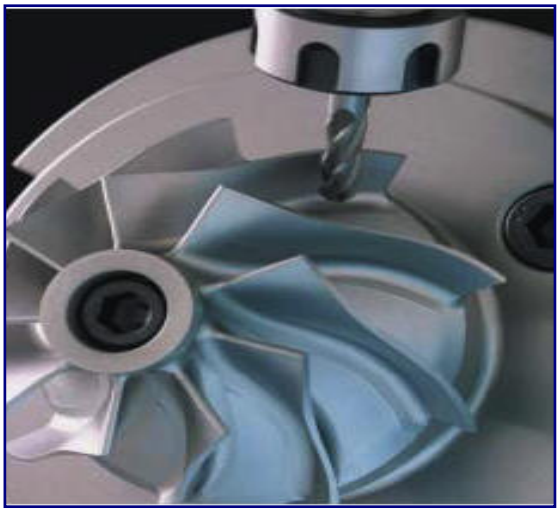
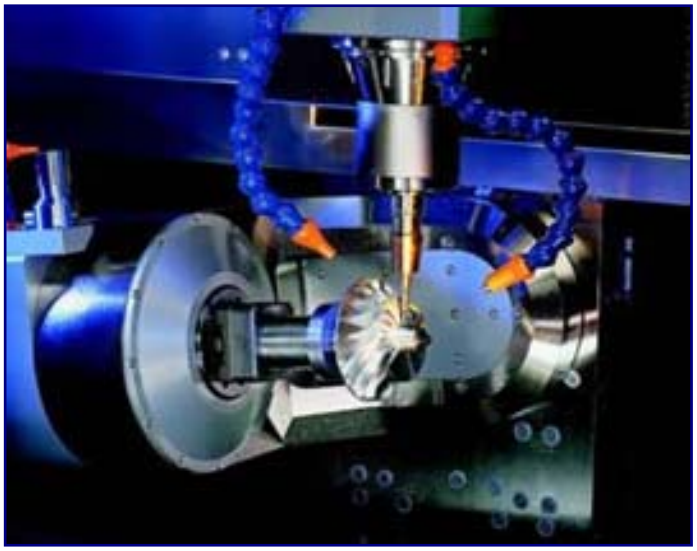
Critical Technology Assessment:
Five Axis Simultaneous Control Machine Tools





Office of Technology Evaluation
Bureau of Industry and Security
U.S. Department of Commerce

JULY 2009

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I. Executive Summary

The Bureau of Industry and Security (BIS) conducts critical technology assessments to examine the impact of export controls on key existing or emerging technologies subject to the Export Administration Regulations (EAR). These technologies are dual-use, meaning they have both civilian and military applications. For a given technology, BIS evaluates the scope and impact of current U.S. export controls, foreign export control practices, the sector's economic status, and the foreign availability of product substitutes.

This assessment focuses on machine tools for milling and for grinding having five or more axes that can be coordinated simultaneously for "contouring control" (i.e., mills, grinders, mill/turns, and machining centers). It also examines the health and competitiveness of U.S. machine tool manufacturers and distributors, and identifies issues relevant to domestic and foreign machine tool procurements by the Department of Defense and its contractors necessary to produce and support critical defense systems.

In this assessment, BIS specifically examined:

- The application of Export Control Classification Numbers (ECCN) 2B001.b.2 and 2B001.c.2 controls and related licensing practices;
- Foreign export control practices on subject machine tools;
- Foreign availability (i.e., availability-in-fact, non-U.S. source, sufficient quantity, and comparable quality) of five axis simultaneous control mills, grinders, mill/turns, and machining centers;
- Economic status and health and competitiveness of the U.S. five axis machine tool industrial base;
- Issues relevant to procurements necessary to support critical defense systems.

Based on data received from survey respondents and other sources, BIS concludes the following:

- Foreign availability of certain five axis simultaneous control mills, mill/turns, and machining centers controlled by ECCN 2B001.b.2 (but not grinders controlled by ECCN 2B001.c.2) exists to China and Taiwan, which both have an indigenous capability to produce five axis simultaneous control machine tools with linear positioning accuracies comparable to the United States;
- U.S. export license processing times, especially to China, are longer than those of other Wassenaar Arrangement members, placing U.S. exporters at a competitive disadvantage;
- Compared with other exporting countries of this technology, the United States is losing market share to its European and Asian competitors, particularly South Korea;

- U.S. producers of five axis simultaneous control machine tools, while currently profitable, face an uncertain future for their five axis machine tool product lines with imports outpacing domestic sales and increasing customer demand (commercial and U.S. Government) for foreign machine tools;

- Lack of U.S. training programs has created a shortage in skilled labor in the machine tool industry, which threatens to impede domestic ability to produce machine tools and manufacture complex products; and

- A potential vulnerability exists with regard to sensitive data (e.g., designs) stored in the computerized numerical controllers (CNCs) of machine tools connected to the Internet.

Accordingly, BIS recommends that the U.S. Government (USG):

- Amend the EAR to facilitate the export of five axis simultaneous control mills, mill/turns, and machining centers of certain precision accuracies controlled by ECCN 2B001.b.2 with foreign availability to controlled countries under license exception or similar-type authorization, and work with international partners (via the Wassenaar Arrangement and Nuclear Suppliers Group) to modify the existing multilateral export control of five axis simultaneous control machine tools by adding a linear positioning accuracy control parameter, while working towards a better capability measure of this technology (e.g., volumetric accuracy);

- Encourage producers and distributors to identify or develop anti-tampering and anti-diversion features for their machine tools that can be utilized to mitigate concerns of machine tool misuse or diversion after export to facilitate interagency review of license applications to sensitive destinations;

- Improve communication between U.S. companies and U.S. export licensing officials to decrease processing times of license applications for exports destined to China;

- Monitor, on a routine basis, the competitive position of U.S. machine tool producers to support critical industrial base needs;

- Identify training proposals for educational institutions to address the growing problem of a lack of skilled labor to design, build, and use machine tools; and

- Heighten the awareness among USG end-users and contractors, especially those that machine parts for defense-related components, of the risk of unauthorized access to and exfiltration of CNC data.

II. Introduction

A. Assessment Overview

The Bureau of Industry and Security (BIS) conducts critical technology assessments to examine the impact of export controls on key existing or emerging technologies subject to the Export Administration Regulations (EAR). These technologies are dual-use, meaning they have both civilian and military applications. For a given technology, BIS evaluates the scope and impact of current U.S. export controls, foreign export control practices, the sector's economic status, and the foreign availability of product substitutes.

This assessment focuses on machine tools for milling and for grinding having five or more axes that can be coordinated simultaneously for "contouring control" (i.e., mills, grinders, mill/turns and machining centers). It also examines the health and competitiveness of U.S. manufacturers and distributors, and identifies issues relevant to domestic and foreign procurements by the Department of Defense (DOD) and its contractors necessary to produce and support critical defense systems.

Machine tools subject to this assessment are controlled for national security (NS), non-proliferation (NP), and anti-terrorism (AT) reasons under ECCNs 2B001.b.2 and 2B001.c.2 of Supplement No.1 to Part 774 of the EAR.[1] This technology assessment does not analyze machine tools that only perform turning operations (i.e., lathes) that are subject to control under ECCN 2B001.a.

BIS evaluated the technical specifications and capabilities of these machine tools, and the scope and impact of U.S. export controls on U.S. manufacturers of these machine tools in comparison to the export control practices of Wassenaar Arrangement (WA) and Nuclear Suppliers Group (NSG) member countries. A foreign availability analysis was also conducted to determine whether mills, grinders, mill/turns, and machining centers of comparable quality are available-in-fact from non-U.S. sources to countries that are not members of the WA and the NSG in quantities sufficient to render the U.S. export control of these machine tools ineffective.

In order to assess the overall health and competitiveness of the U.S. industrial base for these machine tools, BIS surveyed relevant machine tool producers, distributors, and end-users and evaluated trade data, import and export penetration, and market share statistics. This data was used to determine a baseline for current U.S. production and distribution capabilities. These were later compared to the expected needs of end-users to identify future gaps and opportunities in domestic supply and demand.

[1] Related controls for NS, NP, and AT reasons include: Software for the development, production or use of machine tools (ECCN 2D001); Software enabling an electronic device to function as a numerical control unit capable of coordinating simultaneously more than 4 axes for contouring control (ECCN 2D002); Technology for the development of equipment or software (ECCN 2E001); and Technology for the production of equipment (ECCN 2E002). Also related is technology for the use of equipment or software (ECCN 2E201) that is controlled for NP and AT reasons.

Finally, BIS examined issues related to the ability of the DOD and its contractors to securely source high-quality machine tools from foreign providers in a timely manner while mitigating the risk for the illicit or inadvertent transfer of sensitive data to unauthorized persons (e.g., machine tool service provider).

B. Origin of Assessment

Four factors influenced the Office of Technology Evaluation's (OTE's) initiation of this assessment:

- Review of BIS licensing and global export data from 2001-2007, which identified losses in U.S. competitive advantage and a decline in exports subject to ECCN 2B001;
- Receipt of foreign availability data on Chinese and Taiwanese five axis simultaneous control machine tools from the Association for Manufacturing Technology (AMT);
- Lack of sufficient data to support USG interagency draft proposals for modification of existing export controls related to the Wassenaar Arrangement; and
- Results of a DOD study questioning whether an indigenous capability to manufacture cutting edge technology machine tools is a critical defense need based on the ability of DOD to securely source machine tools abroad.[2]

III. Product Description

This assessment focuses on a small subset of machine tools subject to the EAR that are controlled by the sole parameter of having five or more axes that can be coordinated simultaneously for contouring control through the use of a computerized numerical controller (CNC). The CNC is a dedicated computer that controls the movement of the axes of the machine tool, and can be programmed automatically with desired part parameters and specifications. ECCNs 2B001.b.2 and 2B001.c.2 cover this group of machine tools, namely mills, grinders, mill/turns, and machining centers. These machine tools are used in a variety of both commercial and military manufacturing processes to cut, grind, and shape a variety of materials, mainly metals. This equipment has matured over the years, moving from manual machines to CNC machines, increasing in speed, and achieving more precise accuracies.

A. General Description

Machine tools subject to this assessment are characterized by five axes that are a combination of three linear axes (x-, y- and z-axes) plus two rotary axes (either a dual rotary axis, a rotary axis with a rotary table, or a compound rotary table) that are capable of moving around a work piece simultaneously. This allows for the creation of complex shapes and angles with greater accuracy than otherwise achieved with three or four axis machine tools and with better efficiency and precision.

[2] *Export Controls and the U.S. Defense Industrial Base,* Appendix C. Institute for Defense Analyses, Jan 2007.

The length of the linear axes, or slides, determines the size of the part or component than can be contoured. Large-sized milling machines have linear slides that are many meters in length and are capable of machining large aircraft parts, whereas smaller machines can machine small engine parts and items for medical use, for example.

B. Civilian Applications

Five axis machine tools are used for a variety of civilian applications, mainly the manufacture of aircraft parts and components, gas and diesel engines (e.g., aircraft, helicopter, rail, auto), and automobile parts. Other end-uses include training, research and teaching, and a wide variety of applications in the medical, textile, oil, glass, heavy industrial equipment, tool, and manufacturing industries. Although these high-performance machine tools were once mainly used for industries where simultaneous control of all five axes of the machine tool is critical, such as the aerospace and medical industries, it is clear that many other industries are discovering the advantages of these machines.

A significant savings in efficiency can be realized, both in time and in cost, by using a five axis machine tool in place of several machine tools with fewer axes, which require the operator to stop the machine to reposition the work piece, or even to continue cutting or grinding the piece on another machine. This introduces more chances for human error and less precision accuracy than can be achieved by machining a piece from start to finish on one five axis simultaneous control machine tool. For example, some of the less traditional end-uses cited in export license applications for these particular machine tools include the manufacture of artificial insemination equipment for cattle and the manufacture of moulds for the soles of shoes.

C. Military Applications

According to DOD's Military Critical Technologies List (MCTL), modern weapon systems require a variety of production equipment to manufacture necessary components. For example, turning, milling, and grinding machines are required for the fabrication of a range of items, from large aircraft structures, submarine and ship propellers (particularly quiet propellers), and turbine and compressor blades to small parts for gyroscopes, engine parts, and even nuclear weapons. Five axis machine tools are an essential part of the U.S. industrial base.[3]

Grinding machines are used to produce parts for stealth applications, smart weapons, sensors, night vision devices, laser mirrors, molds for radar and sonar domes, and missile applications such as forward looking infrared (FLIR) capabilities, gyroscopes, inertial navigation, and high-performance engine parts. Nearly every aircraft in service today requires precision-ground parts.[4]

[3] U.S. Department of Defense. Military Critical Technologies List, Section 12.5, September 2007, p. MCTL-12-47.
[4] Ibid.

IV. Export Controls

A. Export Administration Regulations

Five axis machine tools are controlled by the EAR under 2B001.b.2 (mills) and 2B001.c.2 (grinders). Both ECCN controls derive from Category 2 of the Wassenaar Arrangement's *Lists of Dual-Use Goods and Technologies* and from Part 2 of the Nuclear Suppliers Group Guidelines, *Transfers of Nuclear-Related Dual-Use Equipment, Material, and Related Technology*. Exports of these machine tools are controlled for NS, NP, and AT reasons and no license exceptions apply. Table *a* below contains a list of countries that do not require a license for these items based on these controls (i.e., NS 2, NP 1, and AT).

Table a: Countries for which an Export License is Not Required for NS 2, NP 1, or AT Reasons for ECCNs 2B001.b.2 and 2B001.c.2

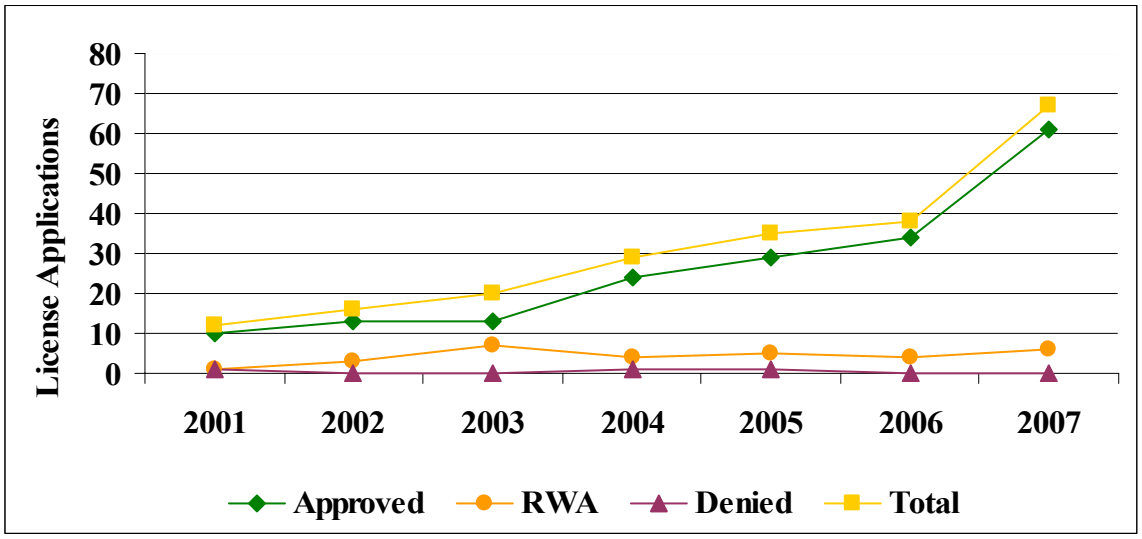
Australia	France	Luxembourg	Slovakia
Austria	Germany	Netherlands	Slovenia
Belgium	Greece	New Zealand	Spain
Bulgaria	Hungary	Norway	Sweden
Canada	Ireland	Poland	Switzerland
Czech Republic	Italy	Portugal	Turkey
Denmark	Japan	Republic of Korea	United Kingdom
Finland	Latvia	Romania	

Source: EAR

1. BIS Licensing Data

BIS processed 588 export license applications for machine tools controlled by ECCN 2B001 from 2001-2007. Two hundred and seventeen of these export license applications were for five axis mills, grinders, mill/turns, and machining centers (controlled by subparagraphs b.2 and c.2 of ECCN 2B001), of which BIS approved 184 (84.8%). Thirty of the 217 applications were returned without action (RWA) to the applicants, mostly due to applicant failure to provide the additional technical or end-use information requested by BIS licensing officers. Only two applicants requested that their applications be returned because of a loss of the sale due to the processing time of the license application. The remaining three applications (1.6%) were denied due to a risk of diversion of the machine tool or due to sanctions. Figure *1* contains a breakdown by year of BIS determinations of these export license applications.

