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High Performance Computers and Export Control Policy: Issues for Congress

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High Performance Computers and Export Control Policy: Issues for Congress

Summary

Congress has a strong interest in export control policy with regard to technologies that may have both commercial and military applications outside of the United States. Through its constitutionally delegated authority to regulate foreign commerce, Congress has the authority to control exports for national security or foreign policy purposes. The 109th Congress may examine issues of national export control policy, including reauthorization of the Export Administration Act (EAA), and control policies concerning key technologies. Among these technologies are High Performance Computers — HPCs. HPCs are either single computing machines (usually called supercomputers) or a cluster of easily available, high-end workstations or personal computers. Congressional interest in HPCs has primarily, but not exclusively, been focused on the dual-use applications of HPCs. That is, commercial HPCs that may also be used to simulate nuclear weapon tests, chemical and biological weapons production, and for military command, control, and communications. The 109th Congress likely will again consider the reauthorization of the EAA. Both chambers last considered EAA legislation in the 107th Congress. Legislation may also be introduced to repeal specific controls on HPCs enacted as part of the National Defense Authorization Act of 1998.

There are several issues that congressional policymakers are addressing concerning reauthorization of the Export Administration Act. One is proliferation — who obtains this technology and how they use it. In response to concerns about proliferation, Congress legislated licensing, post-shipment verification, Congressional notification of exports, and changes in licensing thresholds for HPCs. Some contend that these safeguards and restrictions have not been effective. Another issue is the notification process, in which the executive branch not only notifies the legislative branch of HPC export control changes, but describes the national security implications as well. Critics contend that the last several HPC export control changes did not sufficiently provide this national security context. The U.S. computer industry has also raised concerns about another issue — that restrictions only hurt U.S. commercial interests. The computer industry and their supporters, as well as others, contend that the computing benchmark for HPCs (Million Theoretical Operations Per Second, or MTOPS), no longer reflects rapid technology innovations in the field. Some have called for replacing MTOPS with a benchmark measuring teraflops. Among the issues facing the 109th Congress are whether to maintain HPC export controls by using MTOPS, revise them by using a benchmark other than MTOPS, or to eliminate controls completely.

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Overview

Congressional Interest. Congress, through its constitutionally delegated authority to regulate foreign commerce, has the authority to control exports for national security or foreign policy purposes. The 109th Congress may examine issues of national export control policy, including reauthorization of the Export Administration Act (EAA), and control policies concerning several key technologies. Among these technologies are High Performance Computers — HPCs. HPCs are either single computing machines (usually called supercomputers) or a cluster of widely available, high-end workstations or personal computers. Congressional interest in HPCs has primarily, but not exclusively, been focused on the dual-use applications of HPCs. That is, HPCs may be commercially obtained in the open global market, but they also may have military applications, such as simulating nuclear weapon tests, producing chemical and biological weapons production, and for enhancing military command, control, and communications.

Legislation was last acted upon in the 107th Congress to reauthorize the Export Administration Act, the statutory authority regulating exports of dual-use items, including HPCs. In May 2003, the House rejected an attempt to repeal Title XII (B) of Division A of the National Defense Authorization Act of 1998 (NDAA98), which mandated licensing, notification, and post-shipment verification requirements of HPC exporters by a vote of 207-217.

Proliferation. Technology is only as important as its applications. HPCs can be used for various military applications from design and testing of weapons of mass destruction to battlefield management. In response to concerns about proliferation, Congress legislated licensing, post-shipment verification and Congressional notification of exports and changes in licensing thresholds for HPCs in 1997. Congress has focused attention on export control restrictions on certain countries. China, India, Pakistan, the former republics of the Soviet Union, and others are suspected of engaging or assisting in weapons proliferation. Administrative changes in the export control system have made HPCs more available, while also attempting to provide end-use and end-user post-shipment verification of HPCs. Many critics contend that post-shipment verification has been ineffective, permitting HPCs to fall into the hands of nations or entities without obtaining any clear knowledge of their applications. Others contend that this technology is so widely available that to try to restrict HPC sales only hurts U.S. commercial interests. There is also the issue of rapidly evolving U.S. engagement with Pakistan, Russian, India, and China in shaping an anti-terrorist strategy in the aftermath of the September 11 attacks.

U.S. Industry Concerns. While congressional policymakers are concerned about the use of HPCs to assist in the proliferation of weapons of mass destruction, they also have been responsive to U.S. industry concerns of competing fully in the global economy. U.S. HPC firms tend to dominate global sales, but they are not the only source of this technology. Therefore, several industry groups have cautioned Congress that restricting HPCs will only mean that comparable technology will be available from non-U.S. competitors. In the face of increasing global competition, many in the U.S. computer industry, as well as supporters in the government and elsewhere, have sought to expand, not restrict, HPC sales. Some have called for the continued raising of the computing benchmark, Million Theoretical Operations Per Second (MTOPS), which under current export control law determines which HPCs can be sold to which users. Others have called for the complete elimination of MTOPS as a control benchmark, contending that it is flawed and does not reflect recent technology innovations. Some have called for replacing MTOPS with a benchmark measuring teraflops, a standard measuring trillions of floating point operations per second.

Congressional Oversight. Since 1998, the executive branch has raised the MTOPS benchmark several times. The rationale for these actions has been that HPCs are also widely available from non-U.S. sources, and continued restrictions in the face of technological innovation only hurts U.S. firms. But many congressional policymakers are concerned that executive branch notifications for rapidly raising the MTOPS benchmark have not given Congress a clear assessment of the national security implications involved. They would likely revisit the notification process and call for greater information for assessing the national security implications for raising export control thresholds of HPCs.

Issues for Policymakers. Among the HPC export control issues that the 109th Congress may consider include whether to maintain HPC export controls by using MTOPS; revising HPC export control policy by using a benchmark other than MTOPS; or to eliminate completely HPC export controls. In addition, the events of September 11, 2001, may continue to affect the congressional debate on HPC export controls as the United States reviews its national security concerns and foreign policy alignments in light of the terrorist attacks.

Background

High performance computers (HPCs) are computers that can perform multiple, complex digital operations within seconds. Sometimes called supercomputers, HPCs are actually a wide range of technologies that also include bundled workstations, mainframe computers, advanced microprocessors and software.[1] A benchmark used for gauging HPC computing performance is to count the millions of theoretical operations per second, or MTOPS, that the computer can perform. The actual MTOPS a computer can perform over time can vary, based on the operations

[1] A supercomputer is usually defined as a single, complex, mainframe computer that can undertake a series of specific computer functions. Michael S. Malone, ed., "Big Iron; Supercomputers are Back and Changing Business, Science, and Even You," Forbes ASAP. February 22, 1999. 96 pages.

performed (some can take longer than others or can be performed while other operations take place) and the real time cycle of the computer. In 2004, most new desktop computers, available as off-the-shelf commercial products, ranged in computing power from 6,000 to 12,000 MTOPS.[2]

HPC technologies have removed many of the technological restraints in advanced computing by reducing long computing times and complex functions that hindered solving mathematical, scientific, and engineering problems.[3] The executive branch has recognized that HPCs are critical in a variety of defense and security-related areas, including nuclear and conventional weapons programs, encryption, and military operations.[4] Continual increases in the computing power of HPCs, the extent of foreign availability of models comparable to some of those produced in the United States, the adequacy of relying on high computing power alone as a basis for determining the potential ability of HPCs to fulfill specific user goals, and the degree to which foreign use of HPCs in ways that adversely affect U.S. interests can be accurately predicted and successfully monitored, are among the factors in the export control debate.

