, potential users, and decision makers in universities, government, and industry. These people wish to know not only the number of systems installed, but also the locations of the various supercomputers within the high-performance computing community, and the applications for which a computer system is used. Such statistics provide a better understanding of the high-performance market and can facilitate the exchange of data and software.

In the past, various system counts of the major vector computer manufacturers by continents and countries have been published. Such records have several limitations, however. The data was difficult to obtain, and often was not reliable. Most important, more extensive statistics (than simply a list of manufacturers' names) are now required because of the diversification of supercomputers, the enormous performance difference between low-end and high-end models, the increasing availability of massively parallel processing (MPP) systems, and the strong increase in computing power of the high-end models of workstation suppliers including symmetric multiprocessing (SMP) systems.

This report is meant as an interface between the TOP500 list and the reader who wishes more background information and explanation. Here various experts present detailed analyses of the TOP500 and discuss the changes that have occurred in the supercomputing market over the past year.

We plan to continue to update this report annually and to distribute it widely to the high-performance computing community. The first TOP500 Reports were covering the situation in 1993, 1994 and 1995.

The Contents

This report consists of nine articles. They present a detailed analysis of the high-performance computing situation as of November 1996.

Meuer and Strohmaier analyze in the first article the general worldwide trends, which are revealed by the eight releases of the TOP500 published in the past four years. They present the changes over time with respect to geography, manufacturers, applications, architectures, and technology. Dongarra and Simon present an in-depth analysis of the U.S. situation of the field of high-performance computing. Schnepf gives an overview of the Japanese installations and Japanese vendors and the differences to the overall market. Harms discusses the European situation and provide a brief summary on computing in the United Kingdom, France, Germany, and the Benelux nations. Simon present a short description of the 25 centers with the highest accumulated performance installed. Van der Steen summarizes the new architectures of the different systems in the TOP500 giving a concise description for each architecture. Strohmaier, Dongarra, Meuer and Simon present a detailed analysis with respect to the different industrial application areas in which system in the TOP500 are used. The final two article are the complete reprints of the June and November 1996 issues of the "TOP500 Supercomputer Sites," which provides the basis of this report.

The Audience

The report has been prepared for the high-performance computing community in general, and specifically for managers of supercomputer centers, users of supercomputers, computer/supercomputer manufacturers, consultants, professional market analysts, decision makers, politicians, Wall Street analysts, computer science people, and students.

Acknowledgments

Without the help of high-performance experts, computational scientists, manufacturers, and the Internet community, our TOP500—the basis of this report—could not have been compiled. We cordially thank all colleagues supporting us, and we ask for their continued support in order to present future TOP500 lists and reports like the one presented here.

Mannheim / Tennessee, December, 1996

Jack J. Dongarra • Hans-Werner Meuer • Erich Strohmaier

Contents

Chapter 1

1996: The Industrial Usage of HPC Systems takes off

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Abstract

1996 was again a year full of changes for the High Performance Computing (HPC) community. The shake out of vendors culminated in Silicon Graphics (SGI) buying Cray Research. A few month later died the father of "Supercomputing" Seymour Cray after a car accident. New systems like the T3E entered the market place quite impressive and there is a new number one on the TOP500. It is again a Japanese system, a special version of Hitachi's SR2201 massively parallel (MPP) system with 2048 processors. However the most important change took place behind the title-pages of newspapers and was not easy to follow. During this year the industrial usage of HPC systems in general and of MPP systems specifically gained a lot of momentum. The U.S. is leading this trend very strongly with already 38% of all systems installed at commercial customers. Many of these system are used for non traditional applications in finance or for data mining. We will discuss in this paper the different developments based on the TOP500 lists of supercomputer sites available since June 1993 [1] and which, for the first time, provide a reliable base for a well-founded analysis of the high-performance computing field. Reports about the situation

in previous years have been published before [3, 4, 5].

1.1 General Discussion

Last year we speculated at this time that we will see a new system at the top position of the TOP500 during this year [5]. We had indeed for both issues of TOP500 a new number one. In June 1996 it was a model of Hitachi's SR2201 system with 1024 processors installed at the Computing Center of the University of Tokyo. But this system of a new generation which is described in detail in one article of this special issue [6] kept this position only for one list. In November 1996 a customized version of the same architecture with 2048 processors is the new number one. An additional processor added to the Numerical Wind Tunnel (NWT) — the former leader of the TOP500 for 4 issues shifted it's performance also ahead of the 1024 SR2201 system which is now number three. Due to the late arrival of the T3E and the big ASCI machines the TOP500 is leaded by three Japanese machines all installed in Japan as well.

But this cannot be taken as a sign of leadership in the field of HPC. Looking at all the 500 systems in the TOP500 we see a different picture with the USA as clear leader as producer and consumer of HPC systems. In 1996 it also became evident that the industrial usage of HPC systems was taking off in the USA. Europe and especially Japan are lagging quite behind in this very important aspect of HPC.

High end workstations with symmetrical multiprocessor design (SMP) which have been quite successful since they entered the market in 1994 are now starting to fall off the TOP500 list. This is due to their limited architectural scalability which limits the performance level they can achieve. SGI introduced as follow up its first distributed memory system ORIGIN 2000. At the same time Cray which now belongs to SGI started to deliver the T3E system. The T3E shows up in the list with already 23 systems and 746 accumulated GFlop/s.

Looking at the computing power of the individual machines present in the TOP500 and the evolution of the total market size, we plot the performance of the systems at positions 1, 100 and 500 in the list as well as the total accumulated performance. In Fig. 1.1 the curves of position 100 and 500 show on the average an increase of a factor of two within one year. The curves for position 1 and for the accumulated performance however show only a factor of 1.8 increase per year.

1.2 Geographical Distribution

Looking at the TOP500 systems installed we see a quite stable distribution over time in Fig. 1.2. The upward trend of systems in the US still goes on while it changed in Japan and we see a small upward trend now. Even as Japan is

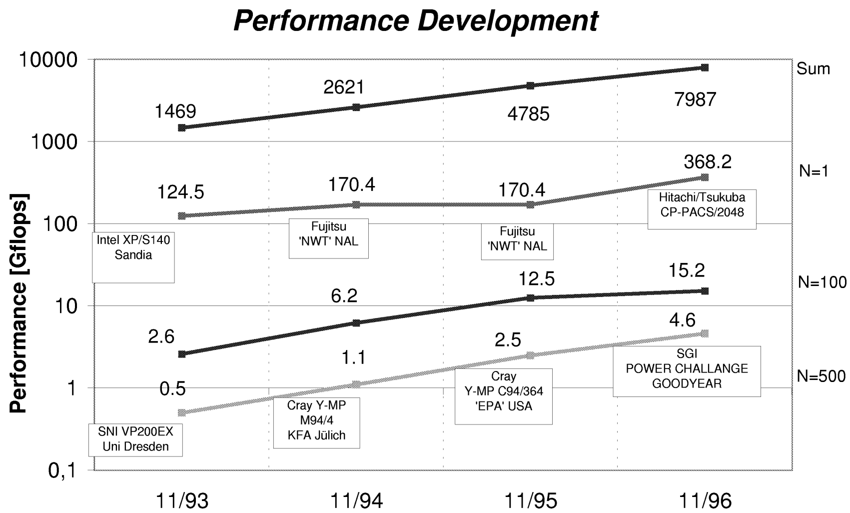

Figure 1.1: The performance over time as it can be seen in the TOP500.

behind in the number of installed SMP systems the new generation of Japanese parallel supercomputer is showing up in the TOP500 now.

Looking at the total of installed performance in Fig. 1.3, contrary to the number of systems seen in Fig. 1.2, Japan is again well ahead of Europe as it was in the last years. This reflects the fact that during the last years several very powerful systems of the latest Japanese supercomputer generations were installed in Japan. These Fujitsu VPP500, NEC SX4 and Hitachi SR2201 systems all make it to the TOP500. Taking a closer look at the strong increase of the installed performance in the US during the last year, we find that Cray Research installed 535 Gflop/s, IBM 336 Gflop/s, HP/Convex 54 Gflop/s and SGI gained only 2 Gflop/s. The share of all other vendors together went down by 6 Gflop/s. In Europe Cray took a big jump from 281 Gflop/s to 782 Gflop/swhile in Japan Hitachi gained the most installed performance and is now second with 775 Gflop/s behind Fujitsu with 911 Gflop/s. In case of Hitachi however the first two of their systems already accumulate 589 Gflop/s.

If we not only look at where the systems are installed but where they are manufactured, we see in Table 3.3 that almost all systems located in the US were built in the US. In Japan, too, the majority of systems come from Japanese manufacturers, but the share of US manufacturers is much higher than vice versa. The European vendors lost five systems compared to 1995 and are far from dominating their home market. Most of the systems installed in Europe are coming from US vendors. The share of Japanese systems is slightly lower

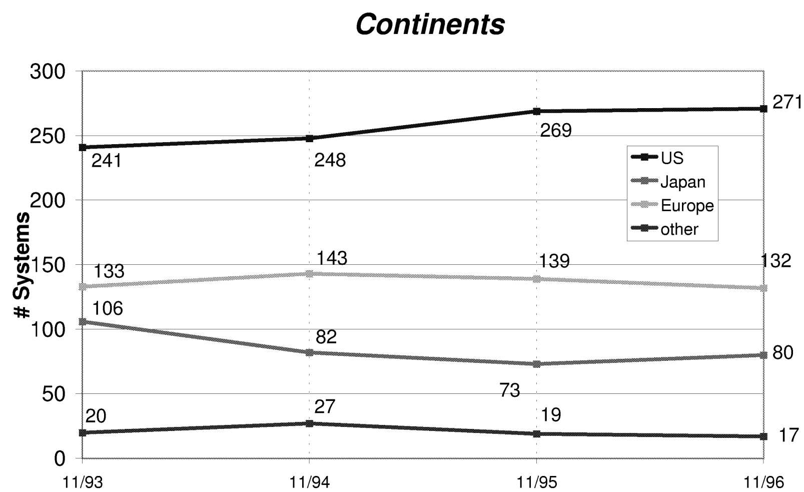

Figure 1.2: The geographical distribution of the system counts over time.

compared to their world-wide average. Looking at the installed performance on Table 1.2, we get a similar picture with an even stronger dominance of the US and Japanese vendors on their home market.

Systems Manufactured In	Installed In USA	Japan	Europe	Others	Total
USA	261	31	110	16	418
Japan	8	48	15	1	72
Europe	2	1	7		10
Total	271	80	132	17	500

Table 1.1: Geographical distribution where systems are installed and where they are manufactured.

1.3 Market Shares of Vendors

The shake out of the HPC manufacturers culminated 1996 in SGI buying Cray Research. This merger created a strong new market leader in the HPC arena. Together they are dominating the market with a total share of 44% of the

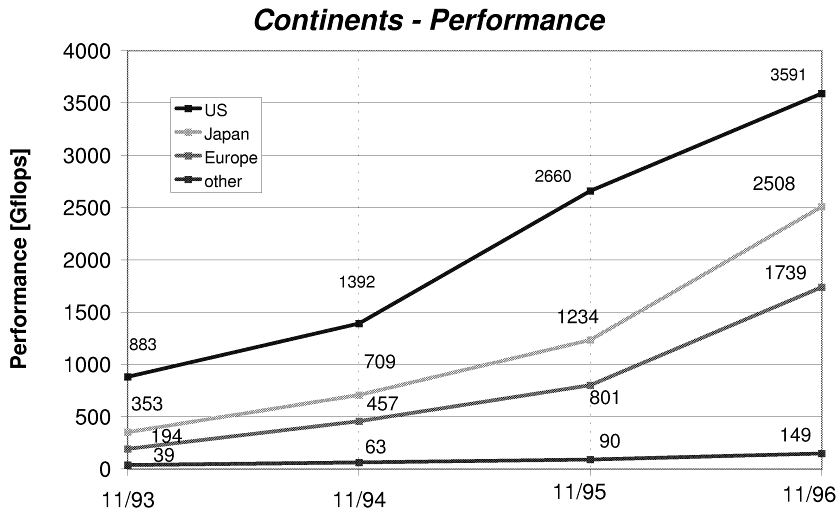

Figure 1.3: The geographical distribution of the performance over time.

installed systems. However, this is only slightly more than Cray Research had on its own (41%) when we started the TOP500 in June 1993. In Fig. 1.4 we see that Cray Research by itself has gained back the pole position from SGI with which it switch positions if we look at the situation in June 1996. Most of the raise of Cray is due to the 23 early T3E installations in the list.IBM is close second to Cray Research with 25% of systems installed. SGI/Cray and IBM hold together 2/3 of the market. The three Japanese companies Fujitsu, NEC and Hitachi have together 72 (14%) systems in the list. Looking at the changes in the accumulated performances of the different vendors in Fig. 1.5, we see that the installed performance of Cray made a big jump due to the T3E. The strong increase of the Japanese vendors and IBM is continuing.

1.4 Architectural Changes

The big increase in the number of installed symmetrical multiprocessor workstations (SMP) in 1995 was the dominating effect with respect to computer architecture. In 1996 SMPs are already on their way out of the TOP500 again while the number of MPP systems is still raising. This reflects the product announcement of single companies like SGI. They introduced the Origin 2000 series (6 system on the list) which is an MPP system as follow up to their very successful SMP series PowerChallenge. The share of parallel vector pro-

R_{max} in Gflop/s Manufactured In	Installed In USA	Japan	Europe	Others	Total
USA	3464	391	1332	122	5308
Japan	117	2111	365	28	2622
Europe	10	5	42		57
Total	3591	2508	1739	149	7987

Table 1.2: Geographical distribution of the accumulated performance showing where it is installed and where it is manufactured.

cessors (PVP) remained stable at a level slightly above 20%. MPP systems are the clearly dominating class of systems in the TOP500 with 2/3 of all systems belonging to this class.

In our very first report [3] Japan was very much behind with the number of installed MPP systems in 1993. This began to change in 1994 [4]. The number of installed MPP systems in Japan is with 58% now only a little behind the world wide average of 64%. But like in the previous years almost no SMP systems have been installed in Japan.

Average System Sizes Installed				
R_{max} in Gflop/s	MPP	PVP	SMP	ALL
USA	16.3	10.3	5.5	13.3
Japan	38.6	22.6	6.0	31.3
Europe	14.3	14.6	5.7	13.1
other	10.2	13.7	5.5	8.8
ALL	18.8	14.6	5.6	16.0

Table 1.3: Average system size for the different classes of systems.

Looking at the average performance of a system in the different classes for the different regions we see in Table 1.3 that the MPP systems installed in Japan are quite powerful. Most of them are build in Japan and are based on system architectures with distributed memory and nodes with vector capabilities. This type of architecture is still not able to enter the US market, but is already entering the European market. The average system size in Japan is now measured in Gflop/s more than twice as high than in the US or in Europe. Compared to 1995 the European installations have substantially gained in average size when the average size was 5.8 Gflop/s compared to 13.1 Gflop/s now.

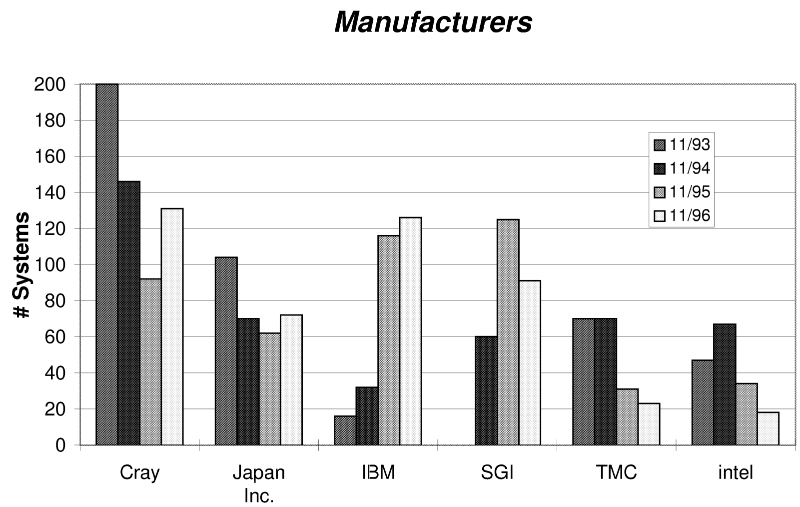

Figure 1.4: The market share of the most important vendors over time.

1.5 Technological Changes

Let us now try to analyze the technology used for the processors. With respect to the chip technology we find that the number of systems based on ECL chip technology is steadily decreasing from 332 in mid 1993 to now 79 by the end of 1996. During the same time the number of systems using proprietary processors with custom chips decreased from 59 to 35 in late 1995 and raised again to 60 by November 1996. This increase is due to the number of vector processors build with CMOS technology. It does not reflect any increasing use of proprietary CMOS-RISC processors. 342 of the systems in the current list are built by using 'off-the-shelf' processors.

In Fig. 1.7 we see that the number of systems with nodes binary-compatible to workstation systems is keeping its high share with now 50%. This class of systems includes the ones from Silicon Graphics, the Convex SPP and the IBM SP1 and SP2. This high market share of systems with such a node design shows the advantage of using standard workstation nodes keeping the design costs low. Also all available software for the workstations can immediately be used on the parallel systems, at least on a single processor. This seems to be a big advantage for selling systems to industrial users as can be seen in Table 1.4. 75% of all system installed at industrial customers are using systems build out of workstation compatible nodes. This includes systems with shared memory like the SGI PowerChallenge and systems with distributed memory like the IBM

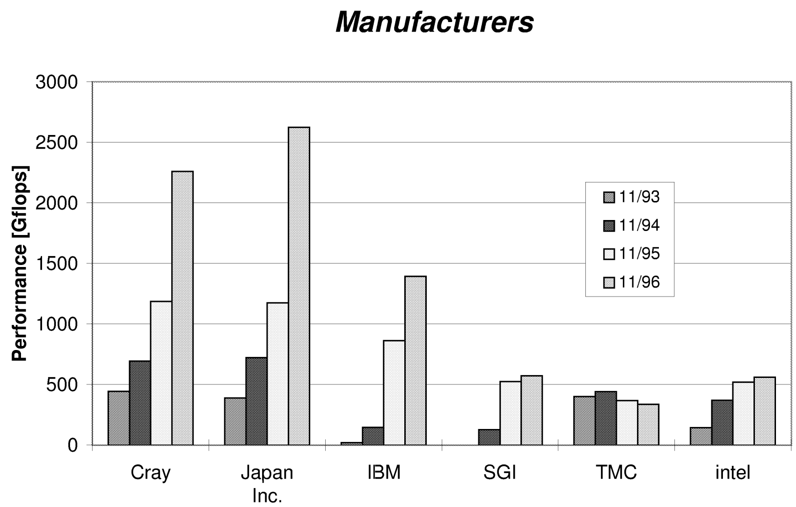

Figure 1.5: The market share in performance of the most important vendors over time.

SP2.

1.6 Application Areas

Looking at the different application areas in Fig. 7.1 and Fig. 7.2 we see an increasing share for 1996 with finally 30% of installed systems and 14.8% of the installed performance after the decreasing share of industrial installations during the last years. If you look at the TOP500 in more detail you see that only IBM with 53%, SGI with 38% and HP/Convex with 32% have an over proportional share of industrial installations in their customer base. This is a very strong indication which advantage binary compatible nodes might have in the HPC market. IBM is leader in the industrial market place with 67 systems (45%) installed even ahead of the team SGI/Cray with 58 systems (39%). Convex has 7 industrial installations (5%) and all other vendors share 11% in the industrial market place.

In Table 1.5 we see the geographical distribution of the systems installed. It is evident that the USA are the clear leader in the industrial usage of HPC technology.

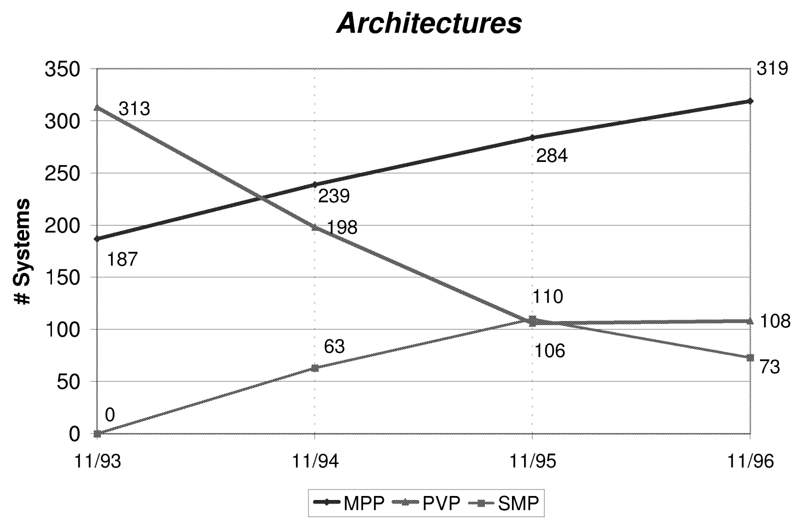

Figure 1.6: The evolution of the architectures as it can be seen in the TOP500.

Number of Systems Installed						
Systems	Research	Industry	Academic	Classified	Vendor	Total
CMOS/off-the-shelf	51	111	68	12	7	249
CMOS/proprietary	86	20	47	10	9	172
ECL	36	17	12	10	4	79
Total	173	148	127	32	20	500

Table 1.4: Number of systems with different node technologies for the different application areas.

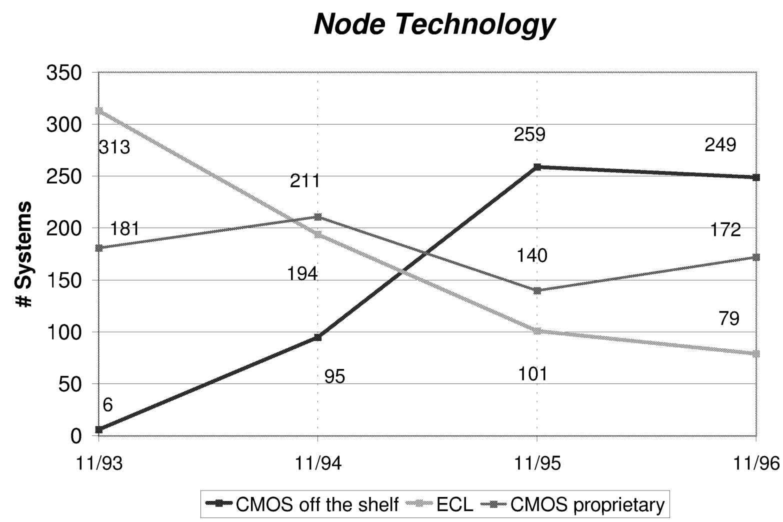

Figure 1.7: The usage of different node technologies as can be seen in the TOP500. We count for this figure the following systems as CMOS off-the-shelf: Convex SPP, IBM SP1/2, SGI.

1.7 Conclusions

From the present eight releases of the TOP500 we see:

- For positions in the range of 100—500 the performance of the individual systems is increasing by a factor of 2 every year while the total installed performance is increasing by a factor of 1.8 every year.
- The new number one for both releases of the TOP500 in 1996 have been Japanese systems and not the announced systems from US manufacturers.
- The US and Japanese vendors are dominating their home markets, while European manufacturers are playing no role at all even not in Europe.
- The shake out of the HPC manufacturers culminated in SGI buying Cray Research.
- SGI/Cray and IBM are leading the list with respect to the number of installed systems and with respect to installed performance.
- MPP systems are the dominating architecture, while the number of SMP systems started to go down in the TOP500.

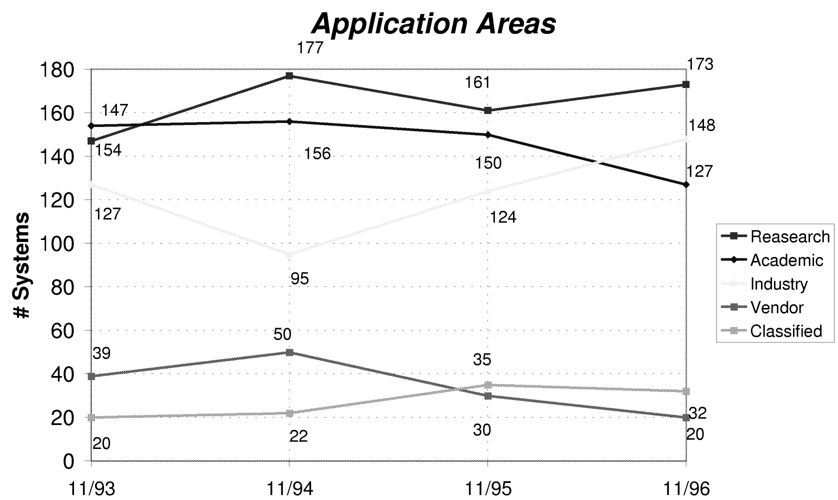

Figure 1.8: The distribution of systems on the different application areas.

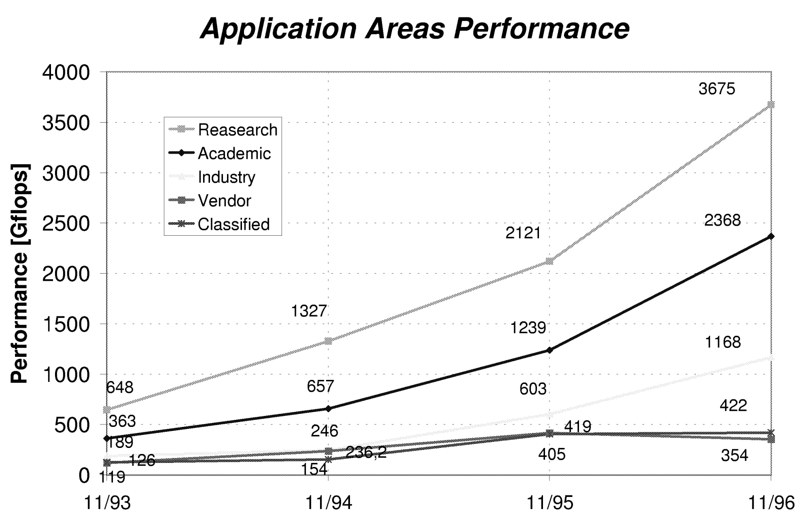

Figure 1.9: The distribution of performance on the different application areas.

Number of Systems Installed					
Systems	USA/Canada	Europe	Japan	others	Total
Research	81	52	39	1	173
Industry	104	31	9	4	148
Academic	44	44	28	11	127
Classified	28	3		1	32
Vendor	14	2	4		20
Total	271	132	80	17	500

Table 1.5: Number of systems in USA/Canada, Europe, Japan for the different application areas.

- The number of ECL based systems is strongly decreasing all the time, and by the end of 1996 about 84% of the systems in the TOP500 were built with CMOS technology.
- In the TOP500 a strong trend to nodes being binary-compatible to major workstation families can be seen since 1995.
- Vendors using such "off-the-shelf" nodes (IBM, SGI and Convex) are in the position to sell an over proportional number of systems to industrial customers .
- IBM is leader in the industrial market place with 67 systems installed even ahead of the team SGI/Cray with 58 systems.
- The USA are the clear leader in the industrial usage of HPC technology.

With the TOP500 project going into its fifth year, many trends and evolutions of the HPC market could be made quite transparent. This has proven the TOP500 to be a valuable tool. Some of the trends mentioned can surely be stated and anticipated without the TOP500 while many others are certainly surprising and could not be visualized without it.

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Chapter 2

High Performance Computing in the U.S. in 1996 – An Analysis on the Basis of the TOP500 List

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Abstract

In 1993 for the first time a list of the top 500 supercomputer sites worldwide has been made available. The TOP500 list allows a much more detailed and well

founded analysis of the state of high performance computing. Previously data such as the number and geographical distribution of supercomputer installations were difficult to obtain, and only a few analysts undertook the effort to track the press releases by dozens of vendors. With the TOP500 report now generally and easily available it is possible to present an analysis of the state of High Performance Computing (HPC) in the U.S. This note summarizes some of the most important observations about HPC in the U.S. as of late 1996. The major trends we document here are the continued dominance of the world market in HPC by the U.S., the completion of a technology transition to commodity microprocessor based highly parallel systems, and the increased industrial use of supercomputers in areas previously no represented on the TOP500 list.

2.1 Major Trends in 1996

2.1.1 Architecture and Technology

The rapid transformation of the high performance computing market in the U.S. which began in 1994, and continued at an accelerated rate in 1995, came to a conclusion in 1996. All major microprocessor vendors continued to introduce new more powerful CMOS microprocessors such as the MIPS R10000 or the HP PA RISC 8000, or released significantly faster versions of existing architectures such as the 120 MHz version of as the IBM Power2, and 300 MHz versions of the DEC Alpha processors. Supercomputing in the U.S. has now almost completely moved to highly parallel machines based on these processors.

In 1996 the trend towards rapid replacement continued. More that half (252) of the systems on the TOP500 list were installed during 1996. By now more than 90% of the systems on the list were installed during the last three years. All these figures confirm that the HPC market as expressed by the TOP500 now has moved completely to match the Moore's law growth curve, of performance doubling every 18 month and replacement or obsolescence after 3 years.

The major new product introductions of impact in the US market in 1996 were the Cray T3E, and the SGI Origin 2000. The T3E leads new product installations with 23 sites, the O2000 has 6. Internationally the NEC SX-4 has 17 new installations which is equally remarkably for a new product. It is well known that the only planned U.S. acquisition of an SX-4 at NCAR led to a protest by Cray, a Dept. of Commerce investigations, and to protracted legal proceedings, which eventually resulted in no new machine at NCAR at all.

Another trend which is now becoming increasingly clear is that there is a lack of "massively" parallel machines. No new machines with more than 1024 processors have been installed in the U.S. during 1996. The total number of machines in the U.S. with more than 1024 processors on the list remains at eleven. Interestingly three new massively parallel machines have been installed in Japan. Eight of these eleven machines are computers made by TMC (one

CM-5 and 7 CM-200s), and probably won't be replaced by similar machines, since TMC is out of the hardware business. Thus, the HPC situation in the U.S. can be summarized as follows:

- a small number of massively parallel (1024+ processor) and highly parallel (128 and more processor) supercomputers, mainly in research institutes, based on message passing, (IBM SP, Cray T3D and T3E, Intel Paragon, TMC CM-5);
- a fair, but shrinking number of parallel vector machines, mostly C90's and relatively few T90s, about evenly spread in universities, research institutes, and industry;
- a large number of moderately parallel (less than 128 processors) supercomputers based on fast commodity microprocessors (IBM SP-2, SGI Power Challenge and O2000, Convex SPP), or CMOS vector technology (Cray J90) found in smaller universities, research labs, and quite frequently in industry.

2.1.2 Vendors

The world wide market for HPC in 1993 was estimated to be about $2.4 Billion, with overall growth of the market by very modest aggregate rate of only 1.4% in five years until 1998. These projections were essentially correct. They implied a very fierce competition because in 1993 there were more than 10 vendors competing in the U.S. market place for a roughly constant (in terms of $s) market. The main event in 1996 was a further consolidation of the number of vendors down to only three serious U.S. vendors competing at the very high-end. (see Table 2.1). The two major events in 1996 were the totally unexpected acquisition of Cray Research by SGI, and the decision by Intel SSD to quit the supercomputer business. With SGI/Cray, IBM, and HP/Convex as the major U.S. vendors, we are now facing a "Japanese" situation: the U.S. supercomputer "vendors" are now divisions of the major, vertically integrated computer manufacturers. Thus the market forces have come to the realization that supercomputing is not a profitable business. Vendors are competing in the very high end of the market for reasons such as driving technological innovation for the profitable mainstream product lines, prestige and visibility, and providing an integrated products line for the engineering/technical market which covers everything from the desktop to the supercomputer.

The list of currently active vendors in the U.S. is longer than three, however, the other vendors are either from outside the U.S. (Fujitsu and NEC, as well as Parsytec and Meiko), or are in the "up and coming" list. Non U.S. vendors have for a variety of reasons played a marginal role in the U.S. This was recently acknowledged by Fujitsu, who restructured their U.S. operations to focus exclusively on commercial customers. Tera is hopeful to deliver their

Table 2.1: **Commercial HPC Vendors in the US (late 1996)**

Status	Vendors
Out of business	Alliant, American Supercomputer, Ametek, Culler, Cydrome, Cray Computer Corp., Denelcor, Elexsi, Kendall Square, Multiflow, Myrias, Prevec, Prisma, Saxpy, SCS, SSI(2), Trilogy, Wavetracer
Division closed	Astronautics, BBN, CDC/ETA Systems, E&S Goodyear, Gould, Loral, Vitesse
Merged	Convex, Cray Research, Celerity, FPS, Key, Supertek, Ardent/Stellar
Down, not out	AMT(Cambridge), CHoPP, Encore, Stardent/Kubota, Neovista (Masspar), Thinking Machines
Not (or no longer) active in U.S.	Hitachi, Meiko, Parsytec
Currently active	DEC, Fujitsu, HP/Convex, IBM, Intel, NEC, SGI/Cray, Sun, Tera

first system in 1997, and their impact on the market remains to be seen. DEC and Sun recently strengthened their HPC related activities, and we might see some additional systems from these vendors on the TOP500 list, but probably not among the TOP50.

2.1.3 Federal Funding and Support for HPC

HPC in the U.S. has been critically dependent on federal funding which provided the support for large supercomputer centers by DOD, DOE, NSF, and NASA. In 1996 the federal High Performance Computing and Communications Program (HPCCP) came to an end. Considerable progress has been made as documented in the famous "Blue Book" series [3]. However, the focus of federal programs on the federal level has shifted more towards networking with the "Next Generation Internet" (NGI) currently considered for new funding at the rate of about $100 M a year. While the HPCCP continues in the form of the NCO (National Coordination Office) (see `http://www.hpcc.gov/`) and the associated Committee on Computing, Information, and Communications (CCIC) as interagency coordination council, the major activity in HPC has clearly shifted toward the ASCI (accelerated strategic computing initiative) program of the DOE defense program [1]. ASCI installed two new IBM SP systems at Lawrence Livermore National Labs (ASCI Blue Pacific), followed by a demonstration of 1 Tflop/s on an Intel Pentium Pro based system in December. This system will be installed at Sandia National Laboratories in Albuquerque, New Mexico in 1997, and will most certainly take the number one spot on the TOP500 list.

The discussion about HPC in the commercial and in the government market place continues to be based on beliefs and impressions, and often lacks hard data. Claims in the early years of the HPCC that a Teraflop/s performance on significant applications will come to pass by 1996, has not happened. However, this was the wrong metric to pursue from the very beginning. It continues to surprise that a field such as HPC that is deemed so critically important to the national agenda lacks almost completely any quantitative assessment of its progress.

On the federal level supercomputing is undergoing a substantial re-evaluation in the 1996-98 time frame. All federal agencies are taking a closer look at their HPC needs. Most significant in 1996 was the recompetition of the NSF supercomputer centers. Proposal for new academic collaborations in supercomputing (NPACI) were due by the end of the summer. Current knowledge is that the number of centers will be reduced from four (Cornell, NCSA, Pittsburgh, and San Diego) down to two. The winners will be announced in March of 1997. The consolidation of DOD's supercomputing efforts resulted in the awards of contracts for the major resource centers at ARL (Army Research Lab, Aberdeen, MD), Wright-Patterson Airforce Base, Ohio, the Navy Center in Mississippi, and the Waterway Experimental Station (WES) also in Mississippi. In the 1996 list only WES made a significant new entry with a 256 node T3E. In 1997 we expect all four centers to list significant new machines, mostly from Cray/SGI. Finally in DOE the NERSC center was moved from Lawrence Livermore National Labs to Lawrence Berkeley National Labs. The new NERSC center at Berkeley was completely restructured to address the new realities of supercomputing in the late 90ies [7].

2.1.4 Remarks on the TOP500 data

Before investigating some of the data in [1] in more detail, it is important to understand the limitations of the TOP500 study. These limitations can be summarized in the past. In spite of these inherent limitations, the TOP500 report can provide extremely useful information, and valuable insights. It is more accurate than many marketing studies, and the possible sources of error discussed above are probably statistically insignificant, if we consider only summary statistics, and not individual data. All Mflop/s or Gflop/s performance figures here refer to performance in terms of LINPACK $Rmax$.

In the analysis of geographical distribution, machines in Canada have been included in the figures for the U.S., and the figures for Europe include all European countries, not just EC members. The other country category includes mostly countries of the Pacific Rim with the exclusion of Japan, as well as some countries in the Near East and in Africa. Surprisingly there are no supercomputers from Latin America on the TOP500 list.

2.2 U.S. Dominance of the World Wide HPC Market

The TOP500 continues to demonstrate the dominant position the U.S. assumes in the world both as producer and as consumer of high performance computers. In Table 5.1 the total number of installed systems in the major world regions is given with respect to the origin of the computers.

If one considers in Table 5.1 the country of origin then it is striking that 418 out of the TOP500 systems are produced in the U.S., which amounts to 84% of all installed systems. Japan accounts for 14% of the systems, and Europe produces only 2%. This extent of the American dominance of the market is slightly less than in 1995 when the U.S. share was 85%. But it is the same as in 1994.

For years, in particular in the mid 80's, there were ominous and ubiquitous warnings that the American supercomputer industry (which was essentially Cray Research at that time) is highly vulnerable to an "attack" by the Japanese vertically integrated computer giants Fujitsu, NEC, and Hitachi. Obviously this has not happened. How much various efforts such as the NSF Supercomputing Initiative in the mid 80's, or more recently the HPCC Program have contributed to the current vast superiority of the U.S. high performance computing industry, remains to be investigated.

The numbers for Europe are even worse than last year (15 machines in Nov. 96 versus 12 machines in November '96). This situation is probably not going to change, since there seem to be no new European hardware vendors on the horizon. With lack of immediate access to the newest hardware, and the absence of the close interaction of users with vendors as is prevalent in the U.S., the best the European High Performance Computing and Networking Initiative can accomplish is maintaining the status quo of Europe as a distant third in high performance computing technologies. On the positive side, several large sites in Europe have installed major US or Japanese systems in 1996, e.g. a VPP 700 at ECMWF, and large Cray T3Es in Stuttgart, Juelich, and at IDRIS in France.