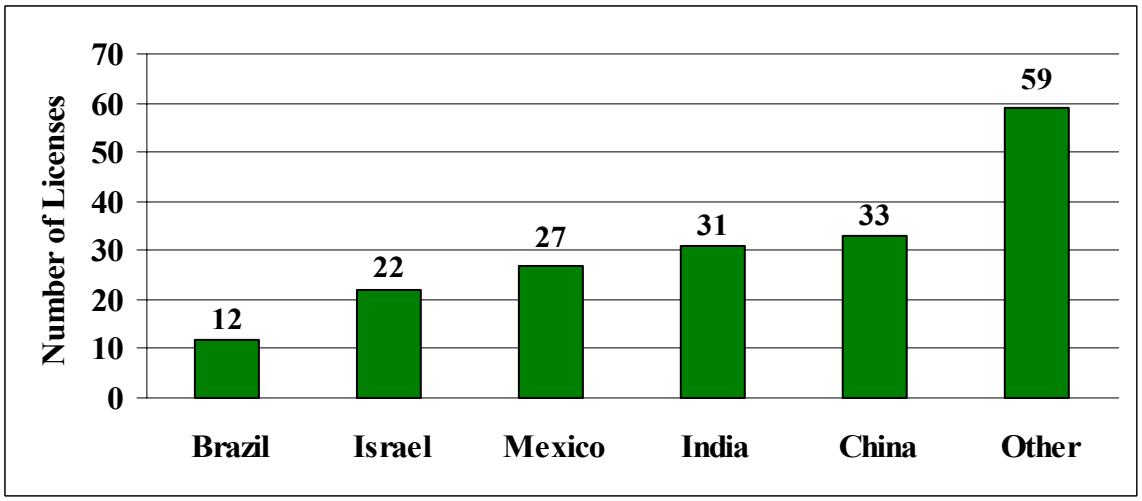
Figure 1: 2B001.b.2 and 2B001.c.2 Export License Applications Processed by BIS from 2001-2007



Source: ECASS

BIS licensed exports of these machine tools to 27 different countries, four of which no longer require a license for NS 2, NP 1, or AT reasons (Czech Republic, Hungary, Poland, and Romania). The top five destinations by number of licenses approved, representing 68 percent of the total licenses issued for these types of machine tools, are detailed in Figure *2*. Only five export licenses or less was approved for each of the remaining 22 destinations represented by the "Other" category. [5]

Figure 2: Top Five Destinations by Number of Licenses Approved 2001-2007



Source: ECASS

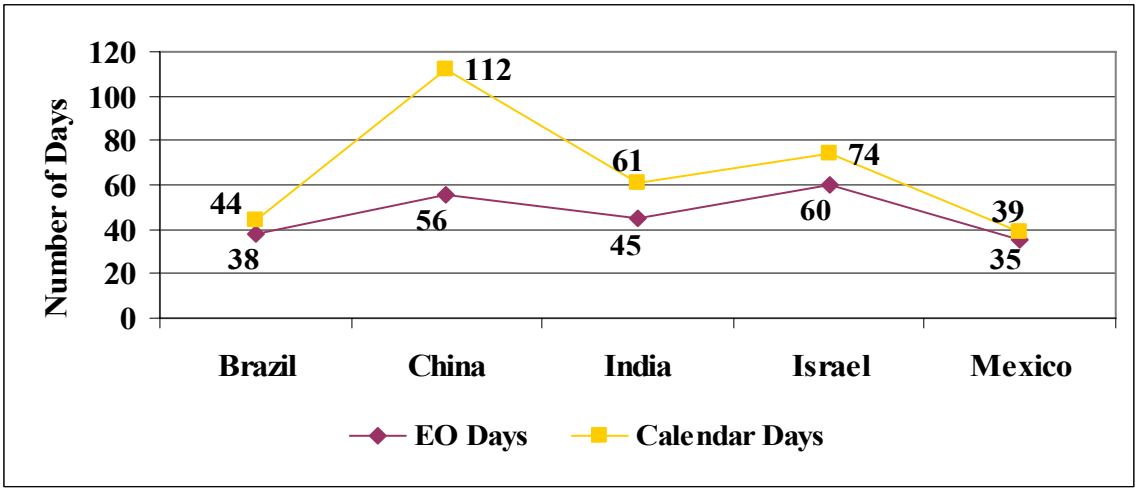
[5] The other 22 destinations include: Argentina, Chile, Colombia, Costa Rica, Croatia, Czech Republic, Hong Kong, Hungary, Lebanon, Malaysia, Philippines, Poland, Romania, Russian Federation, Saudi Arabia, Singapore, South Africa, Taiwan, Thailand, Uzbekistan, and Vietnam.

Under Executive Order (EO) 12981, BIS and other interagency partners have 39 days (Executive Order or EO days) to make a determination on an export license application once it is received from the applicant. This 39 day clock can be stopped, and the case can be "held without action" (HWA) for specific reasons, including: 1) waiting for the applicant to provide additional information about the intended export (e.g., information on the end-user, end-use, or technical specifications of the item or technology to be shipped); 2) the reviewing agencies cannot agree on the disposition of the application, and the case is escalated to the Operating Committee (OC); or 3) the case is escalated from the OC to the Advisory Committee on Export Policy (ACEP).

The average processing time for export license applications for machine tools controlled by ECCNs 2B001b.2 and 2B001.c.2 was 45 EO days (70 calendar days) for years 2001-2007, which is significantly longer than the average processing time of 32 EO days for all export license applications received by BIS during this time period. Figure *3* below identifies the average number of EO days and calendar days for the processing of export license applications for each of the top five destinations and an "Other" category (representing the other 22 destinations) for years 2001-2007.

For most destinations, BIS issued export licenses for these types of machine tools two and one half months after an application was submitted, on average. However, as Figure *3* shows, licenses for China were issued roughly three and one half months after an application was submitted, on average. In fact, of the 33 export licenses issued for China from 2001-2007, 11 (33%) were issued five months or more after the export application was submitted.

Figure 3: Average Number of Executive Order and Calendar Days for Processing of Certain Machine Tool Export License Applications by Top Destinations for 2001-2007

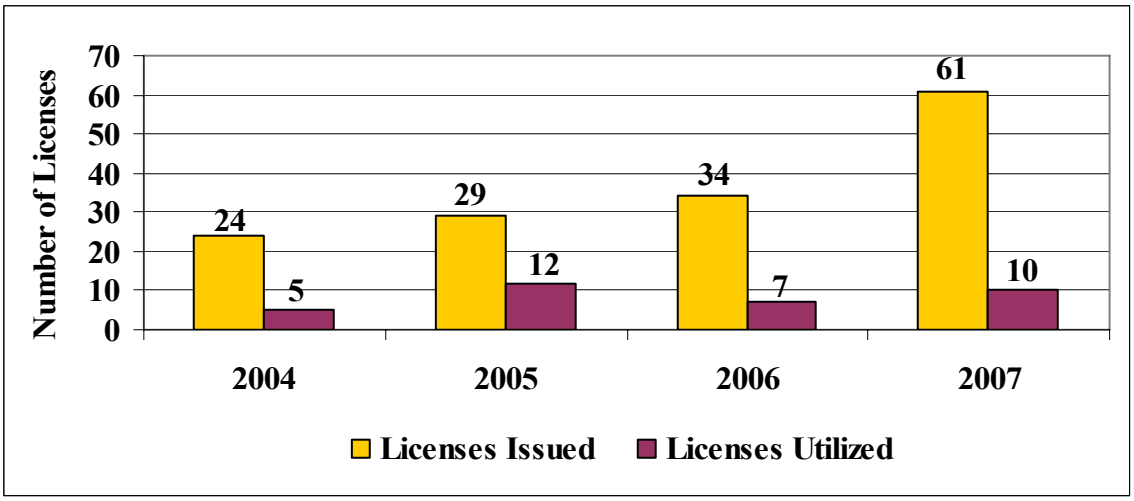


Source: ECASS

BIS does not require export license applicants to obtain a purchase order prior to issuing an export license. Therefore, the number of licenses issued and the dollar value noted on these licenses is not a true measure of the number of five axis machine tools that are actually exported. Despite these caveats, an examination of shipping data, as detailed in Figure *4*, shows that many

of the export licenses BIS issued for the export of five axis machine tools from 2004-2007 were never utilized, or have yet to be utilized.[6]

Figure 4: Number of BIS Export Licenses for Five Axis Machine Tools Issued in 2004-2007 Utilized by Exporters



Sources: U.S. Census Bureau, ECASS

In fact, only 23 percent of the licenses BIS issued during this time period have been utilized, representing $23.4 million in actual exports out of the total of $62.6 million authorized (37.4%).

Ninety of the 148 export licenses approved in 2004-2007 (60.8%) were issued to the same company, which only utilized 6 of the 90 licenses. If this company is not included in the comparison of licenses issued versus licenses utilized, the utilization rate rises to 48 percent, which is roughly the same percentage of utilization for all export licenses BIS issues for commodities, but means that applicants are still exporting less than half of the machine tools for which they have received shipping authorization.

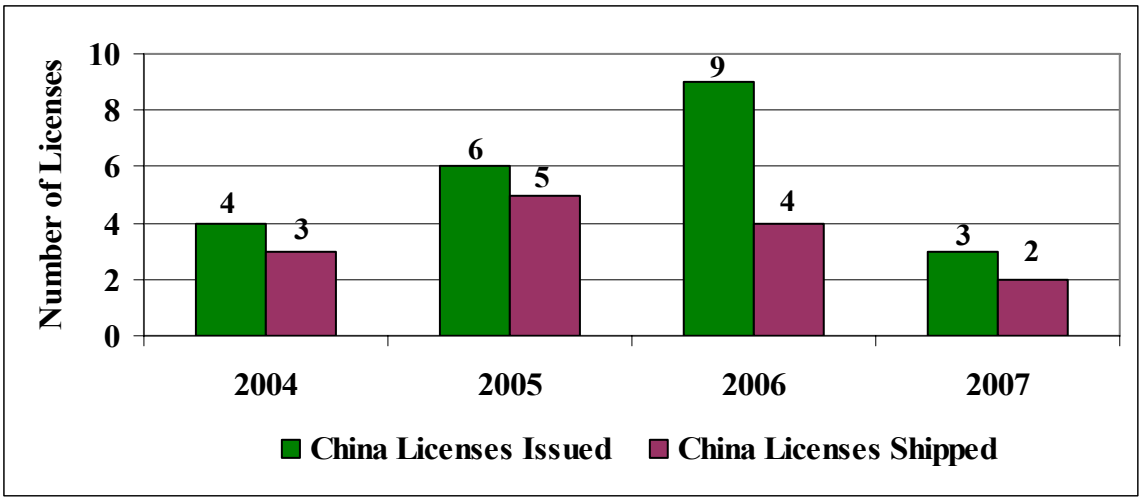
BIS surveyed U.S. producers and distributors of five axis machine tools and asked why so many of these licenses were not utilized. Many respondents indicated that the customer cancelled the sale after the export license was obtained or bought a competitor's product. One Chinese customer cancelled a sale because it took the U.S. company seven months to obtain an export license, and in the end the license conditions were too extreme in the customer's view.

Figure *5* shows those licenses that were issued and shipped against in 2004-2007 for the export of five axis machine tools destined for China. From 2004-2006, there is an increase in the number of licenses issued, but 2006 shows the beginning of a decrease in the number of machine tools shipped, and 2007 shows that only three licenses were issued for China compared to the

[6] BIS only has partial shipping data statistics for those export licenses issued prior to 2004; thus data for licenses issued in years 2001-2003 is not included. BIS licenses are valid for two years in most cases, meaning an export license issued on June 1, 2004 could be shipped against until June 1, 2006. Therefore, some of the licenses BIS issued in 2006 and 2007 reflected in Figure *3* may still be utilized by the exporters until they expire in 2008 or 2009, but historical trends show that the likelihood of utilization decreases as time passes and it gets closer to the expiration date of the license.

nine issued in 2006. This data is consistent with exporters' claims of lengthy processing times and burdensome licensing conditions that not only lead to lost sales, but also appear to discourage U.S. exporters from even trying to obtain licenses for the export of these advanced machine tools. As one exporter noted, "The costs associated with the uncertainty of obtaining a license, [and] the protracted process and impact on customer relations offset the financial rewards of pursuing the [five axis] business."

Figure 5: Number of BIS Export Licenses for Five Axis Machine Tools Destined for China Issued in 2004-2007 Utilized by Exporters



Sources: U.S. Census Bureau, ECASS

2. Impact of Export Controls

The few remaining five axis machine tool producers in the United States have stated that export controls are affecting their ability to export these tools and remain competitive globally. Many foreign competitors are able to obtain licenses for five axis machine tools of the same or superior quality as U.S. machine tools from European and Japanese Governments much more quickly than U.S. companies, sometimes in half the time, and in many cases with fewer restrictive export license conditions. One U.S. five axis machine tool producer surveyed by BIS "believes that foreign entities with knowledge of the multi-axis simultaneous control machine tool industry view the U.S. export control policies and requirements as an additional burden to consider when dealing with U.S. multi-axis machine tool manufacturers. Consequently, the U.S. multi-axis machine tool manufacturer's products must possess an extraordinary amount of appeal or distinction in the market to offset that perceived burden. To date (this U.S. producer) is still struggling to re-establish a presence in the multi-axis simultaneous control machine tool markets."[7] As discussed in Section V.C.2 later in this report, U.S. producers have not been able to remarkably distinguish their machine tools from those offered by foreign manufacturers.

Seventy five percent of the U.S. five axis machine tool producers surveyed indicated that they are adversely affected by U.S. export controls, especially when trying to export to China. When asked to estimate the amount of five axis machine tool sales lost due to U.S. export controls, U.S.

[7] *2008 BIS Machine Tool Survey.*

producers surveyed estimated a total loss of $95.8 million in sales between 2005 and 2008. One company reported its loss during this time period as $65 million (68% of total lost sales estimated by producers). Most of these lost potential sales were destined for China and Russia, with German and French machine tool producers frequently proving the alternate suppliers.

B. Foreign Export Control Practices

Member countries of the WA and/or the NSG must have an effective export control system and control items (e.g., via license) on the corresponding lists with the objective of preventing the unauthorized transfer or retransfer of those items. The details of how these export control systems work are left to the members' national discretion, giving rise to questions about the comparative effectiveness of these control systems, especially in comparison to the United States.

Interviews with exporters, foreign trade associations, and foreign government officials at machine tool shows have confirmed that export controls put in place and enforced by other regime members are comparable to U.S. export regulations. Other regime members require the same information from export license applicants and follow relatively the same standard operating procedures as do BIS export licensing officers, including the referral of export license applications through several government agencies (e.g., defense, commerce, foreign affairs, and intelligence) prior to making a determination. Areas where member countries differ dramatically include the openness of communication between exporters and government officials and the time each foreign government takes in processing its export license applications.

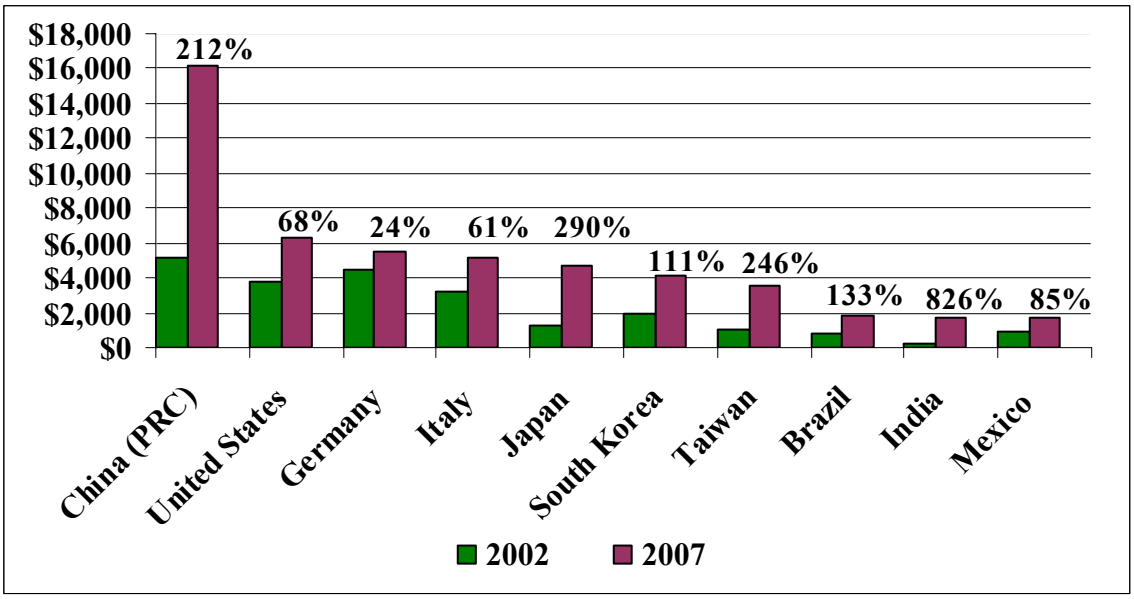
According to representatives from several U.S. and non-U.S. machine tool companies, foreign competitors may be provided preliminary information from export control authorities (whether officially or unofficially) about the likelihood of government approval of a particular export license application. This allows them to confidently guarantee a customer that it will receive an export license at the time of sale. U.S. companies and U.S. export licensing officials do not have this relationship, which means that a U.S. exporter has no indication as to whether or not the license will be approved, and can only tell their customers that a license application has been submitted. The customer may wait several months only to find that the license was not approved or that additional information is needed.

The amount of time it takes for the USG to make a determination on a license application is comparable to that in other regime member countries, with two very important exceptions: 1) in comparison with Swiss processing times; and 2) in comparison with other regime members' processing times for licensed exports to China. The Swiss are by far the most expeditious in their processing of export license applications, with an average processing time of two to four weeks, although some applications do take significantly more time. Exporters interviewed at the 2007 Exposition Mondiale de la Machine Outil (EMO) machine tool show in Hanover, Germany indicated frustration at being beat to sale by their Swiss competitors due to the Swiss advantage in license processing times.

With respect to licensing to China, U.S. exporters of five axis machine tools are most disadvantaged compared to other regime members. Referring back to Figure *3*, U.S. export

licenses for five axis machine tools destined for China were issued roughly three and one half months after an application was submitted, on average; 33 percent of these export licenses were issued five months or more after the initial application was filed with BIS, and recently, one U.S. company waited 12 months for one export license and 18 months for another. Compared to the two to four weeks that Swiss companies wait, and the three months that European and Japanese companies wait, on average, U.S. export controls are likely a contributing factor behind the low number of sales (i.e., 14 five axis machine tools) to China in the past four years. China is the fastest growing market for machine tools, as indicated in Figure *6*, while U.S. exporters wait the longest for approvals of export licenses to this destination.

