All Your Games Belong to Us: A Case Study of the Eighth Generation of Video Game Consoles and the Export Control of High-Performance Computers

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Abstract

This article, in a case study of the eighth generation of video game consoles and specifically the Sony PlayStation 4 (PS4), appraises the international, Japanese, and United States TeraFLOP (TFLOP) based classification-metric export control systems for dual-use high performance computers (HPCs). This is done in order to ascertain whether these export control systems are (1) sufficient or insufficient, (2) up-to-date or outdated, and (3) what if anything can or should be done to improve current HPC export control regimes internationally and in Japan and the United States. In the case study, it is found that these HPC export control systems are pragmatic, up-to-date and not unduly restrictive. However, points of concern emerging from the study include (1) the questionable status of HPCs as dual-use threats, (2) the costs inherent in sustaining HPC export control regimes in contemporary international trade, (3) whether TFLOP based classification-metrics for trade controls in fact affect HPCs or vice versa, (4) the changing nature of HPCs in an age of increasing ease and effectiveness of HPC clustering, and thus (5) the value of shifting from a relativistic and individual HPC based export control system to a quantity or gross transaction-value based system.

Keywords

Dual-use, export control, strategic trade control , high powered computers, TFLOP, non-proliferation, video-game console, PlayStation, Wassenaar Arrangement

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Introduction

Due to the live and active competition of many companies within the massive and lucrative international consumer electronics market, surges and waves of improvements in technology released to the general public frequently take the market by storm. While these technological improvements in the public consumer electronics market have benefitted many, the fear that these advancements will also benefit internationally hostile and violent regimes in modern warfare capabilities is also a very real side effect. In response, national governments have created and promoted export regimes to limit the export of the most advanced levels of computer processing hardware.

However, rapid advances over time paired with bureaucratic inertia have exacerbated issues regarding the metric for measuring what "advanced levels" of processing are, what levels are appropriate for pervasive public use, what levels are appropriate for export controls and how to go about controlling exports of devices deemed necessary for export controls. Specifically, a regularly reanimated point of contention on this subject is the export control needs surrounding personal video-gaming consoles. Attempts in the past to control the export of these powerful computing hardware devices have spurred heated public debate and bureaucratic reclassification, such as when the Japanese government attempted, under its international obligations, to limit the export of the Sony PlayStation 2 (The predecessor of the currently available PlayStation 4, and only a modest computing device by today's standards).[2] To put it simply, as United States Secretary of Commerce Don Evans stated in 2001, "yesterday's supercomputer is today's PlayStation."[3]

This report will address the question of whether the current international trade control regime and trade control systems in Japan and the US to limit the export of high performance computers (HPCs) are (1) sufficient or insufficient, (2) up-to-date or outdated, and (3) what if anything can or should be done to improve current HPC trade control regimes internationally and in Japan and the US. This paper will be a legal, logistical, and technical study that works to illustrate these nuanced export control systems, evaluate them, and create an understanding of the progressive and changing nature of these systems for addressing the inevitable and regular changes in these regimes. The eighth generation of video-gaming consoles, and specifically the Sony PlayStation 4 (PS4), will be used as a case in this study to compare the international, Japanese, and US TeraFLOP (TFLOP) based classification-metric export control systems.

This report is organized as follows. The first part consists of the paper's general introduction, followed question to be investigated. Hereafter, the paper will present a literature review on the topic of strategic trade controls generally, in order to set the context for later discussion and analysis. Thereafter, the paper will present the case study and go about a technical and logistical study of the case in question. A relevant legal review will then be presented for which the case will be applied. A conclusion and recommendations will be offered in the end, consolidating the aforementioned investigations and discussions.

The Development of Strategic Trade Controls

Strategic trade controls are passive and active measures taken by nation-states that interfere with the free flow of economic goods, intellectual property or technological knowledge beyond said nation-state's territory, usually in a defensive gesture aimed at avoiding inadvertently empowering a rival nation-state or sub-national entity. Specifically, the US government "controls exports of sensitive

[2] "Military Fears over PlayStation 2," *BBC News*, 17 April, 2000, www.news.bbc.co.uk.

[3] "Secretary of Commerce Don Evans Applauds Senate Passage of Export Administration Act as Modern-day Legislation for Modern-day Technology," Bureau of Industry and Security, U.S. Department of Commerce, 6 September 2001, www.bis.doc.gov.

equipment, software, and technology as a means to promote [its] national security interests and foreign policy objectives" and states that effective export control systems require "comprehensive controls, implementing directives, enforcement power and penalties, interagency coordination, international cooperation and, lastly, protection against governmental dissemination of sensitive business information."[4] General commonalities of multilateral export control regimes include, but are not limited to, rule by consensus, non-transparency, exclusionary membership, the use of control lists and guidelines, and a dependence on information sharing.

The first modern strategic trade control regime, as well as a direct predecessor and inspiration for many modern strategic trade control regimes, was the Coordinating Committee for Multilateral Export Controls (CoCom), established by the Northern Atlantic Treaty Organization (NATO) in 1950 and aimed at stemming military-applicable goods and technology exports to Soviet-allied nations in the Council for Mutual Economic Assistance (COMECON). However, following the collapse of the Soviet Union and the peaceful close of the Cold War, export control systems became more internationally inclusive and transparent, emphasizing the need to work across nations and across industries in the rapidly interconnecting and globalizing free market world order.

Measures for strategic trade controls can come in many, varied forms. The terms "non-proliferation" and "counter-proliferation" are used commonly and frequently to describe these measures, but do not clearly conceptualize or categorize these different measures. "In fact, there is no agreed understanding of the definitions […] and whether there is a real distinction."[5] For the benefit of this paper, the contemporary international strategic trade control system can be conceptually divided into active (somewhat akin to counter-proliferation) and passive (somewhat akin to non-proliferation) measures taken to stem the proliferation of security-sensitive materials, products, and technologies. Active measures consist of actions taken after a target has been deemed suspect by a state party and has seemingly violated national and/or international trade control laws. Examples include, but are not limited to thorough investigation, search and seizure, detainment, arrest, maritime interdiction, and prosecution. Passive measures consist of established systems of checks and balances designed to alert the authorities, or "flag" a suspect item, transaction, entity, or individual. Examples include, but are not limited to industry internal compliance programs, documentation standards, outreach programs, restricted end user lists, control lists of specified items, international confidence building measures, sanctions targeting specific countries, as well as regular and standardized investigations or background checks.