Table 5.3 is analogous to Table 5.1, but instead of the number of systems, the aggregate performance in $Rmax$-Gflop/s is listed. Table 5.3 demonstrates a continued astounding growth in 1996: within 12 months the total number of installed Tflop/s in the U.S. increased from 2.6 Tflop/s in November 95 to 3.5 Tflop/s in November 1996. This is an increase of 35% in only 12 months. This growth is less than in the previous year, where performance in the US increased by 92%. At the same time growth in other regions was substantially higher:

Table 2.2: **US Share of Total Number of Installed TOP500 Systems**

Systems Manufactured In	Systems Installed In U.S.	Japan	Europe	Other	Total
U.S.	261	31	110	16	418
Japan	8	48	15	1	72
Europe	2	1	7	0	10
Total	271	80	132	17	500

Table 2.3: **US Share of Total Rmax (in Tflop/s) of Installed TOP500 Systems.**

Systems Manufactured In	Systems Installed In U.S.	Japan	Europe	Other	Total
U.S.	3.5	0.4	1.3	0.1	5.3
Japan	0.1	2.1	0.4	0.02	2.6
Europe	0.01	0.005	0.04	0	0.06
Total	3.6	2.5	1.7	0.1	7.9

from 0.8 Tflop/s to 1.7 Tflop/s in Europe, and from 1.2 Tflop/s to 2.5 Tflop/s in Japan. Both regions/countries more than doubled installed performance and thus show in 1996 the growth the U.S. experienced in 1995. Overall it thus appears that all three regions in average seem to grow at about the same rate and no fundamental change in their relative positions appears to take place.

However, it appears that the performance growth in Japan and Europe happens by installing a few very large machines, since the actual number of machines has remained about stable. In the US a large number of new smaller machines were installed, which now occupy medium to lower ranks on the TOP500 list. One conclusion from this data is that the HPCC initiative in the U.S. has succeeded in the sense that the infrastructure for HPC is dramatically changing. A large number of institutions now has access to Gflop/s level computing for machines which cost not much more than \$ 1M. Only five years ago this compute power was accessible only to the elite few institutions being able to spend tens of millions of dollars. We can anticipate exciting times for HPC: more and more people in the U.S. will have access to inexpensive computational modeling tools. It will be worthwhile to examine what this revolution will do to economic productivity measures such as the GDP in the U.S.

In an international comparison one should however also consider the relative size of countries and their economies. Here we present a new TOP500 set of

Table 2.4: **Population (in thousands) per TOP500 supercomputer.**

Country	Rank in 1995	Population (in thousands)	Number of TOP500 entries	Population per Supercomputer
Luxembourg		396	1	396
Switzerland	1	6,813	9	757
USA	3	255,200	266	959
Japan	9	124,500	80	1,556
Germany	7	80,250	51	1,574
Netherlands	8	15,160	9	1,684
Finland	6	5,008	3	1,669
Denmark	4	5,158	3	1,719
Austria	13	7,776	4	1,944
Slovenia		2,002	1	2,002
Singapore	2	2,769	1	2,769
Sweden	11	8,652	3	2,884
UK	14	57,700	18	3,205
France	12	57,180	17	3,363
Australia		18,154	5	3,631
Norway	5	4,288	1	4,288
Canada	15	27,370	5	5,475
Israel		5,698	1	5,698
Hong Kong	10	5,800	1	5,800

statistics. In Table 2.4 we list the a measure of the supercomputer density by ranking the top ten countries with the highest number of supercomputer per capita. Population date are from the "Interactive 3D Atlas" and date from 1992.

Table 2.4 shows that on an international comparison most industrialized countries are providing about one supercomputer per 1 - 3.5 million inhabitants. The number of US installations is no longer that dramatically different from the rest of industrialized countries. It should be mentioned that the among the major industrialized nations the big anomaly with respect to supercomputing usage is Italy. In Italy there is only one supercomputer per 9.6 million inhabitants, far below the number of all other western European countries.

Table 2.5: **Architecture (in number of installations).**

Region	MPP	SMP	PVP
U.S./Canada	170	46	55
share	63%	17%	20%
Worldwide	319	73	108
share	64%	15%	21%

2.3 Market Penetration by Technology and Architecture

The penetration of the supercomputer market by microprocessor based supercomputers and the increased use of SMPs and arrays of SMP is another often debated trend. The trend towards commodity CMOS is now firmly established. In Table 2.5 we present the number of installations for the different machine architectures used among the TOP500, both world-wide and in the US/Canada.

In 1994 MPPs moved ahead of PVP and are now clearly the largest architectural category, both in the US and worldwide. The share of MPP installations has increased even more in the US in 1996, mainly because of Cray T3E and IBM SP installations. In the U.S. there are now fewer SMPs as compared to 1995. This can be explained with an increase in Cray J90 installations, which count in the PVP category. In 1995 SMP systems for the first time surpassed also PVP worldwide. This tend has been reversed because of the introduction of more powerful CMOS vector processors, e.g. the SX-4. Contrary to 1995 we do not see any significant difference in the distribution of architectures, when comparing the US versus other regions.

2.4 Conclusions

The analysis of the data provided by the TOP500 report has led us to a number of conclusions concerning the state of HPC in the U.S. at the end of 1996. Some of these conclusions are:

- The U.S. continues to be the clear world leader both as producer and as consumer of high performance computers. This leadership position has been even more strengthened compared to 1995.
- Microprocessor based supercomputers have brought a major change in the accessibility and affordability of supercomputers. The installed base of supercomputer Gflop/s continued to increase in 1996 in the US, but not in the same rapid rate as in 1996, and not as fast as in other regions.

This appears to be a catching up by the others, and not a slowing down in the US. This increase in the US is due to a large number of medium to small size installations.

- MPPs continue to account for more that half of all installed supercomputers worldwide and in the US. Market penetration by MPPs worldwide is now at the same level as the US. SMP system use in the US actually has declined compared to 1995. This may be an indication of a trend towards replacing older custom PVP systems with CMOS PVP systems, since the number of PVP systems in the US has actually increased compared to 1995.

Generally the TOP500 list has proven itself to be an extremely valuable tool for evaluating trends in the HPC market. Future releases of this report should enable the HPC community to track important developments much more accurately than in the past.

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Chapter 3

Developments in Japan

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Abstract

The supercomputer situation in Japan is characterized by the installation of many supercomputers of the new CMOS based generation. Fujitsu entered the list with new VPP300 and VPP700 installations, while NEC continued to install more SX-4 systems. Finally, Hitachi succeeded to deliver the currently most powerful system in the world to the University of Tsukuba with the CP-PACS computer. Following the former leader NWT, again a system is leading the list that has been developed in a collaboration between computer industry and a research institute. With these new systems Fujitsu, Hitachi and NEC increased their competitiveness by advanced CMOS technology together with an attractive price/performance ratio. This also resulted in the success of winning several procurements outside of Japan.

The market distribution in Japan became somewhat more balanced compared to 1995 when Fujitsu was leading far ahead. In terms of performance Hitachi (774.5 GFlop/s) now became second behind Fujitsu (910.5 GFlop/s) while in terms of number of sites NEC (15) is second behind Fujitsu (21). IBM also progessed well increasing its number of sites from 8 to 13. Cray kept its 10 sites but lost part of its performance share relative to the other vendors. SGI's success in Japan is again not visible in the TOP500. Only 3 Japanese sites entered the list. Most SGI systems are smaller in size.

Japan increased its share of the TOP500 sites from 73 to 80 entries which corresponds to 16%. Traditionally, the Japanese supercomputer sites are in average more powerful than the sites in other countries. Consequently, 21 Japanese sites are listed in the world-wide TOP50. Japan's share in the world-wide installed R_{max} GFlop/s capacity increased even more. The aggregate performance of the Japanese TOP500 sites doubled from 1,234 GFlop/s to 2,508 GFlop/s which corresponds to 31.4%.

In summary, Japan strengthened its position world-wide as the second largest user of supercomputers. The three most powerful systems of the world are installed in Japan!

3.1 Background

In the past years the Japanese supercomputer market [1, 2] was dominated by mono and multiprocessor vector computers manufactured by the big Japanese vendors Fujitsu, Hitachi and NEC. Fujitsu and Hitachi started in the early 80's to deliver the first vector computers in Japan. NEC joined them few years later. The companies improved steadily the performance of their monoprocessors before delivering multiprocessor systems end of the 80's. In the early 90's all three vendors again improved the performance and scalability of their systems while investigating new architectures in collaborations with research institutes or laboratories. Fujitsu together with the National Aerospace Lab developed the Numerical Wind Tunnel (NWT) as the prototype of the VPP series. Hitachi together with the University of Tsukuba developed the CP-PACS system which can be seen as a prototype of the SR2201.

The acceptance of MPP systems started slowly in Japan. Some customers bought various MPP systems from American vendors. This could be considered as an evaluation phase. The acceptance of systems with distributed memory started to grow after the NWT demonstrated unprecedented performance while maintaining the vector 'culture'. The success of the Hitachi MPP system will also contribute to the broader use of this architecture.

All three vendors are also marketing their systems outside of Japan with remarkable success. The biggest success for Fujitsu was the contract with the ECMWF in Reading to deliver a VPP700 system. Hitachi got a first contract for its SR2201 system from Cambridge University, UK. NEC won several major SX-4 contracts in Europe, but the public attention was drawn on the NCAR project in the USA.

3.2 The CP-PACS Project

The CP-PACS project [3, 4] formally started in 1992 with a funding of 1.5 billion Yen spread over a five-year period. The project name CP-PACS stands for Computational Physics - Parallel Array Computer System. The name was chosen to reflect the two phases of the project - development of a massively parallel computer optimized for physics problems describable in terms of space-time fields, and subsequent research with it in several key areas of computational physics with primary emphasis on lattice QCD. With the start of the project the Center for Computational Physics was founded at the University of Tsukuba in order to serve as a base for a collaborative effort between physicists and computer scientists for the development of the CP-PACS computer and its utilization for research in computational physics.

Through a formal bidding process in summer 1992, Hitachi Ltd. was selected for the manufacturing of the CP-PACS computer. Since then, the Center for Computational Physics and Hitachi Ltd. have been working in a close collaboration both on the hardware and software development of the CP-PACS computer. The fundamental design of the computer was laid down in 1992, its details worked out in 1993, and the logical design and the physical packaging design was completed in 1994. Chip fabrication and assembling of parts started in early 1995, resulting in the completion of the CP-PACS with 1024 processors and a peak speed of more than 300 GFlop/s in March 1996. In fall 1996 the configuration of CP-PACS has been doubled to 2048 processors, 128 GB memory and more than 600 GFlop/s.

The CP-PACS computer is an MIMD system with distributed memory. Each processor has a performance of 300 MFlop/s. The design of the processor is based on the HP PA-RISC 1.1 architecture. To achieve a better efficiency for applications that intensively perform vector operations, the PVP-SW feature has been added to the processor design. PVP-SW stands for "pseudo vector processor based on slide-windowed registers". Each processor is equipped with 128 physical floating-point registers, while the logical registers are split into g global registers and $32 - g$ local registers. These local registers can slide by means of a window along the physical registers. While carrying out computations using the registers of a specific window position, the processor can issue preload instructions which fetch data from memory to registers in any forward window, and issue poststore instructions which store data in any previous window to memory. With a proper selection of the windows for calculations and memory load/store one can achieve that data already reside in registers when the window is shifted to the specific position for calculations, thereby effectively reducing the memory latency.

Other important characteristics of the processor are the clock frequency of 150 MHz, a first level cache containing 16 KB of instructions and 16 KB of data, and a second level cache with a capacity of 2x512 KB. Each processor is connected to a local memory with a capacity of 64 MB of DRAM which is pipelined with multiple interleaved memory banks.

The processors are connected via a 3 dimensional crossbar network. A number of crossbar switches are placed in the x, y and z direction. The crossbars for different directions are connected at each crossing point by a router which is a

4x4 crossbar itself. A maximum configuration with 2048 processors is arranged in a three- dimensional 8x16x16 array. Together with the connection of the IOUs (Input Output Units) the crossbar network has the size of 8x17x16. The bandwidth via the crossbar network is 300 MB/s with a latency of 3 microsec.

On each processor runs a UNIX micro kernel. The CP-PACS computer is controlled by a front-end computer that also schedules the jobs and acts as a file server. The programming languages of the CP-PACS are Fortran, C and assembly language.

The highest LINPACK performance reported so far has been measured on the CP-PACS/2048 system with R_{max}=368.2 GFlop/s. This performance was achieved by solving a system of 103,680 linear equations. Half the performance could be achieved for a system of 30,720 equations.

3.3 Current commercial offerings

The three Japanese supercomputer vendors have decided for different architectures to increase scalability.

Fujitsu is continuing with the VPP architecture that was for the first time implemented in the NWT. The current offering ranges from the departmental system VX with up to 4 processors over the VPP300 system with up to 16 processors up to the high-end VPP700 system with up to 256 processors. All systems are based on CMOS technology and use the same processing element (PE) with a peak performance of 2.2 GFlop/s. The PEs are connected via a crossbar network and have their own SDRAM memory each.

NEC continues to build traditional PVP systems in its SX-4 system also based on CMOS technology. One node can have up to 32 vector processors with a peak performance of 2 GFlop/s each connected to a shared fast SSRAM memory. Bigger configurations are planned by coupling several nodes together. NEC is also offering compact models with a limited number of processors for departmental use.

Hitachi decided for a typical MPP design. Microprocessors based on the PA-RISC design enhanced by “pseudo vector” processing capabilities are connected via a 3-dimensional crossbar network. This architecture was tested in a joint project with Tsukuba University. In the CP-PACS system that is used for QCD calculations 2048 processors are coupled together setting a new performance record. The biggest commercial system with that architecture is the SR2201 with 1024 processors at Tokyo University. Hitachi also started marketing the SR2201 series outside of Japan with a first sale in the UK. Little is known whether Hitachi will continue also their PVP line S-3800. If the market acceptance of the SR2201 is big enough, in particular for traditional vector computer users, then Hitachi may concentrate on the SR architecture only.

3.4 Procurements

In the fiscal year '95 (ending March '96) several systems of the new CMOS generation have been ordered in the government market. The contract for a Hitachi SR2201 system at Tokyo University drew a lot of attention since this was the first time that one of the computing centers of the 7 major universities in Japan decided to replace a classical main frame computer by an MPP system. The biggest variety of systems can be seen at the Japan Atomic Energy Research Institute (JAERI). They procured the following systems: Cray T90, Fujitsu VPP300, Hitachi SR2201, IBM SP2, Intel XP and NEC SX-4. Fujitsu is acting as the system integrator for these systems. Further SX-4 systems have been procured by the National Research Institute for Metals, the Japan Marine Science and Technology Center, the National Cardiovascular Center and the Geographical Survey Institute. The National Astronomical Observatory of Japan ordered one of the first VPP300 systems together with several departmental VX systems. Another VPP300 system was ordered by the Power Reactor and Nuclear Fuel Development Corporation.

Several decisions have already been made in procurements of the fiscal year '96. Kyushu University ordered and installed a Fujitsu VPP700 system. The National Astronomical Observatory of Japan ordered a VPP700 together with a Fujitsu AP3000 - an MPP system based on UltraSparc processors. These systems will be installed in 1997. A VPP300 system has been ordered by the Japan Science and Technology Corporation. Osaka University installed a NEC SX-4 complex. NEC also won contracts from the National Aerospace Laboratory and the National Institute for Environmental Study. Cray Research obtained contracts from Kyoto University, the National Research Institute for Earth Science and Disaster Prevention, and the Real World Computing Partnership. Details have not been disclosed yet. This outlook shows that due to the competitive supercomputer market a variety of systems are procured from different vendors. The fierce competition reduces the traditional loyality of customers to their traditional computer supplier.

3.5 Current market situation

80 supercomputers in Japan entered the TOP500 list. This represents a 16% share of the 500 entries - an increase from 73 systems one year ago. The accumalated R_{max} performance of these 80 systems reaches 2.5 TFlop/s which represents 31.4% of the accumulated R_{max} performance of the TOP500. These figures show that in particular the big Japanese supercomputer installations have in average a significantly higher performance than sites in other countries. In table 3.1 the distribution of the number of systems and the accumulated R_{max} performance are listed for different vendors.

The market leader in Japan is still Fujitsu with 26.3% of the number of sites

Vendor	Sites	R_{max} (GFlops/s)
Convex:	1	4.80
Cray:	10	124.20
Fujitsu:	21	910.46
Hitachi:	12	774.50
IBM:	13	115.08
Intel:	3	121.10
NEC:	15	426.75
Parsytec:	1	5.25
SGI:	3	17.96
TMC:	1	7.70
Total:	80	2,507.79

Table 3.1: Distribution of systems to different vendors.

and 36.3% of the accumulated R_{max} performance of the TOP500 sites in Japan. But the lead over the following vendors Hitachi and NEC has reduced significantly. Hitachi made the biggest step ahead in accumulated R_{max} performance pushing from 157.7 to 774.5 GFlop/s reaching 30.9% of the Japanese market and a solid number 2 position. This is essentially due to the two big sites at Tsukuba and Tokyo. These two systems represent already 588.6 GFlop/s, i.e. 24.9%.

Now we want to look at the distribution into MPP, PVP and SMP systems (see table 3.2). Last year we discussed whether the VPP500 should be considered as MPP as this system dominated last years Japanese list. This year MPP systems from several vendors dominate the list. In particular, Fujitsu and Hitachi systems in terms of performance and IBM systems in terms of number of sites contribute to the success of MPP. 47 of the 80 systems, i.e. 58.8%, can be counted as MPP. These systems account for 1,813.4 GFlop/s, i.e. 72.3% of the performance of the Japanese TOP500 sites. The traditional PVP systems reduced their share. 30 systems, i.e. 38%, account for 676.4 GFlop/s. New PVP systems came only from CRAY and NEC. Fujitsu disappeared from the PVP camp concentrating on their VPP series. Hitachi also moved to the MPP camp with the SR series. The only SMP vendor in the Japanese list is SGI contributing 3 systems and 18 GFlop/s to the list.

What is the reason for the success of MPP in Japan as the Japanese customers have been in favour of traditional vector (PVP) systems for so many years? Fujitsu and Hitachi included vector features in their systems with distributed memory. The Fujitsu VPP series consists of powerful classical vector processors while the Hitachi SR series and the CP-PACS system contain processors based on the PA-RISC design enhanced with “pseudo vector processing”.

Type:	Sites	R_{max} (GFlops/s)
MPP	47	1,813.4
PVP	30	676.4
SMP	3	18.0
Total:	80	2,507.8

Table 3.2: Distribution of systems to different architectures.

It is obvious, that keeping the benefits of using vector features convinced many customers and end-users to move from PVP to 'vector'-MPP. These users can incrementally parallelize their applications which had been vectorized in the past. On the VPP series we can clearly observe, that more parallelized applications are performed compared to one year ago when many VPP systems have been mainly used in throughput mode. The use of message-passing for parallelization has increased, although still many Japanese VPP users prefer the compiler directive based VPP-Fortran parallelization style.

Another interesting aspect is the distribution of the Japanese TOP500 systems into application areas (see table 3.3). 39 systems are installed at research laboratories and account for 1,105.8 GFlop/s. 28 systems are installed in the academic sector at universities and account for 1,171.1 GFlop/s. There is no classified system on the list. The vendors have reduced the number of their internal systems to 4 contributing 111.2 GFlop/s to the list.

Application area:	Sites	R_{max} (GFlops/s)
Academic	28	1,171.1
Industry	9	119.7
Research	39	1,105.8
Vendor	4	111.2
Total:	80	2,507.8

Table 3.3: Distribution of systems to different application areas.

The number of industry sites decreased from 11 to 9. Only 3 of these systems are new on the list. Toyota, a traditional industry user of supercomputers, installed a new NEC SX-4/20 system in addition to its older systems: NEC SX-3/14, CRAY T94 and Fujitsu VPP500/4. The second new industry entry comes from Nippon Telegraph and Telephone (NTT). They installed one of the first full blown CRAY T932 end of last year (shortly after last year's TOP500 deadline). The third new industry entry is a real breakthrough. Kirin Beer installed an IBM SP2/38. To the author's knowledge, this is the first supercomputer used in the food industry. What will be the purpose of that system? Will they try to improve the taste of beer by “molecular modelling” methods? Or do they want to simulate the impact of drinking beer to Japanese business men? The reality is that the system will be used for data warehouse applications with parallel DB2.

The other industry systems in Japan have been installed in former years. Nuclear Power Engineering continues to use an IBM SP2/72. Suzuki Motor still uses the 4 year old Hitachi S-3800 system. Mitsubishi Electric Corporation is continuing to use one of the few CRAY T3D systems in Japan. Does that mean that the Japanese industry is investing less money in supercomputing? This is most likely a misinterpretation. We know of a lot of SGI SMP systems, smaller IBM SP systems and departmental vector systems based on CMOS technology from Fujitsu and NEC. Supercomputing technology can now be afforded by industry departments. These departments make use of that technology at a performance level below the entry level for the TOP500.

3.6 The Japanese TOP20

This year Hitachi took over the number one position. After several years when Fujitsu's NWT was leading the list, again a kind of prototype system is the number one. The CP-PACS with 2048 processors at the Center for Computational Physics at Tsukuba University has set a new record with R_{max} equal to 368.2 GFlop/s. This system is very similar to the Hitachi SR2201 series. Tsukuba University and Hitachi developed that system in a joint collaboration between 1992 and 1996 specifically for QCD applications. A commercial version of this system - the SR2201 with 1024 processors - is installed at Tokyo University ranging on position 3. Second of the list is now the NWT which has been upgraded from 140 to 167 processors. On rank 4 we find the only system on the TOP20 that was manufactured in the US - an Intel XP/S-MP 125 with 2502 processors installed at the Japan Atomic Energy Research Institute (JAERI). On position 6 we see today's biggest VPP700 installation. Fujitsu installed a system with 56 processing elements at Kyushu University. The positions 5, 10 to 15 and 19 are occupied by Fujitsu VPP500 systems that have been installed in former years. A Fujitsu VPP300/16 at JAERI is listed on rank 20. On positions 7 to 9 three NEC SX-4/32 systems are listed. Beside the benchmarking system two new systems have been installed at Osaka University. Probably, these two systems will be combined later to a bigger complex when the necessary hardware and software support will be available. On rank 16 to 18 we find three NEC SX-4/20 systems.

In total we count 11 Fujitsu VPP systems, 6 NEC SX-4 systems, 2 Hitachi SR systems and 1 Intel XP system in the TOP20. The continuing effort in improving the supercomputer capacity in Japan can also be seen in the fact that 11 of the TOP20 systems in Japan have been installed or upgraded within the last 12 months.

3.7 Conclusions

The Japanese supercomputer manufacturers succeeded in bringing their new CMOS based supercomputer generation to the market. However, Fujitsu, Hitachi and NEC decided for different ways to lead their customers to highly scalable systems. While Fujitsu decided for powerful vector processors combined with distributed memory and a crossbar network, NEC continued in the PVP style with shared memory. Hitachi, on the other side, decided for an MPP system based on a RISC processor enhanced by "pseudo vector" capabilities. Thus, all three vendors continue to offer in some way vector processing. A Japanese customer can therefore easily select between three different architectures whatever fits best to his application. This combination of continuity and innovation is for sure very attractive not only for Japanese customers but has already shown success in the world market.

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TOP20 Supercomputers - Japan

N *local* *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]
1 1	Hitachi CP-PACS/2048	Center for Computational Physics, Univ of Tsukuba Tsukuba Japan /1996	Academic	2048	**368200** 614000
2 2	Fujitsu Numerical Wind Tunnel	NAL Japan /1996	Research Aerospace	167	**229700** 281000
3 3	Hitachi SR2201/1024	University of Tokyo Tokyo Japan /1996	Academic	1024	**220400** 307000
4 6	Intel XP/S-MP 125	Japan Atomic Energy Research Japan /1996	Research	2502	**103500** 125100
5 8	Fujitsu VPP500/80	National Lab. for High Energy Physics Japan /1994	Research	80	**98900** 128000
6 9	Fujitsu VPP700/56	Kyushu University Kyushu Japan /1996	Academic	56	**94300** 123200
7 17	NEC SX-4/32	NEC Fuchu Plant Tokyo Japan /1995	Vendor Benchmarking	32	**60650** 64000
8 18	NEC SX-4/32	Osaka University Osaka Japan /1996	Academic	32	**60650** 64000
9 19	NEC SX-4/32	Osaka University Osaka Japan /1996	Academic	32	**60650** 64000
10 22	Fujitsu VPP500/42	Japan Atomic Energy Research Japan /1994	Research	42	**54500** 67200
11 23	Fujitsu VPP500/42	Nagoya University Nagoya Japan /1995	Academic	42	**54500** 67200
12 26	Fujitsu VPP500/40	National Genetics Research Lab. Japan /1995	Research	40	**52070** 64000
13 27	Fujitsu VPP500/40	Tokyo University - Inst. of Solid State Physics Tokyo Japan /1994	Academic	40	**52070** 64000
14 39	Fujitsu VPP500/32	The Angstrom Technology Partnership Tsukuba Japan /1993	Research	32	**42400** 51200
15 40	Fujitsu VPP500/30	Tsukuba University Tsukuba Japan /1993	Research	30	**39812** 48000
16 41	NEC SX-4/20	Japan Marine Science and Technology Japan /1995	Research	20	**38195** 40000
17 42	NEC SX-4/20	National Research Institute for Metals Japan /1996	Research	20	**38195** 40000
18 43	NEC SX-4/20	Toyota Central Research Development Japan /1996	Industry Automotive	20	**38195** 40000
19 44	Fujitsu VPP500/28	Institute of Physical and Chemical Res. (RIKEN) Tokyo Japan /1993	Research	28	**37225** 44800
20 46	Fujitsu VPP300/16	Japan Atomic Energy Research Japan /1996	Research	16	**34100** 35200

Chapter 4

High Performance Computing in Europe

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4.1 General Situation

Cray has just installed 22 T3Es worldwide and 15 of them in Europe. They announced it beginning of October to the TOP500 board, so the situation has changed within one week drastically - only one European T3E system was listed in the TOP500 of end of September. So we had to integrate them and to give an impression of the influence of 22 computers.The total number of Cray systems increased from 120 (24%) October 1996 to 132 (26.4%) in the November list, and 5 T3Es to 23 in this actual list.

Although several countries in Europe installed new machines (e.g. Spain from one system last year to 5 this year) the total number of systems in Europe decreased to 132 that is 26% of the worldwide installations. In 1995 we could report that 140 systems are in used here. This time R_{max} grew from 808 Gflops/s and R_{peak} from 1180 Gflops/s to 1.7 Tflop/s (22% of the worldwide capacity) and 2.4 TFlop/s (22%) respectively. It is interesting to note that this year the percentage grew by 30% compared to 1995, at that time Europe held 17% of the worldwide figures. The growth in R_{max} and R_{peak} comes to more than 100%, much higher than the world trend of 32% in R_{max} and 60% in R_{peak}, comparable to the world trend.

The major delay of the delivery of Cray's T3E with all the ordered processors causes an smaller percentage in the TOP500 than expected. In Germany for example the following institutions ordered T3Es, Max-Planck-Ges. in Garching (400 processors, 128 delivered), the Research Center Juelich (512 processors, actually delivered 136) and Univ. Stuttgart (512, now having 128). This means that Juelich and Stuttgart would have been number 4 and 5 in the list with about 190 Gflop/s, Garching about 150 Gflop/s. Thus we miss about 350 Gflop/s compared to the procurements only with these three installations. In other European countries there are also orders for more and bigger T3Es.

This time the most powerful machine in Europe - still in the UK as last year - changed from an American vendor to a Japanese one, from Cray T3D to Fujitsu's VPP 700 with 46 processors, a vector-parallel machine, at ECMWF in Reading that is number 10 worldwide. This weather forecast center moved from Cray (C90s and T3D) machines to the Japanese vendor and installed the first processors in March this year. Some details will be mentioned in the UK section. Number two in Europe is a Cray T3E 256 processors in France at CNRS/IDRIS, followed by the 32 processor NEX SX-4 machine in Germany at Stutgart. This year Europe jumped back with 8 computers into the first 50 TOP500 machines, compared to 6 last year, from whom one was a vendor machine.

In Europe HPC computers are mainly used in academic and research environment, about 73% compared to 23% for industrial usage, vendors and classified institutions can nearly neglected with 2% compared to America. The academia and research fall back to 96 computers compared to 105 in 1995. This means that not so powerful computers have left this list and had not been replaced by faster computers. If one changes to R_{max}, academic and research keep the percentage with 82% (1.4 Tflop/s), an increase compared to the last year, also in R_{max} of 220%, 630 Gflop/s in 1995. An other interesting fact can be seen, research was pushed by the local governments. Last year their R_{max} was comparable (310 Gflop/s), now academia comes to 500 Gflop/s compared to 940 on the research side. Industry came to 13%, R_{max} grew from 122 Gflop/s to 220, nearly doubled. A similar situation can be observed with R_{peak}.

Industry uses smaller and less powerful TOP500 computers (mean value 7/9 Gflop/s, R_{max}/R_{peak}) than research (17/25 Gflop/s), academia (11/16 Gflop/s) and classified institutions (18/24 Gflop/s). Compared to Europe, Japan has access to much powerful machines (R_{max}) in the different areas, academia 40 Gflop/s, research 27 Gflop/s and industry 12 Gflop/s. If one looks at USA/Canada the academia gets 13 Gflop/s, research 20 Gflop/s, industry 8 Gflop/s and the classified come to 13 Gflop/s R_{max} performance. Surely this changes, when the all the ordered machines are in operation in Europe. We will see the results in June.

Europe does not want their own machines, or the acceptance is too low, only 5% of all the computers. They buy American HPC computers machines, 83 % of the computers, but the Japanese are improving their market share from 8 to 11%. Nearly the share can be found with R_{max}. American computers sum up to 79% while the Japanese come to 18%, the rest are European computers. This underlines again the dominance of US-incorporated, but that the Japanese computers are now accepted by users and the heads of the computer centers.

4.1.1 Distribution on country groups

Although most of the countries in Europe decreased in numbers, some could stay at the same number, for example Germany still 51. France dropped from 24 to 17 and Poland from 3 to 1, the big countries are still leading. The percentages of the computers and the R_{max} of some countries in relation to the European figures: Germany 39%/38%, UK 14%/21%, France 13%/14% and surprisingly Switzerland 7%/9% and the Netherlands with 7%/6%. These figures show that 80% of the machines and 88% of the R_{max} are collected in these countries. To show the R_{max} figures of the available performance: Germany 666 Gflop/s, UK 361 Gflop/s, France 239 Gflop/s, Switzerland 151 GFlop/s, Netherlands 112 Gflop/s, the other countries as Italy, Denmark, Spain, follow in the range of 30 - 40 Gflop/s. The rest is nearly neglectable.

Comparing the actual results with the last years list, the improvement in R_{max} can be seen clearly, in 1995 we got in: Germany 277 Gflops/s (240%), UK 144 Gflops/s (250%), France 124 Gflops/s (190%), Switzerland came up to 96 Gflops/s (157%), as Benelux 53 GFlops/s (211%).

Eastern Europe fall back this year and is still underdeveloped in the supercomputer field, only a Convex in Poland and Slovenia are listed.

As you compare the factor R_{max}/machine concerning the different countries, one can recognize the "best" equipped countries: Switzerland this year comes to 13 Gflops/s/computer (10 in 1995), UK 20 (8.5 in 1995), Germany 12 (5.4), France 14 (5.2). The factor for Europe as a total divides to 13 Gflp/s/machine (6 last year). If one sets these results in relationship with the other continents, Japan 30 (17 in 1995) and the USA with 13 (10 in 1995). Compared to America, the European countries now had made up this time.

4.1.2 The different manufacturers

Number one in Europe in machines on the vendors side is Cray, 42 systems and 783 Gflop/s, if one adds the SGI figures, 20 machines and 126 Gflop/s, nearly 50% of the machines and 52% of R_{max} show the dominance of this new group in Europe. As the SGIs are not extremely high ended, the decrease from 34 systems in 1995 to 20 machines. They are followed by IBM, 35 computers (7%) of Europe and 322 Gflop/s (19%). Last year IBM came up to 41 machines, Cray Research to 28 pieces. HP-Convex is still active with its SPP machine, 8 computers (7%) with 53 Gflop/s, two new Exemplar S-class have been sold in Germany. Very interesting is the improvement in figures of NEC, from 4 last year to 7 now and a performance of 182 Gflop/s (10%). Fujitsu/Siemens Nixdorf got the same number but improved the R_{max} performance to 170 Gflop/s (10%).

There is one bad aspect, European vendors don't play a role in the TOP500 business. Meiko is represented by only two machines in Europe, two others at

Lawrence Livermore in the US. Parsytec decreased from 10 to only 6 systems, 5 in Europe and one in Japan. In this list we are missing the Italian company Alenia Spazio again that took over/cooperates with Meiko - they are mainly selling their computers in the theoretical physics arena. The UK based vendor of parallel systems Parsys probably has not sold big systems - they use the Digital Alpha processor.

4.1.3 Architectures

Last year I mentioned the trend that SMP's are in. Because of the lack in R_{max} performance this changed like a wave this year.

MPPs are still the number one in Europe, 92 systems (70% of all architectures) with an R_{max} of 1.32 Tflop/s (76%) - a mean value of 14 Gflop/s/computer. Japan has about double the performance with nearly half the machines, 47 MPPs with a peak of 1.8 Tflop/s, nearly 38 Gflop/s/computer. Although America is leading here too, they do not use such powerful MPPs, 170 systems with an R_{max} of 2.8 Tflop/s. The percentage of MPPs compared to all the machines in the region comes to 60% in numbers and 77% in performance in Japan, and 63% and 78% in performance in America. Last year we found 81 machines compared to 89 in 1994, with an R_{max} of 534 Gflops/s versus 274 Gflops/s in 1994. This shows that MPPs are very important in respect to the LINPACK benchmark

But the vector machines are still workhorses in the computer centers, 22 computers (17% of the European) vector processors with 320 Gflop/s (18%). The number had reduced from 27 machines but grown to 188% in the performance with 170 Gflops/s last year.

SGI and other SMP vendors had to stop their attack in the top HPC market. From 33 systems with an R_{max} of 104 Gflops/s in 1995 they decreased to only 18 machines with 100 Gflop/s. The same trend can be seen in Japan, there they have nearly no importance, 3 machines with 18 Gflop/s. In the US the number reduced from 74 last year to 46 this year. With an minimal performance increase from 248 to 255 Gflop/s. But one should not forget that the SMPs are not dedicated for the top high-end market but are used heavily in the CAD and CAE departments for example in the automotive industry.

Thus in total the trend in the TOP500-HPC systems shows the still growing importance of MPPs.

4.2 Germany

Germany is much stronger than ever and again the leader in Europe. In short: 39% of the computers in Europe, and 10% worldwide, in all 51 pieces; 38% in R_{max} in Europe and 8% worldwide with 666 Gflop/s; 38% of R_{peak} in Europe and 8% compared to the world with 918 Gflop/s.

There are some major changes in the philosophy of HPCN in academia and research and a new approach will be realized. The proposal of the German Wissenschaftsrat to install two to four HPC centers for Germany is now in the realization phase. On the research side this is Research Center Juelich, a Cray T90 12 processors, a Cray T3E 512 processors (actually there are 136 installed), a Cray J90 and Cray M94. It supports the German theoretical physics and chemists with 50% of its computing power, 35% can be used by the Research Center itself. The last 15% are scheduled for industrial projects. In the field of chemistry, exploration end environmental sciences they now offer expertise of their institutes and the HPC power to the industry. This approach will improve and speed up the transfer of research results from the centers to industry.

The other just opened center is in Stuttgart, there the University, Porsche AG and debis Systemhaus cooperate in a joint company. At the University they have installed a NEC SX4 32 processors, a Cray T3E 512 processors is scheduled (128 delivered), at debis Systemhaus a Cray T90 4 processors, a C90 and a J90 are accessible. The University is offering 50% of its power to academic researchers all over Germany. About 7% is reserved for industry, debis Systemhaus distribute the computing time within the Daimler-Benz Group and will sell it to major companies but also to small and medium enterprises. An other, just published idea will be realized at debis Systemhaus for engineers of the Daimler-Benz Group. If a research project with very innovative elements needs HPC computing time, the researchers can apply for a funding that will be granted by a Research Council of Daimler.

With these two centers it is now possible to support industrial users at their first steps on HPC machines on a low level of costs. There is no need to install systems, but only to use them.

As the University Stuttgart mentioned during the opening ceremony, several European research institutes showed their interest to use the machines in this new center. That opens new perspectives for an inter-European HPC usage.

In Bavaria, just before Christmas, LRZ (Leibniz Computer Center of the Bavarian Academy of Sciences) in Munich and SNI signed a contract for a major VPP700 system. In March about 36 processors will be installed—2 of them are rented to University Erlangen-Nurenberg. In a second step 14 more processors will be added. This 52 processor systems will serve as the HPC computer for the state of Bavaria. This will add approximately 90 GFlop/s R_{max} in Germany.

Some details on these activities can be found in the last TOP500 issue and Primeur, the European virtual magazine (http://www.hoise.com/primeur).

4.3 United Kingdom

In 1996 UK improved its number of systems a bit to 18, but much better the performance rather drastically, from 144 Gflop/s to 360 in R_{max} and from 200 to 470. These figures mean in installations 14% of Europe and 4% worldwide, 21% of Europe and 5% worldwide of R_{max} and 20% Europe and 4% of the world of R_{peak}.

A very interesting fact is that Fujitsu won the big procurement of ECMWF in Reading, the European weather forecast center. They declared that this machine fits their requirements. In March this year they installed a 16 processor VPP300 that should perform comparable or better to the old Cray C90-16. The next step mid of this year an improvement of a factor of 5, in March 1998 the tenfold improvement and in September 1998 the factor of 25. The United Kingdom Meteorological Office in Bracknell installed a Cray T3E with 128 processors. So the meteorologists work with different computers. That reminds me of the early days of HPC, when ECMWF had a Cray and their British colleagues a CDC Cyber 205.

An other interesting event started Hitachi, the first parallel machine outside Japan was installed at their research center in Great Britain. Then they sold an SR2201 to University of Cambridge.

4.4 France

This year there are only 17 machines in France (13% of Europe, 3% of the world) which deliver an R_{max} of 240 Gflop/s (14% Europe, 3% world) and an R_{peak} of 356 Gflop/s (15% Europe, 3% world). Their fist machine ranks on number 11, a very powerful Cray T3E with 256 processors. In France there is a variety of machines from different vendors.