Figure 6: Global Machine Tool Consumption 2002 and 2007 ($ Millions)[8]



Source: AMT

In addition, greater informal feedback from foreign governments to companies and shorter license processing times may further put U.S. exporters at a significant disadvantage. Shorter export license processing times is even used by foreign competitors in their marketing campaigns as a reason to buy their machine tool rather than one from the United States. In fact, several European machine tool companies have been seen to have booths at machine tool shows with advertisements indicating that buyers can avoid lengthy U.S. export license approval times and burdensome license conditions by purchasing their machine tool rather than one from a U.S. company. According to U.S. industry, lengthy license reviews, in combination with lack of customer assurance of the likelihood of approval of an individual license, result in lost sales for many U.S. exporters.

C. Non-Diversion and Anti-Tampering Efforts

A major concern with five axis machine tools is the possibility that they will be diverted or altered in order to machine items for unauthorized military uses. Many companies worldwide,

[8] Includes all finished machine tools excluding parts and accessories.

including Mori Seiki Co. Ltd., Yamazaki Mazak Corp., Matsuura, Okuma Corporation, and Citizen Machinery Co., Ltd. have developed and installed automatic movement detection devices that will render their machine tools inoperable if physically moved from the location of installation.[9] Over the years, many U.S. and non-U.S. companies have developed means for monitoring the specifications and types of products their customers are machining using their five axis machine tools. The connectivity of CNCs to the Internet for on-line diagnostics and data transfer between machine tool sellers and purchasers has greatly permitted companies to access their customers' machining specification data. This ability to check-in on what a machine has been doing provides companies and the USG with an additional level of assurance that the machine tool is being used for its intended purpose. However, as noted later in Section VII.B of this assessment, CNC connectivity with the Internet can have adverse national security consequences if measures are not taken to mitigate the risks of unauthorized access to the data stored in the CNC.

V. Economic Status

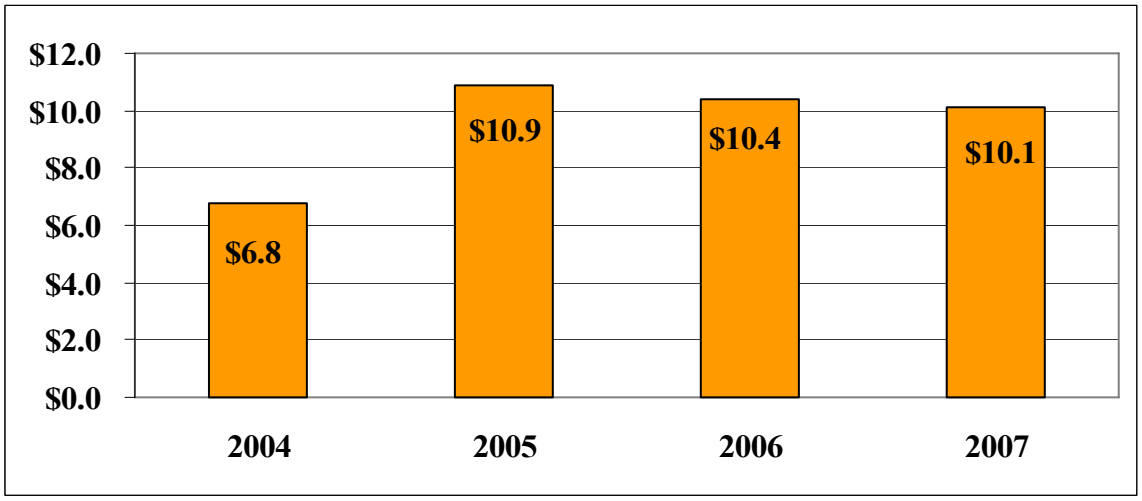
For the purpose of this assessment, BIS conducted an economic analysis of U.S. export growth and global market share data of certain types of five axis simultaneous control machine tools (i.e., mills, grinders, mill/turns, and machining centers), and conducted a comprehensive survey of U.S. producers, distributors, and end-users of such machine tools to gauge the health and competitiveness of the U.S. industry. Using the survey responses of U.S. end-users, BIS also calculated projected domestic demand for these types of machine tools for the next several years.

A. U.S. Export Growth and Global Market Share

Five axis simultaneous control machine tools are a very small segment of a much larger machine tool industry, and this assessment focuses only on mills, grinders, mill/turns, and machining centers. Whether these machine tools require individual licenses under ECCNs 2B001.b.2 and 2B001.c.2 of the EAR or not generally depend on the destination of their export. Using Bureau of Census data from the Automated Export System and BIS export licensing data from 2004 to 2007, BIS identified the value of licensed exports of five axis simultaneous control machine tools relevant to this assessment. Figure *7* indicates that after a significant increase between 2004 and 2005, relevant licensed exports have slightly declined from 2005 to 2007.[10]

[9] FujiSankei Business, "*Machine Tool Manufacturers Accelerating the Installation of Device to Prevent Machine Movement and Prevent Diversion for Use in the Manufacture of Weapons"*, 22 October 2007.
[10] Figure *7* reflects licensed exports on an annual basis, which may represent several years of export licenses.

Figure 7: Licensed Exports of Relevant Five Axis Simultaneous Control Machine Tools for 2004-2007 ($ Millions)



Sources: U.S. Census Bureau, BIS

Requiring a reliable measure of comparing U.S. and global exports of five axis simultaneous control machine tools, BIS identified relevant Harmonized Tariff Schedule (HTS) data at the 10 digit level, the most detailed level of categorization. Sources for this data included licensed export data from the Bureau of Census, survey response information provided to BIS in its industrial base survey by 20 producers and more than 100 U.S.-located five axis simultaneous control machine tool distributors, and AMT's 2008 report on the Chinese machine tool industry.[11]

Table *b* shows several of these 10 digit HTS codes against which licensed exports of five axis simultaneous control machine tools were shipped in 2007, and illustrates that only two and one half percent of total exports under these HTS codes represent relevant licensed exports.

[11] Even at the 10 digit level, these HTS codes still include many more machine tools than are relevant to this study, including three and four axis machine tools and even non-CNC machine tools.

Table b: Ten Digit HTS Codes Corresponding to 2007 Licensed Exports of Five Axis Simultaneous Control Machine Tools

HTS Code	Value of Total HTS Code Exports	Value of Relevant Licensed Exports	% of Relevant Licensed Shipments
8457100005	$33,817,596	$1,160,580	3.4%
8457100015	$246,436,009	$744,600	0.3%
8457100039	$35,317,124	$1,169,400	3.3%
8457200010	$12,922,620	$130,000	1.0%
8457200090	$6,974,606	$136,605	2.0%
8459290010	$3,568,993	$53,213	1.5%
8459610040	$7,128,713	$130,000	1.8%
8459610080	$21,524,395	$5,451,000	25.3%
8460210080	$34,117,654	$1,086,720	3.2%
Total	**$401,807,710**	**$10,062,118**	**2.5%**

Sources: U.S. Census Bureau, BIS, Global Trade Atlas

HTS codes are harmonized between all countries only at the six digit level. In order to compare U.S. and global trade data, BIS converted all of the relevant 10 digit HTS codes to six digit level form. These 14 six digit level HTS codes are the principal macro from which BIS assessed relevant five axis simultaneous control machine tool export patterns abroad.[12]

Table *c* shows how these machine tool exports more than doubled globally from 2002-2007, rising 115 percent from eight to $17 billion. Leading nations in the export of these machine tools, in descending order, included Germany, Japan, Taiwan, and Italy. Each of these four exporter nations had more than one billion in total annual dollar exports in 2007.

Table c: Leading Global Exporters of Machine Tools Represented by Relevant 14 HTS Codes 2002-2007(in $ millions)

Country	2002	2003	2004	2005	2006	2007
Germany	$2,114	$2,481	$2,979	$3,295	$3,795	$4,382
Japan	$1,590	$2,182	$2,599	$3,168	$3,476	$3,846
Taiwan	$549	$654	$904	$1,046	$1,231	$1,545
Italy	$829	$922	$1,122	$1,081	$1,247	$1,516
Switzerland	$547	$533	$621	$727	$827	$877
United States	$594	$522	$570	$599	$760	$740
South Korea	$133	$215	$285	$284	$364	$478
Czech Republic	$142	$150	$231	$267	$292	$438
Spain	$239	$266	$251	$279	$321	$405
China	$104	$129	$149	$185	$258	$400
Global Total	**$7,971**	**$9,407**	**$11,206**	**$12,641**	**$14,368**	**$17,170**

Source: Global Trade Atlas

[12] The 14 HTS codes at the six digit level representative of five axis simultaneous control machine tools examined in this assessment include: 845710, 845720, 845730, 845921, 845929, 845931, 845940, 845951, 845961, 845969, 846021, 846031, 846490, 846510.

Based on 2007 data, the United States is sixth, with four percent of the global value of exports. Behind the United States in the tenth position lies China. This 2007 ranking introduced China to the top 10 list of leading export nations.

China proved the fastest growing exporter nation across all reporting years and countries at 32 percent, on average, followed by South Korea (31%) and Taiwan (23%). Germany and Japan, in each of the last five years, combined for at least 50 percent of these global machine tool exports. Although Germany's and Japan's respective market shares declined in the reporting period, each maintained double-digit growth rates.

For every dollar exported by the United States, five dollars is exported by Germany and four dollars by Japan. This ratio has been maintained across all reporting years, from 2002-2007. Indeed, prospects for the United States retaining the sixth export market share position in 2008 are low, primarily due to faster export growth rates across European and Asian countries, as detailed in Table *d*.

Table d: Net Change in Global Market Share and Percent Net Change in Export Value for Machine Tool Exports Represented by Relevant 14 HTS Codes (2002-2007)

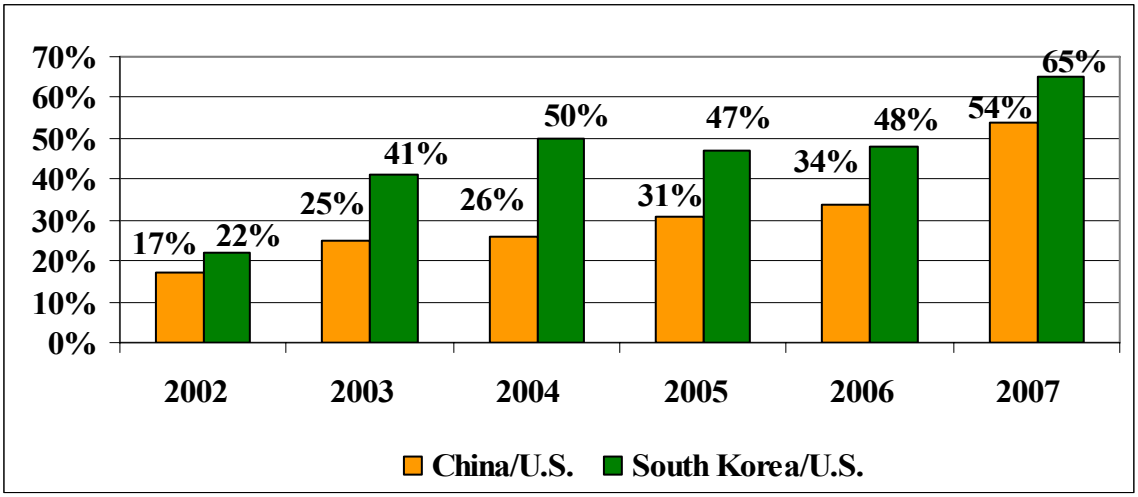
Country	Net Change in Market Share	Percent Net Change in Export Value
Germany	-1.0%	107.3%
Japan	2.5%	141.9%
Taiwan	2.1%	181.4%
Italy	-1.6%	82.9%
Switzerland	-1.8%	60.3%
United States	-3.1%	24.6%
South Korea	1.1%	259.4%
Czech Republic	0.8%	208.5%
Spain	-0.6%	69.5%
China	1.0%	284.6%

Source: Global Trade Atlas

To further illustrate the decline in U.S. dollar exports of CNC machine tools as compared to competitors in China and South Korea, the proportional export relationship between these nations merits analysis, providing a clear indication of Asia's rapidly rising market position. For instance, for every dollar exported by the United States in 2002, $0.17 was exported by China. By 2007, for every dollar exported by the United States, China was exporting $0.54. These incremental, elevated rates in proportion to U.S. exports suggest a forthcoming parity between the two countries in the next five to ten years.

Prospects for export parity between South Korea and the United States actually represents a more immediate and likely more competitive circumstance than presented by China, at least in the near term. The pace of South Korea's exports in metal cutting CNC machine tools proved similar to China's. Proportionally, however, South Korea displayed a more robust dollar profile than China.

Figure 8: Percentage of China and South Korea Exports to U.S. Exports 2002-2007



Source: Global Trade Atlas

For every dollar exported by the United States in 2002, $0.22 was exported by South Korea. By 2007, for every dollar exported by the United States, South Korea was exporting $0.65. Behind Taiwan, which surpassed the United States in net dollar exports in 2003, South Korea is the most immediate Asian challenger to the U.S. global position.

B. Health and Competitiveness of the U.S. Industrial Base

Despite significant declines in global machine tool market share over the last 20-30 years, the United States retains the capability, although limited, to manufacture five axis simultaneous control mills, mill/turns, grinders, and machining centers. Due to a combination of factors, including lower production costs, public-private partnerships, and heavy investment in research and development, countries like Japan and Germany have largely supplanted U.S. manufacturer leadership in this area.

To better understand the health and competitiveness of the industrial base and prospects for its recovery in the global marketplace, BIS, with the assistance of industry and government stakeholders, identified and performed a robust survey-based assessment of 129 producers and distributors of five axis simultaneous control machine tools in the U.S market. In their survey responses, these producers and distributors identified 78 domestic end-users (i.e., customers) that BIS subsequently also surveyed. This section is principally concerned with producer and distributor survey results. End-user related findings and impacts are contained in Section V.C.

1. Defining U.S. Producers

The machine tool industry, like many industries, has experienced a number of mergers, consolidations, buy-outs, and bankruptcies. As a result, BIS defined the following U.S. and non-U.S.-owned manufacturers of five axis simultaneous control machine tools as U.S. producers for the purpose of this study:

Table e: U.S. Five Axis Simultaneous Control Machine Tool Producers

Company	U.S. Parent	U.S. Subsidiary of a Non-U.S. Parent
Ametek Precitech Inc.	X	
Bertsche Engineering Corp.	X	
Cincinnati Machine LLC		X
Fadal Machining Centers LLC		X
Giddings & Lewis Machine Tools, LLC		X
Grob Systems, Inc.		X
Haas Automation Inc.	X	
Hardinge, Inc.	X	
Heller Machine Tools LLP		X
Hurco Companies, Inc.	X	
Ingersoll Machine Tools, Inc.		X
M D Tool DBA Dayton Machine Tool	X	
Makino Incorporated		X
Mazak Corporation		X
Milltronics	X	
Monarch Machine Tool, Inc.	X	
Okuma America Corporation		X
OptiPro Systems	X	
PMT Group	X	
Thermwood	X	

Source: Websites

U.S.-owned five axis simultaneous control machine tool manufacturers comprise roughly half of the total production capability of these types of machine tools in the United States. A few companies, namely Haas and Hurco, have machine tool production facilities outside of the United States, but the majority of U.S.-owned producers manufacture only domestically.

Over the last several years, the number of U.S.-owned five axis machine tool producers has decreased as foreign entities have acquired U.S. firms. The most notable of these consolidations involved the acquisition of three U.S. producers – Cincinnati Machine, Fadal, and Giddings & Lewis – by German conglomerate MAG-Industrial Automation Systems. Similarly, Ingersoll Machine Tools of Rockford, Illinois, the former part of Ingersoll USA with a five axis simultaneous control machine tool manufacturing capability, was acquired in 2003 by the Camozzi Group of Italy after Ingersoll USA filed for bankruptcy. While the country of ownership changed hands for all four of these firms, the location of U.S. production facilities related to these types of machine tools did not.

Five non-U.S.-owned companies with five axis simultaneous control machine tool production facilities in the United States make up the remaining domestic producers of these types of machine tools. Heller Machine Tools and Grob Systems are both German-owned companies with production in the United States. The three remaining companies are all Japanese-owned: Okuma America has operated in Charlotte, North Carolina since 1987; Mazak, owned by the

Yamazaki Mazak Corporation, has had operations in its Florence, Kentucky facility since 1974 and has several regional technical centers located across the United States; and Makino is the third Japanese-owned company with production in Mason, Ohio.

