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Trends in Globalization around Supercomputers

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1 Introduction

High Performance Computing (hereinafter referred to as HPC) refers to a computing process that requires an enormous amount of complicated computations, such as simulations of natural phenomena or analysis of biological structures. More specifically, simulations and analysis of phenomena beyond human prediction and control, such as the global meteorological system or automobile-collision simulations, are included in HPC. They would require huge costs by experimental measures. Although HPC is often performed by using grids[NOTE 1] as well as supercomputers, this article will focus on supercomputers and give a general view of the current situation.

At the International Supercomputing Conference, June 2011, the 37th TOP500 was released, with the Japanese next-generation supercomputer “Kei” ranked at the top. This K Computer has been jointly developed and enhanced by the Institute of Physical and Chemical Research (hereinafter referred to as RIKEN) and Fujitsu Ltd.,

Supercomputers used in large-scale scientific computations will have a critical role in the future of individual countries in both science-technology and economy. Such a notion has been spreading across the globe. Therefore, countries around the world are now in fierce competition in supercomputer development and installation. Analyzing the situation of world’s supercomputers on the basis of a series of TOP500 lists, there seems to be three types of globalization going on: the first is a globalization in installation; the second is a globalization in development of supercomputers with a rise in the number of countries who developed supercomputers domestically; and the third is a globalization in research and development through international collaborations. This article will introduce at first a general view of the situation of world supercomputers in Chapter 2, and then, in Chapter 3 to Chapter 5, present an analysis of the actual situations of the three types of globalization.

2 World Supercomputers shown in the TOP500

2-1 About TOP500

TOP500 list provides the top-to-500th ranking of supercomputers by the performance measured in LINPACK Benchmark[NOTE 2]. The list is updated twice a year, in June and November, by a group of researchers from Mannheim University, Germany, University of Tennessee, the United States, and NERSC / LBNL (refer to the glossary for the full name), the United States. The latest ranking (released in June 2011) is the 37th version of the list.

[NOTE 1]
Supercomputer and Grid: A supercomputer refers to an ultra-high-speed computer for scientific computing. Various types of architecture are employed in supercomputers, depending on their applications. So the range of performance is wide, from high to low. A grid refers to an environment where a variety of computing and information resources distributed on a network, such as computers, memory systems, visualization systems and large-scale monitoring systems, are available as a single virtual computer to members belonging to the virtual organization.

[NOTE 2]
LINPACK Benchmark: LINPACK (LINear equations software PACKage) Benchmark is a program for solving a system of linear equations for floating point operations, developed by Dr. J. Dongara of the University of Tennessee, et al. The benchmark has been widely used for a wide range of computers from supercomputers to workstations or personal computers, and their performance values have been published. LINPACK performance is shown as the number of floating point operations executed in a second, as FLOPS (Floating point number Operations Per Second).

In the list, we can see general trends in supercomputers. However, the list is sometimes called into question, as whether supercomputers developed for different purposes can be appropriately compared using a single benchmark such as LINPACK. While LINPACK puts emphasis on the performance of the computation processes using mainly floating-point operations, in actual situations, where computational environments are widely different, over-all performance is important and is affected by other factors such as data-transmission time between memories and CPUs or communication time between CPUs[2]. So, for the evaluation of system performance, various methods or indexes have been developed, and the rankings based on those have been released[3].

2-2 Findings in the Latest (the 37th) TOP500

The latest version of TOP500 was released at the "International Supercomputing Conference 11: ISC 11" held in Hamburg, Germany from June 20 to 23 in 2011. Most relevant to Japan, the Japanese next-generation supercomputer "Kei," which has been developed and enhanced jointly by RIKEN and Fujitsu Ltd. as a part of the Next-Generation Supercomputer Project[NOTE3], was ranked at the top. As for other Japanese supercomputers listed in recent versions of TOP500, "Earth Simulator" was ranked at the top in June 2002 and held the top position until June 2004. After that, the position was held mainly by U.S. supercomputers, but this year, the Japanese supercomputer came back to the top.

The LINPACK performance of "Kei" is 8.162 Peta FLOPS (where Peta means one thousand trillion, so Peta FLOPS means one thousand trillion floating point operations per second, hereinafter referred to as PF), three times faster than the Chinese supercomputer "Tianhe-1A" which was at the top in the 36th list six months earlier. "Kei," now under development and enhancement and aiming at a roll-out in November 2012[4], stood at the top position despite being in the middle of development.

All of the top 10 supercomputers on the list have higher than 1 PF LINPACK Performance. This means that the world supercomputers have already been racing at PF performance in the international track. From now on, the more fierce international competition will be expected to aim for around 10 PF performance.

In the following sub-sections, several findings to note in the present version of TOP500 will be introduced.

2-2-1 Number of Supercomputer Systems

In TOP500, "country" refers to a country that has supercomputers (hereinafter referred to as systems). So even systems developed in other countries are counted as systems belonging to the country. The number of countries with systems in the latest list is 28 (more details later).

2-2-2 Progress in LINPACK Performance

Figure 1 shows the line-plot of the total of LINPACK Performance values of the five hundred systems listed in a series of TOP500 along with those of the top and the 500th. It should be noted that there are two parts of the rapid progress in the performance of the top system in June 2002 and June 2011 in the chart (marked by a circle in the chart). Both were attained by Japanese systems: "Earth Simulator" in 2002 and "Kei" in 2011.

By extrapolating the trends in performance, we can predict that the performance of supercomputers will reach Exascale (thousand-fold of Petascale) around 2018 or 2020.