High performance computing can be performed in a number of ways. The scope and effect of HPC technologies depends on several factors — how the computing capability is structured, how the computing capability is used, and what is the desired result of the computing capability. The first high-speed computers developed in the late 1950s and the early 1960s, such as the IBM 704 and the IBM STRETCH, were single computers performing a series of sequential, arithmetic functions (one operation per one instruction in a sequential order). In the late 1960s and into the 1970s, improvements in computing memory capacity and speed led to developments in which repetitive operations could be undertaken per instruction. An HPC which performs one operation per one instruction uses **scalar speed**; an HPC which performs repetitive operations per single instruction uses **vector speed**. The key technology development was that computing capability was contained in a single machine, or what is commonly referred to as a supercomputer.[5]

In the 1960s, U.S. military researchers began employing different combinations of computers to achieve high-performance computing levels. By the 1990s, commercial users began to more commonly link several computers with multiple

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[2] The growing complexity and sophistication of off-the-shelf commercial computing products also means that pure computing power is not the only benchmark for consumer preference; network capabilities and network interface is also an important consideration for consumers.

[3] See GAO Report GAO/NSIAD-98-196, *Export Controls: Information on the Decision to Revise High Performance Computer Controls* (September 1998), and GAO Report GAO/NSIAD-98-200, *Export Controls: National Security Issues and Foreign Availability of High Performance Computers (*September 1998).

[4] See GAO Report GAO/NSIAD-98-200, pp. 2-4; GAO Report GAO/NSIAD-98-196, at 7-8.

[5] It is important to note that scalar processing is not "better" than vector processing. The computing application, the number of processors needed, the time, cost, and other factors all play a role in how HPCs are used.

processing capability together, to alleviate delays that may occur when highly complex data calculations reach the level of billions of operations. This permits computations to be undertaken simultaneously, rather than sequentially, and is called **parallel processing**. The most common form of parallel processing is **clustering**, in which independent computers are linked, or clustered, together by a single system of software, hardware, and network technologies. Clusters of parallel processors have dramatically driven down the cost while increasing the scale, scope and capacity of computing systems. **Computing grids** and **Internet computing** are extensions of clustering — networks of computers, which may be physically separated by great distances, but are linked (sometimes globally) together to work as a single unit.[6]

There are many architectures, or combinations, of computers and processing capability, that employ parallel processing through clusters, grids, and the Internet. Two factors that affect HPC architecture are the complexity of the operation being performed and the response time needed for a solution. The response time may need to be measured in microseconds (such as in a space launch) or in minutes, hours or days. Response time determines how many computers should be used and at what speed. Are benchmarks required at certain points of the calculation, requiring one processor to continue to work while others remain dormant? Does the calculation require a pre-production or post-production run to verify results?[7] Regardless of the factors considered and results sought, parallel processing requires multiple computing processing, usually housed in multiple computers.

These advances in scalar, vector, and parallel processing have given users many options. They have removed many of the technical constraints in advanced computing by reducing long computing times and complex computing functions that hindered solving mathematical, scientific, and engineering problems. Recent HPC applications range from accurate real-time weather forecasting and climate change modeling to simulations of nuclear weapons tests. For example, vector processing is an integral part of Doppler radar, a computer imaging system that provides real time weather patterns with extreme accuracy.

Military Uses of HPCs. High performance computers are used in many military situations including weapons design, testing, battlefield modeling, and command, control, coordination and intelligence activities (C3I). (See Appendix Table 1 for computer performance levels used for specific military applications.)

Many experts have noted that it is possible to design nuclear weapons with current commercially available computers. (Indeed, the first atomic weapons were designed with slide rules). Nonetheless, it is pointed out that highly advanced computers such as those used in nuclear weapons laboratories are necessary to

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[6] Nance, Scott. *Clusters, Grids Moving Quickly From Lab to Market.* New Technology Week. 23 July 2001. P. 1; 4.

[7] Before a long calculation is executed, it is often submitted for a shorter run to determine if all of the inputs and factors are correct (to avoid wasting time and money). In addition, after a long production run is made, it is often necessary to analyze the results in additional calculations that last minutes to hours in time. National Research Council, *Supercomputers: Directions in Technology and Applications.* Washington: D.C. 1989: 32-33.

produce successive generations of such weapons with greater sophistication and capabilities.[8] According to one proliferation expert, "acquiring supercomputers could assist China in building smaller and more efficient nuclear weapons-improvements in order to upgrade its strategic rocket forces to include multiple independent reentry vehicles (MIRV) systems- and for cruise missiles."[9]

Supercomputing capabilities can be used to simulate nuclear explosions. However, these simulations rely on extensive data and codes obtained in part from actual tests. Relatively few countries have tested nuclear weapons, and this data is highly guarded classified material. Therefore, computing capacity is not enough to successfully simulate nuclear tests. However, for countries that have conducted tests and presumably have this data, advanced computing capability can reduce or eliminate the number of tests needed. Not only does this contribute to greater weapons capability, it also allows that country to conceal progress towards the development of such weaponry.[10]

Battlefield management encompasses the components of command, control, communications/computers, intelligence (C3I), and reconnaissance. In the networked battlefield, management applications collect data from many sources simultaneously, favoring the input-output capabilities of a mainframe HPC. The software codes used to create battlefield management applications likewise need HPCs, but they involve computational aspects in which clustered computers can be employed.[11] Commercially available laptops such as are manufactured in numerous countries can run these operations in the field.

U.S. Government and Industry Roles

It is important to note that the federal government has had an important role in the development and growth of computer technology, especially HPC technology. In the early 1950s, federal funding for computer science supported developments in several fields: electronic components, magnetic storage, computer architectures, and software.[12] Many federally-sponsored R&D programs that supported early computer science and technology research were undertaken for military and national security purposes. The first two electronic digital computers, the Colossus and the ENIAC, were developed as a consequence of the Allied war effort in the 1940s and are the

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[8] CSIS Commission of Technology Security in the 21st Century (CSIS), "*Computer Exports and National Security in a Global Era*," May 2001, p. 12.