2. Producer and Distributor Machine Tool Sales

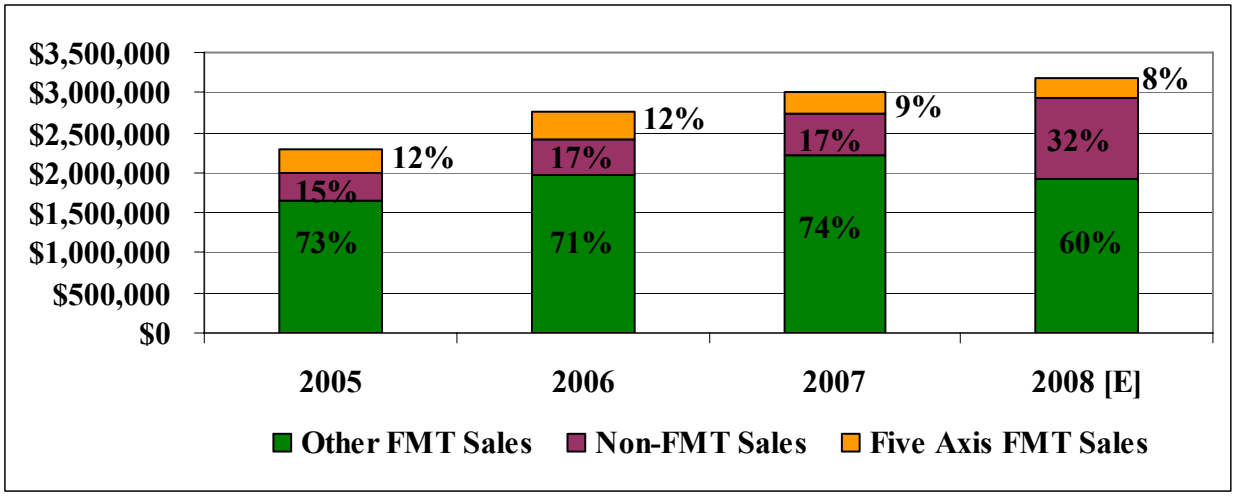
BIS requested from producers and distributors a break-out of domestic and export sales information, including overall machine tool sales, five axis simultaneous control machine tool sales, and the proportion of these five axis sales dedicated to commercial, government, and non-profit customers. The sales data was reported on an annual basis from 2005-2008. Due to the risk of double counting posed by collecting sales information from both producers and distributors, as some producers sell through distributors and others directly to their customers, sales figures in this section are reported and analyzed separately.

a. Producer Sales

There are 20 domestic manufacturers *capable* of producing five axis simultaneous control machine tools, all of which were included in the BIS survey sample. These manufacturers represent four percent of the 550 machine tool firms in the United States, and 42 percent of U.S. machine tool manufacturers with 100+ employees.[13]

From 2005-2008, net operating revenues (i.e., net sales), in aggregate, increased 40 percent from $2.3 to $3.2 billion, but annual net sales growth rates declined from 21 percent in 2005-2006 to six percent by the end of the period. These net sales figures represent the aggregate business lines reflected in these producers' income statements, including finished machine tools (FMT) and parts, components, and services as reflected in Figure *9.*

Figure 9: Distribution of Producer Net Sales 2005-2008



Source: 2008 BIS Machine Tool Survey

[13] There are 33 machine tool manufacturers located in the United States with more than 100 employees [DOC 2002 Census of Manufacturing]. Of the 20 domestic five axis simultaneous control machine tool producers included in BIS's study, 14 reported more than 100 employees.

Producer FMT sales in 2005-2008 rose 12 percent from $1.9 to $2.2 billion. The prospects for continued growth within this group of producers remain low, however, as FMT sales growth rates decreased incrementally from 19 percent growth in 2005-2006 to negative 12 percent in 2007-2008. Additionally, net FMT sales as a proportion of net sales decreased from 85 percent in 2005 to 68 percent in 2008. Due to this reported shift in overall revenue contribution, and the declines also evident in previous years, the proportion of producer revenues dedicated to parts, components, and services will likely increase in the forthcoming years.[14]

Only a handful of U.S. producers actually manufacture subject five axis machine tools in high volume and most generate less than 10 percent of their annual net FMT sales from five axis machine tool business lines. Table *f* shows that from 2005-2008, total producer sales of five axis simultaneous control machine tools declined 11 percent from $284 to $253 million. This decline can be attributed to a 19 percent decrease in domestic sales of these machine tools during this time period. Exports of these machine tools represented only 10 percent of net FMT producer exports in 2008, but the growth rate of these exports during this same time period actually jumped by 38 percent from $42 to $58 million, more than double that of the 17 percent increase in total FMT exports for these producers. This increase in the growth rate of exports of five axis machine tools during this time period was largely due to increased exports to France, Canada, Italy, Denmark, and South Korea, all countries for which a BIS export license is not required.

Table f: U.S. Producers Sales (in $ millions) 2005-2008

	2005	2006	2007	2008 [E]	% of 2008 Net Sales	2005-08 % Δ
Total Net Sales	$2,282	$2,759	$2,995	$3,188	NA	39.7%
Total FMT Sales	$1,941	$2,300	$2,477	$2,168	68.0%	11.7%
U.S. Sales	$1,455	$1,712	$1,740	$1,598	50.1%	9.8%
Exports	$486	$588	$737	$571	17.9%	17.4%
Total Five Axis Sales	$284	$336	$270	$253	7.9%	-10.9%
U.S. Sales	$242	$290	$213	$195	6.1%	-19.2%
Exports	$42	$46	$56	$58	1.8%	37.7%
Non-FMT Sales	$341	$459	$518	$1,020	32.0%	199%

Source: 2008 BIS Machine Tool Survey

The viability of producers is not attributed to increased sales in five axis machine tools. Rather, non-five axis machine tool sales, in addition to sales of parts, components, and after-market services, have proven the primary source of revenue growth and profitability in recent years. Indeed, in the aggregate, five axis machine tool sales fell annually from 12 percent of producer net sales in 2005 to eight percent in 2008. This reveals a shift in product-mix among producers and a reluctance of manufacturers to rely on five axis machine tool sales to drive core revenue.

b. Distributor Sales

The 109 participating U.S. distributors in the BIS survey accounted for between $1.7 and $2.2 billion in annual FMT sales across all reporting years. Distributor FMT sales climbed 15 percent

[14] Producer and distributor surveys were submitted to BIS through Q2 2008. Estimates were requested of producers/distributors for the remaining 2008 quarters to provide complete annual figures.

in the 2005-2008 period. BIS found that distributors are net importers of machine tools, and thus, as anticipated, most of their FMT sales (98%) were to domestic customers.

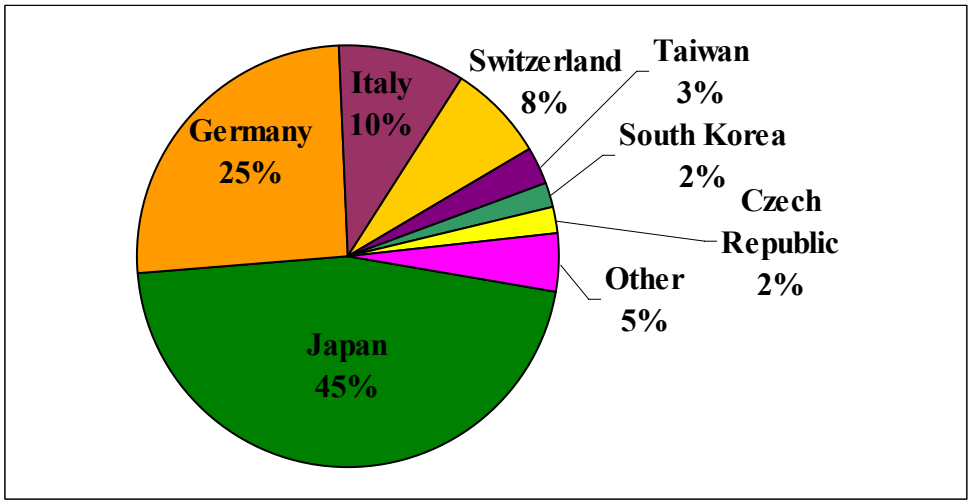
Table g: U.S. Distributor Sales (in $ millions) 2005-2008

	2005	2006	2007	2008 [E]	% of 2008 Total FMT	2005-08 % Δ
Total FMT Sales	$1,706	$2,039	$2,182	$1,963	NA	15.1%
U.S. Sales	$1,680	$1,999	$2,130	$1,913	97.5%	13.9%
Exports	$25	$39	$51	$51	2.6%	104.0%
Total Five Axis Sales	$230	$303	$331	$243	12.4%	5.7%
U.S. Sales	$224	$298	$324	$230	11.7%	2.7%
Exports	$6	$4	$7	$13	0.7%	116.7%

Source: 2008 BIS Machine Tool Survey

Distributor sales of five axis simultaneous control machine tools in the United States increased by 2.7 percent from 2005 to 2008. Roughly 80 percent of the five axis machine tool *models* distributors reported selling during this time period were imported from abroad for distribution in the United States, with Japanese and German machine tools making up the majority of imported models, as shown in Figure *10*. Distributors represented 16 percent of total annual U.S. five axis machine tool exports—nine percent by unit volume. Most of these machines, primarily headed to Canada or Mexico, were exported by three distributors of non-U.S.-made machine tools.

Figure 10: Percentage of Five Axis Simultaneous Control Machine Tool Models Imported from 2005 to 2008 by Country of Origin



Source: 2008 BIS Machine Tool Survey

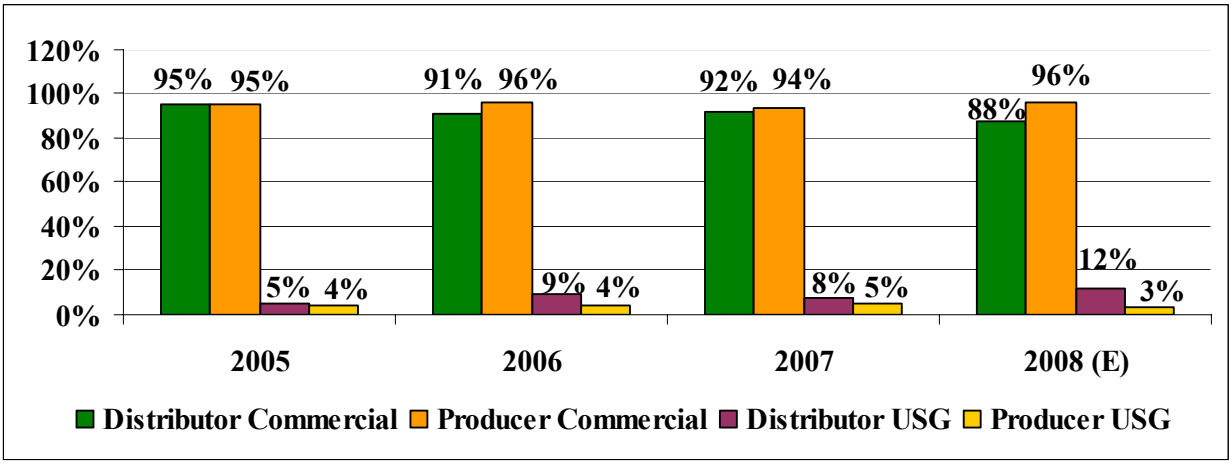
Much like producers, non-five axis machine tool sales have driven distributor FMT revenues, ranging from 85-88 percent of their aggregate FMT sales. Nevertheless, five axis machine tool distributors, most of which are selling only non-U.S. five axis machine tool models, have clearly positioned themselves more effectively in the domestic market.

The growth rate of distributor domestic five axis simultaneous control machine tool sales in 2005-2008 was three percent. This compares to a precipitous decline of 20 percent in domestic sales among U.S. producers over the same 2005-2008 period.

c. Customer Make-Up

BIS also asked producers and distributors to breakout their five axis simultaneous control machine tool sales for 2005-2008 by commercial and USG customers. Among producers and distributors, the majority of five axis buyers consisted of commercial end-users, but the proportion of total sales devoted to USG sales contrasted sharply, as shown in Figure *11*.

Figure 11: Breakout of Producer and Distributor Sales of Five Axis Simultaneous Control Machine Tools by Commercial v. U.S. Government Sales 2005-2008



Source: 2008 BIS Machine Tool Survey

In sharp contrast to producers, distributors maintained a rapidly growing share of USG five axis revenues. Distributor five axis sales to USG customers increased as a proportion of total five axis machine tool sales from five percent in 2005 to 12 percent in 2008, whereas producer sales to USG customers decreased from four to three percent over the period. As previously mentioned, distributors are net importers of these type of machine tools, which indicates an increasing USG preference for foreign-made versus domestic machine tools of this type.

d. U.S. Government Contracts

Historically, the U.S. machine tool industry and the USG, especially the DOD, have collaborated closely in the areas of materials processing, manufacturer assembly, and industrial applications. No longer global leaders in machine tool manufacture, some producers remained reliable suppliers of five axis simultaneous control machine tools to the USG and its affiliated contractors from 2005 to 2008. Furthermore, the rising importance of foreign-made machine tools in support of USG requirements has elevated the role of distributors in the public sector supply chain.

To better assess the impact of USG purchasing on the viability of the U.S. five axis simultaneous control machine tool industrial base, including its domestic production and distribution

segments, BIS asked producers and distributors to provide information on USG sales from 2005-2008.

Only nine of the 20 producers bid on USG requests for proposal (RFP/RFQ) during this time; six were awarded contracts, but 93 percent of the contracts were awarded to only two producers.[15] Nevertheless, 86 of the 120 bids (72%) submitted to the USG by producers in 2005-2008 were awarded. The reasons some producers did not participate in USG RFPs/RFQs included simply a lack of USG tenders, the limited scope of products manufactured, or a focus on automotive industry requirements. Moreover, for three producers, only their distributor network would respond to USG RFPs/RFQs. However, most, if not all, of these distributors were among the respondents BIS pre-identified and included in the survey data collection. Most producers did not have difficulties in the contracting process, but those that did cited instances of USG refusal to entertain milestone payment plans, and the preference for foreign-made machine tools at certain USG facilities.

Only 25 of the 109 surveyed distributors bid on USG RFPs/RFQs from 2005-2008, and 18 distributors were awarded contracts. Fifty eight of the 103 bids distributors submitted to the USG were awarded (56%). The vast majority of distributors who did not submit bids had either not been asked to participate in the process or were simply unaware of the RFPs/RFQs. Some distributors also cited difficulties with USG payment plans, the role of the General Services Administration (GSA) in facilitating RFP/RFQ issuance, and USG restriction of site visits for green card holders.

Most producers and distributors did not indicate having a difficult time identifying USG procurement needs in 2005-2008. Respondents who did report problems recommended the USG introduce more direct RFP/RFQ industry solicitation programs. Lack of information and RFP/RFQ awareness among survey respondents was the most common complaint, and also shaped most respondent process recommendations, including: 1) provision of a single RFP/RFQ industry notification portal on-line; 2) improved access to USG tenders for small- to medium-sized companies; and 3) additional training on USG RFP/RFQ policies and procedures.

The vast majority of surveyed producers and distributors do not rely on USG direct sales to remain viable. Rather, as mentioned in Section V.B.2.c above, commercial purchases are the primary sources of five axis machine tool sales. Nevertheless, BIS recognizes that significant portions of USG-related five axis machine tool applications, like in aerospace or shipbuilding, are contracted-out to domestic industry. Depending on the particular type, application, and cost of a five axis machine tool, moreover, the USG might not need to purchase a five axis machine as part of a federal program if the participating contractor(s) already has one in possession or installed. This intricate and sometimes complex procurement relationship between USG and commercial buyers is articulated in Section V.C.

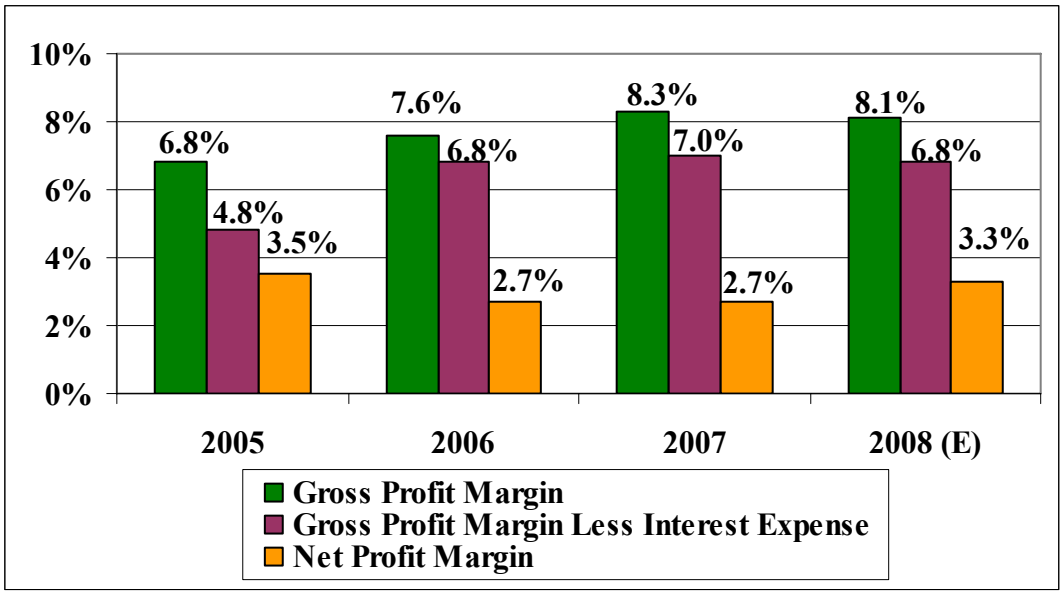
[15] One of the two producers receiving 93 percent of USG contracts during the period has been operating at a loss since 2004.

3. Producer Financial Health and Competitiveness

a. Profitability

In addition to sales and customer information, BIS asked producers to provide financial line items corresponding to the 2005-2008 period. During this period, five axis simultaneous control machine tool producers recorded increased annual gross profit margins, signaling the ability to keep costs controlled and increase sales revenue. However, gross profit margins do not capture the influence of interest expense on earnings and profitability, a critical factor when assessing the health of any capital intensive industry like machine tools, nor do they account for producer tax expense. Figure *12* shows five axis producers incurred a significant impact from interest expenses, but interest expenses as a percentage of gross profit margins have declined 0.7 percent, from 2.0 percent in 2005 to an estimated 1.3% in 2008.