Although considerably less dramatic than the imagery conjured by active forms of strategic trade controls, passive strategic trade controls make up the bulk and crux of the modern international trade control regime. The days of Cold War showdowns and confrontations have passed, and globalization has shifted national and international priorities toward cooperative and inclusive security agendas. Aaron Karp notes that some of the greatest contemporary threats to international peace and stability are not the technologically advanced superpowers, but the internationally uncooperative regimes which are, in fact, "technological laggards."[6]

While these uncooperative regimes represent a great threat to the contemporary peace and stability afforded through international complex interdependence, these same regimes are static, stable, and

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[4] "Overview of U.S. Export Control System," A Resource on Strategic Trade Management and Export Controls, US Department of State. www.state.gov, <http://www.state.gov/strategictrade/overview/index.htm>.
[5] Fitzpatrick, Mark. "Non-Proliferation and Counter-Proliferation: What is the Difference?," *Defense & Security Analysis 24:1,* (March 2008), p. 73-79.
[6] Karp, Aaron."Stemming the Spread of Missiles: Hits, Misses, and Hard Cases," *Arms Control Association*, April 2012, www.armscontrol.org: p. 4.

predictable in their intractability.[7] However, the chief dynamism that concerns the field of strategic trade controls lies in the ever changing and inexorably accelerating capacities, standards, and spread of swift and constant technological progression and breakthroughs.[8] For example, it has been noted that Japan's efforts to limit the proliferation of military-usable technologies and products to the obstinate regime of the Democratic People's Republic of Korea have little to do with active interception and confrontation, but are rather centered primarily around more passive procedures such as intelligence collection, investigation, information sharing, industry compliance, and general government oversight.[9]

US and Japanese Strategic Trade Control Systems

The Japanese export control system is administered by the Ministry of Economy, Trade and Industry (METI). Like most export control systems, Japan's is based around outreach and communication, licensing, enforcement and a controlled items list. The controlled exports lists of METI are the Export Trade Control Order "Attachment List No. 1" and the Foreign Exchange Order "Attachment List." Notably Japan employs an additional passive export control system centered on a concept known as "catch-alls." Specifically, catch-all controls address the issues inherent in the rapidly technologically advancing, application-dynamic, and globalized free-trade world economy by creating guidelines for which exporters can judge for themselves whether an item needs to be investigated further and cleared for export with corresponding standards and consequences for non-adherence or resistance therein.[10]

On a generalized level, the US export control system can be divided into several item categories and the respective offices dedicated to overseeing each category's export control standards, procedures, and mechanisms. Controls on military items are administered by the Directorate of Defense Trade Controls under the Department of State. Controls surrounding embargoed nations are administered by the Office of Foreign Assets Control under the Department of the Treasury. Controls on nuclear-related technologies are administered by the Office of Export Control Policy and Cooperation under the Department of Energy. Controls on nuclear-related items and materials are administered by the Export Controls and International Organizations branch of the Office of International Programs under the Nuclear Regulatory Commission.[11]

National export controls on dual-use goods and technologies fall under the purview of the Bureau of Industry and Security (BIS), under the US Department of Commerce. The BIS is legally empowered to take action via its Export Administration Regulations (EAR) codified at 15 Code of Federal Regulations, Chapter 7.[12] The BIS EARs address the issue of dual-use exports through the Commerce Control List and end-user verification and enforcement system.[13] Like Japan, the US dual-use export control system is accentuated by catch-all controls regarding potential dual-use items.[14]

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[7] For more information on the concept of Complex Interdependence, see Keohane, Robert O. and Nye, Joseph. "Realism and Complex Interdependence," *Power and Interdependence*, 3rd ed.. (Boston: Addison-Wesley Longman: 2001).

[8] Gahlaut, Seema. "Multilateral Export Control Regimes: Operations, Successes, Failures and Challenges Ahead," in *Non-proliferation Export Controls* (Burlington, VT: Ashgate, 2006), pp. 7-28.

[9] Lieggi, Stephanie, Shaw, Robert and Toki, Masako. "Taking Control: Stopping North Korean WMD-related Procurement," *Bulletin of the Atomic Scientists*, May 2013. http://thebulletin.org/2010/septemberoctober/taking-control-stopping-north-korean-wmd-related-procurement.

[10] "Overview of Japan's Export Controls," Fourth Edition, Center for Information on Security Trade Control (CISTEC), June 2015. http://www.cistec.or.jp/english/export/Overview4th.pdf.

[11] For more information on the US export control system, see "Overview of U.S. Export Control System," Overview of U.S. Export Control System, Export Control and Related Border Security Assistance Program, www.exportcontrol.org, <http://www.state.gov/strategictrade/overview/index.htm>.

[12] "Policies and Regulations," Bureau of Industry and Security, U.S. Department of Commerce, www.bis.doc.gov, <http://www.bis.doc.gov/policiesandregulations/>.

[13] "Export Administration Regulation Downloadable Files," Policies and Regulations, Bureau of Industry and Security, U.S. Department of Commerce, www.bis.doc.gov, <http://www.bis.doc.gov/policiesandregulations/ear/>. More details on BIS export enforcement and end-user verification can be found at "Export Enforcement," Compliance and Enforcement, Bureau of Industry and Security, U.S. Department of Commerce, www.bis.doc.gov, <http://www.bis.doc.gov/complianceandenforcement/>.

[14] "Catch-All Controls," Best Practices, Export Control and Related Border Security Assistance Program, www.exportcontrol.org, <http://www.state.gov/strategictrade/practices/c43179.htm>.

The Role of Exporters

In addition to the logistical difficulties of overseeing product and technology transfers abroad on a day-to-day basis, national governments must balance the needs of security with the needs of a fast-paced and competitive free trade world economy. Both of these concerns are addressed by industry outreach and compliance programs that empower the sellers themselves to become the watchdogs. Although occasional egregious export control violations have occurred in the past by industry leaders, such as when two executives of the Toshiba Machine Co. were arrested and sentenced for falsifying end-user certificates and exporting security-sensitive industrial machines to the Soviet Union in the early 1980s, most firms are compliant, cooperative, and contributing Samaritans that simply seek to go about their trade ethically and responsibly.[15]

A past example of the latter can be found in the company Oerlikon Leybold. After the discovery of Leybold AktienGesellschaft (AG) products in the Iraqi nuclear weapons development program uncovered in the aftermath of the 1991 Gulf War, Oerlikon Leybold was required by the German government to take action. The company had an astounding turnaround and now serves as a paradigm for responsible export control compliance. Notably, following its own run-in with the law, Toshiba today also has an exceptional export control compliance program.[16]

A good contemporary example of responsible industry conduct, when the sellers are empowered as the watchdogs, is the Coalition for Excellence in Export Compliance (CEEC). A loose alliance of professionals with various backgrounds and expertise representing various professions, the CEEC offers relevant, international, export control law-related industry best practices in order to encourage and assist the development of compliant, cooperative, responsible and efficient conduct in firms.[17] Reasonable legislation, requirements, and procedures for efficient and unobtrusive industry compliance that empowers the suppliers of these goods and technologies is critical to the current international trade control regime.[18]

The Nature of Controls

The centerpiece of most multilateral export control regimes is a control list that enumerates specific physical and nonphysical items that are controlled to varying degrees. While tangible, defined, and classified commodities are relatively easy to locate and control, this is not necessarily the case for intangible items such as pieces of intellectual property, production techniques or technological research.

