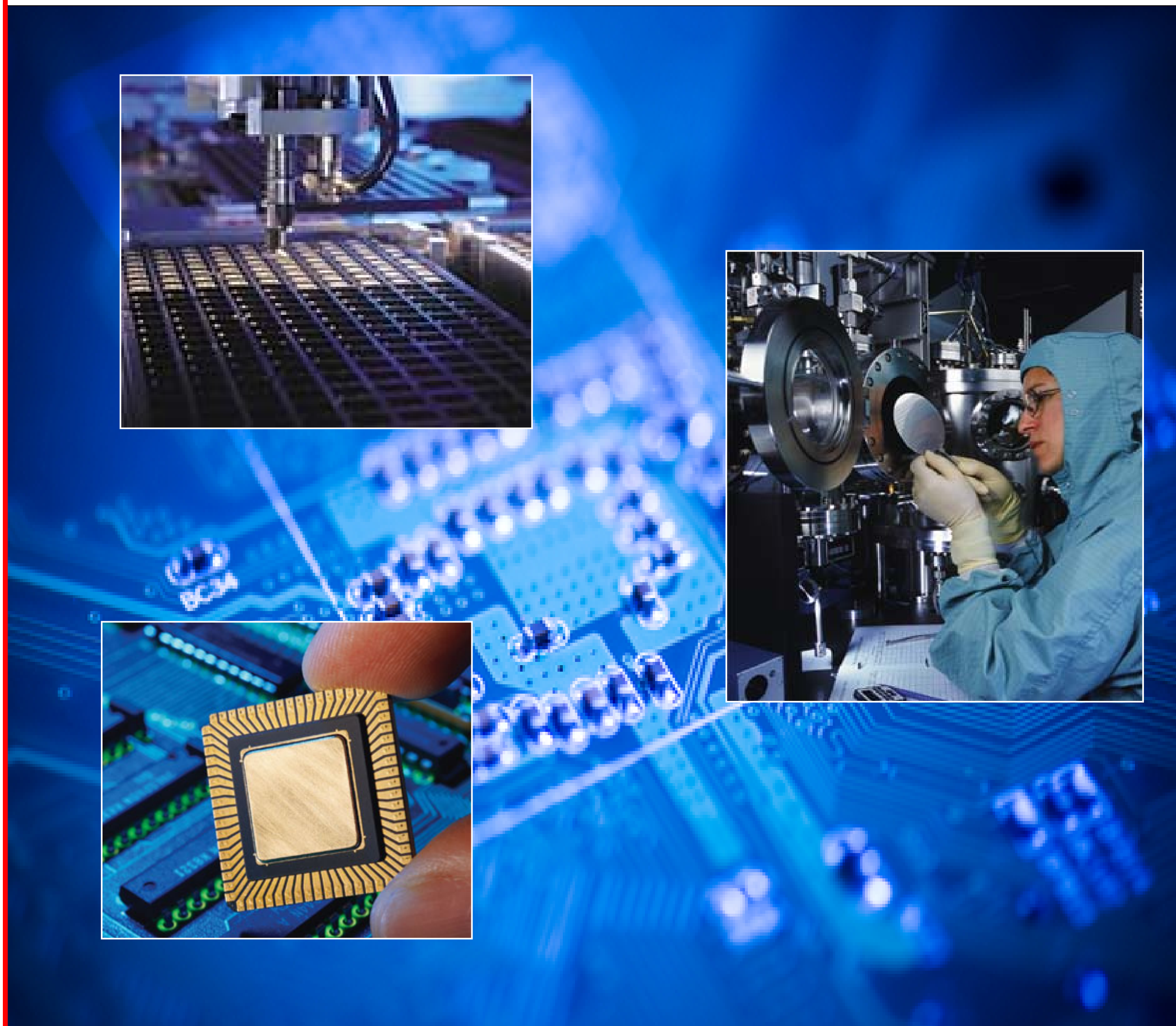
Defense Industrial Base Assessment:

U.S. Integrated Circuit Design and Fabrication Capability



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DEFENSE INDUSTRIAL BASE ASSESSMENT: U.S. INTEGRATED CIRCUIT FABRICATION AND DESIGN CAPABILITY

PREPARED BY

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EXECUTIVE SUMMARY

The capability to design and fabricate integrated circuit (IC) products is critical to the economic and national security of the United States. IC products are fundamental building blocks for commercial, industrial, and national security electronic systems. In recent years, there have been questions about the possible erosion of the U.S. manufacturing base and increasing reliance on offshore producers to supply microprocessors, memory chips, and other IC devices.

In July 2007, the Department of Commerce's (DOC) Office of Technology Evaluation (OTE) in the Bureau of Industry and Security (BIS), with support from the U.S. Department of Defense, initiated a study to assess U.S. IC design and fabrication capabilities. Forty-nine fabricators and 106 fabless firms participated in an OTE survey and provided detailed information on their ability to create a range of conventional and radiation resistant IC devices across technology nodes, using standard and non-standard semiconductor materials. Data collected through the OTE survey covered the period of 2003 to 2006, with projections through 2011.

Overall, companies reported broad capability in the United States to manufacture and design both conventional and radiation resistant ICs across almost all technology nodes, materials, wafer sizes, and device types. Based on projections through 2011, this core capability reportedly will be maintained despite some increases in outsourcing to non-U.S. locations.

During the 2003-2006 period, U.S. manufacturing and design activity was supported by significant growth in corporate net sales, research and development (R&D) spending, and capital expenditures. The vast majority of R&D and capital expenditures was allocated to activities within the United States, with a small but growing portion directed to overseas operations.

It is important to note that five large-size fabricators dominate most facets of the U.S. IC industry in terms of production, design, employment, and financial performance. However, small- and medium-size fabrication and fabless companies serving commercial and defense markets are important to the supply base. Much of the capability to manufacture radiation resistant ICs and

ICs using non-standard materials, which are required for critical industrial and national security applications, resides with these companies.

RECOMMENDATIONS

The Department of Commerce, Bureau of Industry and Security, in coordination with the Office of the Under Secretary of Defense for Acquisition, Technology & Logistics, will review and report every two years on the following:

- Changes in the health, competitiveness, and global operations of the top five large-size fabrication companies, which could have significant repercussions for the U.S. IC industry and national security because of these companies' dominant positions in the industry;

- Future activity in leading-edge IC production to assess any erosion or expansion of domestic capabilities, as few companies can currently fabricate ICs at the leading-edge technology nodes below 65 nm;

- The state of domestic mask making capability, because there is currently minimal in-house production capability and outsourcing to non-U.S. companies is projected to increase;

- The financial performance of the U.S. IC industry in order to assess the impact of the current global financial situation on the stability of the domestic IC industry, particularly on small- and medium-size IC fabrication and design companies.

BACKGROUND

This defense industrial base assessment was initiated by the Bureau of Industry and Security to provide a comprehensive overview of the U.S. design and fabrication infrastructure available for manufacturing Integrated Circuit (IC) products now and in the future. ICs are used to meet U.S. national security and other defense critical requirements, as well as commercial/industrial needs. On a world-wide basis, IC production totaled $257 billion in 2007, with U.S. producers accounting for $118 billion or 46 percent of output.[1]

Over the past decade, questions have been raised by a number of industry and government-sponsored entities regarding the state of U.S. IC design and fabrication capabilities, with some attention being focused on facility shutdowns and the addition of new production capacity offshore. For example, a February 2005 report issued by the Defense Science Board (DSB) Task Force on High Performance Microchip Supply, in particular, warned of significant erosion of U.S. IC technical, human capital, and manufacturing advantages to foreign countries, and of the negative strategic consequences of such trends continuing in the future.[2]

For the U.S. national security community, the central problem associated with this diminishing capability to design and fabricate IC products is a lessening of trustworthiness in components used in critical applications.[3] This concern has several dimensions, including the quality of component manufacturing, protection of design intellectual property, and assurance that component function is not compromised by design changes made in unsecured settings. The DSB report stated that the United States must retain leading edge IC design and fabrication capability in order to maintain technological advantage in weapon systems and other national security products.[4]

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[1] Semiconductor Industry Assn., April 29, 2008. www.sia-online.org/pre_release.cfm?ID=474
[2] See the *Defense Science Board Task Force on High Performance Microchip Supply* report, December 2005, Office of the Under Secretary for Acquisition, Technology, and Logistics, U.S. Department of Defense.
[3] IBID; also see Office of the Secretary of Defense Research, Development, Technology, and Engineering Budget Item Justification (R2 Exhibit) February 2006, p. 412.
[4] See the *Defense Science Board Task Force on High Performance Microchip Supply* report, December 2005, Office of the Under Secretary for Acquisition, Technology, and Logistics, U.S. Department of Defense, p. 12 and p. 47.

The U.S. Department of Commerce, Bureau of Industry and Security (BIS), Office of Technology Evaluation (OTE) performed this assessment in cooperation with the U.S. Department of Defense (DOD), Office of the Deputy Under Secretary of Defense for Industrial Policy. Extensive input was also provided by IC experts in government, industry, and academia. Initiated in August 2007, the assessment's overall goal is to provide decision-makers in both industry and government with: (1) the status of conventional and radiation-resistant IC fabrication and design capabilities in the United States; (2) information on domestic and foreign outsourcing of IC design and fabrication capabilities; (3) detailed information on the financial health of fabrication and fabless companies, including capital investment and research and development spending; and (4) the outlook for maintaining domestic design and fabrication activities in the future.

This report, based almost exclusively on the comprehensive survey data collected from industry, government, and university facilities, also provides background support by way of facility-specific information for the defense community's management and procurement of electronic components and systems, including the Defense Department's Trusted Foundry Program for ICs and printed circuit boards.

Survey Respondents

A total of 155 surveys were received, representing responses from 106 U.S. IC design/fabless companies and 49 U.S. IC manufacturing/fabrication companies. Survey respondents were designated as fabrication or fabless companies based upon their capabilities in the United States. Fabrication companies are those that have IC manufacturing operations in the United States; most of these companies also have significant design capabilities. Fabless companies only have IC design capability in the United States. Although these companies may have fabrication operations overseas, from an OTE perspective they are considered fabless.

These 155 responses represent more than 379 facilities in the United States. Data collected from the 49 fabrication firms covers the operations of more than 90 facilities located in 23 states; 45 of the 49 companies have related design capabilities. In addition, OTE surveyed three government facilities (two have both design/fabrication capabilities; one design only) and five university facilities (all have both design/fabrication capabilities).[5] Data supplied by respondents covered their operations for 2003-2007 period, and included projections on future fabrication and design capability through 2011.

The capabilities of IC fabrication companies were analyzed based on their net sales: small-size companies had net sales of less than $100 million; medium-size companies had net sales of $100 million to $1 billion; and large-size companies had net sales exceeding $1 billion. The capabilities of IC fabless firms were also analyzed based on their net sales: small-size companies had net sales of less than $25 million; medium-size companies had net sales of $25 to $350 million; and large-size companies had net sales greater than $350 million.

METHODOLOGY

Working with industry and government experts, OTE created a survey questionnaire to assess both IC fabrication and design capabilities in the U.S for the period 2003-2006, with projections to 2011.[6] The resulting draft OTE survey was field tested for accuracy and usability with a variety of fabrication and fabless firms, as well as government facilities. Once comments were received and incorporated into the survey instrument, the document was formally sent to the Office of Management and Budget (OMB) for review and approval as required under the Paperwork Reduction Act.

After receiving OMB approval, OTE disseminated the survey to fabrication and fabless companies, government facilities, and universities. Data collected through the survey was supplemented with OTE staff site visits to a number of design and manufacturing facilities, interviews with industry and government experts, participation in IC-related conferences and technical sessions, and reviews of previous studies of the U.S. and global IC industry.

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[5] Results on government and university facilities were not included due to the proprietary nature of the limited number of responses.

[6] A copy of the Defense Industrial Base Assessment: U.S. Integrated Circuit Design and Fabrication Capability survey questionnaire is included in Appendix E.

REPORT FINDINGS[7]

I. CONVENTIONAL IC PRODUCTS – FABRICATION CAPABILITY

Fabrication companies were asked to report on their fabrication capabilities for the 2003 – 2006 period. The 49 companies that reported data operated more than 90 fabrication facilities in the United States in 2006 that were capable of making conventional IC products.

Almost all of these companies (45), can manufacture IC products with technology nodes between 10,000 nanometers (nm) and 250 nm. Approximately half of the companies (22) can make ICs in the United States with technology nodes from 250 nm - 65 nm. A significantly smaller number of firms, six, can make IC products at dimensions below 65 nm, and just three of them have commercial-volume capability for 45 nm and 32 nm dimensions.

Most of the 49 fabrication companies manufacture IC products using three standard silicon materials: bulk silicon (35 companies), silicon-on-insulator (19 companies), and silicon geranium (11 companies). Substantially fewer companies can manufacture using seven non-standard materials, which are required for some high-performance IC products. For example, 15 companies can manufacture ICs using gallium arsenide and 11 companies can manufacture ICs using gallium nitride materials. Company capability diminishes with more exotic materials such as antimonides (7), silicon-on-sapphire (4), and silicon carbide (3). Much of the capability to manufacture ICs using non-standard materials, which are important to the performance of some national security ICs, resides with small- and medium-size companies.

The bulk of IC manufacturing capacity is concentrated in facilities using 4-inch (21 companies), 6-inch (35 companies), and 8-inch wafers (25 companies). Eight U.S. fabricators, mostly large-size companies, reported operating 14 facilities capable of manufacturing ICs on 12-inch wafers. The capability to manufacture ICs on 2-or-3 inch wafers resides with small- and medium-size companies.

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[7] This section is based on the Report Data and Analysis portion of this document, which explores each of the finding categories in extensive detail.

U.S. fabrication companies can manufacture a wide array of IC devices ranging from memory products and microprocessors to custom application specific integrated circuits (ASICs) to field programmable gate arrays (FPGAs). Companies of all sizes can manufacture these IC devices.

II. Radiation Resistant IC Products – Fabrication Capability

In addition to conventional IC products, fabrication companies were asked to identify their abilities to manufacture radiation resistant IC products for the 2003 – 2006 period.[8] Twenty-six of 49 fabrication companies in the United States reported they can produce one or more types of radiation resistant IC products: 16 are capable of making single-event effects resistant ICs; 15 can produce radiation tolerant ICs; 12 can produce radiation hardened ICs; and eight companies can fabricate neutron hardened ICs. A majority of this fabrication capability rests within small- and medium-size companies, eight and 12 respectively, with only six large-size companies able to do so.

Nine of the fabrication companies reported having previous experience manufacturing all four types of radiation resistant ICs, but do not currently perform such work. The majority of these companies, four, were large-size firms.

Twenty-eight fabrication companies indicated a willingness to manufacture radiation resistant ICs for the U.S. Government. Of these companies, 15 currently manufacture radiation resistant IC products. The majority of companies (25) were interested in producing radiation tolerant ICs for the U.S. Government.

The capability of the 26 fabrication companies that manufacture radiation resistant IC products is largely concentrated in three ranges of technology nodes: 10,000 nm - 1,000 nm (14 companies),

[8] Due to evolving refinements in the IC manufacturing process, which cause some commercial IC products to become unintentionally radiation hardened, the U.S. Department of State transferred control of exports of IC products at lower radiation hardened thresholds to the U.S. Department of Commerce on July 17th, 2007. For more information, see 72 *Federal Register* 136.

1,000 nm - 250 nm (19 companies), and 250 nm - 65 nm (16 companies). Four companies, three of them large in size, can fabricate radiation resistant ICs at dimensions smaller than 65 nm.

Bulk silicon is the standard semiconductor material most frequently employed by fabricators producing radiation resistant IC products, with 21 companies reporting capability to manufacture product using it. Eleven companies can use silicon-on-insulator and five are able to manufacture with silicon germanium. With the exception of gallium nitride, fewer than six companies are able to fabricate radiation resistant IC product using non-standard materials; none of these companies are large-size fabricators.

Most capability to manufacture radiation resistant IC products resides in fabrication facilities using 4-inch (14 companies), 6-inch (18 companies), and 8-inch (12 companies). Only three companies reported a capability to manufacture radiation resistant products on 12-inch wafers, all of them classified as large-size IC manufacturers.

Twenty-one of the 26 companies can fabricate custom ASIC radiation resistant IC products. There is less fabrication capability for other kinds of radiation resistant IC devices. Small-, medium-, and large-size fabrication companies have diverse capabilities across all device types.

III. CONVENTIONAL PRODUCTS – DESIGN CAPABILITY OF FABRICATION COMPANIES

Fabrication companies were also asked to report on their design capabilities for the 2003 - 2006 period. Forty-five of the 49 companies that reported data had in-house capability to design IC products in 2006, although this capability varied by company and facility.

Thirty-two fabrication companies can design ICs with technology nodes in the 10,000 nm - 1,000 nm range, 36 are able to design for the 1,000 nm - 250 nm range, and 32 are able to design for 250 nm - 65 nm range. Nine fabricators are able to design IC products using leading-edge technology nodes (45 nm and 32 nm). Most of this capability is held by six large-size IC fabricators.

The design capability of fabricators is focused primarily in products using standard silicon materials: bulk silicon (37 companies), silicon-on-insulator (26 companies), or silicon geranium (17 companies). The design capabilities of fabricators decrease for IC products employing non-standard materials. For example, 13 of 49 companies reported design capability for ICs using gallium arsenide material, while three are able to design devices using antimonides material.

U.S. fabricators are capable of designing a wide variety of IC products, including custom chips, memory devices, and processors. More than 70 percent of fabricators surveyed are able to design mixed signal ICs and custom ASICs. Capability resides in 17 companies to make static random access memory (SRAM), but only four fabricator design houses can produce dynamic random access memory (DRAM) devices. Sixteen fabricators can design for nonvolatile memory ICs.

IV. Radiation Resistant IC Products – Design Capability of Fabrication Companies

In addition to conventional IC products, fabrication companies were asked to identify their abilities to design radiation resistant IC products for the 2003 – 2006 period. Thirty-one of 49 fabrication companies have experience designing one or more types of radiation resistant IC products: 18 are capable of designing single-event effects resistant ICs; 14 can design radiation tolerant ICs; 10 can design radiation hardened ICs, and nine companies can design neutron hardened ICs. Fifteen of these manufacturers are medium-size, eight are small-size, and eight are large-size companies.

Across all four types of radiation resistant ICs, a majority of design capability is found in small- and medium-size companies. Only five large-size companies can design single-event effects resistant ICs, two can design radiation tolerant ICs, one can design radiation hardened ICs, and two can design neutron hardened ICs. Design capability is nearly equal between and small- and medium-size companies for all four types of radiation resistant products.

Twenty-one companies have previous experience designing radiation resistant ICs, but do not currently perform such work. Eight companies each no longer design single event effects resistant, radiation tolerant, and neutron hardened ICs, while six companies no longer design radiation hardened ICs.

Thirty-four companies are willing to design radiation resistant products for the U.S. Government, including 12 companies that did not indicate that they have previous experience doing so. There was a relatively even level of interest across companies, regardless of size, in designing radiation resistant ICs for the U.S. Government.

There are significant differences in the ability of the 31 fabrication companies to design radiation resistant products across the range of technology nodes. Fifteen companies reported capability to design IC products with circuit feature sizes ranging from 10,000 nm - 1,000 nm; 22 companies have capability to design ICs from 1,000 nm - 250 nm; and 24 companies are able to design ICs at dimensions of 250 nm - 65 nm. Seven companies, mostly large-size firms, can design radiation resistant ICs with circuit feature dimensions smaller than 65 nm.

Fabrication company design capability for radiation resistant IC products is concentrated in standard semiconductor materials. Of the 31 companies with this capability, 23 reported they can design devices based on bulk silicon; 13 can design devices using silicon-on-insulator; and 10 can design for silicon germanium material.

There is limited capability across fabrication companies to design radiation resistant ICs using non-standard materials. Small- and medium-size companies are the sole providers of design for radiation resistant ICs using non-standard materials.

Significant capability exists among the 31 fabricators that have experience in designing radiation resistant ICs to create a wide variety of products. Twenty-three companies reported the capability to design custom ASIC products. In contrast, nine companies can design standard cell ASICs and eight can design structured ASICs. Capability to design radiation resistant gate array ICs varies. Sixteen companies are able to design one-time electronically programmable gate array (EPGA) products while nine are able to design FPGA products. Fourteen fabricators are able to design radiation resistant SRAM products, but only one company can design DRAM ICs.

V. Conventional Products – Fabless Design Capability

Fabless companies, those firms that only have design capability in the United States, were asked to report on their design capabilities for the 2003 - 2006 period. The 106 fabless companies that reported data showed significant capability to design a wide range of products in 2006. The vast majority of fabless companies (65) are small-size companies, while 27 are medium-size companies and 14 are large-size companies.

The capability of the 106 fabless companies surveyed spans all technology nodes. Most of their design capability, however, is concentrated in two technology ranges: 51 companies can design product in the 1,000 nm - 250 nm range, and 76 companies have design capability at nodes between 250 nm - 65 nm. For the technology nodes of 10,000 nm - 1,000 nm, 21 companies reported capability. Twenty-three fabless companies stated they can work at technology nodes below 65 nm. Most of this capability (71 percent) is held within large-size fabless companies.

Much of the design capability of fabless companies is concentrated in three standard silicon materials: bulk silicon (88 companies), silicon-on-insulator (13 companies), or silicon germanium (19 companies). Only a small number of fabless companies can design product employing non-standard materials, which are required for some high-performance IC products. Seven companies can design ICs using gallium arsenide, and 11 can design ICs using gallium nitride materials. The number of companies with capability diminishes with more exotic materials such as antimonides (7), silicon-on-sapphire (4), or silicon carbide (1).

U.S. fabless companies possess capability to design a broad selection of IC devices. Of the 106 companies queried, 63 are able to design mixed signal technology devices and 57 can design custom ASIC products. Twenty-eight companies can create microprocessor designs. Fewer fabless IC design companies can design memory products. For example, 16 have SRAM capability, eight can design nonvolatile memory, and seven can design DRAM product designs.

VI. RADIATION RESISTANT IC PRODUCTS – FABLESS DESIGN CAPABILITY

In addition to conventional IC products, design companies were asked to identify their abilities to design radiation resistant IC products in the 2003 – 2006 period. Only 19 of 106 fabless IC companies can design radiation resistant products: 14 firms are capable of designing single-event effects resistant ICs, nine can design radiation tolerant ICs, eight can design radiation hardened ICs, and six companies can develop neutron hardened ICs.

The capability to design radiation resistant IC products is held by eight small-size, six medium-size, and five large-size companies. Four small-, six medium-, and four large-size firms can design single-event effects resistant ICs. One small-, six medium-, and two large-size fabless companies can design radiation tolerant product, while radiation hardened ICs can be designed by one small-, five medium-, and one large-size fabless company. Of the six fabless firms capable of designing neutron-hardened ICs, two are small-, three are medium-, and one is large-size.

Five companies reported having previous experience designing radiation resistant ICs, but do not currently perform such work. This previous experience is largely concentrated in small-size companies, though large-size companies did report previous capability across all four types of radiation resistant devices. Medium-size companies did not indicate any previous capability.

Twenty-three companies, mostly small- and medium-size, indicated they are willing to design radiation resistant products for the U.S. Government. This includes nine companies that did not indicate having previous experience.

The capability of the 19 fabless companies that can design radiation resistant IC products spans all technology nodes. Most of their design capability, however, is concentrated in two technology ranges: 13 companies reported capability for the technology nodes spanning 1,000 nm - 250 nm, and 17 reported capability product in the 250 nm - 65 nm range. Nine companies are able to design ICs for technology nodes between 10,000 nm and 1,000 nm, and nine fabless companies can design products with circuit features below 65 nm. The latter capability resides in one small-, three medium-, and five large-size fabless companies.

Fabless company capability to design radiation resistant ICs is concentrated in products using standard semiconductor materials. Sixteen of the 19 companies can design products using bulk silicon, seven can design ICs using silicon-on-insulator, and three can design ICs using silicon germanium. The ability of fabless companies to design radiation resistant ICs using non-standard materials is very limited. Most of this capability is centered in medium-size fabless companies.

Significant capability exists among the 19 fabless companies to design radiation resistant ICs. The majority of fabless design ability for these products rests with medium- and large-size companies. The greatest IC design ability is for custom ASIC products, with 15 companies able to undertake this work. In contrast, only six companies design standard cell ASICs and five design structured ASICs. Capability to design radiation resistant gate array ICs varies. Thirteen companies are able to design one-time Electronically Programmable Gate Arrays (EPGAs) while nine are able to design Field Programmable Gate Arrays (FPGAs). Eight fabless companies are able to design radiation resistant SRAM product, but only four companies can design DRAM products.

VII. UTILIZATION RATES

Average utilization rates of fabrication facilities operating in the United States for years 2003-2007 showed steady increases overall. Large-size companies saw facility utilization climb from 78 percent in 2004 to 90 percent in 2006 before falling in 2007 to 81 percent. Utilization rates for medium-size companies rose from 72 percent to 82 percent in 2007. Small-size companies experienced a rise in utilization rates, but relative to bigger competitors operated at significantly lower levels ranging from 47 percent in 2004 to 52 percent in 2006, before slipping to 50 percent in 2007.

Most IC wafer processing capacity in the United States is held by large-size fabricators, which collectively had a maximum capacity to process 291,262 wafers per week in 2007. Medium-size companies have a fraction of the processing capacity of large-size fabricators, approximately 54,811 wafer starts per week in 2007. Small-size companies operated at far less processing capacity – 11,947 wafer starts per week in 2007.

Fabricators project there will be two fewer fabrication facilities (net) operating in the United States in 2011 than there were in 2006. Medium-size companies expect to close three wafer processing facilities by 2011, and large-size companies plan to close four facilities. Small-size companies plan to close two facilities. At the same time fabricators indicated they would build at least seven new fabrication facilities in the United States; small-size fabricators plan to add at least four of those seven new facilities.

VIII. FABRICATION AND DESIGN OF NATIONAL SECURITY PRODUCTS

Twenty-three of the 49 fabricators surveyed manufactured IC products used for national security-related applications in 2007.[9] Eighteen companies reported that this work now occupies 10 percent or less of their capacity. Nineteen companies are willing to dedicate more production capacity to national security-related work. Fifteen of the 49 companies surveyed are not willing manufacture ICs for national security applications. Eleven other fabricators reported that they are willing to start accepting orders to produce ICs for national security applications under the appropriate financial conditions.

[9] Access to commercial IC design and fabrication capabilities in the United States is important for the Department of Defense (DOD) and other federal agencies to maintain and upgrade the capabilities of existing defense systems, as well as to produce critical parts for future national security applications. See *Joint U.S. Defense Science Board/UK Defense Scientific Advisory Council - Task Force on Defense Critical Technologies*, March 2006, p. 67.

Eighteen fabrication companies also perform IC design work for national security-related products; the activity accounts for more than 50 percent of their design work. Sixteen fabrication companies indicated they would undertake work designing national security-related products if given an opportunity. Another 15 companies declared they were not interested in this kind of work.

Fourteen of the 106 fabless companies currently perform design work for national security-related IC products. Of these, five allocate more than 50 percent of their capacity for this purpose. Forty fabless design companies not now engaged in developing IC products for national security applications indicated they would consider taking on such work.

Nine fabrication companies are accredited as trusted suppliers to the Department of Defense.[10] Fifteen additional fabrication and six fabless companies are now seeking or plan to seek U.S. Government certification as a trusted supplier. Eleven fabrication and 18 fabless companies have reviewed federal requirements to be trusted suppliers and concluded they would be able to comply, but have not been certified at this time.

Some companies have not pursued national security-related IC product fabrication and design work because they do not have adequate knowledge of the opportunities or do not comprehend the requirements and associated costs. Others are concerned that working with federal agencies would be too complicated, or that the order volume and predictability for national security work is too uncertain.

IX. Performance and Outsourcing of Production Functions by Fabrication Companies

U.S. IC fabricators retain significant in-house capability to perform seven IC manufacturing steps (mask making, wafer manufacturing [front-end and back-end], wafer sorting, circuit testing, packaging, and final testing), although capability to perform the mask making and packaging steps is much smaller.

[10] For a full explanation of the trusted supplier program, see Section VIII of the Report Data.

Fabrication companies only utilize a small number of U.S.-based vendors for six of the seven key manufacturing steps. However, more than 71 percent of the fabrication companies, or 35 firms, utilize other U.S.-based vendors for the mask making manufacturing step.

Outside of the United States, fabrication companies tend to outsource to non-U.S., non-affiliated facilities more often than to non-U.S. facilities they own and operate, although companies still use a significant number of their own non-U.S. facilities to perform select IC processing steps. Only five fabrication companies utilize non-U.S. facilities they own and operate for mask making, while 17 use non-U.S., non-affiliated facilities for this manufacturing step. Since so few fabrication companies perform mask making in their own facilities, fabrication companies largely rely on both domestic and non-U.S. outsourced support for this operation.

Fabrication companies, in addition to maintaining domestic capabilities, outsource manufacturing steps across all technology nodes, with the 1,000 nm – 250 nm and the 250 nm – 65 nm ranges being the most common. Of the six fabrication companies that can manufacture at less than 65 nm, five outsource manufacturing steps for this technology node range.

The majority of outsourced manufacturing steps (88 percent) are conducted in Asia, with Taiwan and China being the most prominent locations. Six percent of outsourced manufacturing steps are conducted in Europe, and three percent are conducted in Canada and Mexico.

Most U.S. fabrication companies expect to maintain capability to perform each of the seven IC manufacturing steps at their U.S.-based operations through 2011. A slight decrease in the number of companies capable of in-house production is anticipated for each of the seven manufacturing steps. The majority of fabricators expect to maintain or increase their level of capability for each manufacturing step through 2011, with mask making being the only step where there is no planned increase in capability level.

The number of companies that anticipate outsourcing manufacturing steps to U.S.-based vendors is projected to remain steady through 2011. However, the overall level of manufacturing step capability they outsource is anticipated to increase.

X. PERFORMANCE AND OUTSOURCING OF DESIGN FUNCTIONS BY FABRICATION COMPANIES

More than half of U.S. fabricators are capable of performing all seven key IC design functions (digital, analog, RTL design, synthesis, physical layout, function verification, and test vector generation) in their domestic facilities. While most fabrication companies do not outsource any design steps to U.S.-based vendors, 20 fabricators outsource design work to varying degrees to non-U.S. locations. Most of these companies, however, outsource to non-U.S. facilities they own and operate. Relatively few fabricators reported outsourcing design functions to non-affiliated, non-U.S. facilities.

China and India are the prime locations for design work outsourced by fabricators, although France, Japan, and Taiwan also are significant service providers. As a region, European countries are more prevalent destinations for the outsourcing of design operations by fabricators, representing 35 percent of outsourcing operations.

Most U.S. fabricators expect that they will still retain most, if not all of the domestic IC design capabilities, from 2006 through 2011. Three companies acknowledged that their abilities will diminish by 2011 in the digital, analog, and synthesis design functions; 18 fabricators plan to strengthen in-house design capability through 2011. Fifteen fabricators plan to increase outsourcing of one or more design functions to United States and non-U.S. locations by 2011.

XI. PERFORMANCE AND OUTSOURCING OF DESIGN FUNCTIONS BY FABLESS COMPANIES

Eighty-one of 106 fabless companies have capability to perform all seven major design steps (digital, analog, RTL design, synthesis, physical layout, function verification, and test vector generation) in their domestic facilities. Twenty-one fabless companies outsource portions of their design work to U.S.-based vendors, with analog and test vector generation being the most frequently cited.

Forty-nine fabless firms report outsourcing one or more design functions to non-U.S. locations, but mostly to facilities they own and operate. Approximately 20 percent of fabless companies outsource one or more design steps to non-affiliated, non-U.S. facilities. In addition, approximately 20 percent of fabless companies outsource design steps to both non-U.S. facilities they own and operate and to non-affiliated, non-U.S. facilities. Countries most cited by U.S. fabless companies for performing outsourced IC design work are: India, Taiwan, China, United Kingdom, Israel, and Canada.

Almost all of the 81 fabless companies reporting capability to perform all seven design steps expect to retain this ability through 2011. Nearly 50 percent of those fabless design companies expect to strengthen their design capabilities between now and 2011. Most fabless companies will retain or expand current capability levels. A significant number of companies also plan to expand outsourcing of design steps between now and 2011.

XII. INDUSTRY FINANCIAL PERFORMANCE

The 49 IC fabrication companies and 106 fabless companies surveyed experienced steady growth in net sales for the 2003-2006 period. Combined net sales rose from $81.4 billion to $116 billion over four years, an average annual increase of 19.3 percent.

Fabricators in total accounted for 75 percent of net sales on average for the four-year period. Net sales climbed from $62 billion in 2003 to $83.5 billion in 2006, an average annual increase of 10.6 percent. Ten large-size companies generated 90 percent of IC fabricator net sales over the reporting period; five large-size fabricators dominate U.S. IC production, accounting for $65.2 million in net sales in 2006, or 86 percent of all net sales of large-size companies surveyed. Net sales of 20 medium-size companies in 2006 represented nine percent of total industry sales, while net sales of 19 small-size IC fabricators represented one percent.

Net sales for 106 reporting fabless IC companies increased rapidly from 2003-2006, rising from $19.3 billion to $32.8 billion. As with IC fabricators, 14 large-size fabless companies dominated their segment of the market, generating 90 percent of net revenues in 2006. Net sales by 27 medium-size companies in 2006 totaled $2.9 billion, just less than nine percent of total fabless IC company net sales. Sixty-five small-size companies reported collective net sales of $500 million.

For the four-year period, fabricator and fabless IC design companies had an average combined current ratio score of 2.77.[11] This means the industry's overall assets are more than double its liabilities, and it could theoretically pay its debts with its existing resources. Their combined current ratio scores decreased from 2.88 in 2003 to 2.71 in 2006.

Fabrication companies had an average current ratio score of 2.56. Their combined current ratio scores declined over the 2003-2006 period from 2.75 to 2.38, reflecting sliding performance in some large-size companies. Small-size fabrication companies experienced an increase in their current ratios from 2.65 in 2003 to 3.79 in 2006.

Fabless companies had an average current ratio score of 3.37. Their combined current ratio scores increased from 3.26 in 2003 to 3.51 in 2006. Improvements in current ratio scores is attributed to gains in financial performance of large- and medium-size fabless companies. Small-size fabless companies as a group experienced a decline in current ratio scores from 4.73 in 2003 to 2.7 in 2006.

[11] A company's current ratio measures its ability to pay its debts with its existing resources over a twelve-month period. It is calculated by dividing current assets by current liabilities.

XIII. Research and Development and Related Employment

R&D spending by fabrication and fabless companies grew substantially from 2003 to 2006, rising from $14.8 billion to $19.9 billion – a 34 percent increase. Seventy-one percent of the $19.9 billion in R&D expenditures reported in 2006 was made by fabricators.

Fabricator R&D spending as a group rose 28 percent from $11.1 billion to $14.1 billion for the 2003-2006 period. Most R&D spending by fabricators is attributable to the top five companies. Their expenditures of $10.8 billion in 2006 accounted for 76 percent of the $14.1 billion in R&D funding reported.

Of the $14.1 billion spent on four R&D functions in 2006 by fabricators, $6.6 billion (49 percent) was focused on product development; $3.9 billion was spent by just five large-size companies. Spending on process development in 2006 accounted for about 28 percent of all R&D spending.

R&D expenditures by fabless companies increased between 2003 and 2006, rising from $3.8 billion to $5.8 billion. Of the $5.8 billion in R&D investment made by fabless IC design companies in 2006, $4.5 billion (79 percent) is attributable to the 10 largest fabless design firms. Medium-size fabless companies allocated $1.4 billion to R&D in 2006. R&D expenditures by small-size companies totaled $77 million, or one percent of R&D spending.

Of the $5.8 billion spent on four R&D functions in 2006 by fabless companies, $3.1 billion (55 percent) of it was focused on product development. Applied research also commanded substantial R&D support, claiming 38 percent of all R&D funding in 2006.

Fabrication and fabless companies obtained 95 percent of R&D funding from parent company and/or internal corporate resources in 2006. External funding from U.S. private entities totaled 2.3 percent of 2006 R&D funding, while funding from foreign sources represented 1.9 percent. Federal and local government support for IC R&D in 2006 was less than one percent of R&D spending.

There was substantial growth in R&D staffs employed by fabrication and fabless companies in the 2003-2006 period; total employment increased from 83,000 to 95,000 positions. Fabricators account for the majority of R&D employment, which increased 12 percent from 60,000 to more than 67,000 positions from 2003 through 2006. R&D employment is concentrated in large-size fabrication companies, which in 2006 accounted for 57,000 positions.

Fabless companies' R&D staffing levels rose from just over 23,000 to nearly 28,000 positions. Most R&D employment in fabless firms occurs in large-size companies, which in 2006 employed nearly 22,000 people.

Non-U.S. countries were recipients of $3.1 billion or 16 percent of total R&D expenditures by U.S. fabrication and fabless companies in 2006. This non-U.S. funding increased at an average rate of 19 percent for the 2003-2006 period. Fabrication companies were responsible for $2.19 billion in non-U.S. R&D spending in 2006, 66 percent of the total; fabless company R&D spending outside the United States totaled $880 million. Expenditures for R&D conducted at non-U.S. locations in 2006 were concentrated in five countries: Israel ($728 million); India ($464 million); Germany ($386 million); France ($270 million); and Malaysia ($190 million).

XIV. CAPITAL EXPENDITURES

Capital spending by U.S. fabrication and fabless companies rose rapidly from 2003 to 2006, climbing from $8.3 billion to $14.7 billion. Fabrication companies spending accounted for 89 percent of the total, increasing from $7.5 billion in 2003 to $13 billion in 2006. As a percent of net sales, capital expenditures by fabricators during this period jumped from 12 percent in 2003 to 16 percent in 2006. Expenditures by large-size fabricators accounted for $12.3 billion of the $13 billion total capital spending by fabricators in 2006.

Fabless companies devote a small portion of net sales to capital spending. For 2003-2006, capital spending by fabless companies averaged 5.5 percent. Capital spending increased from

$817 million to $1.57 billion over the four-year period. Large-size fabless companies fueled the majority of growth in capital spending, boosting expenditures from $700 million in 2003 to $1.3 billion in 2006.