Figure 12: U.S. Five Axis Simultaneous Control Machine Tool Producer Gross Profit, Gross Profit Less Interest Expense, and Net Profit Comparison (median measure)



Source: 2008 BIS Machine Tool Survey

Though net profit margins fell slightly in 2005-2006, across all years net profit margins remained relatively consistent at 3.3 percent on average.

U.S. producers of five axis simultaneous control machine tools have remained largely profitable from 2005-2008, with most firms reporting positive net income in any given year. The few producers operating at a loss remained relatively consistent between years, raising questions of their long-term viability and competitiveness.

b. Debt

Producers are efficient at management of long-term and short-term debt burdens. The debt ratio (total debt/total assets) among participating producers fell from 0.75 in 2005 to 0.45 in 2008.

However, this measure does not account for pension liabilities or lease obligations, so BIS performed additional ratio analyses. To measure how effective these producers are at meeting short-term debt obligations, BIS used average current ratios across all reporting years. Benchmark information was also provided for the aggregate domestic machine tool industry and all of U.S. manufacturing for 2006.

The machine tool industry at large had a current ratio of 2.5 in 2006. This exceeded the average ratio of 2.06 for five axis simultaneous control machine tool producers in 2006, meaning five axis producers, in general, faced a greater burden from short term liabilities than their overall U.S. machine tool peers.[16] Domestic manufacturing as a whole, however, had a 1.4 current ratio in 2006. Therefore, as determined from ratio comparison, U.S. manufacturers overall had greater difficulty meeting short-term debt obligations than the machine tool industry, including five axis simultaneous control machine tool producers.

Producers' reduction of long-term debt has improved on an annual basis, with a decline in the ratio of total debt to total assets from 0.75 in 2005 to 0.45 in 2008. Moreover, incurred interest expenditures proportional to producer gross profit margins also have declined. Despite the pervasive recessionary conditions affecting manufacturer spending and curtailing procurement among select customer segments, favorable lending rates and improved producer debt capacity should help most U.S. five axis machine tool producers persevere.

c. Capital Expenditure

To remain competitive and support ongoing operations, machine tool companies must invest in capital goods like machinery, information technology, and property. BIS requested annual capital expenditure line items from U.S. producers from 2005-2008 corresponding to four broad categories of investment.[17] As a percent of revenue, capital expenditures steadily increased over this time period (five to ten percent annually), from 0.96 percent in 2005 to 1.58 percent in 2008, likely due to increased demand, improved profit margins, increased debt capacity, and an overall improvement in liquidity.

Table *h* shows the breakout of aggregated capital expenditure for these producers over this time period across four categories: 1) Machinery, Equipment, and Vehicles; 2) Land, Buildings, and Leasehold Improvements; 3) Information Technology; and 4) Other.

Table h: Net Five Axis Simultaneous Control Machine Tool Producer Capital Expenditure Average Allocations 2005-2008

Categories	2005	2006	2007	2008 (E)
Machinery, Equipment, and Vehicles	56%	58%	54%	55%
Land, Buildings, and Leasehold Improvements	6%	21%	24%	18%
Information Technology	24%	16%	13%	17%
Other	3%	5%	5%	4%

Source: 2008 BIS Machine Tool Survey

[16] Benchmark domestic machine tool and manufacturing ratios for 2006 established with U.S. Census Bureau "Quarterly Financial Report for Manufacturing Corporations" and AMT data.

[17] The four categories of capital investment defined in the BIS survey mirrored those used in AMT's 2007 Financial Performance Survey.

For any given year during this time period, roughly 50 percent of producer net capital expenditures were for purchases of machinery, equipment, and vehicles. The second largest concentration of capital expenditure was in land, buildings, and leasehold improvements, despite the fact that most producers did not invest in this area during this time period. However, producers who did invest here in 2005-2008 normally spent 30 percent or more of their capital expenditure in this area.

Producers investing in information technology allocated roughly 23 percent of their capital expenditure budget to this category, reporting a sizeable increase in 2008. BIS did not identify the other capital expenditures reported by producers out of concern that doing so would either easily identify the individual producer or reveal proprietary information.

Producer capital expenditures outpaced net operating revenue growth in 2005-2008. This proportional rise portends of increased demand for select U.S.-built machine tools, improved margins, increased debt capacity, and better overall manufacturer liquidity.

d. Competitiveness

BIS, in coordination with industry and the USG, established a list of 19 parameters relating to five axis simultaneous control machine tool quality to better establish the competitive advantages and disadvantages of the U.S. five axis machine tool industry. BIS then asked producers to identify those areas where they hold a competitive advantage and disadvantage as compared to their foreign competitors. Table *i* shows their responses listed in descending order of frequency.

Table i: Categories of Competitive Advantage as Identified by U.S. Producers and Distributors for 2005-2008

U.S. Competitive Advantage	U.S. Competitive Disadvantage
Machine rigidity and/or durability	CNC IS/IT network/interface
Lifespan of machine	Precision/Repeatability
Thermal stability and control	Rotary table make
Service and support	Materials of construction
Precision/Repeatability	Spindle speed/durability

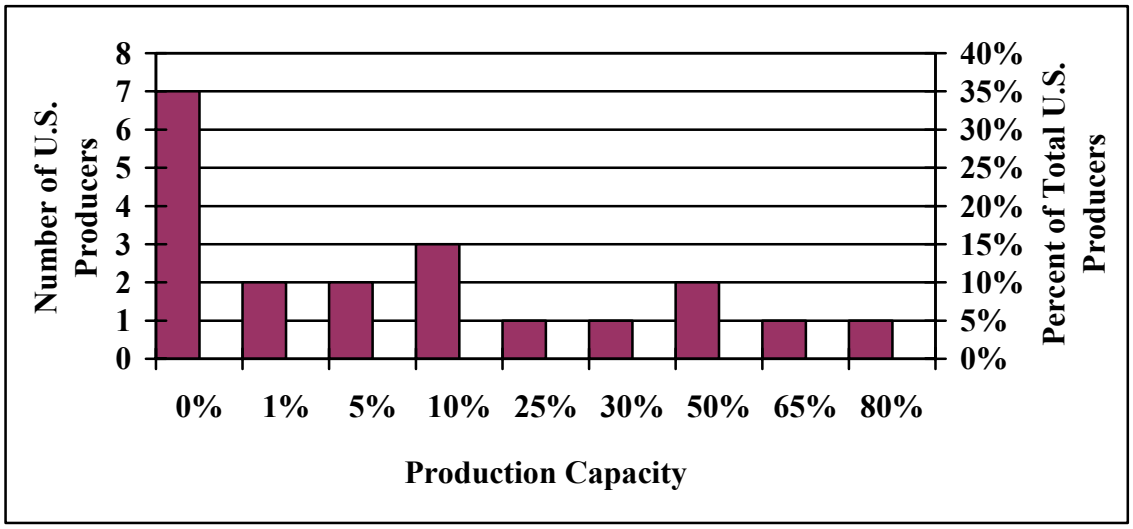
Source: 2008 BIS Machine Tool Survey

4. Production and Supply Chain

a. Capacity Utilization

BIS asked producers to report the percent of their current (2008) production capacity dedicated to the manufacture of five axis simultaneous control machine tools. Figure *13* indicates that only six producers have 25 percent or more of their current production capacity dedicated to these types of machine tools. The remaining producers have dedicated a small percentage of their production capacity or are not currently producing any of these types this year.

Figure 13: Percentage of Production Capacity Dedicated to Five Axis Simultaneous Control Machine Tools by U.S. Producer for 2008



Source: 2008 BIS Machine Tool Survey

Some of these producers shifted production to other machine tool lines temporarily until the export market proved more viable, while others are manufacturing five axis machine tools abroad until domestic production costs decline. One surveyed producer stated, "My company currently does not produce a five axis machine in the United States. We are in the process of evaluating if we should be producing in the United States. That determination will be made prior to the end of 2008...U.S. export restrictions on five axis machines may negatively impact that decision."

BIS asked distributors to identify the percent of their import volume dedicated to five axis machine tools in 2008. Only 15 percent of the distributors responding to this question reported that over half of their import volume was devoted to these machine tools. In fact, 65 percent of these distributors attributed less than 5 percent of their import volume to five axis machine tools, and 63 distributors did not import any of these machine tools in 2008.

Most of the production capacity among producer participants is dedicated to non-five axis machine tools. In fact, seven of the 20 producers did not produce any five axis machine tools in 2008.

Furthermore, among domestic distributors, most of the 109 surveyed companies do not import five axis machine tools. In fact, only 43 percent imported five axis machine tools in 2008, and among these companies, as a percentage of finished machine tool imports, most dedicated only between 10 to 20 percent to five axis simultaneous control machine tools.

b. Build Time

To better understand and compare U.S. and non-U.S. manufacturing processes, producers and distributors were asked for estimated build times for all of the five axis simultaneous control machine tool models they produced and distributed from 2005-2008. BIS distinguished custom

built models from standard models in performing its analysis, and also disaggregated domestically produced and imported five axis machine tool models. Information was provided on 477 distinct five axis models, 96 of which were produced in the United States and 381 that were imported.

BIS found that U.S. producers take almost twice as long as foreign producers to manufacture custom built models, on average. However, as shown in Table *j*, U.S. producers were able to manufacture standard models 25 percent faster than their foreign competitors.

Table j: Average Build Time of U.S. Produced and Imported Five Axis Simultaneous Control Machine Tools

	Custom Built		**Standard Product**	
	U.S. Produced	**Imported**	**U.S. Produced**	**Imported**
# of Models Identified	17	64	79	317
Average Build Time	44 weeks	24 weeks	15 weeks	20 weeks

Source: 2008 BIS Machine Tool Survey

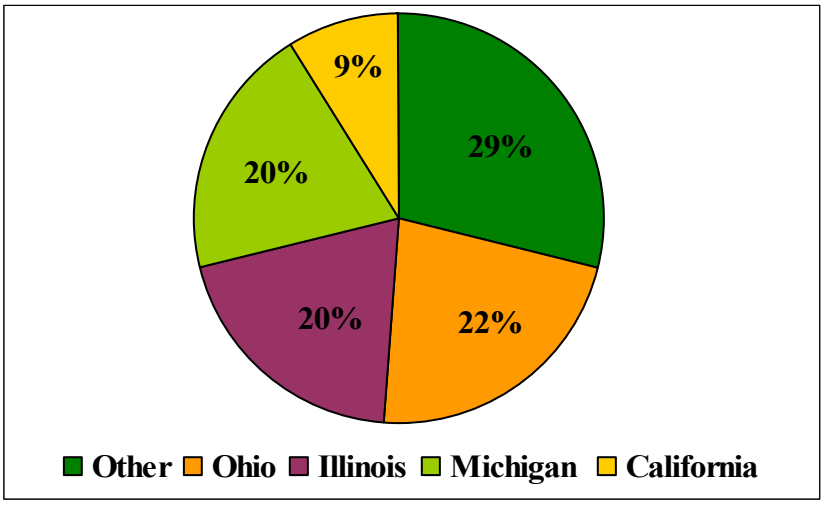
c. Supply Chain

Builders of machine tools are only as healthy and competitive as their supply chain is reliable and cost effective. Significant portions of the U.S. machine tool supply chain remain. Tailored primarily to the subject five axis machine tool supply chain, BIS asked producers detailed questions in its survey related to parts and components sourced; the location of U.S. and non-U.S. suppliers; short supply of related parts and components; and sourcing practices.

BIS collected U.S. content information on a per model basis in an attempt to measure how dependent domestic five axis producers were on foreign-made parts and components during this time period, and what effect such dependence would have on build times. On average, of the domestically-produced five axis machine tools, the custom built models contained 84 percent of U.S. content (eight models reported 100% U.S. content), and standard models were 75 percent. In contrast, 87 percent of reported imported machine tool models contained an average level of only three percent U.S. content.

Producers were asked to identify the five "most significant" domestic and foreign-sourced parts and components corresponding to their five axis simultaneous control machine tool lines. A broad range of materials of construction were identified, including roughly 30 part and component categories, as well as the names and locations of nearly 100 suppliers. Domestically, leading supply categories included major castings and fabrications, CNC-related software and equipment, rotary tables, and linear motion components. The highest concentration of identified suppliers (71%) was in the Midwest (namely Ohio, Illinois, and Michigan) and California, as represented in Figure *14*. The suppliers associated with these four states and the parts and components supplied are included in the Appendix.

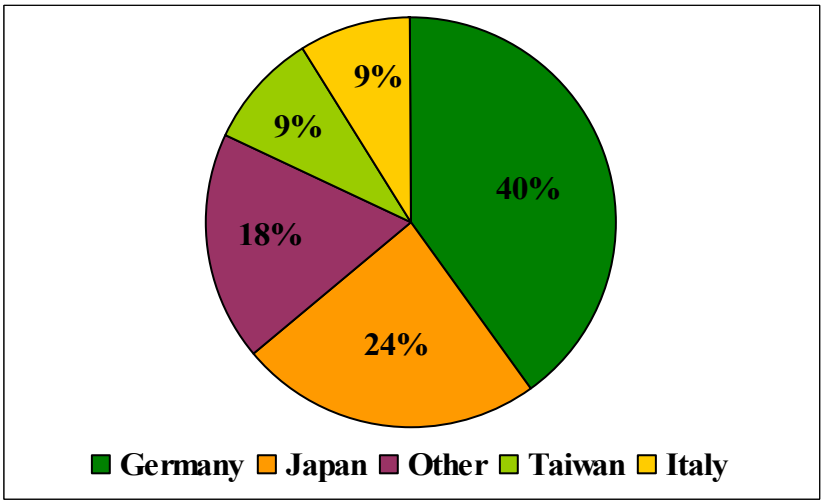
Figure 14: Geographic Concentration of U.S. Five Axis Simultaneous Control Machine Tool Supply Chain, as Identified by Producers



Source: 2008 BIS Machine Tool Survey

Internationally, leading supply categories were the same as those identified domestically, with the addition of CNCs and spindles. Producers identified suppliers for these parts and components in 11 countries, with most foreign-sourced parts imported from Germany, Japan, Taiwan, and Italy, as shown in Figure *15*.

Figure 15: Geographic Concentration of Non-U.S. Five Axis Simultaneous Control Machine Tool Supply Chain, as Identified by Producers



Source: 2008 BIS Machine Tool Survey

Producers also identified parts, components, and materials in short supply from 2005-2008, including temporary or foreseen reductions in the supply chain. Only 40 percent of producers identified parts and components in short supply, some of which are identified in Table *k*.

Table k: Parts, Components, and Materials in Short Supply for 2005-2008 Identified by Producers

Frequently Mentioned by Surveyed Producers	Noted by Surveyed Producers
Bearings (YRTM 180, YRT 180, 2KLDF150)	Spindles
Linear guideways	Steel
Ball screws	Trunion tables
Castings	Gears
Rotary tables	Motors

Source: 2008 BIS Machine Tool Survey

The lack of short supply concerns among most producers does not necessarily infer a plurality of sourcing relationships in the industry. In fact, 70 percent of producers reported a "sole source" supplier relationship, meaning they had no alternate domestic or foreign supplier in the machine tool supply chain for a particular part, component, material, or service. Most producers that indicated sole source relationships identified a sole foreign supplier for a particular part, component, or material, examples of which are contained in Table *l*.

Table l: Examples of Non-U.S. Sole Source Relationships Identified by Producers

Part/Component/Material
Coolant nozzles
Coolant filtration systems
Electrospindles
Racks
Rotary and trunion tables
Software
Spindle motors
Tilt heads

Source: 2008 BIS Machine Tool Survey

Only half of these producers identified a sole domestic supplier, examples of which are contained in Table *m*. The make-up of domestic sole source products is largely distinct from the parts, components, and materials sourced from non-U.S. sole source suppliers. Indeed, no product descriptions are shared between the foreign and domestic sole source lists.

Table m: Examples of U.S. Sole Source Relationships Identified by Producers

Part/Component/Material
Ball screws
Bearings
Gear sets
Servo motors
Steel
Steel castings

Source: 2008 BIS Machine Tool Survey

The supply chain for domestic builders of five axis simultaneous control machine tools is largely diversified, consisting of domestic and foreign suppliers with concentrations in the Midwest United States, Japan, and Germany. Having multiple suppliers participating in five axis machine

tool manufacture has offered U.S. builders some flexibility in pricing and, predictably, more alternatives for supplier selection.

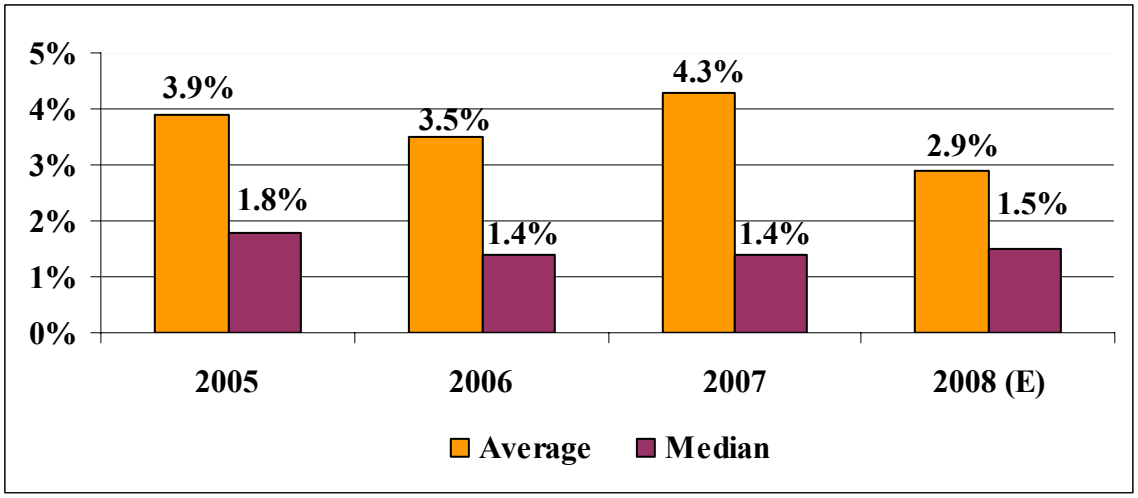
Nevertheless, diminishing U.S. sources for select machine tool parts and components--like ball screws, bearings, and castings--pose additional problems for U.S. builders. Dependence on non-U.S. suppliers for select parts and components can jeopardize producer lead times--a significant problem if the machine is intended for USG applications.