[9] Bryen, Stephen D. "The Future of Strategic Export Controls," CSIS-Stimson Working Paper #2, April 2001, p.22.

[10] Ibid, p. 23.

[11] CSIS, p. 12.

[12] Flamm, Kenneth. *Creating The Computer: Government, Industry, and High Technology*. The Brookings Institution. 1985: 8-28.

origins of the U.S. commercial computer industry.[13] The Defense Advanced Projects Research Agency (DARPA), a part of the Department of Defense that supports long-term, high-risk, potentially high-payoff R&D, also has been instrumental in technology developments ranging from the computer mouse to flat panel display technology. The Internet was created as a network in which university researchers undertaking contract work for DOD could easily exchange data. The U.S. Navy, Air Force, and other parts of the Armed Services also provided significant funding for early computer science research, and the National Science Foundation and what was formerly the National Bureau of Standards have played a significant role in supporting targeted, non-military computer science.[14]

As computers and computer technologies became more complex — and as global competition for making these machines became more intense — policymakers sought to address perceived shortcomings in technologies and applications. In 1989, representatives from the federal government, U.S. industry, and academia called for policymakers to address the "grand challenge" of supporting new computing and networking applications. In FY1991, the 102nd Congress authorized the High Performance Computing Initiative as part of a five year effort to advance high performance computing in conjunction with the mission of federal agencies. While authorization of this program ended at the end of FY1995, appropriations for federal high performance computing research and development has continued. In FY2000, support for federal HPC programs totaled $1.8 billion.[15]

While U.S. HPC manufacturers continue to provide technological innovations, global competition is intense. Today's global market leaders include IBM and Sun Microsystems/Cray in the United States, and Japan's NEC. Beyond the United States and Japan, many other industrialized nations have developed high performance capabilities, although they lag performance benchmarks of the industry leaders. Computer software, networking, semiconductor chip manufacturing, and other segments of the computer industry also have benefitted from, and contributed to, HPC advances.[16]

HPCs and Export Policy Revisions

Before HPC technology advances in the 1990s, HPC export controls were fairly simple. There were only a few supercomputers in the world; they were almost all

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[13] While the Colossus was built in England during 1942-43, the effort was considered a joint U.S.-British accomplishment. ENIAC stands for Electronic Numerical Integrator and Calculator. Ibid., 46-47.

[14] Ibid., 29-46. The National Bureau of Standards became the National Institute of Standards and Technology in 1995.

[15] For more on the origins and history of this program, see *Computing, Information, and Communications R&D: Issues in High-Performance Computing*, by Glenn J. McLoughlin. CRS Report 97-31 SPR.

[16] Computer Industry Almanac, "Top Computer Companies," [http://www.c-i-a.com/statistics/prz].

made by U.S. firms; and computing capability ranged in the low 100 MTOPS range. U.S. export control policy focused on controlling a single set of technologies incorporated into specific products.

Multilateral Regimes

The Coordinating Committee (CoCom). CoCom was originally established in 1949 to restrict the transfer of technology to the Soviet Union and its satellite states. The organization, headquartered in Paris, met regularly to determine which goods could be sent to the Eastern Bloc. CoCom was characterized by a coordinated list of goods and technology, the ability to prevent the export of goods from a member state, and frequent consultations. Its impact was realized after the collapse of the Eastern bloc, when the woeful state of Soviet-bloc technology was confirmed. CoCom did not long survive the end of the Cold War, as the lack of agreement on control destinations contributed to its demise in 1994.

U.S. Japan Supercomputer Agreement. The first multilateral attempt explicitly to control the export of supercomputers for non-proliferation purposes was the U.S.-Japan Supercomputer Agreement of 1984. Modifications of the agreement were adopted in 1986, 1990, and 1994. At that time, the two major supercomputer manufacturing nations agreed to coordinate the sale of these machines to third parties. The agreement supplemented CoCom by controlling transfers to non-Communist countries. In 1993, the U.S. unilaterally liberalized its export controls on supercomputers (500 MTOPS for CoCom; 2,000 for the bilateral agreement). The Japanese protested this decision and only raised controls to 1,500 MTOPS. The controls prohibited sales to end-users known to be engaged in weapons development, proscribed activities, or known to be terrorist entities.

Wassenaar Arrangement. In the mid-1990s, an international agreement, called the Wassenaar Arrangement (WA), created a multilateral framework to control conventional arms and dual-use technology, including HPCs. The WA resulted from negotiations culminating in July 1996 to replace the Coordinating Committee (CoCom). The WA is a voluntary arrangement that stresses transparency, consultation, and national restraint. WA members report on the transfers of dual-use goods semi-annually. Sensitive List transfers are also reported semi-annually, however, license denials are reported to the group within 60 days. WA members also consult on the security implications of transfers of conventional arms and dual-use goods. The WA conventional arms and dual-use lists are maintained by the participating states and are revised as needed.

The decision to license any good or weapon remains with the Member state based on that state's national export control laws. Unlike CoCom, national decisions cannot be overturned or considered by the other Member states. Neither are there prohibitions to prevent an "undercut", the act of selling an exact or similar good after another country has denied such a sale. WA is not targeted at any nation, although an informal consensus has developed against sending arms or sensitive technologies to certain states. Current Wassenaar controls are set at 190,000 MTOPS.

U.S. Domestic Policy and Regulations

As both the computing power and applications of HPCs grew, so did concerns about adjusting export controls and changing MTOPS benchmarks. In 1992, the U.S. Commerce Department defined an HPC as 195 MTOPS; any export above this level required an export license. This definition was revised in 1994 (1,500 MTOPS)[17], to reflect new HPC technologies and expanding applications. It is important to note that at that time, HPCs were still almost exclusively stand-alone machines.

MTOPS and Country Tiers. At the end of 1995, a study on high performance computing and export control policy was published by the Center for International Security and Cooperation (CISAC) and Stanford University. This study, "Building on the Basics: An Examination of High-Performance Computing, Export Control Policy in the 1990s" was commissioned by the Departments of Commerce and Defense to address concerns about HPCs and export control policy. The report analyzed then-current technology trends, applications, and export control policy. It concluded that technological advances in computing, diffusion of HPC technology worldwide, new applications of HPCs, and changing U.S. national security policy in a post-Cold War era effectively made MTOPS a poor export control benchmark. The study's authors recommended that in the short-term, new upper and lower export control thresholds should be based on militarily important applications, and recognize the inability to control specific technologies.[18]

The current licensing process for HPCs was established by Commerce Department rulemakings of January 25, 1996 and March 25, 1996. The former implemented the policy of computer export reforms announced by President Clinton on October 5, 1995; the latter implemented the reorganization of the Export Administration Regulations (EAR) broadly, but it also announced the policy of License Exceptions for computer exports. A License Exception is an authorization contained in the EAR that permits exports of an item that otherwise would require a License under certain circumstances. An exporter invoking a License Exception certifies that all licensing criteria have been met on its export documentation.