For 2006, U.S. IC fabricators allocated $3.9 billion to non-U.S. capital investment, an increase of $1.25 billion from 2003 levels. Non-U.S. locations receiving this capital investment from fabricators included Ireland ($528 million), Singapore ($493 million), Malaysia ($348 million), Philippines ($274 million), Japan ($223 million), China ($189 million), and Thailand ($123 million).

U.S. fabless companies increased capital spending in non-U.S. locations from $98 million in 2003 to $417 million in 2006. In 2006, the destinations for non-U.S. capital investment by fabless companies included Japan ($123 million), Thailand ($96 million), India ($31 million), China ($26 million), Singapore ($16 million), Korea ($4 million) and Taiwan ($3 million).

RECOMMENDATIONS

The Department of Commerce, Bureau of Industry and Security, in coordination with the Office of the Under Secretary of Defense for Acquisition, Technology & Logistics, will review and report every two years on the following:

- Changes in the health, competitiveness, and global operations of the top five large-size fabrication companies, which could have significant repercussions for the U.S. IC industry and national security because of these companies' dominant positions in the industry;

- Future activity in leading-edge IC production to assess any erosion or expansion of domestic capabilities, as few companies can currently fabricate ICs at the leading-edge technology nodes below 65 nm;

- The state of domestic mask making capability, because there currently is minimal in-house production capability and outsourcing to non-U.S. companies is projected to increase;

- The financial performance of the U.S. IC industry in order to assess the impact of the current global financial situation on the stability of the domestic IC industry, particularly on small- and medium-size IC fabrication and design companies.

REPORT DATA AND ANALYSIS

I. CONVENTIONAL IC PRODUCTS – FABRICATION CAPABILITY

To assess the state of IC fabrication capability in the United States, OTE surveyed 49 fabrication companies. Responses were requested on a facility basis, and data was provided for more than 90 facilities.[12] Fabricators were categorized as small-, medium-, and large-size based on average net sales from 2003 – 2006 (see Figure I-1).

Figure I-1: Total Number of Fabrication Companies Manufacturing Conventional IC Products

Size	Number of Companies	Net Sales
Small	19	Less than $100 million
Medium	20	$100 million - $1 billion
Large	10	Greater than $1 billion
Total	**49**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Fabrication companies were asked whether they can manufacture ICs with circuit feature sizes ranging from 10,000 nanometers (nm) to less than 32 nm, a range encompassing most major industry technology nodes.[13] In addition, OTE requested companies to provide detailed information on the types of IC devices they are capable of producing. Survey participants also specified the types of semiconductor materials they could employ in manufacturing IC products. Besides standard silicon formulations (bulk silicon, silicon-on-insulator, and silicon germanium), fabricators were queried on their ability to manufacture products using gallium arsenide, gallium nitride, indium phosphate, and other non-standard materials. Finally, manufacturers were asked to identify capability in terms of the size of semiconductor wafers (e.g. 2-, 4-, 6-, 8-, 12-inch diameter) their fabrication plants can process. The larger the wafer size, the greater the number of ICs produced from a single wafer processing cycle.[14]

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[12] Certain companies were permitted by OTE to consolidate facility responses.

[13] Responses indicating an ability to manufacture at a given technology node, semiconductor chemistry, or device type does not mean the company is actually producing product at this time.

[14] IC design patterns are imaged onto silicon wafers coated with light-sensitive films and are etched. Once a wafer is fully processed, IC die or "chips" are cut from the wafer, which can hold hundreds of copies of an IC product.

TECHNOLOGY NODE RANGE

A technology node, sometimes referred to as a "process node" or "process technology," indicates the smallest circuit feature size that can be drawn on a chip with a microlithography tool. Most commonly measured in nanometers (nm), technology nodes are generally accepted manufacturing benchmarks used by fabricators. Circuit feature dimensions dictate how much circuitry can be placed in a given area on a microchip. As technology nodes step down, circuit lines can be placed closer together, allowing for the manufacture of more complex devices and enabling enhanced performance.

For the purposes of this study, technology nodes were grouped into four ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm (see Figure I-2).

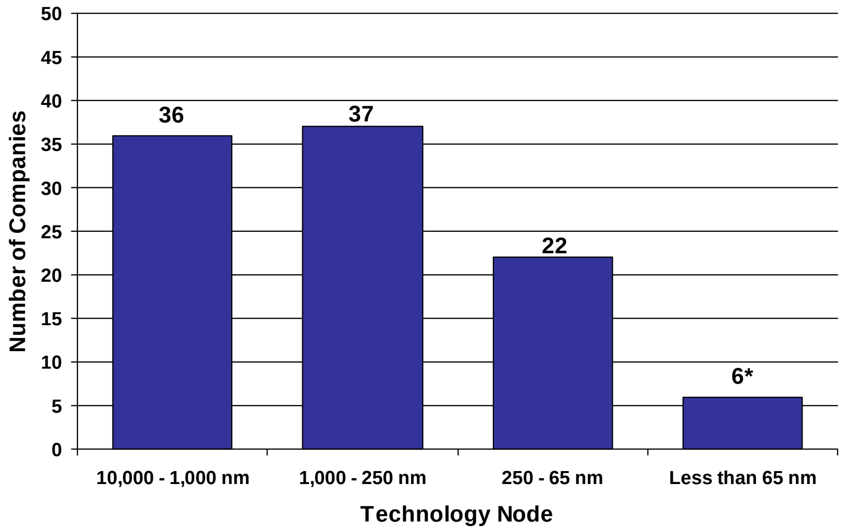
Figure I-2: IC Technology Node Groups

Technology Node (*nanometers)*	Number of Companies
10,000- 6,000	19
6,000-3,000	24
3,000-1,500	28
1,500-1,000	28
1,000-800	18
800-500	24
500-350	24
350-250	21
250-180	16
180-130	17
130-90	15
90-65	10
65-45	6
45-32	4
32 or smaller	2

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

U.S.-based IC fabrication capability in 2006 was primarily concentrated across two technology node ranges: 10,000 nm – 1,000 nm and 1,000 nm – 250 nm (see Figure I-3). Thirty-six fabricators were identified as operating fabrication facilities in the United States that can manufacture IC product in the 10,000 nm – 1,000 nm range. Most of this production capability is owned by small- and medium-size companies. Six of the 10 large-size companies produce IC product using this older IC manufacturing technology node.

Figure I-3: U.S.-Based Integrated Circuit Fabrication Capability by Technology Node Range



* 3 of these organizations are not capable of high volume production

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Similarly, survey data shows 37 companies have the capability to manufacture ICs at 1,000-250 nm technology node range. Again, the majority of this manufacturing capability is held by 15 of the 21 small-size companies and 16 of the 18 medium-size IC fabricators. Six large-size companies also operate such production facilities.

Far fewer companies operating in the United States, 22 of the 49 fabricators, are able to manufacture IC products in the 250 nm – 65 nm range. Of those 22, seven companies can fabricate product at 65 nm.

At the leading edge, the fabrication of commercial ICs at 65 nm began in 2005, and some fabricators are now making product at 45 nm and 32 nm.[15] Six IC companies in the United

[15]*Intel Demonstrates Industry's First 32 nm Chip and Next-Generation Nehalem Microprocessor Architecture*, Intel Corp., September 18, 2007. www.intel.com/archive/releases/20-70918corp_a.htm; *IBM Alliance Partners 'Open for*

States, 12 percent of fabrication companies, can manufacture conventional IC products with circuit line widths below 65 nm. Of these six, three have limited production capability; their facilities are not designed for sustained, high-volume manufacturing.

Based on company size, small- and medium-size companies have the vast majority of their capability in two technology node ranges: 10,000 nm – 1,000 nm and 1,000 nm – 250 nm (see Figure I-4). As stated previously, these are the most common technology node ranges for the fabrication of conventional IC products. Large-size companies, however, fabricate more often on the 250 nm – 65 nm range. Eighty percent of large-size companies manufacture IC products in this range, as opposed to only 32 percent and 40 percent of small- and medium-size companies, respectively.

Figure I-4: Percent of Companies Capable of Fabrication Per Technology Node Range

	Small (19 Companies)	**Medium** (20 Companies)	**Large** (10 Companies)
10,000 nm – 1,000 nm	84%	70%	60%
1,000 nm – 250 nm	79%	80%	60%
250 nm – 65 nm	32%	40%	80%
Less than 65 nm	5%	5%	40%

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Business' for 32 nm High-k/Metal Gate Designs, Semiconductor International, April 14, 2008. www.semiconductor.net/article/CA6551303.html

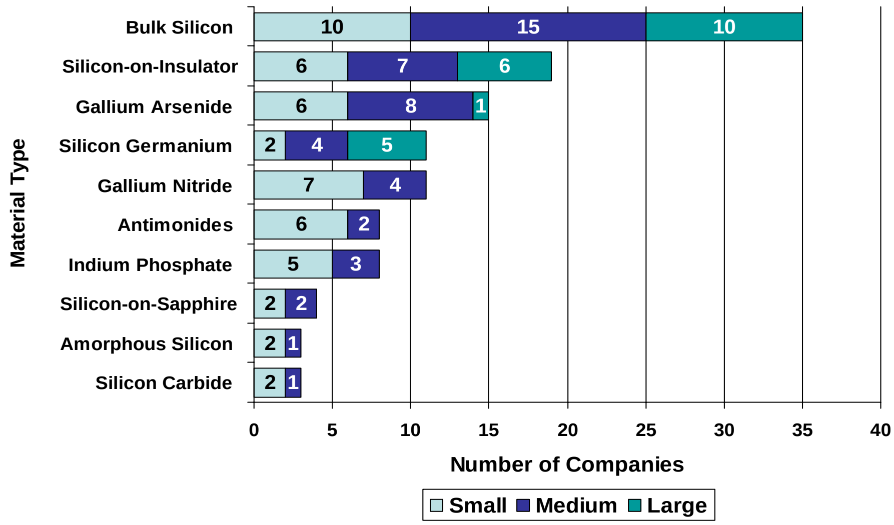
These numbers indicate that large-size companies are at the forefront of leading-edge IC fabrication in the United States. Four of the companies able to manufacture IC products at less than 65 nm are large-size, whereas only one small- and medium-size company possess this capability.

SEMICONDUCTOR MATERIALS

Most IC products manufactured are based on one of three standard silicon materials – bulk silicon, silicon-on-insulator, and silicon germanium. Other types of non-standard silicon and non-silicon materials are also used in manufacturing ICs and other semiconductor devices. Materials such as gallium arsenide, gallium nitride, and indium phosphate are increasingly employed in ICs used in products such as cell phones and network switches to enable higher operating speed than what may be achieved with conventional silicon-based devices. These materials also more readily support low-voltage electronic device architectures.

OTE surveyed manufacturers on their capabilities to produce IC products using 10 standard and non-standard materials. Most fabrication capacity in the United States in 2006 was concentrated in standard silicon technologies (see Figure I-5). Specifically, 35 of 49 companies can produce IC product in bulk silicon. Of these, 10 companies are large-size, 15 are medium-size, and another 10 are small-size. Nineteen companies reported being able to manufacture ICs using silicon-on-insulator technology: six large-size, seven medium-size, and six small-size. Eleven IC fabricators can make product using silicon germanium alloy. Five of these fabricators are large-size, four are medium-size, and two are small-size.

Figure I-5: U.S.-Based Fabrication Capability - By Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Beyond standard materials, OTE asked fabricators to identify their capabilities to manufacture IC products using non-standard materials: silicon-on-sapphire (SOS), silicon carbide, gallium arsenide, gallium nitride, indium phosphate, amorphous silicon, and compounds containing antimonides.

Gallium arsenide IC products first received significant use in military, aerospace, and supercomputer applications, but in recent years ICs built with this material have been widely deployed in cell phones, networking equipment, telecommunications switches, and other devices. Fifteen of 49 companies reported an ability to manufacture gallium arsenide IC products. One of these 15 companies is large-size, eight are medium-size, and six are small-size.

IC products fashioned from gallium nitride offer performance advantages superior to those of gallium arsenide, including faster speed and far better heat tolerance for power amplifiers, microwave communications, and radar uses. Eleven companies reported capability to manufacture gallium nitride ICs in the United States. Seven of these are small-size companies and four are medium-size.

Antimonides encompass a class of semiconductor alloys including indium antimonide, gallium antimonide, and aluminum antimonide. Three companies operating in the United States, two medium-size and one small-size, reported a capability to manufacture products with antimonide materials.

Indium phosphate is a compound semiconductor material that can achieve faster speeds in ICs than what is attainable with common silicon transistors. Its advantages for some applications, however, have been eclipsed by advances in silicon germanium.[16] Eight companies stated they are capable of fabricating IC products employing indium phosphate materials. Of these, five are small-size and three are medium-size manufacturers.

IC products built using SOS offer performance advantages over standard silicon for high frequency devices and superior thermal conductivity. The use of this material for ICs, however, has been limited because of cost and process problems. Just four companies in the United States report an ability to manufacture SOS product – two are medium-size and two are small-size.

Amorphous silicon has limited application in IC products, but is used in some devices such as specialized silicon memory devices. Three companies operating in the United States, one medium-size and the other two small-size, indicated they can fabricate with the material for IC and sensor products.

The manufacturing base for IC products based on silicon carbide is similar to that of SOS. Silicon carbide is used in high-voltage ICs, light-emitting diodes, Schottky diodes, high temperature thyristors, and other products made using semiconductor device manufacturing processes. There are just three companies that can make devices in the United States using this material, which has excellent thermal conduction properties. Of these three fabricators, one is medium-size and two are small-size companies.

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[16] *Slimmer Chips Handle Fast Nets*, Kimberly Patch, Technology Research News, June 27, 2001.

Figure I-6 below summarizes the percent of fabrication capability per material type for the 49 U.S.-based fabrication companies.

Figure I-6: Fabrication Capability – by Material Type
(As a Percent of 49 Total Fabrication Companies)

Standard Silicon Materials	
Bulk Silicon	71 %
Silicon on Insulator	39 %
Silicon Germanium	22 %
Non-Standard Materials	
Gallium Arsenide	31 %
Gallium Nitride	22 %
Indium Phosphate	16 %
Antimonides	16 %
Silicon Sapphire	8 %
Silicon Carbide	6 %

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Several patterns emerge in summarizing fabrication capabilities by material types (see Figure I-7). Large-size companies fabricate nearly exclusively on the three most common material types: bulk silicon, silicon-on-insulator, and silicon germanium. The percent of large-size companies fabricating with these material types is much greater than for small- and medium-size companies. Only 53 percent of small-size companies and 75 percent of medium-size companies fabricate IC bulk silicon, whereas all large-size companies do so.

Figure I-7: Percent of U.S.-Based Companies Capable of Fabricating by Material Type

	Small (19 Companies)	Medium (20 Companies)	Large (10 Companies)
Standard Silicon Materials			
Bulk Silicon	53%	75%	100%
Silicon-on-Insulator	32%	35%	60%
Silicon Germanium	11%	20%	50%
Non-Standard Materials			
Silicon-on-Sapphire	11%	10%	0%
Gallium Nitride	37%	20%	0%
Silicon Carbide	11%	5%	0%
Gallium Arsenide	32%	40%	10%
Indium Phosphate	26%	15%	0%
Antimonides	32%	10%	0%
Amorphous Silicon	11%	5%	0%

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

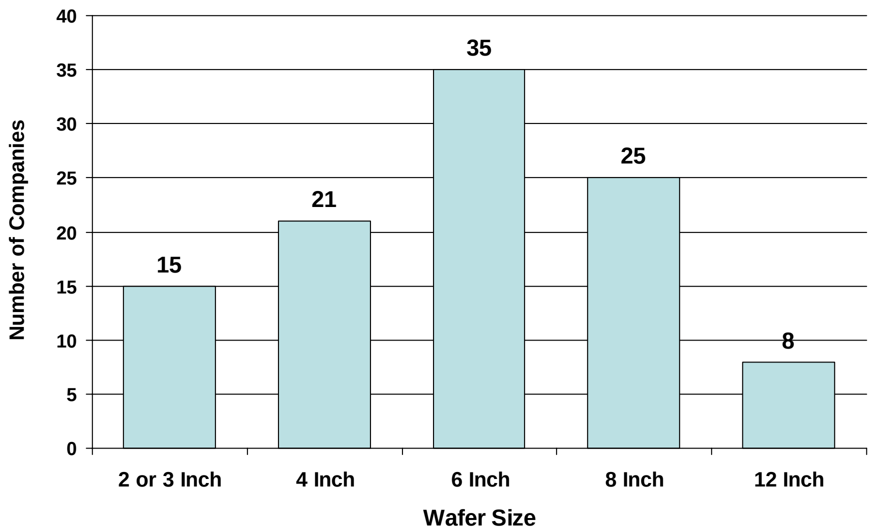
Survey findings highlight that many small- and medium-size companies often fabricate across a more diverse range of material types compared to larger manufacturers. Frequently, the reason for this is the opportunity to exploit niche markets and to manufacture product lines where sales volumes are not sufficiently high to interest larger manufacturers. In fact, the large-size companies surveyed reported having capability to fabricate IC products using only the non-standard material gallium arsenide.

Fabrication Capability By Wafer Size

The foundation upon which IC devices are fabricated are circular wafers made of silicon, gallium arsenide, or other materials. Silicon is the most widely used wafer material. Wafers come in a range of sizes, including 2-, 3-, 4-, 6-, 8-, and 12-inch diameter. The IC industry has steadily migrated to larger diameter wafers because they offer significant improvements in economies-of-scale in manufacturing. The larger the diameter of a wafer, the larger the area there is on which to pattern IC die and the greater the number of microchips that can be produced in a single processing cycle.

The most common wafer size fabrication capability reported is 6-inch wafers, followed by 8-inch and then 4-inch (See Figure I-8). Thirty-five of 49 fabrication companies can utilize a 6-inch wafer, 71 percent of the total. Twelve-inch wafer fabrication capability is limited; only eight companies are able to manufacture on the largest wafer diameter now in use, 16 percent of total fabrication companies.

Figure I-8: U.S.-Based Fabrication Capability - by Wafer Size

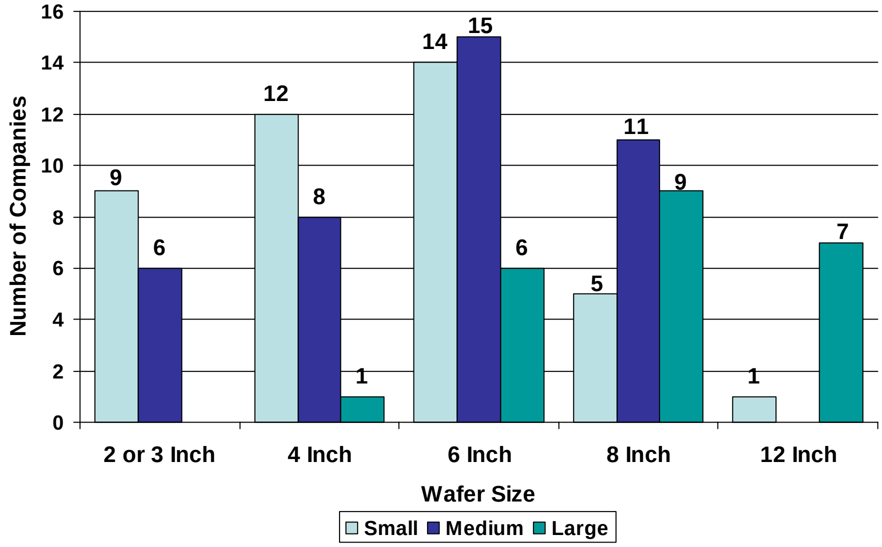


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

There appears to be correlation between company size as measured in net sales and wafer-size capability of the production facilities they operate. Large-size company production capacity is concentrated in 8- and 12-inch wafer production, although six companies operate 6-inch fabrication lines (see Figure I-9). Similarly, 65 percent of medium-size companies operate 6- and 8-inch production capacity; the remaining 35 percent being facilities using 2-, 3-, and 4-inch wafers. For 2-, 3-, and 4-inch wafers, more small-size companies have fabrication capability than medium- and large-size companies.

The fact that large-size fabricators are virtually the only companies operating 12-inch production lines can be attributed to the high costs associated with building and operating this kind of manufacturing facility – and the need for a steady flow of high-volume orders to sustain them economically. It makes economic sense for small- and medium-size firms to use smaller wafer sizes, because they use smaller production runs of ICs to meet their customers' needs.

Figure I-9: U.S.-Based Fabrication Capability - by Wafer and Company

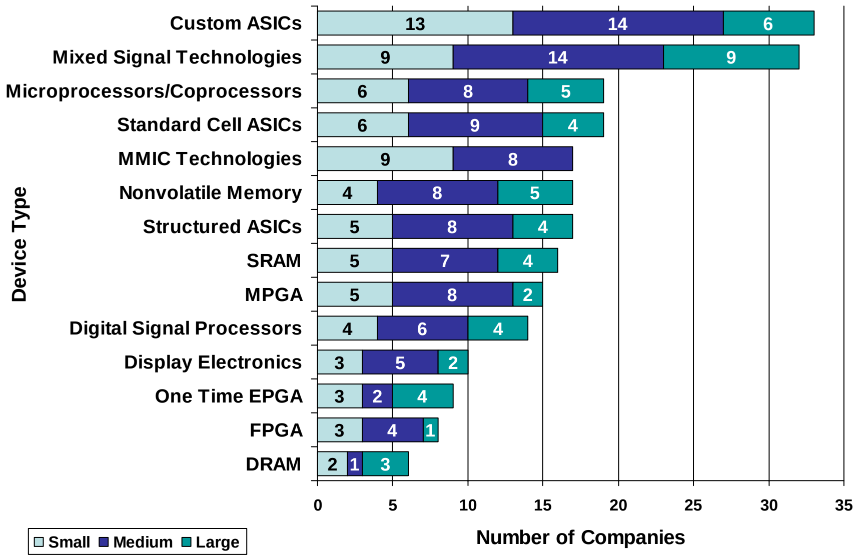


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Device Fabrication Capabilities

The OTE survey requested information on the types of IC components companies are capable of manufacturing. OTE queried companies on four groups of IC product: application specific integrated circuits (ASICs), gate arrays, memory, and other IC products (see Figure I-10).

Figure I-10: U.S.-Based Device Manufacturing - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

ASIC chips are designed to perform specific instructions and tasks and can provide performance advantages over general purpose microprocessors. Manufacturers were asked whether they could make any of four types of ASIC products: structured ASICs, standard cell ASICs, custom ASICs, and microprocessors/coprocessors.[17]

Seventeen manufacturers can make structured ASIC products, including four large-size companies, eight medium-size, and five small-size. For standard cell ASICs, 19 companies said they csn fabricate such products – four large-size, nine medium-size, and six small-size firms. Thirty-three companies reported an ability to produce custom ASICs – six large-size, 14 medium-size, and 13 small-size. Nineteen companies stated that they can manufacture microprocessors and coprocessors – five of them large-size, eight medium-size, and six small-size.

Gate arrays are IC devices containing cells with rows of transistors and resistors that are not connected. The appropriate interconnections are made using software to form a custom-designed working device. For the purpose of this report, the gate arrays group consists of field

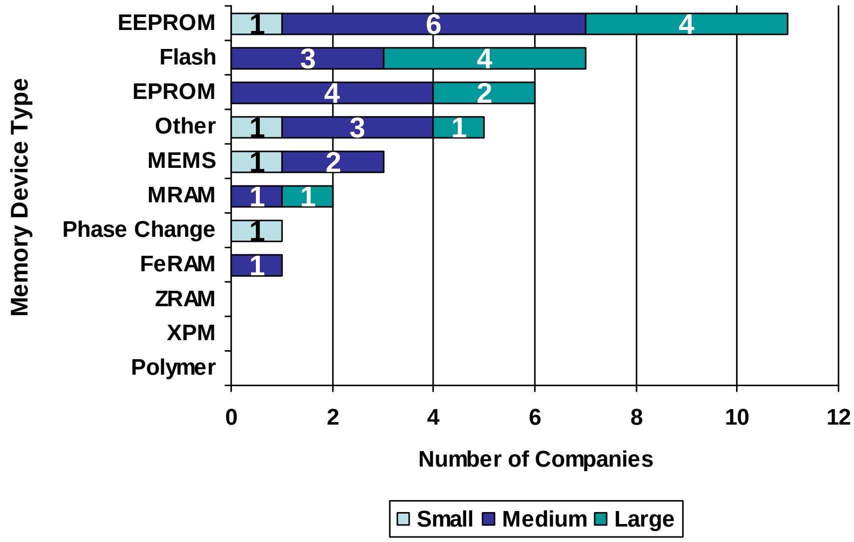
[17] For definitions of each type of ASIC product, see Appendix C.

programmable gate arrays (FPGAs), one-time electronically programmable gate arrays (EPGAs), and mask programmable gate arrays (MPGAs). Fifteen companies reported a capability to manufacture MPGAs – two large-size, eight medium-size, and five small-size. Nine manufacturers were able to produce one-time EPGAs - four large-size, two medium-size, and three small-size. Slightly fewer companies can manufacture FPGAS: one large-size, four medium-size, and three small-size fabricators.

Manufacturers provided information on their ability to make three forms of memory ICs: dynamic random access memory (DRAM), static random access memory (SRAM), and nonvolatile memory. These are widely used in consumer, industrial, and defense electronic systems. Six companies reported an ability to fabricate DRAM in the United States – three large-size companies, one medium-size, and two small-size. Almost three times as many companies, 16 in total, can make SRAM in the United States: four large-size, seven medium-size, and six small-size.

Seventeen companies said they possess domestic manufacturing capability to produce nonvolatile memory products – six large-size, eight medium-size, and four small-size fabricators. Specifically, manufacturers were queried on 11 different categories of nonvolatile memory products: electronically erasable read-only memory (EEPROM), erasable read-only memory (EPROM), flash memory, ferro-electric random access memory (FeRAM), micro electro-mechanical systems memory (MEMS), magneto-resistive random access memory (MRAM), polymer memory, one-time programmable memory (XPM), phase change memory, zero capacitor random access memory (ZRAM), and other memory types (see Figure I-11).

Figure I-11: U.S.-Based Capability to Manufacture Nonvolatile Memory Products



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Eleven companies are able to manufacture EEPROMs and six can produce EPROMs. Seven companies reported an ability to make flash memory. Three companies stated they can fabricate MEMS memory product and two can make MRAM product. Only one company is able to produce phase change memory and only one can manufacture FeRAM memory. No company reported an ability to produce ZRAM, XPM, or polymer non-volatile memory in the United States.

Fabricators were also asked about their ability to produce digital signal processors, micromonolithic integrated circuits (MMICs), mixed signal analog-digital ICs, and visual display IC devices (see Figure I-10). Digital signal processors can be fabricated by 14 manufacturers: four large-size companies, six medium-size companies, and four small-size companies.

Seventeen companies posted capabilities to manufacture MMICs in the United States – eight medium-size companies and nine small-size. For mixed-signal analog-digital ICs, 32 companies stated they can produce the devices – nine large-size, 14 medium-size, and nine small-size companies. In the area of digital display ICs, fabrication capability was reported by two large-size, five medium-size, and three small-size companies.

II. RADIATION RESISTANT IC PRODUCTS – FABRICATION CAPABILITY

To assess the state of radiation resistant IC manufacturing capability in the United States, OTE surveyed 49 companies on their ability to make radiation tolerant, radiation hardened, neutron hardened, and single-event-effects resistant IC products.[18] Fabrication companies were asked whether they could manufacture radiation resistant ICs with circuit feature sizes ranging from 10,000 nanometers (nm) to 32 nm.[19]

Survey participants were also asked to specify the types of semiconductor materials they could employ in manufacturing radiation resistant IC products. These materials were divided into standard silicon and non-standard groups. The former consists of bulk silicon, silicon-on-insulator, and silicon germanium materials. The non-standard materials included in the survey were silicon-on-sapphire, silicon carbide, gallium nitride, gallium arsenide, indium phosphate, antimonides, and amorphous silicon. Finally, fabrication companies were asked to identify these capabilities in relation to the size of semiconductor wafers (2-, 4-, 6-, 8-, and 12-inch) used in fabricating IC products.[20]

IC fabricators were categorized as small-, medium-, and large-size based on average net corporate sales from 2003-2006 (see Figure II-1). Of the 49 fabrication companies surveyed, 26 were capable of manufacturing radiation resistant products in 2006, 53 percent of the total. Eight of these companies were small-size, 12 were medium-size, and six were large-size.

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[18] A discussion of conventional fabrication capabilities is in Chapter I.

[19] Responses indicating an ability to manufacture at a given technology node, semiconductor chemistry, or device type does not mean the company is actually producing product at this time.

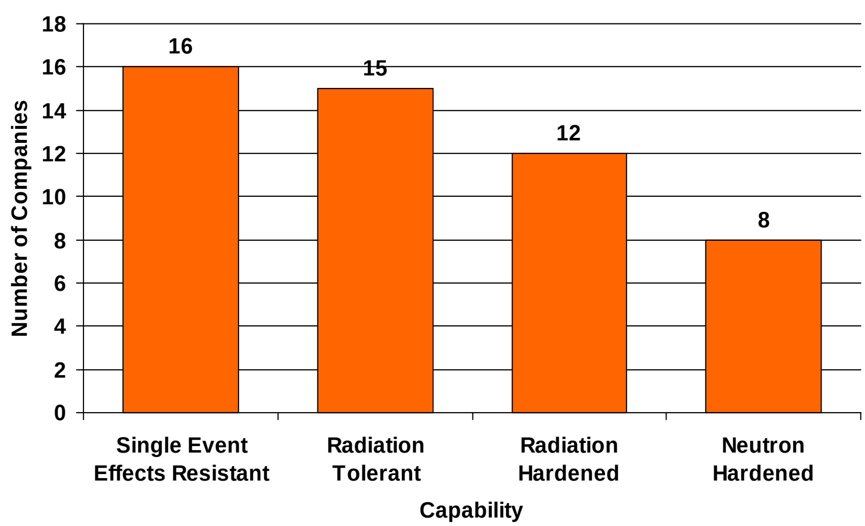
[20] IC design patterns are imaged onto silicon wafers coated with light-sensitive films (resist) and are etched. Once a wafer is fully processed, IC die or "chips" are cut from the wafer, which can hold hundreds of copies of an IC product.

Figure II-1: Total Number of Fabrication Companies Manufacturing Radiation Resistant IC Products		
Size	Number of Companies	Net Sales
Small	8	Less than $100 million
Medium	12	$100 million - $1 billion
Large	6	Greater than $1 billion
Total	**26**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Fabrication companies were asked to identify the types of radiation resistant products they can produce (see Figure II-2 and II-3). The greatest capability reported was for single-event effects resistant IC products, which are designed to continue functioning after a single energetic particle strikes the device. Sixteen out of 26 companies manufacture these products, a third of all fabrication companies.

Figure II-2: U.S.-Based Companies With Radiation Resistant Fabrication Capability in 2006

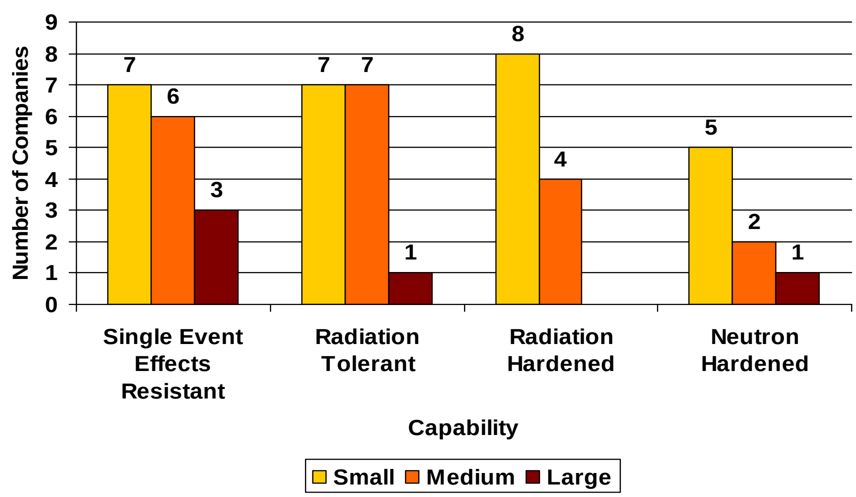


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Radiation tolerant products have a limited capacity to resist radiation damage that would otherwise disable the IC device.[21] Fifteen companies manufacture radiation tolerant products, 58 percent of all fabrication companies with radiation resistant capabilities. Radiation hardened IC products are designed to withstand even higher doses of radiation than radiation tolerant products.[22] Twelve fabrication companies manufacture these types of IC products, 46 percent of radiation resistant-capable fabrication companies.

Finally, only eight companies manufacture neutron hardened products. These chips are designed to withstand the effects of high speed neutrons, gamma rays, and electromagnetic pulses that accompany a nuclear weapons detonation.

Figure II-3: U.S.-Based Companies With Radiation Resistant Fabrication Capability - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

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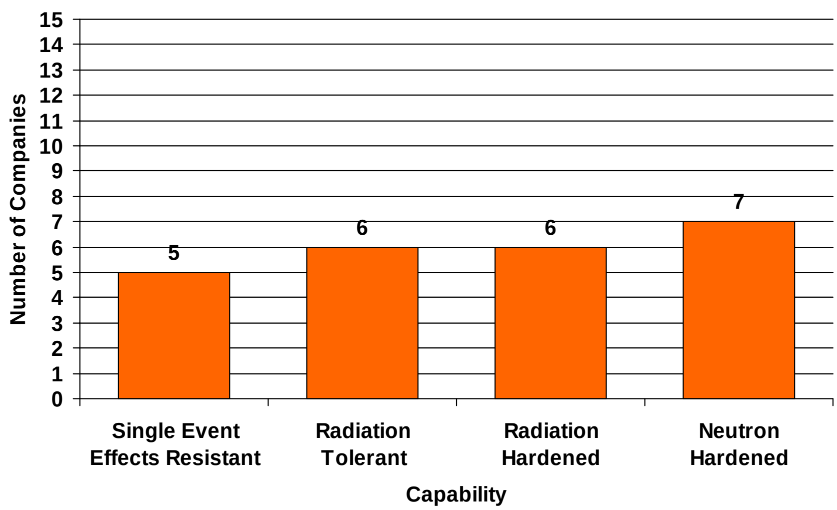
[21] Radiation tolerant refers to parts that can withstand a total dose failure of greater than 100 kilorad (krad), but less than 300 krad. A krad equals 1,000 rad. One rad = 0.01 joules/kilogram; 1 krad = 10J/kg.

[22] Radiation hardened refers to parts that can withstand a total dose failure of greater than 300 krad. The International Traffic in Arms (ITAR) regulations have a baseline of 500 krad for radiation hardened products.

PREVIOUS RADIATION RESISTANT MANUFACTURING EXPERIENCE

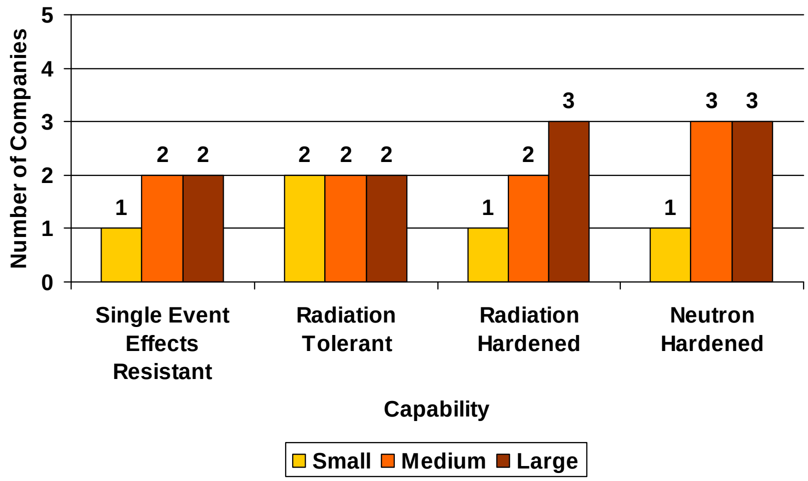
There are a number of fabrication companies that have previous experience with, but do not currently engage in the manufacture of radiation resistant ICs. In total, nine fabrication companies, 18 percent of the total, previously manufactured radiation resistant ICs but no longer did so as of 2006. Of these, four companies were large-size, three medium-size, and two small-size. This previous experience is spread relatively evenly amongst the four radiation resistant product types (see Figure II-4 and II-5).