5. Producer Research and Development

Research and development (R&D) activity for any technology can indicate future prospects for innovation and product growth. Expenditures in the machine tool industry are normally not directed solely at five axis simultaneous control machine tools. BIS made an effort to analyze those funding sources and project descriptions related to this specific category of machine tools in its assessment of broader R&D spending patterns.

Total producer R&D expenditures grew annually from 2005 to 2008, reaching roughly $1 million per year in 2008. However, on a per company basis, net sales growth slightly outpaced R&D expenditures for each of the four years, and thus R&D as a percentage of net sales (both median and average ratios) declined. Due to the disproportionate percentage of net sales invested in R&D among select producers, BIS found median measures more reliable, as detailed in Figure *16*.

Figure 16: R&D as a Percentage of Net Sales for Five Axis Simultaneous Control Machine Tool Producers for 2005 to 2008

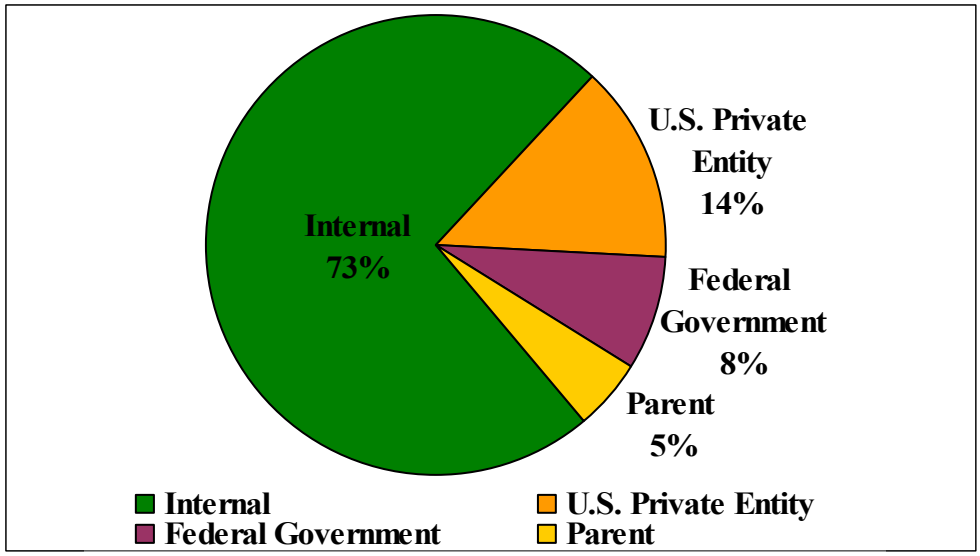


Source: 2008 BIS Machine Tool Survey

For all reporting years, most producers allocated between 70-90 percent of their R&D spending to process and product development. Less than half of the producers surveyed allocated resources to basic and applied research, but those that did allocated as much as 50-100 percent of their R&D resources to these categories, and relied on institutions without a production capability to perform this work.

Producers also indicated that almost all monetary resources made available for R&D investment were not provided by outside investors but originated internally, as shown in Figure *17*. However, three producers did report some USG investment in R&D, and two producers received funding from private external sources. The proportionally large contributions of select manufacturers to the knowledge base indicate increased concentrations of expertise and technology leadership among producers in the forthcoming years.

Figure 17: U.S. Producer Funding Sources for Projects Related to Five Axis Simultaneous Control Machine Tools



Source: 2008 BIS Machine Tool Survey

Producers also provided BIS a description of 37 R&D projects performed from 2005-2008 that related to five axis simultaneous control machine tools. Table *n* provides a sample of reported R&D projects and the source of investment associated with each initiative.

Table n: Sample Producer R&D Projects Related to Five Axis Simultaneous Control Machine Tools by Funding Source for 2005-2008

Internal	High-speed linear motor five axis gantry
	Automatic vertical axis counterbalance servo system
	Develop method of volumetric compensation
	Integrate five axis head into existing product line
	Improvement and commercialization of novel oil bearing rotary axis design
	Develop generalized kinematics software library to standardize five axis machine tool configurations
	Develop new five axis interpolation methods to improve surface finish and simplify part programming
U.S. Private Entity	High-speed five axis linear motor gantry
	Titanium profiler headstock
	Five axis finish porting of cylinder head
	New linear motor A-C axis head
	Multi-tasking mill-turn horizontal machining center
Federal Government	Small business innovation research for future production
	Five axis mega horizontal machining center
Parent	Flexible fixturing system
	Direct drive torque motor; two axis head, three axis linear

Source: 2008 BIS Machine Tool Survey

6. Producer Employment Considerations

Employment factors remain a source of significant consternation among domestic machine tool producers. Lack of qualified engineers and machine tool builders, rising labor costs, and an aging workforce are but samples of the human capital problems affecting producer health and competitiveness.

BIS provided producers with several labor categories and asked that they classify their workforce accordingly. The aggregate number of employees for all 20 producers across all reported labor categories rose nine percent, from 4,897 employees in 2005 to 5,330 employees in 2008. Nearly half of all producer employees in any given year from 2005-2008 were allocated to production/assembly positions, and the number of workers in this category has increased by 12 percent since 2005. Engineering/design/research positions made up 13 percent of total employees, with a 16 percent increase over all four years.

Nevertheless, 65 percent of producers indicated they had a difficult time hiring skilled labor, which reduced their ability to be responsive to customer needs. Resulting impacts also included higher labor and training costs, lower production capacity, and lost orders to non-U.S. competitors. Like companies in other industrial sectors facing aging workforce issues, the inability of machine tool manufacturers to replace an aging and skilled labor force jeopardizes their viability. As one producer explained, “Our experienced workforce is aging and skilled

replacements are very hard to find. On-job experience in this field is rare and the hands-on skills are simply not being taught anymore."

This problem has led some firms to seek qualified labor abroad. Another producer noted in the BIS survey that, "Many of our youngest and best engineers are foreign born and are on visas working their way to permanent resident status."

Some of the predominant factors contributing to these difficulties include the high cost of living in certain regions of the United States, lack of training in public schools for industrial machinery jobs, students with poor basic skills in math and science, maintaining visas for non-U.S. professionals, and a need for innovative R&D programs. One producer commented in the survey that, "The machine tool industry is highly specialized and requires significant skills, abilities, and experience. We have encountered growing difficulties in recruiting, hiring, and keeping such skilled employees, whether they are machinists, engineers, software designers or even experienced machine tool operators. Our ability to compete in the world market is heavily impacted by our ability to find a skilled and experienced work force."

Most of these producers (70%) have established partnerships with local high schools and vocational colleges to offer students apprenticeships and on-the-job production and machinist training. However, 15 percent of producers said yes when asked if they were aware of comparatively better training programs abroad. Details of such programs were not provided in response to the producer survey, but were provided by several end-users. One end-user noted that, "Germany, Austria, Poland, Czech Republic, and Switzerland all have nationwide formalized skills training built into their educational systems. The U.S. has none; only private industry (which is forced to train at its own cost)!" Another end-user offered, "Take China for example….The Chinese government is investing millions into new equipment and training operators (assisted by large U.S. companies) on technology that is as good as or better than U.S. manufactures. We are talking about Aerospace, not toys."

Despite the training partnerships many producers have developed with educational institutions, a lack of U.S. training programs for related employment has created a shortage in skilled labor in the machine tool industry.

C. Five Axis Simultaneous Control Machine Tool End-Users

BIS surveyed both commercial and government end-users on their five axis machine tool purchases over the 2005-2008 period.[18] A total of 61 surveyed end-users purchased 502 five axis machine tools and spent over $900 million during the period.[19] Purchase trends show a preference toward imported five axis machine tools, which make up close to 70 percent of all five axis models purchased. Across model types, the number of imported models greatly surpasses the number of domestic models for grinders, mill/turns, and machining centers; however, domestic-produced mills slightly outnumber imported mills. The following examination of end-user purchase trends and considerations, a comparison of U.S. and non-U.S.

[18] End-users provided estimates of purchases for the remainder of CY 2008.
[19] Reflects consolidation of business unit responses.

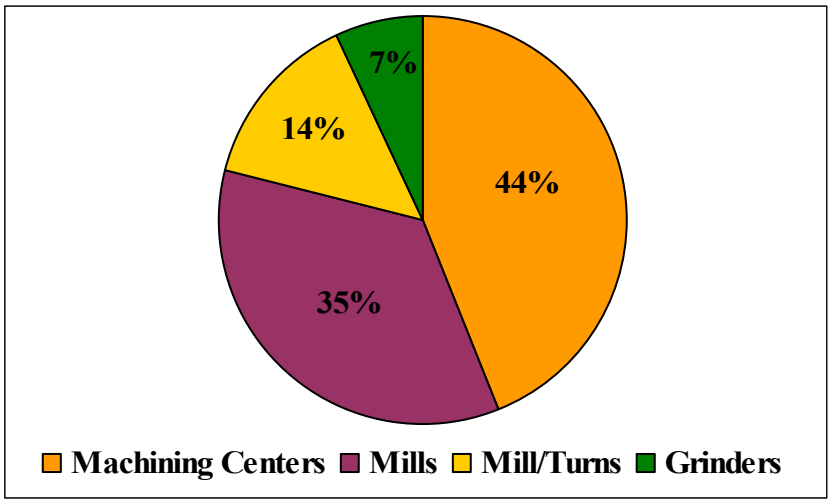
machine tools, USG end-user demand, future demand, and labor concerns provides a snapshot of current and future domestic demand for five axis machine tools.

1. Purchase Trends

The main factor influencing the purchase of five axis technology is the resulting increase in the efficiency of end-user production processes. Although five axis machine tools comprise a small portion (25% or less) of most end-users' capital stock compared to other types of machine tools (e.g., 3- or 4-axis), their high utilization rate suggests five axis machinery is replacing machinery with fewer axes. End-users cited specifically that their motive for acquiring five axis machine tools over other types is that they consolidate multiple production steps into one machine tool, which lowers production time and reduces the number of new capital equipment purchases.

By type, five axis simultaneous control mills and machining centers made up the majority of total purchase volume over the period, as can be seen in Figure *18*. Although the number of total units purchased did not increase much over the period, the total number of buyers increased each year, with a total increase of 25 percent from 2005 to 2008.

Figure 18: Total End-User Five Axis Simultaneous Control Machine Tool Volume 2005-2008



Source: 2008 BIS Machine Tool Survey

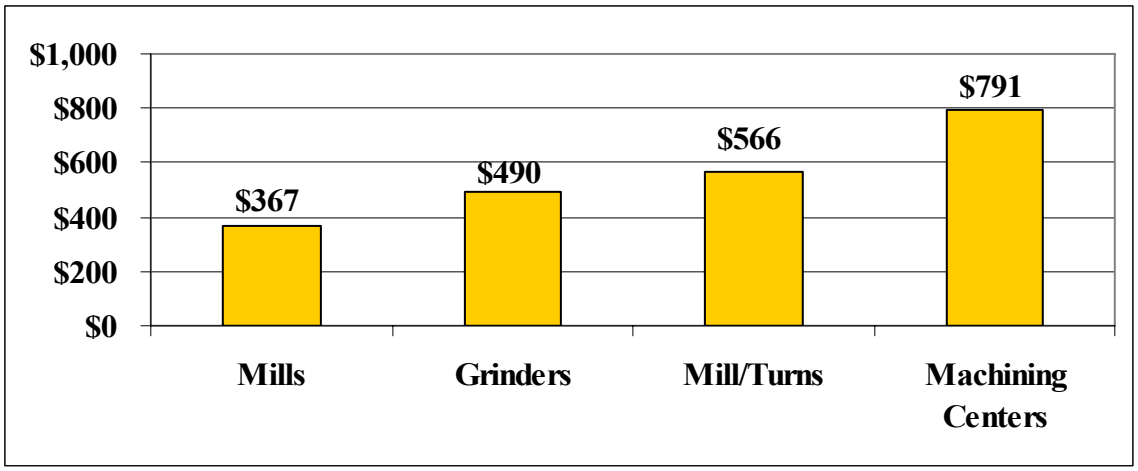
However, the number of units purchased for machining centers, along with mill/turns, declined over the period; a trend that may be explained by the purchase values of these types, which are typically higher than mills and grinders as shown in Figure *19*.

Across all types of five axis simultaneous control machine tools included in this survey, end-users spent roughly $800,000 on their five axis machine tool volume, and purchased between two and three units over the period.[20] They spent about $330,000 per each five axis unit, and favored standard over custom built products. High-dollar, large volume purchasers spent nearly

[20] From the aggregate survey data, BIS found that three end-users represented 70 percent of the total value of all five axis simultaneous control machine tool purchases and 40 percent of all units purchased. Due to these outliers, BIS relied on median values to describe aggregate data where necessary.

10 times more than the average end-user, by both value and volume. Custom-built machine tools were preferred by this group of end-users, who paid, on average, $1 million per unit.

Figure 19: Median Purchase Value by Type of Five Axis Simultaneous Control Machine Tool per End-User (in $ thousands) 2005-2008



Source: 2008 BIS Machine Tool Survey

2. Purchase Considerations

From a list of 21 factors, end-users were asked to select the top five that they considered when making their five axis machine tool purchases. Table *o* shows the most and least considered factors among all surveyed end-users. Results indicate that the rigidity and durability of a five axis simultaneous control machine tool is most important, while the least considered feature was the pump and coolant devices. Other factors not on the list, but specified by end-users as important, were cost of the machine tool and reputation of the builder.

Table o: Purchase Factors End-Users Consider for Five Axis Simultaneous Control Machine Tools

Most Considered		Least Considered	
Machine Rigidity/Durability	79%	Maintenance Agreement	4%
Precision/Repeatability	78%	Hand Scraped Parts	3%
Service/Support	56%	Rotary Table Make	3%
Spindle Speed	44%	Spindle Chillers Make	1%
CNC Make	40%	Pump Coolant Devices	0%

Source: 2008 BIS Machine Tool Survey

BIS then asked end-users to assess U.S. and non-U.S. producers of five axis machine tools based on these same 21 purchase factors. Table *p* indicates that of the purchase factors end-users indicated as most important, the United States has a competitive advantage in only one – service/support. End-users indicated that non-U.S. producers have a competitive advantage in three of the five purchase factors they consider to be most important (i.e., precision/repeatability, spindle speed, and CNC make).

Table p: Competitive Advantage Comparison of U.S. and Non-U.S. Five Axis Simultaneous Control Machine Tool Producers according to Surveyed End-Users

U.S. Better		Non-U.S. Better		Same	
Service & Support	37%	Precision/Repeatability	36%	Materials of Construction	37%
Technical Support	31%	CNC Make/Related Services	28%	Manufacturer Warranty	36%
Build-/Lead-Time	22%	Spindle Speed	28%	Pump/Coolant Devices	31%
		Lifespan of Machine	24%	Tool Weigh/Footprint	31%
		Rotary Table Make	22%	Rigidity/Durability	29%

Source: 2008 BIS Machine Tool Survey

These findings are consistent with U.S. customers' high demand for non-U.S. produced five axis simultaneous control machine tools. Seventy five percent of surveyed end-users have purchased five axis machine tools from non-U.S. producers, and a majority of these purchasers do not have any domestic produced machine tools of this type in their capital stock. The primary reason cited for purchasing non-U.S. over U.S. machine tools is that non-U.S. models are more widely available. Several end-users claimed that they were not aware of any domestic producers capable of meeting their purchase needs. One commercial end-user responded in the survey that, "The overall precision, accuracy, machine tool features, and control capability is not available in the United States with reasonable delivery or cost. There just simply are not enough machine tool builders in the United States (that can build the type of equipment we need) to choose from anymore." End-users also cited quality and value as reasons for choosing non-U.S. over U.S. machine tools of this type.

