

EXECUTIVE SUMMARY

ASSESSMENT OF JAPANESE RESEARCH, DEVELOPMENT, AND APPLICATION OF HIGH-END COMPUTER SYSTEMS

Alvin W. Trivelpiece

STUDY PROCESS

This report is an account of an effort to better understand High-End Computer Systems (HEC) in Japan. This effort had its origins in discussions in late 2003 among several U.S. government agencies with responsibilities for funding programs in the U.S. HEC enterprise. They include the Department of Energy Office of Science (DOE/SC), the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA). These agencies, in cooperation with Dr. David B. Nelson, Director of the National Coordination Office for Information Technology R&D, asked the World Technology Evaluation Center (WTEC) to organize a group of scientists and engineers with appropriate knowledge to review, analyze and report on Japanese projects in high-end computing. This assessment included a study tour to Japan to allow the panel members to meet with Japanese scientists, engineers, managers and government officials involved in the support and operation of HEC at universities, national laboratories and industrial organizations.

This study complements three others underway at about the same time, all inspired by the challenge presented by the achievements of the Japanese Earth Simulator in taking the lead as the world's fastest supercomputer in March, 2002. (1) The National Academy of Sciences kicked off a study in March 2003 focused on assessing the U.S. scene. Their report, "Getting Up to Speed: The Future of Supercomputing," is available in draft form on the Web as of this writing at <http://www.nap.edu/catalog/11148.html>. (2) The National Science and Technology Council organized a High-End Computing Revitalization Task Force to develop a plan for a U.S. HEC program to maintain U.S. leadership in science and technology. That report, "Federal Plan for High-end Computing," (May 10, 2004) is available at <http://www.itrd.gov/hecrtf-outreach>. (3) Finally, Congress also commissioned a study by the JASONs on the HEC requirements for nuclear stockpile stewardship.

The WTEC Panel was organized at a kick-off meeting on January 9, 2004. It conducted a study tour in Japan from March 28 through April 3, 2004. During this time the Panel met with many individuals at the 22 institutions listed in the full report. In an effort to optimize its efforts, the Panel divided itself into two groups, assigning members to each group depending on the nature of the functions performed at each particular site. For each site, Panel members prepared a site report, which has been included in the appendix.

As part of its assignment, the Panel briefed individuals from the sponsoring agencies on May 24, 2004, and presented its preliminary findings at a public workshop on May 25. Representatives from many U.S. stakeholders were in attendance, and several representatives from Japanese organizations traveled from Japan to participate in the event. This report has tried to reflect this feedback from the workshop and on-going developments in the field while it was being prepared.

STUDY FINDINGS

In general, there is no doubt that the quality of Japanese research and development in many scientific disciplines is competitive with the world's best, as it is in high-end computing. These principal conclusions specific to this discipline are brief summaries of those given in the full report.

Conclusions on the Earth Simulator and Special Purpose Supercomputers

The ES is a superb engineering achievement and impressively led the world for about two years. At the Supercomputer 2004 conference in Pittsburgh in November, 2004, a new Top500 list was released that showed two American computers passing the ES (at 35.9 Tflop/s). These were the IBM Blue Gene/L supercomputer at 70.7 Tflop/s and the Columbia made by SGI Altix / Voltaire at 51.9 Tflop/s. Even before these latest American achievements, the WTEC panel concluded that considering the whole spectrum of HEC, the U.S. is ahead of Japan. However, Japan has a justifiable right to be proud of what it has accomplished.

There are three reasons how the Earth Simulator came about:

- At the time it was first considered for support, government funding was robust in Japan.
- Japan has regarded the climate and environment as critically important to its interests.
- Dr. Hajime Miyoshi was the key visionary and driving force behind the effort to fund and build the ES.

In the WTEC panel's visits in Japan, the hosts did not identify any plans to expand the ES itself. However, Dr. Sato, the ES director, has made a proposal for a new generation machine 10,000 times more powerful. This is conceived to be a heterogeneous machine that would be internationally funded.

A recent development is that a new Japanese consortium has been organized to build a 1 Pflop/s (1000 Tflop/s) supercomputer by around 2010. The consortium includes NEC, Toshiba, Hitachi, as well as universities and national labs. The budget for the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) for the Japanese 2005 fiscal year includes about \$20 million in top priority funding that appears to be directed toward this effort.