Figure II-4: U.S.-Based Companies With Previous Fabrication Radiation Resistant Experience



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Figure II-5: U.S.-Based Companies With Previous Fabrication Radiation Resistant Experience - by Company Size

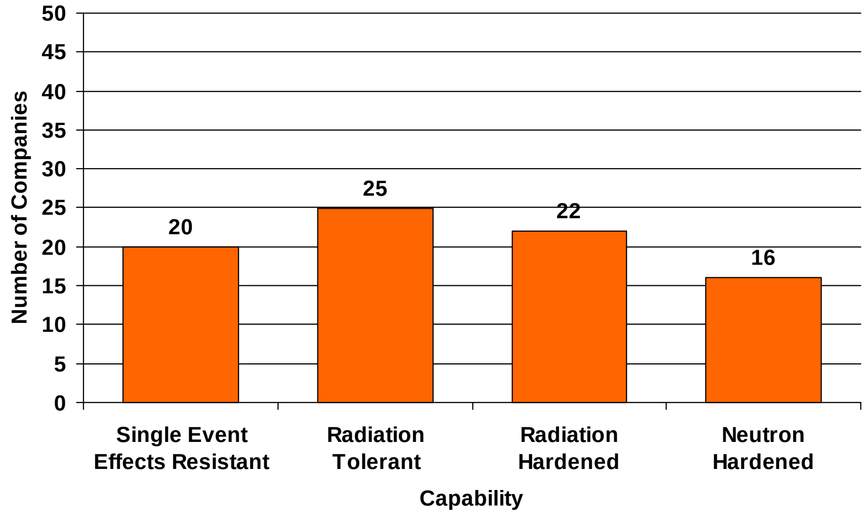


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

WILLINGNESS TO MANUFACTURE FOR THE U.S. GOVERNMENT

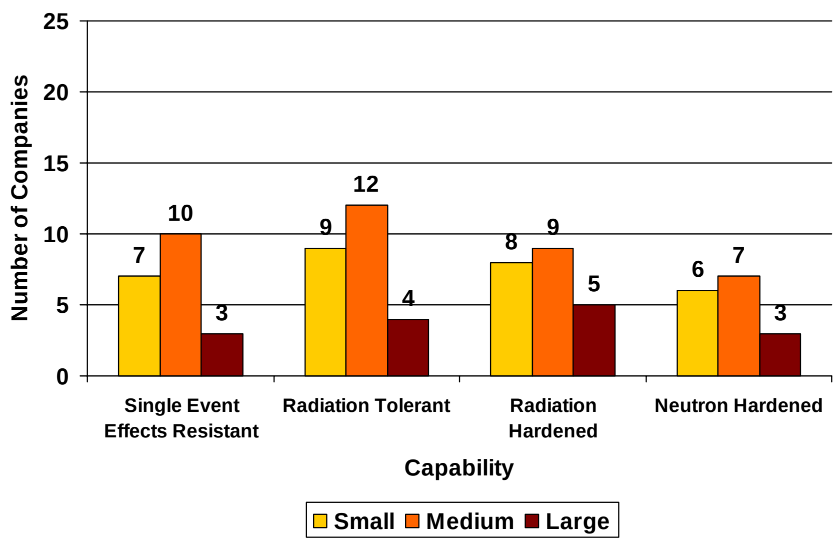
Fabrication companies were also asked to indicate whether or not they would be willing to manufacture radiation resistant ICs for the U.S. Government. Twenty-eight fabrication companies indicated a willingness to do so (see Figure II-6 and II-7). Of those responding favorably, 13 do not currently engage in the manufacture of radiation resistant IC products. There was a relatively even spread of interest by company size in designing these products for the U.S. Government.

Figure II-6: Interest in Fabricating Radiation Resistant Products for the U.S. Government



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Figure II-7: Interest in Fabricating Radiation Resistant Products for the U.S. Government - By Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

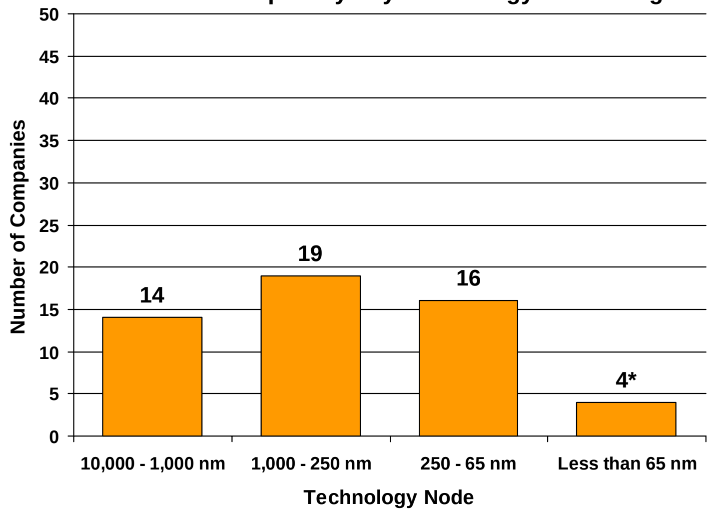
TECHNOLOGY NODE RANGE

A technology node, sometimes referred to as a "process node" or "process technology," indicates the smallest circuit feature size that can be drawn on a chip with a microlithography tool. Most commonly measured in nanometers (nm), technology nodes are generally accepted manufacturing benchmarks used by fabricators. Circuit feature dimensions dictate how much circuitry can be placed in a given area on a microchip. As technology nodes step down, circuit lines can be placed closer together, allowing for the manufacture of more complex devices and enabling enhanced performance.

For the purpose of this study, technology nodes were grouped into four ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm. Fabrication at less than 65 nm is a relatively recent practice in the industry.

Nineteen of the 26 companies capable of fabricating radiation resistant products, 73 percent, could manufacture in the 1,000 nm – 250 nm range in 2006 (see figure II-8). There is slightly less manufacturing capability at the 250 nm – 65 nm and 10,000 nm – 1,000 nm ranges, with 16 and 14 companies capable of utilizing these technology node ranges, respectively.

Figure II-8: U.S.-Based Integrated Circuit Radiation Resistant Fabrication Capability - by Technology Node Range



* 3 of these organizations are not capable of high volume production

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Few companies manufacture radiation resistant products at the leading edge. Only four companies, 8 percent of total fabrication companies, are capable of manufacturing radiation resistant products at less than 65 nm. Three of these companies are not capable of high volume production of ICs at less than 65 nm because of limitations in their fabrication facilities.

Based on company size, small- and medium-size companies are able to manufacture radiation resistant ICs almost exclusively in the 10,000nm – 1,000nm, 1,000nm – 250nm, and 250nm – 65nm technology node ranges (see Figure II-9). These companies are commonly capable of manufacturing radiation resistant ICs in the 1,000 nm – 250 nm range, with slightly fewer companies able to fabricate in the other two ranges. Only one medium-size company can manufacture radiation resistant products at less than 65 nm.

Large-size companies possess capabilities across all technology node ranges, with the capability to manufacture in the 250 nm – 65 nm range being the most common. Three of the four companies that can fabricate radiation resistant ICs at less than 65 nm are large-size.

Figure II-9: Percent of Companies Capable of Radiation Resistant Fabrication Per Technology Node Range

	Small (8 Companies)	**Medium** (12 Companies)	**Large** (6 Companies)
10,000 nm – 1,000 nm	63%	58%	33%
1,000 nm – 250 nm	88%	75%	50%
250 nm – 65 nm	63%	58%	67%
Less than 65 nm	0%	8%	50%

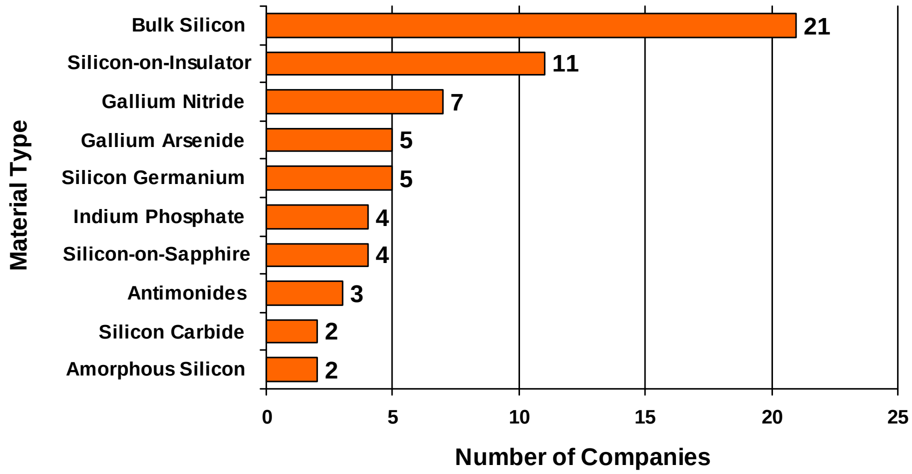
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

SEMICONDUCTOR MATERIALS

Most IC products are based on one of three silicon materials – bulk silicon, silicon-on-insulator, silicon germanium. Other types of non-standard materials are also used in manufacturing ICs and other semiconductor devices. Materials such as gallium arsenide, gallium nitride, and indium phosphate are increasingly employed in ICs used in products such as cell phones, network switches to enable higher operating speeds than what may be achieved with conventional silicon-based devices. These materials also more readily support low-voltage electronic device architectures.

As with conventional products, bulk silicon was the most commonly cited material for radiation resistant IC products in 2006 (see Figure II-10). Twenty-one companies, or 81 percent of radiation resistant-capable fabricators, can utilize bulk silicon. This includes all six large-size companies. In contrast, 11 fabricators reported being able to manufacture ICs using silicon-on-insulator (SOI) technology. Only five companies can manufacture radiation resistant ICs using silicon germanium.

Figure II-10: Scope of U.S.-Based Radiation Resistant Fabrication Capability



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

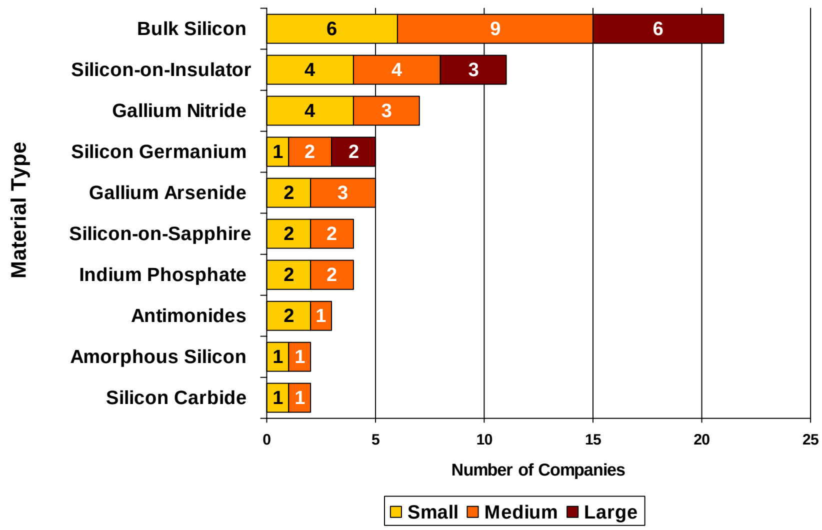
In addition, there is capability in the United States to manufacture radiation resistant IC devices using non-standard IC materials (see figure II-11). These materials offer various performance advantages over standard silicon materials, with some materials offering inherent resistance to radiation. However, they often require specialized manufacturing processes and present higher production costs.

Figure II-11: Fabrication Capability – by Material Type (As a Percent of 26 Fabrication Companies Manufacturing Radiation Resistant Products)	
Standard Silicon Materials	
Bulk Silicon	81%
Silicon on Insulator	42%
Silicon Germanium	19%
Non-Standard Materials	
Gallium Nitride	27%
Gallium Arsenide	19%
Indium Phosphate	15%
Silicon Sapphire	15%
Antimonides	12%
Silicon Carbide	8%

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Gallium nitride is the most commonly cited non-standard material type used in radiation resistant ICs. Seven of the 26 companies, 27 percent of all radiation resistant-capable fabricators, can manufacture gallium nitride radiation resistant IC products. There are fewer fabricators capable of utilizing the other non-standard material types (see Figures II-12 and II-13). Survey data showed no large-size companies are able to manufacture radiation resistant products using non-standard material types.

Figure II-12: Scope of U.S.-Based Radiation Resistant Fabrication Capability - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Figure II-13: Percent of U.S.-Based Companies Capable of Fabricating Radiation Resistant Products - by Material Type

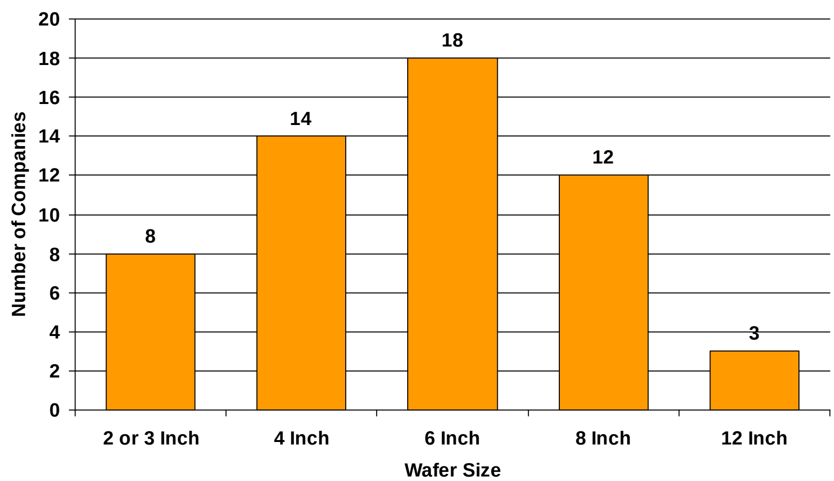
	Small (19 Companies)	**Medium** (20 Companies)	**Large** (10 Companies)
Standard Silicon Materials			
Bulk Silicon	32%	45%	60%
Silicon-on-Insulator	21%	20%	30%
Silicon Germanium	5%	10%	20%
Non-Standard Materials			
Silicon-on-Sapphire	11%	10%	0%
Gallium Nitride	21%	15%	0%
Silicon Carbide	5%	5%	0%
Gallium Arsenide	11%	15%	0%
Indium Phosphate	11%	10%	0%
Antimonides	11%	5%	0%
Amorphous Silicon	5%	5%	0%

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

FABRICATION CAPABILITY BY WAFER SIZE

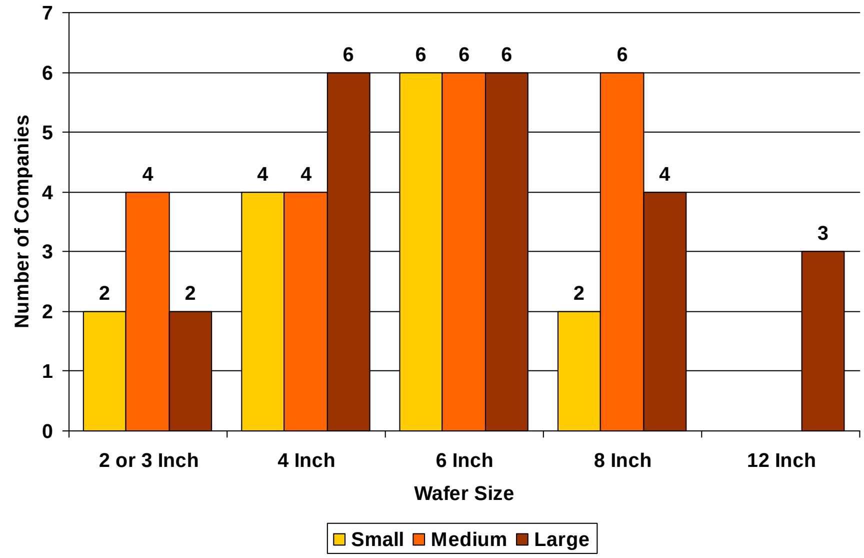
Only three companies reported that they can manufacture radiation resistant products on 12-inch wafers (the largest wafer size), 11.5 percent of the 26 radiation resistant-capable fabrication companies surveyed. There is broader capability across the 26 fabrication companies that manufacture radiation resistant products at smaller wafer diameters. Twelve companies can operate production lines using 8-inch wafers and 18 firms report operating 6-inch wafer facilities. Fourteen companies can manufacture using 4-inch facilities, and eight companies said they use plants processing 2- or 3-inch wafers for producing radiation resistant IC products.

Figure II-14: U.S.-Based Radiation Resistant Fabrication Capability - by Wafer Size



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Figure II-15: U.S.-Based Radiation Resistant Fabrication Capability - by Wafer and Company Size

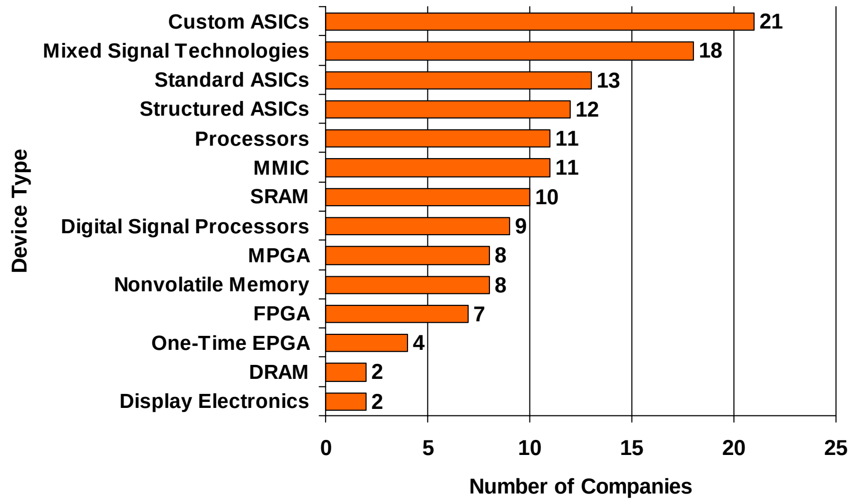


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Device Fabrication Capabilities

The OTE survey requested fabrication companies to identify their capability to manufacture various radiation resistant devices. OTE queried companies on four groups of IC products: application specific integrated circuits (ASICs), gate arrays, memory, and other IC products (see figure II-16).

Figure II-16: U.S.-Based Radiation Resistant Fabrication Capability - by Device Type



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Manufacturers were asked whether they could make any of four types of ASIC products: structured ASICs, standard ASICs, custom ASICs, and microprocessors/coprocessors. The greatest capability is in custom ASICS, which 21 companies reported being able to manufacture. The second greatest capability is in standard ASICs, with 13 companies reporting capability. Twelve companies can manufacture radiation resistant structured ASICs, while 11 are able to manufacture microprocessors/coprocessors.

The gate arrays group consists of field programmable gate arrays (FPGAs), one-time electronically programmable gate arrays (EPGAs), and mask programmable gate arrays (MPGAs). MPGAs are the most common, with 16 percent of all fabrication companies able to manufacture radiation resistant versions of these devices. There are four companies that can make radiation resistant one-time EPGAs, and seven that can make radiation resistant FPGAs.

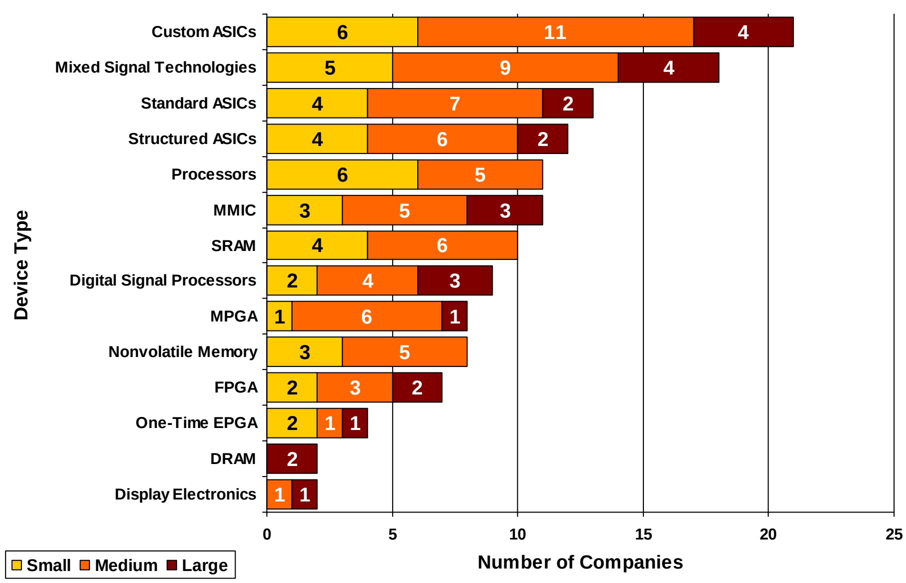
With regard to radiation resistant memory ICs, manufacturers provided information on their ability to make three forms of memory ICs: dynamic random access memory (DRAM), static random access memory (SRAM), and nonvolatile memory. Two companies reported an ability to fabricate DRAM in 2006. Ten companies are able to manufacture radiation resistant SRAM, while eight companies can manufacture nonvolatile memory.

For the remaining IC products, the number of fabricators capable of producing radiation resistant products are as follows:

- Digital signal processors – 9
- Micromonolithic integrated circuits (MMICs) – 11
- Mixed signal analog-digital ICs - 18
- Anti-tamper technology - 4
- Infrared focal plane arrays – 9

There is little correlation between company size and their fabrication of particular radiation resistant devices. Small-, medium-, and large-size fabrication companies have diverse capabilities across all the device types. Generally, large-size companies are capable of manufacturing a wider range of devices, albeit on a narrower band of material types. Small- and medium-size companies are more likely to specialize in one or two device types on a wider spectrum of material types (see Figure II-17).

Figure II-17: U.S.-Based Radiation Resistant Fabrication Capability - by Device Type



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

III. CONVENTIONAL PRODUCTS – DESIGN CAPABILITY OF FABRICATION COMPANIES

In addition to their capability to manufacture integrated circuit (IC) products, most fabrication companies operating in the United States also have capability to design IC components. To understand the extent of this design capability relative to fabless firms, OTE asked fabrication companies to describe their design capabilities. The 49 IC fabrication companies that participated in the survey were divided by size into three groups based on average net sales for 2003-2006 (see Figure III-1).

Figure III-1: Total Number of Fabrication Companies Designing Conventional IC Products

Size	Number of Companies	Net Sales
Small	19	Less than $100 million
Medium	20	$100 million - $1 billion
Large	10	Greater than $1 billion
Total	**49**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

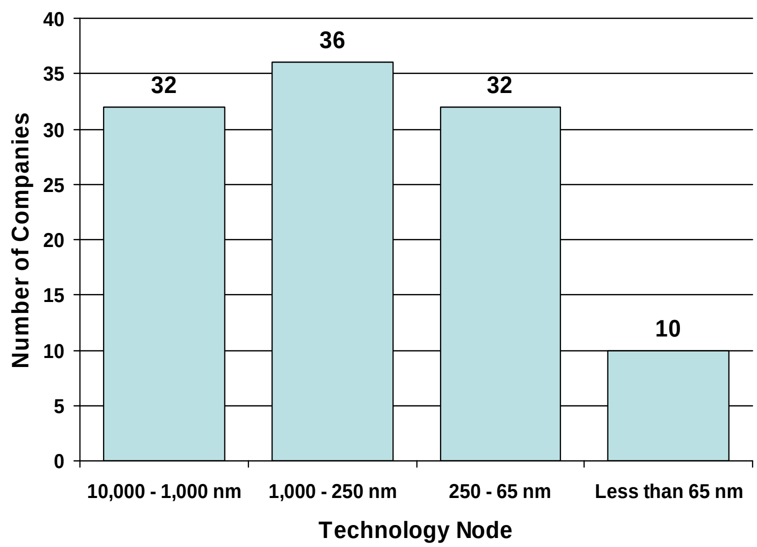
OTE asked fabrication companies to identify their capability to develop ICs with circuit feature sizes ranging from 10,000 nanometers (nm) to less than 32 nm.[23] Companies were also requested to specify the kinds of IC products they can design, as well as the specific types of semiconductor materials their designs can employ. This included their ability to employ standard silicon formulations (bulk silicon, silicon-on-insulator, and silicon germanium), as well as non-standard materials such as gallium arsenide, gallium nitride, indium phosphate, and other semiconducting materials.

[23] Responses indicating an ability to manufacture at a given technology node, semiconductor chemistry, or device type does not mean the company is actually producing product at this time corresponding to their responses.

TECHNOLOGY NODE RANGE

The technical design abilities of the 49 fabrication companies vary considerably, with some able to develop IC products for a broad range of physical requirements while other firms have distinctly narrower capabilities. As with manufacturing capability, fabrication companies can primarily design products for the 1,000 nm – 250 nm technology node ranges (see Figure III-2).[24] Fewer fabrication companies design products for less than 65 nm, only 10 out of 49.

Figure III-2: U.S.-Based Fabrication Company Design Capability - by Technology Node Range



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

When company size is factored into the ability of fabrication companies to design by technology node, some differences appear. At least 60 percent of small-, medium-, and large-size companies can design IC products over the 10,000 nm – 1,000 nm and 1,000 nm – 250 nm ranges (see Figure III-3). However, there is a substantial drop in the number of small- and medium-size companies that can design in the 250 – 65nm and less than 65nm ranges. Six large-size companies design products at less than 65 nm, while only two small- and two medium-size companies do the same.

[24] For the purposes of this study, technology nodes were grouped into four ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm.

Figure III-3: Percent of Fabrication Companies Capable of Design Per Technology Node Range

	Small (19 Companies)	**Medium** (20 Companies)	**Large** (10 Companies)
10,000 nm – 1,000 nm	63%	70%	60%
1,000 nm – 250 nm	63%	90%	60%
250 nm – 65 nm	37%	80%	90%
Less than 65 nm	11%	10%	60%

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

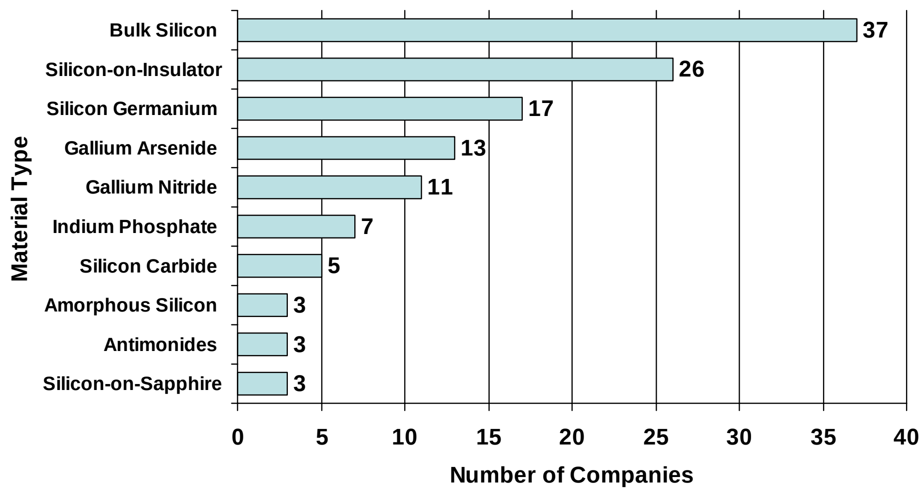
SEMICONDUCTOR MATERIALS

Fabrication companies were asked to state their ability to design IC products that rely not only on the standard silicon materials (bulk silicon, silicon-on-insulator, and silicon germanium), but also on a range of non-standard materials: gallium arsenide, silicon-on-sapphire, gallium nitride, antimonides, indium phosphate, silicon carbide, and amorphous silicon. In all, fabrication companies described their capabilities to design IC devices utilizing 10 different material types.

Similar to fabless companies, the majority of fabrication companies, 76 percent, design IC products with bulk silicon (Figure III-4). Fabrication companies are more likely to design with the other standard silicon materials than design-only companies. Fifty-three percent of fabrication companies design with silicon-on-insulator materials, whereas only 12 percent of fabless companies do the same. This also holds true for silicon germanium where 35 percent of fabrication companies reported capability while only 18 percent of design-only companies can design products using this material.

With regard to non-standard materials, 13 fabrication companies are able to design IC devices based on gallium arsenide and 11 can design ICs employing gallium nitride. Design capability of the fabrication companies declines steadily for the other non-standard materials.

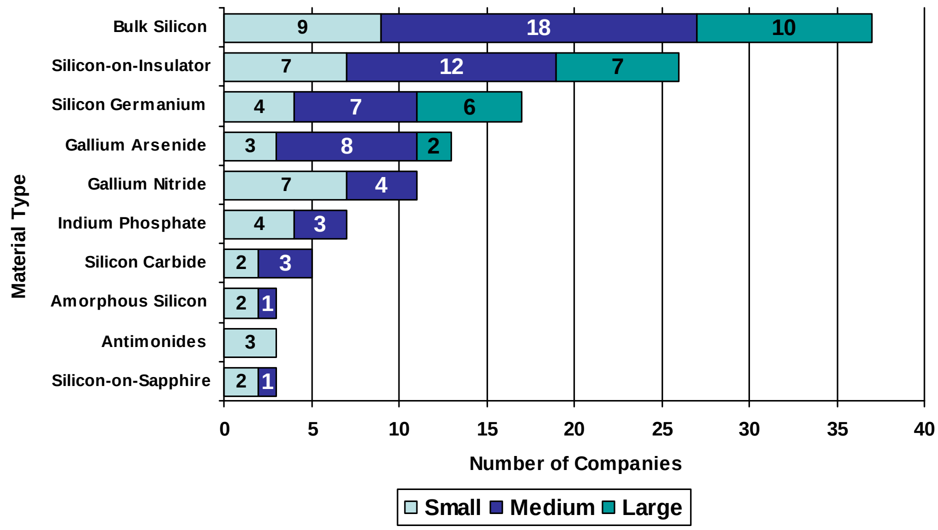
Figure III-4: Scope of U.S.-Based Conventional Design Capability - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

The design capabilities of IC fabricators vary by size. Large-size fabrication companies, for example, focus their design efforts on products employing the four most common IC materials: bulk silicon, silicon-on-insulator, silicon germanium, and gallium arsenide (see Figure III-5). The design capabilities of the small- and medium-size companies are more diverse, covering the three most-commonly utilized materials as well as the full range of non-standard materials.

Figure III-5: Scope of U.S.-Based Fabrication Company Design Capability - by Company Size

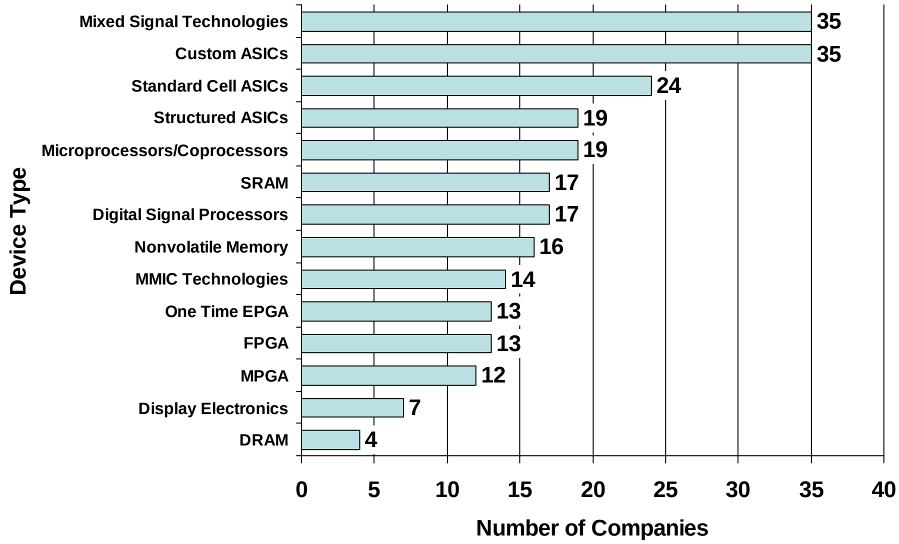


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Device Design Capability

OTE asked fabrication companies to identify the types of IC components they can design in the United States. Specific information was requested on four product groups: application specific integrated circuits (ASICs), gate arrays, memory, and other IC products (see Figure III-6).

Figure III-6: U.S.-Based Device Design Capability - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Survey participants reported capability to design four types of ASIC products: structured ASICs, standard ASICs, custom ASICs, and microprocessors/coprocessors.[25] Significant differences in fabricators' design abilities can be seen across these product categories. The largest reported capability is for custom ASICs where 35 fabrication companies (71 percent) possess the manufacturing capability. Twenty-four companies reported capability for standard ASICs, while 19 firms can design structured ASICs and 19 can design microprocessors/coprocessors.

Fabrication companies also reported capability to design a variety of gate array devices.[26] For the purposes of this report, the gate arrays group consists of field programmable gate arrays (FPGAs), one-time electronically programmable gate arrays (EPGAs), and mask programmable gate arrays (MPGAs). Thirteen fabrication companies are capable of designing FPGAs and one-time EPGAs, 27 percent of the total, while twelve companies, or 24 percent, design can MPGAs.

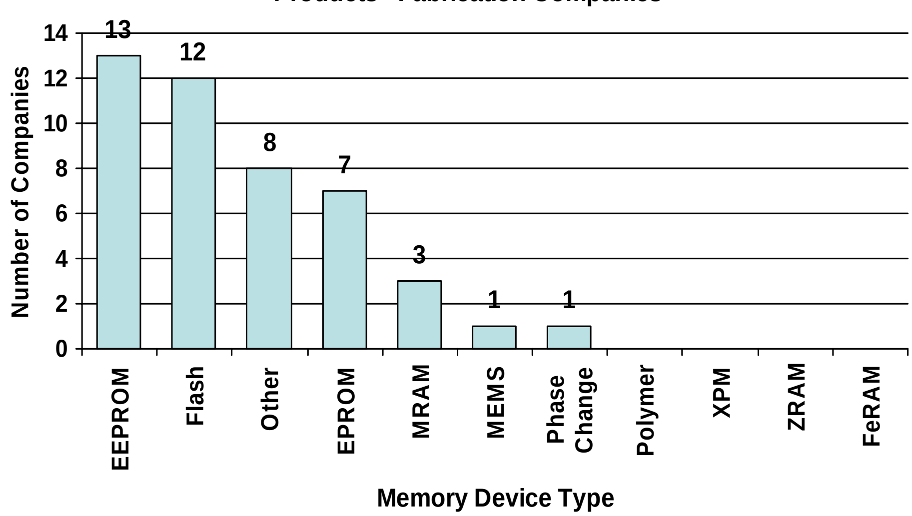
[25] ASIC chips are designed to perform specific instructions and tasks, and can provide performance advantages over general purpose microprocessors.

[26] Gate arrays are IC devices containing cells with rows of transistors and resistors that are not connected. The appropriate interconnections are made using software to form a custom-designed working device.

With regard to memory, IC fabrication companies indicated their capability to design three forms of memory: dynamic random access memory (DRAM), static random access memory (SRAM), and nonvolatile memory.[27] SRAM is the most commonly designed memory device, with 17 fabrication companies doing so. Sixteen fabrication companies design nonvolatile memory, nearly a third of the total companies. Only four out of 49 fabrication companies indicated an ability to design DRAM products.

IC fabrication companies were asked to further delineate their nonvolatile memory product capabilities in 11 different categories: electronically erasable read-only memory (EEPROM), erasable read-only memory (EPROM), flash memory, ferro-electric random access memory (FeRAM), micro electro-mechanical systems memory (MEMS), magneto-resistive random access memory (MRAM), polymer memory, one-time programmable memory (XPM), zero capacitor random access memory (ZRAM), phase change memory, and other memory types (see Figure III-7).

Figure III-7: U.S.-Based Capability to Design Nonvolatile Memory Products - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

[27] These are widely used in consumer, industrial, and defense electronic systems.

Of the 11 nonvolatile memory categories, only EEPROM, flash, other, EPROM, and MRAM memory can be developed by multiple fabrication companies. Only one company can design MEMS and phase change products, respectively. No fabrication company reported an ability to design polymer, XPM, ZRAM, or FeRAM nonvolatile memory.

For the remaining device types, there is a variety of design capability present in the fabrication companies. This ranges from 35 firms that can design mixed signal technologies, to 19 firms capable of designing digital signal processors, to seven firms that can design display electronics.

IV. RADIATION RESISTANT IC PRODUCTS – DESIGN CAPABILITY OF FABRICATION COMPANIES

OTE surveyed 49 integrated circuit (IC) fabrication companies with regard to their ability to design four types of radiation resistant products: single-event effects resistant, radiation tolerant, radiation hardened, and neutron hardened. Fabrication firms were asked to state their ability to design radiation resistant ICs with circuit feature sizes ranging from 10,000 nanometers (nm) to 32 nm.[28]

Of the 49 fabrication companies surveyed, 31 indicated an ability to design some form of radiation resistant IC product (Figure IV-1). Eighty percent of all large-size companies surveyed can design radiation resistant ICs and 75 percent of all medium-size companies can do the same. Only 42 percent of all small-size firms reported this capability.

Figure IV-1: Total Number of Fabrication Companies Designing Radiation Resistant IC Products

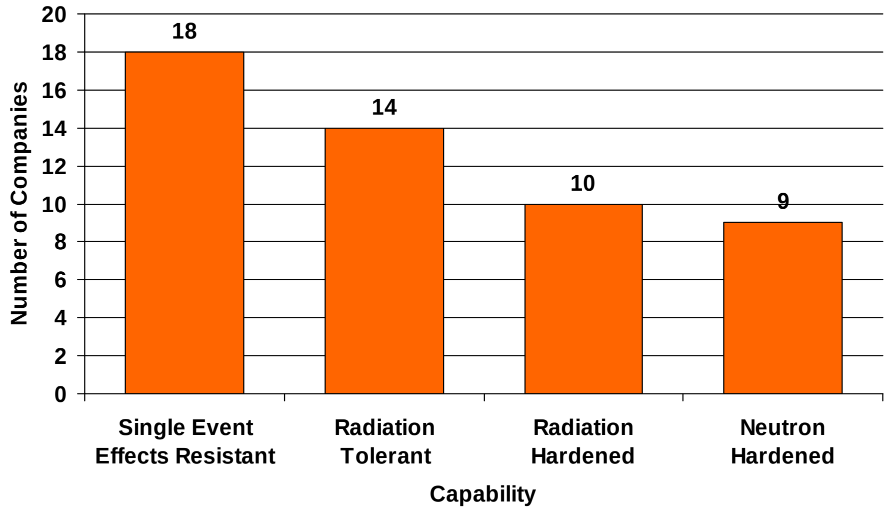
Size	Number of Companies	Net Sales
Small	8	Less than $100 million
Medium	15	$100 million - $1 billion
Large	8	Greater than $1 billion
Total	**31**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Eighteen fabricators, 58 percent of companies capable of designing radiation resistant ICs, indicated that in 2006 they were able to design single-event effect resistant products (see Figure IV-2 and IV-3). These ICs can continue operating after being disrupted by a single energetic particle that would cause a conventional device to fail.

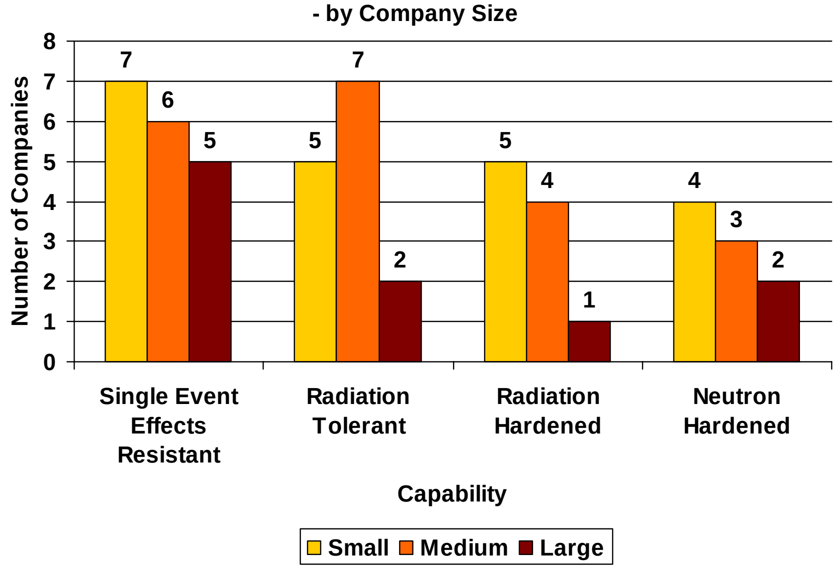
[28] Responses indicating an ability to design at a given technology node, semiconductor chemistry, or device type does not mean the company is actually performing such work at this time.