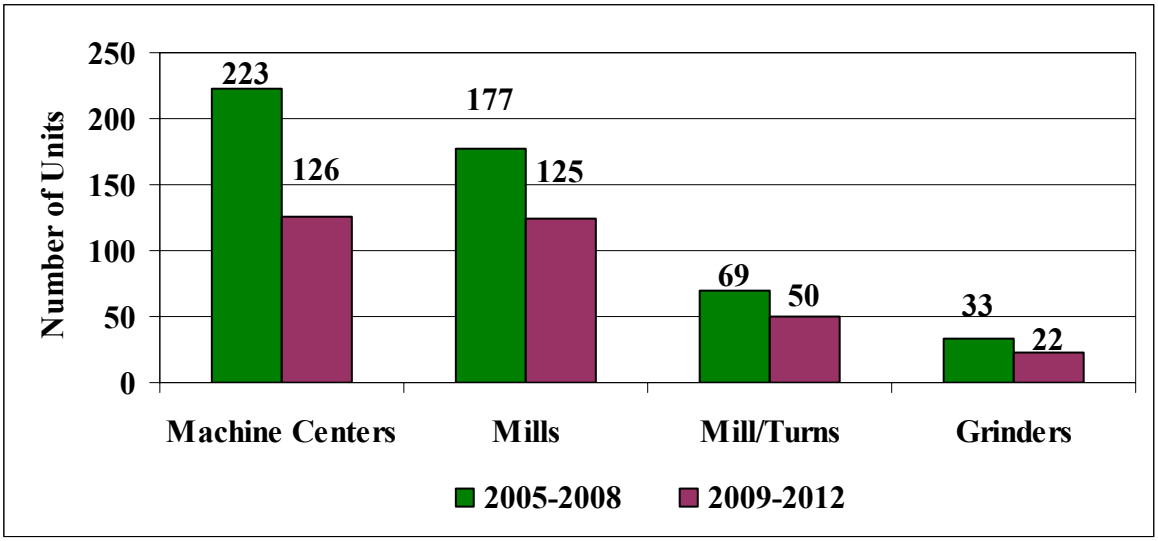
3. U.S. Government Demand

USG work drives a significant portion of the commercial demand for five axis machine tools. About half of all purchasers of these machine tools are commercial end-users that buy them for USG contracts and/or projects, and a majority of these purchasers use these machine tools solely for the purpose of USG work. USG contractors are more likely than commercial end-users to purchase high-priced, custom-built machine tools, and often those that are non-U.S. versus U.S.-produced. Non-U.S. produced models made up 64 percent of five axis simultaneous control machine tool models in the inventory of USG contractors. USG contractors also purchased more five axis machine tools, on average, than commercial end-users from 2005 to 2008. Similar to aggregate demand, mills and machining centers make up the largest portion of USG demand by type, and this proportion is expected vary over the 2009-2012 period.

4. Future Demand

Slightly over half of end-users surveyed projected their future five axis simultaneous control machine tool needs for 2009-2012. By machine tool type, results suggest that demand is expected to be equivalent to the proportion of types purchased since 2005, where mills and machining centers make up the largest proportion of type purchased. While the projected number of five axis machine tools purchases in 2009-2012 is expected to be less than the number of units purchased from 2005-2008, as shown in Figure *20*, end-users are predicted to spend 30 percent more per unit, on average, during the next four years. Some of the increase in projected value per unit could be attributed to an expectation of an overall price increase over the next four years.

Figure 20: Five Axis Simultaneous Control Machine Tool Demand 2005-2008 vs. 2009-2012



Source: 2008 BIS Machine Tool Survey

5. Labor

A skilled labor shortage has not only impacted firms that build five axis machine tools, as reported by surveyed producers, but firms that operate them as well. Over half of surveyed end-users have had difficulty finding qualified machinists; a problem that most claim has negatively impacted their business by increasing production costs and lowering productivity. "While our current workload and prospective sales would justify further investment in high-end machine tools, the lack of available skilled labor to operate the new equipment has prevented further expansion," stated one commercial end-user.

Many noted increased product lead times and higher workforce training costs as a result of not finding qualified candidates. Qualified machine tool operators are vital to certain sectors of industrial production, especially those sectors that utilize high-end machine tools that require the capability of controlling five or more axes simultaneously. Twenty five percent of all end-users claim that their inability to find skilled labor has impacted their utilization and/or purchase of these machine tools. Some have purposely avoided investment in five axis machine tools knowing that they lack qualified machinists to program and operate them. Another commercial end-user noted, "This is more than a casual problem. It may eventually lead to a failure in our ability to provide complex products to our customers in the future if this problem is not addressed."

Like U.S. producers, many end-users have attempted to ameliorate the labor shortage problem by partnering with educational institutions to recruit and train prospective employees. Close to 40 percent of end-users work with local and regional colleges and technical schools, and offer training programs, internships, and apprenticeships. Nevertheless, more support for U.S. training programs needs to be developed to maintain a skilled workforce and retain U.S. jobs.

VI. Evidence of Foreign Availability

Foreign availability is an assessment BIS conducts to evaluate the effectiveness of U.S. export controls. The criteria for making a foreign availability determination is that an item of comparable quality must be "available-in-fact" to a country, from a non-U.S. source, in sufficient quantity to render the U.S. export control of that item ineffective.

Unless specified otherwise, the following foreign availability analysis relates to five axis simultaneous control mills, mill/turns, and machining centers controlled by ECCN 2B001.b.2. BIS did not identify sufficient data to assess foreign availability for grinders controlled by ECCN 2B001.c.2.

A. Available-In-Fact

An item is "available-in-fact" to a country if that country: (1) indigenously produces the item; (2) can obtain the item from another country that does not restrict the export of that item; or (3) can obtain the item from a country whose export controls are not effective or licensing approval policy is pro forma for an item. As discussed in Section IV.B above, BIS has no evidence that countries that are members of the WA or the NSG have in place ineffective export control policies.

However, several of the destinations for which exporters are required to obtain U.S. export licenses (i.e., license required countries, or LRCs) are either indigenously producing these machine tools or can obtain them from other LRCs. BIS has identified five LRCs with a combined total of 45 indigenous companies producing a total of 183 models of five axis simultaneous control mills, mill/turns, and machining centers. Taiwan has 22 of these companies, China 20, and Brazil, India, and Russia each have a single company indigenously producing five axis simultaneous control machine tools (i.e., Taurus Wotan of Brazil, JYOTI CNC of India, and JSC Sterlitamak of Russia). Table *q* below contains a complete list of Taiwanese and Chinese five axis machine tool producers.

Table q: Five Axis Machine Tool Producers in China and Taiwan

China	Taiwan
Beijing Machine Tool Institute (BMTI) Precision Mechatronics Co. Ltd.	Arix
	AWEA
Beijing No. 1 Machine Tool (BYJC)	Dah Lih
BMEI Co. Ltd.	Eumach
Dalian Machine Tool Group Corp. (DMTG)	EUMA-Spinner
Guilin Machine Tool Company, Ltd.	FEMCO
Hanchuan Machine Tool Group Co.	First Long Chang
Jiangsu Duoleng CNC Machine Tool Co.	Fortune
Jiangsu Shinri Machinery Co., Ltd.	Fulland Machinery
Jier Machine Tool	Gentiger
Jinan No. 2 Machine Tool Group Co., Ltd.	Hartford She Hong
Jingdiao (Beijing)	Johnford
Nanjing Sky CNC Electronic Enterprise Co.,	KAFO
Ningjiang Machine Tool Group Co., Ltd.	L&W Machine
Qinghai No. 1 CNC Machine Tool Co., Ltd.	Leadwell CNC
Qier Machine Tool Group Co., Ltd.	OR Victor
Shanghai Heavy Duty	Quaser Machine
Shenyang Machine Tool Co., Ltd.	Shenq Fang Yuan
Shenzhen First CNC Machine Tool Co., Ltd.	Takumi Seiki
T LUNAN - Shandong Lunan Machine Tool Co.	Tongtai
Zigong Changzheng/Zigong Long March Machine Tool Co.	Viper
	Yeong Chin

Sources: Websites, Company Brochures, Machine Tool Shows, 2008 BIS Machine Tool Survey

The indigenous production capability and the ability of LRCs to obtain five axis simultaneous control mills, mill/turns, and machining centers from other LRCs make these machine tools "available-in-fact." There is currently not enough evidence to suggest that five axis simultaneous control grinders are "available-in-fact" at this time.

B. Non-U.S. Source

To qualify as being of non-U.S. source, items: (1) cannot be goods of U.S. origin, subject to export controls; (2) cannot be foreign manufactured items that are the direct product of U.S. technical data; and (3) cannot be foreign-made items incorporating parts, components, or materials of U.S. origin that exceed predefined thresholds.[21]

The 45 companies indigenous to Brazil, China, India, Russia, and Taiwan that are producing five axis simultaneous control machine tools do not incorporate U.S. technology, parts, components or materials exceeding the thresholds identified in Part 734 of the EAR. BIS confirmed through its review of licensing data that no export licenses have been issued to any of these companies under ECCNs 2B001, 2D001, 2D002, 2E001, 2E002, or 2E201.

[21] Refer to Parts 734 and 772 in the Export Administration Regulations (EAR) for additional detail.

Joint ventures and acquisitions have allowed LRC machine tool producers to enhance production capability and acquire technical know-how from machine tool producers in the 31 countries for which a U.S. export license is not required for five axis machine tools (i.e., non-license required countries, or NLRCs). Table *r* below captures such relationships and the entities involved.

Table r: NLRC and LRC Company Relationships

NLRCs and Firms		**LRCs and Firms**							
		China					**India**	**Taiwan**	
		BYJC	DMTG	SMTL	BAMTRI	CATIC	JYOTI CNC	EUMA	Quaser
France	Forest Line				JV				
	Huron						A		
Germany	Index		JV						
	Schiess			A					
	Spinner							JV	
	Waldrich-Coburg	A							
	Zimmerman		A						
Italy	Fidia			JV					
Japan	Nippei Toyama		JV						
	OKK		JV						
	Okuma	JV							
Switzerland	Starragheckert					JV			
U.K.	600/Colchester		JV						
U.S.	Hardinge								JV
	Ingersoll CM		A						
	Ingersoll PS		A						
A = Acquisition; JV = Joint Venture									

Sources: Websites, Company Brochures, Machine Tool Shows, 2008 BIS Machine Tool Survey

Certain relationships in this table clearly benefit LRC machine tool producers. One such relationship is that between China's Beijing No. 1 Machine Tool (BYJC) and Japan's OKUMA Corporation, which led to the creation of a co-production operation in China, BYJC-OKUMA (OKUMA 51%, BYJC 49%). Another notable co-production relationship is that between the Beijing Aeronautical Manufacturing Technology Research Institute (BAMTRI) and Forest-Line of France. The relationship between these entities is aimed specifically at five axis machine tool production.[22]

Although it is important to note other strategic relationships such as JYOTI CNC Automation's acquisition of Huron, a "pioneer for 5-axis technology," or BYJC's purchase of Waldrich-

[22] American Chamber of Commerce Export Compliance Working Group, *Machine Tool Industry in China (*Beijing: Larkin Trade International, 2007), 17.

Coburg (a former European division of Ingersoll International), the company benefiting most from relationship formation is Dalian Machine Tool Group Corp. (DMTG).[23] DMTG has entered into relationships with companies including Index of Germany, Nippei Toyama and OKK of Japan, and 600/Colchester of the United Kingdom, which can provide advanced machine tool production capabilities to this Chinese company.

Additionally, in 2005, DMTG acquired 70 percent of Zimmerman of Germany to "…tap Zimmerman's advanced technology for application in their home market (i.e., China) as well as [use] the German firm as its overseas base for R&D and training."[24] Zimmerman is a well-known supplier of five axis gantry milling machines, and has achieved good sales results in China's aviation and auto industries.[25] In 2002, DMTG acquired Ingersoll Production Systems, and in 2003 acquired Ingersoll CM Systems, both former divisions of Ingersoll International Inc. (these are not the Ingersoll divisions that produced five axis machine tools). These acquisitions helped provide DMTG with the requisite knowledge to break into the U.S. market. "Over the last several years, [DMTG] has been building its distribution lines in order to sell equipment outside its home market. Its subsidiary, DMTG North America (Rockford, Ill.), was formed last year to sell Dalian-built lathes, machining centers, and other machine tools in the United States, Canada, and Mexico."[26] However, it does not appear that DMTG is selling any of its five axis machine tools yet in the United States.

DMTG is the largest machine tool producer in China, and one of the top producers of machine tools by output in the world, exporting its products to over 100 countries. DMTG vice president Jiang Huaishen stated, "Ninety-nine percent of our products are independently developed machine tools. Our output value was about 11 billion yuan in 2007 and CNC machine tool products accounted for approximately 45 percent of it. We put about 400 million yuan into researching CNC machine tools. The investment will increase next year."[27]

Another way LRCs can acquire advanced machine tool technology is indirectly through wholly-owned foreign enterprises. The presence of NLRC companies producing machine tools in LRCs provides LRCs with easier access to this technology than otherwise gained through indigenous research, as the NLRC companies have more contact with LRC nationals. Through export licenses that permit sharing of production data, NLRCs also can transfer technology to LRC nationals at a higher rate than they would if producing solely in NLRCs. While foreign companies operating in LRCs are still subject to the export regulations of their home country, the presence of machine tool production in LRCs creates an opportunity for LRCs' machine tool producers to acquire knowledge about advanced machine tool production processes from a more

[23] Machinist, *Jyoti CNC acquires French machine manufacturer – Huron Graffenstaden*, 11 Dec 2007 <http://machinist.in/index2.php?option=com_content&task=view&id=658&pop=1&page=0&Itemid=2>.
[24] Auto-Asia, *Dalian Machine Tool Acquires Zimmerman AG*, 20 Apr 2005 <http://www.indiacar.net/news/n9663.htm>.
[25] Ibid.
[26] "Dalian Grows its Distributor Network", September 4, 2008, Metalworking Insiders' Report, <http://www.metalworkinginsider.info/>.
[27] China Daily Information, *Machine Tool Manufacturers Raise Game*, 18 Jun 2008, <http://www.chinadaily.com.cn/bizchina/2008-06/18/content_6772217.htm>.

highly trained workforce. Table *s* below shows the extent to which NLRC machine tool producers have moved their production capabilities to LRCs.

Table s: NLRC Firms with a Machine Tool Production Presence in LRCs

NLRCs	NLRC Firms	LRC Production Presence			
		China	Taiwan	Brazil	India
Germany	DMG	X			
	Grob			X	
	Heller			X	
	Index	X		X	
	MAG	X		X	
Italy	Fidia	X			
Japan	Enshu		X		
	Makino				X
	Mazak	X			
	NTC	X			
	Okuma	X	X		
	Toyoda	X			
U.S.	Haas	X			
	Hurco		X		
U.S./U.K.	Hardinge	X	X		

Sources: Websites, Company Brochures, Machine Tool Shows, 2008 BIS Machine Tool Survey

Joint venture relationships, acquisitions, and the presence of NLRC machine tool producers in LRCs have all contributed to the extensive growth in the number and capabilities of five axis simultaneous control machine tool producers indigenous to LRCs. Moreover, BIS confirmed through its review of licensing data that no export licenses have been issued to any of the 45 companies indigenously producing five axis simultaneous control machine tools in these LRCs under ECCNs 2B001, 2D001, 2D002, 2E001, 2E002, or 2E201. Therefore, these machine tools qualify as non-U.S. source.

C. Sufficient Quantity

Another foreign availability criterion is sufficient quantity, which for LRCs refers to the quantity of an item that meets their military needs so that U.S. exports of the item to that country would not make a significant contribution to its military potential.

With one company each, Brazil, India, and Russia may not have the indigenous capability to produce five axis machine tools in sufficient quantity, but China and Taiwan, with 20 or more indigenous five axis machine tool producers each, and with less restrictive export control laws than WA country members, not only are able to produce these machine tools in sufficient quantity to meet domestic demands, but are also able to produce in sufficient quantity to export to other LRCs.

There are six indigenous machine tool producers in China that are each producing seven or more distinct models of five axis machine tools, one of which is producing 24 distinct models. "The number of CNC machine tool companies, with an annual production capacity of over 1,000 machine tools, has reached 28, and those with an annual capacity of more than 100 machine tools reached 130 in China by the end of last year (2007)," according to Liang Xunxuan, founder and honorary chairman of China Machine Tool & Tool Builders Association.[28]

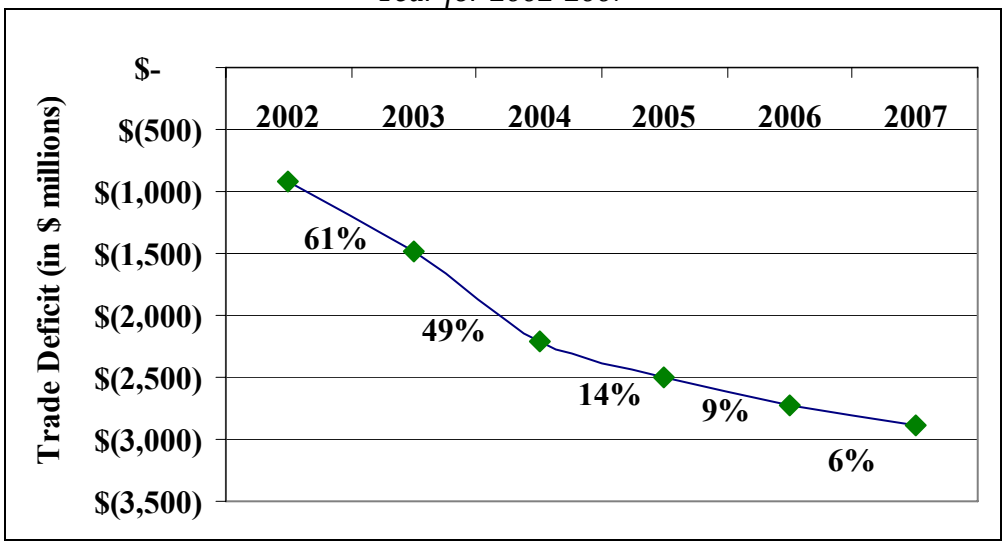
China's growing machine tool production capability means less reliance on foreign machine tool imports, including those from WA members. China has been reported to have experienced a declining import growth rate of high-quality machine tools and increasing use of domestic equivalents. Customs statistics show China's CNC machine tool imports dropped from 40 percent of all high-end machine tools sold in 2005 to just 10 percent last year.[29]

Statistics show that domestically-produced CNC machine tools are increasing in market share within China. "In 2005, approximately 59,600 units of CNC machine tools were produced in China, among which the proportion of high-grade products had significantly increased from previous years. Domestically produced CNC machine tools have quickly gained market share in China's market, rising by nearly 3 percent in 2005…By 2010, China estimates that the Chinese market share of numerically controlled machine tools held by domestic companies will account for 50 percent of the value and 65 percent of the output volume."[30]

In 2007, the combined amount of CNC metal-cutting and forming machine tools produced in China was 126,268, more than double the amount produced in 2005.[31] In Figure *21*, the dramatic decrease in the percent change of China's trade deficit in overall imports of machine tools (from 61% between 2002 and 2003 to 6% between 2006 and 2007) would support a claim that the Chinese are on track to achieve their 2010 domestic production goals.