In the top 10 of the latest TOP500, five systems belong to the United States, two belong to Japan, two belong to China, and one belongs to France. The Tianhe-1A of China (by the National Supercomputer Center in Tianjin), which topped the previous list (November 2010), was ranked second this time, with the same performance as the previous one, 2.566 PF. The Jaguar, from the United States (DoE Oak Ridge National Laboratory), which topped the list in June 2010, was ranked third this time, with the same performance as the previous one, 1.759 PF. The performance value of "Kei" is larger than the sum of

[NOTE 3]
Next-Generation Supercomputer Project: The project, started in 2006, consists of three core objectives as follows: development of the 10 Peta FLOPS supercomputer "Kei"; development of application software available on the computer; and enhancement of research and education facilities focused on the next-generation supercomputers. The project has been updated to a development project of "High Performance Computing Infrastructure (HPCI)" through discussions triggered by the screening process in November 2010.

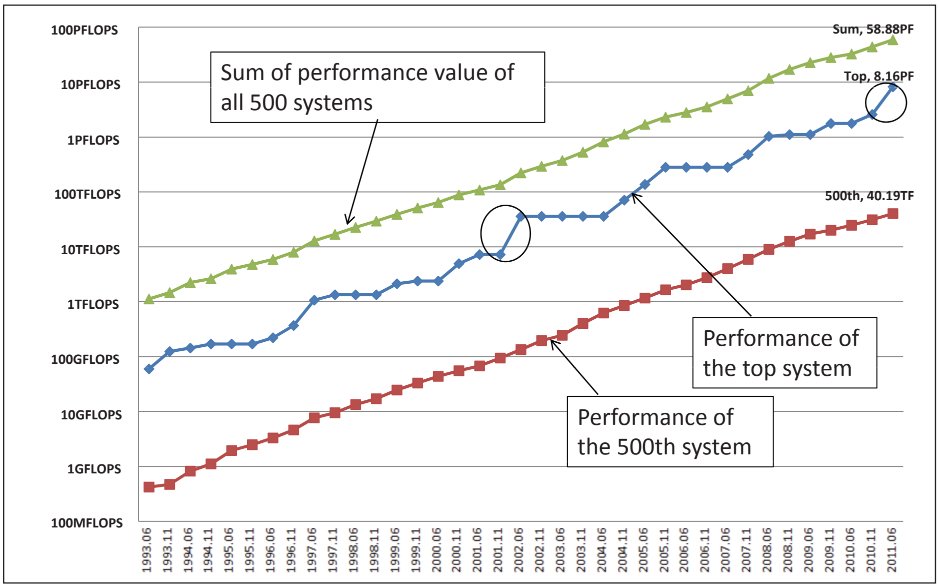


Figure 1: LINPACK Performance of Systems in TOP500: Sum of the performance values of all systems, Performance of the top system and Performance of the 500th system

Prepared by the STFC based on a series of TOP500 in the past

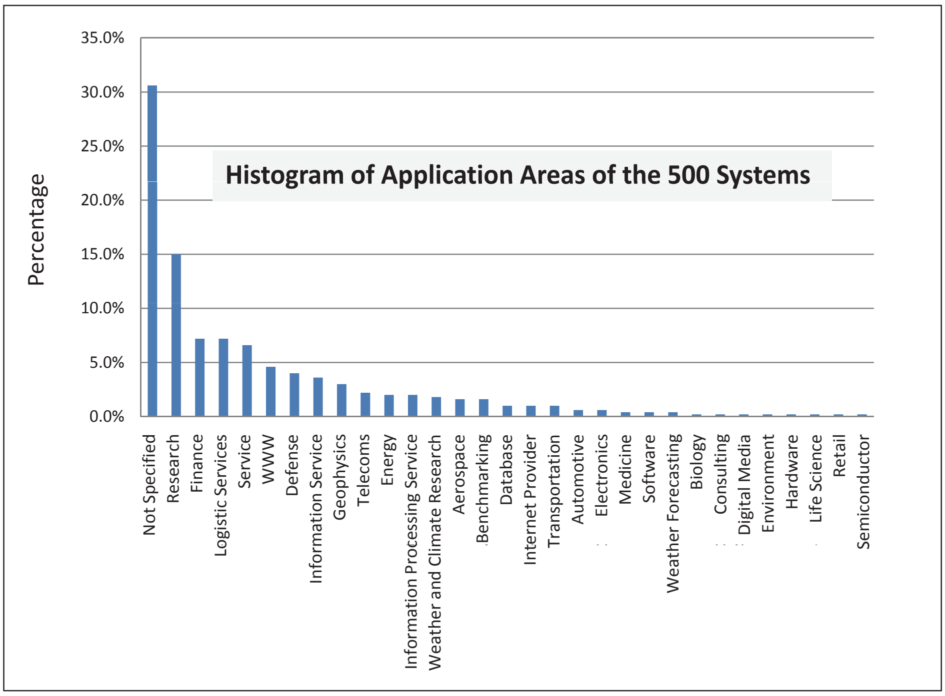


Figure 2 : Histogram of Application Areas

Prepared by the STFC based on the 37th TOP500

the LINPACK Performance values of the five systems ranked below "Kei."

2-2-3 Application Areas

Figure 2 shows the distribution of the major application-areas ("Application Area" registered in TOP500 List) of all five hundred systems, and reveals that those application areas distribute in a wide range of fields. Those areas were declared by the countries that own the systems and registered as the major application areas of systems. However, for the systems with an application area such as "Not Specified" or "Research," we can believe that the application area is not open to the public. Furthermore, for the declared application-areas of the top 50 systems, which are ten percent of all listed systems, forty percent are "Not Specified" and another forty percent are "Research." So it is unclear for what purpose those systems are used actually.

2-2-4 Variety in Hardware Architecture (Configuration)

A variety of hardware architectures (configurations) came to be employed in supercomputers[6] as follows:

systems whose computing parts consist only of CPUs (Central Processing Unit), called CPU based systems; and systems that have a combination of CPUs and accelerators (GPUs, Graphics Processing Units, etc.), called accelerator-embedded systems or hybrid systems. Each type of architecture has advantages and disadvantages, and it is hard to say that there is a single type capable of satisfying all the requirements of high performance operations in a wide range of applications. Most of the systems listed in the 37th TOP500 are CPU based, and only nineteen are accelerator-embedded systems, although the number has increased from eleven in the 36th list.