These regulations created the License Exception CTP under which computers are exported today. Previously, all computers over the prevailing MTOPS threshold required a license based on destination or type of transaction. The January 25 rule implemented a country tiering system for computer licensing. Under the March 25 rule, a license exception could be granted based on the destination. The power or MTOPS level eligible for a destination would be determined by the tier in which that country was placed. The tier in which a country was placed was determined by its adherence to proliferation control regimes, its relations with the United States, and the potential for transhipment or diversion to particular uses (See Appendix 2).

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[17] The exception was the U.S.-Japan Supercomputer Agreement, which set the threshold at 2,000 MTOPS; however, as noted on the previous page, Japan protested the unilateral nature of this decision and only raised controls to 1,500.

[18] See *Building on the Basics: An Examination of High-Performance Computing Export Control Policy in the 1990's*, Seymour Goodman, Peter Wolcott, and Grey Burkhart (November 1995).

Tier 1 countries (Canada, Western Europe, Australia, Mexico, Japan, and New Zealand), categorized as those countries belonging to and adhering to proliferation control regimes, would require no license for HPC exports, while Tier 2 countries (South America, ASEAN nations, several former Eastern European bloc nations and South Africa) had a 10,000 MTOPS threshold and reporting requirements for U.S. sales above that level. Tier 2 represented countries in which the risk of proliferation was relatively minimal, although greater than Tier 1.

Tier 3 countries represented countries in which there was a risk of proliferation or diversion, either by the countries themselves or by virtue of the regions they inhabited. These countries- China, Russia and other countries of the CIS, India, and Pakistan- became subject to a dual control system. This system distinguishes between civilian and military end-users and end-uses. Export licenses would be required for HPCs above 2,000 MTOPS for military and weapons end-users and end-uses, and above 7,000 MTOPS for any recipient or for any use. Licenses for items in the former category would be considered on a case-by-case basis; licenses for those in the latter would generally be approved. This end-user differentiation ended in 2000.

Licenses were required to Tier 4 countries (Cuba, Iran, Iraq, Libya, North Korea, Sudan, and Syria) which operationally presupposed a presumption of denial. Since the promulgation of these regulations, the country tiers have not remained static. Countries have been moved between tiers to reflect different geopolitical and proliferation circumstances. MTOPS levels and destination criteria have also been adjusted for each tier, recognizing the changes in computing power.

Under the 1996 policy change, civilian consumers in Russia, other CIS countries, and China could buy high-performance computers without going through the rigorous U.S. export licensing process if, for example, the computers were not to be used at a nuclear weapons facility. After several refusals by the United States to approve exports to Russia of computers for nuclear-related purposes, Russia reportedly obtained 16 IBM computers through evasion of U.S. export license requirements and installed the computers at Arzamaz-16 (now Sarov), the site where the former Soviet Union had designed its hydrogen bomb and Russia conducts nuclear weapons research. The United States originally insisted that the computers be returned, but instead, after two years of negotiations, Russia agreed to remove the computers from the nuclear weapons facility and transfer them to a new commercial computing center which opened in Sarov in October 1999.

The Cox Committee. Policymakers also were concerned about exports of HPCs to the People's Republic of China. Reportedly, end-user and verification problems have arisen with regard to China, since many state owned enterprises (SOEs) have close ties to the Chinese military.[19] For example, an executive branch review reportedly discovered an HPC built by Sun Microsystems in the possession of the Changsha Institute of Science and Technology, a weapons research facility run

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[19] *Technology, Trade and Security Issues Between the United States and the People's Republic of China: A Trip Report, August 1997*, by Glenn J. McLoughlin, CRS Report 98-617.

by China's People's Liberation Army. The computer was allegedly sold to the Institute in 1997 by one of Sun's Hong Kong distributors without an export license. The computer was returned to the United States in November of that year. In addition, until 1998 China had not allowed the United States to conduct post-shipment checks to establish end-use control; even since that time, some contend that post-shipment verification has been erratic and incomplete.

In 1998, the House of Representatives created the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China (PRC). Chaired by Representative Christopher Cox, the "Cox Committee" was created in response to allegations that two U.S. satellite companies (Loral and Hughes) might have transferred technology to China in the course of launching satellites on Chinese launch vehicles. However, the committee's mandate was broader, and included investigations of other instances where illicit technology transfer may have occurred — including HPCs.[20] The public, declassified version of the Committee's report was released on May 25, 1999 (the Committee's final report remains classified).

The Cox Committee report was considered important (if controversial) by U.S. policymakers, industry leaders and others because it not only assessed the amount of HPC technology transferred to the PRC, but painted in larger brush strokes what many consider to be the inefficacy of current U.S. HPC export control policy to Tier 3 countries. For some, the examples of HPC technology transfer to the PRC provide concrete examples of why U.S. HPC export control policy needed substantial revision.

The Cox Committee determined that U.S. HPC export policy has been circumvented by PRC end users, has not been properly monitored or enforced by U.S. officials, and that U.S. industry generally had been unaware of PRC applications of HPCs. The major Cox Committee report findings on HPCs were: that the number of HPCs exported to China had increased and had provided PRC end-users with many different combinations of computing power and speed; that PRC end users were clustering lower-end HPCs together to increase computing power and speed; that the distinction between PRC private companies and SOEs was blurred, affecting end-use verification and resulting in HPCs being used for military purposes and contributing to proliferation; that PRC students visiting U.S. federal laboratories and universities with HPC technologies may act on behalf of the Chinese intelligence organizations, further blurring civilian, military, and academic lines; that the U.S. Government's ability to verify the location and use of HPCs in the PRC was blocked by that country's resistance to post-shipment, on-site verification visits; and that these findings raised significant security issues for U.S. policymakers in formulating export control policy and U.S.-PRC relations.[21]

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[20] See Congressional Research Service, *Technology Transfer to China: An Overview of the Cox Committee Investigation Regarding Satellites, Computers, and DOE Laboratory Management.* By Marcia S. Smith, Glenn J. McLoughlin, and William C. Boesman, CRS Report RL30231, 11 June 1999.

[21] *Ibid.*

The Cox Committee report offered four policy recommendations.

- Legislation to require testing of computers proposed for export, and which may be potentially used for clustering and other combinations of HPCs.

- An annual comprehensive threat assessment of HPC exports to the PRC by the U.S. intelligence community.

- Legislation to require transparent end-use verification of PRC use of HPCs; failure by the PRC to cooperate would result in actions by the United States to lower the benchmark levels of HPCs sold to the PRC, to deny certain export licenses for computers to the PRC, and other related measures.

- Legislation to require the Executive branch to encourage other computer-manufacturing countries, especially those countries that manufacture HPCs, to adopt similar export policies towards the PRC.