Figure IV-2: U.S.-Based Fabrication Companies With Radiation Resistant Design Capability in 2006



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Figure IV-3: U.S.-Based Fabrication Companies With Radiation Resistant Design Capability in 2006 - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Fourteen fabrication companies, 45 percent of all radiation resistant-capable fabrication firms, said they can design radiation tolerant products. Radiation tolerant products have a limited capacity to resist radiation that would otherwise disable an IC device.[29] Ten fabrication companies, 32 percent of radiation resistant-capable fabrication firms, are able to design radiation hardened IC products, which can withstand higher doses of radiation relative to radiation tolerant products.

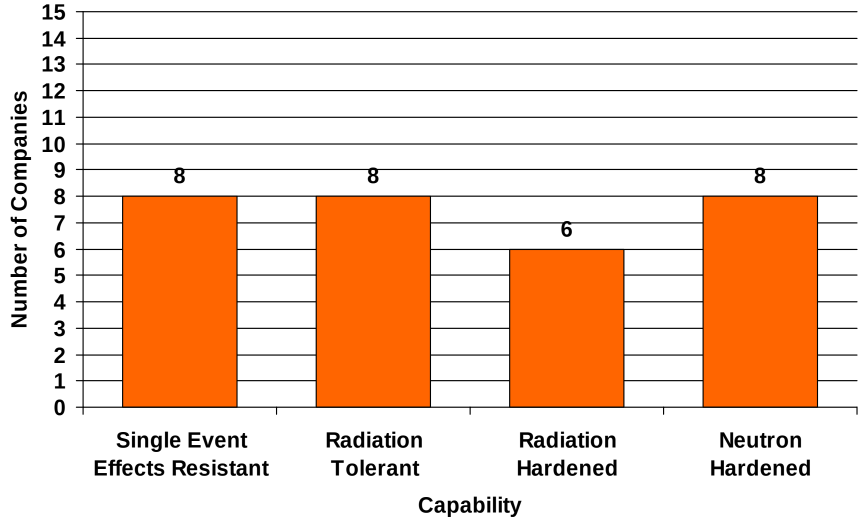
Finally, nine fabrication companies, 29 percent of radiation resistant-capable fabrication firms, can design neutron-hardened IC products. Neutron-hardened ICs are able to withstand neutron radiation damage caused by gamma rays and electromagnetic pulses, such as those associated with a nuclear weapon detonation.

Previous Radiation Resistant Design Experience

Twenty-one companies indicated previous experience in designing with one or more of these products (Figure IV-4).[30] Seventy-six percent of these companies (eight firms) indicated that they had previously but no longer design for each of the single-event effects resistant, radiation hardened, or neutron hardened product types. Six companies indicated that they previously designed radiation tolerant products, 29 percent of fabrication companies with previous experience.

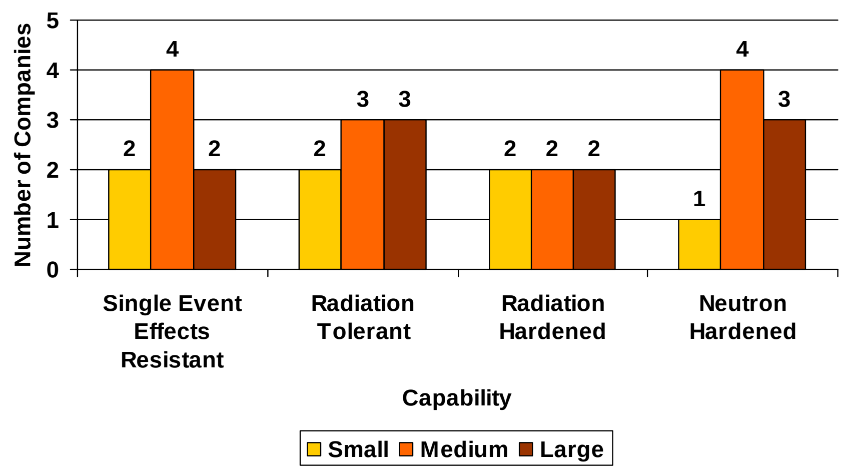
[29] Radiation tolerant consists of parts that can withstand a total dose failure of greater than 100 krad, but less than 300 krad.
[30] Previous experience does not indicate a company currently has capability.

Figure IV-4: U.S.-Based Fabrication Companies With Previous Radiation Resistant Design Experience



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Figure IV-5: U.S.-Based Fabrication Companies With Previous Radiation Resistant Design Experience - by Company Size

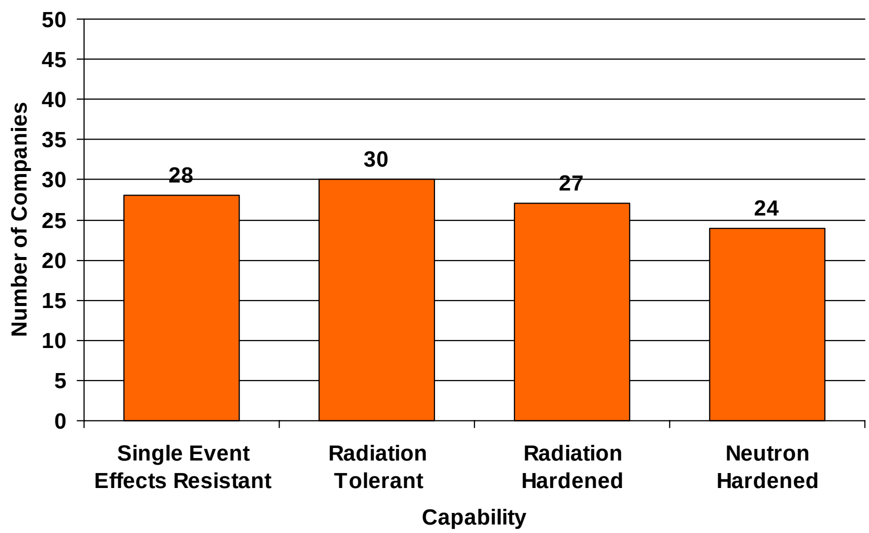


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

WILLINGNESS TO DESIGN FOR THE U.S. GOVERNMENT

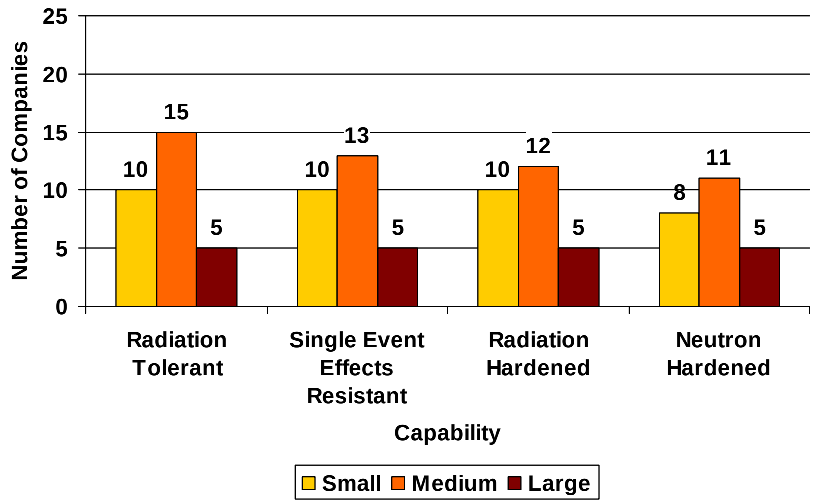
Fabrication companies were also asked whether they would be interested in designing radiation resistant IC products if called upon by the U.S. Government (see Figure IV-6). Thirty-four companies responded favorably, including twelve companies that did not indicate having an existing capability to design radiation resistant IC products. There was a relatively even level of interest across companies, regardless of size, in designing radiation resistant IC products for the U.S. Government.

Figure IV-6: Interest in Designing Radiation Resistant Products for the U.S. Government - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Figure IV-7: Interest in Designing Radiation Resistant Products for the U.S. Government by Company Size - Fabrication Companies



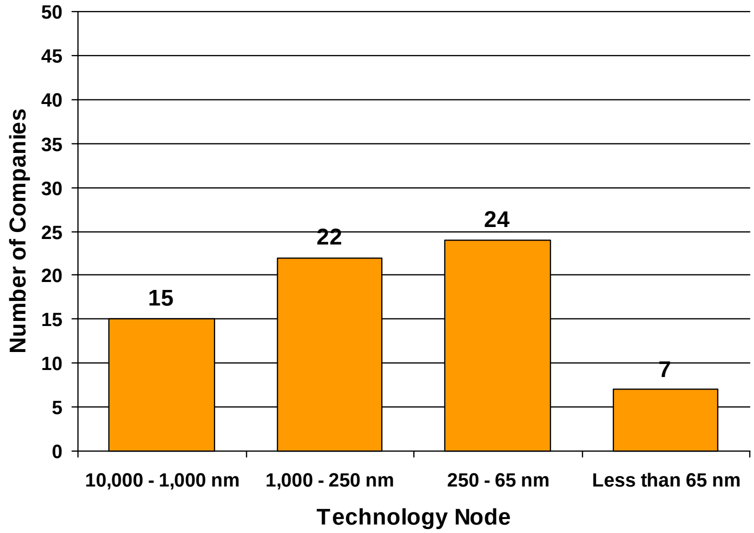
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

TECHNOLOGY NODE RANGE

Although 31 IC fabricators stated they can design radiation resistant products, not all have equal capabilities. Beyond differences in company ability to design specific types of radiation resistant products, there are major differences in the ability to create ICs to meet some physical and performance characteristics. This is illustrated in the number of companies able to design for certain technology nodes.

Fabrication companies were asked to specify capabilities to design radiation resistant IC products for 15 technology nodes, ranging from 10,000nm to less than 65mn. For the purposes of this study, technology nodes were grouped into four ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm. Fifteen fabrication firms reported having design ability in the 10,000 – 1,000 nm range, 22 companies in the 1,000 - 250 nm range, 24 companies in the 250 – 65 nm range, and seven companies at technology nodes less than 65 nm (see Figure IV-8).

Figure IV-8: U.S.-Based Radiation Resistant Design Capability by Technology Node Range - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Design capability for radiation resistant products at different technology nodes is spread evenly amongst the fabrication companies, although some trends based on company size are apparent (see Figure IV-9). Small- and medium-size companies mainly design in the 1,000 nm -250 nm and 250 nm – 65 nm ranges. Large-size companies are more focused on designing for the 250 nm – 65 nm and less than 65 nm ranges.

Figure IV-9: Percent of Fabrication Companies Capable of Radiation Resistant Design Per Technology Node Range

	Small (19 Companies)	**Medium** (20 Companies)	**Large** (10 Companies)
10,000 nm – 1,000 nm	21%	40%	30%
1,000 nm – 250 nm	32%	65%	30%
250 nm – 65 nm	32%	60%	60%
Less than 65 nm	5%	10%	40%

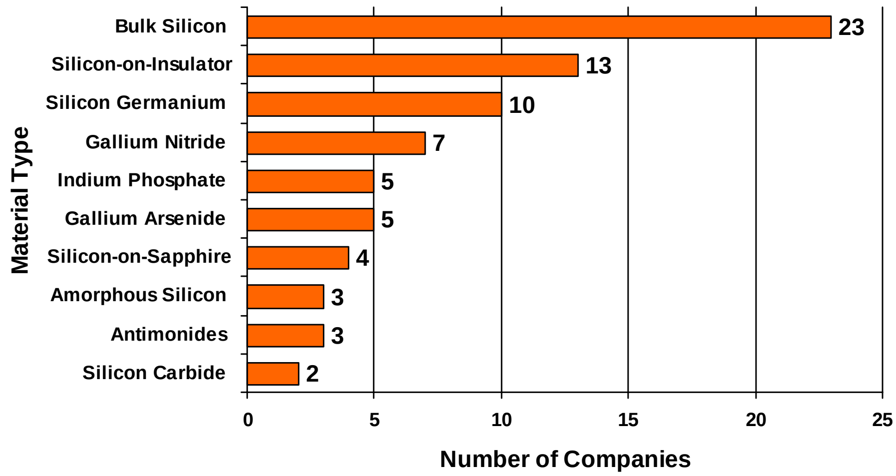
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

SEMICONDUCTOR MATERIALS

Survey participants identified their ability to design radiation resistant IC products employing specific types of semiconductor materials. For the purposes of analysis, these materials were divided into two groups: standard silicon materials – bulk silicon, silicon-on-insulator, and silicon germanium materials; and non-standard materials – silicon-on-sapphire, silicon carbide, gallium nitride, gallium arsenide, indium phosphate, antimonides, and amorphous silicon.

As with conventional IC products, fabrication companies are most capable of designing radiation resistant products utilizing bulk silicon. Twenty-three of the 31 fabrication companies declaring capability to design radiation resistant products (74 percent) said they could design devices based on bulk silicon (see Figure IV-10). For the other standard silicon materials, thirteen companies said they could design radiation resistant ICs manufactured using silicon-on-insulator, and 10 could design for devices using silicon germanium.

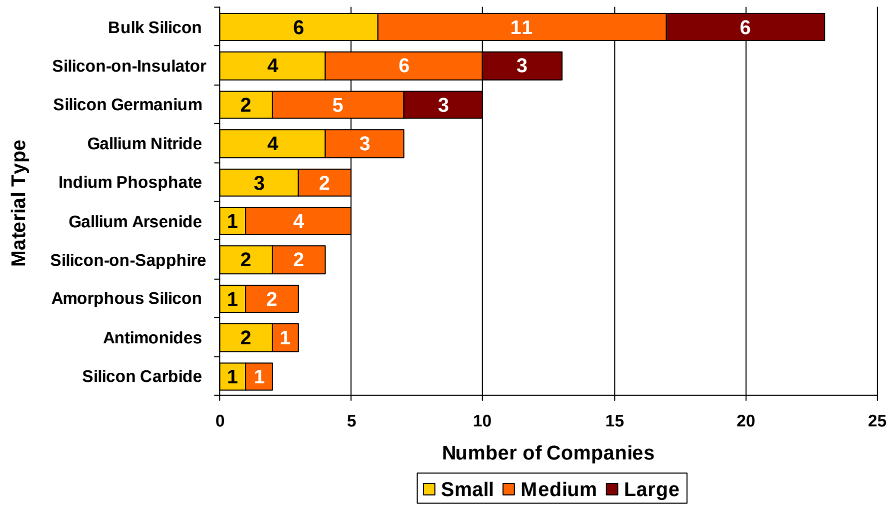
Figure IV-10: Scope of U.S.-Based Radiation Resistant Design Capability - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

The ability of fabrication companies to design radiation resistant products using non-standard materials drops significantly when compared to standard materials. Gallium nitride is the most prevalent with seven companies, four small-size and three medium-size, capable of designing on this material. On the other hand, silicon carbide is the least prevalent, with only two fabrication companies, one small-size and one medium-size, indicating capability (see Figure IV-11). No large-size fabrication companies design for non-standard materials.

Figure IV-11: Scope of U.S.-Based Radiation Resistant Design Capability by Company Size - Fabrication Companies

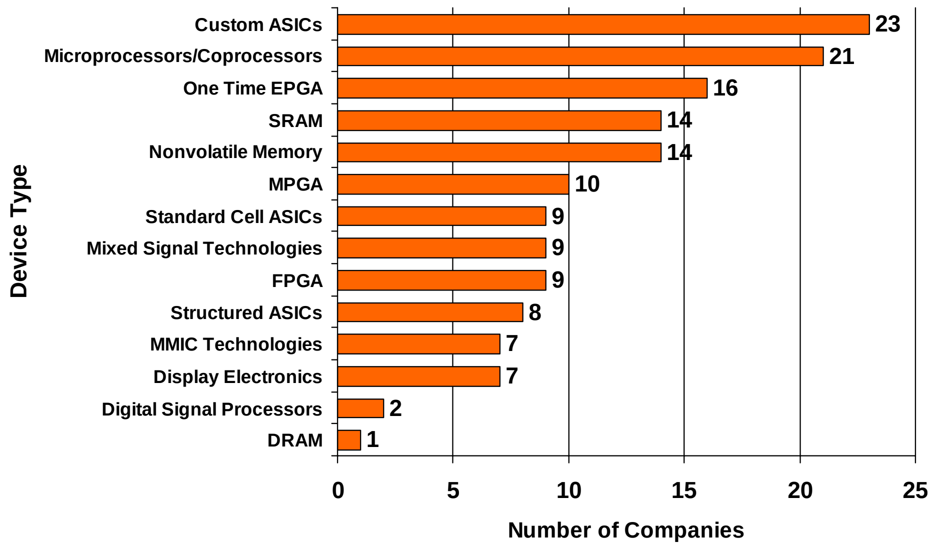


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

DEVICE TYPE DESIGN CAPABILITY

Fabrication companies also identified the types of radiation resistant IC devices they are capable of designing. OTE queried companies on four groups of IC products: application specific integrated circuits (ASICs), gate arrays, memory, and other IC products (see figure IV-12).

Figure IV-12: U.S.-Based Radiation Resistant Device Design Capability - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

For the purpose of this survey, the ASICs group consists of four device types: custom ASICs, standard cell ASICs, structured ASICs, and microprocessors/coprocessors. Amongst this group, custom ASICs is the most commonly designed device, with 23 fabrication companies indicating a capability to design these devices. Twenty-one fabrication companies can design radiation resistant microprocessors/ coprocessors, the second most common device design capability. Companies have less capability to design radiation resistant standard cell ASICs and structured ASICs, with nine and eight companies designing these devices, respectively.

Gate arrays consist of one-time electronically programmable gate arrays (EPGAs), mask programmable gate arrays (MPGAs), and field programmable gate arrays (FGPAs). One-time EPGAs are the most prevalent gate array, with 16 companies that can design these devices. Ten companies can design MPGAs, while nine companies are capable of designing FPGAs.

Fabrication companies indicated their ability to develop three forms of radiation resistant memory: dynamic random access memory (DRAM), static random access memory (SRAM), and nonvolatile memory. SRAM and nonvolatile memory are the memory devices most commonly designed, with 14 fabrication companies doing so. Significantly fewer can design radiation resistant DRAM products, only one of 31 fabrication companies.

Beyond these devices, mixed signal technologies are the most commonly designed radiation resistant product. Nine companies can design radiation resistant versions of these devices, 29 percent of radiation resistant-capable fabrication companies. Seven companies can design radiation resistant MMIC technologies or display electronics, 22.5 percent of fabrication companies with radiation resistant capabilities. Only two fabrication companies can design digital signal processors, six percent of radiation resistant-capable fabrication companies.

V. CONVENTIONAL PRODUCTS – FABLESS DESIGN CAPABILITY

OTE surveyed fabless integrated circuit (IC) companies in the United States, companies that design and develop IC product but do not own and operate fabrication facilities. The 106 fabless companies that participated in the survey were divided into three groups based on average net sales for 2003-2006 (see Figure V-1).

Figure V-1: Total Number of Fabless Companies Designing Conventional IC Products		
Size	Number of Companies	Net Sales
Small	65	Less than $25 million
Medium	27	$25 million - $350 million
Large	14	Greater than $350 million
Total	**106**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

OTE asked fabless companies to indicate their capability to develop ICs with circuit feature sizes ranging from 10,000 nanometers (nm) to less than 32 nm.[31] Companies were also requested to specify the kinds of IC products they can design, as well as the specific types of semiconductor materials their designs can employ. This included their ability to employ standard silicon formulations (bulk silicon, silicon-on-insulator, and silicon germanium), as well as non-standard materials such as gallium arsenide, gallium nitride, indium phosphate, and other semiconducting materials.

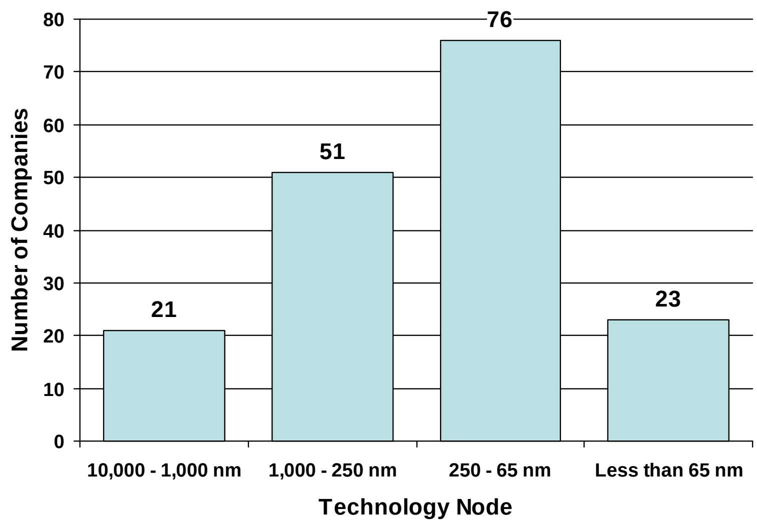
TECHNOLOGY NODE RANGE

The technical abilities of the 106 fabless companies vary considerably. Some are able to develop IC products for a broad range of physical requirements, while other firms have distinctly narrower capabilities. The capability of the majority of surveyed fabless firms is primarily

[31] Responses indicating an ability to manufacture at a given technology node, semiconductor chemistry, or device type does not mean the company is actually producing product at this time corresponding to their responses.

concentrated across two technology node ranges, 250 – 65 nm and 1,000 – 250 nm, with 76 companies able to design for the former and 51 for the latter (see Table V-2).[32]

Figure V-2: U.S.-Based Fabless Capability for Conventional IC Products - by Technology Node

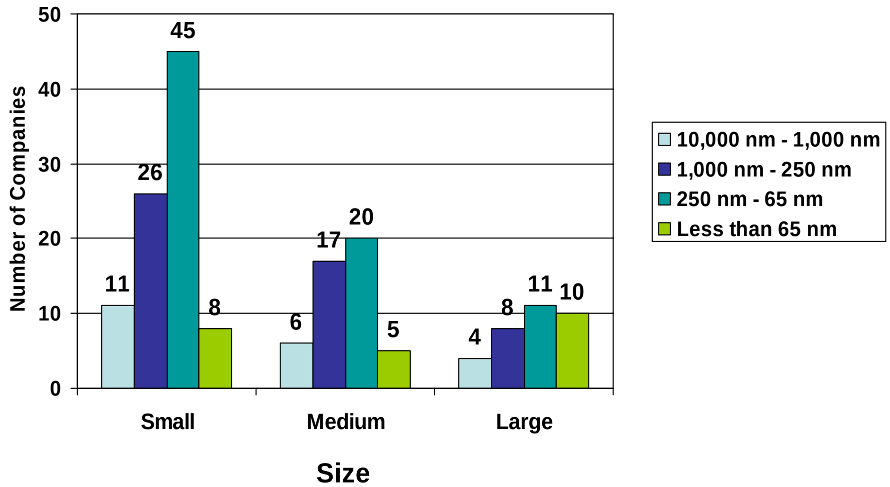


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Fabless company IC design capability is concentrated in the 250 – 65 nm and 1,000 – 250 nm ranges, 76 and 51, respectively; the majority of these companies are small-size (see Figures V-3 and V-4). Considerably fewer fabless companies, 21, are able to design IC product in the 10,000 nm – 1,000 nm technology range. Of this total, 11 are small-size, six are medium-size, and four are large-size fabless firms. At leading edge technology nodes of less than 65 nm, 23 companies report being capable of performing design work for conventional IC product. Much of this design capability rests with 10 large-size fabless firms. Eight small-size and five medium-size companies also have capability to work in this design range.

[32] A technology node indicates the smallest circuit feature size that can be drawn on a chip with a microlithography tool. For the purposes of this study, technology nodes were grouped into four ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm.

Figure V-3: U.S.-Based Fabless Capability for Conventional IC Products - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Figure V-4: Percent of Fabless Companies Capable of Design Per Technology Node Range

	Small (65 Companies)	**Medium** (27 Companies)	**Large** (14 Companies)
10,000 nm – 1,000 nm	17%	22%	29%
1,000 nm – 250 nm	40%	63%	57%
250 nm – 65 nm	69%	74%	79%
Less than 65 nm	12%	19%	71%

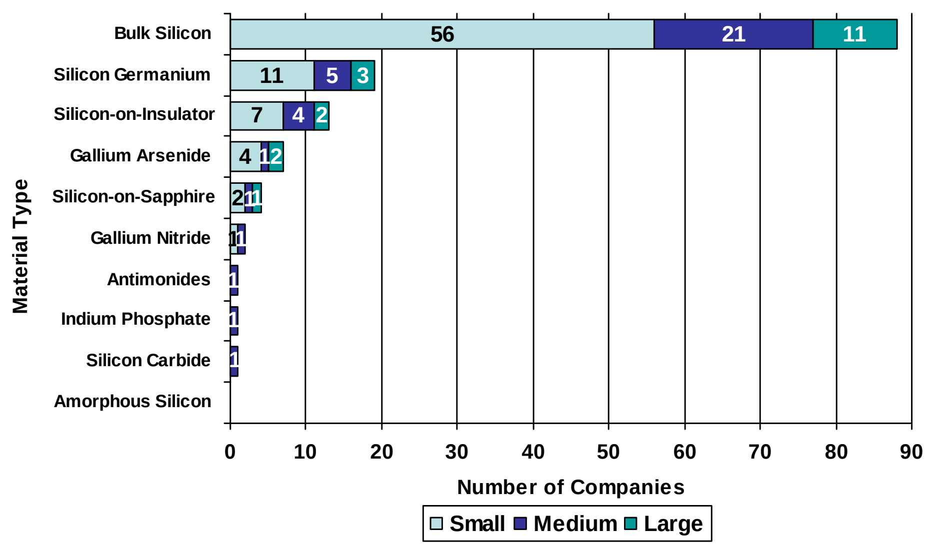
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

SEMICONDUCTOR MATERIALS

Fabless companies were asked to state their ability to develop IC products that rely not only on standard silicon materials (bulk silicon, silicon-on-insulator, and silicon germanium), but also on a range of non-standard materials.[33] In all, design companies addressed their capabilities to develop IC devices utilizing one or more of 10 material types.

Survey data shows most of the IC design capacity in the United States is concentrated in standard silicon technologies (See table V-5). In particular, bulk silicon is the material type most fabless companies are prepared to design products around. Specifically, 88 of 106 companies currently design for IC products in bulk silicon. Of these companies, 11 are large-size, 21 medium-size, and 56 small-size.

Figure V-5: Scope of U.S.-Based Fabless Capability - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

While 83 percent of fabless companies can develop IC product to be manufactured with bulk silicon, only 18 percent of the 106 companies (19 firms) can design ICs using silicon

[33] Silicon-on-sapphire, silicon carbide, gallium arsenide, gallium nitride, indium phosphate, amorphous silicon, and compounds containing antimonides.

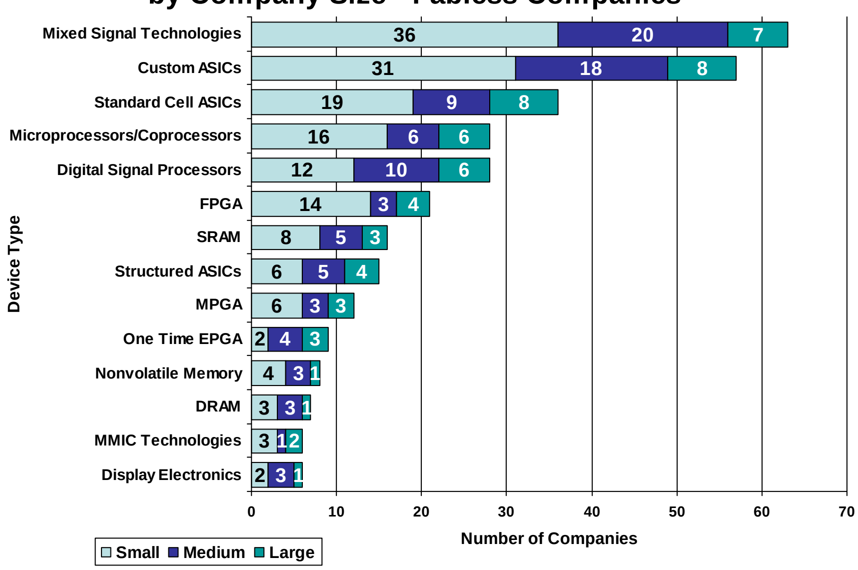
germanium. Three of the companies are large-size companies, five are medium-size, and 11 are small-size. Fabless company capability for designing product using silicon-on-insulator is limited to 13 firms: two large-size, four medium-size, and seven small-size companies.

In the case of non-standard silicon products, fabless companies have minimal to no ability to develop product using these material types. The count of fabless companies capable of using non-standard materials breaks out as follows: gallium arsenide, 7; silicon-on-sapphire, 4; gallium nitride, 2; antimonides, 1; indium phosphate, 1; silicon carbide, 1; organic technologies, 0; and amorphous silicon, 0.

Device Design Capability

OTE also asked fabless companies to identify the types of IC components they are able to develop in the United States. Specific information was requested on four product groups: application specific integrated circuits (ASICs), gate arrays, memory, and other IC products (see Figure V-6).

Figure V-6: U.S.-Based Device Design by Company Size - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Survey participants were also asked whether they could design four types of ASIC products: structured ASICs, standard ASICs, custom ASICs, and microprocessors/coprocessors.[34] Fifty-seven companies reported capability to design custom ASICs, of which eight are large-size companies, 18 are medium-size and 31 are small-size. For standard cell ASICs, 36 companies said they were able to design such products: eight large-size, nine medium-size, and 19 small-size firms. Fifteen companies can design structured ASIC products, including four large-size companies, five medium-size, and six small-size. Twenty-eight companies stated that they can design microprocessors and coprocessors – six of them large-size companies, six medium-size, and 16 small-size

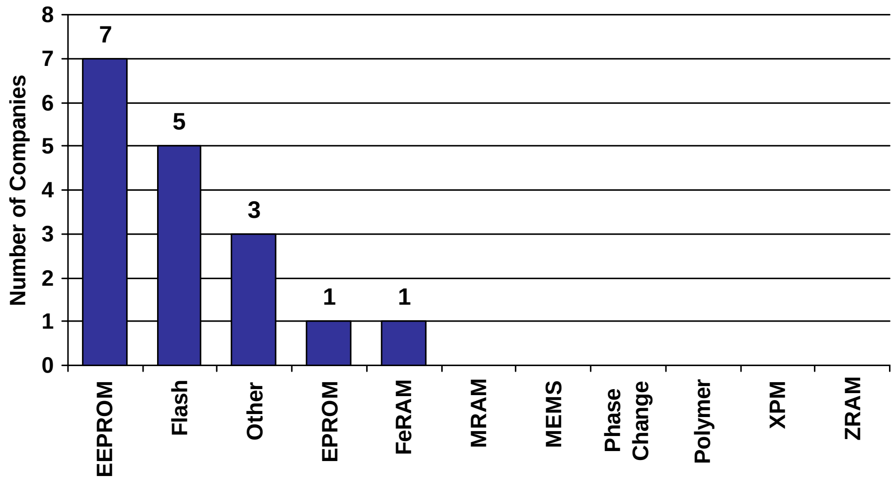
Fabless companies reported capability to design a variety of gate array devices.[35] For the purposes of this report, the gate arrays group consists of field programmable gate arrays (FPGAs), one-time electronically programmable gate arrays (EPGAs), and mask programmable gate arrays (MPGAs). In total, 21 companies can design FPGA product, of which 14 are small-size, three are medium-size, and four are large-size companies. Twelve companies reported capability to manufacture MPGAs, of which three are large-size designers, three are medium-size, and six are small-size. Nine were able to design one-time EPGAs: three large-size companies, four medium-size, and two small-size.

With regard to memory ICs, fabless firms provided responses on their ability to develop three forms of memory: dynamic random access memory (DRAM), static random access memory (SRAM), and nonvolatile memory. These are widely used in consumer, industrial, and defense electronic systems. Seven fabless firms reported being able to design for DRAM, of which one is a large-size company, three are medium-size, and three are small-size. In contrast, twice as many companies (16) can design for SRAM, of which three are large-size firms, five are medium-size, and three are small-size.

[34] ASIC chips are designed to perform specific instructions and tasks, and can provide performance advantages over general purpose microprocessors.
[35] Gate arrays are IC devices containing cells with rows of transistors and resistors that are not connected. The appropriate interconnections are made using software to form a custom-designed working device.

Eight companies said they possess design capability for nonvolatile memory products: one large-size design firm, three medium-size firms, and four small-size firms. Designers were asked to further report their nonvolatile memory product capabilities in 11 categories: electronically erasable read-only memory (EEPROM), erasable read-only memory (EPROM), flash memory, ferro-electric random access memory (FeRAM), micro electro-mechanical systems memory (MEMS), magneto-resistive random access memory (MRAM), polymer memory, one-time programmable memory (XPM), zero capacitor random access memory (ZRAM), phase change memory, and other memory types (see Figure V-7).

Figure V-7: U.S.-Based Capability to Design Nonvolatile Memory Products - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Of the 11 nonvolatile memory categories, only EEPROM, flash, and other memory can be developed by multiple fabless companies. Only one company can design EPROM and FeRAM products, respectively. No fabless company reported an ability to develop MRAM, MEMS, phase change, polymer, one-time programmable (XPM), or ZRAM memory products.

Beyond memory, fabless firms were asked about their ability to design digital signal processors, micromonolithic integrated circuits (MMICs), mixed signal analog-digital ICs, and visual display IC devices. Digital signal processors can be designed by 28 fabless firms: six are large-size, 10 are medium-size, and 12 are small-size. Six companies reported capabilities to design MMICs, including two large-size companies, one medium-size, and three small-size. For mixed-signal analog-digital ICs, 63 companies stated they can design the devices, of which seven are large-size companies, 20 are medium-size, and 36 are small-size. In the area of digital display ICs, design capability was reported by one large-size company, three medium-size, and two small-size – six fabless companies in total.

VI. Radiation Resistant IC Products – Fabless Design Capability

OTE surveyed 106 fabless companies on their ability to develop radiation resistant products: single-event effects resistant, radiation tolerant, radiation hardened, and neutron hardened. Fabless firms were asked to state their ability to design radiation resistant ICs with circuit feature sizes ranging from 10,000 nanometers (nm) to 32 nm.[36]

Survey participants were also asked to specify their ability to design radiation resistant IC products employing specific types of semiconductor materials. For the purposes of analysis, these materials were divided into standard silicon materials – bulk silicon, silicon-on-insulator, and silicon germanium materials, and non-standard materials –silicon-on-sapphire, silicon carbide, gallium nitride, gallium arsenide, indium phosphate, and amorphous silicon.

Fabless IC design companies were categorized as small, medium, and large in size based on average net corporate sales from 2003-2006 (see Figure VI-1). In 2006, 19 fabless firms, 18 percent of the 106 survey respondents, reported capability to design one or more types of radiation resistant products. Based on net sales, eight of these companies were categorized as small, 12 were categorized as medium, and six were categorized as large in size.

Figure VI-1: Total Number of Fabless Companies
Designing Radiation Resistant IC Products

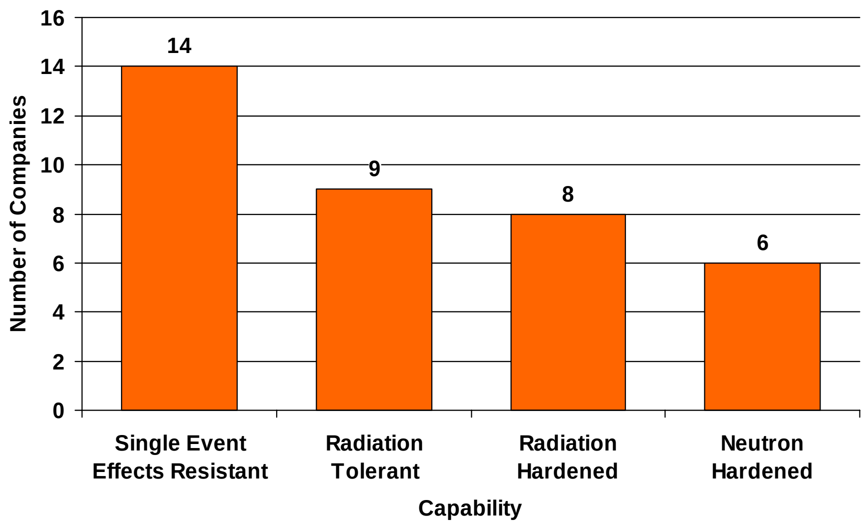
Size	Number of Companies	Net Sales
Small	8	Less than $25 million
Medium	6	$25 million - $350 million
Large	5	Greater than $350 million
Total	**19**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

[36] Responses indicating an ability to design at a given technology node, semiconductor chemistry, or device type does not mean the company is actually performing such work at this time.

Fabless firms specified the types of radiation resistant products they can produce. Fabless design capability, in terms of number of companies, is greatest for single-event effects resistant ICs, which can continue to function after a single energetic particle strikes the device.[37] Fourteen of 19 companies reported capability to design these devices, or 74 percent of all fabless firms with radiation resistant capability (see Figures VI-2 and VI-3).