By using the TOP500 list, we can calculate a proportion of the LINPACK Performance (corresponding to the Rmax value in TOP500 list) to the peak performance (corresponding to the Rpeak value) of a listed system. We will call it LINPACK Efficiency. Figure 3 plots each TOP500 system by LINPACK Efficiency and LINPACK Performance, where, because the horizontal axis corresponds to the ranking order in the TOP500, the systems are plotted from right to left according to the ranking, with the top at the rightmost position and the 500th at the leftmost. There, "Kei" and the Jaguar are CPU based, and the Tianhe-1A is accelerator-embedded.

We can see from Figure 3 that "Kei" is a very-high performance computer both in LINPACK Performance and in LINPACK Efficiency. As the world's top large-scale supercomputer, "Kei" showed a remarkably high execution efficiency of 93.0 percent. RIEKN announced[4] that "this is the result of the integration of all the technologies, such as several tens of thousands of CPUs, interconnections of those CPUs and software making the hardware run at the maximum speed." Moreover, "Kei" is ranked at a high position (0.82 billion operations per 1 W) in Green500[7], where supercomputers are ranked by power efficiency. Because of such superiorities, "Kei" has attracted the attention of the world's experts.

3 Supercomputers Spreading Worldwide (Globalization in Installation)

In this chapter, through analyzing the latest and the past versions of the TOP500 list, the trends that supercomputer-installing countries are going will be described.

3-1 Petascale Supercomputer Development

Figure 4 shows the number of systems of twenty-eight supercomputer-installed countries in the latest TOP500, and the total LINPACK Performance value of each country, which is the sum of the LINPACK Performance values of the listed systems owned by a country in TOP500.

We can see from Figure 4 how widely and how equally spread the supercomputer-installation is to the countries. Sorting the countries in specific regions in a descending order according to the number of systems owned, we can see the following: the United

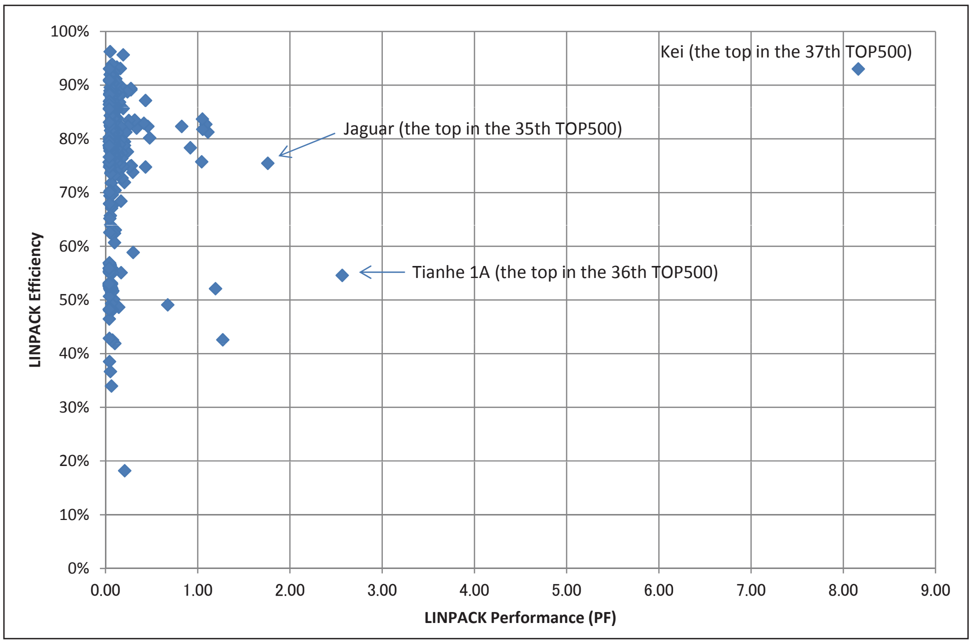


Figure 3 : Scatter Plot of TOP500 Systems on LINPACK Performance-LINPACK Efficiency Plain