Shortly after the release of the report, the Clinton Administration offered a response. The Administration agreed with the Cox Committee report that sales of computers to the PRC should be for commercial, not military, purposes. The Administration also stated that it was reviewing the potential national security uses of various configurations of computers, the extent to which these computers can be controlled, and the impact of controls on the U.S. industrial base. The Administration agreed with the Cox Committee assessment that the United States needs the capability to visit U.S. HPCs licensed for export to China and observe how they are being used (although the Clinton Administration contended that it was not possible to obtain no-notice verification visits to any country, including the PRC). On this last point, the Administration negotiated an agreement with the PRC for increased site visitations in 1998. However, the Clinton Administration continued to contend that requiring the U.S. to visit every HPC site, regardless of what business the end-user was in or how many times it was visited before, would be ineffective and wasteful.[22]

The National Defense Authorization Act of 1998 (NDAA98). The106th Congress also responded in part to the Cox Committee report when it passed the National Defense Authorization Act for FY1998. Congress tightened Tier 3 controls on HPC exports, and enacted new requirements for advance notification and post-shipment verification of these items. The statute requires exporters to notify the Commerce Department in advance of a proposed export or reexport of an HPC greater than 2,000 MTOPS to a Tier 3 country and prohibited the export, or reexport, of an HPC without a license if the Secretary of Commerce, Defense, State, or Energy

[22] Statement by Under Secretary for Export Administration, "Commerce Report: Growing Demand for U.S. High Performance Computers." Washington: U.S. Department of Commerce. 8 January 1999.

objected.[23] The objections would have to be raised within 10 days after the agency received the notification. The President would be authorized to raise the MTOPS level for notification purposes, but the new threshold would not go into effect until six months after the President justified it in a written report to Congress. Similarly, the President had the authority to remove countries from Tier 3 (with some exceptions) but was required to notify Congress 120 days in advance. Congress reduced the notification period from 120 to 60 days in October 2000.[24]

NDAA98 also requires post-shipment verification of exports of computers of more than 2,000 MTOPS to Tier 3 countries, though the provision will not apply to a country moved out of Tier 3 under the authority described above. To facilitate verification of sensitive items, the United States signed an agreement with China in 1998 setting forth terms for post-shipment visits to verify end-use of high technology exports generally. In October 1999, Congress also directed the President to seek an agreement with the PRC to revise the existing verification system as it applies to NDAA-covered HPCs "so as to provide for an open and transparent system providing for effective end-use verification for such computers."[25] It also relaxed the NDAA's verification requirement by making any increased MTOPS level established for purposes of advanced notification applicable to the former requirement as well.[26] On January 24, 2002, Assistant Secretary of Commerce for export enforcement Michael J. Garcia testified that the backlog for end-use inspections stood at approximately 700. He maintained that this number includes inspections for computers that are no longer advanced enough to be controlled. However, he testified that access to advanced computers with potential military applications has been denied by Chinese authorities.[27] In May 2003, the House defeated an amendment to the 2004 NDAA that would have repealed the NDAA98 provisions. The amendment was defeated by a vote of 207-217.

Further Decontrols: 1999-2003. In July 1999, the Clinton Administration announced that it was notifying Congress of its intent to relax more controls on HPC exports, including raising the export license threshold for Tier 3 countries from 7,000 to 12,300 MTOPS for civilian end-users and from 2,000 to 6,500 MTOPS for military end-users. In addition, the President notified Congress July 26, 1999 that the advance notification level would be raised from 2,000 to 6,500 MTOPS. On February 1, 2000, at the conclusion of the six month notification period, the Clinton Administration announced that these changes, the fourth since 1993, would be enforced.

On February 1, 2000, the Clinton Administration raised the Tier 2 levels from 20,000 to 30,000 MTOPS and raised the notification level to Tier 3 countries from

[23] National Defense Authorization Act, FY1998, P.L. 105-85, § 1211.

[24] National Defense Authorization Act, FY2001, P.L. 106-398, §1234.

[25] NDAA, FY2000, P.L. 106-65, § 1407(a)-(b).

[26] NDAA, FY1998, § 1213(e), *as added by* NDAA, FY2000, P.L. 106-65, § 1407(c).

[27] "U.S. Unable to Monitor Computer Exports to China as Required by Congress, Aide Says," *International Trade Reporter*, January 24, 2002.

6,500 MTOPS to 12,500 MTOPS.[28] These changes went into effect on August 14, 2000. On August 30, 2000 the Clinton Administration notified Congress of additional export control changes. The license exception limit for Tier 2 countries was raised from 33,000 to 45,000 MTOPS; and the license exception limit for Tier 3 countries was raised from 20,000 to 28,000 MTOPS.

In January 2001, President Clinton adjusted MTOPS levels by Presidential directive and merged country tiers 1-2. The President stated his support for ending high-performance computer export controls, citing the lack of a meaningful or relevant export control standard. However, he maintained the controls due to the statutory requirements of NDAA and recommended that the incoming Administration seek repeal of the NDAA mandates.[29] Currently, a License Exception is available to all Tier 1 countries for computers over 6,500 MTOPS. In addition, the WA notification requirements have ended for Tier 1 countries. A Tier 3 country is eligible for a license exception for computers with performances ranging from 6,500-85,000 MTOPS. As of this date, exports of computers with performance capabilities of over 85,000 MTOPS continue to need licenses, as do all potential sales to Tier 4 countries.

The Bush Administration implemented its first change in HPC export control policy on January 2, 2002. It raised the license exception threshold from 6,500 to 12,000 MTOPS. Tier I countries may receive a license exception for any processors over 12,000 MTOPS. The Administration also raised the licensing threshold from 85,000 MTOPS to 190,000 MTOPS. Thus, exporters to Tier III countries may obtain a license exception for computers with a CTP of 12,000-190,000 MTOPS. A license will still be required to ship computers with a CTP greater than 190,000 MTOPS to Tier III countries. This change took effect on March 5, 2002. It has been reported that these changes were prompted by the introduction of the Pentium Itanium Chip. A single Itanium chip has the CTP of 6,500 MTOPS, while a popular server configuration with 32 processors would have a CTP of 190,000 MTOPS. The new licensing requirement would allow sales of this server configuration to Tier III countries.[30] In addition, Latvia was moved from a Tier III to a Tier I country, a change that will become effective180 days from January 2.

On January 14, 2003, the Bush Administration announced a general decontrol of general purpose microprocessors to bring the EAR in conformance with the February 2002 revisions of the Wassenaar Arrangement's List of Dual Use Goods and Technologies.[31] These microprocessors are widely produced and are used for

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[28] Other changes included raising individual license levels for civilian end users in Tier 3 countries from 12,300 to 20,000 MTOPS and moving Romania from Tier 3 to Tier 2. See; [http://www.bxa.doc.gov/press/2001].

[29] "Export Controls on High Performance Computers," White House Fact Sheet, January 10, 2001.