4.5 Benelux

This year Belgium fall out of the list, but the small Luxembourg entered it with one machine, a PowerChallenge with 5 Gflop/s. In the Netherlands 9 systems can be accesses, 112 Gflop/s R_{max} and 140 Gflop/s R_{peak}. Big Blue is still dominant with 6 machines, mainly used by Shell, 5 systems, a Cray T3E and J90 and an NEC SX4.

4.6 Switzerland

Although a small country, it has the highest usage of HPC when combining economical factors like inhabitants or net growth into this study. In total 9 machines with an R_{max} of 151 Gflop/s are installed, nearly of each system one machine, one Cray (25 Gflop/s), one Digital (5 Gflop/s), two IBMs (18 Gflop/s), one Intel (19 Gflop/s), one Meiko (5 Gflop/s), two NEC (42 Gflop/s) and one SGI (16 Gflop/s). The HPC machines are used in the academic and research environments, although the SCSC/CSCS center in Manno that is equipped with two NEC machines, SX-3 24, SX-4 16 and parallel systems from NEC, is actively working to attract industry. This compares to the approach in Germany.

TOP20 Supercomputers - Europe

N *local* *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	$N_{\ldots}$ N
1 10	Fujitsu VPP700/46	ECMWF Reading UK /1996	Research Weather	46	**94300** 101200	100 8
2 11	Cray T3E LC256-128	CNRS/IDRIS Orsay France /1996	Research	256	**93200** 154000	53 11
3 20	NEC SX-4/32	Universitaet Stuttgart Stuttgart Germany /1996	Research	32	**60650** 64000	10 1
4 24	Cray T3E LC136-128	Forschungszentrum Juelich (KFA) Juelich Germany /1996	Research	136	**53100** 81800	
5 32	Cray T3D MC512-8	University of Edinburgh Edinburgh UK /1996	Academic	512	**50800** 76000	57 7
6 33	Cray T3E LC128-128	Max-Planck-Gesellschaft MPI/IPP Garching Germany /1996	Research	128	**50430** 77000	58 7
7 35	Cray T3E LC128-128	United Kingdom Meteorological Office Bracknell UK /1996	Research Weather	128	**50430** 77000	58 7
8 36	Cray T3E LC128-128	Universitaet Stuttgart Stuttgart Germany /1996	Research	128	**50430** 77000	58 7
9 49	NEC SX-4/16	National Aerospace Laboratory (NLR) Noordoostpolder Netherlands /1996	Research Aerospace	16	**30710** 32000	10
10 51	NEC SX-4/16	Swiss Scientific Computing Center (CSCS) Manno Switzerland /1996	Research	16	**30710** 32000	10
11 62	Cray T3D MC256-8	Defense Research Agency Farnborough UK /1994	Classified	256	**25300** 38000	40 4
12 64	Cray T3D MC256-8	Ecole Polytechnique Federale de Lausanne Lausanne Switzerland /1994	Academic	256	**25300** 38000	40 4
13 67	Cray T3D SC256-8/464	ZIB/Konrad Zuse-Zentrum fuer Informationstechnik Berlin Germany /1995	Academic	256	**25300** 38000	40 4
14 68	Cray T3E AC64-128	CSC (Center for Scientific Computing) Espoo Finland /1996	Academic	64	**25190** 38000	39 4
15 71	Cray T3E AC64-128	TUD (Technical University Delft) Delft Netherlands /1996	Academic	64	**25190** 38000	39 4
16 72	Cray T3E AC64-128	University of Trondheim Norway /1996	Academic	64	**25190** 38000	39 4
17 76	Fujitsu VPP300/10	Universitaet/Forschungszentrum Karlsruhe Karlsruhe Germany /1996	Academic	10	**22350** 22000	
18 80	IBM SP2/110	KTH - Royal Institute of Technology Stockholm Sweden /1996	Research	110	**20370** 29210	
19 85	Intel XP/S-MP 22	ETH Zuerich Switzerland /1995	Academic	450	**18700** 22500	
20 88	IBM SP2/84	Universitaet/Forschungszentrum Karlsruhe Karlsruhe Germany /1996	Academic	84	**17920** 25870	

Chapter 5

The TOP25 Supercomputer Sites

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Abstract

In this short note the TOP25 supercomputer sites worldwide are introduced. This list of the TOP25 sites has been compiled based on the information given in the TOP500 report. First we briefly explain how this list was established and comment on recent changes. For most of the top twentyfive supercomputer centers we provide a short description of facilities, equipment, and mission.

5.1 Introduction

The TOP500 [1] provides an opportunity to rank the top supercomputer sites worldwide. In the TOP500 report the 500 highest performing supercomputers are listed. The measurement of performance is based on the LINPACK benchmark as reported in [2]. All the information here is based on the TOP500 list of November 1996. We use results from this list because it provides the most comprehensive list of supercomputer sites. Also real LINPACK figures are available for all the machines on the list. Some of the limitations of using LINPACK and relying on the TOP500 list are discussed elsewhere [4].

An alternative "List of the World's Most Powerful Computing Sites" is compiled by Ahrendt [5]. This list is based on the NAS Parallel Benchmarks code BT [6]. There is considerable overlap between these two lists. BT as benchmark generally does not perform as well on highly parallel machines as LINPACK, when compared to vector machines. Also BT results are not always immediately available on new machines, so [5] resorts sometimes to estimates and extrapolations. On the other hand the list [5] is updated more frequently. In general, however, the results and the ranking are fairly consistent. The main point here is that we will give some additional information about the supercomputer sites, beyond just a listing of machines. This provides a general overview and pointers to further reading, on what the most powerful supercomputers on earth are actually used for.

5.2 List of the TOP25 Sites

The TOP25 list of supercomputer sites is given in Table 5.1. This list has been established by simply adding the LINPACK R_{max} performance in Gflop/s of all supercomputers installed at a given site. Generally under a "site" we have combined supercomputers, which are installed in the same geographical location, and belong to the same organizational unit. Thus all machines belonging to a university on the same campus were added, even though they might be in different departments. The previous ranking from November 1995 is given in the second column (see [7]).

The list does not contain any of the vendor machines. Most of the supercomputer vendors have substantial compute capabilities, which would make the TOP25 centers list. However, the intent of this list is to give an indication where most compute power in terms of scientific and research applications is concentrated. Therefore we decided to list the vendors separately in Table 5.3.

In all tables the column "machines" lists the machines whose performance have been added to reach the total performance for a site. The integers refer to the ranking of these supercomputers on the TOP500 list. The performance column lists the aggregate performance of all the machines at the site in LINPACK R_{max}-Gflop/s. An overview of many of the supercomputers in use is [3].

There are several intriguing observations one can make from Table 5.1. In order to qualify as a top supercomputer site, and installation must have at least a machine with about 70 Gflop/s performance. This is almost twice the cutoff one year ago, which was about 35 Gflop/s. Three years ago the cutoff was only 13.7 Gflop/s, and 70 Gflop/s would have placed an institution on rank two. There has been a tremendous acceleration of available cycles at the top supercomputer centers. In 1996 again the number of machines at TOP25 sites and their share of the total performance in Gflop/s increased slightly.

Another significant change is in the geographical distribution. In 1996 the most important change was that there were three European centers which

Table 5.1: **TOP25 Supercomputer Sites**

	1995	Institution	Machines	Perf.
1	24	Tsukuba University	1, 40	408.0
2	9	Tokyo University	3, 27, 58, 180, 485	315.4
3	1	National Aerospace Lab. (NAL), Tokyo	2, 191	239.7
4	11	Japan Atomic Energy Research	6, 22, 46, 118, 365, 391	217.8
5	3	National Security Agency	7, 53, 107, 127, 249, 291, 322, 435, 442, 446	195.5
6	4	Los Alamos National Laboratory	21, 28, 66, 196, 197, 370, 393	166.9
7	13	Pittsburgh Supercomputing Center	13, 31, 143	157.7
8	2	Oak Ridge National Laboratory	5, 104, 178	154.3
9	5	Sandia National Labs, Albuquerque	2	143.4
10	6	University of Minnesota	25, 29, 284, 362, 400, 443	126.4
11		Osaka University	18, 19, 475	126.2
12	19	Lawrence Livermore National Laboratory	32, 38, 65, 438, 441	123.7
13		ECWMF, Reading, UK	10, 128, 164	120.8
14		Univ. Stuttgart, Germany	20, 36, 334	117.3
15		CNRS/IDRIS, France	11, 160, 278	112.9
16		DOD/CEWES, Vicksburg	12, 124	106.9
17	7	Natl. Lab. High Energy Physics, Japan	8	98.9
18		Kyushu University	9	94.3
19	8	Cornell Theory Center	12	88.4
20	12	Tohuku University	74, 79, 145, 169, 209, 425	85.8
21	22	NCSA, Univ. of Illinois	52, 95, 211, 221, 244, 264, 292	85.0
22		NERSC, Lawrence Berkeley Nat. Lab.	34, 140, 373, 374, 375	81.5
23	10	Maui HPCC	16, 175	78.8
24	15	Atmospheric Env. Serv., Dorval, Canada	48, 73, 82	73.9
25	23	Caltech/JPL	61, 103, 120, 251, 261	69.6
Total			95 Systems	3589.1
Percentage			19.0%	44.9%

entered the TOP25 list. In 1995 there were no European sites among the TOP25Table 5.2 shows the change in the geographical distribution of the centers.

Table 5.2: **Geographical Distribution**

Region	1995	1996
USA/Canada	15	14
Japan	10	8
Europe	0	3

The list also shows how much U.S. government spending dominates the supercomputing world. All 13 U.S. sites directly or indirectly are funded by the U.S. government. There are 9 U.S. government laboratories/centers (5 Department of Energy, 1 classified, 1 NASA, 2 Dept. of Defense), and the five U.S. universities receive their support for supercomputers from the NSF or DoD (Minnesota). However, also the foreign sites are also all falling into the same category, and are government institutions in their countries.

5.3 Vendor Sites

Most of the supercomputer vendors maintain substantial benchmarking capabilities. These are usually distributed worldwide. Since the vendor centers are geared towards benchmarking and internal software development, we in 1995 decided not to list them in the same list as the TOP25 supercomputer centers, which are geared towards research. In Table 5.3, we list the all vendor sites. Only the first two, Cray and IBM, would have made it to the TOP25 list. However, we believe that the vendors no longer report benchmarking machines for the TOP500 since there is a limit to the number of vendor machine which can be reported.

5.4 Background Information about some of the TOP25 sites

Wherever available some short summary of the mission and the environment of the TOP25 sites will be given below. If not noted otherwise, this information was gathered from home pages of these sites on the world wide web (WWW). Many of the supercomputer sites have created such home pages. In order to facilitate browsing the net, URLs for site home pages are given.

Table 5.3: **TOP Vendor Sites**

	Institution	No. of Machines	Perf.
1	Cray Res.	8	96.1
2	IBM	1	88.4
3	NEC	1	60.7
4	Hitachi	2	42.6
5	Fujitsu	3	27.2
6	SGI	2	22.4
7	HP/Convex	2	18.3
8	Digital	1	6.7
Total			362.4

5.4.1 University of Tsukuba, Center for Computational Physics, 408.0 Gflop/s

Source: http://www.rccp.tsukuba.ac.jp/

The new entry on the TOP500list, which propelled the University of Tsukuba to the first place of the list is the CP-PACS computer. For the industrial partner for manufacturing of the CP-PACS computer, Hitachi Ltd. was selected in the summer of 1992 by a formal bidding process. The Project members have since worked in a close collaboration with Hitachi Ltd. for the development of the computer.

The first three years of the Project (1992-1994) were spent in the basic and detailed designs of the CP-PACS computer and their verification through simulations. Chip fabrication and assembling of parts started in early 1995. The first stage of the CP-PACS computer consisting of 1024 processing units with a peek speed of 307 Gflop/s were completed in March 1996. An upgrade to a 2048 system reaching the peek speed of 614 Gflop/s began in August of 1996, which has been completed at the end of September 1996.

In computational physics the project aims to use the CP-PACS computer for carrying out research in the areas of particle physics, condensed matter physics, and astrophysics. A major goal of the Project is to significantly advance numerical study of lattice QCD in particle physics. QCD (Quantum Chromodynamics) is believed to be the fundamental theory of strong interactions of elementary particles such as proton, neutron and pion. Large-scale numerical simulations will be pursued with the CP-PACS computer in order to verify the theory and to extract new physical predictions. Important problems also abound in condensed matter physics (strongly interacting electron systems and high-temperature superconductivity, ab initio calculations of material properties etc.) and in astrophysics (gravitational collapse, large-scale structure of the Universe etc.). Application of the CP-PACS computer to these areas will also be pursued.

5.4.2 University of Tokyo, Japan - 315.4 Gflop/s

Source: http://www.ecc.u-tokyo.ac.jp/index-e.html

The Computer Centre was established in 1965 as a national shared facility to offer computing, data processing and information retrieval to researchers in universities, junior colleges and specialized high schools and graduate students. Currently, the Centre is one of 7 such shared computer centers and is making close contact, information interchange and coordination with other centers and also with NACSIS (National Center for Science Information System) through various committees, coordinating meetings and research groups.

The main system is a 1024 processor Hitachi SR2201 parallel computer, which is very similar to the CP-PACS system, and which was installed in 1996.

5.4.3 National Aerospace Laboratory Numerical Wind Tunnel, Tokyo, Japan - 239.7 Gflop/s

Source: http://www.jicst.go.jp/www/Institutes/nal/contents.html

The laboratory was founded as the National Aeronautical Laboratory in 1955, and the space division was incorporated into the newly-designated National Aerospace Laboratory (NAL) in 1963. Since then, NAL has conducted research and development related to aircraft, aeroengines and rockets. At the same time, NAL has directed its effort towards constructing large-scale test facilities for common use with other Government organizations. NAL's research activities have made many important achievements in the field of aerodynamics, material strength, structural mechanics, aeroengines and control systems.

Major Areas of Research activities in the Computational Sciences Division are focused on numerical simulation technology, ranging from basic to applied, which is now a key technology in research and development in the field of aeronautical and space technology. Research on applied artificial intelligence and image processing is also being conducted. Additionally, the Computational Sciences Division is responsible for the management and operation of the Numerical Simulator.

Numerical simulation technology is a key research and development technology in the field of aeronautics and astronautics, which has been advancing rapidly together with the evolution of ultra-high speed computers. NAL's efforts are devoted to the research and development of numerical simulation technologies for results of studies on mathematical and numerical analysis, parallel computers, and image processing. The developed software packages are effective design tools for aircraft and spacecraft in Japan.

The main computational resource at NWT is is a unique parallel computer system of distributed memory architecture composed of vector processors. NWT consists of 140 Processing Elements (PE), two Control Processors(CP) and Crossbar Network. That is, each PE itself is a vector supercomputer similar to VP400. Each PE has 256 MBytes of memory and peak performance of 1.7 Gflop/s. PE has Vector Unit, Scalar Unit and Data Mover which communicates with other PE's. PE is 50% faster than the standard VP400 and same size of memory. CP has 128 MB of memory. CP manages NWT and communicates with VP2600 through SSU. CP's do not execute real computation of CFD code. The cross-bar network has 421 MByte/s x 2 x 142 performance between each processors. The total performance of NWT is 236 Gflop/s and 35 GB main memory.

5.4.4 Japan Atomic Energy Research Institute, Japan - 217.8 Gflop/s

Source: http://www.jicst.go.jp/www/Institutes/jaeri-n/contents.html

As the central area of its research and development, the Japan Atomic Energy Research Institute(JAERI) has continued to search for future opportunities since Japan started development and utilization of atomic energy. At present, JAERI aims at developing innovative technologies such as new atomic energy, maintenance and security of higher safety in nuclear facilities, and expanded utilization of radiation, and it is coping with challenges which are yet known. As an organization researching atomic energy in general, JAERI has a variety of R&D themes, most prominently from the stance of a builder of the future, "to build tomorrow with atomic energy".

This cannot be achieved without integrating a variety of excellent technologies. In JAERI, five Research Establishments and two Research Facilities are engaging in their respective research activities and to integrate these activities enables the unique research and development at JAERI. JAERI's comprehensive research activities, not only serve as scientific and technological basis for nuclear development in Japan, but also contribute to the nuclear development of all over the world through international cooperation.

In the Research Support Computing and Information Systems Center a huge amount of scientific and engineering computation indispensable for key R&Ds is processed by main computer systems. To also meet the needs of advanced R&Ds, pioneering applications such as parallel computing are now under development.

5.4.5 National Security Agency, Fort Meade, Maryland - 195.5 Gflop/s

Source: http://www.nsa.gov:8080

The National Security Agency/Central Security Service is responsible for the centralized coordination, direction, and performance of highly specialized technical functions in support of U.S. Government activities to protect U.S. communications and produce foreign intelligence information. The National

Security Agency (NSA) was established by Presidential directive in 1952 as a separately organized agency within the Department of Defense under the direction, authority, and control of the Secretary of Defense, who acts as Executive Agent of the U.S. government for the production of communications intelligence (COMINT) information.

Detailed information about the computational resources at NSA are not directly available. However, it is believed that the largest Cray T3D ever built, a 1024 processor machine, is installed there. Evidence for the existence of this machine are NAS Parallel Benchmarks results, which were run on a 1024 T3D before this machine was installed at a "classified" site. More recently there might have been two 128 processor Cray T3Es installed as well. These machines are not counted on the TOP500list. The count of actual machines at this site may be inaccurate, but NSA is definitely a TOP10 site as far as supercomputing is concerned.

5.4.6 Los Alamos National Laboratory - 166.9 Gflop/s

Source: http://www.acl.lanl.gov/Home.html

Los Alamos National Laboratory has a long history in high performance computing going back to the early fifties, when machines such as the MANIAC, IBM 701, MANIAC 2, and IBM 704 were installed at Los Alamos National Laboratory. The Advanced Computing Laboratory (ACL) is one of the four DOE High Performance Computing Research Centers established by the Office of Energy Research. In addition to the ACL LANL houses substantial additional computational resources, some of which are classified.

In 1996 the main computational resource at LANL continues to be a 1056 node CM-5, the largest CM-5 ever built, as well as a large 512 processor Cray T3D. LANL is part of the DOE ASCI and has announced the acquisition of an array of SMP based on SGI/Cray technology. This will eventually lead to a multiple Teraflop/s system by 1998.

5.4.7 Pittsburgh Supercomputing Center - 157.7 Gflop/s

Source: http://www.psc.edu/

Pittsburgh Supercomputing Center (PSC) is a joint project of Carnegie Mellon University and the University of Pittsburgh together with Westinghouse Electric Corporation. It is one of four national supercomputing centers funded by a grant from the National Science Foundation, and a member of the National MetaCenter for Computational Science and Engineering.

In 1996 PSC upgraded in computational capability significantly by acquiring a 256 node Cray T3E which eventually will be upgraded to 512 processors.

5.4.8 Oak Ridge National Laboratory - 154.3 Gflop/s

Source: http://www.ccs.ornl.gov/

The Center for Computational Sciences(CCS) at Oak Ridge National Laboratory (ORNL) is one of the four high performance computing research centers established by the United States Department of Energy (DOE) to provide state-of-the-art resources for Grand Challenge computing.

The main computational resource at ORNL is an Intel Paragon with 3072 Intel i860XP processors. This is one of the more recent Intel installations, which features the MP node (with two floating point processors per node).

5.4.9 Sandia National Labs, Albuquerque - 143.4 Gflop/s

Source: http://www.cs.sandia.gov/

The Department of Energy's Sandia National Laboratories is one of the nation's largest and most diverse research and development facilities. It employs more than 8,000 people at two locations in New Mexico and California. One of Sandia's strengths is in computational and experimental mechanics where several advanced code development efforts are in progress. These codes are run on state-of-the-art vector and massively parallel computer systems at Sandia. They support internal customers with analysis capabilities and the codes are also distributed to external customers. In addition, Sandia makes use of commercial and externally developed codes when applicable.

The highly parallel supercomputers are located at Sandia's Massively Parallel Computing Research Laboratory (MPCRL) in Albuquerque, NM. The main computational resource at Sandia is the largest Intel Paragon, a 3680 processor machine. Several applications which run in excess of 100 Gflop/s have been developed at Sandia. Sandia announced in 1995 that it will acquire a Teraflops computer in 1996, under a joint research contract with Intel in the framework of the new DOE ASCI program. Intel won the contract to build this machine based on an MPP design with more than 8000 Pentium based processors. The Teraflop/s benchmark goal was met in late December 1996. The machine was unfortunately not installed in time to be included in the 1996 TOP500 list.

5.4.10 University of Minnesota - 126.4 Gflop/s

Source: http://www.msc.edu/ and http://www.arc.umn.edu/html/ahpcrc.html and http://www.lcse.umn.edu/

Resources at the University of Minnesota include supercomputers at several University associated or managed centers such as the Minnesota Supercomputer Center, the Army High Performance Computing Research Center (AHPCRC), and the "Laboratory for Computational Science and Engineering".

AHPCRC is a university led research and educational consortium. Consortium members include the University of Minnesota as prime contractor and

Howard, Jackson State, and Purdue Universities. The AHPCRC is funded by the Army Research Office's Division of Mathematical and Computer Sciences. The AHPCRC mission is to advance the state of the art in heterogeneous and networked high performance computing, to educate Army researchers and the next generation of engineers and scientists in new techniques in high performance computing, and to promote technology transfer and encourage joint research and development projects which include both university and Army researchers.

5.4.11 Osaka University - 126.2 Gflop/s

Source: http://www.center.osaka-u.ac.jp/center/

The Computation Center, Osaka University was formed 1962 to provide computing facilities to researchers in this university. In 1969, it became one of the seven computation center on the recommendation of the Science Council of Japan for supporting researchers nationwide belonging to universities, colleges and other academic organizations. In 1996 the university installed two NEC-SX4 machines with 32 processors each, which moved it ahead in the list.

5.4.12 Lawrence Livermore National Laboratory - 123.7 Gflop/s

Source: http://www.llnl.gov/comp/

Livermore Computing (LC) provides leading-edge computational infrastructure to support the development and application of breakthrough science and technology to address pressing national issues. LC has been a leader in the development of high-performance computing since the Lawrence Livermore National Laboratory (LLNL) was founded in 1952. LC developed the first time-sharing system in the 1960s and 1970s, large archival storage systems in the 1970s and 1980s, and distributed architectures in the 1980s and 1990s. Our objective for the mid-90's and beyond is tera-scale computing, featuring teraflop processing, terabyte networking, and petabyte archives accessible through the global network.

In 1996 Lawrence Livermore National Laboratory has selected IBM for award of a $ 93 million contract to build a 3 Tflop/s supercomputer. The IBM RS/6000 SP* system will be installed as part of the Department of Energy's Accelerated Strategic Computing Initiative (ASCI), a ten-year, one-billion dollar program designed to deliver tera-scale (a trillion calculations per second) computing capability. Machine number 36 and 37 on the TOP500list are a first step in this direction.

5.4.13 ECWMF, Reading, UK - 120.8 Gflop/s

Source: http://www.ecmwf.int/pr/ecmwf.html

The European Centre for Medium-Range Weather Forecasts (ECMWF, the Centre) is an international organization supported by eighteen European States The principal objectives of the Centre are, the development of numerical methods for medium-range weather forecasting, the preparation, on a regular basis, of medium-range weather forecasts for distribution to the meteorological services of the Member States, scientific and technical research directed to the improvement of these forecasts, and collection and storage of appropriate meteorological data.

In 1996 ECMWF ordered a Fujitsu Vector Parallel Processor (VPP series) to replace the Centre's current Cray C90 and Cray T3D systems. In June 1996, a 46 processor system was installed to provide five times the performance of the C90. Further enhancement in 1998 will lead eventually to a sustained performance of about 25 times that of the C90.

The new computer will be used to support the Centre's operational and research programs. Since it started operational activities in 1979, the Centre has increased the accuracy of its medium-range forecasts by two days: the current 7-day forecasts are as accurate as the original 5-day forecasts. The current 5-day forecasts have an accuracy score above 80%; they are more accurate than the world's best 2-day forecasts of 1972.

5.4.14 Univ. Stuttgart, Germany - 117.3 Gflop/s

Source: http://www.uni-stuttgart.de/Rus/rus.html

The University of Stuttgart substantially upgraded its resource in 1996 by installing a 32 processor NEC SX-4 as well as a 128 processor Cray T3E, which will be upgraded to 512 processors in 1997. The university is one of the four planned German national supercomputer centers.

5.4.15 CNRS/IDRIS, France - 112.9 Gflop/s

Source: http://www.idris.fr/

IDRIS (Institut du Developpement et des Ressources en Informatique Scientifique) was founded in November 1993. It is the French Supercomputing Center for Scientific Research belonging to the CNRS. It is equipped with an IBM scalar cluster, two Cray C9Os, a Mass Storage System (EMASS, CONVEX and FileServ software) and a T3E.

5.4.16 DOD/CEWES, Vicksburg - 106.9 Gflop/s

Source: http://www.wes.army.mil/ The U.S. Army Engineer Waterways Experiment Station (WES) is the principal Research, Testing, and Development facility of the U.S. Army Corps of Engineers. Part of the U.S. Department of Defense (DoD) Laboratory System, its mission is to conceive, plan, study, and execute engineering investigations and research and development studies in support of the civil and military missions of the Corps of Engineers and other Federal agencies.

WES is one of the four High Performance Computing Major Shared Resource Centers (MSRCs) centers established in 1994 as part of the DOD High Performance Computing Modernization plan. The major resource newly installed in 1996 was a Cray T3E with 256 processors.

5.4.17 Natl. Lab. High Energy Physics, Japan - 98.9 Gflop/s

Source: http://ccwww.kek.jp/kek/cc/

The National Laboratory for High Energy Physics (KEK) was established on April 1, 1971, as a national center of high energy physics open to users from universities and other institutions. KEK is the first of thirteen so called "Inter-University Research Institutes", which are a new type of institutes operated under MONBUSHO (Ministry of Education, Science and Culture). The main resource is a 80 processor Fujitsu VPP500, which was already installed in 1994.

5.4.18 Kyushu University - 94.3 Gflop/s

Source: http://www.kyushu-u.ac.jp/

The Computer Center of Kyushu University was established in 1969, and is one of the seven national computer centers serving the computation needs in all academic organizations supervised by Ministry of Education, Science and Culture, the Government of Japan. The large computation powers offered at these centers are available to professors and graduate students in all national/public/private universities and colleges in Japan. The current main computer system is a VPP700 with 56 processors installed in 1996.

5.4.19 Cornell Theory Center - 88.4 Gflop/s

Source: http://www.tc.cornell.edu/Highlights/resources.html

The computational resources at Cornell University are located at the Cornell Theory Center (CTC), one of four supercomputing centers funded by the National Science Foundation.

The CTC's resources have been used by more than 5,000 researchers in fields as diverse as aerospace engineering, economics, and epidemiology. Its staff offers technical expertise in software, visualization, and parallel processing to its users, and investigates new, highly parallel processing resources for the scientific community in order to increase the usability of these computers through systems development and through examination of techniques to improve performance. A variety of education and training programs are also offered to high school, undergraduate, and graduate students, and their professors. The Theory Center's reputation as a world-class high-performance computing resource is based on its research collaborations among academia, industry, and government researchers, integrated and highly parallel high-performance computing environment, world-class education and training programs, and powerful local, national, and international technology exchange networks.

The CTC's main resource is a 512 node IBM SP-2.

5.4.20 Tohuku University - 85.8 Gflop/s

Sources: http://www.tohoku.ac.jp and http://www.imr.tohoku.ac.jp/index-e.html and http://hh.ifs.tohoku.ac.jp/IFS/INFORMATION

The Computer Center of Tohoku University (CCTU) was founded in June 1969 as an inter-university cooperative institution to meet the computation and information processing requirements' of students and research scholars. The SX-1 super computer was introduced in 1986 to meet the demand for large scale scientific computation. In February 1989, the SX-1 was replaced by the SX-2N super computer. And in January 1994, the SX-2N was replaced by a more powerful SX-3/44R. The current architecture is quite new and unique considering the quality as well as the magnitude of the features offered. The peak vector processing rate of SX-3/44R is 25.6 Gflop/s.

5.4.21 NCSA, Univ. of Illinois - 85.0 Gflop/s

Source: http://www.ncsa.uiuc.edu/

The National Center for Supercomputing Applications (NCSA) located at the University of Illinois at Urbana-Champaign is one of four NSF supercomputer centers. It has evolved into a scientific research center built around a national services facility. NCSA is developing and implementing a national strategy to create, use, and transfer advanced computing and communication tools and information technologies. These advances serve the center's diverse set of constituencies in the areas of science, engineering, education, and business. In addition to a CM-5, NCSA installed in 1996, SGI PowerChallenge Array and Origin 2000 machines, as well as Convex SPP equipment.

5.4.22 NERSC, Lawrence Berkeley Nat. Lab. - 81.5 Gflop/s

Source: http://www.nersc.gov/

The National Energy Research Scientific Computing Center provides high-performance computing services to researchers supported by the US Department of Energy Office of Energy Research. It is a national facility supporting more than 2000 researches nationwide. It was relocated to Berkeley in 1996, and added a 128 processor Cray T3E as a major new resource. NERSC provides researchers with high-performance computing tools to tackle science's biggest and most challenging problems. In addition to providing high-end computing services, our goal is to play a major role in advancing large-scale computational science and computing technology. NERSC is also one of the four DOE high performance computing research centers.

5.4.23 Maui HPCC - 78.8 Gflop/s

Source: http://www.mhpcc.edu/general/about.mhpcc.html

The Maui High Performance Computing Center (MHPCC) was developed and is managed by a consortium led by the University of New Mexico under a cooperative agreement administered by Phillips Laboratory, United States Air Force.

This center of the University of New Mexico is designated as a Support Center for the Department of Defense High Performance Computing Modernization Program. The funding source for the cooperative agreement, awarded in September 1993, is the Air Force Phillips Laboratory, Advanced Research Projects Agency, U.S. Dept. of Defense High Performance Computing Modernization Program. Of the $21 million initial funding, approximately 70% will be spent on equipment and communications.

Its main resource is a 384 processor IBM SP-2.

5.4.24 Atmospheric Env. Serv., Dorval, Canada - 58.67 Gflop/s

Source: http://www.on.doe.ca/ and http://www.tor.ec.gc.ca/

The Atmospheric Environment Service is a national service of Environment Canada, a Canadian government department. Atmospheric Services Division promotes national quality service and delivery, sets data and environmental forecast product standards, manages warning delivery technologies, and publishes documentation. It currently has one NEC SX-4 and two SX-3 supercomputers.

5.4.25 Caltech/JPL - 69.6 Gflop/s

Source: http://olympic.jpl.nasa.gov/Testbeds/Testbeds.html
and http://www.cacr.caltech.edu/about/compute-resources.html

The Center for Advanced Computing Research (CACR) is located on the campus of the California Institute of Technology. CACR is dedicated to the pursuit of excellence in the field of high-performance computing, communication and data engineering. Major activities include carrying out large-scale scientific and engineering applications on parallel supercomputers and coordinating collaborative research projects on high-speed network technologies, distributed computing and database methodologies, and related topics. The major resources at Caltech are two Intel machines: a 512 node Paragon, and the Delta machine. A few miles away JPL (Jet Propulsion Laboratory) operates two parallel computing testbeds as part of the HPCC ESS project, and coordinates NASA's participation in the CACR. These machines are made available to NASA HPCC participants for the purpose of developing Grand Challenge Applications and software tools which enhance the usability of parallel computers. JPL has a 256 node Cray T3D.

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Chapter 6

Short description of newly featuring archictectures in the Top500

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6.1 The new list of the TOP500 systems

Since the last TOP500 [3] report the list has changed on quite some points. In this section we indicate the systems that have dropped out and we describe the architectures that have come in newly. The new list is given in Table 6.1

The changes in the list are less caused by systems that disappeared than by (variants of) systems that appear for the first time. The following systems have dropped from the list:

– Fujitsu VP2000.
– HP/Convex C4/XA.
– Intel iPSC/860.
– Kendall Square KSR-1.

The first two systems are vector processors. From these the Fujitsu VP2000 has been replaced by the newer VX systems that newly appear in the TOP500 list. The Fujitsu VP2000, Intel iPSC/860, and Kendall Square KSR-1 are not marketed anymore. The technology in the last two systems and their distribution is such that they could not hold their place anymore within the TOP500. For the description of the various types of architectures one is referred to [2] or the

Table 6.1: *Machines are ordered by their frequency of occurrence in the TOP500 list. This list is ordered by* R_{max} *is the maximum observed performance for the machine entry and* R_{peak} *is the theoretical peak performance for each system type. The unit is Gflop/s. The systems that appear for the first time in the table are marked with a *.*

	N	R_{max}	R_{peak}	first	median	last
SP2	117	1309.5	1825.9	14	271	490
Cray C90	41	464.8	518.1	122	193	495
PC 100 - 2MB*	39	214.8	283.9	222	409	484
T3D	36	800.1	1197.6	7	143	312
T3E*	23	745.5	1166.4	11	141	321
Pow Chal 100*	22	130.2	197.3	336	364	418
Cray T90	19	179.9	260.4	54	298	396
SX4*	17	560.6	588.0	17	73	256
VPP500	17	751.3	921.0	2	128	403
CM5	15	283.1	620.5	21	175	398
VPP300/VPP700*	14	375.6	415.8	9	131	306
Paragon	12	253.1	366.1	4	201	364
Jedi90*	12	68.9	76.0	367	377	435
PC-Array 90	11	93.3	141.1	95	288	493
SX3	11	146.0	162.8	73	218	448
SPP2000*	9	70.0	103.5	238	242	246
S-3800	8	157.5	176.0	56	123	276
SP2 - 77MHz	8	77.8	108.1	88	237	406
SPP1600*	8	51.0	73.0	188	360	412
PC-Array 75	7	59.2	90.6	86	283	462
AlphaServer*	6	32.3	47.6	296	411	446
GC/PP	6	37.0	71.7	230	363	430
ORIGIN 2000*	6	43.4	96.7	211	304	460
Paragon SMP	6	307.3	371.5	5	83	178
CM200	5	34.6	70.0	196	344	444
Pow Chal 90	5	23.1	32.4	496	498	500
CS	4	20.0	97.8	438	440	441
SR2201*	4	263.0	364.0	3	89	119
SPP1000	3	17.2	35.2	324	378	485
CM2	2	10.4	28.0	431	432	432
SPP1200	2	13.2	26.9	264	324	384
CM5E	1	7.7	20.0	247	247	247
CP-PACS*	1	368.2	614.0	1	1	1
KSR2	1	4.8	6.4	491	491	491
PC-Array 102	1	8.2	28.1	221	221	221
SP1	1	4.8	16.0	486	486	486
Total	500	7987.4	11218			

experimental WWW version at
http://www.netlib.org/utk/papers/advanced-computers/paper.html.

In this section we only describe the machines that appear for the first time in Table 6.1 in alphabetical order. Apart from the systems parameter list that is given for each system also the values of R_{peak} and R_{max} as available from [1] are quoted together with the number of nodes associated with these values. The reason that the system parameter list is not sufficient is that the maximal theoretical peak performance is given for the maximal configuration of a system. Such a system may not actually exist.

6.1.1 The CP-PACS (Hitachi&Univ. of Tsukuba).

Machine type: RISC-based distributed-memory multi-processor.
Models: CP-PACS.
Operating system: HP-UX, based on OSF/1 AD microkernel.
Connection structure: 3-D Hypercrossbar.
Compilers: Fortran 90, C, C++.
Information Web page: www.rccp.tsukuba.ac.jp/
System parameters:

Model	CP-PACS
Clock cycle	6.6 ns
Theor. peak performance:	
Per proc. (64-bit)	300 Mflop/s
Maximal (64-bit)	614 Gflop/s
Main memory	≤128 GB
Memory/node	≤ 64 MB
Communication bandwidth	300 GB/s
No. of processors	4–2048

Performance:
R_{peak} (2048 proc.) 614.4 Gflop/s
R_{max} (2048 proc.) 368.2 Gflop/s

The CP-PACS is a research machine jointly built by Hitachi and the University of Tsukuba. CP-PACS stands for Computational Physics by Parallel Array Computer Systems. It is a dedicated machine which will be used for the Computational Physics problems addressed at Tsukuba University. These problems include the areas of particle physics, astrophysics, and the physics of condensed matter.

The basic processor employed is a customised HP PA-RISC 1.1 processor which is produced by Hitachi under licence. The machine uses the same pseudo-vector processing (PVP-SW) enhancements that are implemented in the Hitachi SR2201 (see section 6.1.6) to overcome the adverse effects of cache misses. The PVP allows for upward compatibility with future PA-RISC procrssors.

The system also has the same 3-D crossbar as employed in the SR2201. This means that messages can be routed to any destination in the system in at most three hops.

As in the SR2201 it is possible to communicate between processors by remote DMA instructions as also found in the Cray T3E, the NEC Cenju-3, and the Meiko CS-2 (see [2]).

6.1.2 The Cray Research Inc. T3E.

Machine type: RISC-based distributed-memory multi-processor.
Models: T3E.
Operating system: UNICOS MAX (micro-kernel Unix).
Connection structure: 3-D Torus.
Compilers: CFT77_M (Fortran 77 with extensions), C.
Vendors information Web page: `www.cray.com/PUBLIC/T3E/`.

System parameters:

Model	T3E
Clock cycle	3.3 ns
Theor. peak performance	
Per proc. (64-bit)	600 Mflop/s
Maximal (64-bit)	1229 Gflop/s
Main memory	≤4096 GB
Memory/node	≤ 2 GB
Communication bandwidth	300 MB/s
No. of processors	16–2048

Performance:

R_{peak} (256 proc.)	153.6 Gflop/s
R_{max} (256 proc.)	93.2 Gflop/s

The T3E is the second generation of DM-MIMD systems from CRI. Lexically, it follows in name after its predecessor T3D which name referred to its connection structure: a 3-D torus. In this respect it has still the same interconnection structure as the T3D. In many other respects, however, there are quite some differences. A first and important difference is that no front-end system is required anymore (although it is still possible to connect to a Cray T90). The systems up to 128 processors are air-cooled. The larger ones, from 256–2,048 processors, are liquid cooled.