Prepared by the STFC based on the 37th TOP500

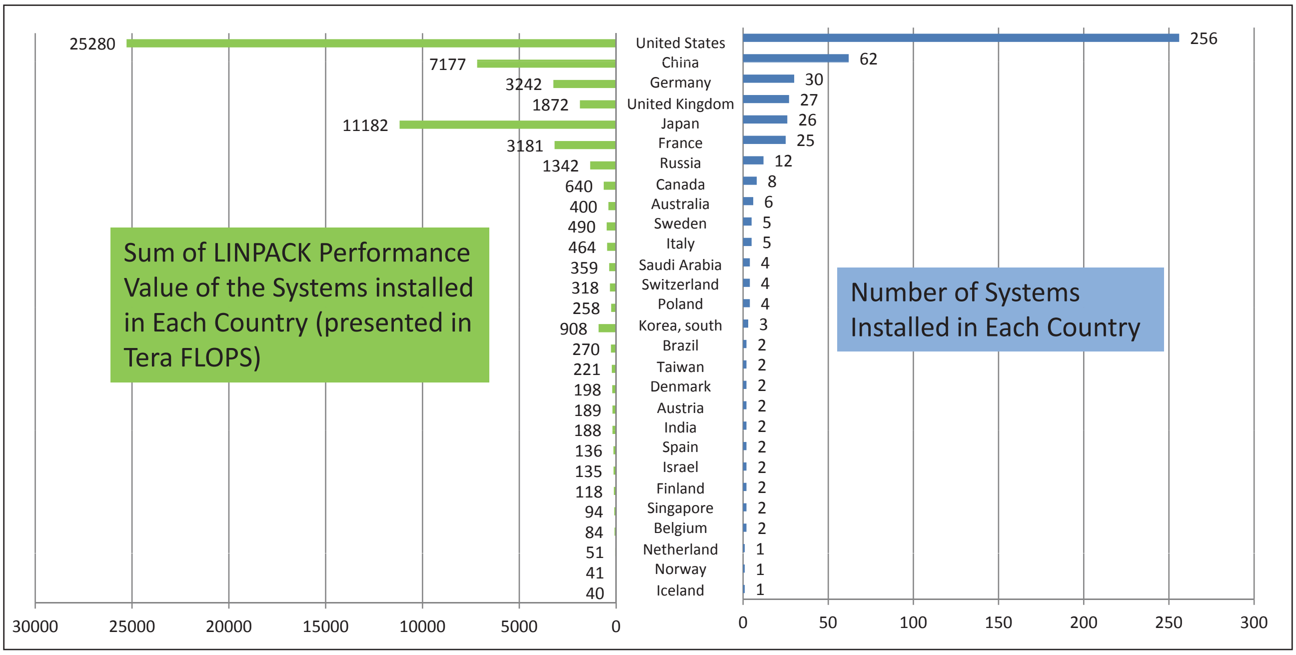


Figure 4: Number of Systems and Sum of LINPACK Performance Value in Each Country

Prepared by the STFC based on the 37th TOP500

States has 256 systems (274 listed in the 36th TOP500 in November 2010); Europe has 126 systems (125 listed in the 36th), where Germany has 30 systems (26 listed in the 36th), the UK has 27 systems (24 listed in the 36th), France has 25 systems (26 listed in the 36th), and Russia has 12 systems; and Asia has 103 systems (83 listed in the 36th), where China has 62 systems (42 listed in the 36th) and Japan has 26 (the same number listed in the 36th).

What we should pay more attention to is the increase in countries that have Petascale performance supercomputers (with a peak performance of over 1 PF). As of June 2011, six countries have Petascale supercomputers; and in seven countries, the total LINPACK Performance value exceeds 1 PF, for which countries Figure 5 shows the history of the total LINPACK Performance value in the past ten years.

We can see from Figure 5 the following:
The United States is still in the lead position; other than the United States, although Japan had kept the second position until 2007, no country has kept the position since then; as of June 2011, the order after the United States is Japan, China, France, Germany, the UK, and Russia; the six countries except the United States can be divided into two, a group of European countries and two Asian countries; those European countries and Asian countries can be said forming the second group; and the second group has recently been showing a remarkably steep progress.

Figure 6 shows the system names and performances of the Petascale supercomputers that have been installed or are planned in the prominent HPC countries. We can see from the figure that supercomputer-enhancement plans will be coming one after another. Therefore, a lot of supercomputers with performance over 10 PF are expected to appear on the scene after 2012.

3-2 Changes in the Last 20 Years in the World

Figure 7 shows five-year changes of the total of LINPACK Performance values in the last twenty years of the systems held by the United States, Europe, and Asia. The latest distribution of regional shares of the United States, Europe, and Asia looks similar to that of 1996, which shows Asian countries' revitalization.

Looking into the Asian countries, we can see the big growth of China's share since 2006, threatening Japan which had 95 percent share of Asian supercomputers in 1996. The European share has remained unchanged for twenty years.

Although not so distinguishable in Figure 7, the present movements in Korea toward supercomputer installation are notable. The Korean government announced the National Supercomputing Promotion Act in May 2011, aiming for the promotion of supercomputing with government funds. The purposes of the Korean act are well-balanced investments on HPC infrastructure, and coordination of the activities of the individual government ministries and agencies. The funds will mainly be applied to supercomputing facilities, applications, research and development, and education / training. For example, the establishment