In addition to overtly military-applicable products and technologies, there are also items, software and technologies that are labeled as "dual-use." A dual-use item is a commodity or technology that is civilian or non-military in nature, but may be manipulated for significant military-related ends.[19] Additionally, there are controls for the release, to a foreign national, of sensitive intangible knowledge of technology, source code, or production and development techniques that a person may hold from

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[15] For more information on and an analysis of the Toshiba-Kongsberg incident, see Kelley, Stephen D. "Curbing Illegal Transfers of Foreign-Developed Critical High Technology from CoCom Nations to the Soviet Union: An Analysis of the Toshiba-Kongsberg Incident," *Boston College International and Comparative Law 12:1,* (December 1989).

[16] "Export Control," Fair Operating Practices, CSR Performance: Integrity Report II, Toshiba, www.toshiba.co.jp. A full text of Toshiba's export control program can be found at <http://www.toshiba.co.jp/csr/en/fair_practices/export.htm>.

[17] For more information on dual-use items, see "CEEC Introduction," The Coalition for Excellence in Export Compliance, www.ceecbestpractices.org, <http://www.ceecbestpractices.org/best-practices-standards-workgroup.html>.

[18] "Suppliers: The First Line of Defense," Chapter 11 in Albright, David. *Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies* (New York: Free Press, 2010).

[19] For more information on dual-use items, see "Dual-use controls," The European Commission, www.ec.europa.eu, <http://ec.europa.eu/trade/import-and-export-rules/export-from-eu/dual-use-controls/>. and "Dual Use Export Licenses," International Trade Administration, U.S. Department of Commerce, www.export.gov, <http://www.export.gov/regulation/eg_main_018229.asp>.

personal or professional experience. These are known as “deemed exports.”[20] The complex, multifaceted and subjective nature of these intangible and ambiguous commodities creates serious challenges and inefficiencies in global export control systems.

There are additional concerns regarding the need for reclassification, new and updated legislation, and organizational and bureaucratic restructuring as well. Constant changes in fast-paced, innovative, and competitive markets race against the bureaucratic lag of widespread networks of large investigative and enforcement organizations that serve as the gatekeepers for export. On a more fundamental level, however, there are often calls to completely remake and consolidate these organizations and abolish many of their requirements. In the US specifically, calls for the reform and consolidation tend to center on the argument that the gatekeeper organizations are structured inefficiently and that the economic opportunity costs of these controls are too high at current trends in today’s cooperative yet highly competitive, free-market, and science and technology-centered globalized world economy.[21]

High Performance Computers: Sensitive Items or Just Fun and Games?

A specifically problematic category for export controls is the group encompassing items and technologies related to high performance computers (HPCs). Computers have become a facet of everyday life around the world and have become indispensable in the modern world economy. Accelerations in technological development and increased standards of living worldwide have brought civilian computing and HPCs to a nexus. However, HPCs have an inherent dual-use nature as military force-multipliers and military research tools for war in the air, on the high seas, and even on the nuclear battlefield (see graph I).[22]

Graph I: Performance levels of computers that support selected applications of military significance[23]

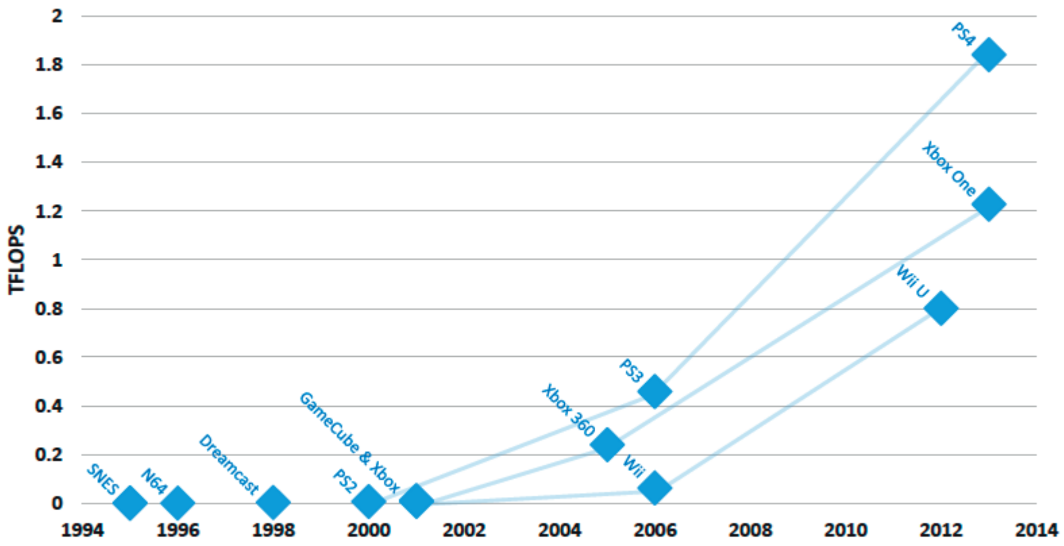
Computer performance level (MTOPS)	Applications
4,000 to 6,000	Joint Attack Strike Aircraft design; nonacoustic antisubmarine warfare sensor development, advanced synthetic aperture radar computation
8,000 to 9,000	Bottom-contour modeling of shallow water in submarine design; some synthetic aperture 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, advance aircraft design
21,125+	Submarine design; shallow water acoustics analysis
24,000+	Automatic target recognition template development
46,000 to 76,000	3D modeling and shock physics simulation for nuclear weapons applications
120,000	Multi line towed array signal processing

[20] For more information on deemed exports, see “”Deemed Export” FAQs,” Bureau of Industry and Security, U.S Department of Commerce, www.bis.doc.gov, <http://www.bis.doc.gov/deemedexports/deemedexportsfaqs.html#1>.
[21] For examples in this debate, see “Fact Sheet on the President’s Export Control Reform Initiative,” Office of the Press Secretary, the White House, 20 April 2010, www.whitehouse.gov. and “Recommendations for a 21st Century Technology Control Regime,” The Coalition for Security and Competitiveness, www.securityandcompetitiveness.org.
[22]Taken from McLoughlin Glenn J. and Fergusson, Ian F. “High Performance Computers and Export Control Policy: Issues for Congress,” CRS Report for Congress, Congressional Research Service, 25 January 2006. With source attribution from 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.

In addition to the modern ubiquity of personal computing, the rate of improvement in the processing power of individually affordable computing devices has accelerated in the past and will continue to do so in a phenomenon known as Moore's Law. While specifically regarding transistor counts, the basic idea behind the phenomenon is that the processing capabilities of computers increase exponentially, at a rate of something like doubling every two years, for example.[24] This presents export control policy makers with many issues regarding how to keep up with these rapid and accelerating changes, as well as issues regarding at which point extremely powerful computing technology becomes ubiquitous enough to render such controls unreasonable.