[30] "White House Eases Computer Export Controls to China, Others,"*Inside U.S. Trade*, January 4, 2002.

[31] "Revision of Export Controls for General Purpose Microprocessors", 68 *Federal Register*

(continued...)

numerous civilian applications including cellular phones, personal digital assistants, and personal computers. However, they are also used for several military applications such as navigation and guidance systems, communications and information warfare systems. Based on the new regulations, microprocessors with a CTP of over 6,500 MTOPS will only be controlled to designated terrorist supporting countries.[32] The rulemaking also establishes a license requirement for microprocessors exported for military end-use or to military end-users in countries such as China, Russia and newly independent states of the former Soviet Union. This latter requirement does not require licenses for export to civilian end-use or end-users in these countries. These regulatory changes refer only to microprocessors and, hence, do not affect the HPC export control policy detailed above.

MTOPS: Technology and Policy Issues

Policymakers have had to face a series of technology-related policy decisions when addressing the export policy of HPCs. The first is whether MTOPS is an adequate and satisfactory benchmark for controlling the export of HPCs. This is a significant policy question because if the MTOPS benchmark is removed in favor of another technology benchmark, then a series of other policy, procedural, and regulatory changes likely would have to be implemented as well. These would include revising statutory authority for export control, and it is likely that export control policy and how that policy is made, would be substantially changed as well.

MTOPS. If the United States continues to use MTOPS as a measurement for HPC export control, it is likely that critics will continue to dispute its effectiveness. For these critics, retaining MTOPS benchmarks (and raising export control threshold levels when technological advances warrant) would not address the growing use of computer clusters outside of the United States; would not differentiate among end-users and whether these users had important ancillary technologies, such as software and networks; would not address the applications of computers by nations and entities not friendly to the United States; would not address the potential loss of HPC sales, even at high MTOPS licensing thresholds, for U.S. firms; and it would not necessarily address concerns of end-use and on-site verification raised in the Cox Committee report and elsewhere.

Even the criteria used to determine the level of MTOPS control has been a subject of controversy. In order to change the NDAA98 notification requirements, the President must report to Congress on (1) the foreign availability of computers with capabilities up to the proposed level; (2) the potential military uses that HPCs at the new level can provide; and (3) the impact of uses on the national security. The General Accounting Office was asked on two occasions to examine the methodology used in the Administration's preparation of these reports. GAO found that the

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[31] (...continued)
1796, January 14, 2003.

[32] The control category AT (anti-terrorism) covers North Korea, Sudan, and Syria. However, comprehensive controls on Cuba, Iran, Iraq, and Libya require licenses (with a presumption of denial) for virtually all goods on or subject to the EAR.

Administration had not clearly articulated specific national security interests to be protected at various performance levels. It did not determine what military critical applications to control or the most effective method to achieve those controls.[33] The GAO also reported that the Administration based decontrol decisions on the availability of computing power at various levels rather than on national security assessments. In fact, 'widely available' and 'controllable' were not (and are not) defined in current law or regulation. Although these criticisms were directed at actions of the Clinton Administration, the Bush administration may also need to grapple with the issue of determining what level of technology can be controlled.

Eliminating MTOPS. Three recent reports have provided policymakers with an extensive analysis of HPCs and export controls, as well as varying recommendations and strategies for addressing policy questions. They are: the General Accounting Office (GAO) report *System for Controlling Exports of High Performance Computing is Ineffective*, December 2000; the Center for Strategic and International Studies (CSIS) report *Computer Exports and National Security in a Global Era: New Tools for a New Century,* April 24, 2001; and the Defense Science Board (DSB) report *Export Control of High Performance Computing: Analysis and Alternative Strategies*, February 2, 2001.

The GAO, the CSIS, and the DSB all call for eliminating MTOPS as a technology benchmark for HPC export control policy. The GAO contends that MTOPS is outdated as a valid measurement of computing speed because it is tied to the clock rate of the computer's processing power, which may vary depending on the computer application. The GAO further contends that MTOPS benchmarks do not take into consideration other factors, such as memory retrieval times, interconnection methods, and internal bus speeds of computers, all of which are more directly tied to computing power and speed. The CSIS report raised similar objections to MTOPS as a benchmark for export control policy. The CSIS report states that MTOPS is a static measurement which does not work well when measuring computing power from clusters, grids, or Internet-connected computers. The DSB report recommends that current software export controls are more functional and reliable than MTOPS as a way to restrict technology transfer to Tier 3 countries.[34]

Increasing computing speeds combined with networking advances have blurred the distinction between supercomputers and mass market computers. Microprocessors that individually comply with export regulations can be linked together to create servers with MTOPS capabilities that breach export thresholds. If enough processors are linked together, they can create a parallel processing system with capabilities that approach those of a super-computer. The Defense Science Board notes in its final report on Globalization and Security that the ability to cluster commodity computers in order to multiply computing power erodes the ability to

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[33] Harold J. Johnson, GAO, Testimony before the Senate Government Affairs Committee, May 26,2000, p.6.

[34] Defense Science Board, *Report on High Performance Computing: Analysis and Alternative Strategies.* Washington, D.C.: February 2, 2001. P. 6.

restrict access to high-performance computing, even if high-performance stand-alone machines can be controlled.[35]

For some proponents, while the MTOPS benchmark is not perfect, in the absence of any viable alternatives, it brings a continued level of stability and continuity to export control policy. Supporters contend that the HPC benchmark is flexible enough to change as technological advances in computing occur. They consider MTOPS a standard that, regardless of the type of computer, provides a common technology classification with which all stakeholders can work. In the absence of any clear technology alternative, some contend that an imperfect benchmark is better than no benchmark.

Teraflops. Still, as computing speed gets faster, and the boundaries of high performance computing have been broken by SGI, IBM, and NEC supercomputers, some have advocated using a new metric for HPC export controls. The current metric for measuring the fastest computing speed is **teraflops**, or trillion floating point calculations per second. Over the last year, NEC's record of computing speed (41 teraflops) has been superseded by SGI (62 teraflops) and in January 2005 by IBM (92 teraflops).[36] As the boundaries of supercomputing speed are raised, some contend that MTOPS, which now apply to more commercially available technologies, should be completely eliminated for any barrier or export control. In its place, teraflop computing speed could be the new threshold for export control.

Advocates contend that since many believe that controlling MTOP technology is impractical, using a higher threshold for computing speed will keep advanced technologies from falling into the hands of those who may use the technology against the United States. The SGI supercomputer that set a speed and performance record of 61 teraflops was developed for NASA; other federal agencies, particularly those connected with defense and homeland security may find a need to both use and limit the availability of technologies with teraflop computing speed outside of the United States. In addition, since there are now relatively few supercomputers with teraflop computing speed, exports of this technology may be easier to manage and control.