The T3E uses the DEC Alpha 21164 RISC processor for its computational tasks just like the Avalon A12. Cray stresses, however, that the processors are encapsulated in such a way that they can be exchanged easily for any other (faster) processor as soon as this would be available without affecting the macro-architecture of the system.

Each node in the system contains one processing element (PE) which in turn contains a CPU, memory, and a communication engine that takes care of communication between PEs. The bandwidth between nodes is quite high: 300 MB/s. Like the T3D, the T3E has hardware support for fast synchronisation. E.g., barrier synchronisation takes only one cycle per check.

In the microarchitecture most changes have taken place with the transition from the T3D to the T3E. First, there is only one CPU per node instead of two, which removes a source of asymmetry between processors. Second, the new node processor has a 96 KB 3-way set-associative secondary cache which may relieve some of the problems of data fetching that were present in the T3D where only a primary cache was present. Third, the Block Transfer Engine has been replaced by a set of E-registers that are believed to be much more flexible and at least removes some odd restrictions on the size of shared arrays and the number of processes when using Cray-specific PVM. An interesting additional feature is the availability of 32 contexts per processor which opens the door for multiprocessing.

In the T3D all I/O had to be handled by the front-end, a system at least from the Cray Y-MPE class. In the T3E distributed I/O is present. For every 8 PEs an I/O channel can be configured in the air-cooled systems and 1 I/O channel per 16 nodes in the liquid-cooled systems. The maximum bandwidth for a channel is about 1 GB/s, the actual speed will be in the order of 700 MB/s.

The T3E supports various programming models. Apart from PVM 3.x and MPI for message passing and HPF for data distribution, a Cray proprietary work sharing model, called CRAFT, can be employed. Cray views HPF and Fortran 90 array syntax as subsets of the CRAFT model. Within this model data can be exchanged implicitly, thus looking effectively as a shared-memory system to the user. As several other vendors, Cray has extended/altered the implementation of PVM to enhance the communication performance. For small messages this can give an improvement of a factor 3 (20–25 μs instead of 70–80 μs). For SPMD programs channel send/receive functions can be used which reduces the communication time to 4–5 μs.

6.1.3 The Cray Research Inc. Cray J90-series.

Machine type: Shared-memory multi-vectorprocessor.
Models: Cray J90.
Operating system: UNICOS (Cray Unix variant).
Compilers: Fortran, C, C++, Pascal, ADA.
Vendor information Web page: `www.cray.com`.

System parameters:

Model	Cray J90
Clock cycle	10 ns
Theor. peak performance	
Per processor	200 Mflop/s
Maximal	3.2 Gflop/s
Main memory	≤4 GB
Memory bandwidth	
Single proc. bandwidth	1.6 GB/s
No. of processors	4–32

Performance:

R_{peak} (32 proc.)	6.4 Gflop/s
R_{max} (32 proc.)	5.8 Gflop/s

The J90 are multi-headed vector processors. The Cray J90 series is the entry level model marketed by CRI since September 1994. The J90 series is based on CMOS technology which has a low power consumption (all J90s are air cooled) and low production costs. The machine is binary compatible with the high-end systems. It has one multiply and add vector pipe set per CPU at a clock cycle of 10 ns which results in a theoretical peak performance of 200 Mflop/s. Furthermore, a cache has been added to speed up scalar processing. It is interesting to note that the strategy of using more (four) multi-functional pipes as in the predecessor, the Y-MP EL has been left again to return to the classic two-pipe/CPU design. Unlike the Cray T90 systems Cray J90 series has separate scalar processors.

The CPU/memory bandwidth of the J90 series is 16 bytes/cycle. This is regrettably less than was available in its predecessors, Y-MP EL machines, and in some cases it might adversely affect the efficiency.

6.1.4 The Digital Equipment Corp. AlphaServer.

Machine type: RISC-based distributed-memory multi-processor.
Models: AlphaServer 8400 5/400.
Operating system: Digital Unix (DEC's flavour of Unix).
Connection structure: Crossbar.
Compilers: Fortran 77, HPF, C, C++.
Vendors information Web page: `www.digital.com:80/info/hpc`.

System parameters:

Model	8400
Clock cycle	2.3 ns
Theor. peak performance	
Per proc. (64-bit)	875 Mflop/s
Maximal (64-bit)	10.5 Gflop/s
Main memory	≤14 GB
Memory bandwidth	
Processor/memory	1.6 GB/s
No. of processors	12

Performance:
R_{peak} (12 proc.) 10.5 Gflop/s
R_{max} (12 proc.) 6.7 Gflop/s

The AlphaServers are symmetric multi-processing systems which are based on the Alpha 21164 processor. The 8400 model can accomodate 12 processors. The 8400 can house 14 GB of memory. The amount of CPUs and memory is not independent. For instance, the 8400 has 9 system slots. One of these is reserved for I/O and one will have to contain at least one CPU module which can contain 1 or 2 CPUs. From the remaining slots 6 can be used either for memory or for a CPU module. So, one has to choose for either higher computational power or for more memory. This can potentially be a problem for large applications that require both.

AlphaServers can be clustered using a PCI bus Memory channel for interconnection of the systems. The systems need not be of the same model. The bandwidth of this interconnect is 100 MB/s. Eight systems can be coupled in this way. To support this kind of cluster computing, HPF and optimised versions of PVM and MPI are available.

6.1.5 The Fujitsu VPP300/700 series.

Machine type: Distributed-memory vector multi-processor.
Models: VX, VPP300, VPP700.
Operating system: UXP/VPP (a V5.4 based variant of Unix).
Connection structure: Distributed crossbar.
Compilers: Fortran 90/VP (Fortran 90 Vector compiler), Fortran 90/VPP (Fortran 90 Vector Parallel compiler),C/VP (C Vector compiler), C, C++.
Vendors information Web page:
`www.fujitsu.co.jp/hypertext/Products/Info_process/hpc/vx-e/`.

System parameters:

Model	VX	VPP300	VPP700
Clock cycle	7/10 ns	7/10 ns	7 ns
Theor. peak performance			
Per proc. (64-bit)	1.6/2.2 Gflop/s	1.6/2.2 Gflop/s	2.2 Gflop/s
Maximal (64-bit)	6.4/8.8 Gflop/s	25.6/35.2 Gflop/s	563.2 Gflop/s
Main memory	≤8 GB	≤32 GB	≤512 GB
Memory/node	≤2 GB	≤2 GB	≤2 GB
Memory bandwidth			
Memory banwidth/proc.	12.8/18.2 GB/s	12.8/18.2 GB/s	18.2 GB/s
Communication bandwidth	400/570 MB/s		
No. of processors	1–4	1–16	8–256

Performance:

R_{peak} (4/16/56 proc.)	8.8 Gflop/s	35.2 Gflop/s	123.2 Gflop/s
R_{max} (4/16/56 proc.)	8.6 Gflop/s	34.1 Gflop/s	94.3 Gflop/s

The VPP300 is a sucessor to the earlier VPP500. It is a much cheaper CMOS implementation of its predecessor with some important differences. First, no VPX200 front-end system is required anymore. Second, the crossbar that is used to connect the vector nodes is distributed. Therefore, the cost of a system is scalable: one does not need to buy a complete enclosure with the full crossbar for only a few nodes. The VX series is in fact a smaller version of the VPP300 with a maximum of 4 processors. Both the VX machines and the larger VPP300 systems are air-cooled. The systems are marketed either with a 10 ns or a 7 ns clock.

At this moment the VPP300 is officially only available with 16 processors connected by a direct crossbar. However, it is presumed that an announcement of larger systems will be made in the first quarter of 1996 in which multiple 16-processor machines are connected by a second level crossbar.

The architecture of the VPP300 nodes is almost identical to that of the VPP500: Each node, called a Processing Element (PE) in the system is a powerful (2.2 Gflop/s peak speed with a 7 ns clock) vector processor in its own right. The vector processor is complemented by a RISC scalar processor with a peak speed of 200 or 285 Mflop/s dependent on the clock speed. The scalar instruction format is 64 bits wide and may cause the execution of three operations in parallel. Each PE has a memory of up to 2 GB while a PE communicates with its fellow PEs at a point-to-point speed of 400 or 570 MB/s. This communication is cared for by separate Data Transfer Units (DTUs). To enhance the communication efficiency, the DTU has various transfer modes like contiguous, stride, sub array, and indirect access. Also translation of logical to physical PE-ids and from Logical in-PE address to real address are handled by the DTUs. When synchronisation is required each PE can set its corresponding bit in the SR. The value of the SR is broadcast to all PEs and synchronisation has occurred if the

SR has all its bits set for the relevant PEs. This method is comparable to the use of synchronisation registers in shared-memory vector processors and much faster than synchronising via memory.

The Fortran compiler that comes with the VPP300 has extensions that enable data decomposition by compiler directives. This evades in many cases restructuring of the code. The directives are different from those as defined in the High Performance Fortran Proposal but it should be easy to adapt them. Furthermore, it is possible to define parallel regions, barriers, etc., via directives, while there are several intrinsic functions to enquire about the number of processors and to execute `POST/WAIT` commands. Furthermore, also a message passing programming style is possible by using the PVM or PARMACS communication libraries that are available.

The VPP700 is a logical extension of the Fujitsu VPP300. While the processors in the latter machine are connected by a full crossbar, the maximum configuration of a VPP700 consists of 16 clusters of 16 processors connected by a level-2 crossbar. So, a fully configured VPP700 consists in fact of 16 full VPP300s. Because the diameter of the network is 2 (for the larger configurations) instead of 1 as in the VPP300, the communication time between processors will be slightly larger. At the moment this worst case increase is not exactly known to the author.

Of course the software for the VPP700 and the VPP300 is exactly the same and the systems can run each others executables.

6.1.6 The Hitachi SR2201 series.

Machine type: RISC-based distributed memory multi-processor.
Models: SR2201.
Operating system: HI-UX/MPP (Micro kernel Mach 3.0).
Connection structure: Hyper crossbar.
Compilers: Fortran 77, Fortran 90, Parallel Fortran, HPF, C, C++.
System parameters:

Model	SR2201
Clock cycle	6.7 ns
Theor. peak performance	
Per proc. (64-bit)	300 Mflop/s
Maximal (64-bit)	307 Gflop/s
Main memory	≤256 GB
Memory/node	≤256 MB
Communication bandwidth	300 MB/s
No. of processors	32–1024

Performance:

R_{peak} (1024 proc.)	307.0 Gflop/s
R_{max} (1024 proc.)	220.4 Gflop/s

The SR2201 is the second generation of distributed memory parallel systems of Hitachi. The basic node processor is again an Hitachi implementation of the PA-RISC architecture of HP running at a clock cycle of 6.7 ns. However, in contrast with its predecessor, the SR2001, in the SR2201 the node processors are somewhat modified to allow for "pseudo vector processing" (both hardware and instructions). This means that for operations on long vectors one does not have to care about the detrimental effects of cache misses that often ruin the performance of RISC processors unless code is carefully blocked and unrolled. First experiments have shown that this idea seems to work quite well. The system supports distributed I/O with a possibility to connect disks to every node.

As in the earlier SR2001, the connection structure is a hyper (3-D) crossbar which connects all nodes directly at high speed (300 MB/s point-to-point). In February 1996 two 1024-node systems will be installed at the Universities of Tokyo and Tsukuba respectively.

Like in some other systems as the Cray T3E and the Meiko CS-2, and the NEC Cenju-3 (see [2]), one is able to directly access the memories of remote processors. Together with the very fast hardware-based barrier synchronisation this should allow for writing distributed programs with very low parallelisation overhead.

The following software products will be supported in addition to those already mentioned above: PVM, MPI, PARMACS, Linda, Express, FORGE90, and PARALLELWARE. In addition a numerical libraries (MATRIX/MPP, MATRIX/MPP/SSS) will be offered. These libraries support basic linear algebra operations with dense and band matrices, Fast Fourier Transformations, and skyline solvers.

6.1.7 The HP/Convex Exemplar SPP-1600.

Machine type: RISC-based distributed-memory multi-processor.
Models: SPP-1600.
Operating system: SPP-UX, based on OSF/1 AD microkernel.
Connection structure: Ring.
Compilers: Fortran, C.

System parameters:

Model	SPP-1600
Clock cycle	8.3 ns
Theor. peak performance:	
Per proc. (64-bit)	240 Mflop/s
Maximal (64-bit)	30.7 Gflop/s
Main memory	≤32 GB
Memory/node	≤256 MB
Communication bandwidth:	
aggregate (see remarks)	16 GB/s, 4GB/s
No. of processors	4–128

Performance:

R_{peak}(64 proc.)	15.4 Gflop/s
R_{max}(64 proc.)	10.4 Gflop/s

The SPP-1600 is the successor of the SPP-1200 and structurally there are no differences with this machine on the macro level. However, the local caches of the CPUs are significantly larger than those in the SPP-1200. This leads in many cases to a higher overall performance of applications. Up to 8 PA-RISC 7200 processors can be placed in what is called a *hypernode* by Convex. A maximal system consists of 16 nodes, i.e., 128 processors.

Within each hypernode up to 2 GB of memory can be accommodated which can be reached by the local processors via a crossbar with an aggregate bandwidth of 16 GB/s. The hypernodes in turn are connected to each other by a crossbar with an aggregate bandwidth of 4 GB/s. So, the system concept is somewhat hybrid: within a hypernode the machine is effectively a shared-memory system, while between hypernodes it is a distributed memory system. Each node supports local I/O, while external global I/O can be done at an aggregate rate of 4 GB/s.

The Exemplar programming environment complements the SPP-1600 at the software side. This environment includes a message passing programming model (PVM) and a virtual shared memory model which allows the user to have shared-memory view of the system.

6.1.8 The HP/Convex Exemplar SPP-2000S.

Machine type: RISC-based shared-memory multi-processor.
Models: SPP-2000S.
Operating system: SPP-UX, based on OSF/1 AD microkernel.
Connection structure: Full crossbar.
Compilers: Fortran, C.

System parameters:

Model	SPP-2000S
Clock cycle	5.55 ns
Theor. peak performance:	
Per proc. (64-bit)	720 Mflop/s
Maximal (64-bit)	30.7 Gflop/s
Main memory	≤16 GB
Memory/node	≤1 GB
Communication bandwidth:	
aggregate (see remarks)	15.4 GB/s
No. of processors	4–16

Performance:

R_{peak}(16 proc.)	11.5 Gflop/s
R_{max}(16 proc.)	7.8 Gflop/s

The SPP-2000S is one system from the family the successors of the SPP-1600 (the larger SPP-2000X systems will be discussed in the next version of [2]). There are significant differences with respect to the preceding SPP-1600 generation. The SPP-2000S is a shared memory machine connecting its maximally 16 PA-RISC 8000 processors by a crossbar. Each of the processors have a peak performance of 720 Mflop/s and because the processors feature out-of-order execution of instructions it may be expected that memory latency effects can be evaded or diminished in a good many cases. This should make the impact of cache misses much less severe. Data and instruction caches are large (1 MB both) which also will help in minimising cache misses.

One SPP-2000S can be viewed as the successor of a hypernode in the earlier SPP-1200/SPP-1600 systems (see above). As such the number of processors within a hypernode has doubled. Also the amount of memory per system has increased 8-fold from 8×256 MB to 16×1 GB. The internal aggregate bandwidth is 15.36 GB/s. I/O can be done at an aggregate rate of 960 MB/s.

The Exemplar programming environment as was available for the SPP-1200/SPP-1600 carries over to the SPP-2000S without changes. This environment includes a message passing programming model (PVM) and a virtual shared memory model which allows the user to have shared-memory view of the system. Of course the shared memory model is not surprising for a symmetrical multiprocessor machine like the SPP-2000S but it is still valid in the SPP-2000X systems which effectively clusters four SPP-2000S systems.

6.1.9 The NEC SX-4.

Machine type: Distributed-memory multi-vector processor.
Models: SX-4C, SX-4.
Operating system: EWS-UX/V (Unix variant based on Unix System V.4).
Connection structure: Multi-stage crossbar (see Remarks).
Compilers: Fortran 77, Fortran 90, HPF, ANSI C, C++.
Vendors information Web page: `www.nec.co.jp/english/product/computer/sx`.

System parameters:

Model	SX-4Ce	SX-4C	SX-4
Clock cycle	8 ns	8 ns	8 ns
Theor. peak performance			
Per Proc. (64 bits)	1 Gflop/s	2 Gflop/s	2 Gflop/s
Single frame:			
Maximal (64 bits)	1 Gflop/s	8 Gflop/s	64 Gflop/s
Multi frame: Maximal (64 bits)	—	—	1 Tflop/s
Main memory	< 2 GB	< 2 GB	< 128 GB
Communication bandwidth			
(see Remarks)	—	—	—
No. of processors	1	1–4	4–512

Performance:

R_{peak}(32 proc.)	64.0 Gflop/s
R_{max}(32 proc.)	60.6 Gflop/s

The SX-4 series is comprised of a large range of machine sizes. The smallest of these is the SX-4Ce. This machine has one CPU housing 4 vector pipe sets. As the clock cycle is 8 ns and each pipe set is able to deliver 2 floating-point results per cycle, the total maximum performance is 1 Gflop/s for this system. In all other systems the replication factor of the pipe sets is 8 which doubles the speed per CPU to a maximum of 2 Gflop/s. The bandwidth from memory to the CPUs is 16 64-bit words per cycle per CPU. With a replication factor of 8 this is enough to provide two operands per pipe set but it is not sufficient to transport the results back to the memory at the same time. So, some trade-offs with the re-use of operands have to be made to attain the peak performance.

The technology used is CMOS. This lowers the fabrication costs and the power consumption appreciably (the same approach is being used in the Fujitsu VPP300, see 3.4.6) and all models are air cooled. This enables the placement of up to 32 CPUs in one frame (for the SX-4 model). Beyond this maximum single frame system, it is possible to couple up to 16 frames together to form a distributed memory system. This is equivalent to the PowerChallenge Array idea (see 3.3.6). There are two ways to couple the SX-4 frames: NEC provides a full crossbar, the so-called IXS crossbar, to connect the various frames together at a speed of 16 GB/s for point-to-point out-of-frame communication (128 GB/s bi-sectional bandwidth for a maximum configuration). In addition, a HiPPI interface is available for interframe communication at lower cost and speed.

For distributed computing there is an HPF compiler and for message passing an optimised MPI (MPI/SX) is available. The SX-4 is the only system that supports three floating-point number systems: IBM-compatible, Cray-compatible, and the IEEE 754 standard.

6.1.10 Silicon Graphics PowerChallenge R10000

Machine type: Shared-memory multi-processor.
Models: PowerChallenge R10000.
Operating system: IRIX (SGI's Unix variant).
Compilers: Fortran 77, C, C++ , Pascal.

System parameters:

Model	Model XL R10000
Clock cycle	10 ns
Theor. peak performance:	
Per proc. (64-bit)	400 Mflop/s
Maximal (64-bit)	14.4 Gflop/s
Main memory	16 GB
Memory bandwidth:	
Proc. to cache/proc.	1.2 GB/s
Main memory/cache	1.2 GB/s
No. of processors	36

Performance:

R_{peak}(24 proc.)	9.4 Gflop/s
R_{max}(24 proc.)	6.9 Gflop/s

The PowerChallenge XL system was shipped with the R10000 processor since the autumn of 1995. The macrostructure of the system was not changed with regard to the earlier R8000 based machines, be it that one processor board can house four processors instead of two. Therefore the maximum number of processors per system could double to 36 processors.

Internally data is transported from the main memory to the CPUs by the so-called POWERpath-2 bus. It is 256 bits wide and has a bandwidth of 1.2 GB/s. This is very fast as busses go but even then the data rates that are needed by the CPUs cannot possibly be fulfilled when no special provisions would exist. These provisions are present in the form of large data and instruction caches for each of the CPUs.

Because the R10000 features out-of-order execution and has a lower clock cycle than the R8000 processors the traffic on the central bus will in many cases become a bottleneck because the data traffic was already problematic for fully configured R8000 systems. Such bandwidth problems have been addressed in the newer SGI Origin 2000 systems (see below).

Parallelisation is done either automatically by the (Fortran or C) compiler or explicitly by the user, mainly through the use of directives. As synchronisation, etc., has to be done via memory the parallelisation overhead is fairly large.

6.1.11 Silicon Graphics Origin 2000.

Machine type: Shared-memory multi-processor.

Models: Origin 2000.
Connection structure: Crossbar/hypercube (see below).
Operating system: IRIX (SGI's Unix variant).
Compilers: Fortran 77, C, C++ , Pascal.

System parameters:

Model	Origin 2000
Clock cycle	10 ns
Theor. peak performance:	
Per proc. (64-bit)	400 Mflop/s
Maximal (64-bit)	51.2 Gflop/s
Main memory	256 GB
Memory bandwidth:	
Aggregate peak	102 GB/s
Bisectional	82 GB/s
No. of processors	≤128

Performance:

R_{peak}(128 proc., 10.5 ns clock)	49.9 Gflop/s
R_{max}(128 proc.)	8.8 Gflop/s

The Origin 2000 is the newest high-end parallel server marketed by SGI. The basic processor is the earlier introduced R10000. A maximum of 128 processors can be configured in the system. The interconnection is somewhat hybrid: 4 CPUs on two node cards can communicate directly with the memory partitions of each other via the hub, a 4-ported non-blocking crossbar. Hubs can be coupled to other hubs in a hypercube fashion.

The structure of the machine makes it somewhat difficult to classify: SGI prefers to call it a shared-memory non-uniform memory architecture system. The memory is physically distributed over the node boards but the system has one system image. Because of the structure of the system, the bisectional bandwidth of the system remains constant from 4 processors on: 82 GB/s. This is a large improvement over the earlier PowerChallenge systems which possessed a 1.2 GB/s bus.

Parallelisation is done either automatically by the (Fortran or C) compiler or explicitly by the user, mainly through the use of directives. As synchronisation, etc., has to be done via memory. This may the cause potentially a fairly large parallelisation overhead. Also a message passing model is allowed on the Origin 2000 using the optimised SGI versions of PVM and MPI. Programs implemented in this way will possibly run very efficiently on the system.

A nice feature of the new system is that it may migrate processes to nodes that should satisfy the data requests of these processes. So, the overhead involved in transferring data across the machine are minimised in this way. The technique is reminiscent of the late Kendall Square Systems although in these systems the data were moved to the active process.

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Chapter 7

High-Performance Computing in Industry

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Abstract

In 1993, a list of the top 500 supercomputer sites worldwide was made available for the first time. Since then, the TOP500 list has been published twice a year. The list allows a detailed and well-founded analysis of the state of high-performance computing (HPC). This article summarizes the recent trends in application areas of HPC systems, focusing on the increase in industrial installations and applications. A detailed analysis with respect to the geographical distribution, the market share of manufacturers and the architectures used for different application areas is presented.

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7.1 Introduction

Within the TOP500 project we are collecting information about the 500 most powerful computer systems, ranked by LINPACK performance. Since June 1993 we have been publishing the TOP500 lists twice a year [1]. Because these lists record a variety of different data, they furnish an excellent basis for studying the high-performance computing (HPC) market (see, for example, [3], [4], [5] and [5]). Moreover, such lists can provide valuable insights about changes over time; see, for example, a study on the technologies used in HPC systems [6].

In this article, we analyze the type of customer and applications of the HPC systems in the TOP500 since 1993. During this time there has been a strong growth in the number of industrial users, and a comparable increase in the number of computer installations at industrial sites. One reason for this increase is that companies such as IBM and SGI have offered binary-compatible systems, from single workstations up to full-scale parallel systems. These companies thus have been able to sell a large number of systems to commercial customers; in turn, their systems often are selected for new supercomputer application areas. Another reason for the increase in industrial installations is that industrial customers have gained the needed experience to use medium-sized parallel systems (with up to 128 processors, and in some cases even more) and are now pressuring their companies to purchase high-performance supercomputers.

The variety of applications areas represented in the TOP500 has also been increasing during this time. The most important examples of new areas are database applications and image processing.

7.2 Performance Measure

For practical reasons we are using the LINPACK [2] performance for all systems listed in the TOP500 regardless of the application. LINPACK provides an adequate unit of measurement if one is interested in floating-point performance of computer systems. It is certainly not adequate for systems used for database applications, however. More useful benchmarks such as the TPC benchmarks are available for such applications[5]. By using the LINPACK benchmark, we miss all "pure" database systems, such as those from Teradata or Tandem, since no adequate LINPACK performance values are available for them (most likely, even a Fortran compiler would not be available). Therefore, we cannot produce statistics for the different vendors in the database market. Nevertheless, since we can track a reasonable sample of this market, we can see the fundamental trends, and we can compare the importance of these new applications for parallel systems with the more traditional numerically intensive applications.

[5]http://www.tpc.org/

7.3 Type of Customer

The year 1995 was a remarkable one for the TOP500 in several respects. In addition to new technologies used for HPC systems [6], there were considerable changes in the distribution of the systems in the TOP500 for the different types of customer (academic sites, research labs, industrial/commercial users, vendor installations, and confidential sites) (see Fig. 7.1).

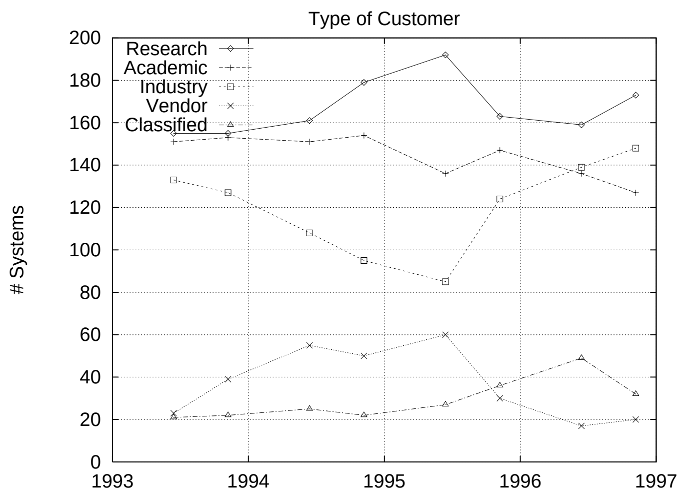

Figure 7.1: The number of systems on the different types of customers over time.

Until June 1995, the major trend seen in the TOP500 data was a steady decrease of industrial customers, matched by an increase in the number of government-funded research sites. This trend reflects the influence of the different governmental HPC programs that enabled research sites to buy parallel systems, especially systems with distributed memory. Industry was understandably reluctant to follow this step, since systems with distributed memory have often been far from mature or stable. Hence, industrial customers stayed with their older vector systems, which gradually dropped off the TOP500 list because of low performance.

Beginning in 1994, however, companies such as SGI, Digital, and Sun started to sell symmetrical multiprocessor (SMP) models of their major workstation families. From the very beginning, these systems were popular with industrial customers because of the maturity of these architectures and their superior price/performance ratio. At the same time, IBM SP2 systems started to appear at a reasonable number of industrial sites. While the SP initially was sold for numerically intensive applications, the system began selling successfully to a larger market, including database applications, in the second half of 1995. Subsequently, the number of industrial customers listed in the TOP500 increased from 85, or 17%, in June 1995 to about 148, or 29.6%, in November 1996.

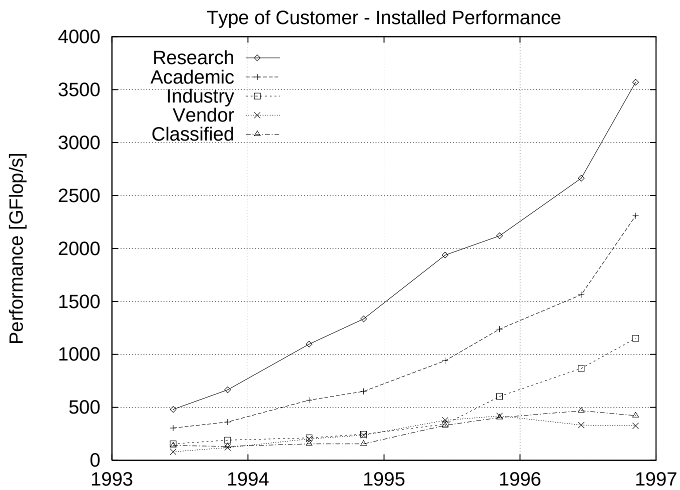

Figure 7.2: The accumulated performance of the different types of customers over time.

Figure 7.2 shows that the increase in the number of systems installed at industrial sites is matched by a similar increase in the installed accumulated performance. The relative share of industrial sites rose from 8.7% in June 1995 to 14.8% in November 1996. Thus, even though industrial systems are typically smaller than systems at research laboratories and universities, their average performance and size are growing at the same rate as at research installations. The strong increase in the number of processors in systems at industrial sites is another major reason for the rise of industrial sites in the TOP500. The industry is ready to use bigger parallel systems than in the past.

7.4 Geographical Distribution of Industrial HPC Systems

The United States clearly leads the world, both as producer and as consumer of high-performance computers [6]. Analyzing the geographical distribution of

Table 7.1: Geographical distribution of type of customer as of November 1996.

TOP500 Statistics — Number of Systems Installed					
	U.S.	Europe	Japan	Others	Total
Research	81	52	39	1	173
Academic	44	44	28	11	127
Industry	104	31	9	4	148
Classified	28	3		1	32
Vendor	14	2	4		20
Total	271	132	80	17	500

Table 7.2: Geographical distribution of the accumulated performance for the different types of customers as of November 1996.

TOP500 Statistics — Installed R_{max} [Gflop/s]					
	U.S.	Europe	Japan	Others	Total
Research	1622.0	940.7	1105.8	6.6	3675.1
Academic	586.2	500.2	1171.1	111.0	2368.5
Industry	801.7	220.3	119.7	25.9	1167.6
Classified	362.7	53.4		5.9	422.0
Vendor	218.9	24.2	111.2		354.2
Total	3591.5	1738.8	2507.8	149.3	7987.4

the customers in the TOP500 we see that this leadership pattern is reflected in industrial siting of high-performance computers. As Table 7.1 indicates, in the United States, 38% of the systems are installed at industrial sites compared with 23% in Europe and only 11% in Japan. In the United States, there are more systems at industrial sites than at governmental research labs or at academic sites. While having installed 54% of all systems worldwide, the United States holds 70% of all industrial sites.

Table 7.2 shows that the United States is also a market leader for the accumulated installed performance; where the United States has 45% of the overall performance and 69% of the total industrial performance worldwide.

7.5 Distribution of Industrial HPC Systems by Manufacturer

SGI with it's new subsidiary Cray Research is the clear leader market leader with respect to the number of systems (see Table 7.3) and the accumulated installed performance (see Table 7.4). Focusing on the industrial market segment we see

Table 7.3: Geographical distribution of type of customer as of November 1996.

TOP500 Statistics — Number of Systems Installed						
	Research	Academic	Industry	Classified	Vendor	Total
SGI/Cray	80	50	58	24	10	222
Cray only	62	23	23	15	8	131
SGI only	18	27	35	9	2	91
IBM	28	29	67	1	1	126
Fujitsu	12	14	2		3	31
NEC	20	3	4		1	28
TMC	8	5	6	4		23
Hewlett-Packard	3	9	7	1	2	22
Intel	12	4	1	1		18
Hitachi	4	6	1		2	13
Others	6	7	2	1	1	17
Total	173	127	148	32	20	500

however that IBM is ahead of SGI/Cray with respect to the number of systems as with the accumulated installed performance. The major reason for this is IBMs success in selling the SP2 system as parallel database system.

7.6 Application Areas

For research sites or academic installations, it is often difficult—if not impossible—to specify a single dominant application. The situation is different for industrial installations, however, where systems are often dedicated to specialized tasks or even to single major application programs. Since the very beginning of the TOP500 project, we have tried to record the major application area for the industrial systems in the list. We have managed to track the application area for almost 90% of the industrial systems over time.

Since June 1995 we see many systems involved in new application areas entering the list. Figure 7.3 shows the total numbers of all industrial systems

Table 7.4: Geographical distribution of the accumulated performance for the different types of customers as of November 1996.

TOP500 Statistics — Installed R_{max} [Gflop/s]						
	Research	Academic	Industry	Classified	Vendor	Total
SGI/Cray	2488.0	607.1	452.3	332.7	110.5	2831.5
Cray only	1192.8	449.9	262.7	265.7	88.1	2259.2
SGI only	136.0	157.2	189.6	67.0	22.4	572.3
IBM	456.5	331.9	500.9	14.4	88.4	1392.1
Fujitsu	728.0	357.5	14.2		27.2	1126.9
NEC	428.6	144.5	72.9		60.7	706.6
TMC	125.2	98.6	53.8	58.2		335.8
Hewlett-Packard	17.1	60.1	50.6	5.5	18.2	151.4
Intel	496.2	52.1	5.8	6.3		560.4
Hitachi	64.6	674.4	7.1		42.6	788.7
Others	30.1	42.3	10.1	5.0	6.7	94.1
Total	3675.1	2368.5	1167.6	422.0	354.2	7987.4

which is made up of three components: traditional engineering applications, new emerging applications, and unknown application areas. Figure 7.4 shows the accumulated performance for these components. It is evident that the new emerging applications show a strong rise since mid 1995 in the number of systems and in the installed performance as well.

In 1993, the applications in industry typically were numerically-intensive applications, for example,

- geophysics and oil applications,
- automotive applications,
- chemical and pharmaceutical studies,
- aerospace studies,
- electronics, and
- other engineering including energy research, mechanical engineering etc.

The share of these areas from 1993 to 1996 remained fairly constant over time, as can be seen in Figure 7.5 and Figure 7.6. The possible exception was the electronics industry: the number of recorded systems continuously decreased from 14 in June 1993 to 5 in November 1996 and the installed performance

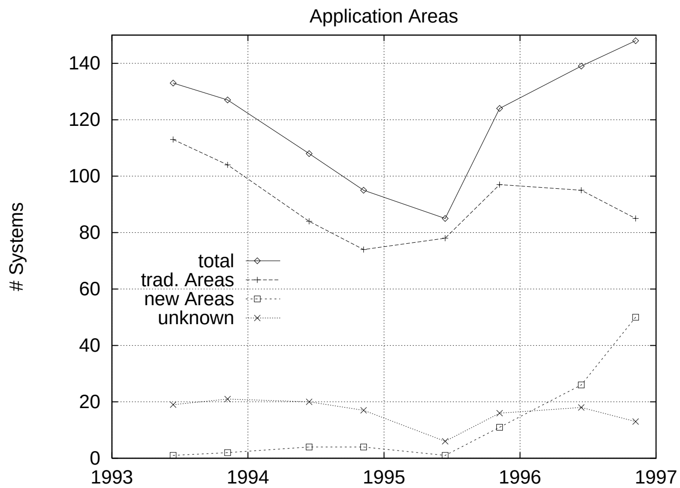

Figure 7.3: The total number of systems at industrial sites together with the numbers of sites with traditional engineering applications, new emerging application areas and unknown application areas.

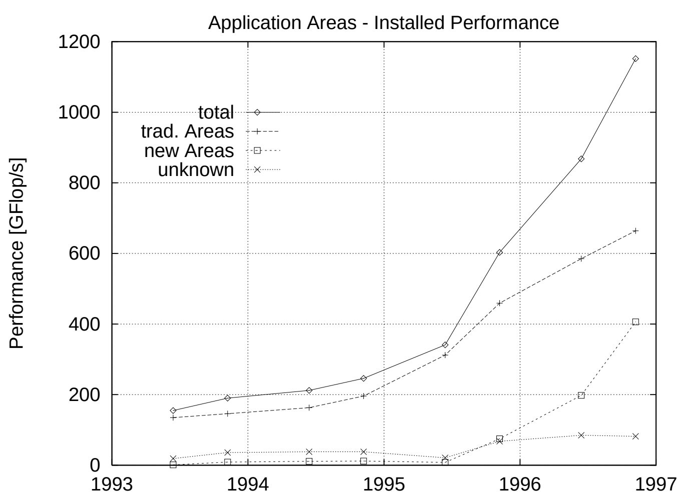

Figure 7.4: The accumulated performance of the different classes of industrial sites.

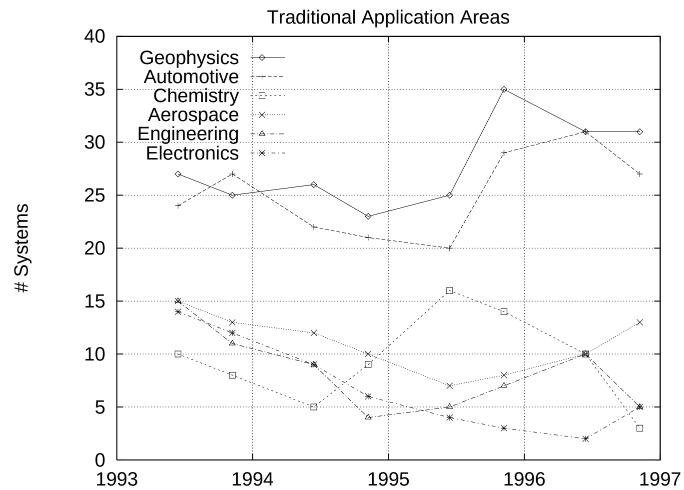

Figure 7.5: The number of systems at industrial sites used for traditional engineering applications.

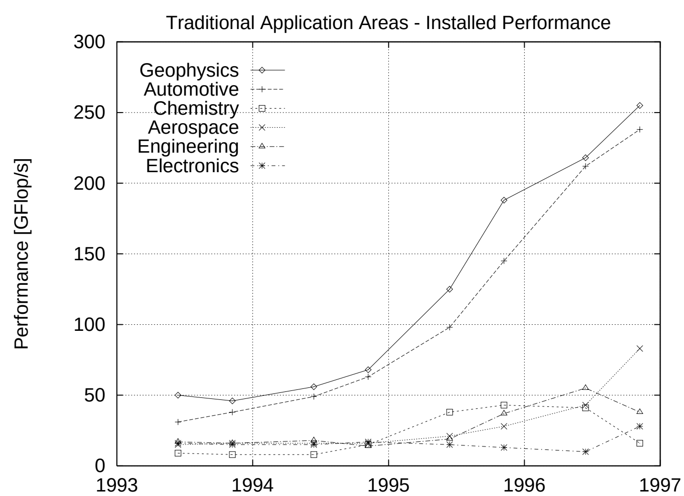

Figure 7.6: The accumulated performance at industrial sites used for traditional engineering applications.

shows no substantial increase over time. It is unclear to us if the recent drop of the numbers for the chemical industry are only a temporary effect or a signal that this industry no longer need the very high end supercomputers.