An excellent example of a day-to-day, civilian-use HPC is the modern video game console. While the content of many of their games may well be considered violent and even harmful, the consoles themselves are in and of themselves harmless. Consistent with Moore's Law, the processing capabilities of these impressive playthings have increased exponentially over the years (see Graph I, II).

Graph II, III: Two graphs, showing the measured TeraFLOP (TFLOP) performance of video-gaming specific consoles and which generation of gaming console they fall into, respectively, from 1995 to 2013[25]



Year	Generation	System	MFLOPS	TFLOPS
1995	4	Super Nintendo Entertainment System	0	0.000000
1996	5	Nintendo 64	200	0.000200
1998	6	Sega Dreamcast	2800	0.002800
2000	6	Sony PlayStation 2	6200	0.006200
2001	6	Microsoft Xbox	7300	0.007300
2001	6	Nintendo GameCube	11000	0.011000
2005	7	Microsoft Xbox 360	240000	0.240000
2006	7	Nintendo Wii	62900	0.062900
2006	7	Sony PlayStation 3	459200	0.459200
2012	8	Nintendo Wii U	800987	0.800987
2013	8	Microsoft Xbox One	1228800	1.228800
2013	8	Sony PlayStation 4	1843200	1.843200

[24] For more information regarding Moore's Law, see "50 Years of Moore's Law," The Intel Corporation, www.intel.com, <http://www.intel.com/content/www/us/en/silicon-innovations/moores-law-technology.html>.
[25] Graph made using data compiled from "Instructions per second," Encyclopedia Gamia: The Gaming Wiki, Wikia Inc., accessed: 23 August 2015, www.gaming.wikia.com, <http://gaming.wikia.com/wiki/Instructions_per_second>. Video-gaming consoles included were developed by the Microsoft Corporation, the Nintendo Co., the Sega Holdings Co. and Sony Computer Entertainment. Light blue lines connect video-gaming consoles manufactured by the same company

What were once simplistic and limited 8-bit systems have evolved to become extremely powerful computing machines, even by contemporary standards, which have nowadays far surpassed past benchmarks for military-applicable computers. Specifically, the most contemporary video game consoles, amongst what is considered the "eighth generation" of video-gaming consoles developed, are very powerful computers in their own right and will be compared to international export control laws as a case in this paper.[26] Specifically, a ubiquitous, yet highly advanced eighth generation video game console that falls into this category of potential dual-use capacities is the Sony PS4, which will serve as the detailed case study in this paper.

The choice of the Sony PS4 as a case in this study is appropriate and useful in that the item (1) is a powerful computing device, (2) is popular, (3) has been released relatively recently, and (4) is specifically the most appropriate example in the field of consumer video-gaming console hardware for this study. On the first point, the Sony PS4 has a combined Central Processing Unit (CPU) and Graphics Processing Unit (GPU) capable, on paper, of a maximum output of 1.84 TFLOPS.[27] Specifically, the CPU is an eight core, low power x86-64 AMD "Jaguar" unit and the GPU is an AMD Radeon Graphics Core Next engine.[28] Notably, it has been argued that the PS4 will be even more powerful than publically available customized personal computers, although this has been disputed.[29]

On the second point, due to the fact that the PS4 is mass-produced, relatively cheap, and in high demand internationally, it will be a significant, widespread, and popular tool for HPC proliferation internationally. In fact, the popularity of the PS4 can well spur disproportionate debate and uncharacteristically quick bureaucratic reaction in regards to trade restrictions, as was the case when, under Japan's Foreign Exchange and Trade law, export of the PlayStation 2 was halted and then quickly permitted in knee-jerk reaction.[30] Additionally, as it is a single model, the PS4 will be more efficient, pragmatic, easily conceptualized, and relatable as a case for study for the limited scope of this report, as opposed to creating specific classification criterion for publically available, individually-customized personal computers with similar or greater processing capacities.

On the third point, Sony's first public release date of the PS4 was 15 November 2013 in Canada and the US.[31] As the item's relatively recent release date is a time when economic forces push for greater hardware capacity while bureaucratic inertia pushes for greater international security on the topic, it is also the most likely time for the two to be at odds. As such the PS4 is an appropriate case to study in this regard. This timing also makes the study concurrently relevant and relatively up-to-date (as of the eighth generation of video-gaming consoles and before the release of consoles in the subsequent generation) in a market that is constantly upgrading.

On the fourth point, while other video-gaming consoles share many of these characteristics with the PS4, the PS4 is the most appropriate example amongst the eighth generation of video-gaming consoles. Other eighth generation consoles, such as the Nintendo Wii U and the Ouya are not as powerful as the PS4 in terms of computing power. The PS4's chief computing competitor in the eighth generation of consoles, the Xbox One, has considerable processing power in and of itself. However, compared to the PS4's 1.84 TFLOPS, the Xbox One's GPU only clocks in at a documented maximum of approximately

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[26] An explanation of each generation and examples of each, please see Miller, Michael. "A History of Home Video Game Consoles," InformIT, Pearson Education, 1 April 2005, www.informit.com.

[27] See "Press Release: Sony Computer Entertainment Inc. Introduces PlayStation 4 (PS4)," Sony Computer Entertainment Inc., 21 February 2013, www.scei.co.jp. A full copy of the press release can be found at <http://www.scei.co.jp/corporate/release/130221a_e.html>.

[28] "Specifications: PlayStation 4," PlayStation Official Website, 20 February 2013, www.us.playstation.com/ps4/.

[29] Kain, Erik "You Can't Build a PS4: Why Sony's Next Console is Truly Next-Gen and your PC Isn't," *Forbes*, February 25, 2013. www.forbes.com. and Kain, Erik "PS4 vs. PC: Where the Wild Things Are," *Forbes*, 26 February 2013. www.forbes.com.

[30] "Military Fears over PlayStation 2," *BBC News*, 17 April, 2000, www.news.bbc.co.uk.

[31] Koller, John. "PS4 Launches in North America on November 15th, Gamescom Wrap-up," PlayStation.Blog, 20 August 2013, www.blog.us.playstation.com.

1.31 or 1.32 TFLOPS.