In October, 2004 NEC announced the launch of the SX-8 supercomputer, which is based on the ES. On paper a full-blown SX-8 could achieve a peak vector performance of 65 Tflop/s.

Japan has had a broad-based strategic effort in high-performance computing over the past decade. The ES is the principal embodiment of that strategic effort. As intended, the ES has had a major impact in the Earth sciences in that it led to significant advances in the field (e.g. increased resolution, shortened turnaround time). ES is now extending its applications to other fields beyond earth sciences, including biosciences and nanotechnology. However, continued progress in large-scale high-fidelity modeling and simulation will require a significant increase in power beyond the ES.

Japan has a broadly based and carefully planned but audacious program in advanced scientific simulations. The strategic attack on protein structure, cell simulations, and computational bioscience is especially noteworthy. The Protein Explorer, with its huge increase in power for molecular dynamics, could put Japan into world leadership in this area.

The Panel concluded that the investment in software for ES is not in proportion to the investment in hardware. The software research agenda in Japan is currently skewed toward grid middleware, which overlaps cluster computing, and there are only modest research programs at the Japan Marine Science and Technology Center (JAMSTEC) for compilers, programming languages, and tools. High-performance Fortran (HPF) is much more successful in Japan than in the U.S., but there is an increasing interest in message passing interface (MPI) to enhance portability.

There is some resentment to the Earth Simulator by some research groups in Japan. Their feeling is that the ES is too expensive and drains critical resources from other essential scientific and technical programs. In

discussions with the major players in Japan, there did not yet seem to be a broad consensus for a follow-on project of similar magnitude in the near term. Some feel that distributed heterogeneous grid environments promise to satisfy HEC requirements.

Conclusions on Grids

There was more emphasis on grids than the Panel had expected. Grid computing is a high priority for government agencies, and the funding levels for grid programs are much greater than for vector supercomputing programs like the Earth Simulator. The effect of this shift in emphasis on research institutions and vendors has been dramatic, as there is currently relatively little research on supercomputing technologies or tools, but a broad interdisciplinary effort in grids. Because the boundary between grid and cluster computing is somewhat blurred, some of the research in application-level libraries and problems solving environments could easily be considered to be a high-performance computing project, rather than a grid-computing project. However, the emphasis is on commodity processors and the development of software technologies that are applicable to business and government in addition to science and engineering.

The Japanese grid agenda highlights the performance heterogeneity of systems in the grid as an opportunity, allowing applications to select the best hardware for a given part of a computation. The most aggressive use of heterogeneity combines special purpose processors like Grape with vector supercomputers, PC clusters, and shared memory workstations. These ideas have also influenced plans for an international follow-on to the Earth Simulator, which has been described by Director Sato as having exactly this type of heterogeneous architecture.

Conclusions on Government Policy Toward HEC

The Panel visited the three main government agencies involved in high-end computing: the Council on Science and Technology Policy (CSTP), MEXT, and the Ministry of Economy, Trade and Industry (METI).

CSTP is the highest policy-making body for science and technology in the Japanese government, chaired by the Prime Minister himself. It has many strategic planning functions, aimed at steering Japan's science and technology into a more competitive position in the world. Its role includes prioritization of research initiatives, like the one that led to the ES. CSTP representatives stated that proposals for follow-ons to the ES would have to come from the ministries, and the process for building such a consensus would take time.

MEXT now takes the lead in guiding and funding supercomputing through both education programs at universities and science programs at several government agencies under its jurisdiction. The ES was developed under MEXT guidance, and the Panel learned much about how it came to pass during its visit. It was proposed as a tool to promote basic research, not to promote a particular kind of computer technology. It cost about ¥60 billion, including an unexpected supplement that permitted completion in five years instead of the projected eight years. At the time of the visit, MEXT officials said that no specific plans are in place to build a follow-on to the ES. There was also no policy to subsidize the Japanese supercomputing companies. They are, instead, investing in grid computing and other long-term research areas, including quantum computing and nanotechnology.

METI is in charge of administering Japan's policies covering a broad area of economy, trade, and industry. Ten years ago, METI (then MITI) invested in supercomputing, but there were not enough applications to sustain a market. METI is no longer interested in supercomputing, but is interested in PC clusters, because of their cost effectiveness.