Recently industrial systems in the TOP500 have been used for new application areas. These include

- database applications,
- finance applications, and
- image processing.

The most dominant trend seen in Figure 7.7 and Figure 7.8 is the strong rise of database applications since mid 1995. These applications include on-line transaction processing as well as data mining. The HPC systems being sold and installed for such applications are large enough to enter the first hundred systems—a clear sign of the growing maturity of the systems and their practicality for industrial usage.

7.7 Architectures used in different Application Areas

It is also important to notice that industrial customers are buying not only systems with traditional architectures, such as the SGI PowerChallenge or Cray Triton, but MPP systems with distributed memory, such as the IBM SP2. Distributed memory is no longer a hindrance to success in the commercial marketplace. In Table 7.5 we see that only in the automotive industry vector processing is still dominating.

In all other industrial application areas such as aerospace, geophysics and new applications MPP have replaced the vector systems. In the automotive, geophysics and aerospace industry we also see a substantial number of SMP systems.

In figure 7.9 we see the continuous replacement of the vector systems (PVP) by MPP systems and SMP systems over the last five years.

7.8 Conclusions

The success of massively parallel systems in commercial environments is not bound to any special architecture. Maturity of systems and availability of key application software in a standard Unix system environment are much more important than details of the system architecture. The use of standard workstation technology for single nodes is one key factor. This eases the task of building reliable systems with portable application software.

From the present eight releases of the TOP500 we see the following trends:

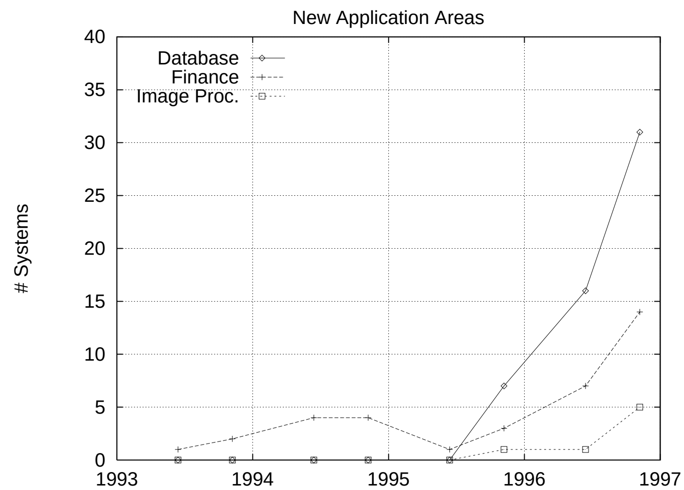

Figure 7.7: The number of systems at industrial sites used in new application areas.

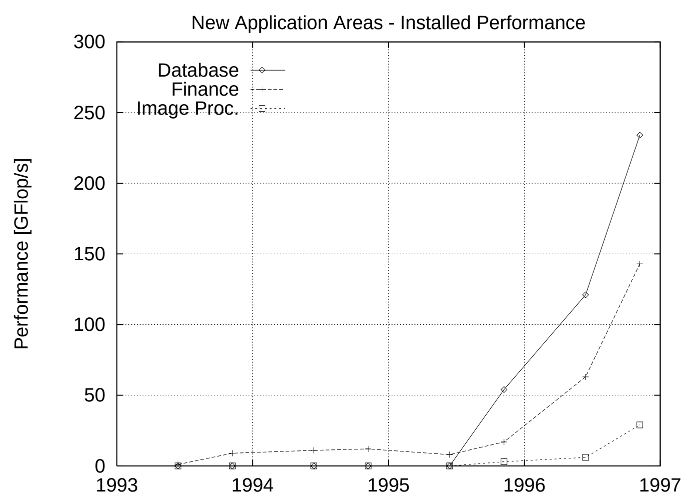

Figure 7.8: The accumulated performance at industrial sites used in new application areas.

Table 7.5: The different architectures used in industrial systems as of November 1996.

TOP500 Statistics — Number of Systems Installed				
	MPP	PVP	SMP	Total
Aerospace	6	3	4	13
Automotive	3	14	10	27
Chemistry		1	2	3
Electronics	1		4	5
Engineering	3	1	1	5
Geophysics	22	1	8	31
Database	27		4	31
Finance	13	1		14
Image Proc.	1		4	5
others	1			1
Unknown	13			13
Total	90	21	37	148

- The number of industrial customers in the TOP500 has risen steadily since June 1995.
- The most successful companies (IBM and SGI) are selling disproportionately well in the industrial market.
- The average system size at industrial sites is increasing strongly.
- Database applications is the most important and most successful new application area for supercomputers.
- Distributed-memory systems are being installed at industrial sites in reasonable numbers and have outnumbered shared memory vector systems in the meantime.
- Only in the automotive industry vector processing is still dominant.
- IBM is leading in the industrial market place ahead of SGI/Cray.
- The United States is the world leader in the industrial usage of HPC systems.

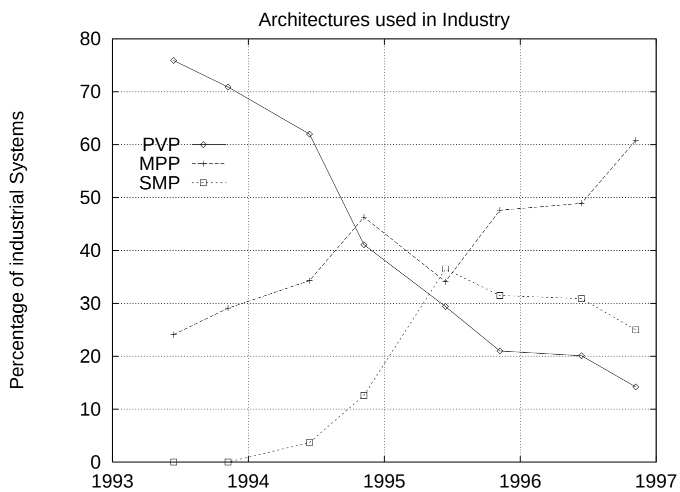

Figure 7.9: The percentage of the different architectures installed at industrial sites based on system counts.

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TOP20 Supercomputers - Industry

N *local* *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{ma}}$ R_{pea} [Mflop/
1 43	NEC SX-4/20	Toyota Central Research Development Japan /1996	Industry Automotive	20	**3819** 4000
2 54	Cray Y-MP T932/321024	Nippon Telegraph and Telephone (NTT) Japan /1995	Industry Finance	32	**2936** 5800
3 60	Cray T3D MC256-8/464	Bear Stearns USA /1996	Industry Finance	256	**2530** 3800
4 63	Cray T3D MC256-8	EXXON USA /1995	Industry Geophysics	256	**2530** 3800
5 70	Cray T3E AC64-128	EDS/General Motors Auburn Hills USA /1996	Industry Automotive	64	**2519** 3800
6 83	IBM SP2/104	MCI USA /1994	Industry Database	104	**1934** 2762
7 87	IBM SP2/98	Citicorp USA /1996	Industry Finance	98	**1831** 2603
8 90	NEC SX-3/34R	VW (Volkswagen AG) Wolfsburg Germany /1996	Industry Automotive	3	**1740** 1950
9 105	TMC CM-5/256	Geco-Prakla Houston USA /1994	Industry Geophysics	256	**1510** 3300
10 106	TMC CM-5/256	Geco-Prakla Houston USA /1995	Industry Geophysics	256	**1510** 3300
11 112	IBM SP2/77	Sears Product Service Group USA /1996	Industry Database	77	**1472** 2045
12 113	IBM SP2/77	Sears Roebuck USA /1996	Industry Database	77	**1472** 2045
13 121	IBM SP2/72	Nuclear Power Engineering Japan /1995	Industry Energy	72	**1386** 1912
14 129	Cray Y-MP C916/16512	Ford Motor Company Dearborn USA /1993	Industry Automotive	16	**1370** 1523
15 130	Cray Y-MP C916/16512	Ford Motor Company Dearborn USA /1995	Industry Automotive	16	**1370** 1523
16 152	Cray Y-MP T932/101024	EDS/General Motors Auburn Hills USA /1996	Industry Automotive	10	**1315** 1812
17 153	IBM SP2/67	Bell South USA /1995	Industry Database	67	**1301** 1779
18 161	Cray T3D MCA128-8	Compagnie Generale de Geophysique (CGG) Massy France /1995	Industry Geophysics	128	**1280** 1900
19 167	Cray T3D MC128-8	Phillips Petroleum Company Bartlesville USA /1994	Industry Geophysics	128	**1280** 1900
20 183	NEC SX-4/6	DIGICON Houston USA /1996	Industry Geophysics	6	**1151** 1200

Mannheim/Tennessee November, 18,1996

Chapter 8

TOP500 Supercomputer Sites - June 1996

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TOP500 Supercomputer Sites

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June 7, 1996

Abstract

To provide a better basis for statistics on high-performance computers, we list the sites that have the 500 most powerful computer systems installed. The best LINPACK benchmark performance achieved is used as a performance measure in ranking the computers.

8.1 Introduction and Objectives

Statistics on high-performance computers are of major interest to manufacturers, users, and potential users. These people wish to know not only the number of systems installed, but also the location of the various supercomputers within the high-performance computing community and the applications for which a computer system is being used. Such statistics can facilitate the establishment of collaborations, the exchange of data and software, and provide a better understanding of the high-performance computer market.

Statistical lists of supercomputers are not new. Every year since 1986 Hans Meuer [1] has published system counts of the major vector computer manufacturers, based principally on those at the Mannheim Supercomputer Seminar. Statistics based merely on the name of the manufacturer are no longer useful, however. New statistics are required that reflect the diversification of supercomputers, the enormous performance difference between low-end and high-end models, the increasing availability of massively parallel processing (MPP) systems, and the strong increase in computing power of the high-end models of workstation suppliers (SMP).

To provide this new statistical foundation, we have decided in 1993 to assemble and maintain a list of the 500 most powerful computer systems. Our list has been compiled twice a year since June 1993 with the help of high-performance computer experts, computational scientists, manufacturers, and the Internet community in general who responded to a questionnaire we sent out; we thank all the contributors for their cooperation. We have also used parts of statistical lists published by others for different purposes [2].

In the present list (which we call the TOP500), we list computers ranked by their performance on the LINPACK Benchmark. While we make every attempt to verify the results obtained from users and vendors, errors are bound to exist and should be brought to our attention. We intend to continue to update this

list half-yearly and, in this way, to keep track with the evolution of computers. Hence, we welcome any comments and information; please send electronic mail to *top500@rz.uni-mannheim.de*. The list is freely available by anonymous ftp to ftp.uni-mannheim.de/top500/ or to www.netlib.org/benchmark/top500.ps. The interested reader can additionally create sublists out of the TOP500 database and can make statistics on his own by using the WWW interface at
http://parallel.rz.uni-mannheim.de/top500.html or
http://www.netlib.org/benchmark/top500.html.
Here you also have access to postscript versions of slides dealing with the interpretation of the present situation as well as with the evolution over time since we started this project.

8.2 The LINPACK Benchmark

As a yardstick of performance we are using the "best" performance as measured by the LINPACK Benchmark [2]. LINPACK was chosen because it is widely used and performance numbers are available for almost all relevant systems.

The LINPACK Benchmark was introduced by Jack Dongarra. A detailed description as well as a list of performance results on a wide variety of machines is available in postscript form from *netlib*. To retrieve a copy send electronic mail to *netlib@ornl.gov* and by typing the message *send performance from benchmark* or from any machine on the internet type:
rcp anon@netlib2.cs.utk.edu:benchmark/performance performance.

The benchmark used in the LINPACK Benchmark is to solve a dense system of linear equations. For the TOP500, we used that version of the benchmark that allows the user to scale the size of the problem and to optimize the software in order to achieve the best performance for a given machine. This performance does not reflect the *overall performance* of a given system, as no single number ever can. It does, however, reflect the *performance of a dedicated system for solving a dense system of linear equations.* Since the problem is very regular, the performance achieved is quite high, and the performance numbers give a good correction of peak performance.

By measuring the actual performance for different problem sizes n, a user can get not only the maximal achieved performance R_{max} for the problem size N_{max} but also the problem size $N_{1/2}$ where half of the performance R_{max} is achieved. These numbers together with the theoretical peak performance R_{peak} are the numbers given in the TOP500. To use a consistent yardstick for all systemwe we do not use results achieved by advanced parallel algorithm as defined in [2]. If in the future a more realistic metric finds widespread usage, so that numbers for all systems in question are available, we may convert to that performance measure.

8.3 The TOP500 List

Table 1 shows the 500 most powerful commercially available computer systems known to us. To keep the list as compact as possible, we show only a part of our information here:

• N_{world}	Position within the TOP500 ranking
• Manufacturer	Manufacturer or vendor
• Computer	Type indicated by manufacturer or vendor
• Installation Site	Customer
• Location	Location and country
• Year	Year of installation/last major update
• Field of Application	
• # Proc.	Number of processors[1]
• R_{max}	Maximal LINPACK performance achieved
• R_{peak}	Theoretical peak performance
• N_{max}	Problemsize for achieving R_{max}
• $N_{1/2}$	Problemsize for achieving half of R_{max}

If R_{max} from Table 3 of the LINPACK Report [2] is not available, we use the TPP performance given in Table 1 of the LINPACK Report [2] for solving a system of 1000 equations. To use a consistent yardstick for all systemwe we do not use results achieved by advancef parallel algorithm as defined in [2]. In a few cases we interpolated between two measured system sizes or we scaled by cycle times. For models where we did not receive the requested data, the performance of the next smaller system measured is used.

If there should be any changes in the performances given in Table 1 we will update them.

In addition to cross checking different sources of information, we select randomly a statistical representative sample of the first 500 systems of our database. For these systems we ask the supplier of the information to establish direct contact between the installation site and us to verify the given information. This gives us basic information about the quality of the list in total.

As the TOP500 should provide a basis for statistics on the market of high-performance computers, we limit the number of systems installed at vendor sites. This is done for each vendor separately by limiting the accumulated performance of systems at vendor sites to a maximum of 5% of the total accumulated installed performance of this vendor. Rounding is done in favor of the vendor in question.

In Table 1, the computers are ordered first by their R_{max} value. In the case of equal performances (R_{max} value) for different computers, we have chosen to order by R_{peak}. For sites that have the same computer, the order is by memory size and then alphabetically.

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
1	Hitachi SR2201/1024	University of Tokyo Tokyo Japan /1996	Academic	1024	**220400** 307000	138240 34560
2	Fujitsu Numerical Wind Tunnel	NAL Japan /1996	Research Aerospace	166	**170400** 280000	42000 13800
3	Intel XP/S140	Sandia National Labs Albuquerque USA /1993	Research	3680	**143400** 184000	55700 20500
4	Intel XP/S-MP 150	Oak Ridge National Laboratory Oak Ridge USA /1995	Research	3072	**127100** 154000	86000 17800
5	Intel XP/S-MP 125	Japan Atomic Energy Research Japan /1996	Research	2502	**103500** 125100	. .
6	Cray T3D MC1024-8	Government USA /1994	Classified	1024	**100500** 152000	81920 10224
7	Fujitsu VPP500/80	National Lab. for High Energy Physics Japan /1994	Research	80	**98900** 128000	32640 10050
8	IBM SP2/512	Cornell Theory Center Ithaca USA /1994	Academic	512	**88400** 136000	73500 20150
9	IBM SP2/512	IBM/Poughkeepsie Poughkeepsie USA /1995	Vendor	512	**88400** 136000	73500 20150
10	NEC SX-4/32	NEC Fuchu Plant Tokyo Japan /1995	Vendor Benchmarking	32	**66530** 64000	15360 1792
11	NEC SX-4/32	Universitaet Stuttgart Stuttgart Germany /1996	Research	32	**66530** 64000	15360 1792
12	IBM SP2/384	Maui High-Performance Computing Center (MHPCC) USA /1994	Research	384	**66300** 102400	. .
13	TMC CM-5/1056	Los Alamos National Laboratory Los Alamos USA /1993	Research Energy	1056	**59700** 135100	52224 24064
14	Fujitsu VPP500/42	Japan Atomic Energy Research Japan /1994	Research	42	**54500** 67200	. .
15	Fujitsu VPP500/42	Nagoya University Nagoya Japan /1995	Academic	42	**54500** 67200	. .
16	TMC CM-5/896	Minnesota Supercomputer Center USA /1994	Academic	896	**52300** 114700	. .
17	Fujitsu VPP500/40	National Genetics Research Lab. Japan /1995	Research	40	**52070** 64000	. .
18	Fujitsu VPP500/40	Tokyo University - Inst. of Solid State Physics Tokyo Japan /1994	Academic	40	**52070** 64000	. .
19	Cray T3D MC512-8	Los Alamos National Laboratory Los Alamos USA /1994	Research Energy	512	**50800** 76000	57856 7136
20	Cray T3D MC512-8	Minnesota Supercomputer Center USA /1995	Academic	512	**50800** 76000	57856 7136

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
21	Cray T3D MC512-8	Pittsburgh Supercomputing Center Pittsburgh USA /1994	Academic	512	**50800** 76000	57856 7136
22	Cray T3D MC512-8	University of Edinburgh Edinburgh UK /1996	Academic	512	**50800** 76000	57856 7136
23	Fujitsu VPP500/32	The Angstrom Technology Partnership Tsukuba Japan /1993	Research	32	**42400** 51200	20736 4940
24	NEC SX-4/20	Japan Marine Science and Technology Japan /1995	Research	20	**42400** 40000	. .
25	NEC SX-4/20	National Research Institute for Metals Japan /1996	Research	20	**42400** 40000	. .
26	NEC SX-4/20	Toyota Central Research Development Japan /1996	Industry Automotive	20	**42400** 40000	. .
27	Fujitsu VPP500/30	Tsukuba University Tsukuba Japan /1993	Research	30	**39812** 48000	. .
28	Fujitsu VPP500/28	Institute of Physical and Chemical Res. (RIKEN) Tokyo Japan /1993	Research	28	**37225** 44800	. .
29	IBM SP2/208	Pacific Northwest Laboratories/Batelle Richland USA /1996	Research	208	**36450** 55000	42200 10300
30	NEC SX-4/16	National Aerospace Laboratory (NLR) Noordoostpolder Netherlands /1996	Research Aerospace	16	**34420** 32000	14336 960
31	NEC SX-4/16	National Cardiovascular Center Japan /1996	Research	16	**34420** 32000	14336 960
32	Intel XP/S-MP 41	Rome Laboratory USA /1995	Research	816	**33700** 40800	. .
33	TMC CM-5/512	NCSA Urbana-Champaign USA /1993	Academic	512	**30400** 66000	36864 16384
34	TMC CM-5/512	National Security Agency USA /1993	Classified	512	**30400** 66000	36864 16384
35	Cray Y-MP T932/321024	Nippon Telegraph and Telephone (NTT) Japan /1995	Industry	32	**29360** 58000	. .
36	IBM SP2/160	NASA/Ames Research Center/NAS Moffett Field USA /1994	Research	160	**28700** 42500	42200 10300
37	Hitachi S-3800/480	Hitachi Ltd. GPCD Japan /1994	Vendor Software	4	**28400** 32000	15500 830
38	Hitachi S-3800/480	Japan Meteorological Agency Japan /1995	Research Weather	4	**28400** 32000	15500 830
39	Hitachi S-3800/480	University of Tokyo Tokyo Japan /1993	Academic	4	**28400** 32000	15500 830
40	SGI POWER CHALLENGEarray	Silicon Graphics Mountain View USA /1995	Vendor Benchmarking	128	**26653** 46080	53000 20000

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TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
41	NEC SX-4/12	Swiss Scientific Computing Center (CSCS) Manno Switzerland /1995	Research	12	**25800** 32000	. .
42	Cray T3D SC256-8/264	Caltech/JPL Pasadena USA /1994	Academic	256	**25300** 38000	40960 4918
43	Cray T3D MC256-8	Defense Research Agency Farnborough UK /1994	Classified	256	**25300** 38000	40960 4918
44	Cray T3D MC256-8	EXXON USA /1995	Industry Geophysics	256	**25300** 38000	40960 4918
45	Cray T3D MC256-8	Ecole Polytechnique Federale de Lausanne Lausanne Switzerland /1994	Academic	256	**25300** 38000	40960 4918
46	Cray T3D SC256-8/364	Lawrence Livermore National Laboratory Livermore USA /1994	Research Energy	256	**25300** 38000	40960 4918
47	Cray T3D SC256-8/464	Los Alamos National Laboratory Los Alamos USA /1994	Research Energy	256	**25300** 38000	40960 4918
48	Cray T3D SC256-8/464	ZIB/Konrad Zuse-Zentrum fuer Informationstechnik Berlin Germany /1995	Academic	256	**25300** 38000	40960 4918
49	NEC SX-3/44R	Atmospheric Environment Service (AES) Dorval Canada /1994	Research Weather	4	**23200** 26000	6400 830
50	NEC SX-3/44R	Tohoku University Aramaki Japan /1993	Academic	4	**23200** 26000	6400 830
51	SGI powcha90/96	NCSA Urbana-Champaign USA /1995	Research	96	**22146** 34560	53000 20000
52	Hitachi S-3800/380	Hokkaido University Sapporo Japan /1994	Academic	3	**21600** 24000	15680 760
53	Hitachi S-3800/380	Institute for Materials Research/Tohoku University Japan /1994	Academic	3	**21600** 24000	15680 760
54	Fujitsu VPP500/15	Kyoto University Kyoto Japan /1994	Academic	15	**20360** 24000	. .
55	NEC SX-3/44	Atmospheric Environment Service (AES) Dorval Canada /1991	Research Weather	4	**20000** 22000	6144 832
56	Intel XP/S-MP 22	ETH Zuerich Switzerland /1995	Academic	450	**18700** 22500	. .
57	IBM SP2/104	MCI USA /1994	Industry	104	**18590** 27700	. .
58	SGI POWER CHALLENGEarray	US Army Research Laboratory Aberdeen USA /1995	Research	96	**18455** 28800	53000 20000
59	NEC SX-3/34R	National Inst. for Molecular Science Okozaki Japan /1993	Research	3	**17400** 19500	6144 691
60	NEC SX-4/8	ATR Optical Communication Lab Japan /1996	Research	8	**17200** 16000	. .

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Top500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
61	NEC SX-4/8	Atmospheric Environment Service (AES) Dorval Canada /1995	Research Weather	8	**17200** 16000	. .
62	NEC SX-4/8	Danish Meteorological Institute Copenhagen Denmark /1996	Research	8	**17200** 16000	. .
63	NEC SX-4/8	National Geographic Agency Japan /1996	Research	8	**17200** 16000	. .
64	IBM SP2/96	KTH - Royal Institute of Technology Stockholm Sweden /1996	Research	96	**17170** 25500	. .
65	SGI POWER CHALLENGEarray	Silicon Graphics Cortaillod Switzerland /1995	Vendor Benchmarking	64	**15598** 23040	37000 8500
66	Cray Y-MP T916/12512	KFA Juelich Germany /1996	Research	12	**15430** 21750	. .
67	Intel XP/S35	Caltech Pasadena USA /1994	Research	512	**15200** 25600	23000 9000
68	Intel XP/S35	Oak Ridge National Laboratory Oak Ridge USA /1992	Research	512	**15200** 25600	23000 9000
69	IBM SP2/85	NIH (National Institute of Health) Frederick USA /1995	Research	85	**15190** 22660	. .
70	TMC CM-5/256	Geco-Prakla Houston USA /1994	Industry Geophysics	256	**15100** 33000	26112 12032
71	TMC CM-5/256	Geco-Prakla Houston USA /1995	Industry Geophysics	256	**15100** 33000	26112 12032
72	TMC CM-5/256	Government USA /1993	Classified	256	**15100** 33000	26112 12032
73	TMC CM-5/256	US Naval Research Laboratory Washington D.C. USA /1992	Research	256	**15100** 33000	26112 12032
74	Hitachi S-3800/280	Central Res. Inst. of Electric Power Ind. Japan /1996	Research	2	**14600** 16000	15680 570
75	IBM SP2/76	SARA (Stichting Academisch Rekencentrum) Amsterdam Netherlands /1995	Research	76	**14312** 20260	. .
76	IBM SP2/80	National Center for High Performance Computing Taiwan /1996	Academic	80	**14300** 21120	. .
77	IBM SP2/79	CNUSC Montpellier France /1996	Academic	79	**14120** 20860	. .
78	Intel Delta	Caltech Pasadena USA /1991	Academic	512	**13900** 20480	25000 7500
79	IBM SP2/77	Leibniz Rechenzentrum Muenchen Germany /1995	Academic	77	**13760** 20330	. .
80	IBM SP2/77	Sears Product Ser Grp USA /1996	Industry	77	**13760** 20330	. .

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
81	Cray Y-MP C916/16256	Cray Research Chippewa Falls USA /1992	Vendor	16	**13700** 15238	10000 650
82	Cray Y-MP C916/16512	Cray Research Eagan USA /1992	Vendor	16	**13700** 15238	10000 650
83	Cray Y-MP C916/16256	DKRZ Hamburg Germany /1995	Research Weather	16	**13700** 15238	10000 650
84	Cray Y-MP C916/161024	DOD/CEWES Vicksburg USA /1994	Research Mechanics	16	**13700** 15238	10000 650
85	Cray Y-MP C916/16256	DOE/Bettis Atomic Power Laboratory USA /1993	Research	16	**13700** 15238	10000 650
86	Cray Y-MP C916/16256	DOE/Knolls Atomic Power Laboratory USA /1993	Research	16	**13700** 15238	10000 650
87	Cray Y-MP C916/16512	DOE/National Security Agency USA /1994	Classified	16	**13700** 15238	10000 650
88	Cray Y-MP C916/16256	ECMWF Reading UK /1994	Research Weather	16	**13700** 15238	10000 650
89	Cray Y-MP C916/16512	Ford Motor Company Dearborn USA /1993	Industry Automotive	16	**13700** 15238	10000 650
90	Cray Y-MP C916/16512	Ford Motor Company Dearborn USA /1995	Industry Automotive	16	**13700** 15238	10000 650
91	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
92	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
93	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
94	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
95	Cray Y-MP C916/16512	Government USA /1994	Classified	16	**13700** 15238	10000 650
96	Cray Y-MP C916/16256	Government Communications Headquarters Benhall UK /1994	Classified	16	**13700** 15238	10000 650
97	Cray Y-MP C916/16512	KIST/System Engineering Research Institute Korea /1993	Academic	16	**13700** 15238	10000 650
98	Cray Y-MP C916/16256	Lawrence Livermore National Laboratory Livermore USA /1992	Research Energy	16	**13700** 15238	10000 650
99	Cray Y-MP C916/161024	MITI Osaka Japan /1994	Research	16	**13700** 15238	10000 650
100	Cray Y-MP C916/161024	NASA/Ames Research Center/NAS Moffett Field USA /1993	Research	16	**13700** 15238	10000 650

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N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
101	Cray Y-MP C916/16256	NERSC Berkley USA /1992	Research	16	**13700** 15238	10000 650
102	Cray Y-MP C916/16256	NOAA Suitland USA /1994	Research Weather	16	**13700** 15238	10000 650
103	Cray Y-MP C916/16256	NOAA/GFDL USA /1995	Research Weather	16	**13700** 15238	10000 650
104	Cray Y-MP C916/16256	NOAA/National Center for Environment Prediction Suitland USA /1994	Research	16	**13700** 15238	10000 650
105	Cray Y-MP C916/16512	Pittsburgh Supercomputing Center Pittsburgh USA /1994	Academic	16	**13700** 15238	10000 650
106	Cray Y-MP C916/16256	Res. Inf. Processing System (RIPS) Tsukuba Japan /1994	Research	16	**13700** 15238	10000 650
107	Cray Y-MP C916/161024	Tohoku University, Institute of Fluid Science Aramaki Japan /1994	Academic	16	**13700** 15238	10000 650
108	Cray Y-MP C916/161024	US Naval Oceanographic Command Bay Saint Louis USA /1994	Research Weather	16	**13700** 15238	10000 650
109	Cray Y-MP C916/16256	United Kingdom Meteorological Office Bracknell UK /1994	Research Weather	16	**13700** 15238	10000 650
110	Fujitsu VPP500/10	Communications Res. Lab. (CRL) Tokyo Japan /1993	Research	10	**13675** 16000	. .
111	NEC SX-4/6	DIGICON Montreal Canada /1996	Industry Geophysics	6	**12900** 12000	. .
112	IBM SP2/72	Nuclear Power Engineering Japan /1995	Industry Energy	72	**12870** 19200	. .
113	Cray T3D MC128-8	Air Force/Eglin Air Force Base Eglin USA /1994	Classified	128	**12800** 19000	20736 3408
114	Cray T3D MC128-8	CEA/Centre d'Etudes Limeil-Valenton France /1993	Research	128	**12800** 19000	20736 3408
115	Cray T3D MCA128-8	CEA/Centre d'Etudes Nucleaires Grenoble France /1994	Research Energy	128	**12800** 19000	20736 3408
116	Cray T3D MCA128-8	Compagnie Generale de Geophysique (CGG) Massy France /1995	Industry Geophysics	128	**12800** 19000	20736 3408
117	Cray T3D MC128-8	Cray Research Eagan USA /1995	Vendor	128	**12800** 19000	20736 3408
118	Cray T3D MCA128-8	Cray Research Eagan USA /1996	Vendor	128	**12800** 19000	20736 3408
119	Cray T3D MCA128-8	ECMWF Reading UK /1994	Research Weather	128	**12800** 19000	20736 3408
120	Cray T3D MCA128-8	Environmental Protection Agency USA /1995	Research	128	**12800** 19000	20736 3408

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N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
121	Cray T3D MCA128-8	IRISA Rennes France /1995	Research Aerospace	128	**12800** 19000	20736 3408
122	Cray T3D MCA128-8	Max-Planck-Gesellschaft MPI Munchen Germany /1995	Research	128	**12800** 19000	20736 3408
123	Cray T3D MC128-8	Phillips Petroleum Company Bartlesville USA /1994	Industry Geophysics	128	**12800** 19000	20736 3408
124	Cray T3D MCA128-2	Reactor Nuclear Fuel Development Japan /1994	Research	128	**12800** 19000	20736 3408
125	Cray T3D MCA128-8	Tohoku University, Institute of Fluid Science Aramaki Japan /1994	Academic	128	**12800** 19000	20736 3408
126	Cray T3D MCA128-8	UCSD/San Diego Supercomputer Center San Diego USA /1995	Academic	128	**12800** 19000	20736 3408
127	Cray T3D MC128-8	University of Alaska - ARSC Fairbanks USA /1995	Academic	128	**12800** 19000	20736 3408
128	IBM SP2/56	Universitaet Karlsruhe Karlsruhe Germany /1996	Academic	56	**12700** 17240	. .
129	IBM SP2/69	PIK Potsdam Germany /1996	Research	69	**12330** 18220	. .
130	Intel XP/S-MP 15	ONERA Chatillon France /1995	Research Aerospace	294	**12250** 14700	. .
131	IBM SP2/68	DLR Koeln Germany /1996	Research	68	**12150** 17950	. .
132	Intel XP/S-MP 14	Oak Ridge National Laboratory Oak Ridge USA /1995	Research	288	**12000** 14400	. .
133	IBM SP2/67	Bell South USA /1995	Industry	67	**11970** 17690	. .
134	Intel XP/S30	UCSD/San Diego Supercomputer Center San Diego USA /1993	Academic	400	**11900** 20000	. .
135	IBM SP2/65	CERN Geneva Switzerland /1995	Research	65	**11620** 17330	. .
136	NEC SX-3/24R	German Aerospace Laboratory (DLR) Goettingen Germany /1994	Research Aerospace	2	**11600** 13000	4352 516
137	NEC SX-3/24R	National Institute of Fusion Science (NIFS) Japan /1993	Research	2	**11600** 13000	4352 516
138	NEC SX-3/24R	Swiss Scientific Computing Center (CSCS) Manno Switzerland /1994	Research	2	**11600** 13000	4352 516
139	NEC SX-3/24R	VW (Volkswagen AG) Wolfsburg Germany /1995	Industry Automotive	2	**11600** 13000	4352 516
140	IBM SP2/64	InterUniversity Israel /1996	Academic	64	**11400** 17000	26500 6250

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
141	IBM SP2/64	Maui High-Performance Computing Center (MHPCC) USA /1994	Research	64	**11400** 17000	26500 6250
142	Fujitsu VPP500/8	Fujitsu Ltd. Numazu Japan /1993	Vendor	8	**11000** 12800	10368 2025
143	Cray Y-MP T916/8256	CEA (Commissariat a l'Energie Atomique) Limeil France /1996	Research	8	**10880** 14500	. .
144	IBM SP2/60	Tokyo Metropolitan University Tokyo Japan /1995	Academic	60	**10730** 16000	. .
145	IBM SP2/59	Pennsylvania State University USA /1994	Academic	59	**10525** 15690	. .
146	Convex SPP1600/XA-64	Hewlett-Packard CXTC Richardson USA /1996	Vendor Benchmarking	64	**10402** 15360	. .
147	Cray Y-MP C916/12256	Tokyo Institute of Technology Tokyo Japan /1995	Academic	12	**10270** 11430	. .
148	Intel XP/S25	NAL Japan /1994	Research	336	**10000** 16800	. .
149	Intel XP/S25	NRAD USA /1994	Research	336	**10000** 16800	. .
150	TMC CM-200/64k	Los Alamos National Laboratory Los Alamos USA / .	Research Energy	2048	**9800** 20000	29696 11264
151	TMC CM-200/64k	Los Alamos National Laboratory Los Alamos USA / .	Research Energy	2048	**9800** 20000	29696 11264
152	IBM SP2/54	Autozone USA /1995	Industry	54	**9680** 14400	. .
153	Fujitsu VPP500/7	Institute of Space Astronautical Science (ISAS) Tokyo Japan /1993	Research	7	**9650** 11200	. .
154	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**9398** 14400	27000 6775
155	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**9398** 14400	27000 6775
156	IBM SP2/50	Federal Express USA /1995	Industry	50	**9060** 13200	. .
157	IBM SP2/50	Nihon Genken Tokai Japan /1995	Research	50	**9060** 13200	. .
158	IBM SP2/48	Ensign UK /1996	Industry Geophysics	48	**8600** 12770	. .
159	IBM SP2/48	Institute of Math and Statistics Japan /1995	Research	48	**8600** 12770	. .
160	IBM SP2/48	NASA/Langley Research Center Hampton USA /1994	Research	48	**8600** 12770	. .

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
161	IBM SP2/48	Okazaki Bunshi Ken Japan /1994	Research	48	**8600** 12770	. .
162	IBM SP2/48	PCS Inc USA /1996	Industry	48	**8600** 12770	. .
163	IBM SP2/48	Rika dai Japan /1996	Academic	48	**8600** 12770	. .
164	IBM SP2/48	University of Michigan Michigan USA /1996	Academic	48	**8600** 12770	. .
165	NEC SX-4/4	German Aerospace Laboratory (DLR) Goettingen Germany /1996	Research Aerospace	4	**8600** 8000	. .
166	IBM SP2/46	Tohoku University, Kohgaku-bu Aramaki Japan /1996	Academic	46	**8250** 11620	. .
167	Parsytec GC PowerPlus/192	Universitaet Heidelberg - IWR Heidelberg Germany /1995	Academic	192	**7999** 15360	27192 9500
168	Parsytec GC PowerPlus/192	Universitaet Paderborn - PC2 Paderborn Germany /1995	Academic	192	**7999** 15360	27192 9500
169	IBM SP2/44	Centro de Supercomputacion de Catalunya Barcelona Spain /1996	Academic	44	**7900** 20330	. .
170	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
171	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
172	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
173	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
174	TMC CM-5E/128	The Angstrom Technology Partnership Tsukuba Japan /1994	Research	128	**7700** 20000	18432 8192
175	TMC CM-5/128	AMEX USA /1993	Industry	128	**7700** 16000	18432 8192
176	TMC CM-5/128	Government USA /1993	Classified	128	**7700** 16000	18432 8192
177	TMC CM-5/128	Institut de Physique du Globe de Paris (IPG) Paris France /1992	Research	128	**7700** 16000	18432 8192
178	TMC CM-5/128	JPL Pasadena USA /1995	Research	128	**7700** 16000	18432 8192
179	TMC CM-5/128	MIT Cambridge USA / .	Research	128	**7700** 16000	18432 8192
180	Intel XP/S20	Okayama University Okayama Japan /1994	Academic	256	**7600** 12800	16000 4000

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
181	Intel XP/S20	Wright Patterson AFB USA /1994	Research	256	**7600** 12800	16000 4000
182	IBM SP2/42	Federal Express USA /1996	Industry	42	**7550** 11090	. .
183	IBM SP2/42	Fidelity Investments USA /1995	Industry	42	**7550** 11090	. .
184	SGI POWER CHALLENGEarray	INRIA - Sophia Antipolis Rennes France /1995	Research	32	**7542** 11520	22000 5600
185	SGI POWER CHALLENGEarray	NASA/Ames Mountain View USA /1995	Research Aerospace	32	**7542** 11520	22000 5600
186	SGI POWER CHALLENGEarray	NASA/JPL Pasadena USA /1995	Academic	32	**7542** 11520	22000 5600
187	SGI POWER CHALLENGEarray	Boston University Boston USA /1995	Academic	38	**7445** 11400	27000 6775
188	Convex SPP1200/XA-64	NCSA Urbana-Champaign USA /1995	Academic	64	**7408** 15360	42000 .
189	Hitachi S-3800/180	Meteorological Research Institute Japan /1993	Research Weather	1	**7400** 8000	15680 470
190	IBM SP2/40	National Cancer Research Institute Tokyo Japan /1994	Research	40	**7200** 10640	. .
191	IBM SP2/40	Seoul National University Seoul Korea /1995	Academic	40	**7200** 10640	. .
192	IBM SP2/40	UNI-C/Lyngby Denmark /1995	Academic	40	**7200** 10640	. .
193	IBM SP2/40	Western Geophysical UK /1996	Industry Geophysics	40	**7200** 10640	. .
194	Hitachi S-3800/260	Suzuki Motor Japan /1993	Industry Automotive	2	**7100** 8000	. .
195	IBM SP2/38	GMD Germany /1995	Research	38	**6860** 10130	. .
196	IBM SP2/38	UCLA Los Angeles USA /1994	Academic	38	**6860** 10130	. .
197	Cray Y-MP C98/8256	BMW AG Muenchen Germany /1995	Industry Automotive	8	**6850** 7619	. .
198	Cray Y-MP C98/8512	CNRS/IDRIS Orsay France /1993	Research	8	**6850** 7619	. .
199	Cray Y-MP C98/8256	Direction de la Meteorologie Nationale Toulouse France /1994	Research Weather	8	**6850** 7619	. .
200	Cray Y-MP C98/81024	EDS/General Motors USA /1995	Industry Automotive	8	**6850** 7619	. .