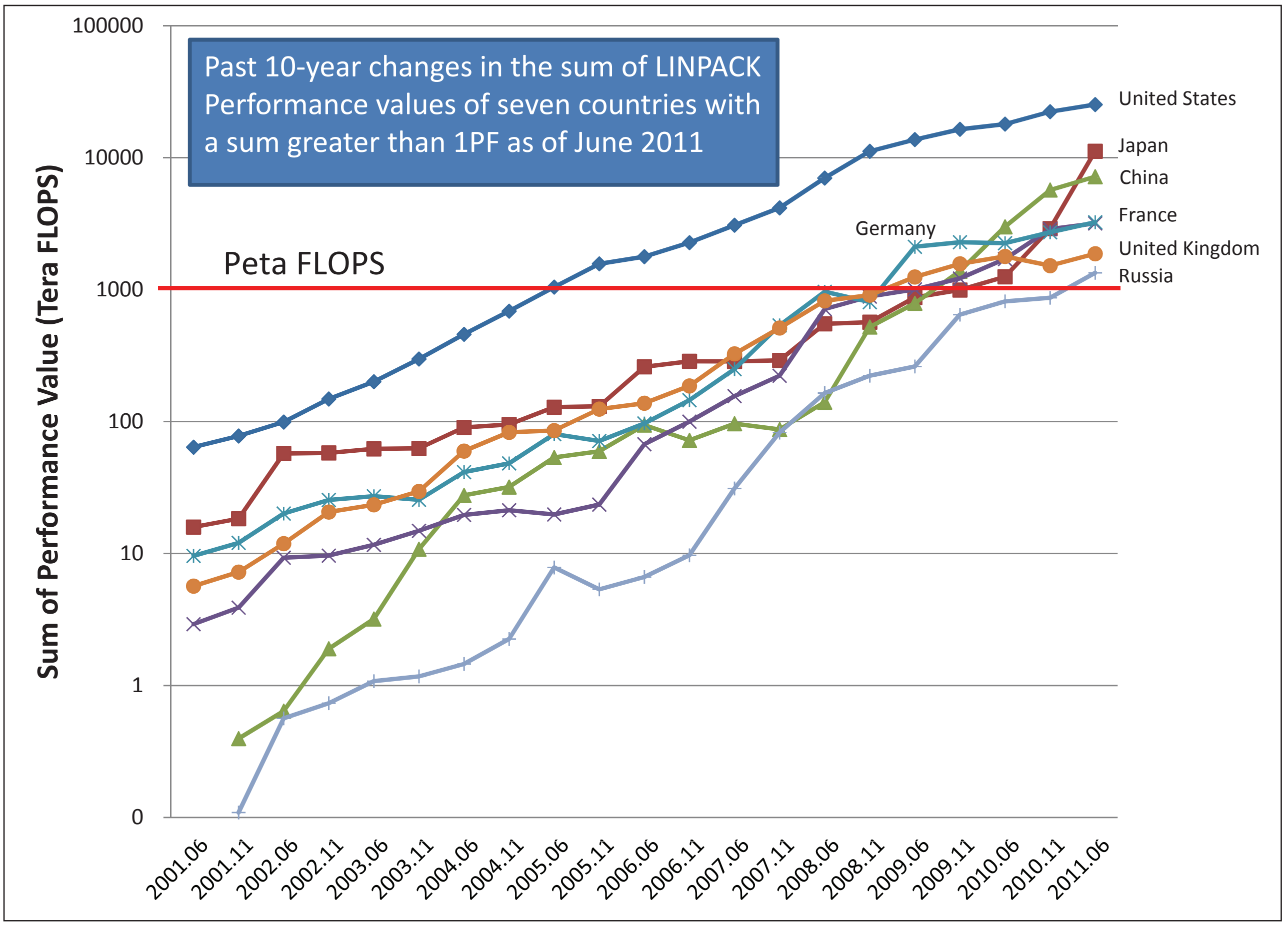
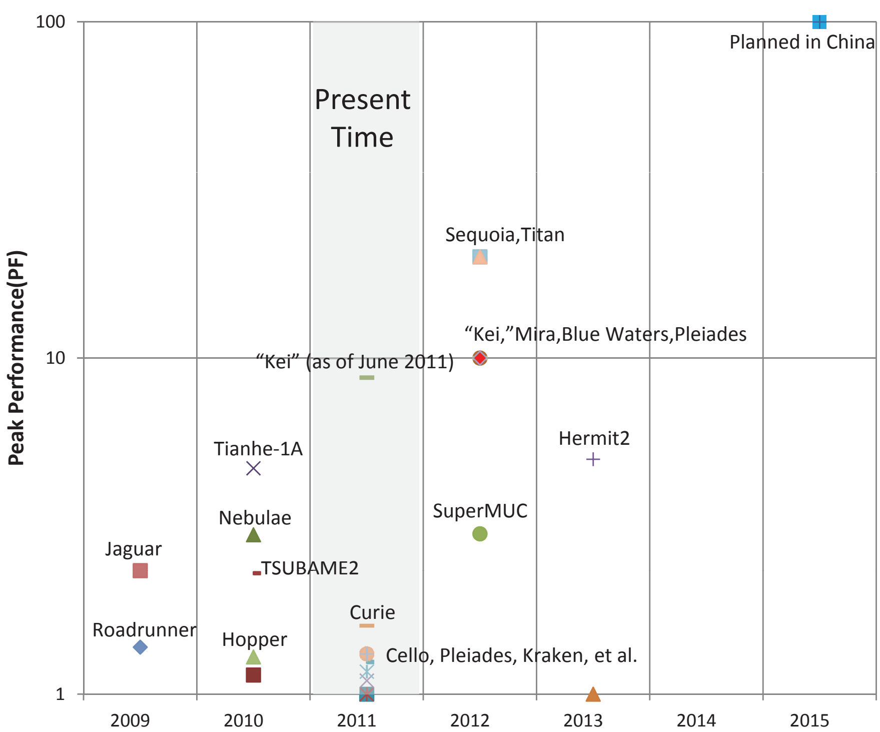


Figure 5: Line Plot of the Sum of LINPACK Performance Values of Countries with a Sum Greater than 1 PF (as of June 2011)

Prepared by the STFC based on the past versions of TOP500



Country	Name of System	Year	Peak Performance (PF)
China	Mole-8.5	2010	1.14
	Nebulae	2010	2.98
	Tianhe-1A	2010	4.7
	Dawning 6000	2011	1
	not yet determined	2012	10
	not yet determined	2015	100
Japan	TSUBAME2	2010	2.29
	Kei	2011	8.77
	Kei	2012	10+
Italy	not yet determined	2012?	1?
Spain	not yet determined	2013?	1?
Germany	JUGENE	2009	1
	Hermit	2011	1
	SuperMUC	2012	3
	Hermit2	2013	4-5
France	TERA-100	2011	1.25
	Curie	2011	1.6
Russia	LOMONOSOV	2011	1.37
United States	Roadrunner	2009	1.38
	Jaguar	2009	2.33
	Hopper	2010	1.29
	NOAA/ORNL	2011	1.1
	Kraken	2011	1.17
	Pleiades	2011	1.32
	Ceilo	2011	1.37
	Mira	2012	10
	Blue Waters	2012	10
	Pleiades	2012	10
	Sequoia	2012	20
	Titan	2012	20

Note that the scheduled completion date of Blue Waters Project of the United States, although scheduled to be shipped in 2012 to the Center for Supercomputer Applications, NCSA, University of Illinois, is unclear because IBM Corp, which used to be in charge of the development, announced in August 2011 that it would withdraw from the development of the system.[8]

Figure 6: Status of Petascale Supercomputers and Future Plans of Prominent HPC Countries

Prepared by the STFC based on the 37th TOP500 of the National Supercomputing Center is planned through the participation of nine government ministries and agencies[9].