Additionally, Sony PlayStation consoles are more common worldwide than Xbox consoles, given that looking forward, the PS4 has (as of March 2015) consistently sold more units than the Xbox One since its release, and, looking back, global sales of the currently available PlayStation 3 have outnumbered those of its comparable rival, the Xbox 360.[32] While the difference in sales between the PlayStation 3 and Xbox 360 is small, and the Nintendo Wii (another seventh generation gaming console) has outsold both of them, it should be noted that in the fifth and sixth generation of video-gaming console sales, the Sony PlayStation and PlayStation 2 respectively outperformed the competition by significant margins in the past.[33] In fact, the best-selling video-gaming console in history is the PlayStation 2.[34] As an established leader in the field, it is likely that Sony Computer Entertainment, Inc. will sell a substantial number of PS4 consoles worldwide over the course of the console's lifetime before the next generation of consoles arrives or before its rivals may be able to overtake it.

Turning a Toy Into a Military-Applicable HPC and Bypassing Controls

Additional technical questions that need to be addressed regard what could be done to make a video game console fall under current export controls, or fall under higher levels of export controls. While diving into the details of how to hypothetically alter a console for enhanced performance is beyond the scope of this report, a brief discussion of possibilities is useful in communicating and creating understanding of another level of dynamism when it comes to evaluating the overall effectiveness of trade control regimes for HPCs. In addition to the rapid and inexorable progression of computer processing technology, these advances also open the doors to new techniques that enable users to push these technologies to new levels. After all, "the street finds its own uses for things."[35]

The altering, enhancing, or boosting of the processing capacity of the PS4 can be achieved either by altering the item's software or hardware. Although technically illegal under the US Digital Millennium Copyright Act, a networked community of users who tamper with and hack, alter, or "jailbreak" the software programming of PlayStation consoles to their limits has regardless sprung up internationally.[36] Additionally, dividing complex computing tasks worthy of some of the world's most powerful supercomputers amongst many, less-capable computers may be used to increase the per-unit efficiency of an item.[37] However, while altering the software or task-burden of an individual console may increase relative performance of the item, it will not be able to take the item beyond the theoretical maximum performance as measured by the limits of the console's hardware (specifically 1.84 TFLOPS for the PS4).

In terms of boosting or enhancing the processing capacity of a video game console via hardware alteration, past experience shows that this is a distinct and very real possibility with just access to more than one of these consoles. To illustrate, the US Air Force Research Laboratory was able to interconnect, or "cluster", some 1,760 Sony PlayStation 3 processors to construct a powerful, yet financial and energy-economy cost-saving supercomputer capable of extreme processing powers useful for military applications, such as large scale reconnaissance analysis. This supercomputer, codenamed "Condor", has a theoretical output of some 500 TFLOPS and, amongst many other functions, processes radar

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[32] Elise, Abagail. "PS4 vs. Xbox One: Sony Sells More Than 20.2 Million Consoles Worldwide," *International Business Times*, IBT Media Inc., 4 March 2015. www.ibttimes.com. and Ward, Lewis. "Worldwide Video Game and Entertainment Console Hardware and Packaged Software 2012-2016 Forecast," International Data Corporation (IDC), December 2012, cited in Agnello, Anthony John. "PlayStation 3 Pulls Ahead of Xbox 360 with 77 Million Consoles Sold," *Digital Trends*, 10 January 2013, www.digitaltrends.com.
[33] "Daily Chart: Game On," Graphic Detail, *The Economist*, 21 May 2013, www.economist.com.
[34] Ibid.
[35] Gibson, William. *Burning Chrome* (New York: HarperCollins Publishers Inc., 2003), p. 199.
[36] See Digital Millennium Copyright Act, Pub. L. No. 105-304, 105th Cong., (28 October 1998). A full text of the legislation can be found at <http://www.gpo.gov/fdsys/pkg/PLAW-105publ304/pdf/PLAW-105publ304.pdf>.
[37] For more information on and examples of crowdsourced computing, see Pearson, Kirk. (ed.), "distributedcomputing.info," 2 May 2012, www.distributedcomputing.info/index.html.

surveillance imagery. It is the most powerful computer in the US Department of Defense. However, it must be noted that other, non-PlayStation 3 components were also integrated into this design.[38]
In a more pragmatic example, eight publicly and internationally available PlayStation 3 gaming consoles were also wired together by an American astrophysicist to create an off-the-shelf supercomputer at a cost of less than $4,000 (USD). The parallel processing-friendly design of the PlayStation 3 makes it conducive to processing hardware interconnectivity, or clustering. Specifically, Sony Senior Development Manager of Research and Development Noam Rimon states that the PlayStation 3 "has a general purpose processor, as well as eight additional processing cores, each of which has two processing pipelines and can process multiple numbers, all at the same time."[39]

It is notable that clustering was the basis of the aforementioned Condor supercomputer design as well. It is doubtful that a sufficiently resourceful and determined user would be unable to achieve similar, if not greater levels of processing capacity, with the now available PS4. This is a considerable issue in attempting to justify an HPC export control regime based on the theoretical processing limits of individual items.

Applicable HPC-Specific Controls

The crux of the international trade control regime relevant to HPCs is the Wassenaar Arrangement, formed in July 1996 by former member states of the then-disbanded CoCom. While the Wassenaar Arrangement does not infringe on member states' sovereign national export control laws, it works to set the precedent and standard to which many of its member states quickly comply. Additionally, Japan and the US also have the bilateral U.S. Japan Supercomputer Agreement regarding exports to third-parties.[40]

The Wassenaar Arrangement's controls or non-controls on HPCs (specifically completed processing hardware units) are categorized by the metric of weighted FLOPS measured at adjusted peak performance (APP). Specifically, FLOPS, or Floating-point Operations per Second, are a metric for computing hardware performance at the 64-bit or greater level, and are a common standard for the Japanese, US, and international Wassenaar Arrangement control regimes on HPCs. One TFLOP is a measure of one trillion FLOPS, and is currently a common measure of HPC performance and a differentiator for more common (as opposed to advanced) computing hardware. Currently, under the Wassenaar Arrangement, the permissible TFLOP limit for free export of an HPC is weighted at an APP of 8.0 TFLOPS (as of 21 June 2015).[41] However, please keep in mind that at the time of the initial public release of the PS4, this limit was set at 3.0 TFLOPS.

It could be construed that the past increase in 2005 from the 0.75 to 1.5 TFLOPS limit could have been a knee-jerk reaction in twilight-hour preparation of the arrival of the seventh generation of video-gaming consoles, simply as to avoid what happened during the release of the much anticipated PlayStation 2 and its deeply unpopular halt of initial exports.[42] However, the increase in 2011 from the 1.5 to 3.0 TFLOPS limit two years before the arrival of the two most powerful consoles of the eighth generation of video-

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[38] See "Condor Supercomputer: DOD's Largest Interactive Supercomputer," presentation at the Ribbon Cutting Ceremony, Air Force Research Laboratory, Rome, New York, 1 December 2010. A copy of the presentation slides can be found at <http:// www.dodlive.mil/files/2010/12/CondorSupercomputerbrochure_101117_kb-3.pdf>.

[39] Gardiner, Bryan. "Astrophysicist Replaces Supercomputer with Eight PlayStation 3s," *WIRED*, Condé Nast, October 17 2007. www.wired.com.