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
201	Cray Y-MP C98/8512	Electricite de France Clamart France /1994	Industry Energy	8	**6850** 7619	. .
202	Cray Y-MP C916/8512	Ford Koeln Germany /1995	Industry Automotive	8	**6850** 7619	. .
203	Cray Y-MP C98/8512	IRISA Rennes France /1993	Research Aerospace	8	**6850** 7619	. .
204	Cray Y-MP C916/8512	Minnesota Supercomputer Center USA /1994	Academic	8	**6850** 7619	. .
205	Cray Y-MP C916/8256	NASA/Ames Research Center/CCF Moffett Field USA /1993	Research Aerospace	8	**6850** 7619	. .
206	Cray Y-MP C98/8128	UCSD/San Diego Supercomputer Center San Diego USA /1993	Academic	8	**6850** 7619	. .
207	Cray Y-MP C916/8256	US Navy/Fleet Numerical Oceanography Center Monterey USA /1994	Research Weather	8	**6850** 7619	. .
208	IBM SP2/36	Rensselaer Polytechnic Troy USA /1994	Academic	36	**6500** 9570	. .
209	Cray T3D MC64-8	CINECA Bologna Italy /1995	Research	64	**6400** 9600	20736 2368
210	Cray T3D MC64-2	Mitsubishi Electric Corporation Kanagawa Japan /1994	Industry Electronics	64	**6400** 9600	20736 2368
211	Cray T3D MCA64-8	Mobil / Technical Center Tulsa USA /1995	Industry Geophysics	64	**6400** 9600	20736 2368
212	Cray T3D MCA64-8	NASA/Lewis Research Center Cleveland USA /1994	Research	64	**6400** 9600	20736 2368
213	Cray T3D MCA64-8	NCAR (National Center for Atmospheric Research) Boulder USA /1994	Research Weather	64	**6400** 9600	20736 2368
214	Cray T3D MCA64-8	US Naval Underwater Weapons Center USA /1995	Classified	64	**6400** 9600	20736 2368
215	IBM SP2/35	MCI USA /1995	Industry	35	**6340** 9330	. .
216	IBM SP2/35	Phillipps University of Marburg Marburg Germany /1995	Academic	35	**6340** 9330	. .
217	IBM SP2/35	Shell KSEPL Netherlands /1996	Industry Geophysics	35	**6340** 9330	. .
218	IBM SP2/35	Shopko Stores USA /1996	Industry	35	**6340** 9330	. .
219	Intel XP/S15	Government Washington DC USA /1995	Classified	208	**6250** 10400	. .
220	Intel XP/S15	NOAA Boulder USA /1994	Research	208	**6250** 10400	. .

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
221	Convex SPP1000/XA-64	HTC Babelsberg Germany /1995	Industry	64	**6192** 12800	41000 11400
222	Convex SPP1000/XA-64	Josef Stefan Institut Ljubljana Slovenia /1994	Research	64	**6192** 12800	41000 11400
223	SGI POWER CHALLENGE 10000	AMOCO Tulsa USA /1996	Industry Geophysics	24	**6118** 9360	15000 3100
224	SGI POWER CHALLENGE 10000	BMW AG Muenchen Germany /1996	Industry Automotive	24	**6118** 9360	15000 3100
225	IBM SP2/33	Westinghouse Electric USA /1996	Industry Energy	33	**5990** 8800	. .
226	Digital AlphaServer 8400 5/350	Digital Equipment Corporation Maynard USA /1996	Vendor Benchmarking	12	**5904** 8400	9548 3010
227	SGI POWER CHALLENGE 10000	Georgia Institute of Technology Atlanta USA /1996	Research	22	**5812** 8580	15000 2900
228	Intel XP/S14	Grant Tensor Houston USA /1995	Industry Geophysics	192	**5800** 9600	. .
229	IBM SP2/32	Amerada Hess USA /1994	Industry	32	**5800** 8500	18000 4500
230	IBM SP2/32	CINECA Bologna Italy /1995	Research	32	**5800** 8500	18000 4500
231	IBM SP2/32	China Meterological Administration China /1995	Research	32	**5800** 8500	18000 4500
232	IBM SP2/32	City University of Hong Kong Hong Kong /1995	Academic	32	**5800** 8500	18000 4500
233	IBM SP2/32	HMC Korea /1996	Industry	32	**5800** 8500	18000 4500
234	IBM SP2/32	Kogiin Kagiken Japan /1996	Research	32	**5800** 8500	18000 4500
235	IBM SP2/32	PGS Tensor USA /1995	Industry	32	**5800** 8500	18000 4500
236	NEC SX-3/41R	Japan Atomic Energy Research Japan /1992	Research	4	**5800** 6400	3584 414
237	NEC SX-3/14R	Osaka University Osaka Japan /1993	Academic	1	**5800** 6400	2816 282
238	NEC SX-3/14R	Toyota Central Research Development Japan /1992	Industry Automotive	1	**5800** 6400	2816 282
239	Cray Y-MP J932/32-4096	Bayer AG Leverkusen Germany /1996	Industry Chemistry	32	**5800** 6400	10000 550
240	Cray Y-MP J932/32-8192	Cray Research Eagan USA /1995	Vendor	32	**5800** 6400	10000 550

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
241	Cray Y-MP J932/32-4096	NASA/Goddard Space Flight Center Greenbelt USA /1995	Research Weather	32	**5800** 6400	10000 550
242	Cray Y-MP J932/32-4096	University Groningen Groningen Netherlands /1996	Academic	32	**5800** 6400	10000 550
243	Convex SPP1200/XA-48	Universitaet Mainz Mainz Germany /1995	Academic	48	**5744** 11520	34000 .
244	Cray Y-MP T94/4128	Boeing Seattle USA / .	Industry Aerospace	4	**5735** 7200	. .
245	Cray Y-MP T94/4128	Cray Research Eagan USA /1995	Vendor	4	**5735** 7200	. .
246	Cray Y-MP T94/4128	Cray Research Eagan USA /1995	Vendor	4	**5735** 7200	. .
247	Cray Y-MP T94/4128	Ford Motor Company Dearborn USA /1995	Industry Automotive	4	**5735** 7200	. .
248	Cray Y-MP T94/4128	Government Colorado Springs USA /1995	Classified	4	**5735** 7200	. .
249	Cray Y-MP T94/4128	Government Colorado Springs USA /1995	Classified	4	**5735** 7200	. .
250	Cray Y-MP T94/4128	Japan Atomic Energy Research Japan /1996	Research	4	**5735** 7200	. .
251	Cray Y-MP T94/4128	Los Alamos National Laboratory Los Alamos USA /1995	Research Energy	4	**5735** 7200	. .
252	Cray Y-MP T916/4256	NASA/Marshall Space Flight Center USA /1996	Research Aerospace	4	**5735** 7200	. .
253	Cray Y-MP T916/4256	North Carolina Supercomputer Center USA /1995	Academic	4	**5735** 7200	. .
254	Cray Y-MP T94/464	Toyota Motor Company Japan /1995	Industry Automotive	4	**5735** 7200	. .
255	TMC CM-5/96	Epsilon USA /1993	Industry	96	**5700** 13370	. .
256	TMC CM-5/96	University of California at Berkeley USA / .	Academic	96	**5700** 13370	. .
257	SGI POWER CHALLENGEarray	University Jaume I Castellon Spain /1995	Academic	24	**5650** 8640	. .
258	SGI POWER CHALLENGEarray	University of Minnesota Minneapolis USA /1995	Academic	24	**5650** 8640	. .
259	IBM SP2/31	NIST - US Department of Commerce Gaithersburg USA /1994	Research	31	**5630** 8260	. .
260	Fujitsu VPP500/4	Fujitsu San Jose USA /1995	Vendor	4	**5600** 6400	7344 1250

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
261	Fujitsu VPP500/4	IFP (Institute Francais du Petrole) Rueil-Malmaison France /1995	Academic Geophysics	4	**5600** 6400	7344 1250
262	Fujitsu VPP500/4	Toritsu Kagaku Gijutsu University Japan /1993	Academic	4	**5600** 6400	7344 1250
263	Fujitsu VPP500/4	Toyota Motor Company Japan /1994	Industry Automotive	4	**5600** 6400	7344 1250
264	Fujitsu/SNI VPP500/4	Universitaet Aachen Aachen Germany /1993	Academic	4	**5600** 6400	7344 1250
265	Fujitsu/SNI VPP500/4	Universitaet Darmstadt Darmstadt Germany /1994	Academic	4	**5600** 6400	7344 1250
266	Convex SPP1600/XA-32	Ford Dearborn USA /1996	Industry Automotive	32	**5452** 7680	27000 4500
267	IBM SP2/30	CRS4 Cagliari Italy /1995	Research	30	**5450** 7980	. .
268	IBM SP2/30	Columbia University Lamont USA /1995	Academic	30	**5450** 7980	. .
269	IBM SP2/30	First Interstate Bank USA /1996	Industry	30	**5450** 7980	. .
270	IBM SP2/30	Shell KSEPL Netherlands /1995	Industry Geophysics	30	**5450** 7980	. .
271	IBM SP2/30	Shell KSLA Netherlands /1995	Industry Geophysics	30	**5450** 7980	. .
272	IBM SP2/30	Shell Oil Corporation USA /1994	Industry Geophysics	30	**5450** 7980	. .
273	IBM SP2/30	Shell Oil Corporation USA /1994	Industry Geophysics	30	**5450** 7980	. .
274	IBM SP2/30	Universitaet Stuttgart Stuttgart Germany /1996	Academic	30	**5450** 7980	. .
275	IBM SP2/30	World Com USA /1995	Industry	30	**5450** 7980	. .
276	Parsytec GC PowerPlus/128	Japan Institute of Advanced Technology Japan /1994	Research	128	**5246** 10240	22000 7800
277	Parsytec GC PowerPlus/128	Swedish National Supercomputer Centre Linkoping Sweden /1994	Academic	128	**5246** 10240	22000 7800
278	Parsytec GC PowerPlus/128	Technische Universitaet Chemnitz Chemnitz Germany /1994	Academic	128	**5246** 10240	22000 7800
279	Parsytec GC PowerPlus/128	Universitaet Hamburg-Harburg Hamburg-Harburg Germany /1994	Academic	128	**5246** 10240	22000 7800
280	TMC CM-2/64k	Florida State University Tallahassee USA / .	Academic	2048	**5200** 14000	26624 11000

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
281	TMC CM-2/64k	SRC USA /1993	Industry	2048	**5200** 14000	26624 11000
282	IBM SP2/28	ABSA South Africa /1996	Industry Database	28	**5100** 7460	. .
283	IBM SP2/28	L.L.Bean USA /1994	Industry	28	**5100** 7460	. .
284	IBM SP2/28	Loral USA /1994	Industry	28	**5100** 7460	. .
285	IBM SP2/28	Morgan Stanley USA /1995	Industry	28	**5100** 7460	. .
286	IBM SP2/28	US West USA /1996	Industry	28	**5100** 7460	. .
287	IBM SP2/28	University of Southern California Los Angeles USA /1996	Academic	28	**5100** 7460	. .
288	Cray Y-MP J932/28-2048	Government USA /1996	Classified	28	**5075** 5600	. .
289	Digital AlphaServer 8400 5/350	CERN Geneva Switzerland /1996	Research	10	**5074** 7000	9540 3010
290	Digital AlphaServer 8400 5/350	Informix USA /1996	Industry Database	10	**5074** 7000	9540 3010
291	Meiko CS-2/224	Lawrence Livermore National Laboratory Livermore USA /1994	Research Energy	224	**5000** 40300	18688 6144
292	Meiko CS-2/128	Universitaet Wien Wien Austria /1994	Academic	128	**5000** 23000	18688 6144
293	Meiko CS-2/64	Lawrence Livermore National Laboratory Livermore USA /1994	Research Energy	64	**5000** 11500	18688 6144
294	TMC CM-200/32k	Government USA /1989	Classified	1024	**5000** 10000	21504 8192
295	TMC CM-200/32k	Minnesota Supercomputer Center USA / .	Academic	1024	**5000** 10000	21504 8192
296	TMC CM-200/32k	Western Geophysical Houston USA /1994	Industry Geophysics	1024	**5000** 10000	21504 8192
297	Digital AlphaServer 8400 5/300	Dial Corporation Phoenix USA /1996	Industry Construction	12	**5000** 7200	9548 1148
298	Digital AlphaServer 8400 5/300	National Security Agency USA /1996	Classified	12	**5000** 7200	9548 1148
299	NEC SX-3/22	NEC Systems Laboratories Inc. Houston USA /1991	Research	2	**5000** 5500	3072 384
300	NEC SX-3/14	National Institute of Environmental Studies Japan /1992	Research Environment	1	**5000** 5500	3072 384

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
301	IBM SP2/27	Hill's Pet Food USA /1996	Industry	27	**4920** 7200	. .
302	IBM SP2/27	ISSC, Unisource USA /1995	Industry	27	**4920** 7200	. .
303	SGI POWER CHALLENGEarray	Pacific Northwest Laboratories/Batelle Hanford USA /1995	Research	24	**4896** 7200	18000 3500
304	SGI POWER CHALLENGEarray	University of Oregon Eugene USA /1995	Academic	24	**4896** 7200	18000 3500
305	Convex SPP1000/XA-48	Tokyo University Tokyo Japan /1996	Academic	48	**4802** 9600	. .
306	Convex SPP1000/XA-48	Universitaet Erlangen Erlangen Germany /1994	Academic	48	**4802** 9600	. .
307	IBM 9076-005 SP1	Argonne Nat. Lab USA /1993	Research	128	**4800** 16000	26000 6000
308	KSR KSR2-80	Pacific Northwest Laboratories/Batelle Richland USA /1994	Research	80	**4770** 6400	. .
309	IBM SP2/26	John Alden Insurance USA /1994	Industry	26	**4740** 6930	. .
310	IBM SP2/26	Tohoku University Aramaki Japan /1996	Academic	26	**4740** 6930	. .
311	SGI POWER CHALLENGEarray	Florida State University Tallahassee USA /1995	Academic	20	**4710** 7200	. .
312	SGI POWER CHALLENGEarray	University of Queensland St Lucia Australia /1995	Academic	20	**4710** 7200	. .
313	Cray Y-MP C98/6256	Chrysler Motors Company USA /1995	Industry Automotive	6	**4630** 5715	. .
314	Cray Y-MP C98/6256	General Electric - Aircraft Eng USA /1995	Industry Aerospace	6	**4630** 5715	. .
315	Cray Y-MP C98/6256	NIST - US Department of Commerce Gaithersburg USA /1996	Research	6	**4630** 5715	. .
316	SGI POWER CHALLENGE	Ford Detroit USA /1995	Industry Automotive	18	**4620** 6480	2500 540
317	SGI POWER CHALLENGE	Government USA /1995	Classified	18	**4620** 6480	2500 540
318	SGI POWER CHALLENGE	Government USA /1996	Classified	18	**4620** 6480	2500 540
319	SGI POWER CHALLENGE	Government USA /1996	Classified	18	**4620** 6480	2500 540
320	SGI POWER CHALLENGE	Government USA /1996	Classified	18	**4620** 6480	2500 540

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
321	SGI POWER CHALLENGE	Government USA /1996	Classified	18	**4620** 6480	2500 540
322	SGI POWER CHALLENGE	NASA/JPL Pasadena USA /1995	Academic	18	**4620** 6480	2500 540
323	SGI POWER CHALLENGE	PEMEX Cd del Carmen Mexico /1995	Industry Geophysics	18	**4620** 6480	2500 540
324	SGI POWER CHALLENGE	Sandoz Hanover USA /1995	Industry Pharmaceutics	18	**4620** 6480	2500 540
325	SGI POWER CHALLENGE	Transquest Atlanta USA /1995	Industry	18	**4620** 6480	2500 540
326	SGI POWER CHALLENGE 10000	Saab Military Aircraft Linkoping Sweden /1996	Industry Aerospace	16	**4527** 6240	15000 2200
327	SGI POWER CHALLENGE 10000	University of Auckland Auckland New Zealand /1996	Academic	16	**4527** 6240	15000 2200
328	SGI POWER CHALLENGE 10000	University of Michigan Ann Arbor USA /1996	Academic	16	**4527** 6240	15000 2200
329	Intel XP/S10	KFA Juelich Germany /1994	Research	144	**4450** 7200	. .
330	Intel XP/S10	Lockheed Advanced Development Palmdale USA /1995	Industry Aerospace	144	**4450** 7200	. .
331	Intel XP/S10	Purdue University West Lafayette USA /1994	Academic	144	**4450** 7200	. .
332	IBM SP2/24	Adapco USA /1996	Industry	24	**4400** 6380	. .
333	IBM SP2/24	Brown University Providence USA /1996	Academic	24	**4400** 6380	. .
334	IBM SP2/24	CSC (Centre for Sientific Computing) Helsinki Finland /1995	Academic	24	**4400** 6380	. .
335	IBM SP2/24	Credit Suisse Switzerland /1995	Industry Finance	24	**4400** 6380	. .
336	IBM SP2/24	DKFZ Heidelberg Germany /1995	Research	24	**4400** 6380	. .
337	IBM SP2/24	La Caixa Spain /1996	Industry Database	24	**4400** 6380	. .
338	IBM SP2/24	National Institute of Environmental Studies Japan /1994	Research	24	**4400** 6380	. .
339	IBM SP2/24	University of Pennsylvania USA /1996	Academic	24	**4400** 6380	. .
340	Cray Y-MP T94/3128	Chrysler Motors Company USA /1995	Industry Automotive	3	**4387** 5400	. .

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
341	Cray Y-MP T94/3128	Honda Research and Development Company Tokyo Japan /1995	Industry Automotive	3	**4387** 5400	. .
342	Cray Y-MP T94/3128	debis Stuttgart Germany /1995	Industry Automotive	3	**4387** 5400	. .
343	Cray Y-MP J932/24-8192	Hiroshima University - IPC Japan /1995	Academic	24	**4350** 4800	. .
344	Cray Y-MP J932/24-8192	Los Alamos National Laboratory Los Alamos USA /1996	Research Energy	24	**4350** 4800	. .
345	Intel XP/S10	Hong Kong University of Science and Technology Hong Kong /1994	Academic	140	**4330** 7000	. .
346	Intel XP/S10	Intel SSD Development Centers USA /1992	Vendor	140	**4330** 7000	. .
347	Intel XP/S10	National Security Agency USA /1994	Classified	140	**4330** 7000	. .
348	SGI POWER CHALLENGE	AMOCO Tulsa USA /1995	Industry Geophysics	16	**4323** 5760	2500 540
349	SGI POWER CHALLENGE	Daewoo Motors Korea /1995	Industry Automotive	16	**4323** 5760	2500 540
350	SGI POWER CHALLENGE	Decision Science Appl. USA /1995	Industry Geophysics	16	**4323** 5760	2500 540
351	SGI POWER CHALLENGE	Ford Geelong Australia /1996	Industry Automotive	16	**4323** 5760	2500 540
352	SGI POWER CHALLENGE	George Wasington University Ashburg USA /1995	Academic	16	**4323** 5760	2500 540
353	SGI POWER CHALLENGE	George Wasington University Ashburg USA /1995	Academic	16	**4323** 5760	2500 540
354	SGI POWER CHALLENGE	Government USA /1995	Classified	16	**4323** 5760	2500 540
355	SGI POWER CHALLENGE	Government USA /1995	Classified	16	**4323** 5760	2500 540
356	SGI POWER CHALLENGE	Government USA /1995	Classified	16	**4323** 5760	2500 540
357	SGI POWER CHALLENGE	Hong Kong University of Science and Technology Hong Kong Hong Kong /1995	Academic	16	**4323** 5760	2500 540
358	SGI POWER CHALLENGE	Marathon Oil Company Houston USA /1995	Industry Geophysics	16	**4323** 5760	2500 540
359	SGI POWER CHALLENGE	Mississippi State University Starkeville USA /1996	Academic	16	**4323** 5760	2500 540
360	SGI POWER CHALLENGE	Ohio Supercomputer Center Columbus USA /1995	Academic	16	**4323** 5760	2500 540

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
361	SGI POWER CHALLENGE	Saab Military Aircraft Linkoping Sweden /1996	Industry Aerospace	16	**4323** 5760	2500 540
362	SGI POWER CHALLENGE	Sikorsky Stratford USA /1995	Industry Aerospace	16	**4323** 5760	2500 540
363	SGI POWER CHALLENGE	Universitaet Magdeburg Magdeburg Germany /1996	Academic	16	**4323** 5760	2500 540
364	SGI POWER CHALLENGE	University of Iowa Iowa USA /1995	Academic	16	**4323** 5760	2500 540
365	SGI POWER CHALLENGE	Vastar Houston USA /1995	Industry Geophysics	16	**4323** 5760	2500 540
366	SGI POWER CHALLENGE	Westinghouse Electric Orlando USA /1995	Industry Energy	16	**4323** 5760	2500 540
367	NEC SX-4/2C	Government France /1996	Classified	2	**4300** 4000	. .
368	NEC SX-4/2C	Houston Area Research Center Houston USA /1996	Research	2	**4300** 4000	. .
369	NEC SX-4/2C	Japan Atomic Energy Research Japan /1996	Research	2	**4300** 4000	. .
370	NEC SX-4/2C	Japan Atomic Energy Research Japan /1996	Research	2	**4300** 4000	. .
371	NEC SX-4/2C	Japan Atomic Energy Research Japan /1996	Research	2	**4300** 4000	. .
372	NEC SX-4/2C	Kajima Corporation Japan /1996	Industry Construction	2	**4300** 4000	. .
373	NEC SX-4/2C	Mitsubishi Heavy Industries Japan /1996	Research	2	**4300** 4000	. .
374	NEC SX-4/2C	Nissan Motor Japan /1996	Industry Automotive	2	**4300** 4000	. .
375	NEC SX-4/2C	Osaka University - Institute Laser Eng Osaka Japan /1996	Academic	2	**4300** 4000	. .
376	NEC SX-4/2C	Sumitomo Rubber Industries Japan /1996	Industry Chemistry	2	**4300** 4000	. .
377	NEC SX-4/2C	Yamaguchi University Japan /1996	Academic	2	**4300** 4000	. .
378	IBM SP2/23	University of Southampton Southampton UK /1996	Academic	23	**4225** 6115	. .
379	IBM SP2/18	Telecom Denmark (Danadata) Denmark /1996	Industry	18	**4150** 5540	. .
380	SGI POWER CHALLENGE	BASF Ludwigshafen Germany /1994	Industry Chemistry	18	**4142** 5400	2604 570

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
381	SGI POWER CHALLENGE	BMW AG Muenchen Germany /1994	Industry Automotive	18	**4142** 5400	2604 570
382	SGI POWER CHALLENGE	General Motors Detroit USA /1995	Industry Automotive	18	**4142** 5400	2604 570
383	SGI POWER CHALLENGE	Government USA /1995	Classified	18	**4142** 5400	2604 570
384	SGI POWER CHALLENGE	US Naval Research Laboratory Washington D.C. USA /1995	Research	18	**4142** 5400	2604 570
385	SGI POWER CHALLENGE	Universidad Autonoma Metropolitana Iztapalapa Mexico /1994	Academic	18	**4142** 5400	2604 570
386	SGI POWER CHALLENGE	Vertex Pharmaceuticals Cambridge USA /1995	Industry Chemistry	18	**4142** 5400	2604 570
387	IBM SP2/22	Colgate-Palmolive USA /1996	Industry	22	**4050** 5850	. .
388	IBM SP2/22	Dassault Aviation France /1995	Industry Aerospace	22	**4050** 5850	. .
389	IBM SP2/22	Petro Canada Canada /1995	Industry Geophysics	22	**4050** 5850	. .
390	IBM SP2/22	Queensland Parallel Supercomputing Facility Brisbane Australia /1994	Academic	22	**4050** 5850	. .
391	IBM SP2/22	Turbomeca Pau France /1996	Industry Aerospace	22	**4050** 5850	. .
392	Fujitsu VP2600/10	Fuji Heavy Japan /1990	Industry Heavy Ind.	1	**4009** 5000	. .
393	Fujitsu VP2600/10	Japan Atomic Energy Research Japan /1991	Research	1	**4009** 5000	. .
394	Fujitsu VP2600/10	Japan Atomic Energy Research Japan /1991	Research	1	**4009** 5000	. .
395	Fujitsu VP2600/10E	Kyoto University Kyoto Japan /1995	Academic	1	**4009** 5000	. .
396	Fujitsu VP2600/10	Kyushu University Kyushu Japan /1992	Academic	1	**4009** 5000	. .
397	Fujitsu VP2600/10	NAL (Space Technology) Japan /1992	Research	1	**4009** 5000	. .
398	Fujitsu VP2600/10	Nagoya University Nagoya Japan /1991	Academic	1	**4009** 5000	. .
399	Fujitsu VP2600/10	Reactor Nuclear Fuel Development Japan /1991	Research	1	**4009** 5000	. .
400	Fujitsu VP2600/10	Reactor Nuclear Fuel Development Japan /1991	Research	1	**4009** 5000	. .

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
401	Fujitsu VP2600/10	Taisei Construction Japan /1992	Industry Construction	1	**4009** 5000	. .
402	Fujitsu/SNI S600/20	Universitaet Aachen Aachen Germany /1991	Academic	1	**4009** 5000	. .
403	Fujitsu/SNI S600/20	Universitaet Karlsruhe Karlsruhe Germany /1990	Academic	1	**4009** 5000	. .
404	Cray Y-MP J932/22-4096	Lawrence Livermore National Laboratory Livermore USA /1996	Research	22	**4000** 4400	. .
405	Convex SPP1200/XA-32	CILEA Milano Italy /1995	Research	32	**3962** 7680	27700 4500
406	Convex SPP1200/XA-32	Cyfronet Krakau Poland /1996	Academic	32	**3962** 7680	27700 4500
407	Convex SPP1200/XA-32	Government USA /1995	Classified	32	**3962** 7680	27700 4500
408	Convex SPP1200/XA-32	Kansas State University Manhattan USA /1996	Academic	32	**3962** 7680	27700 4500
409	Convex SPP1200/XA-32	University of Kentucky Lexington USA /1995	Academic	32	**3962** 7680	27700 4500
410	SGI POWER CHALLENGEarray	Cornell Ithaca USA /1995	Academic	16	**3924** 5760	15000 2200
411	SGI POWER CHALLENGEarray	University of Nevada at Las Vegas USA /1995	Academic	16	**3924** 5760	15000 2200
412	SGI POWER CHALLENGEarray	University of Utah Salt Lake City USA /1996	Academic	16	**3924** 5760	15000 2200
413	Digital AlphaServer 8400 5/300	AltaVista Palo Alto USA /1996	Industry WWW	10	**3900** 6000	9540 812
414	Digital AlphaServer 8400 5/300	AltaVista Palo Alto USA /1996	Industry WWW	10	**3900** 6000	9540 812
415	Digital AlphaServer 8400 5/300	Defense Research Establishment Suffield Canada /1996	Research	10	**3900** 6000	9540 812
416	Digital AlphaServer 8400 5/300	Genentech USA /1996	Industry Pharmaceutics	10	**3900** 6000	9540 812
417	Digital AlphaServer 8400 5/300	Holiday Inns International Atlanta USA /1996	Industry Database	10	**3900** 6000	9540 812
418	IBM SP2/21	Burlington Northern USA /1995	Industry	21	**3875** 5540	. .
419	IBM SP2/21	First Data Corp. USA /1996	Industry	21	**3875** 5540	. .
420	NEC SX-4B/2	Engineering Lab. Japan /1996	Classified	2	**3870** 3600	. .

N world	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**Rmax** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
421	NEC SX-4B/2	Technical Engineering Molecular Japan /1996	Industry Chemistry	2	**3870** 3600	. .
422	Parsytec GC PowerPlus/96	Technische Universitaet Magdeburg Magdeburg Germany /1995	Academic	96	**3865** 7680	19000 6500
423	TMC CM-5/64	AMOCO Tulsa USA / .	Industry Geophysics	64	**3800** 8192	13056 6016
424	TMC CM-5/64	ATR Kyoto Japan / .	Research	64	**3800** 8192	13056 6016
425	TMC CM-5/64	Japanese AIST Hokuriku Japan /1993	Research	64	**3800** 8192	13056 6016
426	TMC CM-5/64	Oregon State University USA / .	Academic	64	**3800** 8192	13056 6016
427	TMC CM-5/64	Real World Computing (RWCP) Tokyo Japan /1992	Classified	64	**3800** 8192	13056 6016
428	TMC CM-5/64	University of Wisconsin USA / .	Academic	64	**3800** 8192	13056 6016
429	SGI POWER CHALLENGE	Audi AG Ingolstadt Germany /1995	Industry Automotive	14	**3767** 5040	2000 470
430	SGI POWER CHALLENGE	Australian National University Canberra Australia /1996	Academic	14	**3767** 5040	2000 470
431	SGI POWER CHALLENGE	BMW AG Muenchen Germany /1995	Industry Automotive	14	**3767** 5040	2000 470
432	SGI POWER CHALLENGE	New South Wales Center for Par. Comp. Sydney Australia /1995	Academic	14	**3767** 5040	2000 470
433	SGI POWER CHALLENGE	Pacific Northwest Laboratories/Batelle Seattle USA /1995	Research	14	**3767** 5040	2000 470
434	SGI POWER CHALLENGE	South Australian Center for Par. Comp. Adelaide Australia /1996	Academic	14	**3767** 5040	2000 470
435	Digital AlphaServer Cluster 300	University of Uppsala Uppsala Sweden /1996	Academic	12	**3750** 7200	. .
436	IBM SP2/20	Academia Sinica Taiwan /1995	Research	20	**3700** 5320	. .
437	IBM SP2/20	Deluxe Check USA /1995	Industry	20	**3700** 5320	. .
438	IBM SP2/20	Gold Star LG Korea /1995	Industry	20	**3700** 5320	. .
439	IBM SP2/20	Revlon USA /1995	Industry	20	**3700** 5320	. .
440	IBM SP2/16	Hoechst AG Germany /1996	Industry Chemistry	16	**3700** 4930	13500 2200

Top500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
441	IBM SP2/16	Universitaet Karlsruhe Karlsruhe Germany /1996	Academic	16	**3700** 4930	13500 2200
442	SGI POWER CHALLENGE	Advanced Geophysical Englewood USA /1995	Industry Geophysics	16	**3700** 4800	2500 540
443	SGI POWER CHALLENGE	Armstrong Labs USA /1994	Classified	16	**3700** 4800	2500 540
444	SGI POWER CHALLENGE	Cornell Ithaca USA /1995	Academic	16	**3700** 4800	2500 540
445	SGI POWER CHALLENGE	EMBL Heidelberg Germany /1994	Research	16	**3700** 4800	2500 540
446	SGI POWER CHALLENGE	Ford Dearborn USA /1996	Industry Automotive	16	**3700** 4800	2500 540
447	SGI POWER CHALLENGE	Government USA /1994	Classified	16	**3700** 4800	2500 540
448	SGI POWER CHALLENGE	NCAR (National Center for Atmospheric Research) Boulder USA /1995	Research	16	**3700** 4800	2500 540
449	SGI POWER CHALLENGE	Pratt Whitney Canada /1995	Industry Aerospace	16	**3700** 4800	2500 540
450	SGI POWER CHALLENGE	Reynolds Metals USA /1995	Industry	16	**3700** 4800	2500 540
451	SGI POWER CHALLENGE	Stanford University Palo Alto USA /1995	Academic	16	**3700** 4800	2500 540
452	SGI POWER CHALLENGE	Texas AM University College Station USA /1994	Academic	16	**3700** 4800	2500 540
453	SGI POWER CHALLENGE	The Aeronautical Res. Inst. of Sweden Bromma Sweden /1995	Research CFD	16	**3700** 4800	2500 540
454	SGI POWER CHALLENGE	UNI-C/Aarhus Copenhagen Denmark /1995	Academic	16	**3700** 4800	2500 540
455	SGI POWER CHALLENGE	US Air Force San Antonio USA /1995	Classified	16	**3700** 4800	2500 540
456	SGI/SNI POWER CHALLENGE	Universitaet Koeln Koeln Germany /1995	Academic	16	**3700** 4800	2500 540
457	SGI POWER CHALLENGE	University of Southern California Los Angeles USA /1994	Academic	16	**3700** 4800	2500 540
458	SGI POWER CHALLENGE	Western Geophysical Houston USA /1995	Industry Geophysics	16	**3700** 4800	2500 540
459	SGI POWER CHALLENGE	Western Geophysical Houston USA /1995	Industry Geophysics	16	**3700** 4800	2500 540
460	SGI POWER CHALLENGE	Western Geophysical Houston USA /1995	Industry Geophysics	16	**3700** 4800	2500 540

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
461	Hitachi S-3800/160	Chiba University Japan /1996	Academic	1	**3700** 4000	. .
462	Cray Y-MP J932/20-4096	NCAR (National Center for Atmospheric Research) Boulder USA /1995	Research Weather	20	**3625** 4000	. .
463	Cray Y-MP J932/20-4096	Universitaet Kiel Kiel Germany /1996	Academic	20	**3625** 4000	. .
464	Fujitsu/SNI S400/40	Universitaet Darmstadt Darmstadt Germany /1991	Academic	2	**3624** 5000	10239 .
465	Fujitsu/SNI S400/40	Universitaet Hannover Hannover Germany /1991	Academic	2	**3624** 5000	10239 .
466	SGI POWER CHALLENGE 10000	Centre Europeo del Parallelismo de Barcelona Barcelona Spain /1996	Academic	12	**3496** 4680	15000 1650
467	SGI POWER CHALLENGE 10000	Statoil Trondheim Norway /1996	Industry Geophysics	12	**3496** 4680	15000 1650
468	SGI POWER CHALLENGE 10000	Tel Aviv University Tel Aviv Israel /1996	Academic	12	**3496** 4680	15000 1650
469	SGI POWER CHALLENGE 10000	Westinghouse Electric Orlando USA /1996	Industry Energy	12	**3496** 4680	15000 1650
470	Intel XP/S8	National Security Agency USA /1994	Classified	110	**3430** 5500	. .
471	SGI POWER CHALLENGE	BASF Ludwigshafen Germany /1996	Industry Chemistry	12	**3398** 4320	2000 450
472	SGI POWER CHALLENGE	Defence Science and Technology AMRL Melbourne Australia /1996	Classified	12	**3398** 4320	2000 450
473	SGI POWER CHALLENGE	Genentech San Franzisko USA /1995	Industry	12	**3398** 4320	2000 450
474	SGI POWER CHALLENGE	General Motors Detroit USA /1995	Industry Automotive	12	**3398** 4320	2000 450
475	SGI POWER CHALLENGE	Government USA /1995	Classified	12	**3398** 4320	2000 450
476	SGI POWER CHALLENGE	Institute for Defense Analysis USA /1995	Classified	12	**3398** 4320	2000 450
477	SGI POWER CHALLENGE	Michelin Clermont-Ferrand France /1995	Industry Automotive	12	**3398** 4320	2000 450
478	SGI POWER CHALLENGE	Missle Space Intelligence Center Huntsville USA /1995	Classified	12	**3398** 4320	2000 450
479	SGI POWER CHALLENGE	Missle Space Intelligence Center Huntsville USA /1995	Classified	12	**3398** 4320	2000 450
480	SGI POWER CHALLENGE	NASA/Goddard Space Flight Center Greenbelt USA /1995	Research Aerospace	12	**3398** 4320	2000 450

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
481	SGI POWER CHALLENGE	NASA/Langley Research Center Langley USA /1995	Research	12	**3398** 4320	2000 450
482	SGI POWER CHALLENGE	NASA/Langley Research Center Langley USA /1995	Research	12	**3398** 4320	2000 450
483	SGI POWER CHALLENGE	Oxford Physiology Oxford UK /1995	Research	12	**3398** 4320	2000 450
484	SGI POWER CHALLENGE	Pennsylvania State University Philadelphia USA /1995	Academic	12	**3398** 4320	2000 450
485	SGI POWER CHALLENGE	Rover UK /1996	Industry Automotive	12	**3398** 4320	2000 450
486	SGI POWER Onyx	Rover UK /1996	Industry Automotive	12	**3398** 4320	2000 450
487	SGI POWER CHALLENGE	Tohoku University Aramaki Japan /1995	Academic	12	**3398** 4320	2000 450
488	SGI POWER CHALLENGE	UNI-C/Aarhus Copenhagen Denmark /1995	Academic	12	**3398** 4320	2000 450
489	SGI POWER CHALLENGE	University of Cincinnatti Cincinnatti USA /1995	Academic	12	**3398** 4320	2000 450
490	SGI POWER CHALLENGE	University of Poznan Poznan Poland /1994	Academic	12	**3398** 4320	2000 450
491	IBM SP2/18	ABN Amro Asv Netherlands /1996	Research	18	**3320** 4800	. .
492	IBM SP2/18	ARAMCO Saudi Arabia /1996	Industry Geophysics	18	**3320** 4800	. .
493	IBM SP2/18	American Airlines USA /1995	Industry Aerospace	18	**3320** 4800	. .
494	IBM SP2/18	Household International USA /1995	Industry	18	**3320** 4800	. .
495	IBM SP2/18	National Library of Australia Australia /1995	Research	18	**3320** 4800	. .
496	IBM SP2/18	Samsung Korea /1995	Industry Electronics	18	**3320** 4800	. .
497	Convex SPP1000/XA-32	JCCWC San Antonio USA /1995	Classified	32	**3306** 6400	25800 4700
498	Convex SPP1000/XA-32	The Scripps Research Institute La Jolla USA /1994	Industry Chemistry	32	**3306** 6400	25800 4700
499	Convex SPP1000/XA-32	US Naval Research and Development Center San Diego USA /1995	Research	32	**3306** 6400	25800 4700
500	Convex SPP1000/XA-32	University of Michigan Ann Arbor USA /1994	Academic	32	**3306** 6400	25800 4700

8.4 Statistics on Manufacturers and Continents

As basic statistics of the complete list, we give the number of systems installed with respect to the different manufacturers in the different countries or continents (Table 2) as well as the accumulated R_{max} values (Table 3) and R_{peak} values (Table 4) for those systems. More extensive analyses of the situation and its evolution over time can be found in the series of TOP500Reports (TOP500Report 1993 [3], 1994 [4] and 1995 [5]). Customized statistics can be obtained by using WWW at http://parallel.rz.uni-mannheim.de/top500.html or http://www.netlib.org/benchmark/top500.html.