Critics contend that shifting the metric from MTOPS to teraflops merely substitutes one kind of relative computing speed for another, and does not address the larger issue of applying rapidly changing innovative technologies in a global economy. Critics also believe that because teraflop computing technology is relatively rare, everyone knows who has the technology; controls are not necessary. In addition, supercomputers with teraflop computing speed tend to be very large machines — "big iron." Therefore, it is very unlikely that an entire supercomputer with teraflop technology could be exported and properly used by a nation if the recipient country does not have the requisite infrastructure, networks, and relatively

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[35] Defense Science Board, *Final Report of Task Force on Globalization and Security*, Washington: Office of the Under Secretary of Defense for Acquisition and Technology, December 1999, p. 27.

[36] Otis Port. *Holy Screaming Teraflops.* BusinessWeek. January 17, 2005. P. 62.

well-educated workforce. Still, federal policymakers are examining this issue, and considering teraflop computing speed as part of the overall export control debate.[37]

Other Alternatives to MTOPS. However, while both GAO and DSB provide several technology options for replacing MTOPS, the CSIS contends that there are no technology alternatives, because HPCs are no longer primarily single, stand-alone products. According to the CSIS, "Neither MTOPS nor any other parameter constitutes an adequate measure of system performance."[38] The CSIS calls for the elimination of MTOPS, and with it any dual-use export control policy for HPCs left over from the Cold War.

Among other technology options, however, two have been considered by the GAO and others. The first is multiprocessing technology. Semiconductor chips are made on thin wafers of material, usually silicon, in which tiny lines (linewidths) are etched that in part determine operation, speed and memory capacity. Multiprocessors are integrated chips which can perform multiple functions at one time. Computers can be measured by the type of multiprocessor it contains (e.g., Intel's 386, 486 and Pentium processors), and can be one indicator of computing capability. Should processing capability replace MTOPS as a metric for export control policy? The GAO has raised two concerns about using microprocessors as a benchmark for export control — it may be no more accurate than using MTOPS as a measurement for computing power; and there is no consensus within the computing research or industry on a single definition of a processor. In addition, the GAO found that exceptions to a procedure for counting processors would be needed to differentiate between high performance single processors and computers that have unique hardware and software designs.[39]

One of the arguments used to eliminate specific metrics, such as MTOPS, as a benchmark for export control policy is that it is computing power, not computer hardware, that is critical for any HPC applications. One substitute control mechanism is to restrict exports of network applications and interconnections. Two options currently are under consideration. The first is to restrict U.S. sales or transfers of high-end network connections that might allow the clustering of HPCs in grids or by the Internet. Under this approach, sales of computer switches, interface cards, fiber optics, and other connective HPC infrastructure would be restricted or prohibited, effectively curtailing clustering of HPCs. However, critics of this approach contend that infrastructure technology is readily available from other countries, and is relatively inexpensive. The GAO has reported that U.S. industry considers only some network technology controllable at the high end of HPC applications, because

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[37] See also: Stephen Shankand. *Two Records in One Day for SGI Supercomputer*. C/Net News. [http://news.com.com/SGI+supercomputer+Two+records+in+one+day/2100-7337_3-5427876.html]. Updated as of February 10, 2005.

[38] CSIS, P.18.

[39] GAO, *Export Controls: System for Controlling Exports of High Performance Computing is Ineffective.* P. 28-29.

of the proprietary nature of the technology, and the importance of vendor support to make the HPC applications effective.[40]

A second approach is to evaluate the current status of a foreign country's network infrastructure, and use this as a benchmark for determining whether HPC exports to that nation should be allowed. The rationale behind this approach is that a nation *without* high-end HPC connections for clustering will have limited use of HPC technologies. This approach may also include an assessment of software and bandwidth capabilities; if a nation does not have the infrastructure, software or communications pipeline for clustering HPCs, then even when it obtains an HPC, its applications are going to be limited. However, this option does not address the possibility that a nation can improve its networking infrastructure and HPC capabilities over time — or that obtaining HPC technologies may be the precursor to a more advanced computing infrastructure in a nation not friendly to the United States.

However, policymakers may decide that neither MTOPS nor any other technology benchmark can adequately control the transfer of high performance and advanced computers in a global economy. If this decision is made, then the possible ramifications would have to be further examined and the questions it raises addressed. How would countries be classified and would country tiers still be useful; how would the United States counter development of sophisticated computing capabilities for warfare by nations and entities not friendly to the United States; and how would the United States control or otherwise restrict computing technologies that industry may develop with federal research dollars?

National Security, Economic Security and Federal R&D: Issues and Options

National Security. The lack of a clear alternative to MTOPS as an export control mechanism does not necessarily mean that all HPC export controls need to be lifted. Even as MTOPS export control levels are raised — and even if they are completely removed — other policy issues may be addressed.

U.S. policymakers usually must balance national security concerns with economic growth and technology development interests. There is an inherent tension in balancing those policies which restrain technology transfer to entities not friendly with the United States, yet encourage U.S. high technology exports to those markets that have a strong demand for these products and applications. The CSIS report states the dynamic as:

> National security can be defined at two levels. Narrowly it depends on the quality of U.S. weapons and the readiness of U.S. forces. This focused definition of national security historically included restrictions on exports as a way of holding back the technical progress of U.S. opponents. . . National security also can be defined as the vitality and strength of the U.S. economy and the dynamism of

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[40] *Ibid*, P. 36.

> American society. . . The development of computers and information technology was crucial to both dimensions of national security.[41]

The advent of the U.S. high technology industry as we know it today — widely available computers, software, networks, and many service and manufacturing applications — began over thirty years ago.[42] In part spurred by intense global competition from European and Asian firms, and also spurred by leaps in technology innovation, many U.S. high technology industries became dominant in the high-end, high-performance computing sector. This coincided with a separate but also important development — the dissolution of the Warsaw Treaty Organization, the breakup of the Soviet Union, and the end of the Cold War. Therefore, as U.S. high technology became predominant and industry sought to expand into global markets, many old restrictions fell and new markets of competition emerged.

Widespread information technology development and innovation also meant that computers and ancillary products became less the province of a few specialized users and more of a commodity common to everyday life. For example, it has been reported that one common 486 semiconductor chip has more computing power than U.S. scientists had when they developed the atomic bomb; in another frequently cited anecdote, the F-22 (which is the most advanced U.S. fighter plane) was designed with a 958 MTOPS Cray supercomputer — approximately one quarter the power now found in mass-produced Pentium multi-processor semiconductor chips.[43]

The proliferation of high technology as a commercial commodity, along with quantum leaps in product capabilities and the change in who the U.S. views as potential adversaries, has had a significant impact on U.S. export control policy. As U.S. businesses push for increased freedom and expansion of its HPC sales, policymakers have asked: who should we keep our technology from — and can we accomplish that goal?