[28] Ibid.
[29] China Daily Information, *Imports Threaten China's Economy – official*, 22 Apr 2007, <http://www.chinadaily.com.cn/china/2007-04/22/content_856499.htm>.
[30] American Chamber of Commerce Export Compliance Working Group, *Cross Sector Report* (Beijing: Larkin Trade International, 2007), 20.
[31] *China Machine Tool Industry Research 2008*, Summary (China Market Report, June 2008) <http://www.reportlinker.com/p091023/China-Machine-Tool-Industry-Research-2008.html>.

Figure 21: Chinese Trade Deficit for Machine Tools: Rate of Trade Deficit Increase Year to Year for 2002-2007



Source: Global Trade Atlas

Many indigenous Chinese five axis machine tool manufacturers are state-owned or were at one time, and many Chinese machine tools are currently used in a variety of national projects, which may indicate that it is easier here than in other economies for the government to redirect indigenous production of these machine tools from commercial to military use. "State-owned enterprises represent 30 percent of China's machine tool and manufacturing industry, while the private sector has a more considerable 60 percent share."[32] BYJC cites weapons as one of the end-uses for the machine tools it produces on its website, and a DMTG representative at the EMO 2007 Machine Tool Show in Hannover, Germany indicated that the Chinese military is one of its customers for five axis machine tools.[33]

Jinan No. 2 Machine Tool Group Co., Ltd. is part of the state-owned JIER Machine Tool Group in China, and although it is not the largest of the indigenous machine tool producers, has sold several five axis machine tools to key Chinese military and aerospace producers, including: (1) Beijing Academy of Spaceflight Technology (2.5 M×12M five axis bridge-type high-speed machining center; 3.5 M×4M high-speed five axis gantry CNC boring and milling machine); (2) China Academy of Launch Vehicle Technology (5.5 M×12M high-speed five axis gantry CNC boring and milling machine); and (3) Shanghai Academy of Spaceflight Technology (4.5 M×8M 5 axis high-speed mobile gantry linkage boring milling machine). Chinese entities involved in production for the Chinese military, space shuttle, and other aerospace applications are now reportedly using exclusively Chinese produced machine tools, including five axis machine tools, for national security reasons.[34]

[32] Butcher, David R, "China's Machine Tool Industry Coming of Age", ThomasNet, July 23, 2008.
[33] DMTG Booth, EMO 2007 Machine Tool Show, Hannover, Germany.
[34] Larkin Trade International (LTI), Data Collected on Machine Tool Production in China by LTI's Beijing Office, November 3, 2008.

According to the Export Compliance Working Group of the American Chamber of Commerce in People's Republic of China, "Given the existing domestic and joint venture development, and the foreign availability of high-level machine tools, U.S. companies could not make a material contribution to China's military development. China's military demands are already satisfied by domestic and foreign supply."[35] In fact, the U.S. exported 515 five axis machine tools between 2005-2007, and only 12 of these were sent to China.

The Chinese and Taiwanese are able to indigenously produce certain five axis machine tools in serial production (i.e., mills, mill/turns, and machining centers), and are exporting these machine tools to other LRCs.

D. Comparable Quality

An item is of comparable quality to an item subject to the EAR if it possesses the characteristics specified in the Commerce Control List (CCL) for that item, and is alike in key characteristics that include, but are not limited to: (1) function; (2) technological approach; (3) performance thresholds; (4) maintainability and service life; and (5) any other attribute relevant to the purpose for which the control was placed on the item. The only characteristic specified in the CCL for five axis mills, grinders, mill/turns, and machining centers is the fact that they have five axes. BIS surveyed U.S. five axis machine tool producers and distributors on 22 different technical parameters, and asked them to identify the best approach to measure the quality of a five axis machine tool. The majority of respondents indicated that a measure of the machine tool's volumetric accuracy would be the best way to measure the quality of a five axis machine tool, as did the National Institute of Standards and Technology. However, given a lack of widespread adoption of any type of volumetric accuracy standard, the secondary response for measuring the quality of a five axis machine tool is by its linear positioning accuracy. Thus, the quality of five axis mills and grinders was judged on linear accuracy for the purposes of this report. This technical parameter is a logical choice for comparison, as there are established standards for measuring linear positioning accuracy to which all machine tool producers adhere internationally, and in fact, export controls on three and four axis machine tools are also based on this parameter.

There are several different standards by which positioning accuracy is measured (ISO 230-2, VDI/DQG 3441, JIS B 6192, etc.), and within these standards, changes have been made over several years. For example, there are several versions of standard ISO 230-2, to include ISO 230-2 1988, ISO 230-2 1997, ISO 230-2 2002, etc. There are several standards that are equivalent to ISO 230-2 1997, which include: ASME B5.54 (2005); GBIT 1721.2 (2000); and JIS B 6192 (1999). However, most machine tool producers, especially those in LRCs, do not provide the precision accuracy, much less which standard was used and the year of the standard. Those producers that do provide a standard, and perhaps also the year of the standard, report across several standards, making it difficult to compare machine tools from two different producers in a meaningful way.

BIS survey data and market research of LRC machine tool producers informed how some of the five axis machine tools we evaluated have been measured by two different standards (i.e., a

[35] *Cross Sector Report*, 18.

single model was measured using both the ISO-232 and VDI/DGQ 3441 standards), which gives the best insight as to how machines could compare across standards (i.e., one five axes model listed a positioning accuracy of 8 microns under ISO 230-2 as well as 4 microns under JIS B6192; another model indicated an accuracy when measured under JIS B 6192 of 3 microns, as well as 10 microns under VDI/DQG 3441).

Another important measure to consider when evaluating linear precision accuracy of five axis machine tools is the travel of the linear axes. Due to the range of travel, a machine tool with all linear axes less than two meters in length can, on average, achieve a higher precision accuracy than a machine tool with at least one linear axis with a travel that is greater than or equal to two meters in length.

Tables *t*, *u*, and *v* below place certain five axis machine tools (mills, mill/turns, and machining centers) produced in the United States next to those produced indigenously in LRCs. The tables identify the range of precision accuracies by standard for machine tools with: 1) all linear axes having less than two meters of travel; 2) any linear axis having greater than or equal to 2 meters of travel but less than or equal to three meters of travel; and 3) any linear axis having greater than three meters of travel. BIS gathered this data from U.S. producers and distributors through its survey, websites, company brochures, and machine tool shows. BIS identified 20 companies in China producing 112 different models of five axis machine tools and 22 companies in Taiwan producing 64 unique models of such tools. Only those companies that identified a precision accuracy standard were included in Tables *t*, *u*, and *v* below, although most of these companies did not identify the year of the standard cited.

Table t: Range of Linear Precision Accuracy for Certain Five Axis Simultaneous Control Machine Tools with Less than Two Meters of Travel for all Linear Axes

Country	# of Firms	# of Models	Range of Linear Precision Accuracy [microns]					
			ISO 230-2	VDI/DGQ 3441	JIS B 6192	JIS 6338	JIS 6336	ANSI B5:54
Brazil	1	1		20				
China	5	8	8-12	8-10	8			
India	1	1		4				
Russia	1	4		10				
Taiwan	7	17	8-10	4-14	4	5	4	40
U.S.	11	91	3-35	2-10			4-50	28

Sources: Websites, Company Brochures, Machine Tool Shows, 2008 BIS Machine Tool Survey

Table u: Range of Linear Precision Accuracy for Certain Five Axis Simultaneous Control Machine Tools with Travels for Any Linear Axis Greater Than or Equal to Two Meters and Less Than or Equal to Three Meters

Country	# of Firms	# of Models	Range of Linear Precision Accuracy [microns]					
			ISO 230-2	VDI/DGQ 3441	JIS B 6192	JIS 6338	JIS 6336	ANSI B5:54
Brazil	1	1	19	20				
China	3	4	16-25	12				
Taiwan	1	1			10			
U.S.	11	91						

Sources: Websites, Company Brochures, Machine Tool Shows, 2008 BIS Machine Tool Survey

Table v: Range of Linear Precision Accuracy for Certain Five Axis Simultaneous Control Machine Tools with Travels for Any Linear Axis Greater Than Three Meters

Country	# of Firms	# of Models	Range of Linear Precision Accuracy [microns]					
			ISO 230-2	VDI/DGQ 3441	JIS B 6192	JIS 6338	JIS 6336	ANSI B5:54
China	4	11		7-35	3 +/-			
Taiwan	2	2	8	15				
U.S.	6	25	3-127			50-50.8	6	25

Sources: Websites, Company Brochures, Machine Tool Shows, 2008 BIS Machine Tool Survey

The tables above show that certain five axis simultaneous control machine tools with travels on all linear axes less than two meters having a positioning accuracy greater (worse) than or equal to eight microns (according to ISO 232-1997) are available in the LRC markets, as are certain five axis simultaneous control machine tools with travel on any single linear axis greater than or equal to two meters with a positioning accuracy greater (worse) than or equal to 16 microns (according to ISO 230-2). There are a few five axis simultaneous control machine tools with travels for any linear axis greater than or equal to three meters with a positioning accuracy greater (worse) than or equal to eight microns (according to ISO 230-2) in Taiwan, but without additional information from other companies, it is not certain that machine tools with this level of accuracy are widely available in LRCs.

Currently, all five axis machine tools requiring a license are subject to export controls for the simple fact that they have five axes that can be controlled simultaneously. CNCs are what provide operators with the capability to simultaneously control multiple axes on a machine tool, and are the integral piece of technology associated with these tools. The most widely used CNC by both NLRC and LRC five axis machine tool producers at this time is the Siemens 840D. BIS is unaware of any restrictions that foreign CNC manufacturers place on the reexport of a Chinese machine tool with their CNC. In addition, several LRCs either have the ability to produce or are already producing their own CNCs indigenously. Some of the Chinese companies indigenously producing CNCs capable of five axis simultaneous control include: Wuhan Huazhong Numerical Control Co., Ltd.; Dalian Golden Numerical Control Company; Beijing Aerospace

Numerical Control System Co., Ltd. (CASNUC); and Dalian Dasen Numerical Controlled Technology Development Center (Dalian Dasen).

This data affirms that several LRCs already have an indigenous capability to produce five axis simultaneous control mills, mill/turns, and machining centers, and to access or produce CNCs comparable to the United States. Accordingly, BIS finds that certain mills, mill/turns, and machining centers having five or more axes that can be coordinated simultaneously for contouring control of comparable quality are "available-in-fact" to China and Taiwan, from a non-U.S. source, in sufficient quantity to render the U.S. export control of that item ineffective.

VII. U.S. Government Secure Sourcing of Foreign Tools

USG agencies procure five axis simultaneous control mills and grinders to support defense-related applications (e.g., aerospace, nuclear, missile) from domestic and foreign sources. Data from the BIS end-user surveys shows that USG end-users purchase more of their five axis machine tools from non-U.S. sources rather than domestic sources. However, the ability to securely source non-U.S. tools in a timely manner and the chance for the illicit or inadvertent transfer of sensitive data to unauthorized persons (e.g., machine tool service provider) are potential risks that USG end-users face.

A. Secure Foreign Sourcing

The issue of secure foreign sourcing is one that has been raised recently as a result of two reported cases where Japanese companies and/or the Japanese Government have denied the sale of five axis simultaneous control machine tools to a USG end-user and a commercial end-user that performs USG defense contract work because of intended nuclear end-uses. This raises some concern over whether USG end-users and defense contractors can reliably procure five axis machine tools from their non-U.S. suppliers, especially given their preference for foreign-made machine tools. As one USG end-user confirms, "Usually our customers consider machines from foreign sources to be of higher quality and possess the capability to machine to closer tolerances."

If foreign governments impede the five axis machine tool acquisition process for U.S. end-users, there would be increased reliance on domestic producers to meet USG needs for defense operations. Some USG customers question whether current five axis domestic production capability can meet this need. Another USG end-user expressed the concern that, "We could not find the configuration, quality, and overall accuracy that was required for our parts. We have numerous older U.S. machines that were state of the art in their day. The U.S. producers have not kept up with the technology gains in the rest of the industry."

Based on survey responses, however, BIS only identified two instances of this type of impediment to USG end-users and contractors. Accordingly, BIS does not now have reason to believe that the USG is unable to securely source machine tools for critical defense needs from abroad.

B. Sensitive Data Transfer

An end-user of five axis simultaneous control machine tools may connect its machine's CNC to the Internet so that the manufacturer or service provider can perform updates or diagnostic testing. However, there is a risk involved with connecting a CNC to the Internet that needs to be addressed in that any data stored in the CNC becomes susceptible to unauthorized access.[36] In particular, USG end-users and contractors that machine parts for defense-related components need to mitigate this risk. To draw attention to the potential vulnerability, BIS asked end-users that connect to the Internet for CNC diagnostics to identify the precautions they take to protect any information that may be stored in the CNC. BIS found that most end-users that connect to the Internet rely on a combination of firewall and password protection to prevent unauthorized access to their CNC's information. While these precautions may be effective, most USG end-users take the most conservative route, and have no connection between their machine tools' CNCs and the Internet.

Protection of information, particularly sensitive design data, must extend to CNCs linked to the Internet. USG end-users and contractors must remain vigilant of cyber security concerns.

VIII. Conclusion and Recommendations

BIS concludes that:

- Foreign availability of certain five axis simultaneous control mills, mill/turns, and machining centers controlled by ECCN 2B001.b.2 (but not grinders controlled by ECCN 2B001.c.2) exists to China and Taiwan, which both have an indigenous capability to produce five axis simultaneous control machine tools with linear positioning accuracies comparable to the United States;

- U.S. export license processing times, especially to China, are longer than those of other WA members, placing U.S. exporters at a competitive disadvantage;

- Compared with other exporting countries of this technology, the United States is losing market share to its European and Asian competitors, namely South Korea;

- U.S. producers of five axis simultaneous control machine tools, while currently profitable, face an uncertain future for their five axis machine tool product lines with imports outpacing domestic sales and increasing customer demand (commercial and USG) for foreign machine tools;

- Lack of U.S. training programs has created a shortage in skilled labor in the machine tool industry, which threatens to impede domestic ability to produce machine tools and manufacture complex products; and

- A potential vulnerability exists with regard to sensitive data (e.g., designs) stored in the CNCs of machine tools connected to the Internet.

[36] See the President's *Cyberspace Policy Review: Assuring a Trusted and Resilient Information and Communications Infrastructure*, May, 2009.

Accordingly, BIS recommends that the USG:

- Amend the EAR to allow the export of five axis simultaneous control mills, mill/turns, and machining centers of certain precision accuracies controlled by ECCN 2B001.b.2 with foreign availability to controlled countries under license exception or similar-type authorization, and work with international partners (e.g., via the WA and NSG) to modify the existing multilateral export control of five axis simultaneous control machine tools by adding a linear positioning accuracy control parameter, while working towards a better capability measure of this technology (e.g., volumetric accuracy);

- Encourage producers and distributors to identify or develop anti-tampering and anti-diversion features for their machine tools that can be utilized to mitigate concerns of machine tool misuse or diversion after export to facilitate interagency review of license applications to sensitive destinations;

- Improve communication between U.S. companies and U.S. export licensing officials to decrease processing times of license applications for exports destined to China;

- Monitor, on a routine basis, the competitive position of U.S. machine tool producers to support critical industrial base needs;

- Identify training proposals for educational institutions to address the growing problem of a lack of skilled labor to design, build, and use machine tools; and

- Heighten the awareness among USG end-users and contractors, especially those that machine parts for defense-related components, of the risk of unauthorized access to and exfiltration of CNC data.

VIII. Appendix

Geographic Concentration of U.S. Five Axis Simultaneous Control Machine Tool Supply Chain by Supplier and Part/Component, as Identified by Producers

Illinois		Ohio		Michigan		California	
Supplier	**Part or Component**	**Supplier**	**Part or Component**	**Supplier**	**Part or Component**	**Supplier**	**Part or Component**
Advanced Machinery and Engineering	Spindles, Rotors	ADL Technologies	Power Panels	Kent	ATC Arm Casting	Delta Tau	Motion Control Systems
Dueblin	Rotary Joint	Dynamic Industries	Machining, Large Castings	SKF	Ball Screws	MEI Corporation	Motion Card
Fagor Automation	CNC Control, Drives, Motors	Ellwood Group	Major Castings	Cone Drive	Gear Sets	OSI Electronics	Printed Circuit Boards
GE Fanuc	CNC Control	Hydrotech	Fluid Components	Electrotech	Cabinet Builder	RG Systems	Cabinet Builder
Heidenhain	Feed Back Linear/Rotary	McKay Electric	Electrical Components	John Crowley	Large Fabrications	Sony	Feedback Scales
IKO International	Linear Rail	Pepperl and Fuchs	Electrical Components	Kurdziel	Castings		
Mitsubishi Electric [MEAU]	SFI/Cabling	S and P	Weldments	Lincoln Park Boring	Large Part Machining		
Parker Hannifin	Cylinders	St. Mary's Foundry	Castings	Marposs	Probes		
Siemens	CNC Control, Servo Motors	Technitron	Rotary Tables	VIS Industries	Major Fabrications		
Youngberg Industries	Large Fabrications	THK, America	Linear Guides				
		Timken	Bearings				

Note: These four states represent the location of 71% of the 55 supplier relationships identified by producers

Source: 2008 BIS Machine Tool Survey