Table 2: Number of Systems Installed

TOP500 Statistics — Number of Systems Installed					
	USA/Canada	Europe	Japan	others	Total
SGI/Cray	141	51	13	13	218
SGI only	77	24	1	12	114
Cray only	64	27	12	1	104
IBM	51	31	11	13	106
NEC	6	9	25		40
Fujitsu	1	7	25		33
TMC	24	1	4		29
Intel	18	3	3	1	25
Convex	10	6	1		17
Digital	9	2			11
Hitachi			10		10
others	3	7	1		11
Total	263	117	93	27	500

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Table 3: Installed $\mathbf{R_{max}}$

TOP500 Statistics — Installed R_{max} [Gflop/s]					
	USA/Canada	Europe	Japan	others	Total
SGI/Cray	1296.9	461.2	136.3	62.9	1957.3
SGI only	407.1	109.5	3.4	49.2	569.1
Cray only	889.8	351.7	132.9	13.7	1388.2
IBM	613.8	231.0	88.9	76.8	1010.5
NEC	82.6	191.7	383.6		657.8
Fujitsu	5.6	32.1	707.9		745.5
TMC	331.8	7.7	19.1		358.6
Intel	429.3	35.4	121.1	4.3	590.1
Convex	48.4	30.9	4.8		84.0
Digital	40.5	8.8			49.3
Hitachi			381.6		381.6
others	14.8	40.6	5.2		60.6
Total	2863.6	1039.3	1848.5	144.0	5895.4

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Table 4: Installed $\mathbf{R_{peak}}$

TOP500 Statistics — Installed R_{peak} [Gflop/s]					
	USA/Canada	Europe	Japan	others	Total
SGI/Cray	1762.6	628.7	191.6	81.9	2664.9
SGI only	582.2	150.0	4.3	66.7	803.2
Cray only	1180.4	478.7	187.3	15.2	1861.7
IBM	930.2	344.8	130.8	112.6	1518.4
NEC	85.5	195.0	374.4		654.9
Fujitsu	6.4	39.2	941.2		986.8
TMC	727.1	16.0	44.6		787.7
Intel	578.8	44.4	154.7	7.0	784.9
Convex	87.0	62.1	9.6		158.7
Digital	59.8	14.2			74.0
Hitachi			487.0		487.0
others	58.2	92.1	10.2		160.6
Total	4295.6	1436.5	2344.2	201.6	8277.9

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Chapter 9

TOP500 Supercomputer Sites - November 1996

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TOP500 Supercomputer Sites

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Abstract

To provide a better basis for statistics on high-performance computers, we list the sites that have the 500 most powerful computer systems installed. The best LINPACK benchmark performance achieved is used as a performance measure in ranking the computers.

9.1 Introduction and Objectives

Statistics on high-performance computers are of major interest to manufacturers, users, and potential users. These people wish to know not only the number of systems installed, but also the location of the various supercomputers within the high-performance computing community and the applications for which a computer system is being used. Such statistics can facilitate the establishment of collaborations, the exchange of data and software, and provide a better understanding of the high-performance computer market.

Statistical lists of supercomputers are not new. Every year since 1986 Hans Meuer [1] has published system counts of the major vector computer manufacturers, based principally on those at the Mannheim Supercomputer Seminar. Statistics based merely on the name of the manufacturer are no longer useful, however. New statistics are required that reflect the diversification of supercomputers, the enormous performance difference between low-end and high-end models, the increasing availability of massively parallel processing (MPP) systems, and the strong increase in computing power of the high-end models of workstation suppliers (SMP).

To provide this new statistical foundation, we have decided in 1993 to assemble and maintain a list of the 500 most powerful computer systems. Our list has been compiled twice a year since June 1993 with the help of high-performance computer experts, computational scientists, manufacturers, and the Internet community in general who responded to a questionnaire we sent out; we thank all the contributors for their cooperation.

In the present list (which we call the TOP500), we list computers ranked by their performance on the LINPACK Benchmark. While we make every attempt to verify the results obtained from users and vendors, errors are bound to exist and should be brought to our attention. We intend to continue to update this list half-yearly and, in this way, to keep track with the evolution of computers.

Hence, we welcome any comments and information; please send electronic mail to *top500@rz.uni-mannheim.de*. The list is freely available by anonymous ftp to ftp.uni-mannheim.de/top500/ or to www.netlib.org/benchmark/top500.ps. The interested reader can additionally create sublists out of the TOP500 database and can make statistics on his own by using the WWW interface at
http://parallel.rz.uni-mannheim.de/top500.html or
http://www.netlib.org/benchmark/top500.html.
Here you also have access to postscript versions of slides dealing with the interpretation of the present situation as well as with the evolution over time since we started this project.

9.2 The LINPACK Benchmark

As a yardstick of performance we are using the "best" performance as measured by the LINPACK Benchmark [2]. LINPACK was chosen because it is widely used and performance numbers are available for almost all relevant systems.

The LINPACK Benchmark was introduced by Jack Dongarra. A detailed description as well as a list of performance results on a wide variety of machines is available in postscript form from *netlib*. To retrieve a copy send electronic mail to *netlib@ornl.gov* and by typing the message *send performance from benchmark* or from any machine on the internet type:
rcp anon@netlib2.cs.utk.edu:benchmark/performance performance.

The benchmark used in the LINPACK Benchmark is to solve a dense system of linear equations. For the TOP500, we used that version of the benchmark that allows the user to scale the size of the problem and to optimize the software in order to achieve the best performance for a given machine. This performance does not reflect the *overall performance* of a given system, as no single number ever can. It does, however, reflect the *performance of a dedicated system for solving a dense system of linear equations.* Since the problem is very regular, the performance achieved is quite high, and the performance numbers give a good correction of peak performance.

By measuring the actual performance for different problem sizes n, a user can get not only the maximal achieved performance R_{max} for the problem size N_{max} but also the problem size $N_{1/2}$ where half of the performance R_{max} is achieved. These numbers together with the theoretical peak performance R_{peak} are the numbers given in the TOP500. In an attempt to obtain uniformity across all computers in performance reporting, the algorithm used in solving the system of equations in the benchmark procedure must confirm to the standard operation count for LU factorization with partial pivoting. In particular, the operation count for the algorithm must be $2/3n^3 + O(n^2)$ floating point operations. This excludes the use of a fast matrix multiply algorithm like "Strassian's Method". This is done to provide a comparable set of performance numbers across all computers. If in the future a more realistic metric finds widespread usage, so that numbers for all systems in question are available, we may convert to that performance measure.

9.3 The TOP500 List

Table 1 shows the 500 most powerful commercially available computer systems known to us. To keep the list as compact as possible, we show only a part of our information here:

• N_{world}	Position within the TOP500 ranking
• Manufacturer	Manufacturer or vendor
• Computer	Type indicated by manufacturer or vendor
• Installation Site	Customer
• Location	Location and country
• Year	Year of installation/last major update
• Field of Application	
• # Proc.	Number of processors[1]
• R_{max}	Maximal LINPACK performance achieved
• R_{peak}	Theoretical peak performance
• N_{max}	Problemsize for achieving R_{max}
• $N_{1/2}$	Problemsize for achieving half of R_{max}

If R_{max} from Table 3 of the LINPACK Report [2] is not available, we use the TPP performance given in Table 1 of the LINPACK Report [2] for solving a system of 1000 equations. To use a consistent yardstick for all systemwe we do not use results achieved by advanced parallel algorithm as defined in [2]. In case of the Cray T90, C90 and J90 systems we had to use older able 3 or Table 1 results. In a few cases we interpolated between two measured system sizes.

For models where we did not receive the requested data, the performance of the next smaller system measured is used.

If there should be any changes in the performances given in Table 1 we will update them.

In addition to cross checking different sources of information, we select randomly a statistical representative sample of the first 500 systems of our database. For these systems we ask the supplier of the information to establish direct contact between the installation site and us to verify the given information. This gives us basic information about the quality of the list in total.

As the TOP500 should provide a basis for statistics on the market of high-performance computers, we limit the number of systems installed at vendor sites. This is done for each vendor separately by limiting the accumulated performance of systems at vendor sites to a maximum of 5% of the total accumulated installed performance of this vendor. Rounding is done in favor of the vendor in question.

In Table 1, the computers are ordered first by their R_{max} value. In the case of equal performances (R_{max} value) for different computers, we have chosen to order by R_{peak}. For sites that have the same computer, the order is by memory size and then alphabetically.

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
1	Hitachi/Tsukuba CP-PACS/2048	Center for Computational Physics, Univ of Tsukuba Tsukuba Japan /1996	Academic	2048	**368200** 614000	103680 30720
2	Fujitsu Numerical Wind Tunnel	NAL Japan /1996	Research Aerospace	167	**229700** 281000	66132 18018
3	Hitachi SR2201/1024	University of Tokyo Tokyo Japan /1996	Academic	1024	**220400** 307000	138240 34560
4	Intel XP/S140	Sandia National Labs Albuquerque USA /1993	Research	3680	**143400** 184000	55700 20500
5	Intel XP/S-MP 150	Oak Ridge National Laboratory Oak Ridge USA /1995	Research	3072	**127100** 154000	86000 17800
6	Intel XP/S-MP 125	Japan Atomic Energy Research Japan /1996	Research	2502	**103500** 125100	. .
7	Cray T3D MC1024-8	Government USA /1994	Classified	1024	**100500** 152000	81920 10224
8	Fujitsu VPP500/80	National Lab. for High Energy Physics Japan /1994	Research	80	**98900** 128000	32640 10050
9	Fujitsu VPP700/56	Kyushu University Kyushu Japan /1996	Academic	56	**94300** 123200	100280 8280
10	Fujitsu VPP700/46	ECMWF Reading UK /1996	Research Weather	46	**94300** 101200	100280 8280
11	Cray T3E LC256-128	CNRS/IDRIS Orsay France /1996	Research	256	**93200** 154000	53664 11040
12	Cray T3E LC256-128	DOD/CEWES Vicksburg USA /1996	Research Mechanics	256	**93200** 154000	53664 11040
13	Cray T3E LC256-128	Pittsburgh Supercomputer Center Pittsburgh USA /1996	Research	256	**93200** 154000	53664 11040
14	IBM SP2/512	Cornell Theory Center Ithaca USA /1994	Academic	512	**88400** 136000	73500 20150
15	IBM SP2/512	IBM/Poughkeepsie Poughkeepsie USA /1995	Vendor	512	**88400** 136000	73500 20150
16	IBM SP2/384	Maui High-Performance Computing Center (MHPCC) USA /1994	Research	384	**66300** 102400	. .
17	NEC SX-4/32	NEC Fuchu Plant Tokyo Japan /1995	Vendor Benchmarking	32	**60650** 64000	10000 1560
18	NEC SX-4/32	Osaka University Osaka Japan /1996	Academic	32	**60650** 64000	10000 1560
19	NEC SX-4/32	Osaka University Osaka Japan /1996	Academic	32	**60650** 64000	10000 1560
20	NEC SX-4/32	Universitaet Stuttgart Stuttgart Germany /1996	Research	32	**60650** 64000	10000 1560

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
21	TMC CM-5/1056	Los Alamos National Laboratory Los Alamos USA /1993	Research Energy	1056	**59700** 135100	52224 24064
22	Fujitsu VPP500/42	Japan Atomic Energy Research Japan /1994	Research	42	**54500** 67200	. .
23	Fujitsu VPP500/42	Nagoya University Nagoya Japan /1995	Academic	42	**54500** 67200	. .
24	Cray T3E LC136-128	Forschungszentrum Juelich (KFA) Juelich Germany /1996	Research	136	**53100** 81800	. .
25	TMC CM-5/896	Minnesota Supercomputer Center USA /1994	Academic	896	**52300** 114700	. .
26	Fujitsu VPP500/40	National Genetics Research Lab. Japan /1995	Research	40	**52070** 64000	. .
27	Fujitsu VPP500/40	Tokyo University - Inst. of Solid State Physics Tokyo Japan /1994	Academic	40	**52070** 64000	. .
28	Cray T3D MC512-8	Los Alamos National Laboratory Los Alamos USA /1994	Research Energy	512	**50800** 76000	57856 7136
29	Cray T3D MC512-8	Minnesota Supercomputer Center USA /1995	Academic	512	**50800** 76000	57856 7136
30	Cray T3D MC512-8	NASA/Goddard Space Flight Center Greenbelt USA /1996	Research Weather	512	**50800** 76000	57856 7136
31	Cray T3D MC512-8	Pittsburgh Supercomputing Center Pittsburgh USA /1994	Academic	512	**50800** 76000	57856 7136
32	Cray T3D MC512-8	University of Edinburgh Edinburgh UK /1996	Academic	512	**50800** 76000	57856 7136
33	Cray T3E LC128-128	Max-Planck-Gesellschaft MPI/IPP Garching Germany /1996	Research	128	**50430** 77000	58848 7392
34	Cray T3E LC128-256	NERSC/LBNL Berkley USA /1996	Research	128	**50430** 77000	58848 7392
35	Cray T3E LC128-128	United Kingdom Meteorological Office Bracknell UK /1996	Research Weather	128	**50430** 77000	58848 7392
36	Cray T3E LC128-128	Universitaet Stuttgart Stuttgart Germany /1996	Research	128	**50430** 77000	58848 7392
37	IBM SP2/256	Lawrence Livermore National Laboratory Livermore USA /1996	Research Energy	256	**44200** 68000	53000 13500
38	IBM SP2/256	Lawrence Livermore National Laboratory Livermore USA /1996	Research Energy	256	**44200** 68000	53000 13500
39	Fujitsu VPP500/32	The Angstrom Technology Partnership Tsukuba Japan /1993	Research	32	**42400** 51200	20736 4940
40	Fujitsu VPP500/30	Tsukuba University Tsukuba Japan /1993	Research	30	**39812** 48000	. .

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**Rmax** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
41	NEC SX-4/20	Japan Marine Science and Technology Japan /1995	Research	20	**38195** 40000	. .
42	NEC SX-4/20	National Research Institute for Metals Japan /1996	Research	20	**38195** 40000	. .
43	NEC SX-4/20	Toyota Central Research Development Japan /1996	Industry Automotive	20	**38195** 40000	. .
44	Fujitsu VPP500/28	Institute of Physical and Chemical Res. (RIKEN) Tokyo Japan /1993	Research	28	**37225** 44800	. .
45	IBM SP2/208	Pacific Northwest Laboratories/Batelle Richland USA /1996	Research	208	**36450** 55000	42200 10300
46	Fujitsu VPP300/16	Japan Atomic Energy Research Japan /1996	Research	16	**34100** 35200	59200 3520
47	Intel XP/S-MP 41	Rome Laboratory USA /1995	Research	816	**33700** 40800	. .
48	NEC SX-4/16	Atmospheric Environment Service (AES) Dorval Canada /1995	Research Weather	16	**30710** 32000	10000 890
49	NEC SX-4/16	National Aerospace Laboratory (NLR) Noordoostpolder Netherlands /1996	Research Aerospace	16	**30710** 32000	10000 890
50	NEC SX-4/16	National Cardiovascular Center Japan /1996	Research	16	**30710** 32000	10000 890
51	NEC SX-4/16	Swiss Scientific Computing Center (CSCS) Manno Switzerland /1996	Research	16	**30710** 32000	10000 890
52	TMC CM-5/512	NCSA Urbana-Champaign USA /1993	Academic	512	**30400** 66000	36864 16384
53	TMC CM-5/512	National Security Agency USA /1993	Classified	512	**30400** 66000	36864 16384
54	Cray Y-MP T932/321024	Nippon Telegraph and Telephone (NTT) Japan /1995	Industry	32	**29360** 58000	. .
55	IBM SP2/160	NASA/Ames Research Center/NAS Moffett Field USA /1994	Research	160	**28700** 42500	42200 10300
56	Hitachi S-3800/480	Hitachi Ltd. GPCD Japan /1994	Vendor Software	4	**28400** 32000	15500 830
57	Hitachi S-3800/480	Japan Meteorological Agency Japan /1995	Research Weather	4	**28400** 32000	15500 830
58	Hitachi S-3800/480	University of Tokyo Tokyo Japan /1993	Academic	4	**28400** 32000	15500 830
59	Fujitsu VPP300/13	Australian National University Canberra Australia /1996	Academic	13	**27720** 28600	. .
60	Cray T3D MC256-8/464	Bear Stearns USA /1996	Industry Finance	256	**25300** 38000	40960 4918

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**Rmax** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
61	Cray T3D SC256-8/264	Caltech/JPL Pasadena USA /1994	Academic	256	**25300** 38000	40960 4918
62	Cray T3D MC256-8	Defense Research Agency Farnborough UK /1994	Classified	256	**25300** 38000	40960 4918
63	Cray T3D MC256-8	EXXON USA /1995	Industry Geophysics	256	**25300** 38000	40960 4918
64	Cray T3D MC256-8	Ecole Polytechnique Federale de Lausanne Lausanne Switzerland /1994	Academic	256	**25300** 38000	40960 4918
65	Cray T3D SC256-8/364	Lawrence Livermore National Laboratory Livermore USA /1994	Research Energy	256	**25300** 38000	40960 4918
66	Cray T3D SC256-8/464	Los Alamos National Laboratory Los Alamos USA /1994	Research Energy	256	**25300** 38000	40960 4918
67	Cray T3D SC256-8/464	ZIB/Konrad Zuse-Zentrum fuer Informationstechnik Berlin Germany /1995	Academic	256	**25300** 38000	40960 4918
68	Cray T3E AC64-128	CSC (Center for Scientific Computing) Espoo Finland /1996	Academic	64	**25190** 38000	39936 4896
69	Cray T3E LC64-128	Cray Research USA /1996	Vendor	64	**25190** 38000	39936 4896
70	Cray T3E AC64-128	EDS/General Motors Auburn Hills USA /1996	Industry Automotive	64	**25190** 38000	39936 4896
71	Cray T3E AC64-128	TUD (Technical University Delft) Delft Netherlands /1996	Academic	64	**25190** 38000	39936 4896
72	Cray T3E AC64-128	University of Trondheim Norway /1996	Academic	64	**25190** 38000	39936 4896
73	NEC SX-3/44R	Atmospheric Environment Service (AES) Dorval Canada /1994	Research Weather	4	**23200** 26000	6400 830
74	NEC SX-3/44R	Tohoku University Aramaki Japan /1993	Academic	4	**23200** 26000	6400 830
75	Cray Y-MP T932/20512	NOAA/Geophysical Fluid Dynamics Laboratory (GFDL) Princeton USA /1996	Research Weather	20	**23075** 36250	. .
76	Fujitsu/SNI VPP300/10	Universitaet/Forschungszentrum Karlsruhe Karlsruhe Germany /1996	Academic	10	**22350** 22000	. .
77	Fujitsu VPP500/16	Reactor Nuclear Fuel Development Japan /1996	Research	16	**21700** 25600	14592 3090
78	Hitachi S-3800/380	Hokkaido University Sapporo Japan /1994	Academic	3	**21600** 24000	15680 760
79	Hitachi S-3800/380	Institute for Materials Research/Tohoku University Japan /1994	Academic	3	**21600** 24000	15680 760
80	IBM SP2/110	KTH - Royal Institute of Technology Stockholm Sweden /1996	Research	110	**20370** 29210	. .

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
81	Fujitsu VPP500/15	Kyoto University Kyoto Japan /1994	Academic	15	**20360** 24000	. .
82	NEC SX-3/44	Atmospheric Environment Service (AES) Dorval Canada /1991	Research Weather	4	**20000** 22000	6144 832
83	IBM SP2/104	MCI USA /1994	Industry	104	**19340** 27620	. .
84	Cray T3E AC40-128	University of Texas Austin USA /1996	Academic	40	**18840** 24000	. .
85	Intel XP/S-MP 22	ETH Zuerich Switzerland /1995	Academic	450	**18700** 22500	. .
86	SGI POWER CHALLENGEarray	US Army Research Laboratory Aberdeen USA /1995	Research	96	**18455** 28800	53000 20000
87	IBM SP2/98	Citicorp USA /1996	Industry Finance	98	**18310** 26030	. .
88	IBM SP2/84	Universitaet/Forschungszentrum Karlsruhe Karlsruhe Germany /1996	Academic	84	**17920** 25870	. .
89	NEC SX-3/34R	National Inst. for Molecular Science Okozaki Japan /1993	Research	3	**17400** 19500	6144 691
90	NEC SX-3/34R	VW (Volkswagen AG) Wolfsburg Germany /1996	Industry Automotive	3	**17400** 19500	6144 691
91	IBM SP2/80	Wright Patterson Air Force Base USA /1996	Research	80	**17230** 24630	. .
92	Fujitsu VPP300/8	Nippon University Japan /1996	Academic	8	**17100** 17600	41600 2080
93	Fujitsu/SNI VPP300/8	Universitaet Aachen Aachen Germany /1996	Academic	8	**17100** 17600	41600 2080
94	IBM SP2/85	NIH (National Institute of Health) Frederick USA /1995	Research	85	**16090** 22570	. .
95	SGI POWER CHALLENGEarray	NCSA Urbana-Champaign USA /1996	Research	64	**15598** 23040	37000 8500
96	SGI POWER CHALLENGEarray	Silicon Graphics Cortaillod Switzerland /1995	Vendor Benchmarking	64	**15598** 23040	37000 8500
97	Cray Y-MP T916/12512	Forschungszentrum Juelich (KFA) Juelich Germany /1996	Research	12	**15430** 21750	. .
98	NEC SX-4/8	ATR Optical Communication Lab Japan /1996	Research	8	**15350** 16000	. .
99	NEC SX-4/8	Danish Meteorological Institute Copenhagen Denmark /1996	Research	8	**15350** 16000	. .
100	NEC SX-4/8	German Aerospace Laboratory (DLR) Goettingen Germany /1996	Research Aerospace	8	**15350** 16000	. .

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
101	NEC SX-4/8	National Geographic Agency Japan /1996	Research	8	**15350** 16000	. .
102	IBM SP2/80	National Center for High Performance Computing Taiwan /1996	Academic	80	**15230** 21250	. .
103	Intel XP/S35	Caltech Pasadena USA /1994	Research	512	**15200** 26000	23000 9000
104	Intel XP/S35	Oak Ridge National Laboratory Oak Ridge USA /1992	Research	512	**15200** 26000	23000 9000
105	TMC CM-5/256	Geco-Prakla Houston USA /1994	Industry Geophysics	256	**15100** 33000	26112 12032
106	TMC CM-5/256	Geco-Prakla Houston USA /1995	Industry Geophysics	256	**15100** 33000	26112 12032
107	TMC CM-5/256	Government USA /1993	Classified	256	**15100** 33000	26112 12032
108	TMC CM-5/256	US Naval Research Laboratory Washington D.C. USA /1992	Research	256	**15100** 33000	26112 12032
109	IBM SP2/79	CNUSC Montpellier France /1996	Academic	79	**15060** 20980	. .
110	IBM SP2/78	DKFZ Heidelberg Germany /1996	Research	78	**14890** 20710	. .
111	IBM SP2/77	Leibniz Rechenzentrum Muenchen Germany /1995	Academic	77	**14720** 20450	. .
112	IBM SP2/77	Sears Product Service Group USA /1996	Industry	77	**14720** 20450	. .
113	IBM SP2/77	Sears Roebuck USA /1996	Industry	77	**14720** 20450	. .
114	Hitachi S-3800/280	Central Res. Inst. of Electric Power Ind. Japan /1996	Research	2	**14600** 16000	15680 570
115	IBM SP2/76	SARA (Stichting Academisch Rekencentrum) Amsterdam Netherlands /1995	Research	76	**14550** 20180	. .
116	IBM SP2/75	Atomic Weapons Establishment Aldermaston UK /1996	Classified	75	**14380** 19920	. .
117	Hitachi SR2201/64	Hitachi RCS Ebina Japan /1996	Vendor	64	**14200** 19000	34560 6720
118	Hitachi SR2201/64	Japan Atomic Energy Research Japan /1996	Research	64	**14200** 19000	34560 6720
119	Hitachi SR2201/64	University of Cambridge Cambridge UK /1996	Academic	64	**14200** 19000	34560 6720
120	Intel Delta	Caltech Pasadena USA /1991	Academic	512	**13900** 20480	25000 7500

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
121	IBM SP2/72	Nuclear Power Engineering Japan /1995	Industry Energy	72	**13860** 19120	. .
122	Cray Y-MP C916/16512	Cray Research Eagan USA /1992	Vendor	16	**13700** 15238	10000 650
123	Cray Y-MP C916/16256	DKRZ Hamburg Germany /1995	Research Weather	16	**13700** 15238	10000 650
124	Cray Y-MP C916/161024	DOD/CEWES Vicksburg USA /1994	Research Mechanics	16	**13700** 15238	10000 650
125	Cray Y-MP C916/16256	DOE/Bettis Atomic Power Laboratory USA /1993	Research	16	**13700** 15238	10000 650
126	Cray Y-MP C916/16256	DOE/Knolls Atomic Power Laboratory USA /1993	Research	16	**13700** 15238	10000 650
127	Cray Y-MP C916/16512	DOE/National Security Agency USA /1994	Classified	16	**13700** 15238	10000 650
128	Cray Y-MP C916/16256	ECMWF Reading UK /1994	Research Weather	16	**13700** 15238	10000 650
129	Cray Y-MP C916/16512	Ford Motor Company Dearborn USA /1993	Industry Automotive	16	**13700** 15238	10000 650
130	Cray Y-MP C916/16512	Ford Motor Company Dearborn USA /1995	Industry Automotive	16	**13700** 15238	10000 650
131	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
132	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
133	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
134	Cray Y-MP C916/161024	Government USA /1992	Classified	16	**13700** 15238	10000 650
135	Cray Y-MP C916/16512	Government USA /1994	Classified	16	**13700** 15238	10000 650
136	Cray Y-MP C916/16256	Government Communications Headquarters Benhall UK /1994	Classified	16	**13700** 15238	10000 650
137	Cray Y-MP C916/16512	KIST/System Engineering Research Institute Korea /1993	Academic	16	**13700** 15238	10000 650
138	Cray Y-MP C916/161024	MITI Osaka Japan /1994	Research	16	**13700** 15238	10000 650
139	Cray Y-MP C916/161024	NASA/Ames Research Center/NAS Moffett Field USA /1993	Research	16	**13700** 15238	10000 650
140	Cray Y-MP C916/16256	NERSC/LBNL Berkley USA /1992	Research	16	**13700** 15238	10000 650

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
141	Cray Y-MP C916/16256	NOAA/Geophysical Fluid Dynamics Laboratory (GFDL) Princeton USA /1995	Research Weather	16	**13700** 15238	10000 650
142	Cray Y-MP C916/16256	NOAA/National Centers for Environment Prediction Suitland USA /1994	Research	16	**13700** 15238	10000 650
143	Cray Y-MP C916/16512	Pittsburgh Supercomputing Center Pittsburgh USA /1994	Academic	16	**13700** 15238	10000 650
144	Cray Y-MP C916/16256	Res. Inf. Processing System (RIPS) Tsukuba Japan /1994	Research	16	**13700** 15238	10000 650
145	Cray Y-MP C916/161024	Tohoku University, Institute of Fluid Science Aramaki Japan /1994	Academic	16	**13700** 15238	10000 650
146	Cray Y-MP C916/161024	US Naval Oceanographic Command Bay Saint Louis USA /1994	Research Weather	16	**13700** 15238	10000 650
147	Cray Y-MP C916/16256	United Kingdom Meteorological Office Bracknell UK /1994	Research Weather	16	**13700** 15238	10000 650
148	Cray Y-MP C916/161024	Wright Patterson Air Force Base USA /1996	Research	16	**13700** 15238	10000 650
149	Fujitsu VPP500/10	Communications Res. Lab. (CRL) Tokyo Japan /1993	Research	10	**13675** 16000	. .
150	IBM SP2/69	PIK Potsdam Germany /1996	Research	69	**13350** 18320	. .
151	IBM SP2/68	DLR Koeln Germany /1996	Research	68	**13180** 18060	. .
152	Cray Y-MP T932/101024	EDS/General Motors Auburn Hills USA /1996	Industry Automotive	10	**13150** 18125	. .
153	IBM SP2/67	Bell South USA /1995	Industry	67	**13010** 17790	. .
154	Fujitsu VPP300/6	Meiji University Japan /1996	Academic	6	**12850** 13200	. .
155	Fujitsu/SNI VPP300/6	Universitaet Darmstadt Darmstadt Germany /1996	Academic	6	**12850** 13200	. .
156	Cray T3D MC128-8	Air Force/Eglin Air Force Base Eglin USA /1994	Classified	128	**12800** 19000	20736 3408
157	Cray T3D MC128-8	CEA/Centre d'Etudes Limeil-Valenton France /1993	Research	128	**12800** 19000	20736 3408
158	Cray T3D MCA128-8	CEA/Centre d'Etudes Nucleaires Grenoble France /1994	Research Energy	128	**12800** 19000	20736 3408
159	Cray T3D MC128-8	CINECA Bologna Italy /1996	Research	128	**12800** 19000	20736 3408
160	Cray T3D MCA128-8	CNRS/IDRIS Orsay France /1995	Research	128	**12800** 19000	20736 3408

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	R_{max} R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
161	Cray T3D MCA128-8	Compagnie Generale de Geophysique (CGG) Massy France /1995	Industry Geophysics	128	**12800** 19000	20736 3408
162	Cray T3D MC128-8	Cray Research Eagan USA /1995	Vendor	128	**12800** 19000	20736 3408
163	Cray T3D MCA128-8	Cray Research Eagan USA /1996	Vendor	128	**12800** 19000	20736 3408
164	Cray T3D MCA128-8	ECMWF Reading UK /1994	Research Weather	128	**12800** 19000	20736 3408
165	Cray T3D MCA128-8	Environmental Protection Agency USA /1995	Research	128	**12800** 19000	20736 3408
166	Cray T3D MCA128-8	Max-Planck-Gesellschaft MPI Munchen Germany /1995	Research	128	**12800** 19000	20736 3408
167	Cray T3D MC128-8	Phillips Petroleum Company Bartlesville USA /1994	Industry Geophysics	128	**12800** 19000	20736 3408
168	Cray T3D MCA128-2	Reactor Nuclear Fuel Development Japan /1994	Research	128	**12800** 19000	20736 3408
169	Cray T3D MCA128-8	Tohoku University, Institute of Fluid Science Aramaki Japan /1994	Academic	128	**12800** 19000	20736 3408
170	Cray T3D MCA128-8	UCSD/San Diego Supercomputer Center San Diego USA /1995	Academic	128	**12800** 19000	20736 3408
171	Cray T3D MC128-8	University of Alaska - ARSC Fairbanks USA /1995	Academic	128	**12800** 19000	20736 3408
172	IBM SP2/65	CERN Geneva Switzerland /1995	Research	65	**12670** 17260	. .
173	Cray T3E AC32-128	NCSC USA /1996	Research	32	**12500** 19000	27936 3360
174	IBM SP2/64	InterUniversity Israel /1996	Academic	64	**12500** 17000	26500 7000
175	IBM SP2/64	Maui High-Performance Computing Center (MHPCC) USA /1994	Research	64	**12500** 17000	26500 7000
176	IBM SP2/64	University of Houston USA /1996	Academic	64	**12500** 17000	26500 7000
177	Intel XP/S-MP 15	ONERA Chatillon France /1995	Research Aerospace	294	**12250** 14700	. .
178	Intel XP/S-MP 14	Oak Ridge National Laboratory Oak Ridge USA /1995	Research	288	**12000** 14400	. .
179	Intel XP/S30	UCSD/San Diego Supercomputer Center San Diego USA /1993	Academic	400	**11900** 20000	. .
180	IBM SP2/60	Tokyo Metropolitan University Tokyo Japan /1995	Academic	60	**11750** 15930	. .

TOP500 Supercomputers - Worldwide

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
181	NEC SX-3/24R	National Institute of Fusion Science (NIFS) Japan /1993	Research	2	**11600** 13000	4352 516
182	NEC SX-3/24R	Swiss Scientific Computing Center (CSCS) Manno Switzerland /1994	Research	2	**11600** 13000	4352 516
183	NEC SX-4/6	DIGICON Montreal Canada /1996	Industry Geophysics	6	**11510** 12000	. .
184	Cray Y-MP T916/8256	CEA (Commissariat a l'Energie Atomique) Limeil France /1996	Research	8	**10880** 14500	. .
185	Cray Y-MP T916/8512	Chrysler Motors Company USA /1996	Industry Automotive	8	**10880** 14500	. .
186	Fujitsu VPP300/5	Fujitsu San Jose USA /1996	Vendor	5	**10720** 11000	. .
187	IBM SP2/54	Autozone Memphis USA /1995	Industry Database	54	**10640** 14340	. .
188	Hewlett-Packard SPP1600/XA-64	Hewlett-Packard CXTC Richardson USA /1996	Vendor Benchmarking	64	**10402** 15360	. .
189	Cray Y-MP C916/12256	Tokyo Institute of Technology Tokyo Japan /1995	Academic	12	**10270** 11430	. .
190	IBM SP2/51	Shell Intl. Petroleum Netherlands /1996	Industry Geophysics	51	**10090** 13540	. .
191	Intel XP/S25	NAL Japan /1994	Research	336	**10000** 16800	. .
192	Intel XP/S25	NRAD USA /1994	Research	336	**10000** 16800	. .
193	IBM SP2/50	Deutsche Telekom AG Germany /1996	Industry Database	50	**9900** 13280	. .
194	IBM SP2/50	Federal Express USA /1995	Industry	50	**9900** 13280	. .
195	IBM SP2/50	Nihon Genken Tokai Japan /1995	Research	50	**9900** 13280	. .
196	TMC CM-200/64k	Los Alamos National Laboratory Los Alamos USA / .	Research Energy	2048	**9800** 20000	29696 11264
197	TMC CM-200/64k	Los Alamos National Laboratory Los Alamos USA / .	Research Energy	2048	**9800** 20000	29696 11264
198	Fujitsu VPP500/7	Institute of Space Astronautical Science (ISAS) Tokyo Japan /1993	Research	7	**9650** 11200	. .
199	IBM SP2/48	Ensign UK /1996	Industry Geophysics	48	**9530** 12750	. .
200	IBM SP2/48	Institute of Math and Statistics Japan /1995	Research	48	**9530** 12750	. .

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
201	IBM SP2/48	NASA/Langley Research Center Hampton USA /1994	Research	48	**9530** 12750	. .
202	IBM SP2/48	Okazaki Bunshi Ken Japan /1994	Research	48	**9530** 12750	. .
203	IBM SP2/48	PCS Inc USA /1996	Industry	48	**9530** 12750	. .
204	IBM SP2/48	Rika dai Japan /1996	Academic	48	**9530** 12750	. .
205	IBM SP2/48	University of Michigan Michigan USA /1996	Academic	48	**9530** 12750	. .
206	Cray T3E AC24-128	TU Berlin Berlin Germany /1996	Research	24	**9420** 14400	. .
207	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**9398** 14400	27000 6775
208	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**9398** 14400	27000 6775
209	IBM SP2/46	Tohoku University, Kohgaku-bu Aramaki Japan /1996	Academic	46	**9160** 12210	. .
210	IBM SP2/44	C4 / Centre de Computacio i Comunicacions de Catal Barcelona Spain /1996	Academic	44	**8790** 11680	. .
211	SGI ORIGIN 2000	NCSA Urbana-Champaign USA /1996	Research	128	**8757** 49920	16000 4000
212	SGI ORIGIN 2000	Boston University Boston USA /1996	Academic	32	**8757** 12480	16000 4000
213	SGI ORIGIN 2000	US Naval Research Laboratory Washington D.C. USA /1996	Research	32	**8757** 12480	16000 4000
214	Fujitsu VX/4	Fujitsu Uxbridge UK /1996	Vendor	4	**8600** 8800	28800 1280
215	Fujitsu/SNI VPP300/4	Universitaet Hannover Hannover Germany /1996	Academic	4	**8600** 8800	28800 1280
216	Fujitsu VPP300/4	Western Geophysical Houston USA /1996	Industry Geophysics	4	**8600** 8800	28800 1280
217	IBM SP2/42	Chuodai Riko Japan /1996	Academic	42	**8420** 11150	. .
218	IBM SP2/42	Federal Express USA /1996	Industry	42	**8420** 11150	. .
219	IBM SP2/42	Fidelity Investments USA /1995	Industry	42	**8420** 11150	. .
220	Cray Y-MP T916/6512	DOD/NAVO USA /1996	Classified	8	**8300** 10850	. .