Economic Security. Some contend that in the post Cold War era, national security is really national economic security. This implies that separating military and economic interests is not only impractical but unrealistic, and that in the absence of a single strategic military threat, technology transfer should flow more freely in a global economy. Traditional national security concerns based on maintaining advances and superiority solely in military technology may represent an iceberg; it is the 10 percent that is visible above the water while 90 percent of the base rests on an economy and society that has grown from commercial developments in the computer industry.[44] Some question whether the 10 percent which is visible should constrain the 90 percent that fosters economic growth and development, especially

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[41] CSIS, p.10.

[42] *Creating the Computer: Government, Industry and High Technology,* by Kenneth Flamm, The Brookings Institution, 1988.

[43] CSIS, p.11. The anecdote regarding the F-22 was reported in Defense Science Board, *Final Report of the Defense Science Board Task Force on Globalization and Security*, Washington, D.C. December 1999. P. i.

[44] CSIS, p.10.

in an increasingly global economy where technology product competition transcends national boundaries.

The argument that national security is enhanced by robust export industries is predicated on the changing nature of defense procurement, research and development. During the Cold War, the formative period of the current export control regime, the military drove much technical research and provided funds for research and development. Now that situation is largely reversed. The military relies to a greater extent on commercial applications and now purchases many items. Industry argues that it is in the national security to sell current technology to generate funds to develop future technology. If American firms are competitively hindered because of export controls, the argument goes, foreign firms will gain market share, increase profits, invest more in R&D, and shrink and possibly surpass our technological lead. Thus, industry argues it needs a streamlined export process that will not needlessly impede exports.

Non-proliferation critics reject this argument. They maintain that the United States does not promote its national security by selling advanced technology to potential proliferators. Debating EAA on the Senate floor, Senator Kyl remarked, "Nations which threaten our security interests should not be armed by the United States. The fight against proliferation and rogue regimes must include some degree of self-discipline within our own borders."[45] Advocates of restraint point to a CIA report released in February that claims that China interprets its non-proliferation commitments very narrowly,[46] and that China recently has used supercomputers to improve its nuclear weapons stockpile, sold fibre optic equipment to Iraq, and sent missiles to Pakistan.[47]

The argument that a robust export industry is essential to maintain competitiveness may have merit, although at present, the reliance of the United States on China and other controlled destinations as a market for U.S. computer products is minimal. In 2004, the United States exported $780 million in "computers and components" as characterized by the Harmonized Tariff Schedule to China.[48] This figure represents 2.2% of total exports to China ($34.7 billion), 3% of total exports of computers and components to all destinations ($24.0 billion), and less than 0.1% of all U.S. exports ($731 billion). The total value of all license applications to China for computer equipment, technology, and software was reported to be $35 million in FY2004.[49]

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[45] Remarks of Senator Kyl, *Congressional Record,* S9098, September 5, 2001

[46] Director of Central Intelligence, "Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions, 1 July Through 31 December 2000," [http://www.cia.gov/cia/reports/721_reports/july_dec2000.htm].

[47] Remarks of Senator Helms, *Congressional Record,* S9051, September 4, 2001.

[48] HTS 8471. Figures from U.S. International Trade Commission Dataweb.

[49] BIS, *2004 Annual Report,* [http://www.bis.doc.gov/News/2005/04AnnualRept/AppF.htm]

Federal R&D. The federal government supports a great deal of HPC R&D through the federal mission agencies. In FY2000, $1.8 billion was funded for high performance computing and communications research and development, ranging from advanced computer software technology algorithms, information infrastructure and applications, education and research, and high performance systems development. In the last category, federal programs under this initiative in scalable and parallel computing systems have advanced the use of workstations and clustered computers in the federal government.

Although to date policymakers have not linked the federal HPC initiative to changes in U.S. export control policy, this issue may arise during future debates. Some may ask whether the federal government should invest a substantial amount of federal funding in HPC research at a time when export controls on these technologies are being relaxed. Is there a potential that federally-funded advances in HPC technologies and applications may be commercialized by the U.S. private sector and then sold to nations or entities not friendly to the United States? Should U.S. HPC export control policy take into consideration the source of HPC research, and whether it comes directly or indirectly from federal agencies? Or, returning to the economic security argument, would curtailment of such research be self-defeating?

Appendix

Table 1. Performance Levels of Computers That Support Selected Applications of Military Significance

Computer performance level (MTOPS)	Applications
4,000 to 6,000	Joint Attack Strike Aircraft design; nonacoustic antisubmarine warfare sensor development; advanced synthetic aperture radar computation
8,000 to 9,000	Bottom-contour modeling of shallow water in submarine design; some synthetic aperture radar applications; algorithm development for shipboards' infrared search and track
10,457 to 21,125	Nuclear blast simulation
15,500 to 17,500	Computational fluid dynamics applications to model turbulence around aircraft under extreme conditions
20,000 to 22,000	Weather forecasting; impact of blasts on underground structures; advanced aircraft design
21,125+	Submarine design; shallow water acoustics analysis
24,000+	Automatic target recognition template development
46,000-76,000	3D modeling and shock physics simulation for nuclear weapons applications
+120,000	Multi-line towed array signal processing

Sources: Seymor Goodman, Peter Wolcott, and Grey Burkhart. *Building on the Basics: An Examination of High Performance Computing Export Control Policy in the 1990s* (1995); and *High Performance Computing, National Security Applications, and Export Control Policy at the Close of the 20th Century* (1998). Stanford University. Palo Alto, California.

Table 2. 1996 HPC Export Control Tiers and Policies

Tier/Countries	Restrictions/Controls	Record Keeping
Tier 1: Western Europe, Japan, Canada, Mexico, Australia, and New Zealand.	No licenses required for exports or re-exports of computers to/among these countries; exports of unlimited MTOPS permitted.	Record keeping by U.S. exporters of HPCs above 2,000 MTOPS required.
Tier 2: South America, South Korea, ASEAN, Hungary, Poland, the Czech Republic, the Slovak Republic, Slovenia, & South Africa.	Licenses required for exports or reexports of HPCs above 10,000 MTOPS	Record keeping and reporting by U.S. exporters of HPCs up to 10,000 MTOPS required.
Tier 3: India, Pakistan, all of the Middle East/Maghreb, all of the states in the former Soviet Union, People's Republic of China (PRC), Vietnam, and the rest of Eastern Europe.	Export licenses are required for exports or reexports of HPCs above 2,000 MTOPS to military end-users or uses, or to nuclear, chemical, biological, or missile end-users or uses; licenses required for HPCs above 7,000 MTOPS to all end-users or uses.	Record keeping and reporting required for all HPCs between 2,000 and 7,000 MTOPS.
Tier 4: Cuba, Iran, Iraq, Libya, North Korea, Sudan, and Syria.	No computers are allowed either through direct or indirect trade.	Not applicable.

Source: [http://www.doc/bxa.gov]