[40] McLoughlin, Glenn J. and Fergusson, Ian F. "High Performance Computers and Export Control Policy: Issues for Congress," CRS Report for Congress, Congressional Research Service, 25 January 2006.

[41] "Dual-Use List - Category 4 - Computers," List of Dual-Use Goods and Technologies and Munitions List, The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 25 March 2015.

[42] "List of Dual-use Goods and Technologies and Munitions list (WA-LIST (05) 1 Corr.)," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 14 December 2005. and "List of Dual-use Goods and Technologies and Munitions list (WA-LIST (09) 1)," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 3 December 2009.

gaming consoles, indicates that the authorities behind these HPC export controls have been keeping up much better with the rapidly evolving nature of HPCs than before, and are not simply acting in knee-jerk reactions just to avoid unpopular public opinion.[43] The raising of the 3.0 TFLOPS limit to 8.0 TFLOPS (on 4 December 2013) well before an anticipated arrival of any subsequent ninth generation of video-gaming consoles also reinforces this view.[44]

In fact, upon closer investigation of the Wassenaar Arrangement's evolving criteria for what constitutes an HPC sufficiently powerful to be considered worthy of strategic trade controls, it can been seen that the cut-off values have increased progressively over time. This data can be parsed most clearly and efficiently by noting the first instance of mention or alteration of controlled items in the Wassenaar Arrangement's control lists, defined as being mentioned under the section for systems, equipment and components for computers (Category 4), yet not including requirements for software nor electronics (Category 3). Before using the TFLOP measure for HPCs, the Wassenaar Arrangement initially utilized a measure of composite theoretical performance, as measured in Million theoretical operations per second (Mtops). The Wassenaar Arrangement's cut-off values increased exponentially from an initial (1) 710 Mtops in 1996, to (2) 2,000 Mtops in 1997, to (3) 6,500 Mtops in 1999, to (4) 28,000 Mtops in 2000 and then to (5) 190,000 Mtops in 2002. Upon conversion to the TFLOP metric, the evolution of the Wassenaar Arrangement's threshold continued increasing exponentially, starting with an initial cut-off value of (1) 0.75 TFLOPS in 2005, to (2) 1.5 TFLOPS in 2009, to (3) 3.0 TFLOPS in 2011 and then finally to (4) 8.0 TFLOPS in 2013 (see Graph III, IV).[45]

Graph IV, V: Two graphs, showing the measured TeraFLOP (TFLOP) performance of video-gaming specific consoles and the Wassenaar Arrangement's permissible Million theoretical operations per second (Mtops) and TFLOP-based limits for free export from 1995 to 2013[46]

Year	System	MFLOPS	TFLOPS
1995	Super Nintendo Entertainment System	0	0.000000
1996	Nintendo 64	200	0.000200
1998	Sega Dreamcast	2800	0.002800
2000	Sony PlayStation 2	6200	0.006200
2001	Microsoft Xbox	7300	0.007300
2001	Nintendo GameCube	11000	0.011000
2005	Microsoft Xbox 360	240000	0.240000
2006	Nintendo Wii	62900	0.062900
2006	Sony PlayStation 3	459200	0.459200
2012	Nintendo Wii U	800987	0.800987
2013	Microsoft Xbox One	1228800	1.228800
2013	Sony PlayStation 4	1843200	1.843200

[43] "List of Dual-use Goods and Technologies and Munitions list (WA-LIST (09) 1)," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 3 December 2009. and "List of Dual-use Goods and Technologies and Munitions list (WA-LIST (11) 1 Corr.)," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 21 February 2011.

[44] "Summary of Changes Adopted at December 2013 Plenary (WA-LIST (13) 1)," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 4 December 2013.

[45] "List of Dual-use Goods and Technologies and Munitions list," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, documents WA-LIST (96) 1, WA-LIST (97) 1, WA-LIST (99) 1, WA-LIST (00) 1, WA-LIST (02) 1, WA-LIST (05) 1 Corr., WA-LIST (09) 1, WA-LIST (11) 1 Corr., WA-LIST (13) 1, with dates March 16, 1996, December 19, 1997, December 3, 1999, 1 January 2000, December 12, 2002, December 14, 2005, December 3, 2009, February 21, 2011, December 4, 2013, respectively.

[46] Graph made using data compiled from "Instructions per Second," *Encyclopedia Gamia: The Gaming Wiki*, Wikia Inc., accessed: August 23, 2015, www.gaming.wikia.com, <http://gaming.wikia.com/wiki/Instructions_per_second> and "List of Dual-use Goods and Technologies and Munitions list," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, documents WA-LIST (96) 1, WA-LIST (97) 1, WA-LIST (99) 1, WA-LIST (00) 1, WA-LIST (02) 1, WA-LIST (05) 1 Corr., WA-LIST (09) 1, WA-LIST (11) 1 Corr., WA-LIST (13) 1, with dates March 16, 1996, December 19, 1997, December 3, 1999, 1 January 1, 2000, December 12, 2002, December 14, 2005, 3 December 2009, 21 February 2011, 4 December 2013, respectively. Video-gaming consoles included were developed by the Microsoft Corporation, the Nintendo Co., the Sega Holdings Co. and Sony Computer Entertainment.

Year	Wassenaar Arrangement Control List	Mtops
1996	WA-LIST (96) 1	710
1997	WA-LIST (97) 1	2000
1999	WA-LIST (99) 1	6500
2000	WA-LIST (00) 1	28000
2002	WA-LIST (02) 1	190000
Year	**Wassenaar Arrangement Control List**	**TFLOPS**
2005	WA-LIST (05) 1 Corr.	0.75
2009	WA-LIST (09) 1	1.5
2011	WA-LIST (11) 1 Corr.	3
2013	WA-LIST (13) 1	8

As per Japan and the US's international obligations under the Wassenaar Arrangement, national export controls regarding HPCs should, at the very least, coincide with the TFLOP limit as set forth in the latest guidelines of the Wassenaar Arrangement. As previously mentioned, the current permissible TFLOP limit for free export is weighted at an APP of 8.0 TFLOPS (as of 21 June 2015).[47] Considering (1) the PS4's combined CPU and GPU are capable, on paper, of a maximum output of 1.84 TFLOPS, (2) that this value is measured at a theoretical maximum but not at the Wassenaar Arrangement's 64-bit or greater APP metric, yet (3) that the processing output of the PS4 under the Wassenaar Arrangement's metric could technically only be capable of scoring a weighted 1.84 TFLOPS or lower, the conclusion is that as per the Wassenaar Arrangement's standards, the PS4 and thus any other eighth generation video game console is not a controlled, dual-use military-capable supercomputer.[48]

Discussion

In this case study, the international export control regime applied to Japan and the US for export controls on dual-use HPCs was found to be pragmatic, up-to-date, and not overly limiting. This is in stark contrast to the criticisms of many against the issues inherent in contemporary export control systems such as bureaucratic lag, technological protectionism, needless or excessive restraints, loss of competitive edge of national exporters and accusations of economic warfare.