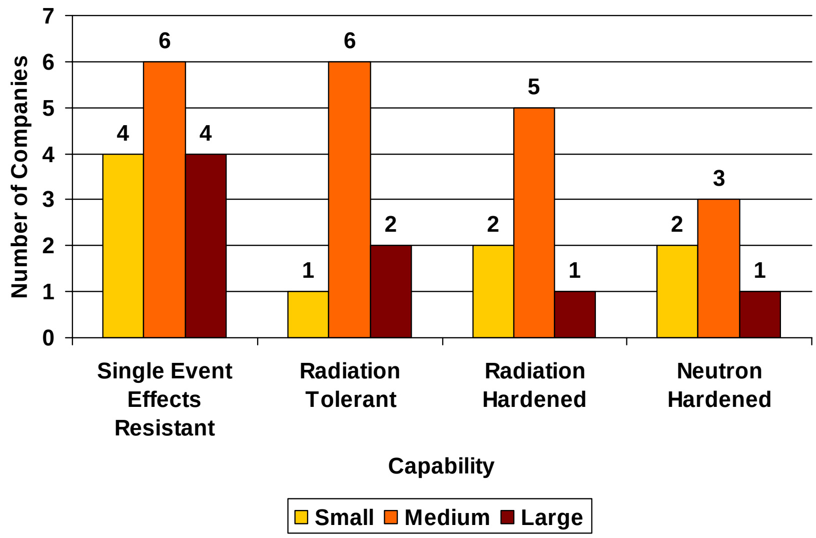
Figure VI-2: U.S.-Based Fabless Companies With Radiation Resistant Design Capability in 2006



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

[37] Single-event effects are caused by a single energetic particle striking an integrated circuit device. Performance of the device is not compromised to a point where it is inoperable or not reliable for executing a mission as a result of latch-up, burnout, or gate rupture.

Figure VI-3: U.S.-Based Fabless Companies With Radiation Resistant Design Capability in 2006 - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Radiation tolerant products have a limited capacity to resist radiation damage that would otherwise critically damage an IC device.[38] Nine fabless companies responding to the survey, 47 percent of radiation resistant-capable fabless firms, said they can design radiation tolerant products.

Radiation hardened IC products can withstand higher doses of radiation relative to radiation tolerant products. Eight fabless companies, or 42 percent of those with radiation resistant capabilities, can produce such IC product designs.

Neutron-hardened ICs are capable of withstanding neutron radiation damage attributable to gamma rays and electromagnetic pulses such as those associated with a nuclear weapon detonation. Six fabless companies stated they can design neutron-hardened ICs.

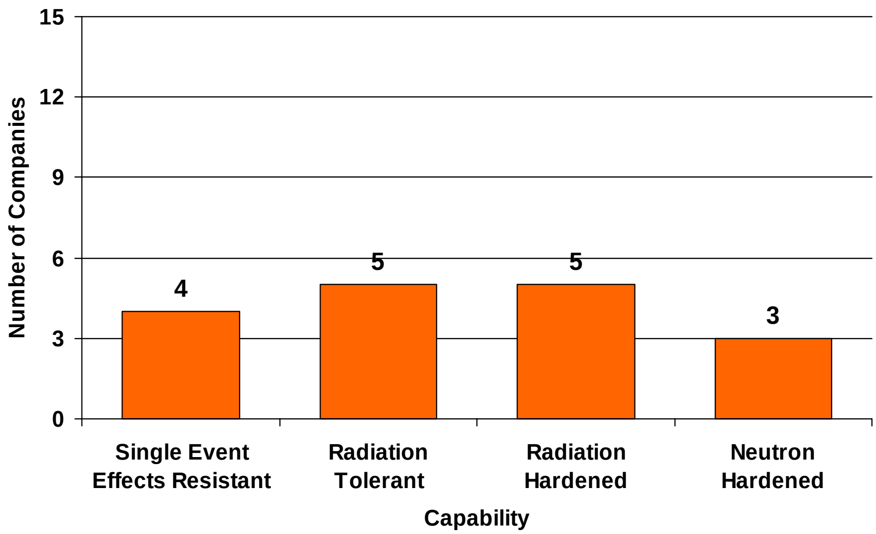
[38] Radiation tolerant consists of parts that can withstand a total dose failure of greater than 100 kilorad (krad), but less than 300 krad. A krad equals 1,000 rad. One rad = 0.01 joules/kilogram; 1 krad = 10J/kg.

Previous Radiation Resistant Design Experience

Five fabless companies reported having previous experience in the design of radiation resistant ICs; as of 2006, they were not designing radiation resistant IC devices. This previous experience is largely concentrated in small-size companies (see Figure VI-4). Large-size companies, however, reported previous capability across all four types of radiation resistant devices covered in the survey. Medium-size companies did not indicate any previous capability.

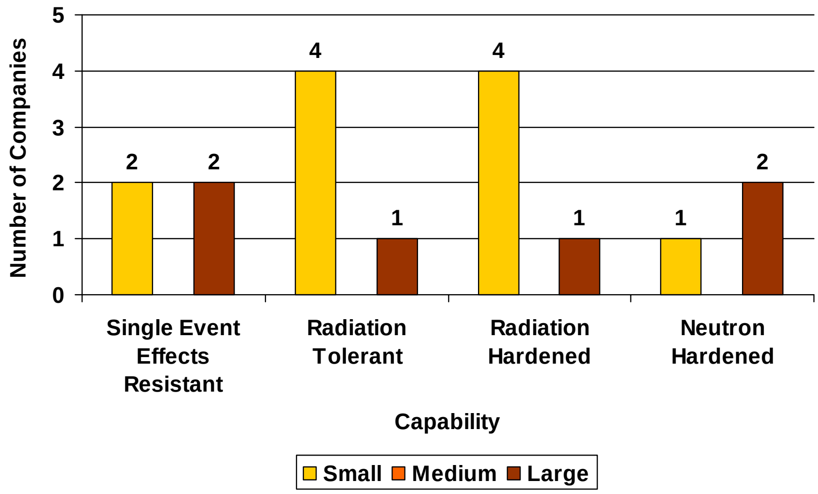
Four fabless firms said they previously have performed design work on single-event effect devices, and five companies reported the same for radiation tolerant ICs. Five companies reported prior design work on radiation hardened devices. Only three companies acknowledged previous design work for neutron hardened ICs.

Figure VI-4: U.S.-Based Fabless Companies With Previous Radiation Resistant Design Experience



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Figure VI-5: U.S.-Based Fabless Companies With Previous Radiation Resistant Design Experience - by Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

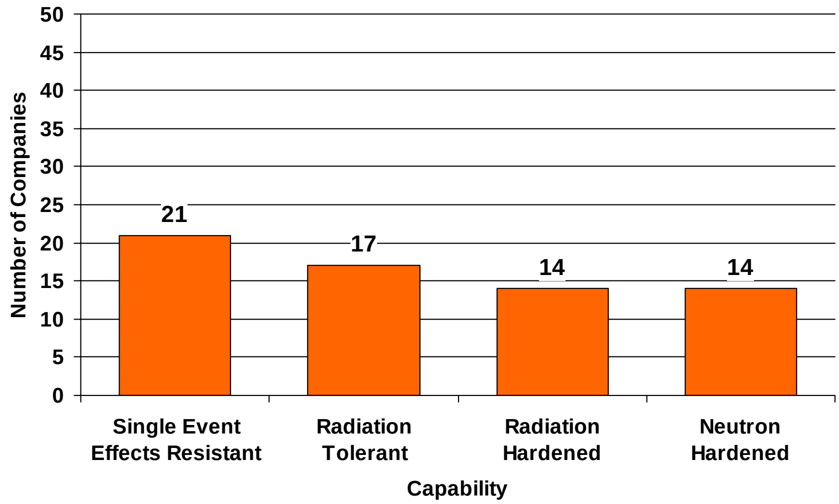
Willingness to Design for the U.S. Government

Although only 19 of the 106 companies reported current business in designing radiation resistant IC products, survey data indicates that if needed, more design companies could engage in such work. Fabless companies were specifically asked if they would be interested in designing radiation resistant IC products if called upon by the U.S. Government. Twenty-three companies responded favorably, including nine companies that did not indicate having an existing capability to design radiation resistant IC products.

IC fabless company interest in carrying out work for U.S. Government customers in the four product categories is greatest in small- and medium-size companies, where 30 small-size and 27 medium-size companies expressed interest (see Figure VI-6). Large-size fabless firms were least interested in performing government work, with nine companies responding positively.

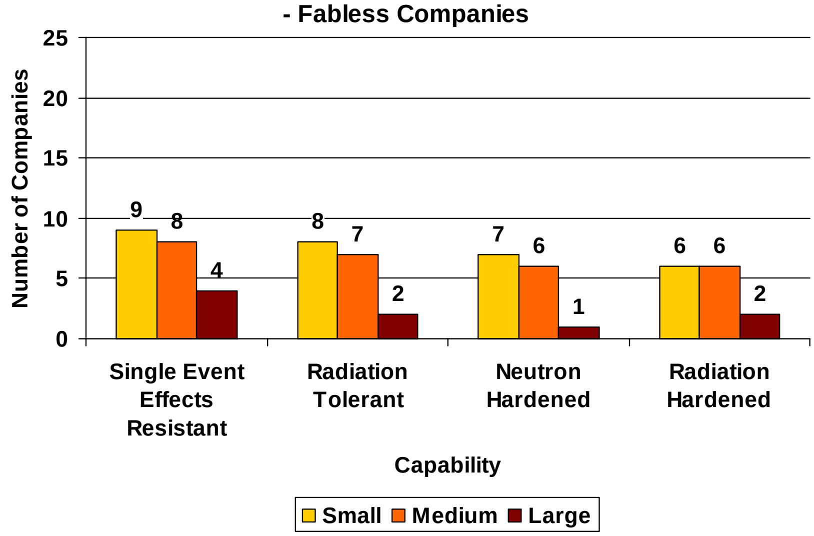
Design work on single-event effects resistant and radiation tolerant IC devices were areas of high interest for 21 and 17 fabless companies, respectively, that expressed a willingness to do work for the U.S. Government. Fourteen companies stated interest in design work for the government for both radiation hardened IC and neutron hardened product.

Figure VI-6: Interest in Designing Radiation Resistant Products for the U.S. Government - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Figure VI-7: Interest in Designing Radiation Resistant Products for the U.S. Government by Company Size - Fabless Companies



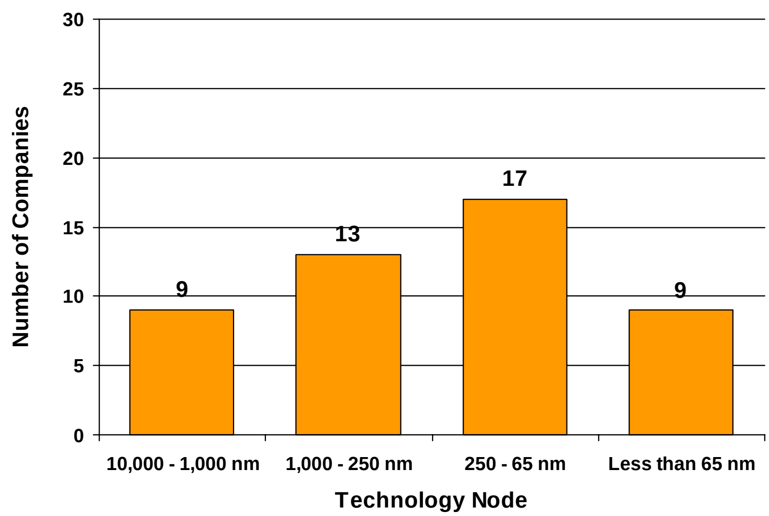
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

TECHNOLOGY NODE RANGE

IC fabless companies were asked to disclose abilities to design radiation resistant products not only by type of radiation resistant product, but also in terms of physical and material characteristics. Capability to design radiation resistant IC products across technology nodes, ranging from 10,000 nm to less than 65 nm, was reported by fabless design firms.

The technology nodes were broken into four ranges. Nine firms reported having design ability in the 10,000 – 1,000 nm range, 13 in the 1,000 - 250 nm range, 17 in the 250 – 65 nm range, and nine at technology nodes below 65 nm (see Figure VI-8).

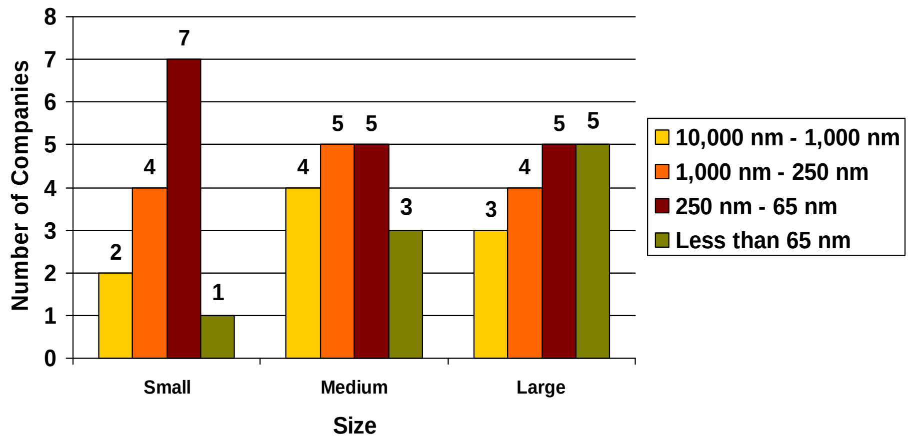
Figure VI-8: U.S.-Based Fabless Companies with Radiation Resistant Design Capability - by Technology Node Range



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Capability to design ICs at larger dimensions, in the 10,000 nm - 1,000 nm range is dispersed across the industry with two small-, four medium-, and three large-size companies (see Figure VI-9). By number of firms, most fabless firm capability for designing radiation resistant product is concentrated in the 1,000 nm-250 nm and 250-65 nm ranges. Three medium-size companies and five large-size companies reported capabilities to design radiation resistant IC products at the 65 nm technology node or smaller; only one small-size company reported such capability.

Figure VI-9: U.S.-Based Radiation Resistant Design Capability by Technology Node - Fabless Companies

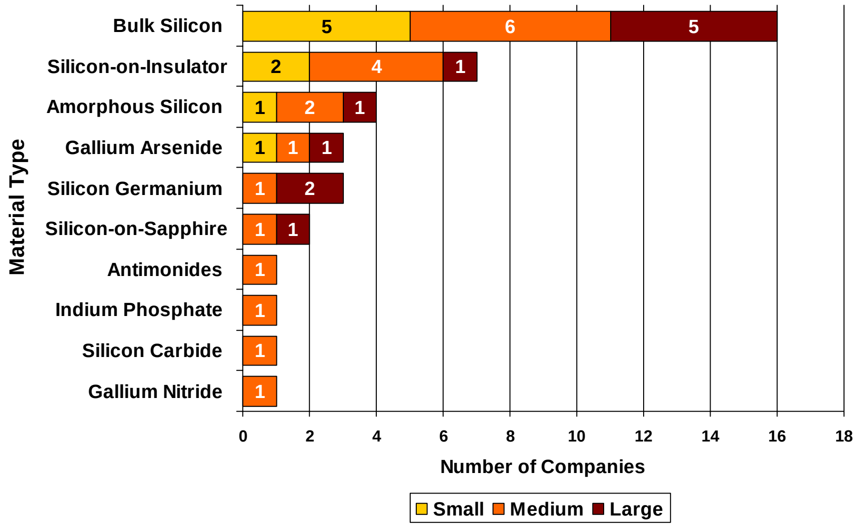


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

SEMICONDUCTOR MATERIALS

IC design companies also stated their capability to design radiation resistant IC devices using a variety of different materials. As with conventional products, bulk silicon is a material with which IC design companies appear most capable (see Figure VI-10). Sixteen of the 19 fabless companies declared capability to design radiation resistant products in bulk silicon. The number of small-, medium-, and large-size companies with this ability are nearly equal. Seven companies said they could design radiation resistant ICs that would be manufactured using silicon-on-insulator, and three could design for devices using silicon germanium.

Figure VI-10: Scope of U.S.-Based Radiation Resistant Design Capability by Company Size - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

As noted earlier, materials such as gallium arsenide, gallium nitride, and indium phosphate are increasingly used in ICs for cell phones, network switches and other products. These materials deliver higher speeds and more readily support lower voltage electronic device architectures compared to conventional silicon-based devices.

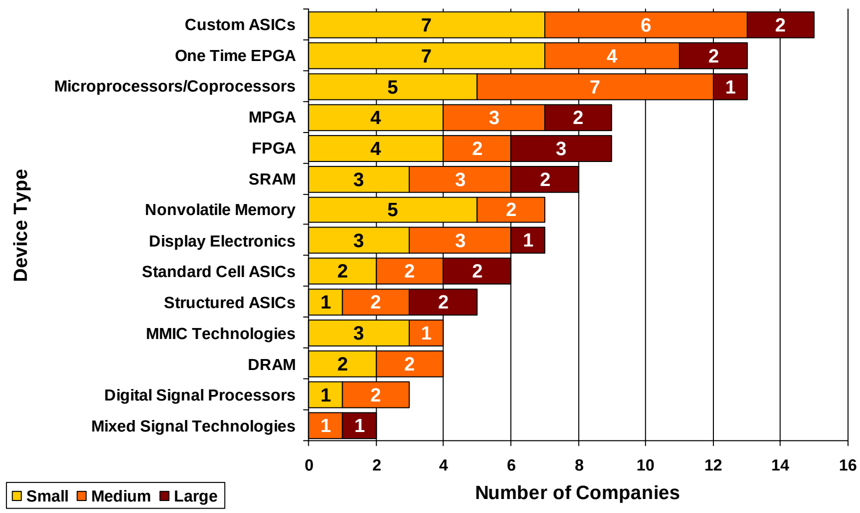
Very few fabless companies, however, declared an ability to design radiation resistant IC products built with non-standard materials. Two companies reported capability to design for silicon-on-sapphire, while three companies stated they were able to design devices using gallium arsenide. For radiation resistant IC devices using gallium nitride, indium phosphate, antimonides, silicon carbide, and amorphous silicon materials, only one company reported capability to design product in each category. All capability to design radiation resistant IC products using non-standard materials resides in medium-size companies.

Device Design Capability

Beyond designing for specific types of materials, fabless companies were also asked to identify the types of IC devices they can design. OTE queried companies on four groups of IC products:

application specific integrated circuits (ASICs), gate arrays, memory, and other IC products (see figure VI-9).

Figure VI-11: U.S.-Based Radiation Resistant Design Capability by Device Type - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

For three types of ASICs – custom, standard cell, and structured – 15 fabless companies can design one or more product types as radiation resistant. Specifically, 15 companies can design custom ASICs, 13 companies can design standard cell ASICs, and eight companies can design structured cell ASICs. Most of this design capability resides in small- and medium-size fabless firms. Only two large-size fabless companies have design capability for custom, standard cell, and structured ASICs. With respect to microprocessors/coprocessors, nine firms said they are able to design radiation resistant devices: four small-, three medium-, and two large-size companies.

Nine fabless firms reported the ability to design one or more varieties of radiation resistant gate arrays: field programmable gate arrays (FPGAs), nine companies; mask programmable gate arrays (MPGAs), six companies; and one-time electrically programmable gate arrays (EPGAs), five companies. For these gate array devices, medium- and large-size companies account for a majority of this design capability.

The design capability of fabless companies narrows for the three types of memory products: dynamic random access memory (DRAM), static random access memory (SRAM), and nonvolatile memory. Seven companies, five small-size and two medium-size, said they were able to design static random access memory (SRAM) product. Three small-size companies and one medium-size can design nonvolatile radiation resistant memory devices. Only one small-size company and two medium-size companies reported having the ability to design dynamic random access (DRAM) memory.

The ability of fabless companies to design for a range of other IC devices is varied. Thirteen firms said they can design for mixed signal technology products: five small-size, seven medium-size, and one large-size. Seven companies – three small-, three medium-, and one large-size – also reported capability to design digital signal processors. Two small- and two medium-size companies said they can design electronic display IC products. Only two firms, one small-size and one medium-size, indicated they can design radiation resistant micromonolithic integrated circuits (MMICs).

VII. UTILIZATION RATES

To understand manufacturing activity levels and gain insight into the industry's ability to handle surges in production orders, fabrication companies were asked to provide their average manufacturing capacity utilization at each of their U.S.-based fabrication facilities for 2003-2006.[39] Each facility was also required to provide their maximum number of wafer starts and average actual wafer starts per week for 2007 to see how well companies could handle a surge in production.[40] Finally, companies reported plans for continuing operation of each of their fabrication facilities through 2011.

WAFER START CAPACITY AND COMPANY UTILIZATION RATES

Large-size companies represent the vast majority of production capability with an average maximum wafer start capacity of 29,126 starts per week in 2007 and actual average wafer starts per week of 23,725, a utilization rate of 81 percent (see Figure VII-1). Medium-size companies have a slightly higher utilization rate of 82 percent, but have a much lower wafer start capacity. In fact, these companies have an average maximum capacity of 26,000 fewer wafer starts per week than large-size companies. Small-size companies have an even lower maximum capacity than medium-size companies, an average of 629 wafer starts per week. Of this small number, the average actual wafer starts for this industry segment was 313 per week, a utilization rate of only 50 percent.

[39] For fabrication companies with more than one facility, utilization rates, maximum wafer starts, and average actual wafer starts per week were averaged to provide a single company response.
[40] The number of semiconductor wafers that can be processed on an integrated circuit product fabrication line in 7-day period.

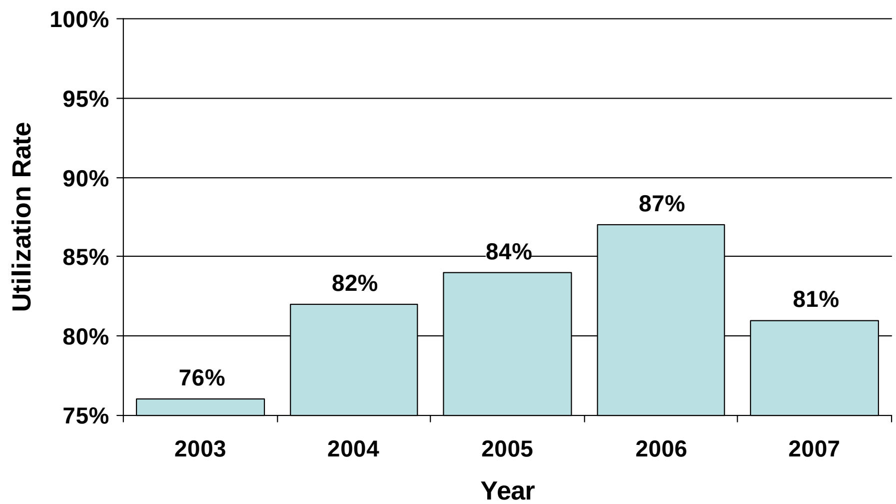
Figure VII-1: Average/Maximum Wafer Starts per Week (2007)

	Average Wafer Starts per Week	Average Maximum Wafer Starts per Week	Average Utilization Rate
Small Companies (19)	313	629	50%
Medium Companies (20)	2,260	2,741	82%
Large Companies (10)	23,725	29,126	81%
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.			

As a group, fabrication companies steadily increased overall utilization rates at U.S. fabrication facilities between 2003 and 2006, peaking at 87 percent (see Figures VII-2).[41] In 2007, however, overall utilization dropped to 81 percent. Survey data shows available capacity to expand production existed at many facilities. It is important to note that most of the excess production capacity is controlled by large-size companies (see Figure VII-3). Accessing this excess capacity for new orders may be difficult, however, because production volumes may not be sufficient or because of manufacturing process compatibility.

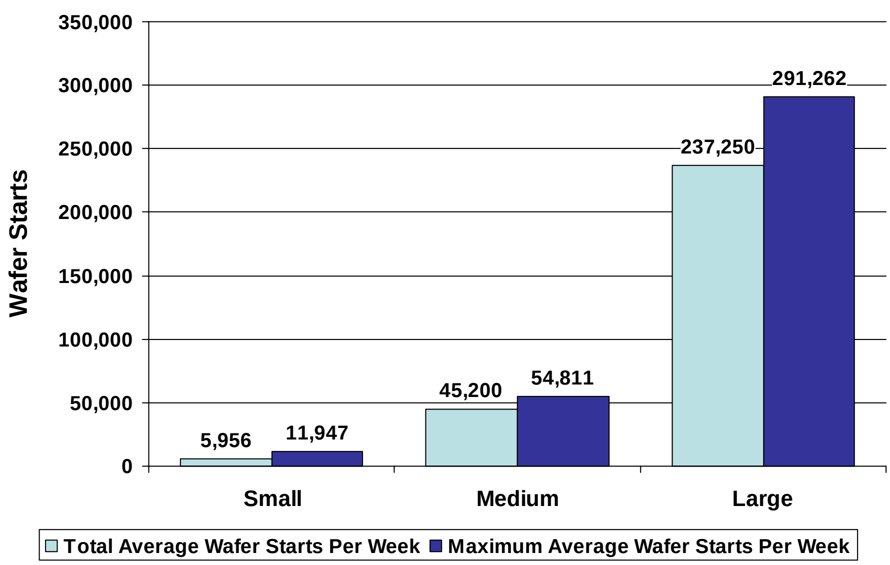
[41] These utilization rates were weighted against the 2007 maximum wafer starts per week. The average actual wafer starts per week were estimated by multiplying the utilization rate per year by the company's maximum wafer starts in 2007. These numbers were added together and divided by the all the fabrication companies' maximum wafer starts per week to get a percentage. This provides a better macro-level analysis of utilization rates that takes into account the capacity of the various companies.

Figure VII-2: Overall Utilization Rate Per Year (Weighted)



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

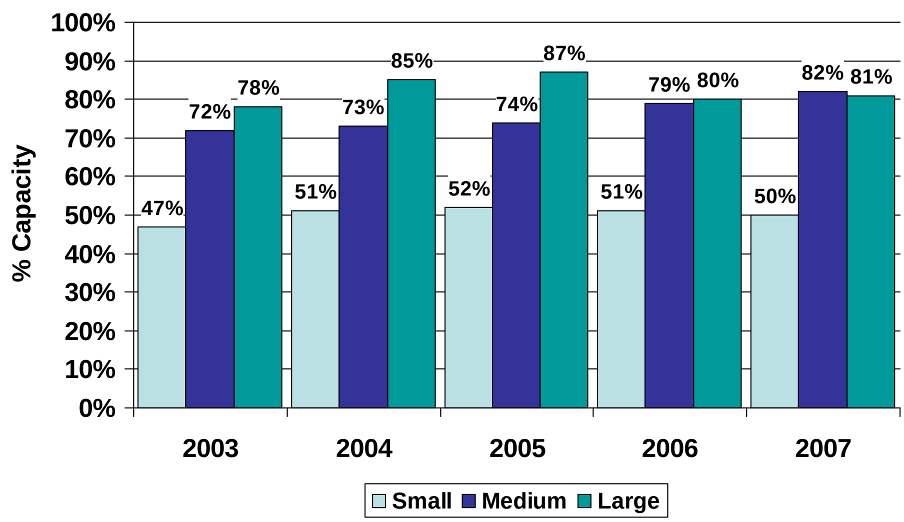
Figure VII-3: Wafer Starts per Week (2007)



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

An examination of utilization rates for large-, medium-, and small-size companies reveals different levels of business activity. Large-size companies increased their utilization from 78 percent in 2003 to 90 percent by 2006, but declined nine percent in 2007 (see Figure VII-4). In fact, eight out of 10 companies experienced reduced average utilization rates at their facilities in 2007. Unlike large-size companies, medium-size fabricators saw utilization rates continue to climb in 2007, reaching 82 percent. Average utilization rates for small-size companies were substantially lower than those of large- and medium-size fabricators, remaining at approximately 50 percent utilization throughout the 2003-2007 period. While utilization data indicates the potential to expand IC production if necessary, small-size companies remain limited by their low overall maximum wafer start capacity.

Figure VII-4: Average Capacity Utilization Rate (Weighted by 2007 Maximum Wafer Starts)



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

FACILITY CLOSINGS BY 2011

Of the 49 fabrication companies surveyed, eight indicated that a facility currently in use will be closed by 2011. One of these companies stated that two of their fabrication facilities will cease operation by the end of this period, bringing the total facility closings to nine.

Figure VII-5: Number of U.S.-Based Fabrication Facilities (2003-2011)

Total Facilities	2003	2004	2005	2006	2011 (Projected)	Total Difference
Small	21	22	21	22	24	**+3**
Medium	32	29	29	29	27	**-5**
Large	35	36	36	35	33	**-2**
Total	**88**	**87**	**86**	**86**	**84**	**-4**

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Based on overall facility count, there will be slightly fewer fabrication facilities in the United States by 2011. Although the facilities count per year remains relatively stable for all company sizes, there is a significant degree of facility openings and closings for individual companies, particularly large-size ones. As stated previously, nine facilities in use in 2007 are predicted to shut down by 2011. Since the overall projection of facility counts remains relatively stable, this means that new facilities will be opening to make up for ‘lost’ capability. As companies begin to transition their operations, utilization at older facilities may begin to drop off before a new facility can open. Based on survey data, large-size companies will open at least four new fabrication facilities between 2007 and 2011.

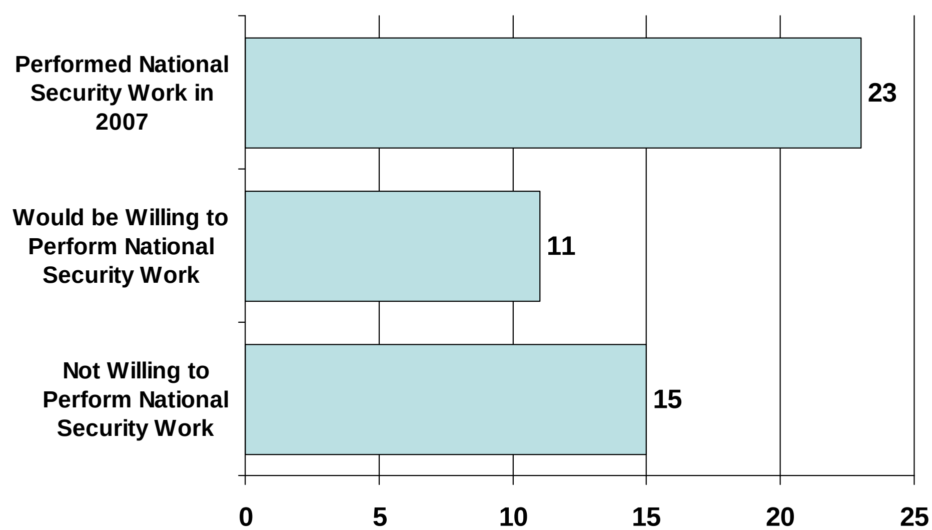
VIII. FABRICATION AND DESIGN OF NATIONAL SECURITY PRODUCTS

Access to commercial integrated circuit (IC) design and fabrication capabilities in the United States is important for the Department of Defense (DOD) and other federal agencies to maintain and upgrade the capabilities of existing defense systems, as well as to produce critical parts for future national security applications. Survey results show at this time there are significant numbers of design and fabrication companies that currently provide defense-related services, or are willing to provide such services if called upon.

FABRICATION OF NATIONAL SECURITY-RELATED PRODUCTS

Twenty-three of 49 fabrication companies participating in the survey reported manufacturing national security-related IC products in their facilities in 2007 (see Figure VIII-1). Eighteen of these companies utilize 10 percent or less of their manufacturing capacity for national security-related products. Four companies, however, reported this type of business represented between 50 and 100 percent of their production capacity. Only one of the 23 companies reported fabricating national security-related items in non-U.S. facilities.

Figure VIII-1: Fabrication of National Security-Related IC Products



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

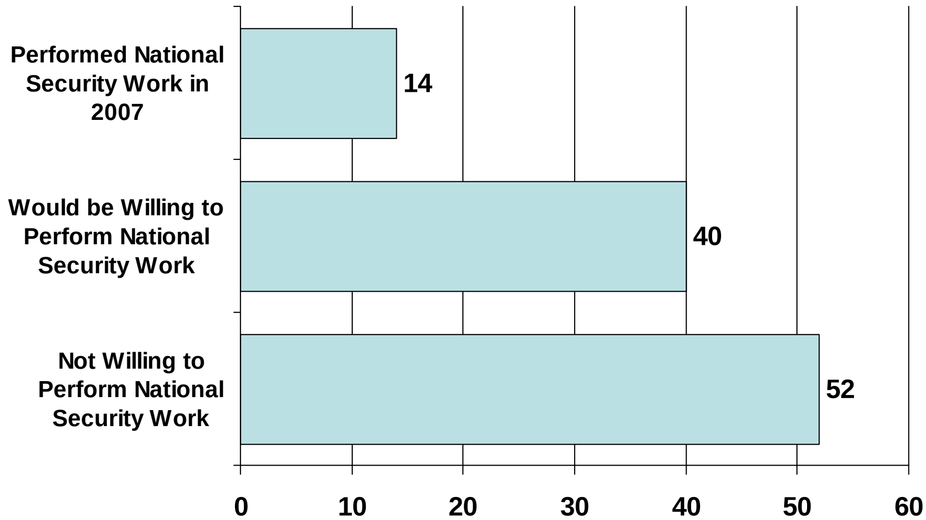
Of the 23 companies that now fabricate national security-related IC products in the United States, 19 said they would be willing to dedicate more of their production capacity to such work. These companies, on average, declared a willingness to increase national security-related production by 24 percent.

An additional 11 fabrication companies operating in the United States indicated they are willing to take on national security-related fabrication work under the right financial circumstances. Of these companies, nine would dedicate over 10 percent of their manufacturing capacity to such production, with two willing to potentially dedicate 90 percent or more.

Design of National Security-Related Products

OTE survey results show that 14 out of 106 IC fabless companies (13 percent) performed work on national security-related IC products in 2007 (see Figure VIII-2). Five of these 14 companies have already committed 50 percent or more of their capabilities to national security-related work. If necessary, eight of the 14 firms were prepared to allocate more design capacity to this line of work. Three fabless companies reported conducting national security-related design work in non-U.S. facilities.

Figure VIII-2: Design of National Security-Related IC Products - Fabless Companies

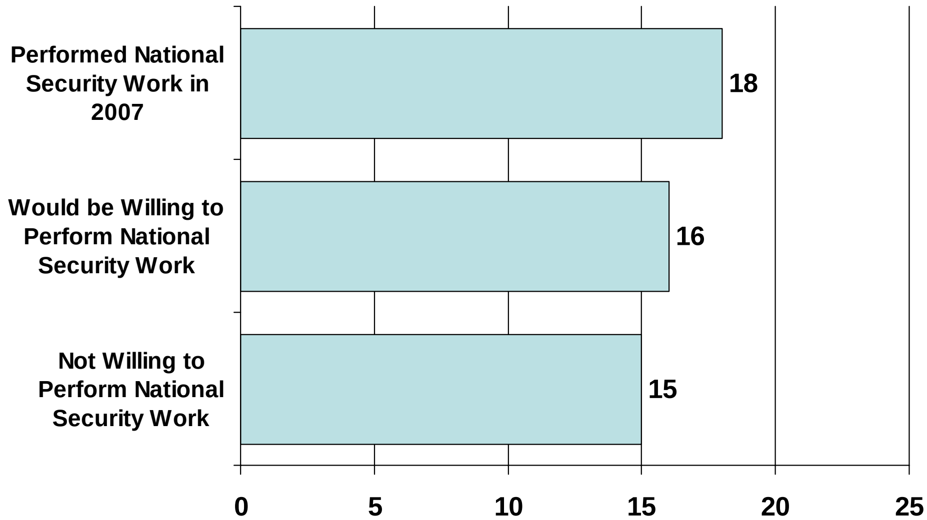


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Another 40 fabless companies indicated they would be willing to commit some portion of their IC design capability to national security-related products in the future. Most offered to dedicate one to 25 percent of current capability to national security-related work. Two companies indicated a willingness to focus upwards of 90 percent of capacity on such work.

In addition to the national security design work carried out by fabless companies, 18 fabrication companies perform design work for national security-related products (see Figure VIII-3). Fourteen of the 18 companies said they were prepared to take on additional national security-related IC product design work. Five of these companies reported that national security-related work consumes 50 percent or more of their IC design capacity. For three of the five companies, more than 90 percent of their design capacity is allocated to national security-related work.

Figure VIII-3: Design of National Security-Related IC Products - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Sixteen fabrication companies indicated that they would be willing to start designing national security-related products. Of these companies, the majority were willing to dedicate between 10 and 50 percent of their design capacity to national security work. Two fabricators would be willing to dedicate upwards of 90 percent of their overall design capacity.

TRUSTED SUPPLIERS - BACKGROUND

For some types of electronic components, DOD and other federal agencies require that U.S. firms possess more than just a capability to design and fabricate national security-related products. They require companies to have very secure design and manufacturing environments for critical design and manufacturing steps.

In 2003, DOD launched the Defense Trusted Integrated Circuits Strategy (DTICS) to prevent infiltration into the supply chain of IC products subjected to tampering or counterfeiting. "Trust" is defined as "the confidence in one's ability to secure national security systems by assessing the integrity of the people and process used to design, generate, manufacture, and distribute national security critical components."[42]

The aims of the program are to assure that DOD and other federal agencies have access to conventional and leading edge design and manufacturing facilities where critical national security IC products can be produced securely. The program is structured to protect critical IC products in design and development phases through each step of IC fabrication, testing and packaging.

Without such capability, operational readiness, battlefield effectiveness, critical infrastructure, and the lives of civilians and military personnel may be placed at risk. U.S. commercial, industrial, and military organizations have experienced problems with the integrity of electronic parts being compromised. Based on data from an ongoing assessment of counterfeit electronic parts, conducted by BIS and the Naval Air Systems Command, BIS has evidence that both new and older IC products can be subject to counterfeiting practices.[43]

A cornerstone of the DTICS effort was the initiation of the Trusted Foundry Program in 2003. The first trusted IC manufacturing center established in the private sector under this program was at IBM's production facilities in Burlington, VT, and East Fishkill, NY, which were selected for their ability to provide leading edge IC product.[44] These facilities can fabricate IC designs carrying "secret" level designations. The fabrication capabilities of these facilities include application specific integrated circuits (ASICs) and tamper-resistant architectures for field programmable gate arrays (FPGAs).