4 Spreading Independent Development

Recently, the "domestic production" of supercomputers has spread. In the past, only the United States and Japan developed supercomputers. However, several countries such as China, France, Russia, and India, have started domestic production of supercomputers. Especially, China has been moving toward the development of the critical components of supercomputers—microprocessors.

The following sections will introduce situations around the world as related to supercomputers, country by country, showing that not only installation but domestic production of supercomputers is spreading worldwide.

4-1 China

The Chinese National High-tech R&D Program (widely known as the 863 program) has allowed China to put efforts on HPC. The 863 program, one of the national science and technology research and development programs in China, was proposed by four senior scientists in March 1986 to Deng Xiaoping, the president of China at the time, and approved. The program has been called "863" to commemorate the year "86" and the month "3." The program included HPC as one of its targets.

Since 1990, China has created supercomputer research and development plans every five years. The goal of the plan of 2001 – 2005 was to develop Tera-FLOPS supercomputers and HPC environments. According to the plan of 2006 – 2010, the development of Peta-FLOPS supercomputers and the enhancement of grid-computing environments have been promoted. The 11th National Five-Year Plan focused on the development of Peta-FLOPS class supercomputers, the development of grid-service environments, and the development of software for supercomputers and grid computing[10, 11].

A two-phased approach was adopted for supercomputer development as follows: in the first phase, two supercomputer systems with performances of 100 Tera-FLOPS were to be developed; and in the second phase, three systems with performances of Peta-FLOPS were to be developed. As an achievement of the first phase, Dawning5000A (installed in the Shanghai Supercomputer Center) and LenovoDeepComp7000 (installed in the Supercomputing Center, Computer Network Information Center, Chinese Academy of Sciences) were developed. As an achievement of the second phase, Tianhe-1A (installed in the National Supercomputer Center, Tianjin), Dawning6000 (installed in the National Supercomputing Center, Shenzhen), and Sunway Bluelight (installed in the National Supercomputing Center, Jinan / Shangdong) were produced[12].

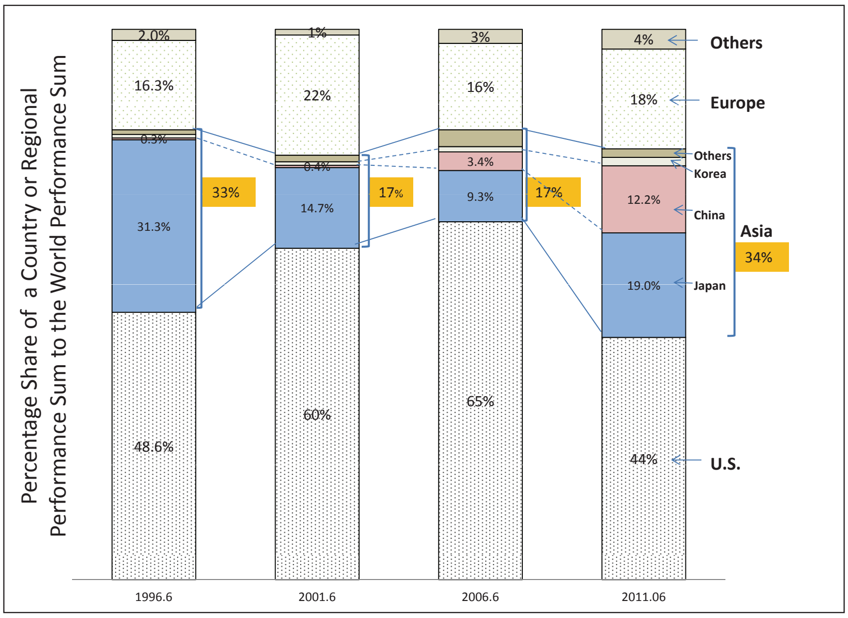


Figure 7: Past 20-year Changes in the Shares of Sum of LINPACK Performance Values of Countries or Regions

Prepared by the STFC based on the past versions of TOP500

In the 2010 version of the top 100 list of supercomputers installed in China, which has been published every autumn since 2002, the top seven slots are occupied by Chinese domestically made supercomputers. According to an official announcement, although about seventy percent of the supercomputers on the list were imported around 2003, in 2010 the share of the Chinese domestically made supercomputers reached about fifty percent, and furthermore, in the performance ranking, eighty-one percent of the listed systems are made by Chinese vendors[13, 14].

The Chinese Ministry of Science and Technology mentioned in an announcement, as achievements realized through the support by the National Project, He-gao-ji, the following as well as "Tianhe-1A" of NUDT, National University of Defense Technology: "FT-1000" microprocessor; "Kylin OS," high security OS; and "Godson / Loongson" microprocessor of the Chinese Academy of Science. It shows that China has also put a great deal of effort into the development of domestically made microprocessors[15].

A report[16] says that the "Indigenous Innovation" policy, which has been employed since the 11th National Five-Year Plan, means in some sense "Made By Chinese Companies." It can be said that the "Indigenous Innovation" policy is what's behind the strong driving of supercomputer and microprocessor development activities in China.

4-2 France

In the past, European countries imported supercomputers from the United States or Japan under a strategy of becoming superior in the development of software for supercomputers. However, Bull, a corporation in France, recently put a great deal of effort into the development of supercomputers themselves. The company has already shipped a supercomputer TERA-100 to the CEA, Commissariat à l'Energie Atomique. The system has a peak performance of 1.25 PF (1.05 PF LINPACK Performance). Supercomputers made by Bull occupied ten places in the latest TOP500 list. Bull's supercomputers were installed in Germany and the UK as well as in France.