However, this case does not represent development in the entire field, but serves merely as an illustrative example. Additionally, this investigation brings up the question of whether trade control regimes inadvertently had affected and limited the development of the PS4 in earlier stages, or whether conversely, items such as the PS4 brought undue pressure from industry leaders for lawmakers to raise the international HPC TFLOP export control limit at excessive rates. Specifically, on this last point, one must note that the TFLOP standard cut-off point for the Wassenaar Arrangement's updates in recent years occurred nearly biennially. While up until the most recent update the TFLOP cut-off value, the value would nearly double every time, the latest update to the value (in force as of 4 December 2013) brought the value up more than two and a half times over (see Graph V, VI).[49] This brings up the question of whether the Wassenaar Arrangement, in regards to such rapidly improving and pervasive commodities as HPCs, acts simply as a rubber stamp parliament for irrelevant post-hoc regulation.

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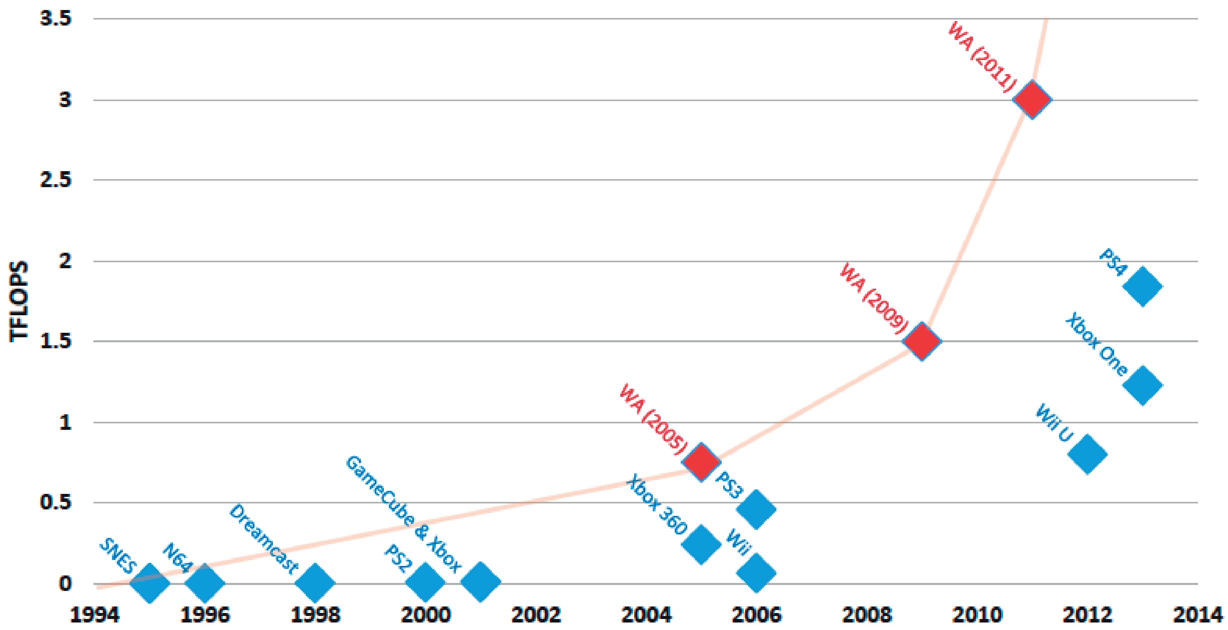
[47] "Dual-Use List - Category 4 - Computers," List of Dual-Use Goods and Technologies and Munitions List, The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, March 25, 2015.

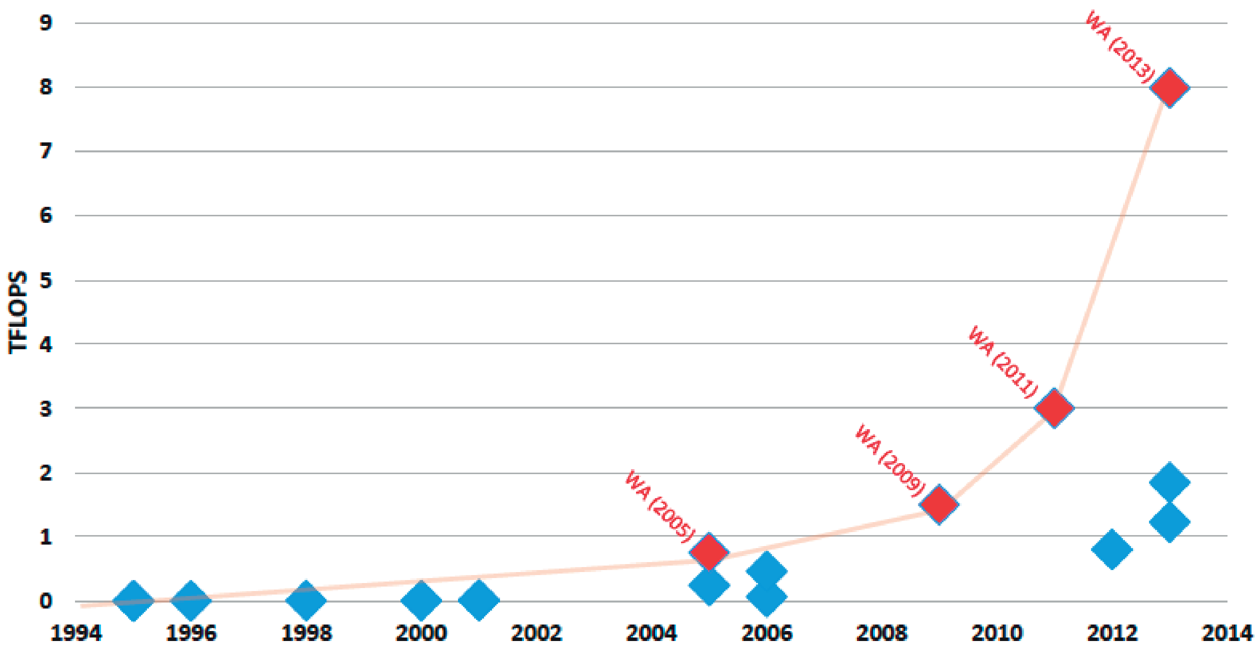
[48] "Press Release: Sony Computer Entertainment Inc. Introduces PlayStation 4 (PS4)," Sony Computer Entertainment Inc., 21 February 2013, www.scei.co.jp. A full copy of the press release can be found at <http://www.scei.co.jp/corporate/release/130221a_e.html>.