Through the Trusted Foundry Program, DOD customers, other U.S. Government agencies, and government contractors are assured access to certified secure design, prototyping and production facilities located in the United States. IC manufacturers interested in supplying certain types of national security IC products to DOD and other federal agencies must be accredited through the Trusted Foundry Access (TFA) program. The process of accrediting companies as "trusted

[42] Military Information Technology, Online Archives, Volume 12 Issue 3, April 25, 2008.
[43] The completed study on counterfeit electronic parts will be released in the summer of 2009.
[44] Gerald Etzold, Technical Director, Trusted Access Programs Office, National Security Agency.

suppliers" is administered by the Trusted Access Programs Office (TAPO) at the National Security Agency (NSA) and by Defense Microelectronic Activity (DMEA).[45] TAPO has accredited eight additional IC companies in the United States that can provide foundry services to DOD and its contractors.[46] DOD recently expanded the scope of the trusted program to include other IC- related manufacturing activities. This includes IC design, IC photomask production, packaging, assembly, and testing of IC die.

Three companies have been accredited to provide packaging, assembly, and test services, while two companies have been accredited to provide design services. Three companies are also accredited to aggregate specialized or low-volume IC product fabrication into consolidated production lots that can be manufactured more efficiently as a group rather than in separate job runs. According to DMEA, another 35 companies have applied for accreditation in what is now being called the Trusted Supplier Program.[47]

The trusted supplier program continues to evolve. In March of 2008, DOD indicated that it will incorporate the production of printed circuit boards (PrCBs) into the DTICS program. Extending the DTICS strategy to include PrCBs (and possibly other PrCB-mounted components) could further mitigate the risks posed by tampering and counterfeiting. DOD noted that it is possible to extend the Defense Logistics Agency's (DLA) current PrCB qualification standards to assure trustworthiness issues in circuit board products.[48]

OUTLOOK FOR TRUSTED SUPPLIERS

Of the 49 fabrication companies surveyed, nine are accredited as trusted suppliers for fabrication work.[49] An additional 14 fabrication companies reported having the self-assessed capability to

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[45] The Defense Microelectronics Activity was established prior to the creation of the Trusted Foundry Program, but its capabilities were limited and it was not able to produce leading edge integrated circuit products. The National Security Agency also operated a foundry, but costs for modernizing it were considered prohibitive. See www.dmea.osd.mil/trustedic.html

[46] A foundry is a wafer production and processing plant that is available on a contract basis to other companies.

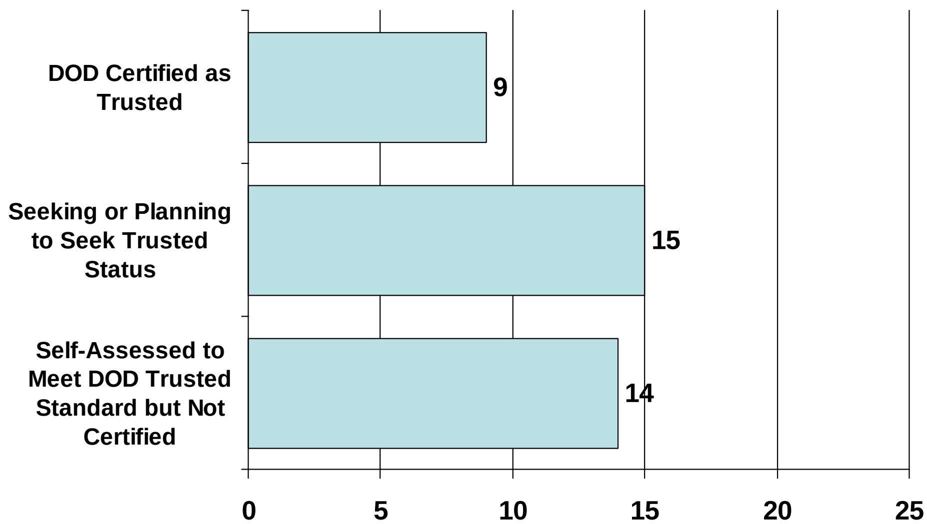
[47] Dan Booth, Defense Microelectronics Activity (DMEA), July 18, 2008.

[48] *Report to United States House and Senate Armed Services Committees on Department of Defense Implementation of The National Research Council Committee on Manufacturing Trends in Printed Circuit Board Technology Recommendations*, U.S. Department of Defense, March 2008.

[49] Companies that have gained accreditation since the conclusion of the survey are not included in this number.

conform to DOD standards to manufacture custom IC products in a trusted environment located in the United States (see Figure VIII-4).[50] Fifteen survey respondents, some already certified in one or more areas and some with self-assessed capability, identified themselves as seeking or planning to seek Trusted Supplier status.

Figure VIII-4: Fabrication Companies Capable of DOD "Trusted" Standards

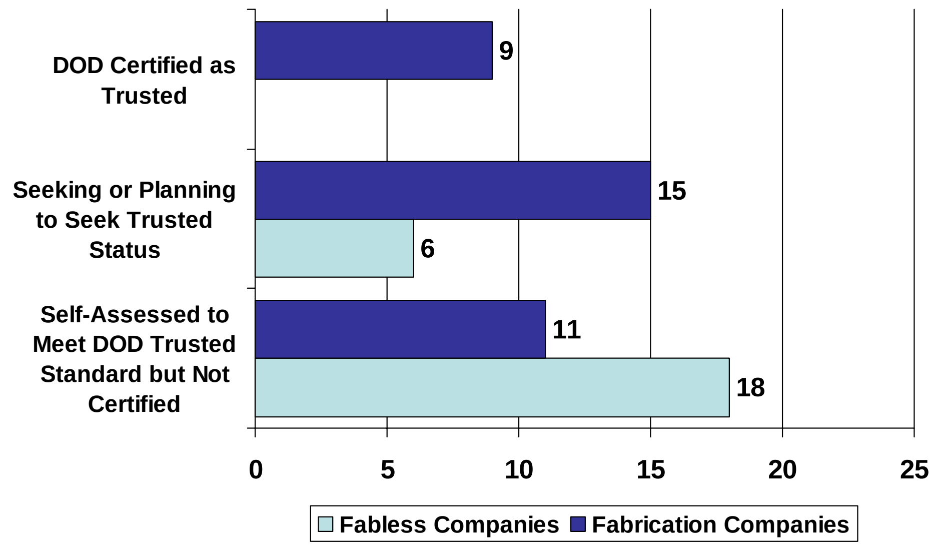


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

For 2007, 29 of 155 survey respondents declared the self-assessed ability to design custom IC products in a trusted, U.S.-located environment that conforms to DOD standards (see Figure VIII-5). Of these companies, 18 were fabless IC design companies and 11 were IC fabrication companies. Six fabless companies, some already certified in one or more areas and some with self-assessed capability, identified themselves as seeking or planning to seek Trusted Supplier status. Nine separate fabrication companies surveyed are accredited as trusted suppliers for design work. Fifteen fabrication companies, some already certified in one or more areas and some with self-assessed capability, identified themselves as seeking or planning to seek Trusted Supplier status for design work.

[50] Self-determination for being qualified to act as a trusted foundry does not mean companies actually can meet Department of Defense standards. Companies must obtain certification for the trusted supplier program through the Trusted Access Programs Office at the National Security Agency and the Defense Microelectronics Activity.

Figure VIII-4: Companies Capable of DOD "Trusted" Design Standards



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

As for why some companies are not interested in performing national security work, survey participants provided the following comments:

- Company is focused on commercial, industrial, and/or consumer markets;
- Can not easily isolate national security IC work from commercial work;
- Order volume and predictability for national security products is too uncertain; and
- Concern that working with federal agencies would be too complicated.

A number of companies left open the possibility that they would undertake IC national security-related design and/or manufacturing work. These IC companies explained that they have not pursued work in national security-related product areas because they do not understand the opportunities or comprehend the requirements and possible associated costs.

IX. PERFORMANCE AND OUTSOURCING OF PRODUCTION FUNCTIONS BY FABRICATION COMPANIES

OTE queried the 49 fabrication companies regarding their ability to execute seven manufacturing steps for the production of integrated circuit products. These functions include mask making, wafer manufacturing (front and back ends), wafer sorting, circuit testing, packaging, and final testing.[51] Fabrication firms reported their in-house production capabilities and capabilities outsourced to domestic and non-U.S. firms. Lastly, firms were asked about the prospects for maintaining and outsourcing future capabilities to perform each of these manufacturing steps through 2011.[52]

U.S.-BASED MANUFACTURING STEPS

A significant number of fabrication companies have the capability to conduct five of seven manufacturing steps: front- and back-end wafer manufacturing, wafer sorting, circuit testing, and final testing and inspection (see Figure IX-1). More than 80 percent of fabrication companies are capable of performing some or all of these manufacturing steps at U.S. facilities they own and operate. There are a limited number of companies, however, that are able to conduct their own mask making operations in the United States. In 2007, only seven, or 14 percent of fabrication companies, produced masks in their U.S. owned and operated facilities. The remaining manufacturing step, packaging, is also commonly outsourced by 27 of the 49 companies.

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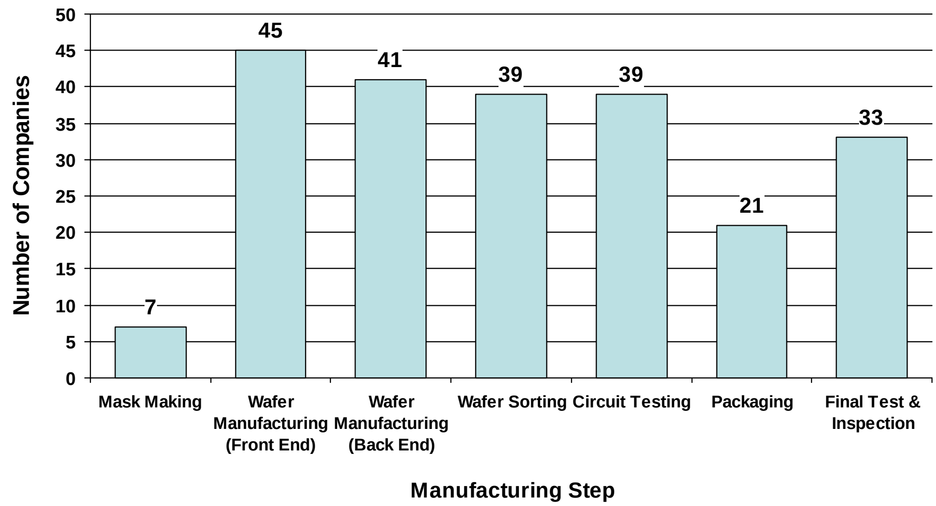
[51] For definitions of these seven manufacturing steps, please see Appendix C.

[52] A number of fabrication companies stated that for certain operations they maintain in-house capability, but they also use outside domestic and foreign companies.

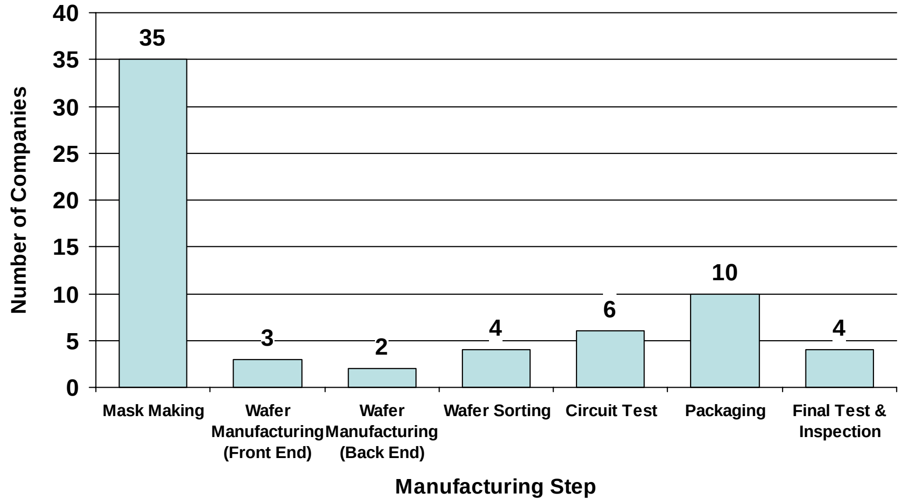
Figure IX-1: Manufacturing Steps Performed at U.S. Owned and Operated Facilities



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Fabrication companies only utilize a small number of U.S.-based vendors for six manufacturing steps, seemingly to augment their in-house capabilities (see Figure IX-2). The exception to this practice is mask making. More than 71 percent of the fabrication companies, or 35 firms, utilize other U.S.-based vendors for this part of the production process. Fabrication companies employing outside vendors to conduct specific manufacturing steps (other than mask making) are more likely to use non-U.S. firms than U.S.-based vendors (see Figures IX-2 and IX-3).

Figure IX-2: Manufacturing Steps Outsourced to Other U.S.-Based Vendors



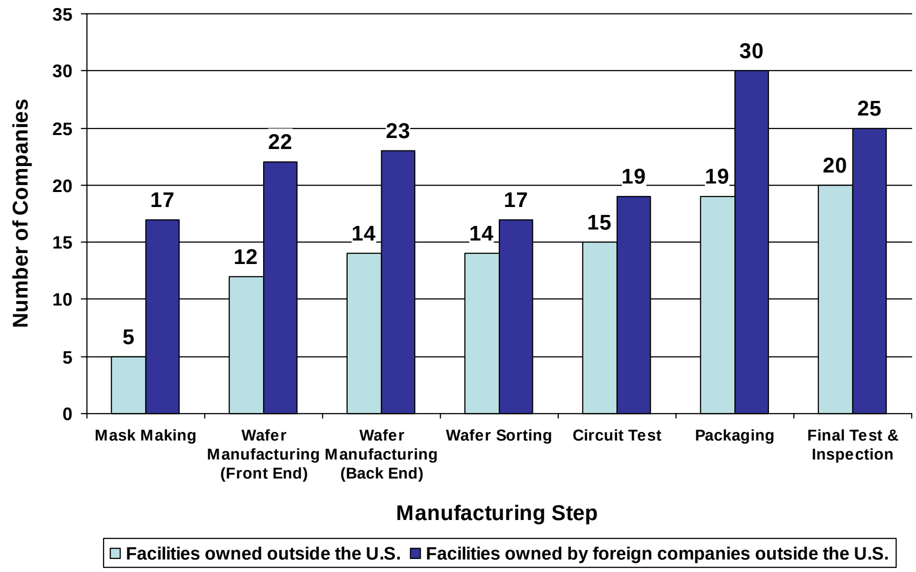
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

NON-U.S. OUTSOURCING OF MANUFACTURING STEPS

When IC fabricators use offshore facilities to conduct one or more of the seven manufacturing steps, they tend to use non-affiliated facilities more often than non-U.S. facilities they own and operate (see Figure IX-3). Although the use of non-affiliated facilities was more prevalent, the companies did report using a significant number of their own non-U.S. facilities.

Dependence on non-affiliated companies to perform production steps is greatest for mask making. Just seven fabrication companies perform mask making in their own U.S.-based facilities, and only five fabrication companies own and operate non-U.S. facilities that can perform this manufacturing step. Most fabrication companies rely on non-affiliated domestic and non-U.S. vendors to produce the masks they require to manufacture IC products.

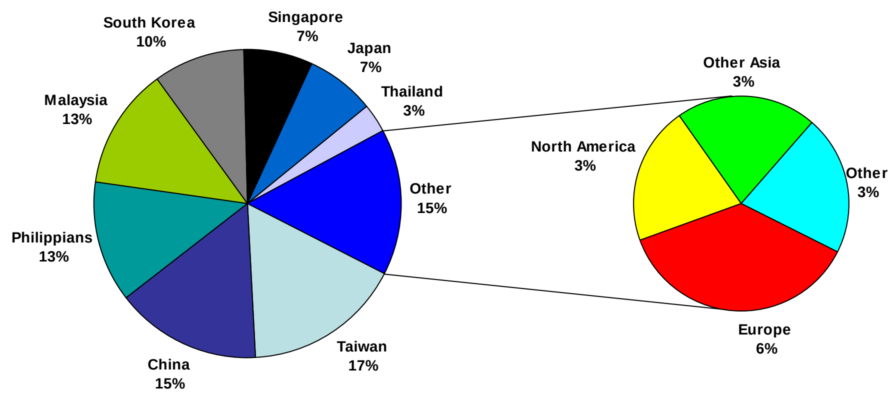
Figure IX-3: Foreign Outsourcing of IC Manufacturing Steps



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Geographically, the overwhelming majority of manufacturing steps outsourced by U.S. fabricators, 88 percent, are sent to Asia (see Figure IX-4). Taiwan and China were the most cited destinations, with a combined 33 percent of all non-U.S. outsourced manufacturing steps. Only seven companies reported outsourcing to European countries, mostly to the United Kingdom, representing six percent of destination countries. Outsourcing to Canada and Mexico accounts for three percent of the total destination countries.

Figure IX-4: Outsourcing of Manufacturing Steps - Destination Countries



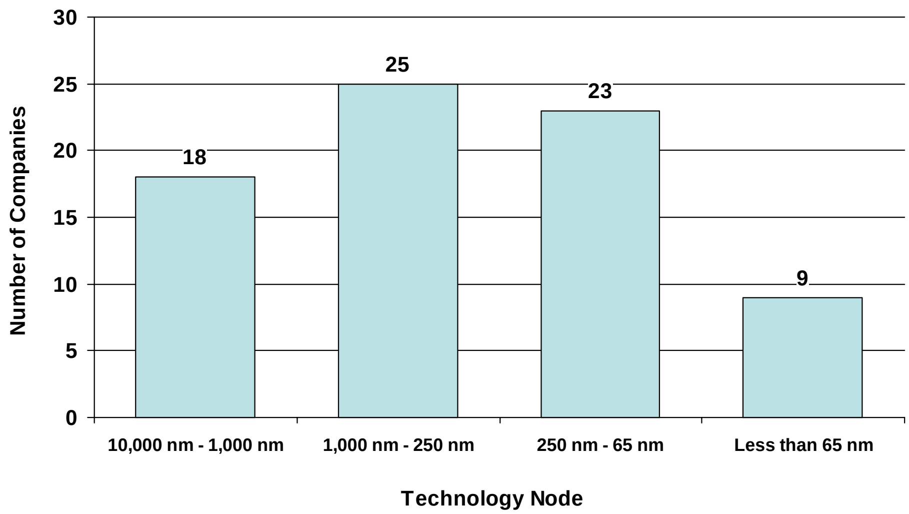
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Outsourcing by Technology Node and Material Type

Companies were asked to identify the technology nodes outsourced ranging from 10,000 nanometers (nm) to less than 65 nm. For the purposes of this assessment, OTE combined the 15 distinct technology node categories into four ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm.

Fabrication companies, in addition to maintaining domestic capabilities, outsource manufacturing steps across all technology nodes, with the 1,000 nm – 250 nm and the 250 nm – 65 nm ranges being the most common (see Figure IX-5). Twenty-five companies, more than half of all fabrication companies, outsource fabrication steps over the 1,000 nm – 250 nm range. Nine companies outsource fabrication steps for products at less than 65 nm. As indicated earlier, only six companies can manufacture at this leading-edge technology node range, and five of these companies outsource fabrication steps at less than 65 nm. Thus, more fabrication companies outsource at the leading-edge technology node range than are fabricating in the United States.

Figure IX-5: Outsourcing by Technology Node Range



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Outsourcing practices are also revealed by examining the types of materials employed in IC products for which fabrication is outsourced. Production functions for IC products based on bulk silicon process technology are most often outsourced, followed by product employing silicon-on-insulator. The types of devices employing these two materials for which some manufacturing steps are most frequently outsourced are custom ASICs and mixed signal ASICs.

REASONS FOR OUTSOURCING

The 49 fabrication companies were asked to identify the primary reasons for outsourcing production to non-U.S. locations. The top three reasons were lower costs, maximizing profits, and competitive pricing pressures (see Figure IX-6). Companies selected these three reasons nearly twice as often as the next highest reason, a lack of tax incentives in the United States. Very few companies found the American workforce to be insufficient for their needs. Direct and indirect foreign government subsidies were a factor for a small number of companies. Based on the survey responses, it appears competition and economics are the driving forces behind U.S. firms shifting IC fabrication operations overseas.

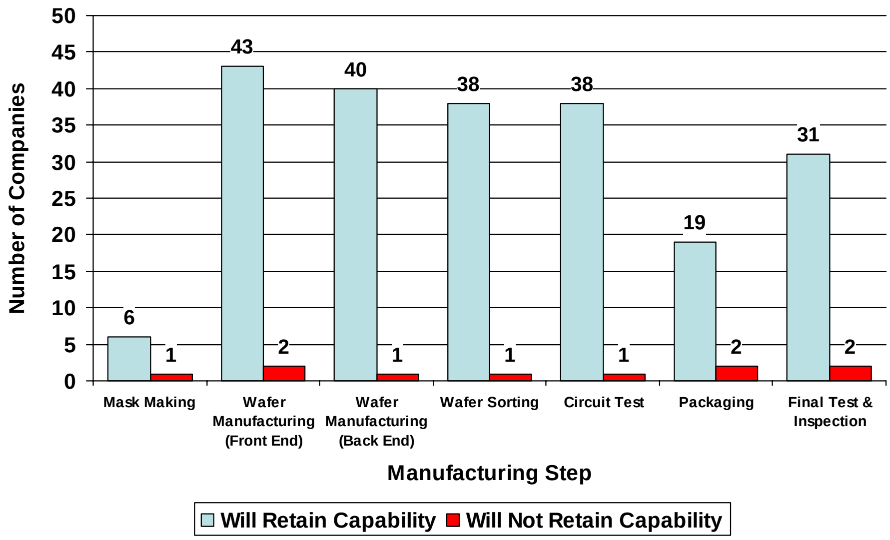
Figure IX-6: Reasons for Outsourcing	
Reasons for Outsourcing	**Number of Companies**
Lower Costs	39
To Maximize Profits	29
Competitive Pricing Pressures	28
Lack of Tax Incentives	15
To Better Serve Overseas Markets	14
To Assure Better Market Access	12
No U.S. Capability	10
Indirect Foreign Government Subsidies	5
No U.S. Contractor Found	4
Direct Foreign Government Subsidies	3
Insufficient U.S. Workforce	3

Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

RETENTION OF MANUFACTURING STEP CAPABILITY THROUGH 2011

Fabrication companies were asked to predict if they will maintain capability to perform each of seven IC manufacturing steps at their U.S.-based operations through 2011. Most firms anticipate maintaining capability to perform manufacturing steps at U.S. owned and operated facilities through this period (see Figure IX-7). The number of companies retaining fabrication capability will remain relatively stable, although there will be a slight decrease in the number of companies capable of in-house production for each of the seven manufacturing steps.

Figure IX-7: Manufacturing Steps Retained by U.S. Owned and Operated Facilities (2008-2011)

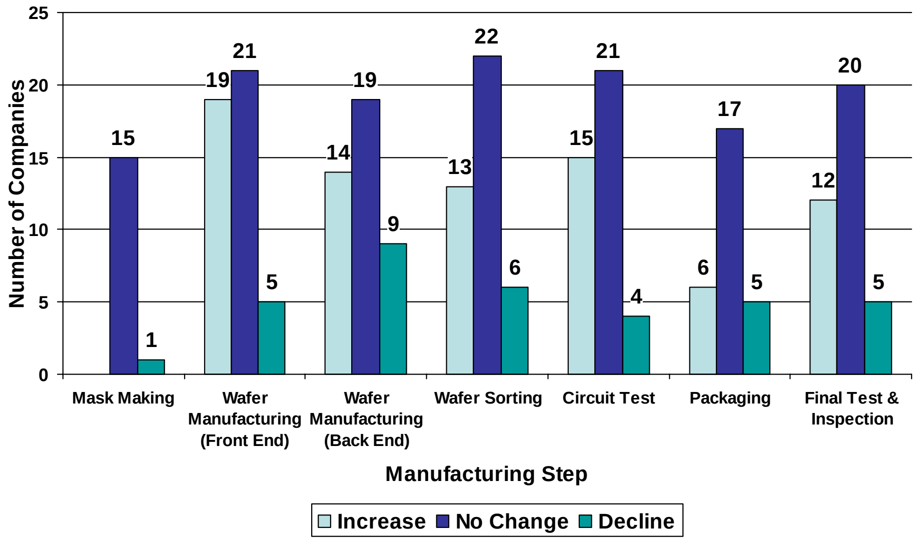


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

The majority of fabrication companies plan to retain their current level of manufacturing capability, with many projecting increases through 2011.[53] For example, U.S.-based capability to perform front end wafer manufacturing will increase as 19 companies expand their domestic capability (see Figure IX-8). Levels of circuit testing will also increase significantly, with 15 companies projected to expand domestic capabilities through 2011. In-house mask making is the only manufacturing step where there is no planned increase in production capability over the 2007-2011 period.

[53] In contrast to the previous section detailing outsourcing trends, this section explains whether levels of production capability will increase, decrease, or remain unchanged through 2011. A company can outsource a portion of a manufacturing step while increasing its base-line capacity to perform this step in its U.S.-based facilities.

Figure IX-8: Projected U.S.-Based Capability Trends for 2007 - 2011

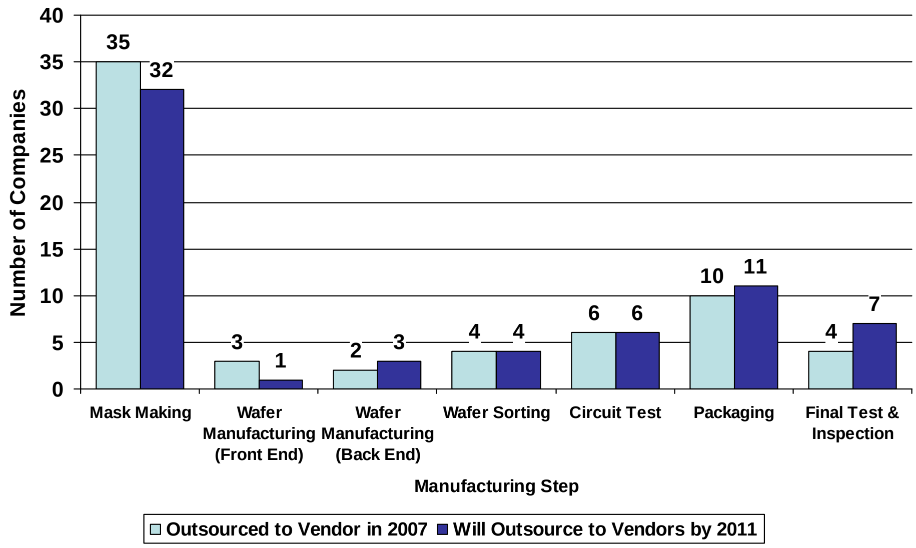


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

PROJECTED U.S.-BASED AND NON-U.S. OUTSOURCING

The number of companies that anticipate outsourcing manufacturing steps to U.S.-based vendors will remain steady through 2011, which is similar to predictions for in-house fabrication activity. During this period, the number of companies outsourcing to U.S.-based vendors is projected to increase slightly for wafer manufacturing (back end), packaging, and final test and inspection. Conversely, the number of fabricators outsourcing the mask making and wafer manufacturing (front end) manufacturing steps to U.S.-based vendors is projected to decrease slightly (see Figure IX-9).

Figure IX-9: Manufacturing Steps Outsourced to Other U.S.-Based Vendors (2008-2011)



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

The number of companies performing mask making and front end wafer manufacturing in U.S.-based facilities is decreasing along with the utilization of U.S.-based vendors for these manufacturing steps. This suggests that a portion of these operations will move to non-U.S. facilities.[54] Specifically, four companies indicated that by 2011 they will shift their entire mask making and front end wafer manufacturing to non-U.S. facilities.

As highlighted in Figure IX-10, fabrication companies anticipate increasing outsourced production capability for all seven manufacturing steps by 2011.[55] The outsourcing of packaging is due to increase the most, with 47 percent of fabrication companies planning to expand domestic and non-U.S., non-affiliated operations. Also noteworthy is the fact that the 17 companies that will increase outsourcing of mask making capabilities. With minimal in-house production, mask making is an area that should be monitored in the future.

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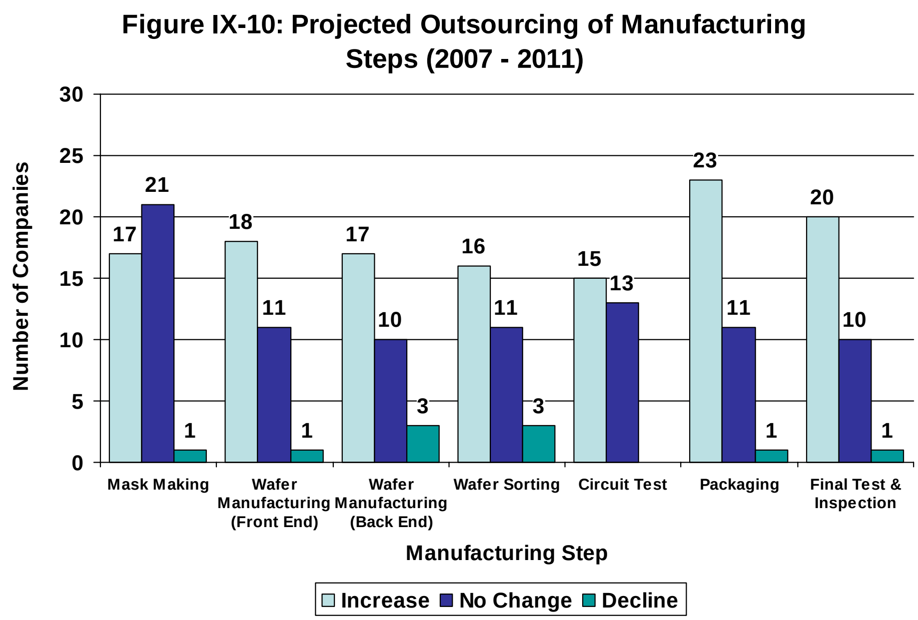
[54] This assumes that IC production will remain at current levels.

[55] It should be noted that outsourcing of capability in this context does not necessarily indicate a company is fully outsourcing that capability. Many companies may split manufacturing steps between U.S. owned and operated facilities, U.S.-based vendors, and/or overseas facilities.



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

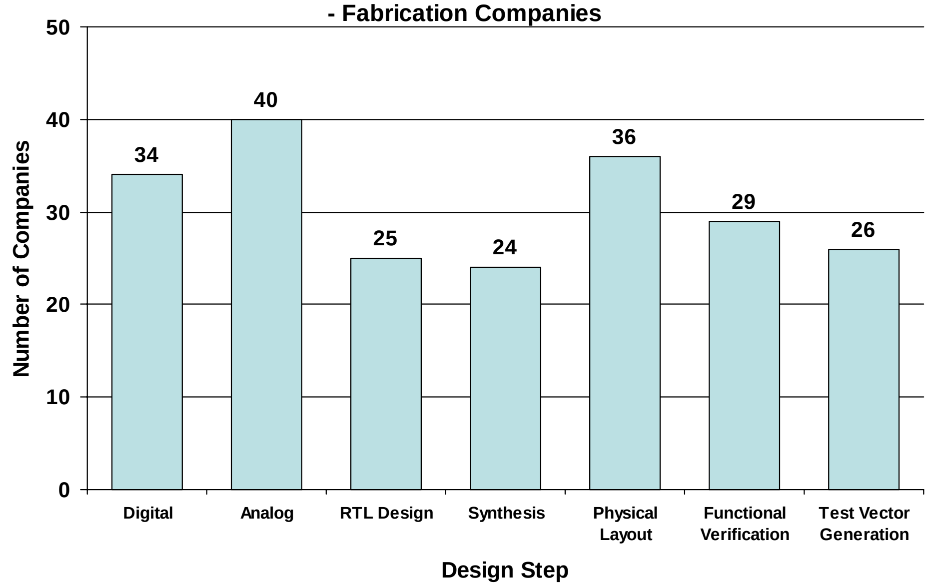
X. PERFORMANCE AND OUTSOURCING OF DESIGN FUNCTIONS BY FABRICATION COMPANIES

OTE queried fabrication companies regarding their ability to perform seven steps in designing integrated circuit (IC) products: digital, analog, RTL design, synthesis, physical layout, function verification, and test vector generation. Fabrication firms reported on their U.S. owned and operated capabilities, design functions outsourced to United States and non-U.S. companies, and future capabilities to perform each of these design steps. This chapter focuses exclusively on design step performance of 49 U.S.-based fabrication companies through 2011.

U.S.-BASED DESIGN STEPS

More than half of fabrication companies are capable of performing all seven design steps in their U.S.-based facilities (see Figure X-1). Synthesis is the design step least likely to be performed in-house, with only 49 percent fabrication companies (24 firms) doing so. Analog design is most commonly performed in-house, with 40 fabrication companies, or 82 percent, doing so. Four fabrication companies reported having no design capability in their U.S.-operated facilities.

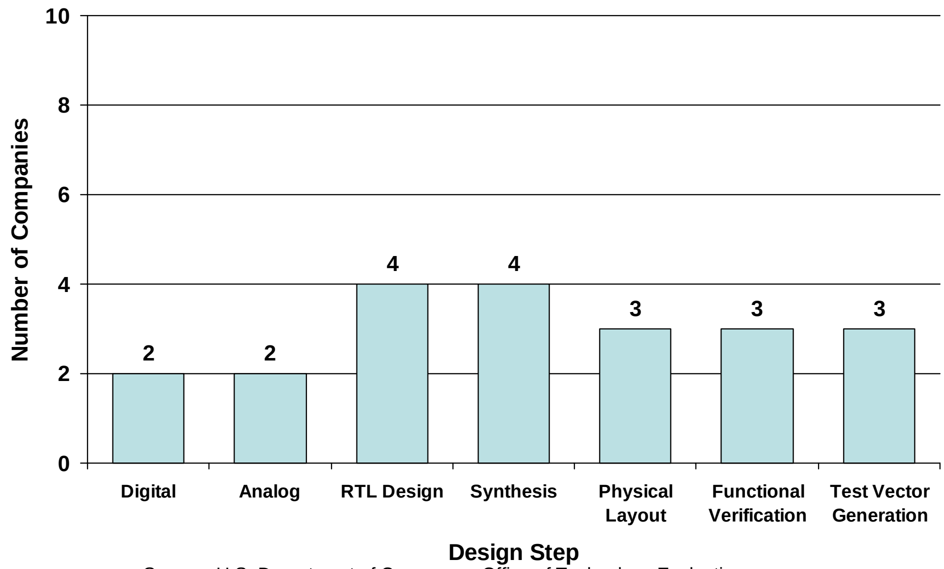
Figure X-1: Design Steps at U.S. Owned and Operated Facilities - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Most IC fabrication companies do not outsource any design steps to U.S.-based vendors (see Figure X-2). The two design steps most frequently outsourced to U.S.-based vendors are RTL design and synthesis, but only four fabrication companies do so for each step.

Figure X-2: Design Steps Outsourced to Other U.S.-Based Vendors - Fabrication Companies

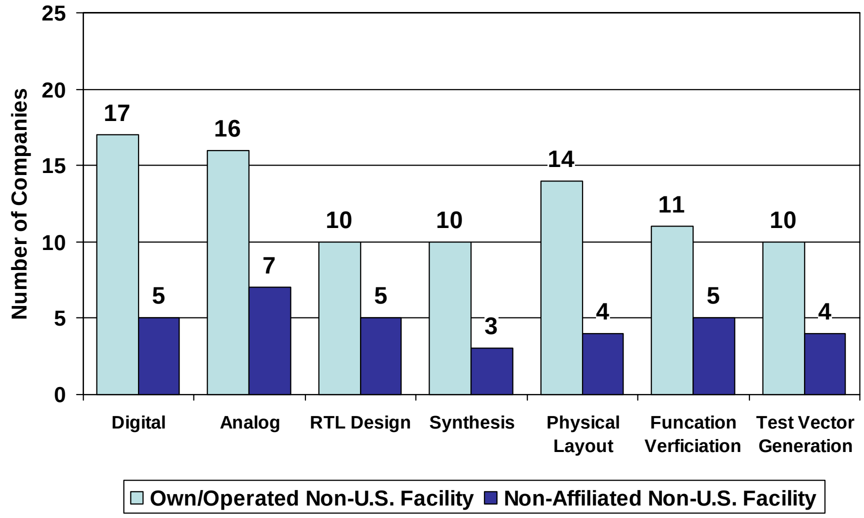


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

NON-U.S. OUTSOURCING OF DESIGN STEPS

Overall, 20 fabrication companies (41 percent) outsource design steps to non-U.S. firms to some degree (see Figure X-3). The majority of these companies outsource to non-U.S. facilities they own and operate. The three design steps most frequently outsourced to affiliated non-U.S. facilities are digital (17 companies), analog (16 companies), and physical layout (14 companies). With regard to non-affiliated, non-U.S. facilities, only seven companies, 14 percent of the total, outsource analog design, the highest level of outsourcing amongst the seven design steps.

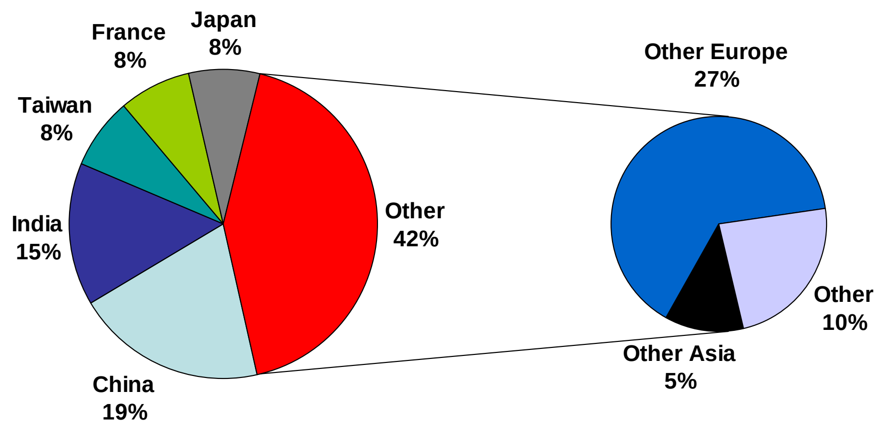
Figure X-3: Outsourcing to Foreign Owned/Operated and Non-Affiliated Facilities – Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

When IC fabrication companies outsource design steps to non-U.S. firms, they do so to providers in a wide range of countries (see Figure X-4). China and India are the most common individual destinations, but are considerably less common for design steps as opposed to manufacturing operations. As a region, European countries are more prevalent destinations for the outsourcing of design operations by fabricators, representing 35 percent of outsourcing operations.