TOP500 **Supercomputers - Worldwide**

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
221	SGI POW CHALLarray 10000	NCSA Urbana-Champaign USA /1996	Research	72	**8233** 28080	. .
222	SGI POWER CHALLENGE 10000	Biomolecular Eng. Research Institute Suita Japan /1996	Research	32	**8233** 12480	16000 4000
223	IBM SP2/41	ISSC, Unisource USA /1996	Industry	41	**8230** 10890	. .
224	IBM SP2/41	Petro Canada Canada /1995	Industry Geophysics	41	**8230** 10890	. .
225	IBM SP2/36	Western Geophysical UK /1996	Industry Geophysics	36	**8200** 11090	. .
226	IBM SP2/40	National Cancer Research Institute Tokyo Japan /1994	Research	40	**8050** 10620	. .
227	IBM SP2/40	Seoul National University Seoul Korea /1995	Academic	40	**8050** 10620	. .
228	IBM SP2/40	UNI-C/Lyngby Denmark /1995	Academic	40	**8050** 10620	. .
229	IBM SP2/40	Western Geophysical UK /1996	Industry Geophysics	40	**8050** 10620	. .
230	Parsytec GC PowerPlus/192	Universitaet Heidelberg - IWR Heidelberg Germany /1995	Academic	192	**7999** 15360	27192 9500
231	Parsytec GC PowerPlus/192	Universitaet Paderborn - PC2 Paderborn Germany /1995	Academic	192	**7999** 15360	27192 9500
232	IBM SP2/35	ARAMCO Saudi Arabia /1996	Industry Geophysics	35	**7970** 10780	. .
233	Hewlett-Packard SPP1600/XA-48	Universitaet Erlangen Erlangen Germany /1996	Academic	48	**7920** 11520	. .
234	Fujitsu VPP500/6	Fujitsu Ltd. Numazu Japan /1996	Vendor	6	**7900** 9600	. .
235	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
236	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
237	SGI POWER CHALLENGEarray	Government USA /1995	Classified	40	**7831** 12000	27000 6775
238	Hewlett-Packard Exemplar S-Class	Defense Contractor USA /1996	Industry Aerospace	16	**7783** 11500	13320 1044
239	Hewlett-Packard Exemplar S-Class	Defense Contractor USA /1996	Industry Aerospace	16	**7783** 11500	13320 1044
240	Hewlett-Packard Exemplar S-Class	Defense Contractor USA /1996	Industry Aerospace	16	**7783** 11500	13320 1044

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N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
241	Hewlett-Packard Exemplar S-Class	Defense Contractor USA /1996	Industry Aerospace	16	**7783** 11500	13320 1044
242	Hewlett-Packard Exemplar S-Class	Defense Contractor USA /1996	Industry Aerospace	16	**7783** 11500	13320 1044
243	Hewlett-Packard Exemplar S-Class	Hewlett-Packard CXTC Richardson USA /1996	Vendor Benchmarking	16	**7783** 11500	13320 1044
244	Hewlett-Packard Exemplar S-Class	NCSA Urbana-Champaign USA /1996	Academic	16	**7783** 11500	13320 1044
245	Hewlett-Packard Exemplar S-Class	Universitaet Leipzig Leipzig Germany /1996	Academic	16	**7783** 11500	13320 1044
246	Hewlett-Packard Exemplar S-Class	Universitaet Leipzig Leipzig Germany /1996	Academic	16	**7783** 11500	13320 1044
247	TMC CM-5E/128	The Angstrom Technology Partnership Tsukuba Japan /1994	Research	128	**7700** 20000	18432 8192
248	TMC CM-5/128	American Express USA /1993	Industry	128	**7700** 16000	18432 8192
249	TMC CM-5/128	Government USA /1993	Classified	128	**7700** 16000	18432 8192
250	TMC CM-5/128	Institut de Physique du Globe de Paris (IPG) Paris France /1992	Research	128	**7700** 16000	18432 8192
251	TMC CM-5/128	JPL Pasadena USA /1995	Research	128	**7700** 16000	18432 8192
252	TMC CM-5/128	MIT Cambridge USA / .	Research	128	**7700** 16000	18432 8192
253	IBM SP2/38	GMD Germany /1995	Research	38	**7680** 10090	. .
254	IBM SP2/38	Kirin Beer Japan /1996	Industry	38	**7680** 10090	. .
255	IBM SP2/38	UCLA Los Angeles USA /1994	Academic	38	**7680** 10090	. .
256	NEC SX-4/4	Houston Area Research Center Houston USA /1996	Research	4	**7670** 8000	. .
257	Intel XP/S20	Okayama University Okayama Japan /1994	Academic	256	**7600** 12800	16000 4000
258	Intel XP/S20	Wright Patterson Air Force Base USA /1994	Research	256	**7600** 12800	16000 4000
259	SGI POWER CHALLENGEarray	INRIA - Sophia Antipolis Rennes France /1995	Research	32	**7542** 11520	22000 5600
260	SGI POWER CHALLENGEarray	NASA/Ames Mountain View USA /1995	Research Aerospace	32	**7542** 11520	22000 5600

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N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
261	SGI POWER CHALLENGEarray	NASA/JPL Pasadena USA /1995	Academic	32	**7542** 11520	22000 5600
262	IBM SP2/37	American Express USA /1995	Industry Finance	37	**7490** 9820	. .
263	SGI POWER CHALLENGEarray	Boston University Boston USA /1995	Academic	38	**7445** 11400	27000 6775
264	Hewlett-Packard SPP1200/XA-64	NCSA Urbana-Champaign USA /1995	Academic	64	**7408** 15360	42000 .
265	Hitachi S-3800/180	Meteorological Research Institute Japan /1993	Research Weather	1	**7400** 8000	15680 470
266	IBM SP2/36	Rensselaer Polytechnic Troy USA /1994	Academic	36	**7310** 9560	. .
267	IBM SP2/36	Telecom Denmark (Danadata) Denmark /1996	Industry Database	36	**7310** 9560	. .
268	IBM SP2/32	HMC Korea /1996	Industry	32	**7300** 9860	19500 3500
269	IBM SP2/32	Kogiin Kagiken Japan /1996	Research	32	**7300** 9860	19500 3500
270	SGI ORIGIN 2000	Baylor College of Medicine Houston USA /1996	Academic	24	**7213** 9360	15000 3500
271	IBM SP2/35	MCI USA /1995	Industry	35	**7120** 9290	. .
272	IBM SP2/35	Phillipps University of Marburg Marburg Germany /1995	Academic	35	**7120** 9290	. .
273	IBM SP2/35	Shell KSEPL Netherlands /1996	Industry Geophysics	35	**7120** 9290	. .
274	IBM SP2/35	Shopko Stores USA /1996	Industry	35	**7120** 9290	. .
275	IBM SP2/35	State Farm USA /1996	Industry	35	**7120** 9290	. .
276	Hitachi S-3800/260	Suzuki Motor Japan /1993	Industry Automotive	2	**7100** 8000	. .
277	Cray Y-MP C98/8256	BMW AG Muenchen Germany /1995	Industry Automotive	8	**6850** 7619	. .
278	Cray Y-MP C98/8512	CNRS/IDRIS Orsay France /1993	Research	8	**6850** 7619	. .
279	Cray Y-MP C98/8256	Chrysler Motors Company USA /1996	Industry Automotive	8	**6850** 7619	. .
280	Cray Y-MP C98/8256	Direction de la Meteorologie Nationale Toulouse France /1994	Research Weather	8	**6850** 7619	. .

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
281	Cray Y-MP C98/81024	EDS/General Motors Auburn Hills USA /1995	Industry Automotive	8	**6850** 7619	. .
282	Cray Y-MP C98/8512	Electricite de France Clamart France /1994	Industry Energy	8	**6850** 7619	. .
283	Cray Y-MP C916/8512	Ford Koeln Germany /1995	Industry Automotive	8	**6850** 7619	. .
284	Cray Y-MP C916/8512	Minnesota Supercomputer Center USA /1994	Academic	8	**6850** 7619	. .
285	Cray Y-MP C916/8256	NASA/Ames Research Center/CCF Moffett Field USA /1993	Research Aerospace	8	**6850** 7619	. .
286	Cray Y-MP C98/8128	UCSD/San Diego Supercomputer Center San Diego USA /1993	Academic	8	**6850** 7619	. .
287	Cray Y-MP C916/8256	US Navy/Fleet Numerical Oceanography Center Monterey USA /1994	Research Weather	8	**6850** 7619	. .
288	SGI POWER CHALLENGE 10000	Audi AG Ludwigshafen Germany /1996	Industry Automotive	24	**6819** 9360	15000 3500
289	SGI POW CHALLarray 10000	C4 / Centre Europeo del Parallelismo de Barcelona Barcelona Spain /1996	Academic	24	**6819** 9360	15000 3500
290	SGI POWER CHALLENGE 10000	Dream Quest Simi Valley USA /1996	Industry Image Proc.	24	**6819** 9360	15000 3500
291	SGI POWER CHALLENGE 10000	Government McLean USA /1996	Classified	24	**6819** 9360	15000 3500
292	SGI POWER CHALLENGE 10000	NCSA Urbana-Champaign USA /1996	Research	24	**6819** 9360	15000 3500
293	SGI POWER CHALLENGE 10000	Silicon Graphics Mountain View USA /1996	Vendor Benchmarking	24	**6819** 9360	15000 3500
294	IBM SP2/33	American Express USA /1996	Industry Finance	33	**6750** 8760	. .
295	IBM SP2/33	Westinghouse Electric USA /1996	Industry Energy	33	**6750** 8760	. .
296	Digital AlphaServer 8400 5/440	Digital Equipment Corporation Maynard USA /1996	Vendor Benchmarking	12	**6654** 10488	. .
297	IBM SP2/32	Amerada Hess USA /1994	Industry	32	**6569** 8500	28000 5200
298	IBM SP2/32	CINECA Bologna Italy /1995	Research	32	**6569** 8500	28000 5200
299	IBM SP2/32	China Meterological Administration China /1995	Research	32	**6569** 8500	28000 5200
300	IBM SP2/32	Clam Associates Inc USA /1996	Industry	32	**6569** 8500	28000 5200

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
301	IBM SP2/32	First Union National Bank USA /1996	Industry Finance	32	**6569** 8500	28000 5200
302	IBM SP2/32	Hong Kong University Hong Kong Hong Kong /1995	Academic	32	**6569** 8500	28000 5200
303	IBM SP2/32	Informix USA /1995	Industry Database	32	**6569** 8500	28000 5200
304	IBM SP2/32	Oracle Corporation Redwood Shores USA /1996	Industry Database	32	**6569** 8500	28000 5200
305	IBM SP2/32	PGS Tensor USA /1995	Industry	32	**6569** 8500	28000 5200
306	Fujitsu VX/3	Waseda University Japan /1996	Academic	3	**6450** 6600	. .
307	Cray T3D MCA64-8	Centro Di Calcolo Interuniversiatrio Dell Italia Italy /1996	Academic	64	**6400** 9600	20736 2368
308	Cray T3D MC64-2	Mitsubishi Electric Corporation Kanagawa Japan /1994	Industry Electronics	64	**6400** 9600	20736 2368
309	Cray T3D MCA64-8	Mobil / Technical Center Tulsa USA /1995	Industry Geophysics	64	**6400** 9600	20736 2368
310	Cray T3D MCA64-8	NASA/Lewis Research Center Cleveland USA /1994	Research	64	**6400** 9600	20736 2368
311	Cray T3D MCA64-8	NCAR (National Center for Atmospheric Research) Boulder USA /1994	Research Weather	64	**6400** 9600	20736 2368
312	Cray T3D MCA64-8	US Naval Underwater Weapons Center USA /1995	Classified	64	**6400** 9600	20736 2368
313	IBM SP2/28	Inf E. Corte Ingles Spain /1996	Industry Database	28	**6400** 8620	. .
314	IBM SP2/31	NIST - US Department of Commerce Gaithersburg USA /1994	Research	31	**6370** 8230	. .
315	Cray T3E AC16-128	Cray Research USA /1996	Vendor	16	**6340** 9600	19968 2208
316	Cray T3E AC16-128	Max-Planck-Gesellschaft MPI/Festkoerperforschung Stuttgart Germany /1996	Research	16	**6340** 9600	19968 2208
317	Cray T3E AC16-128	Max-Planck-Gesellschaft MPI/Fritz-Haber-Institut Berlin Germany /1996	Research	16	**6340** 9600	19968 2208
318	Cray T3E AC16-128	Max-Planck-Gesellschaft MPI/Polymerforschung Mainz Germany /1996	Research	16	**6340** 9600	19968 2208
319	Cray T3E AC16-128	Max-Planck-Gesellschaft MPI/Stroemungsforschung Goettingen Germany /1996	Research	16	**6340** 9600	19968 2208
320	Cray T3E AC16-128	Rechenzentrum Hannover Germany /1996	Research	16	**6340** 9600	19968 2208

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
321	Cray T3E AC16-128	Universitaet Rostock Germany /1996	Research	16	**6340** 9600	19968 2208
322	Intel XP/S15	Government Washington DC USA /1995	Classified	208	**6250** 10400	. .
323	Intel XP/S15	NOAA Boulder USA /1994	Research	208	**6250** 10400	. .
324	Hewlett-Packard SPP1000/XA-64	HTC Babelsberg Germany /1995	Industry	64	**6192** 12800	41000 11400
325	Hewlett-Packard SPP1000/XA-64	Josef Stefan Institut Ljubljana Slovenia /1994	Research	64	**6192** 12800	41000 11400
326	IBM SP2/30	CRS4 Cagliari Italy /1995	Research	30	**6170** 7970	. .
327	IBM SP2/30	Columbia University Lamont USA /1995	Academic	30	**6170** 7970	. .
328	IBM SP2/30	First Interstate Bank USA /1996	Industry	30	**6170** 7970	. .
329	IBM SP2/30	Informix USA /1995	Industry Database	30	**6170** 7970	. .
330	IBM SP2/30	Shell KSEPL Netherlands /1995	Industry Geophysics	30	**6170** 7970	. .
331	IBM SP2/30	Shell KSLA Netherlands /1995	Industry Geophysics	30	**6170** 7970	. .
332	IBM SP2/30	Shell Oil Corporation USA /1994	Industry Geophysics	30	**6170** 7970	. .
333	IBM SP2/30	Shell Oil Corporation USA /1994	Industry Geophysics	30	**6170** 7970	. .
334	IBM SP2/30	Universitaet Stuttgart Stuttgart Germany /1996	Academic	30	**6170** 7970	. .
335	IBM SP2/30	World Com USA /1995	Industry	30	**6170** 7970	. .
336	SGI POWER CHALLENGE 10000	Lockheed Martin Littleton USA /1996	Industry Aerospace	28	**6118** 10920	15000 3100
337	SGI POWER CHALLENGE 10000	AMOCO Tulsa USA /1996	Industry Geophysics	24	**6118** 9360	15000 3100
338	SGI POWER CHALLENGE 10000	BMW AG Muenchen Germany /1996	Industry Automotive	24	**6118** 9360	15000 3100
339	SGI POWER CHALLENGE 10000	BMW AG Muenchen Germany /1996	Industry Automotive	24	**6118** 9360	15000 3100
340	SGI POWER CHALLENGE 10000	BMW AG Muenchen Germany /1996	Industry Automotive	24	**6118** 9360	15000 3100

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
341	SGI POWER CHALLENGE 10000	BMW AG Muenchen Germany /1996	Industry Automotive	24	**6118** 9360	15000 3100
342	SGI POWER CHALLENGE 10000	Chevron La Habra USA /1996	Industry Geophysics	24	**6118** 9360	15000 3100
343	SGI POWER CHALLENGE 10000	Heriot Watt University UK /1996	Academic	24	**6118** 9360	15000 3100
344	SGI POWER CHALLENGE 10000	NIH (National Institute of Health) Frederick USA /1996	Research	24	**6118** 9360	15000 3100
345	SGI POWER CHALLENGE 10000	Oxford University Oxford UK /1996	Academic	24	**6118** 9360	15000 3100
346	SGI POWER CHALLENGE 10000	Sikorsky Stratford USA /1996	Industry Aerospace	24	**6118** 9360	15000 3100
347	SGI POWER CHALLENGE 10000	Texas AM University College Station USA /1996	Academic	24	**6118** 9360	15000 3100
348	SGI POWER CHALLENGE 10000	US Army TACOM Warren USA /1996	Classified	24	**6118** 9360	15000 3100
349	SGI POWER CHALLENGE 10000	University of Maryland Baltimore USA /1996	Academic	24	**6118** 9360	15000 3100
350	SGI POWER CHALLENGE 10000	Volvo Gothenberg Sweden /1996	Industry Automotive	24	**6118** 9360	15000 3100
351	IBM SP2/29	Deluxe Check USA /1996	Industry	29	**5970** 7710	. .
352	IBM SP2/29	Shell Netherlands /1996	Industry Geophysics	29	**5970** 7710	. .
353	SGI POWER CHALLENGE 10000	Australian National University Canberra Australia /1996	Academic	20	**5872** 7800	15000 3000
354	SGI POWER CHALLENGE 10000	Defence Science Organization Singapore /1996	Classified	20	**5872** 7800	15000 3000
355	SGI POWER CHALLENGE 10000	Dream Quest Simi Valley USA /1996	Industry Image Proc.	20	**5872** 7800	15000 3000
356	SGI POWER CHALLENGE 10000	KLA Instruments Semiconductor San Jose USA /1996	Industry Electronics	20	**5872** 7800	15000 3000
357	SGI POWER CHALLENGE 10000	New South Wales Center for Par. Comp. Sydney Australia /1996	Academic	20	**5872** 7800	15000 3000
358	SGI POWER CHALLENGE 10000	South Australian Center for Par. Comp. Adelaide Australia /1996	Academic	20	**5872** 7800	15000 3000
359	SGI POWER CHALLENGE 10000	Technische Universitaet Wien Wien Austria /1996	Academic	20	**5872** 7800	15000 3000
360	SGI POWER CHALLENGE 10000	Technische Universitaet Wien Wien Austria /1996	Academic	20	**5872** 7800	15000 3000

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
361	SGI POWER CHALLENGE 10000	US Air Force/National Test Facility Falcon USA /1996	Classified	20	**5872** 7800	15000 3000
362	SGI POWER CHALLENGE 10000	University of Minnesota Minneapolis USA /1996	Academic	20	**5872** 7800	15000 3000
363	SGI POWER CHALLENGE 10000	Georgia Institute of Technology Atlanta USA /1996	Research	22	**5812** 8580	15000 2900
364	Intel XP/S14	Grant Tensor Houston USA /1995	Industry Geophysics	192	**5800** 9600	. .
365	NEC SX-3/41R	Japan Atomic Energy Research Japan /1992	Research	4	**5800** 6400	3584 414
366	NEC SX-3/14R	Toyota Central Research Development Japan /1992	Industry Automotive	1	**5800** 6400	2816 282
367	Cray Y-MP J932/32-4096	Bayer AG Leverkusen Germany /1996	Industry Chemistry	32	**5800** 6400	10000 550
368	Cray Y-MP J932/32-8192	Cray Research Eagan USA /1995	Vendor	32	**5800** 6400	10000 550
369	Cray Y-MP J932/32-8192	Lockheed Missiles and Space Company USA /1996	Industry Aerospace	32	**5800** 6400	10000 550
370	Cray Y-MP J932/32-8192	Los Alamos National Laboratory Los Alamos USA /1996	Research Energy	32	**5800** 6400	10000 550
371	Cray Y-MP J932/32-4096	NASA/Goddard Space Flight Center Greenbelt USA /1995	Research Weather	32	**5800** 6400	10000 550
372	Cray Y-MP J932/32-4096	NASA/Goddard Space Flight Center Greenbelt USA /1996	Research Weather	32	**5800** 6400	10000 550
373	Cray Y-MP J932/32-8192	NERSC/LBNL Berkley USA /1996	Research	32	**5800** 6400	10000 550
374	Cray Y-MP J932/32-8192	NERSC/LBNL Berkley USA /1996	Research	32	**5800** 6400	10000 550
375	Cray Y-MP J932/32-8192	NERSC/LBNL Berkley USA /1996	Research	32	**5800** 6400	10000 550
376	Cray Y-MP J932/32-4096	Rutherford Appleton Laboratory UK /1996	Research	32	**5800** 6400	10000 550
377	Cray Y-MP J932/32-4096	University Groningen Groningen Netherlands /1996	Academic	32	**5800** 6400	10000 550
378	IBM SP2/28	ABSA South Africa /1996	Industry Database	28	**5780** 7450	. .
379	IBM SP2/28	L.L.Bean USA /1994	Industry	28	**5780** 7450	. .
380	IBM SP2/28	Loral USA /1994	Industry	28	**5780** 7450	. .

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
381	IBM SP2/28	Morgan Stanley USA /1995	Industry	28	**5780** 7450	. .
382	IBM SP2/28	US West USA /1996	Industry	28	**5780** 7450	. .
383	IBM SP2/28	University of Southern California Los Angeles USA /1996	Academic	28	**5780** 7450	. .
384	Hewlett-Packard SPP1200/XA-48	Universitaet Mainz Mainz Germany /1995	Academic	48	**5744** 11520	34000 .
385	Cray Y-MP T94/4128	Boeing Seattle USA / .	Industry Aerospace	4	**5735** 7200	. .
386	Cray Y-MP T94/4128	Cray Research Eagan USA /1995	Vendor	4	**5735** 7200	. .
387	Cray Y-MP T94/4128	Cray Research Eagan USA /1995	Vendor	4	**5735** 7200	. .
388	Cray Y-MP T94/4128	Ford Motor Company Dearborn USA /1995	Industry Automotive	4	**5735** 7200	. .
389	Cray Y-MP T94/4128	Government Colorado Springs USA /1995	Classified	4	**5735** 7200	. .
390	Cray Y-MP T94/4128	Government Colorado Springs USA /1995	Classified	4	**5735** 7200	. .
391	Cray Y-MP T94/4128	Japan Atomic Energy Research Japan /1996	Research	4	**5735** 7200	. .
392	Cray Y-MP T94/4128	Leibniz Rechenzentrum Muenchen Germany /1996	Academic	4	**5735** 7200	. .
393	Cray Y-MP T94/4128	Los Alamos National Laboratory Los Alamos USA /1995	Research Energy	4	**5735** 7200	. .
394	Cray Y-MP T916/4256	NASA/Marshall Space Flight Center Huntsville USA /1996	Research Aerospace	4	**5735** 7200	. .
395	Cray Y-MP T916/4256	North Carolina Supercomputer Center USA /1995	Academic	4	**5735** 7200	. .
396	Cray Y-MP T94/464	Toyota Motor Company Japan /1995	Industry Automotive	4	**5735** 7200	. .
397	TMC CM-5/96	Epsilon USA /1993	Industry	96	**5700** 13370	. .
398	TMC CM-5/96	University of California at Berkeley USA / .	Academic	96	**5700** 13370	. .
399	SGI POWER CHALLENGEarray	University Jaume I Castellon Spain /1995	Academic	24	**5650** 8640	. .
400	SGI POWER CHALLENGEarray	University of Minnesota Minneapolis USA /1995	Academic	24	**5650** 8640	. .

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N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
401	Fujitsu VPP500/4	IFP (Institute Francais du Petrole) Rueil-Malmaison France /1995	Academic Geophysics	4	**5600** 6400	7344 1250
402	Fujitsu VPP500/4	Toritsu Kagaku Gijutsu University Japan /1993	Academic	4	**5600** 6400	7344 1250
403	Fujitsu VPP500/4	Toyota Motor Company Japan /1994	Industry Automotive	4	**5600** 6400	7344 1250
404	IBM SP2/27	Hill's Pet Food USA /1996	Industry	27	**5580** 7180	. .
405	Digital AlphaServer 8400 5/440	CSC (Center for Scientific Computing) Espoo Finland /1996	Academic	10	**5545** 8740	. .
406	IBM SP2/24	Adapco USA /1996	Industry	24	**5500** 7390	. .
407	Hewlett-Packard SPP1600/XA-32	CILEA Milano Italy /1996	Research	32	**5452** 7680	27000 4500
408	Hewlett-Packard SPP1600/XA-32	Cyfronet Krakau Poland /1996	Academic	32	**5452** 7680	27000 4500
409	Hewlett-Packard SPP1600/XA-32	Ford Dearborn USA /1996	Industry Automotive	32	**5452** 7680	27000 4500
410	Hewlett-Packard SPP1600/XA-32	JCCWC San Antonio USA /1995	Classified	32	**5452** 7680	27000 4500
411	Hewlett-Packard SPP1600/XA-32	NCCOSC USA /1996	Research	32	**5452** 7680	27000 4500
412	Hewlett-Packard SPP1600/XA-32	University of Michigan Ann Arbor USA /1996	Academic	32	**5452** 7680	27000 4500
413	SGI POWER CHALLENGE 10000	ATT Murray Hill USA /1996	Industry Electronics	20	**5430** 7800	15000 2600
414	SGI POWER CHALLENGE 10000	ATT Murray Hill USA /1996	Industry Electronics	20	**5430** 7800	15000 2600
415	SGI POWER CHALLENGE 10000	Chevron La Habra USA /1996	Industry Geophysics	20	**5430** 7800	15000 2600
416	SGI POWER CHALLENGE 10000	Dream Quest Simi Valley USA /1996	Industry Image Proc.	20	**5430** 7800	15000 2600
417	SGI POWER Onyx 10000	McDonnell Douglas St. Louis USA /1996	Industry Aerospace	20	**5430** 7800	15000 2600
418	SGI POWER CHALLENGE 10000	Pfizer Groton USA /1996	Industry Pharmaceutics	20	**5430** 7800	15000 2600
419	IBM SP2/26	Dassault Aviation France /1995	Industry Aerospace	26	**5380** 6920	. .
420	IBM SP2/26	James River USA /1995	Industry	26	**5380** 6920	. .

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
421	IBM SP2/26	John Alden Insurance USA /1994	Industry	26	**5380** 6920	. .
422	IBM SP2/26	La Caixa Spain /1996	Industry Database	26	**5380** 6920	. .
423	IBM SP2/26	Norfolk Southern Railroad USA /1995	Industry	26	**5380** 6920	. .
424	IBM SP2/26	Revlon USA /1996	Industry	26	**5380** 6920	. .
425	IBM SP2/26	Tohoku University Aramaki Japan /1996	Academic	26	**5380** 6920	. .
426	IBM SP2/26	University of Pennsylvania USA /1996	Academic	26	**5380** 6920	. .
427	Parsytec GC PowerPlus/128	Japan Institute of Advanced Technology Japan /1994	Research	128	**5246** 10240	22000 7800
428	Parsytec GC PowerPlus/128	Swedish National Supercomputer Centre Linkoping Sweden /1994	Academic	128	**5246** 10240	22000 7800
429	Parsytec GC PowerPlus/128	Technische Universitaet Chemnitz Chemnitz Germany /1994	Academic	128	**5246** 10240	22000 7800
430	Parsytec GC PowerPlus/128	Universitaet Hamburg-Harburg Hamburg-Harburg Germany /1994	Academic	128	**5246** 10240	22000 7800
431	TMC CM-2/64k	Florida State University Tallahassee USA / .	Academic	2048	**5200** 14000	26624 11000
432	TMC CM-2/64k	SRC USA /1993	Industry	2048	**5200** 14000	26624 11000
433	IBM SP2/25	ICG Salzgitter Germany /1996	Industry	25	**5180** 6660	. .
434	IBM SP2/25	MBNA USA /1996	Industry	25	**5180** 6660	. .
435	Cray Y-MP J932/28-2048	Government USA /1996	Classified	28	**5075** 5600	. .
436	Digital AlphaServer 8400 5/350	CERN Geneva Switzerland /1996	Research	10	**5074** 7000	9540 3010
437	Digital AlphaServer 8400 5/350	Informix USA /1996	Industry Database	10	**5074** 7000	9540 3010
438	Meiko CS-2/224	Lawrence Livermore National Laboratory Livermore USA /1994	Research Energy	224	**5000** 40300	18688 6144
439	Meiko CS-2/128	CERN Geneva Switzerland /1996	Research	128	**5000** 23000	18688 6144
440	Meiko CS-2/128	Universitaet Wien Wien Austria /1994	Academic	128	**5000** 23000	18688 6144

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
441	Meiko CS-2/64	Lawrence Livermore National Laboratory Livermore USA /1994	Research Energy	64	**5000** 11500	18688 6144
442	TMC CM-200/32k	Government USA /1989	Classified	1024	**5000** 10000	21504 8192
443	TMC CM-200/32k	Minnesota Supercomputer Center USA / .	Academic	1024	**5000** 10000	21504 8192
444	TMC CM-200/32k	Western Geophysical Houston USA /1994	Industry Geophysics	1024	**5000** 10000	21504 8192
445	Digital AlphaServer 8400 5/300	Dial Corporation Phoenix USA /1996	Industry Construction	12	**5000** 7200	9548 1148
446	Digital AlphaServer 8400 5/300	National Security Agency USA /1996	Classified	12	**5000** 7200	9548 1148
447	NEC SX-3/22	NEC Systems Laboratories Inc. Houston USA /1991	Research	2	**5000** 5500	3072 384
448	NEC SX-3/14	National Institute of Environmental Studies Japan /1992	Research Environment	1	**5000** 5500	3072 384
449	IBM SP2/24	Aetna Life Insurance USA /1995	Industry	24	**4990** 6400	. .
450	IBM SP2/24	Brown University Providence USA /1996	Academic	24	**4990** 6400	. .
451	IBM SP2/24	CSC (Centre for Sientific Computing) Espoo Finland /1995	Academic	24	**4990** 6400	. .
452	IBM SP2/24	Credit Suisse Switzerland /1995	Industry Finance	24	**4990** 6400	. .
453	IBM SP2/24	Equifax USA /1996	Industry	24	**4990** 6400	. .
454	IBM SP2/24	Indiana University USA /1996	Academic	24	**4990** 6400	. .
455	IBM SP2/24	National Institute of Environmental Studies Japan /1994	Research	24	**4990** 6400	. .
456	IBM SP2/24	Nationwide Life Insurance USA /1995	Industry Database	24	**4990** 6400	. .
457	IBM SP2/24	Sybase USA /1995	Industry Database	24	**4990** 6400	. .
458	IBM SP2/24	University of Pennsylvania USA /1996	Academic	24	**4990** 6400	. .
459	SGI ORIGIN 2000	INRIA - Sophia Antipolis Rennes France /1996	Research	16	**4961** 6240	15000 2500
460	SGI ORIGIN 2000	University of Miami Miami USA /1996	Academic	16	**4961** 6240	15000 2500

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N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	**R_{max}** R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
461	SGI POWER CHALLENGEarray	Pacific Northwest Laboratories/Batelle Hanford USA /1995	Research	24	**4896** 7200	18000 3500
462	SGI POWER CHALLENGEarray	University of Oregon Eugene USA /1995	Academic	24	**4896** 7200	18000 3500
463	SGI POWER CHALLENGE 10000	Allison Engine Corp. Indianapolis USA /1996	Industry Aerospace	16	**4862** 6240	15000 2500
464	SGI POWER CHALLENGE 10000	Amgen Inc. Thousand Oaks USA /1996	Industry Pharmaceutics	16	**4862** 6240	15000 2500
465	SGI POWER CHALLENGE 10000	Audi AG Ludwigshafen Germany /1996	Industry Automotive	16	**4862** 6240	15000 2500
466	SGI POWER CHALLENGE 10000	Centro Italiano Ricerche Aerospaziali (CIRA) Capua Italy /1996	Research	16	**4862** 6240	15000 2500
467	SGI POWER CHALLENGE 10000	Mercedes-Benz Sindelfingen Germany /1996	Industry Automotive	16	**4862** 6240	15000 2500
468	SGI POWER CHALLENGE 10000	Mississippi State University Starkeville USA /1996	Academic	16	**4862** 6240	15000 2500
469	SGI POWER CHALLENGE 10000	Motorola Ft. Lauderdale USA /1996	Industry Electronics	16	**4862** 6240	15000 2500
470	SGI POWER CHALLENGE 10000	NIH (National Institute of Health) Frederick USA /1996	Research	16	**4862** 6240	15000 2500
471	SGI POWER CHALLENGE 10000	NIH (National Institute of Health) Frederick USA /1996	Research	16	**4862** 6240	15000 2500
472	SGI POWER CHALLENGE 10000	NIH (National Institute of Health) Frederick USA /1996	Research	16	**4862** 6240	15000 2500
473	SGI POWER CHALLENGE 10000	NIH (National Institute of Health) Frederick USA /1996	Research	16	**4862** 6240	15000 2500
474	SGI POWER CHALLENGE 10000	Nagoya University Nagoya Japan /1996	Academic	16	**4862** 6240	15000 2500
475	SGI POWER CHALLENGE 10000	Osaka University Osaka Japan /1996	Academic	16	**4862** 6240	15000 2500
476	SGI POWER CHALLENGE 10000	Square LA Marina del Rey USA /1996	Industry Image Proc.	16	**4862** 6240	15000 2500
477	SGI POWER CHALLENGE 10000	State University of New York Stonybrook USA /1996	Academic	16	**4862** 6240	15000 2500
478	SGI POWER CHALLENGE 10000	Technische Universitaet Wien Wien Austria /1996	Academic	16	**4862** 6240	15000 2500
479	SGI POWER CHALLENGE 10000	University of Auckland Auckland New Zealand /1996	Academic	16	**4862** 6240	15000 2500
480	SGI POWER CHALLENGE 10000	Western Geophysical Cairo Egypt /1996	Industry Geophysics	16	**4862** 6240	15000 2500

N *world*	Manufacturer Computer	Installation Site Location/Year	Field of Application	# Proc.	$\mathbf{R_{max}}$ R_{peak} [Mflop/s]	N_{max} $N_{1/2}$
481	SGI POWER CHALLENGE 10000	Western Geophysical Houston USA /1996	Industry Geophysics	16	**4862** 6240	15000 2500
482	SGI POWER CHALLENGE 10000	Western Geophysical Houston USA /1996	Industry Geophysics	16	**4862** 6240	15000 2500
483	SGI POWER CHALLENGE 10000	Western Geophysical Houston USA /1996	Industry Geophysics	16	**4862** 6240	15000 2500
484	SGI POWER CHALLENGE 10000	Western Geophysical Houston USA /1996	Industry Geophysics	16	**4862** 6240	15000 2500
485	Hewlett-Packard SPP1000/XA-48	Tokyo University Tokyo Japan /1996	Academic	48	**4802** 9600	. .
486	IBM 9076-005 SP1	Argonne Nat. Lab USA /1993	Research	128	**4800** 16000	26000 6000
487	IBM SP2/23	American Express USA /1996	Industry Finance	23	**4790** 6130	. .
488	IBM SP2/23	CEA/CESTA Bordeaux France /1995	Research	23	**4790** 6130	. .
489	IBM SP2/23	GTE Communications USA /1996	Industry	23	**4790** 6130	. .
490	IBM SP2/23	University of Southampton Southampton UK /1996	Academic	23	**4790** 6130	. .
491	KSR KSR2-80	Pacific Northwest Laboratories/Batelle Richland USA /1994	Research	80	**4770** 6400	. .
492	SGI POWER CHALLENGEarray	Florida State University Tallahassee USA /1995	Academic	20	**4710** 7200	. .
493	SGI POWER CHALLENGEarray	University of Queensland St Lucia Australia /1995	Academic	20	**4710** 7200	. .
494	Cray Y-MP C98/6256	General Electric - Aircraft Eng USA /1995	Industry Aerospace	6	**4630** 5715	. .
495	Cray Y-MP C98/6256	NIST - US Department of Commerce Gaithersburg USA /1996	Research	6	**4630** 5715	. .
496	SGI POWER CHALLENGE	Delta Airlines Atlanta USA /1996	Industry Database	18	**4620** 6480	2500 540
497	SGI POWER CHALLENGE	Delta Airlines Atlanta USA /1996	Industry Database	18	**4620** 6480	2500 540
498	SGI POWER CHALLENGE	Delta Airlines Atlanta USA /1996	Industry Database	18	**4620** 6480	2500 540
499	SGI POWER CHALLENGE	Ford Detroit USA /1995	Industry Automotive	18	**4620** 6480	2500 540
500	SGI POWER CHALLENGE	Goodyear - Technical Center Colmar-Berg Luxembourg /1996	Industry Automotive	18	**4620** 6480	2500 540

9.4 Statistics on Manufacturers and Continents

As basic statistics of the complete list, we give the number of systems installed with respect to the different manufacturers in the different countries or continents (Table 2) as well as the accumulated R_{max} values (Table 3) and R_{peak} values (Table 4) for those systems. More extensive analyses of the situation and its evolution over time can be found in the series of TOP500Reports (TOP500Report 1993 [3], 1994 [4] and 1995 [5]). Customized statistics can be obtained by using WWW at http://parallel.rz.uni-mannheim.de/top500.html or http://www.netlib.org/benchmark/top500.html.

Table 2: Number of Systems Installed

TOP500 Statistics — Number of Systems Installed					
	USA/Canada	Europe	Japan	others	Total
SGI/Cray	139	62	13	8	222
Cray only	78	42	10	1	131
SGI only	61	20	3	7	91
IBM	70	35	13	8	126
Fujitsu	2	7	21	1	31
NEC	6	7	15		28
TMC	21	1	1		23
Hewlett-Packard	13	8	1		22
Intel	13	2	3		18
Hitachi		1	12		13
others	7	9	1		17
Total	271	132	80	17	500

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Table 3: Installed $\mathbf{R_{max}}$

TOP500 Statistics — Installed R_{max} [Gflop/s]					
	USA/Canada	Europe	Japan	others	Total
SGI/Cray	1729.7	907.2	142.2	51.6	2831.5
Cray only	1339.4	781.8	124.2	13.7	2259.2
SGI only	390.3	126.0	18.0	37.9	572.3
IBM	885.0	322.0	115.1	70.0	1392.1
Fujitsu	19.3	169.4	910.5	27.7	1126.9
NEC	98.1	181.8	426.7		706.6
TMC	320.4	7.7	7.7		335.8
Hewlett-Packard	94.1	52.5	4.8		151.4
Intel	408.3	31.0	121.1		560.4
Hitachi		14.2	774.5		788.7
others	36.5	52.4	5.2		94.1
Total	3591.5	1738.8	2507.8	149.3	7987.4

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Table 4: Installed $\mathbf{R_{peak}}$

TOP500 Statistics — Installed R_{peak} [Gflop/s]					
	USA/Canada	Europe	Japan	others	Total
SGI/Cray	2492.6	1327.8	202.1	66.1	4088.7
Cray only	1879.0	1147.1	177.1	15.2	3218.5
SGI only	613.6	180.7	25.0	50.9	870.2
IBM	1267.2	435.0	153.8	94.0	1950.0
Fujitsu	19.8	178.0	1110.4	28.6	1336.8
NEC	105.5	192.5	452.8		750.8
TMC	702.5	16.0	20.0		738.5
Hewlett-Packard	141.9	87.0	9.6		238.5
Intel	545.7	37.2	154.7		737.6
Hitachi		19.0	1135.0		1154.0
others	90.1	123.2	10.2		223.5
Total	5365.3	2415.7	3248.7	188.7	11218

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