4-3 Russia

It was reported in July 2009 that the Russian President Medvedev seriously admitted "the Russian lag in supercomputers or grid computing." The number and the sum of LINPACK Performance values of supercomputers installed in Russia at the time of the Medvedev's comment were less than about one fiftieth of those of the United States, and less than about one third of those of Germany, the UK, France, Japan, or China. So, it is true that Russia was largely behind the other countries. The Russian government reportedly announced a program to offer 2.5 billion ruble (approximately 7 billion yen at the currency rate in June 2011) to develop supercomputers with 1 Peta-FLOPS class performance by 2011 to catch-up with others[17].

This plan has been realized so completely that, in 2011, a Russian company, T-Platforms, is doing business in supercomputer development, and has largely increased their sales mainly in Russia. The company shipped a supercomputer, Lomonosov, with a peak performance of 1.37 PF (674 TF in LINPACK Performance) to Moscow State University in 2011.

4-4 India

In the past, there were domestic supercomputer developing companies in India. However, high-performance supercomputers were never developed. Recently, the Indian Space Research Organization (ISRO) and Wipro Technologies Limited developed the fastest supercomputer in India, called SAGA-220 for aerospace applications, which is a hybrid-architecture system configured with CPUs and GPUs and has a peak performance of 220 TF[18]. Before SAGA-220, the fastest in India was an imported supercomputer with a peak performance of 172 TF.

5 Globalization in Research and Development

This chapter will show the status of the activities of supercomputer research and development through collaborations with other countries, which can be called the third globalization around supercomputers. As the requirements to supercomputers have expanded limitlessly, technical problems have also piled-up in a variety of fields, such as hardware, software pulling out the performance of massively parallel supercomputers to the limit, and applications. To tackle those problems, research and development activities have become the subject of multi-national collaboration in which knowledge and power are gathered from countries around the globe.

5-1 Research and Development in Europe

5-1-1 Activities toward Exascale

(1) European Exascale Software Initiative (EESI)

EESI is an activity funded by the EU. The goals of EESI are as follows: to clarify the technical problems to be solved for executing scientific computations on supercomputers with a performance of multi Peta-FLOPS in 2010 and Exa-FLOPS in 2020; then to determine technical problems on which Europe should put research and development efforts; and to create a roadmap. To work toward the goals, they are now performing activities under working groups. More specifically, they are working to clarify the advantages and disadvantages of Europe to win the global competition, to prioritize the activities, to create education / training programs for computational scientists of the next generation and to find and promote the opportunities of collaboration including countries outside Europe. The project period is eighteen months from the first day of June 2010. At present, one hundred fifteen experts from fourteen countries in Europe are working on the project[19].

(2) EU-Call ICT-2011.9.13

EU-Call ICT-2011.9.13, which is one of the research public offerings in the ICT (Information and Communications Technology) field of the Seventh Framework Programme of EU (FP7), aims for Exascale computing. Its official name is "Exascale computing, software and simulation," and it is the first offering dedicated to Exascale computing in FP7. In January 2011, the three projects[20] that follow, with which several EU countries are involved, were selected to receive a grant of 8 million euro each:

- MontBlanc: European scalable and power efficient HPC platform based on low-power embedded technology;
- DEEP: Dynamical Exascale Entry Platform, Hierarchical Concurrency Approach;
- CRESTA: Collaborative Research into Exascale Systemware, Tools, and Applications.

(3) Opening Research Facilities and Establishing Partnerships for International Collaboration

European countries have been vigorously establishing research facilities and partnerships seeking international collaborations for realizing Exascale. Table 1 summarizes the research facilities and partnerships established recently.

European countries are seeking to enhance the European presence through such collaborations.

5-1-2 Collaboration in Supercomputer Installation and Sharing in Europe

European countries have already established the PRACE Initiative[27-29] (Partnership for Advanced Computing in Europe, hereinafter referred to as PRACE) for the purpose of providing scientists and engineers in Europe across the borders with world-class supercomputer-power. There are twenty-one member countries as of June 2011.

The first of those world-class supercomputers (called Tier-0 systems) available to European countries was JUGENE (with peak performance of 1 PF) of FORSCHUNGSZENTRUM Jülich, Germany. The system has already been in operation. Other Tier-0 systems are also expected to start services as follows: CURIE (with peak performance of 1.6 PF) of the Alternative Energies and Atomic Energy Commission is expected to be the second, and scheduled to start services in the second half of 2011; HERMIT (with peak performance of 1 PF) of Stuttgart HPC Center at the end of 2011 and Upgraded HERMIT (with peak performance of 4 to 5 PF) in 2013; and SUPER-MUC (with peak performance 3 PF) of Leibniz Super Computing Center, Germany in the middle of 2012.

I can predict that the activities observed in PRACE for sharing world-class supercomputers will lead to the sharing of forthcoming Exascale systems.

5-2 International Trends

By extrapolating the plots shown in Figure 1, we can predict that Exaflops systems will come into existence approximately between 2018 and 2020. An international project, called the International Exascale Software Project[30] (hereinafter referred to as IESP), has been working on discussions of what type of architecture Exaflops systems should employ or what will be the problems for software executed on the systems.