Figure X-4: Outsourcing of Design Steps - Countries

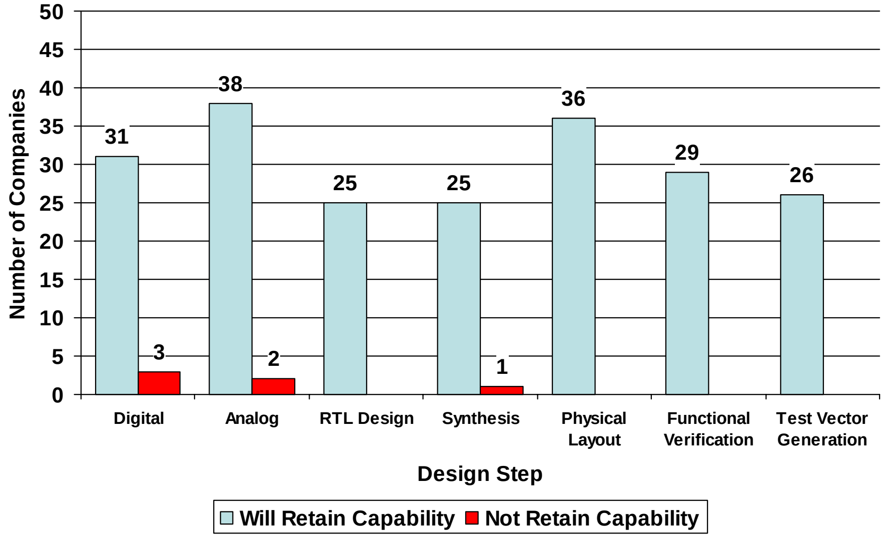


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

RETENTION OF DESIGN STEP CAPABILITY THROUGH 2011

Nearly all IC fabrication companies expect to retain their ability to perform core design steps at their U.S.-based facilities through 2011 (see Figure X-5). In total, only three companies will not retain their ability to perform one or more design steps in-house through 2011. The digital design step will experience the largest reduction, with three fabrication companies, or six percent, projected to diminish capability.

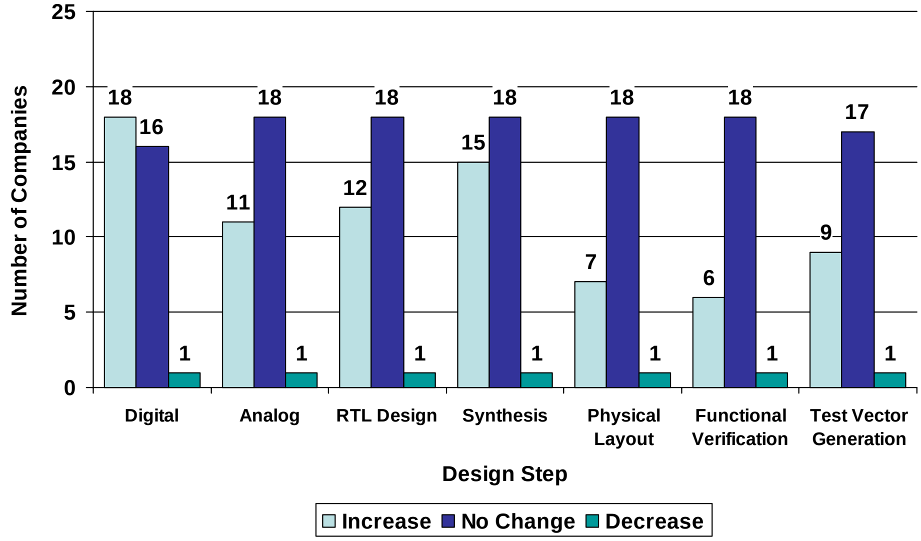
Figure X-5: Design Steps Retained by U.S. Owned and Operated Facilities (2008-2011) - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Fabrication companies do not expect to change the amount of design work done in their U.S. facilities (Figure X-6). For five of the seven design steps, 37 percent of companies anticipate no change in their design capability through 2011, with the test vector generation and digital steps close behind. There is a significant trend, however, of increasing in-house design capability through 2011. Capability to perform the digital design step will increase the most, with 18 companies expanding their operations in the United States.

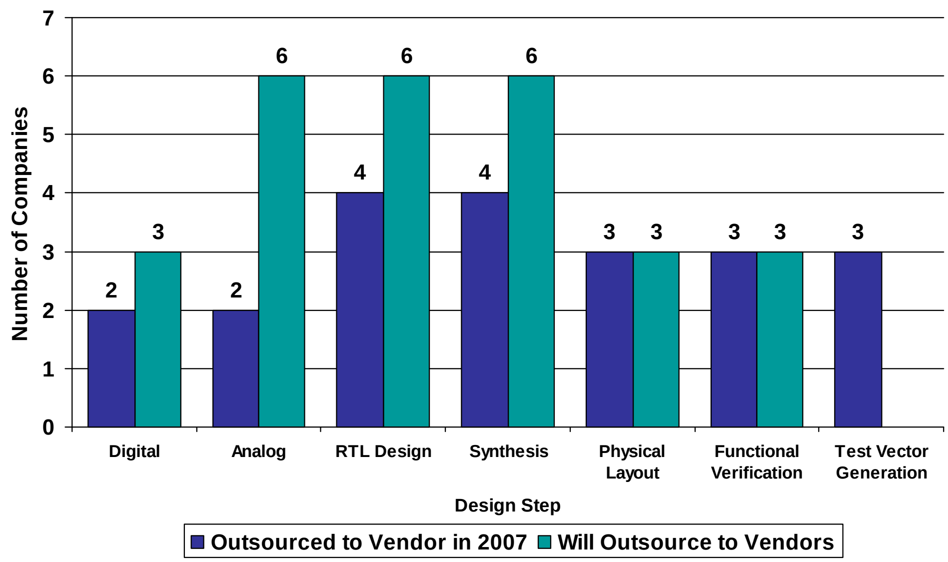
Figure X-6: Projected U.S.-Based Capability Trends for 2007 - 2011 - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

IC fabrication companies reported a wide-range of answers on projected outsourcing of design steps to U.S.-based vendors. Although most companies do not currently utilize U.S.-based vendors to perform design steps, a few fabrication firms predict outsourcing to U.S.-based companies will increase by 2011. This outsourcing will most likely be in the digital, analog, RTL design, and synthesis design steps (see Figure X-7). Outsourcing of physical layout and function verification steps is anticipated to remain steady, while all fabrication companies expect to cease using U.S.-based vendors to perform test vector generation design work.

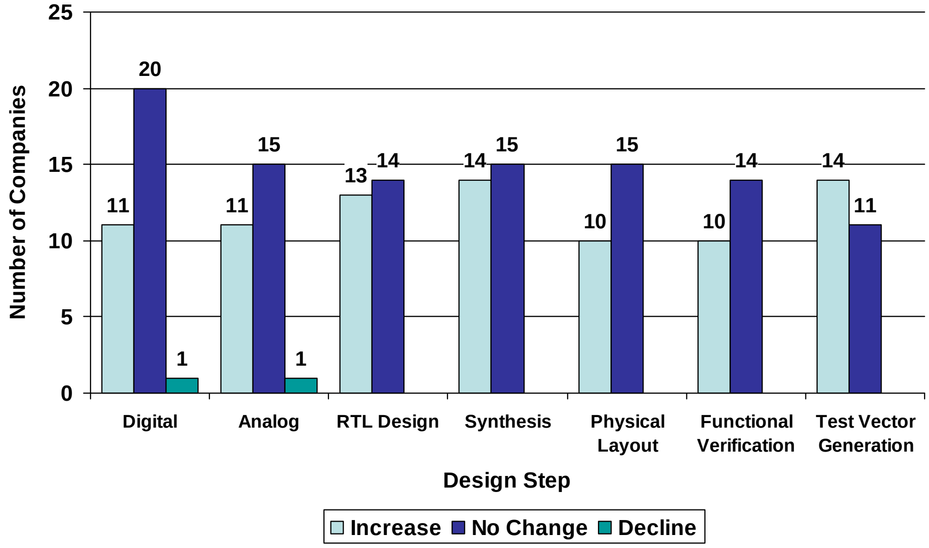
Figure X-7: Design Steps Outsourced to Other U.S.-Based Vendors (2008-2011) - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

For most IC fabrication companies, the level of outsourcing of design steps will not change through 2011 (see Figure X-8). However, 31 percent of fabricators (15 firms) plan to increase their level of outsourcing of at least one design step over this period. Of these companies, 10 (20 percent of all fabrication firms) expect to expand their level of outsourcing for all seven design steps. Data shows that fabrication companies intend to maintain design capability in the United States while expanding outsourcing operations.

Figure X-8: Projected Outsourcing of Design Steps (2007 - 2011) - Fabrication Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

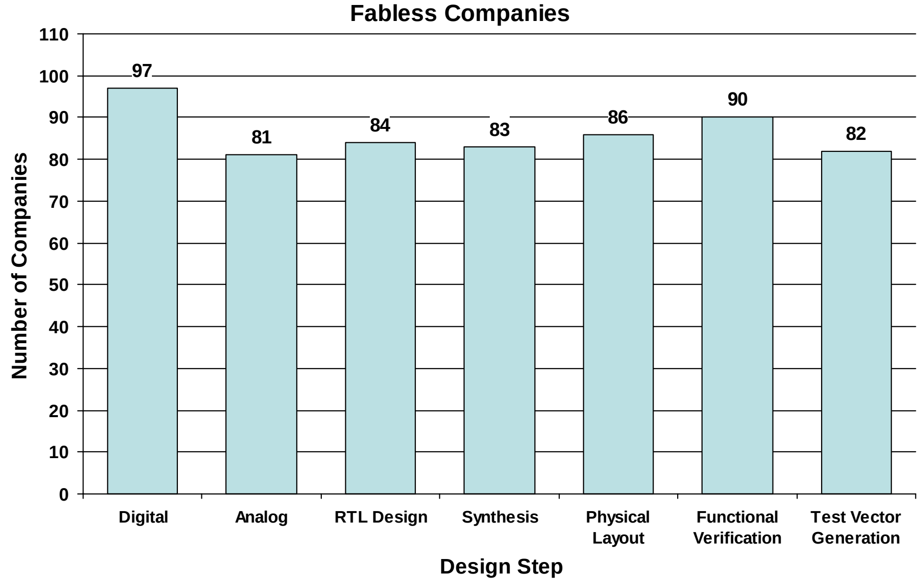
XI. PERFORMANCE AND OUTSOURCING OF DESIGN FUNCTIONS BY FABLESS COMPANIES

OTE queried 106 fabless companies regarding their ability to perform seven main design steps in the development of integrated circuit (IC) products. These steps include digital, analog, RTL design, synthesis, physical layout, function verification, and test vector generation.[56] Fabless firms reported on their U.S. owned and operated capabilities, design functions outsourced to U.S.-based vendors and non-U.S. companies, and future capabilities to perform each of these design steps through 2011.

U.S.-BASED DESIGN STEPS

The vast majority of design companies can perform all seven design steps at U.S. owned and operated facilities (see Figure XI-1). Although analog design work is the least likely step to be performed in-house, more than 76 percent of the 106 design companies (81 firms) have the capability. Ninety-two percent of the 106 design companies (97 firms) can perform the digital design step in U.S. owned and operated facilities, the most frequently identified capability.

Figure XI-1: Design Steps at U.S. Owned and Operated Facilities - Fabless Companies

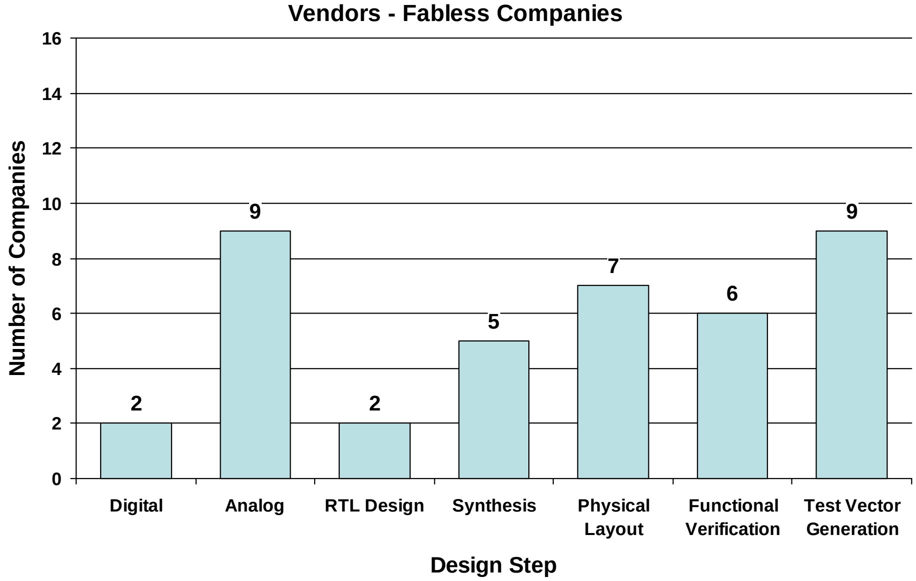


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

[56] For definitions of these seven manufacturing steps, please see Appendix C.

Twenty-one fabless companies outsource specific design steps to U.S.-based vendors (see Figure XI-2). Analog and test vector generation are most frequently cited as design steps outsourced to U.S.-based vendors. Only eight percent of companies (nine firms) outsource each of the analog and test vector generation design steps.

Figure XI-2: Design Steps Outsourced to Other U.S.-Based Vendors - Fabless Companies

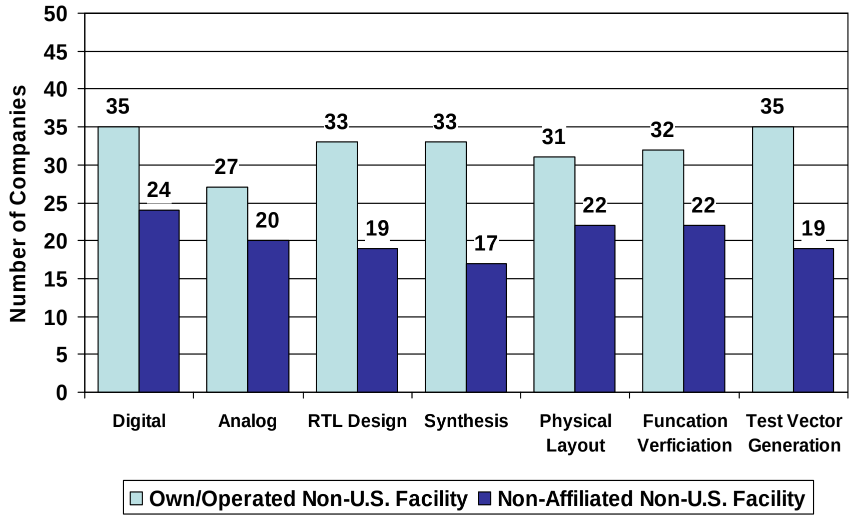


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

NON-U.S. OUTSOURCING OF DESIGN STEPS

In addition to outsourcing to U.S.-based vendors, companies were asked to describe their non-U.S. outsourcing activities. Forty-nine of the 106 IC design companies (46 percent) outsource design steps to non-U.S. locations at some level (see Figure XI-3). Most of the companies that reported outsourcing design steps to other countries do so to non-U.S. facilities they own and operate. A smaller number of design firms outsource to non-affiliated, non-U.S. facilities.

Figure XI-3: Outsourcing to Foreign Owned/Operated and Non-Affiliated Facilities – Fabless Companies

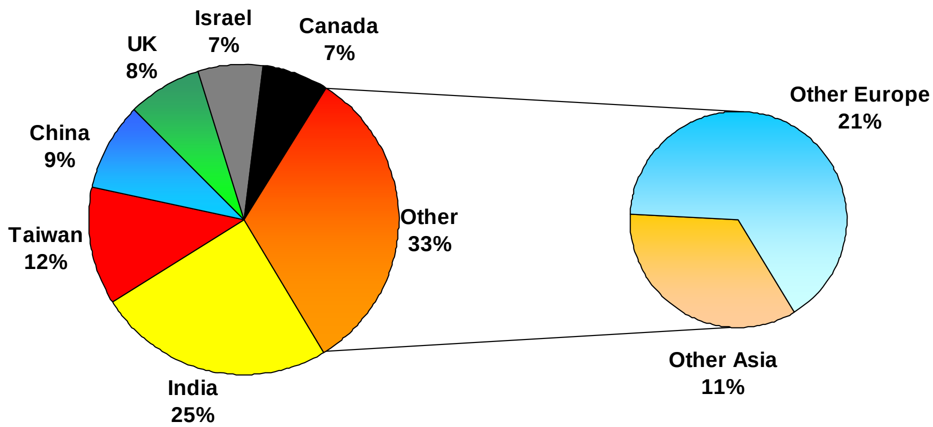


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

A significant number of IC design companies simultaneously outsource design steps to both affiliated and non-affiliated, non-U.S. facilities. For example, 21 of the 24 design companies that outsource the digital design step to non-affiliated, non-U.S. facilities also have non-U.S. facilities they own performing the same step.

Fabless firms were also asked to identify the locations of the non-U.S. facilities where design work is performed. The largest number of fabless companies, 32 percent, outsource design steps to Asia, with 12 percent going to Taiwan and nine percent going to China (see Figure XI-4). Twenty-nine percent of the companies outsource to Europe, with eight percent using facilities in the United Kingdom. A quarter of the fabless companies outsource to India, and seven percent outsource to Israel and to Canada, respectively.

Figure XI-4: Outsourcing of Design Steps - Destination Countries



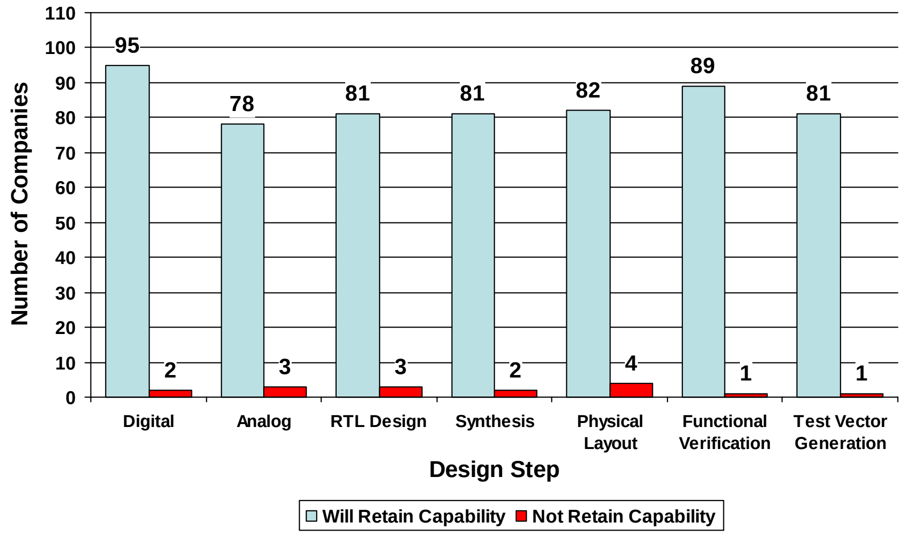
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Design of IC products is most commonly outsourced in the 1,000 nm – 250 nm, 250 nm – 65 nm and the less than 65 nm technology node ranges. Outsourced design work is primarily for devices employing bulk silicon; design steps for devices that employ silicon-on-insulator and silicon germanium are much less commonly outsourced. Design work for ASIC products is outsourced to a greater degree than design work for gate arrays or memory devices. Finally, the vast majority of outsourced design work occurs for conventional IC products; very few design steps are outsourced for radiation resistant products.

Retention of Design Step Capability Through 2011

Nearly all fabless companies expect to retain capability to perform seven main design steps at their U.S. owned and operated facilities through 2011. A slight drop is expected in the number of companies with capabilities in each of the seven categories, with the most companies expecting to eliminate the physical layout design step (see Figure XI-5). Only four of the 106 companies (less than 4 percent), however, plan to eliminate capability for the physical layout step at their U.S. owned and operated facilities.

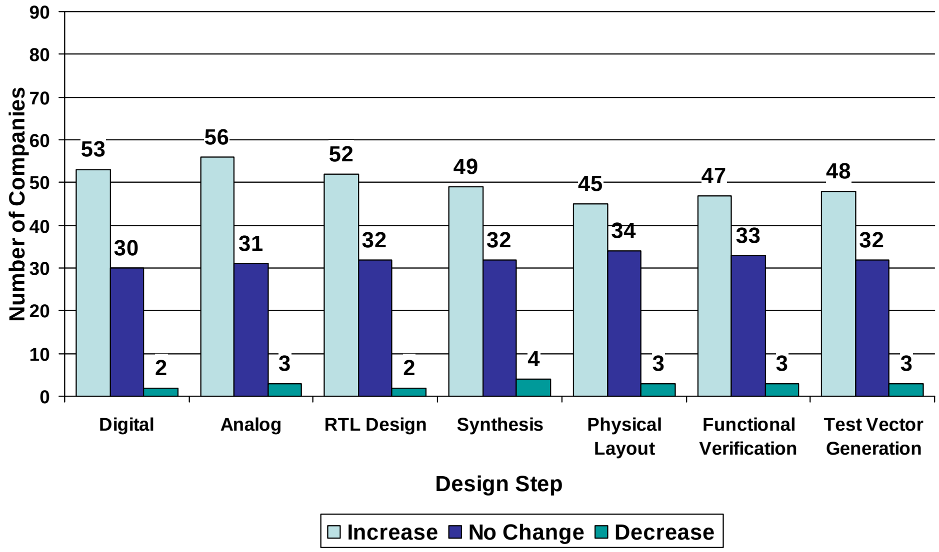
Figure XI-5: Design Steps Retained by U.S. Owned and Operated Facilities (2008-2011) - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Fabless companies were also asked to project the level of capability they will have for each of the seven design steps at their U.S.-based facilities through 2011. The majority of fabless companies expect to increase their capability across all design steps (see Figure XI-6). A lesser number of fabless companies predicted no changes in their design step capabilities. Very few fabless companies plan to decrease capability levels through 2011.

Figure XI-6: Projected U.S.-Based Capability Trends for 2007 - 2011 - Fabless Companies

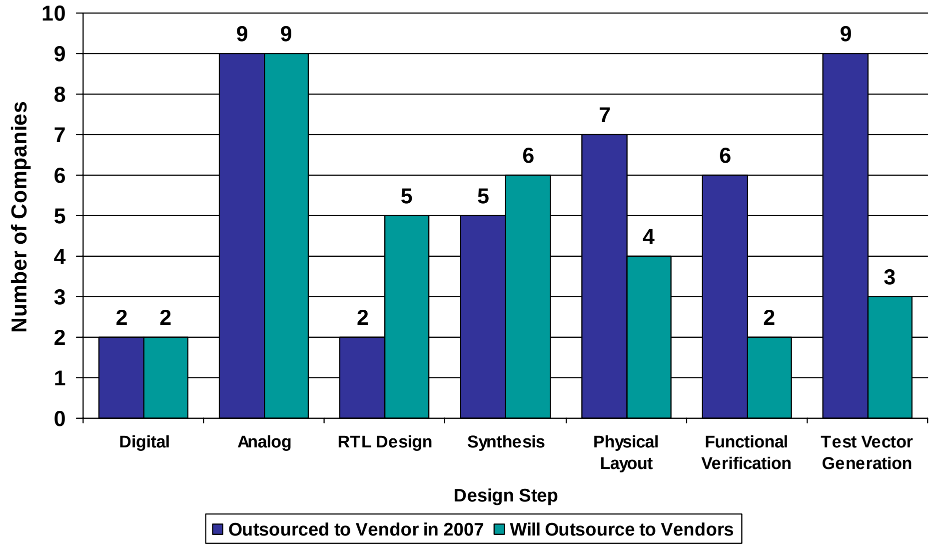


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

PROJECTED U.S.-BASED AND NON-U.S. OUTSOURCING

As stated previously, very few fabless companies outsource the seven design steps to U.S.-based vendors; these low levels of outsourcing are projected to continue through 2011 (see Figure XI-7). The outsourcing of three design steps are projected to decline: physical layout, functional verification, and test vector generation. The RTL design and synthesis design steps will see slight increases in U.S.-based vendor outsourcing. All companies that currently outsource the digital and analog design steps are expected to continue to do so through 2011.

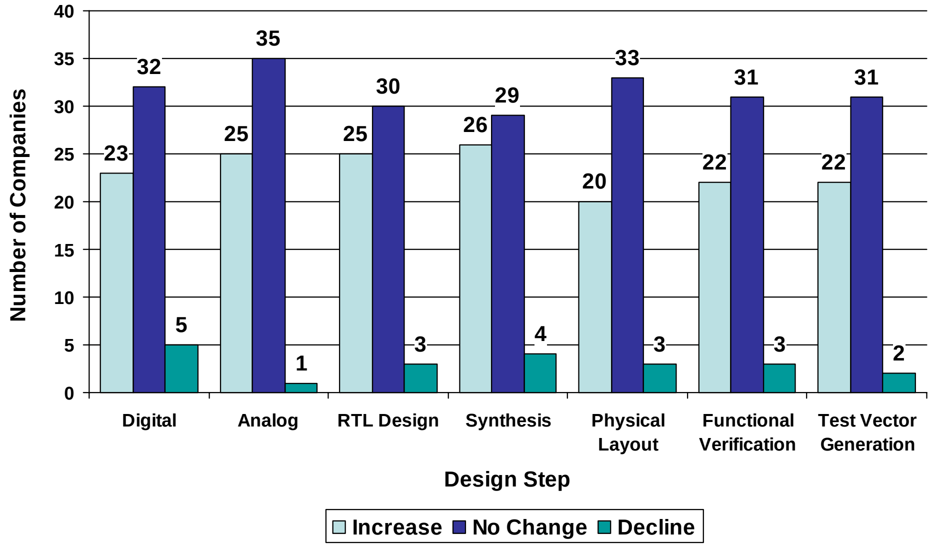
Figure XI-7: Design Steps Outsourced to Other U.S.-Based Vendors (2008-2011) - Fabless Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Most fabless companies project that the amount of outsourcing will not change through 2011 (see Figure XI-8). Nevertheless, the data shows that approximately 40 percent of fabless companies expect to increase their levels of outsourcing through 2011. When compared with the data from Figure X-5, which shows that most companies will retain design capability in their U.S.-based facilities, this indicates that a portion of design companies will seek to expand their operations overseas while maintaining robust capability domestically.

Figure XI-8: Projected Outsourcing of Design Steps (2007 - 2011) - Fabless Companies



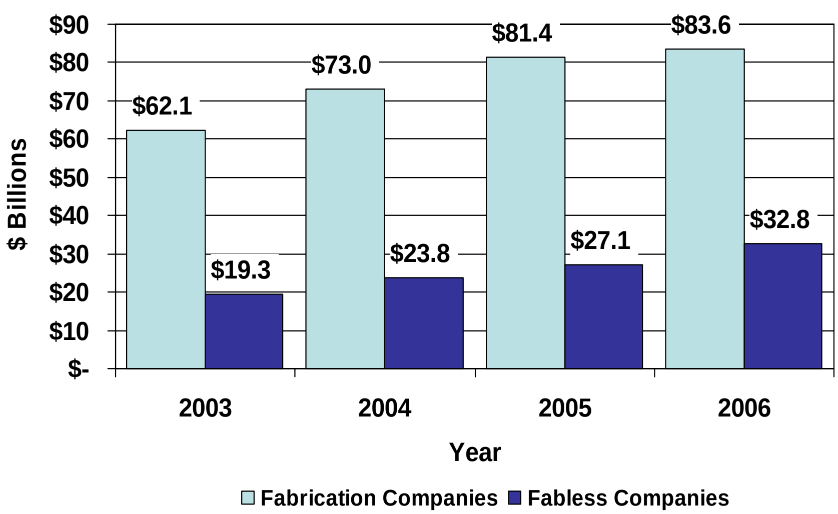
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

XII. INDUSTRY FINANCIAL PERFORMANCE

As a group, integrated circuit (IC) fabrication and fabless companies surveyed by OTE reported steady increases in net sales over a four-year reporting period from 2003 through 2006. Combined net sales climbed from $81.4 billion in 2003 to $116 billion in 2006, growing an average of 12.7 percent annually.

IC fabrication companies accounted for the bulk of combined industry net sales, averaging 75 percent of total sales over the four-year period. Fabricators' net sales grew from $62 billion in 2003 to $83.5 billion in 2006, with an average increase per year of 10.6 percent (see figure XII-1). Fabless companies accounted for the rest of combined industry net sales. Their net sales grew from $19 billion in 2003 to $33 billion in 2006, with an average increase per year of 19.3 percent.

Figure XII-1: Net Sales



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

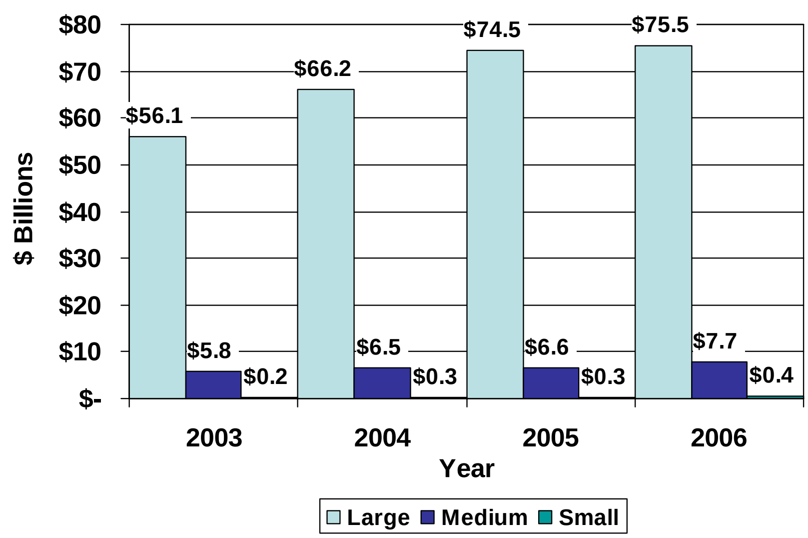
FABRICATION NET SALES

In analyzing net sales data, IC fabricators' were categorized as small-, medium-, and large-size based on average net corporate sales from 2003 – 2006 (see Figures XII-2 and XII-3).

Figure XII-2: Size Classification – Fabrication Companies		
Size	Number of Companies	Net Sales
Small	19	Less than $100 million
Medium	20	$100 million - $1 billion
Large	10	Greater than $1 billion
Total	**49**	**-**

Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Figure XII-3: Fabrication Net Sales



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

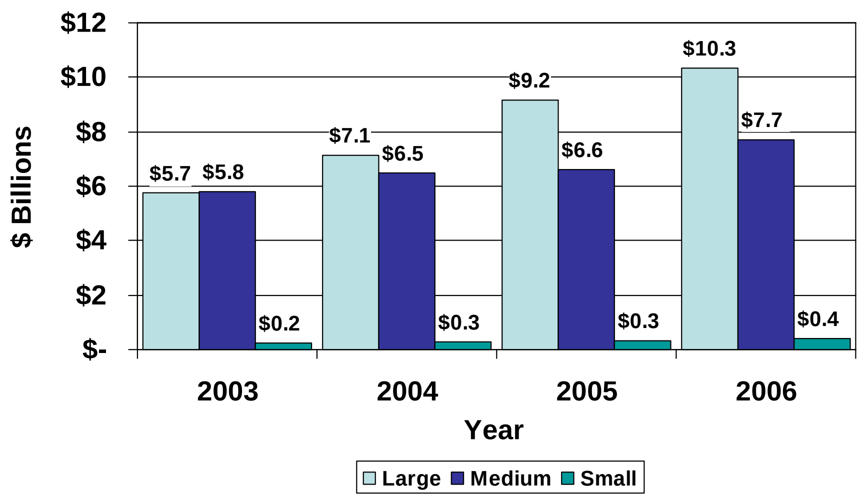
Large-size companies reported net sales of $75.5 billion in 2006 up from $56.1 billion in 2003, an average annual increase of 8.6 percent. Five of the ten large-size fabrication companies dominate the industry, accounting for $240 billion of $272.3 billion nets sales (88 percent) posted for the 2003-2006 period by the large-size companies. Net sales for these five companies over the four-year period grew at a faster rate, 9.2 percent, than for all IC fabricators as a group.

The lower five large-size firms combined net earnings totaled only $32 billion in 2003-2006, although their growth rate as a group, an average of 21.9 percent annually, was stronger than the top five large-size firms. Their net sales rose from $5.7 billion in 2003 to $10.3 billion in 2006 (see Figure XII-4).

Medium-size fabrication companies totaled $26.5 billion in net sales over the four-year period. Net sales increased from $5.7 billion in 2003 to $7.7 billion in 2006, an average annual percent change per year of 10.2 percent.

Small-size fabrication companies recorded the lowest net sales, $1.2 billion from 2003 to 2006. Their combined gains in net sales, however, were high, increasing from $233 million in 2003 to $402 million in 2006, an average percent change per year of 20.1 percent.

Figure XII-4: Fabrication Net Sales – Excluding Top 5 Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

IC DESIGN NET SALES

In analyzing net sales data, fabless companies were categorized as small-, medium-, and large-sized based on average net corporate sales from 2003 – 2006 (see Figure XII-5).

Figure XII-5: Size Classification – Fabless Companies		
Size	Number of Companies	Net Sales
Small	65	Less than $25 million
Medium	27	$25 million - $350 million
Large	14	Greater than $350 million
Total	**106**	**-**

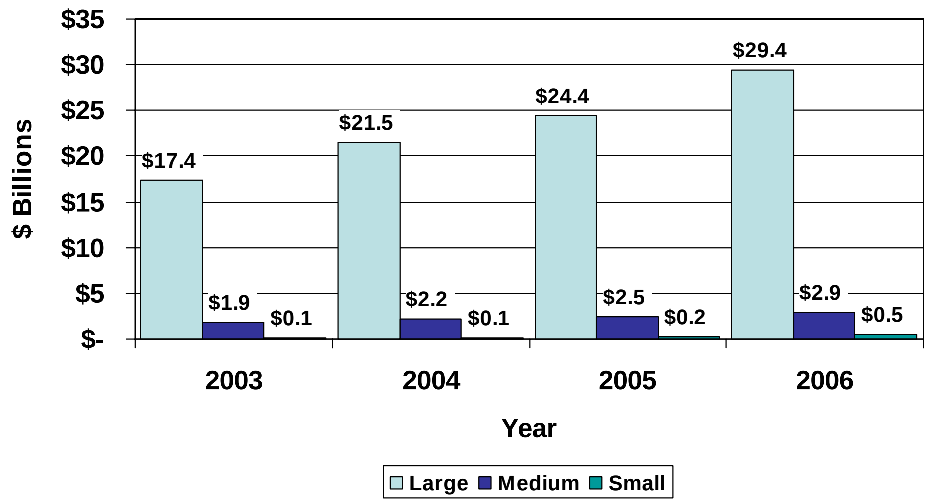
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Based on average net corporate sales from 2003 – 2006, large-size fabless companies reported $92.6 billion in net sales over the four-year period, accounting for 90 percent of total fabless net sales. Their net sales increased from $17 billion in 2003 to $29 billion in 2006, with an average percent change per year of 19.2 percent (see Figure XII-6).

Making up nine percent of total design net sales, medium-size fabless companies totalled $9.6 billion from 2003 to 2006. Their net sales increased at a slightly slower pace than large-size design companies, increasing from 1.9 billion in 2003 to $3 billion in 2006 with an average percent change per year of 16 percent.

Small-size fabless companies registered just one percent of total design sales, totalling $912 million in net sales over the four-year period. This group, however, grew at the fastest pace with an average increase of 80 percent, rising from $82.6 million in 2003 to $469 million in 2006.

Figure XII-6: Fabless Net Sales



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

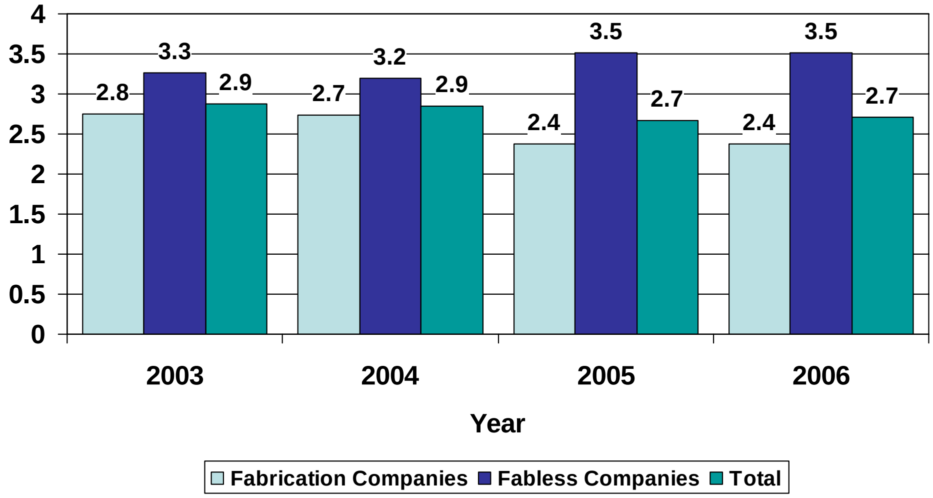
CURRENT RATIO

To gain insight into the competitive position of U.S. IC fabricators and fabless companies, OTE used a standard business measure, the *current ratio.* It measures the ability of a company to pay its debts with its existing resources over the next twelve months.[57] A ratio score of 2.0 or above is generally considered to be acceptable, because it means a company's assets are double its liabilities.

For perspective on financial performance relative to peers, individual company scores were weighed against the overall industry current ratio. As a group, fabrication and fabless companies had a combined average current ratio of 2.77 for the four-year period. The current ratio score during the period slipped from 2.88 in 2003 to 2.71 in 2006 (see Figure XII-7).

[57] The current ratio is calculated by dividing current assets by current liabilities.