[49] "Dual-Use List - Category 4 - Computers," List of Dual-Use Goods and Technologies and Munitions List, The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, 21 February 2012. and "Summary of Changes Adopted at December 2013 Plenary (WA-LIST (13) 1)," The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, December 4, 2013.

Another important question to raise is whether the Wassenaar Arrangement's current approach to controlling the export of HPCs is viable both in the present and in the future. While it may be said that the Wassenaar Arrangement's measures for what constitutes a unusually powerful, military-applicable HPC at one point in the past may have been temporarily considered an absolute and unchanging value, this paper has clearly shown that in the face of an environment characterized by rapid and accelerating changes, the Wassenaar Arrangement's cut-off values are not absolute, but simply relative to general trends in the industry.

Graph VI, VII: Two charts, with varying y-axis ranges, showing the measured TeraFLOP (TFLOP) performance of video-gaming specific consoles and the Wassenaar Arrangement's permissible TFLOP-based limits for free export from 1995 to 2013





However, the consistency of the findings with the phenomenon of Moore's Law begs the question of at which point ubiquitous and personal HPCs will inevitably reach what could be unequivocally considered, by an absolute measure, an unacceptably military-applicable HPC. Denying the export of extremely ubiquitous HPCs, based on an absolute and unbending limit, would have a massive effect akin to simply ignoring contemporary consumer markets and denying the export of the 1.8 TFLOP-capable PS4 based simply on the Wassenaar Arrangement's 2009 cut-off of 1.5 TFLOPS, and would prove extremely unreasonable, unpopular and unenforceable. As such, one must ask, considering that even something as simple as a video-gaming console has nowadays vastly overrun past measures for what was not so long ago considered military-grade processing, whether the industry has already passed what could be considered an absolute measure of military-relevant processing, and whether continuing to raise the bar anymore has any tangible relevance therein.

This report's most unsettling finding relates less to the individual processing capacity of the video-gaming consoles however, but rather on the ease with which multiple units may be clustered together to form pragmatic, economical, and over-the-counter supercomputers. The TFLOP metric for limiting exports on individual units' processing power does not apply here. Other export control standards such as end-user verifications and limitations based on quantity or value could well work as more effective replacements for the constantly updating, relativistic TFLOP metric that cannot account for the simple act of clustering multiple HPCs together. This alternative should be seriously considered in discussions on future export control reform.

While there are these alternatives, it should also be noted that they are not impervious themselves. This is not only due to the fundamental nature of trust and post-hoc prosecution, but also due to the complex nature of acquisition techniques that can bring multiple and disparate end-users together. These end-users can manipulate transshipment points, or can obfuscate many measures by purchasing commodities second-hand. On this last point, all of the aforementioned examples of PlayStation based supercomputer construction were constructed using parts from the PlayStation 3, a video-gaming console that has been sold in vast quantities and has, since the release of the PS4, become a second-hand good subject to fire-sales across the world. In addition to the question of altering the metric for which export control regimes judge an item in requiring trade controls or not, these questions bring up the issue of whether it is possible at all to control a commodity as internationally and individually invested as a video-gaming console or an HPC.

On this last point, one must also revisit one of the most fundamental issues regarding the control of HPC exports; whether an HPC can be realistically considered an item which also has significant or disproportionate military applications. This report reviewed some of the capacities of an HPC to function in military related capacities (see Graph 1), but it must be noted that the mentioned applications are all research oriented and only military-applicable in a passive respect. In this light, it can be argued that controlling exports of HPCs is tantamount to that of boots or textbooks to other nation-states for the purposes of self-defense. The resources and demands invested in HPC export controls can rather be redistributed to dual-use items of a comparatively more consequential nature. Simply put, one can build higher walls with fewer items to guard.

Conclusions

In light of this discussion, one can see that while the wholesale abandonment of the current international trade control system would be completely disproportionate, academic and policy debate indicates that changes and reform are needed and would be welcomed, and rightfully so.[50] Many parts of the international export regime are restrictive and will continue to be so, as that is the meaning behind it. However, many arguments on reform in the sector mention the need to remove frivolous controls in order to streamline the system and concentrate on commodities, technologies, and knowledge that are

[50] For an example, see *Beyond "Fortress America": National Security Controls on Science and Technology in a Globalized World*, National Research Council, (Washington DC: National Academies Press, 2009).

of an active, truly military-applicable nature.[51] If there are to be changes in these trade control systems, a fundamental place to begin would be in addressing the aforementioned issues regarding HPCs.

HPCs are not items of mortal combat, and their dual-use properties are significantly more ambiguous than many other dual-use commodities. All nation-states have access to computers, and access to stronger computers will not enable the leader of any regime to become some kind of god of war. It has been shown that capabilities to upgrade a readily accessible computer into an HPC, or even a supercomputer, are a much greater concern than individual HPC exports and that these capabilities are not far around the bend for any nation-state. This finding brings the very feasibility of truly controlling the export of HPCs or vicariously hindering the development of military-capable supercomputers therein seriously into question. A nation-state would be much better off concentrating resources on pursuing commodities that have active, less-ambiguous, and more directly military-applicable functions.

When one also considers the opportunity cost that such broad and vague export controls have, the issue is compounded. In the post-Cold War world, national priorities have shifted from superpower military confrontation, total war legacy thinking and Containment Theory based strategies to expanding security through forming a network of interdependence through the collaborative development of economies, science and technology worldwide. In this, an HPC can well be considered a comparatively "low-sensitivity but high commercial value technology [commodity that] is being held back by the export control system, thereby dulling U.S. companies' competitive edge and limiting their market share needlessly."[52] Considering these economic benefits, limits on HPC exports should still exist, but should only be applied to the most extreme of cases, such as in the case of a targeted embargo against a directly relevant aggressor or threat.

Additionally, development of HPCs has shown that they are in widespread use across the world and that excessive limitations against them would affect all people from all strata and prove deeply unpopular, harming the legitimacy of the sector itself, one of its central components. Compliance and trust are difficult to sow in the face of illegitimate and heavy-handed action. However, individual use of these items applies to individuals using individual items. It must be noted again that while export controls centered on the measure of an individual HPC would hinder blameless individuals, this would not be the case if the Wassenaar Arrangement and national HPC export control systems changed from an individual model, relativistic based metric to one emphasizing quantity. This would be a first step in the right direction for more nuanced and targeted export control reform.

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[51] Gates, Robert M. "Business Executives for National Security (Export Control Reform)," Speech delivered at Ronald Reagan Building and International Trade Center, Washington D.C., 20 April 2010, www.defense.gov. A full text of the speech can be found at <http://www.defense.gov/speeches/speech.aspx?speechid=1453>.

[52] "Recommendations for a 21st Century Technology Control Regime," The Coalition for Security and Competitiveness, www.securityandcompetitiveness.org.