There are a lot of major technical challenges in system architectures for the realization of Exaflops performance. In order to attain 1 Exaflops, a large enhancement in performance is required. For example, in comparison with 2 PF, which is the best peak performance in the TOP500 as of June 2010, 500 fold enhancements in performance are required. However, the power dissipation of an Exaflops system

Table 2: Research Facilities and Partnerships Aiming at Realization of Exascale

Name	Location	Participant Organization
Exascale Innovation Center[21] (EIC)	Germany	FORSCHUNGSZENTRUM Jülich and IBM Corp.
ExaCluster Laboratory[22] (ECL)	Germany	FORSCHUNGSZENTRUM Jülich, Intel Corp., and others
EX@TEC[23]	France	CEA, GENCI, Intel Corp., and others
Flanders ExaScience Lab[24]	Belgium	IMEC, Intel Corp., and others
Exascale Stream Computing Collaboratory[25]	Ireland	Trinity College, Dublin, IBM Corp., and others
Exascale Technology Center[26]	UK	The University of Edinburgh, Cray Inc.

should be limited within 20 MW, approximately three fold of the power dissipation of 6 MW in 2010, because, by a simple extrapolative extension of the present technologies, an enormously large power would be required and, as a result, realistic system construction with reasonable operational cost would become impossible. For this reason, the 20 MW in power-dissipation has been set as the upper–limit goal. On the way to the goal, there stands a formidable challenge requiring the development of breaking-through low-power technologies. Regarding the scale of the computing unit, in comparison with that of 2010 that contains 18,700 nodes (a node refers to a computing processor containing computing cores), 100,000 to 1,000,000 nodes will be contained in that of an Exaflops computer. It means the scale will be expanded to about 50 folds maximum of that of 2010. In a situation where such a huge number of nodes run simultaneously in parallel, the total performance will be limited by the data transfer time between cores within or across nodes. It means that a primary requirement is to speed up data transmission. By an estimation, data transmission speed between nodes should be 200 Gigabytes per second (GB / s), more than 130 folds of 1.5 GB / s[31] of Petascale. It also means that ultra-high-speed interconnections enabling such high-speed data transmission are required. In addition, high reliability and resiliency of the system is inevitably required for running such a huge amount of hardware. Moreover, software, software development environments, and application software that extracts hardware power to a limit and enables massively parallel processing under such a configuration are required.

The IESP project focuses especially on software, because at present the development of software falls behind that of hardware[6]. The existing software used in Terascale or Petascale computing is suspected of being insufficient for Exascale computing. Breakthroughs in software are considered critical to the realization of software working efficiently in Exascale environments.

The IESP activities were originated with the workshops that have been held by the supercomputer experts in the United States since 2007. Since then, supercomputer experts around the world have been invited and have started collaborating. At present, researchers from Europe, Japan, and China are working collaboratively with U.S. researchers. In February 2011, a roadmap of common technologies expected to be indispensable to the realization of Exaflops systems was released. There, technical challenges in software to attain the goals were presented in general categories as follows: system software, development environments, applications, and cross-cutting dimensions. Also, the predicted technical elements in each category are discussed. The roadmap listed the names of the sixty-five contributors from around the world, including seven from Japan[32, 33]. From now on, discussions will be shifted from "What to make" to "How to make."

6 Conclusion

In this article, I looked into the world's supercomputers listed in TOP500, suggested the current status of three types of globalization, and described their statuses. The reason those types of globalization became distinguishable is considered to be that, among the countries in the world, the recognition has be widely shared that the application of supercomputers would influence the future of their own in science and economy.

The globalization in installation is considered to suggest that supercomputers enabling various kinds of simulations have become acknowledged as a foundation to support national power through science technology. Because numerical simulations are widely acknowledged as “the third science” next to “theory” and “experiment,” supercomputers enabling such simulations have been installed aggressively. It is quite natural to demand higher-performance systems and, as a result, several countries have already installed Petaflops peak performance supercomputers.

The expansion of supercomputer-developing countries is considered to be a result of the spreading notion that scientific and technological advantages should be obtained through the domestic development of supercomputers. Such trends are expected to continue in future. However, it is true that, in the way of the development of higher-performance supercomputers, technological problems are piling-up and it would not be easy for a single country to solve.

Therefore, the third globalization, collaborative development with other countries, has appeared as a solution. Research and development activities where the wisdom and power of researchers are gathered from the world have been going-on.

I can say that it is natural that the three types of globalization occurred sequentially. The international collaboration in the development of future high-performance supercomputers will be essential. However, we should take note that maintaining our own superiority will be inconsistent with international collaboration. It is desirable to know our own advantages first, and then promote collaborations with others while effectively using those advantages.

Most important to the promotion of international collaborations is to actually possess the advantages that the world will acknowledge. If a country were to have no advantages, the world would not pay attention to the country, naturally. Japan has technological power for producing “Kei,” which is ranked at the top of the world’s supercomputers. The power that enabled “Kei” is definitely an advantage for Japan.

Also, it will be effective to show tangible results by fully utilizing the performance of “Kei.” A variety of application technologies (application software, etc.) are under development for utilizing “Kei,” as follows[5]: “Next-Generation Integrated Simulation of Living Matter” Research and Development and “Next-Generation Integrated Nanoscience Simulation Software” Research and Development included in the Grand Challenge Application Development Program; and “Computational Life Science and Application in Drug Discovery and Medical Development,” “New Materials and Energy Creation,” “Projection of Planet Earth Variations for Mitigating Natural Disasters,” “Industrial Innovation,” and “The Origin of Matter and the Universe” included in the Strategic Programs for Innovative Research. It is necessary to show the world Japan’s advantages through attaining such achievements that the world acknowledges as Number 1 in those programs. If Japan can impresses upon the world that Japan has advantages not only in supercomputer system technologies but also in application technologies, it will present big opportunities to garner a great deal of attention from the world.

Researchers are always attracted by environments where they could perform the world’s best research or where they could use the world’s best technologies, and they flock to such places. It would be desirable for Japan from now on to promote activities around “Kei,” show the advantages of Japan, go forward in international collaborations, absorb the wisdom of the world’s top researchers, and as a result elevate Japan’s technological power.

Glossary

- EESI: European Exascale Software Initiative
- FLOPS: Floating point number Operations Per second
- FP7: 7th Framework Programme
- HPC: High Performance Computing
- IESP: International Exascale Software Project
- LBNL: Lawrence Berkeley National Laboratory
- LINPACK: LINear equations software PACKage
- NERSC: National Energy Research Scientific Computing Center
- PF: Peta FLOPS

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