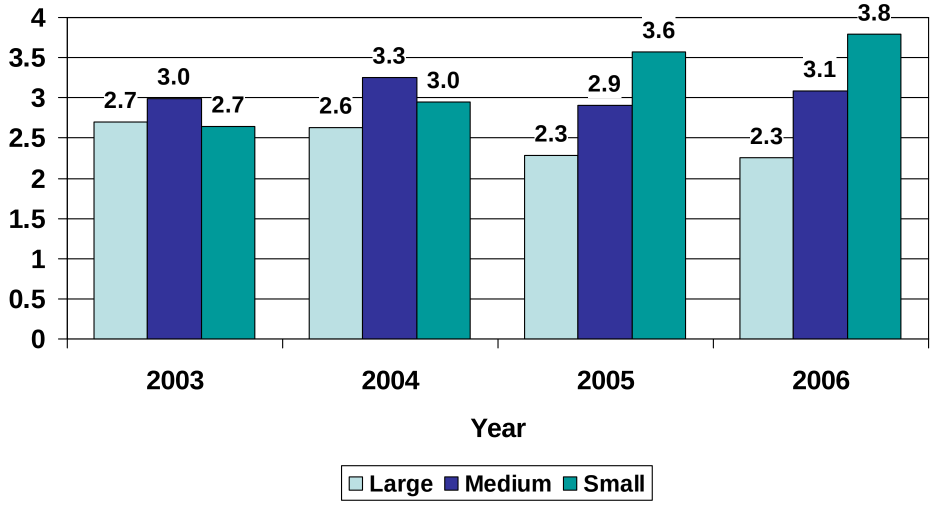
Figure XII-7: Current Ratio



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

For fabrication companies as a group, the current ratio declined from 2.75 in 2003 to 2.38 in 2006. This decrease is attributed largely to sliding financial performance in some large-size IC fabrication companies, which caused their collective current ratio to fall from 2.7 in 2003 to 2.25 in 2006 (see Figure XII-8). In contrast, both medium- and small-size IC fabrication companies saw current ratios scores improve for their respective groups.

Figure XII-8: Fabrication Companies' Current Ratio – By Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

A review of the financial information provided by nine individual large-size fabricators showed that three companies experienced decreases in current ratio scores from 2003 to 2006, indicating either an increase in debt or a decrease in assets. One large-size company posted an average current ratio below 2.0 for each of the four years, but improved its current ratio score over reporting period. Three large-size companies' financial performance produced current ratios that hovered between 2.0 and 3.0 over the four years; one of these companies experienced a net decrease in its ratio score for the reporting period.

Of the 17 medium-size IC fabricators providing adequate financial data, 10 companies scored three or higher for the 2003-2006 period. Seven fabricators, however, saw current ratios fall between 2003 and 2006. Five medium-size companies' current ratios averaged between 2.0 and 3.0, with a decrease in current ratios occurring for two companies over the survey period. One medium-size company's average current ratio scored below 2.0 over the four-year period, but it improved its current ratio during this time.

Only seven small-size IC fabricators provided enough financial data to enable OTE to calculate current ratios. Three of these companies experienced decreases in their current ratios over the survey period. Three small-size companies had average current ratios below 2.0, but all managed to improve their scores over the four-year period. One small-size company's current ratio average floated between 2.0 and 3.0, but the score trended down between 2003 and 2006.

The financial performances of many fabless IC design companies appear stronger than those of IC fabricators when the average current ratios of the two industry segments are compared. Indeed, industry analysts note that fabrication companies have greater scale in terms of net sales and more capital assets that can be used to secure debt.[58] This is not an absolute measure of financial strength, however.

IC Design companies surveyed by OTE had an average current ratio for the four-year period of 3.37 (see Figure XII-7). The score is attributable to improvement in company financial performance, which lifted the average current ratios from 3.26 in 2003 to 3.51 in 2006. This improvement can be traced primarily to current ratios of large- and medium-size design companies. Small-size IC design companies as a group saw their score fall from 4.73 in 2003 to 2.7 in 2006 see Figure XII-9).

Of the 11 large-size IC design companies that reported sufficient financial information, six had current ratios over 3.0. Five other companies, however, saw current ratios decline from 2003 to 2006. Three of these companies scored average current ratios below 2.0, though only one experienced a decrease in its current ratio over the four-year period.

Among the 23 medium-size IC design companies providing adequate financial data, seven experienced decreases in their current ratios over the four-year period. Five companies had current ratios between 2.0 and 3.0, two of which saw current ratios fall from 2003 to 2006. Only two design companies scored average current ratios below 2.0, but scores improved for both of those firms over the survey period.

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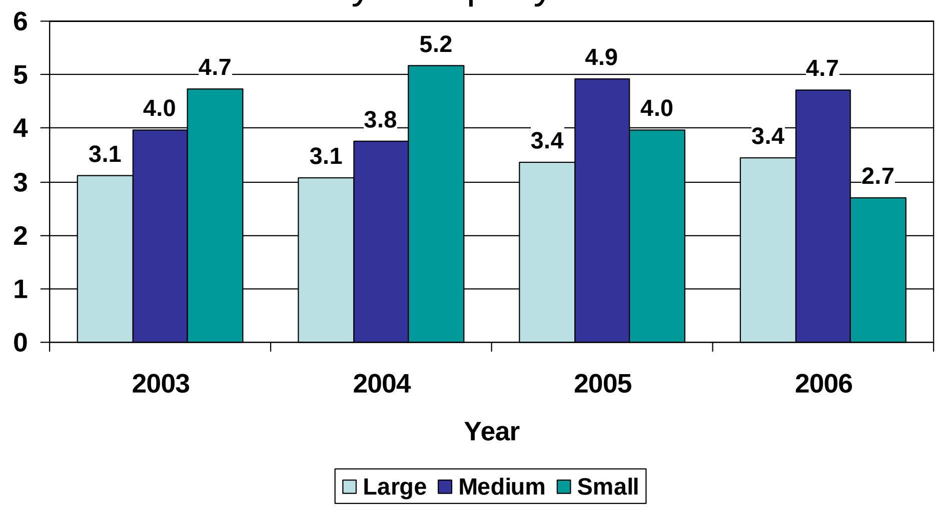
[58] Observations made to OTE in discussions with Robert Markunas, consultant, SoCit LLC; and Tristen Gerra, analyst, Robert W. Baird & Co., Inc., October 2008.

Thirty-five small-size IC design companies provided financial data sufficient for calculating current ratios. For 18 companies current ratios fell from 2003 to 2006. Six small-size companies had current ratios between 2.0 and 3.0, and two experienced decreases in their current ratios over the four-year period. Four companies had current ratios below 2.0, and only one saw improvement in its current ratio over the survey period.

Figure XII-9: Fabless Companies' Current Ratio - By Company Size



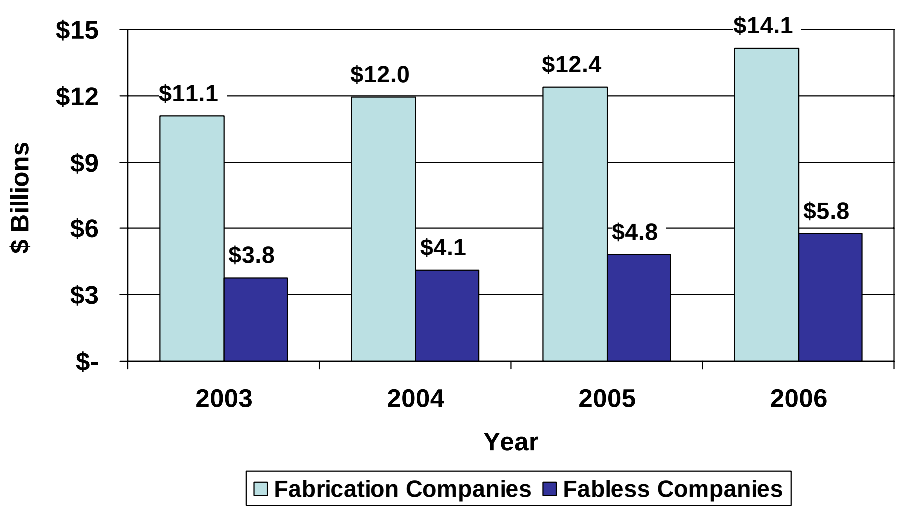
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

XIII. RESEARCH AND DEVELOPMENT AND RELATED EMPLOYMENT

Expenditures for research and development (R&D) have been a pivotal force propelling innovation and expansion in the semiconductor industry over the last four decades. With intensifying global competition, R&D spending remains critical to sustaining the competitiveness of U.S. designers and manufacturers of integrated circuit (IC) products.

From 2003 to 2006, IC fabrication and fabless companies allocated a total of $68 billion for R&D activities (see Figure XIII-1). These expenditures rose from $14.9 billion in 2003 to $19.9 billion in 2006, a 34 percent increase.[59]

Figure XIII-1: Total R&D Expenditures



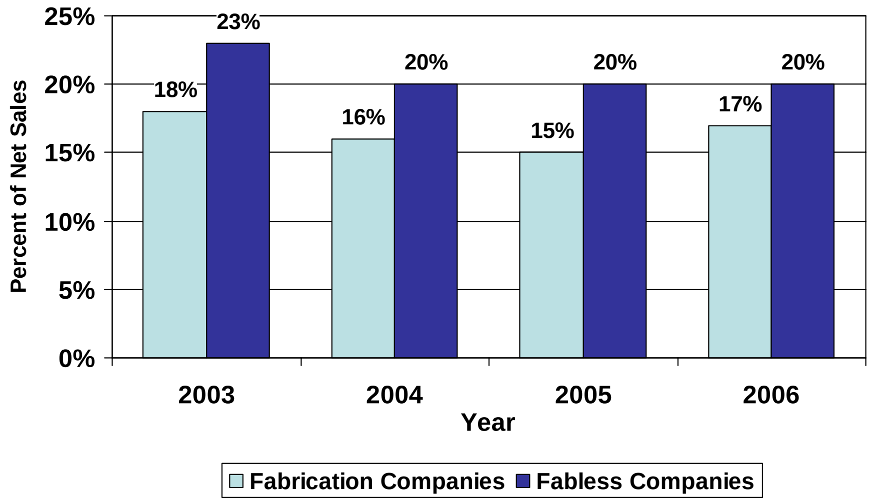
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

To better understand R&D spending by IC firms, expenditures were weighed against net sales figures.[60] R&D spending as a percent of net sales was relatively steady for fabrication companies, decreasing from a high of 18 percent in 2003 to a low of 15 percent in 2005, before

[59] 2003 data is based on 115 company responses; 2006 data is based on 133 company responses.
[60] Calculated by dividing company R&D expenditures by net sales figures.

rising again to 17 percent in 2006 (see Figure XII-2).[61] For fabless companies, R&D spending as a percent of net sales also remained relatively constant, averaging 23 percent in 2003 and then leveling off to 20 percent during each of the following three years.[62]

Figure XIII-2: R&D Spending as a Percent of Net Sales

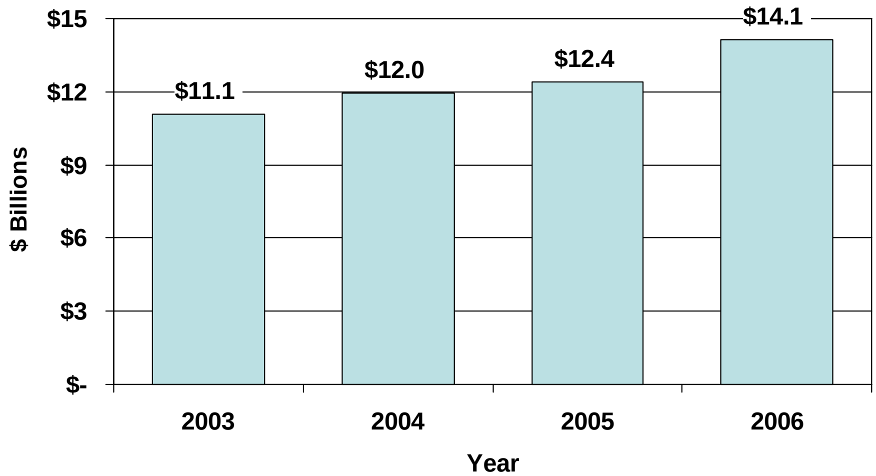


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

IC fabrication companies allotted $49.5 billion to R&D investment over the 2003- 2006 period (see Figure XIII-3). Fabrication R&D expenditures during this period rose from $11 billion to $14 billion, an increase of nearly 28 percent.[63] The top five fabrication firms were responsible for $38.4 billion, or 77 percent, of total IC fabrication company R&D expenditures. In 2006 alone, the top five fabrication firms spent $10.8 billion on R&D, 76 percent of the $14 billion total fabrication R&D expenditures.

[61] Data is based on 77 IC fabless company responses.
[62] Data is based on 40 IC fabrication company responses.
[63] The $14 billion figure is based on 41 IC Fabrication company responses in 2006.

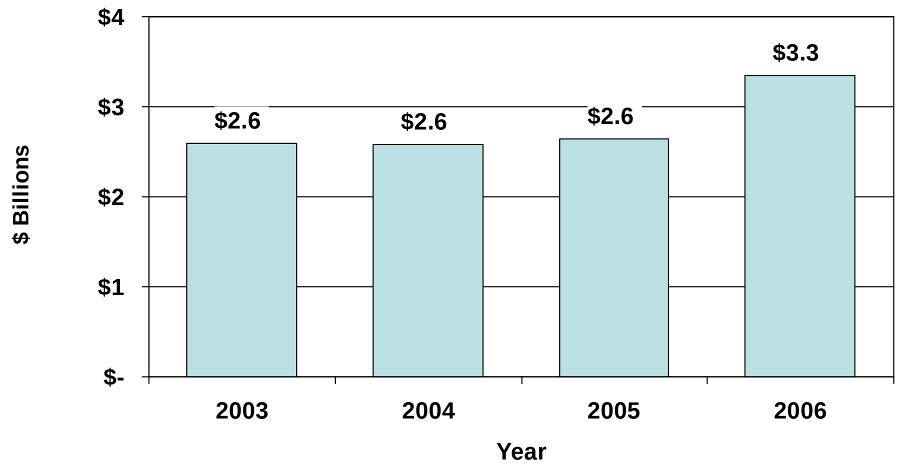
Figure XIII-3: Fabrication Companies' R&D Spending



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Absent the top five fabrication firms, the remaining companies spent $11.1 billion, 23 percent of total fabrication company R&D expenditures, between 2003 and 2006. R&D outlays by this segment of fabricators increased from $2.6 billion to $3.3 billion over the four-year period (see Figure XIII-4).

Figure XIII-4: Fabrication R&D Spending - Excluding Top 5 Companies

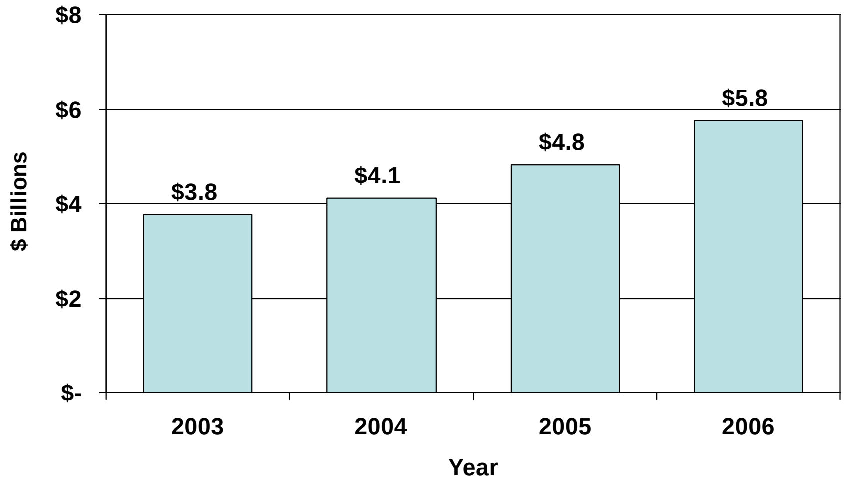


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

While smaller than fabrication investment, fabless R&D outlays increased steadily over the period, representing 29 percent of overall R&D expenditures. Spending rose from $3.8 billion in 2003 to $5.8 billion in 2006, an increase of more than 50 percent (see Figure XIII-5).[64]

[64] Based on 92 IC fabless company responses in 2006, 78 design company responses in 2003.

Figure XIII-5: Fabless Companies' R&D Spending



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

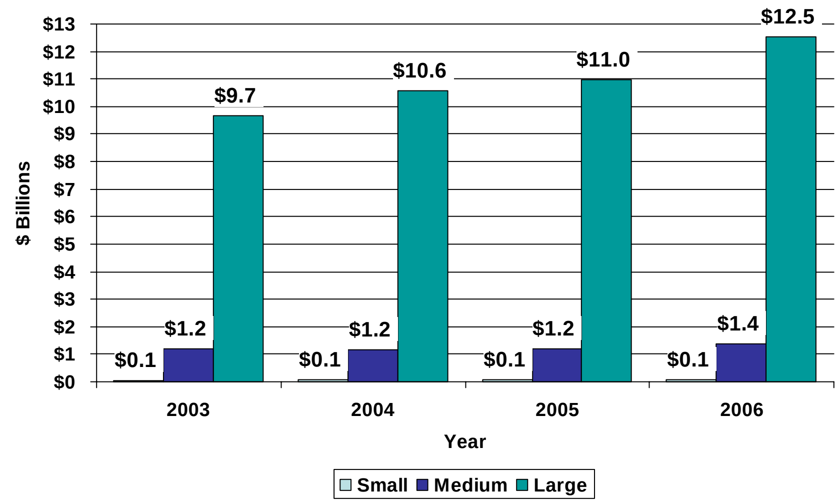
R&D EXPENDITURES BY COMPANY SIZE

An examination of R&D spending based on company size reveals differences in expenditure levels within as well as across fabless and fabrication sectors. To perform this analysis, IC companies were categorized as small-, medium-, and large-sized based on average net corporate sales from 2003-2006.

In terms of expenditures, the 10 large-size fabrication firms surveyed (net sales over $1 billion) accounted for the largest percentage of R&D spending (see Figure XIII-6).[65] They allocated $43.8 billion to R&D between 2003 and 2006. In 2006, their R&D expenditures reached $12.5 billion, 89 percent of all fabrication R&D spending.

[65] Number of fabrication respondents for 2006 data: Large (10); Medium (18); Small (12).

Figure XIII-6: Fabrication R&D Spending - By Company Size



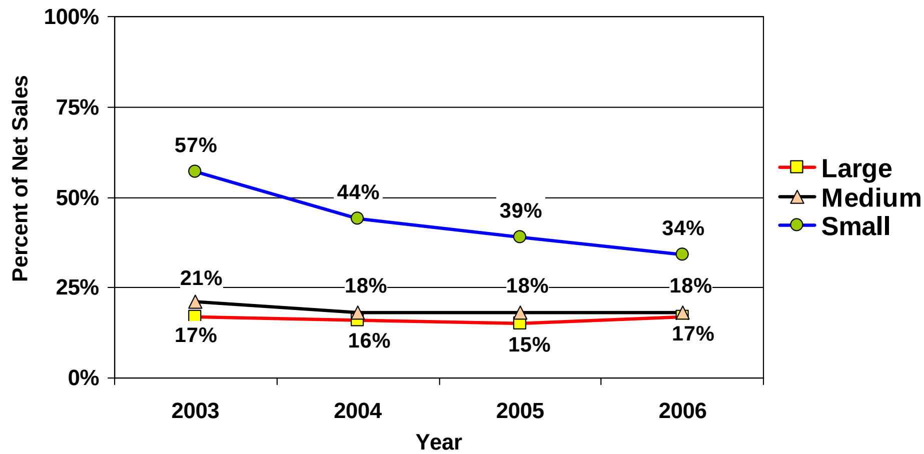
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Eighteen medium-size fabrication companies (net sales between $100 million and $1 billion) accounted for the second-largest percentage of R&D spending by fabricators. They allocated a total of $5 billion between 2003 and 2006. In 2006, their R&D expenditures reached $1.4 billion, 10 percent of all fabrication R&D spending.

The twelve small-size IC fabrication firms (net sales below $100 million) accounted for the smallest percentage of R&D spending. They allocated $254 million to R&D between 2003 and 2006. In 2006, their R&D expenditures totaled $77 million, one percent of all fabrication R&D spending.

As a percent of net sales, R&D investment reported by the small-size fabrication companies is noticeably higher than that for medium- and large-size companies (see Figure XIII-7). In 2003, small-size fabrication companies spent 57 percent of net sales on R&D, compared to 21 percent by medium-size and 17 percent by large-size companies. By 2006, fabrication R&D spending by small-size companies diminished to 34 percent of net sales compared to an 18 percent decrease by medium-size fabrication companies and a 17 percent decrease by large-size companies.

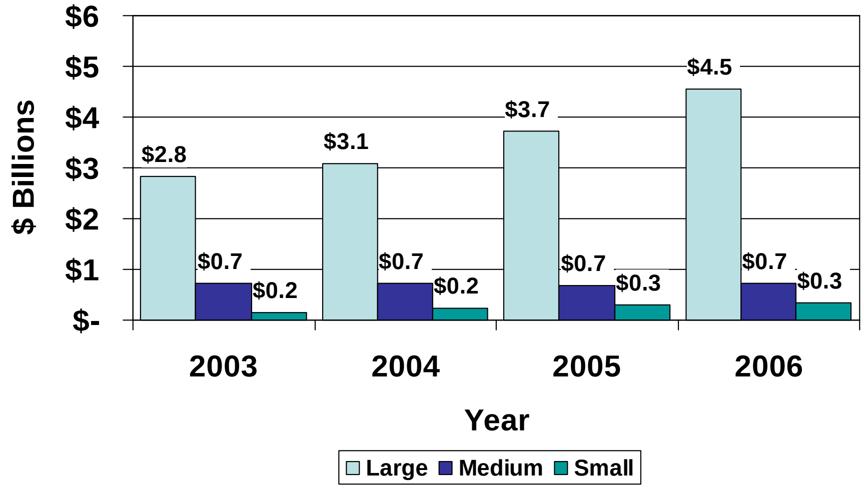
Figure XIII-7: Fabrication R&D Spending as a Percent of Net Sales - By Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

R&D expenditures for fabless firms followed similar patterns to those of fabrication firms. In terms of expenditures, the 10 large-size fabless firms (net sales over $350 million) accounted for the largest percentage of R&D spending. They allocated a total of $14.2 billion between 2003 and 2006 (see Figure XIII-8). In 2006, their spending reached $4.5 billion, 79 percent of total fabless R&D spending.

Figure XIII-8: Fabless R&D Spending - By Company Size



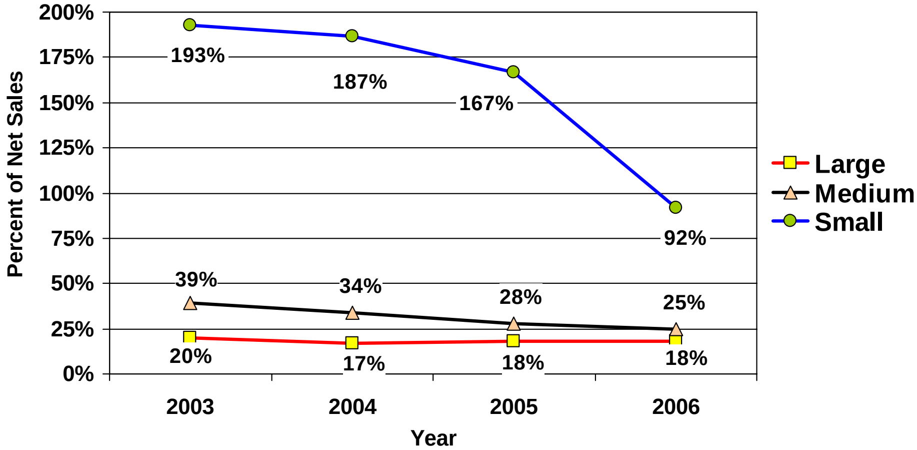
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Medium-size fabless companies (net sales between $25 million and $350 million) accounted for the second-largest percentage of R&D spending. They allocated $2.9 billion to R&D between 2003 and 2006. In 2006, their R&D expenditures reached $733 million, 12.7 percent of all design R&D spending.

Small-size fabless firms (net sales below $25 million) accounted for the smallest percentage of industry R&D spending. They allocated $1 billion to R&D over the 2003-2006 period. In 2006, their R&D expenditures reached $335 million, 5.8 percent of all design R&D spending.

R&D spending patterns for fabless companies are reversed when examined as a percent of net sales (see Figure XIII-9). Small-size fabless companies have a notably higher ratio of R&D spending as a percent of net sales, starting at a high of 193 percent in 2003. That figure receded in the following three years, but still stood at 92 percent in 2006. Twenty-four survey respondents reported R&D spending that exceeded net sales. These companies posted just under $32 million in net sales in 2006, yet allocated over $182 million to R&D - 570 percent of net sales.

Figure XIII-9: Fabless R&D Spending as a Percent of Net Sales - By Company Size



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

R&D spending as a percent of net sales decreased over the survey period for both medium-size and large-size fabless companies. Average company R&D investment by medium-size fabless companies as a percent of net sales declined from 39 percent in 2003 to 25 percent in 2006. Large-size fabless companies also experienced a decline, although to a lesser extent, as R&D spending as a percent of net sales fell from 20 percent in 2003 to 18 percent in 2006.

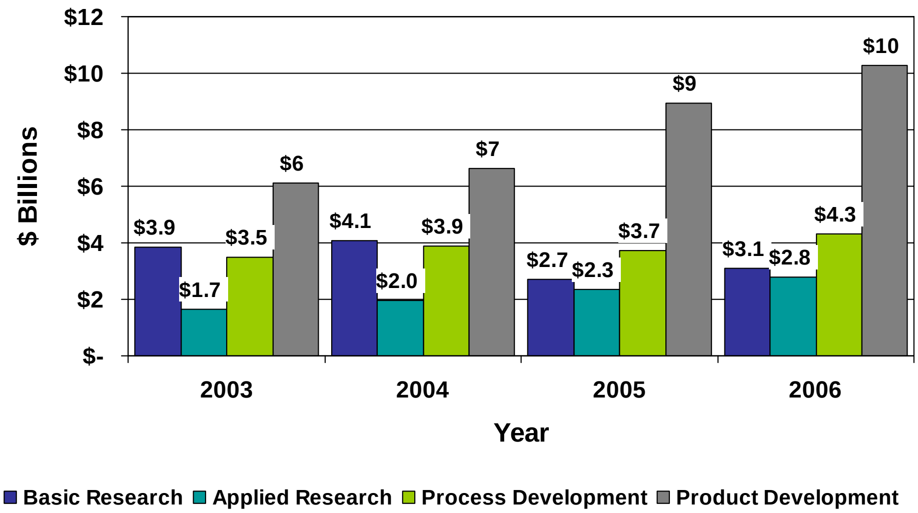
R&D EXPENDITURES BY FUNCTION

Survey participants provided a detailed breakout of R&D spending for the four-year period by the following categories: basic research, applied research, process development, and product development.[66]

Fabrication and fabless companies allocated almost half of their R&D investments from 2003 to 2006 to product development (see figure XIII-10). For the four-year period, R&D spending totaled $68 billion, $30 billion of which was dedicated to product development.

[66] For definitions of these terms, see Appendix C.

Figure XIII-10: Total R&D Spending by Function



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

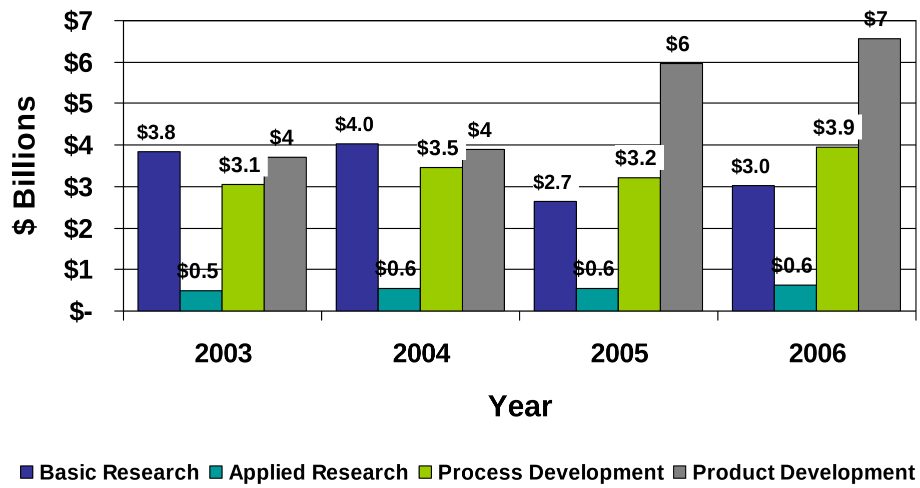
For 2006, overall fabrication and fabless company R&D expenditures by category were:

- Basic research – $3 billion (15 percent);
- Applied research – $2.8 billion (14 percent);
- Process development – $4.3 billion (22 percent);
- Product development – $9.7 billion (49 percent).[67]

In 2006, fabrication companies dedicated $6.6 billion - 49 percent of total R&D expenditures - to product development (see Figure XIII-11). Over the four-year period, product development funding rose 77 percent. The 2006 figures for the other functions were: process development, $3.9 billion; basic research, $3 billion; and applied research, $615 million.

[67] Percentages are based on total fabrication and fabless company R&D expenditures.

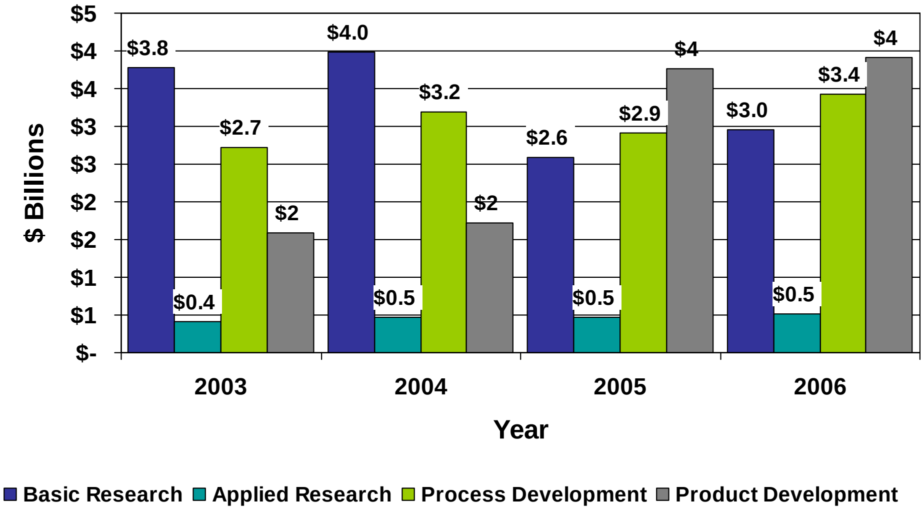
Figure XIII-11: Fabrication R&D Spending by Function



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

For the top five fabrication companies, expenditures on the various functions were fairly evenly distributed: product development, $3.9 billion (36 percent); process development, $3.4 billion (32 percent); and basic research, $3 billion (27 percent) (see Figure XIII-12). The exception to this was applied research, which received $514 million (almost five percent) of fabricator R&D funding. Over the period, however, the focus of spending shifted from basic research to product development. In 2003, the top five fabricators allocated 45 percent of expenditures to basic research and 19 percent to product development. These five companies changed tack in 2006, allotting 27 percent to basic research and 32 percent to product development.

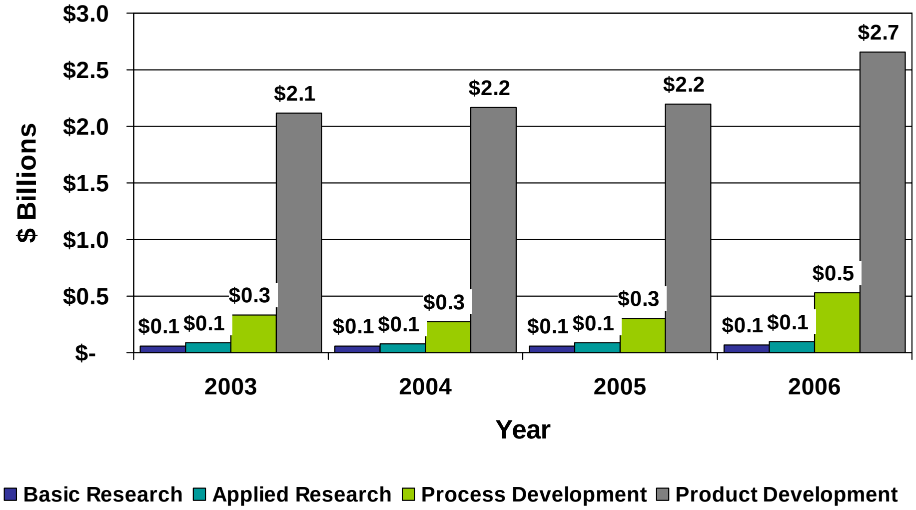
Figure XIII-12: R&D Spending by Function – Top 5 Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

The focus of spending shifts when the top five fabrication companies are excluded from the break-out of R&D expenditures by function (see Figure XIII-13). Of the $3.3 billion spent by the remaining fabrication companies on R&D in 2006, $2.7 billion, or 79 percent, was spent on product development. These fabrication companies spent $67 million, or 2 percent of their total R&D expenditures, on basic research. This is a sharp contrast to the 21 percent of R&D funds allocated to basic research when R&D priorities of the top five fabrication companies are considered.

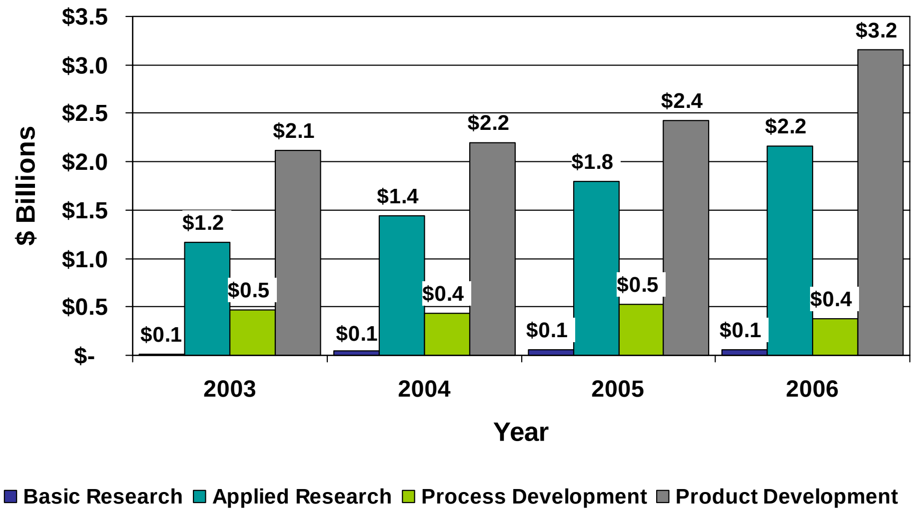
Figure XIII-13: R&D Spending by Function – Excluding the Top 5 Companies



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

In contrast to fabrication companies, fabless companies dedicated a larger portion of funds to applied research. In 2006, fabless companies spent $2.2 billion, or 38 percent of their total R&D expenditures on applied research, as compared to the eight percent spent by fabrication companies (see Figure XIII-14).

Figure XIII-14: Fableless R&D Spending by Function



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Much like their fabrication counterparts, however, fabless companies also invested aggressively in product development. In 2006, fabless companies allocated $3.1 billion (55 percent) to this function – a nearly 50 percent increase from 2003. Process development and basic research received lower levels of funding in 2006: $376 million and $58 million, respectively.

SOURCES OF R&D FUNDING

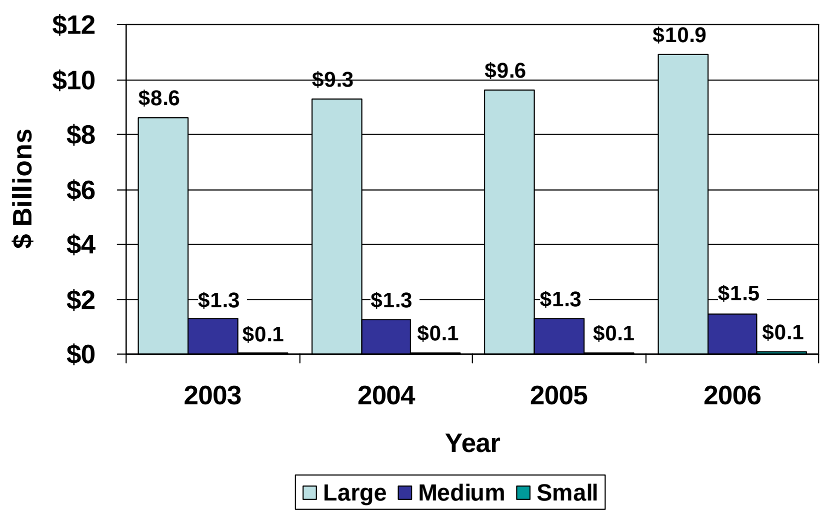
IC fabrication and design companies reported sources of R&D funding derived from five separate categories for the 2003-2006 period: parent company/internal sources, U.S. private entity, foreign investors, federal government, and state and local government. Ninety-eight percent of R&D funds are attributable to parent companies/internal sources.

The sources of R&D funding in 2006 for all companies break down as follows:

- Parent company ($17.6 billion, 95 percent)
- U.S. private entity ($425 million, 2.3 percent)
- Foreign investors ($358 million, 1.9 percent)
- Federal government ($63 million, 0.36 percent)
- Local government ($78 million, 0.44 percent)

Internal R&D funding at fabrication companies rose 25 percent from $10 billion in 2003 to $12.4 billion in 2006 (see Figure XII-15). Ten large-size companies obtained nearly $11 billion (88 percent) of this funding from internal funding. In comparison, medium-size fabrication companies secured only $1.5 billion (12 percent) of R&D funds from internal sources, while small-size fabrication companies attributed just $28.3 million (or less than one percent) to internal funding.

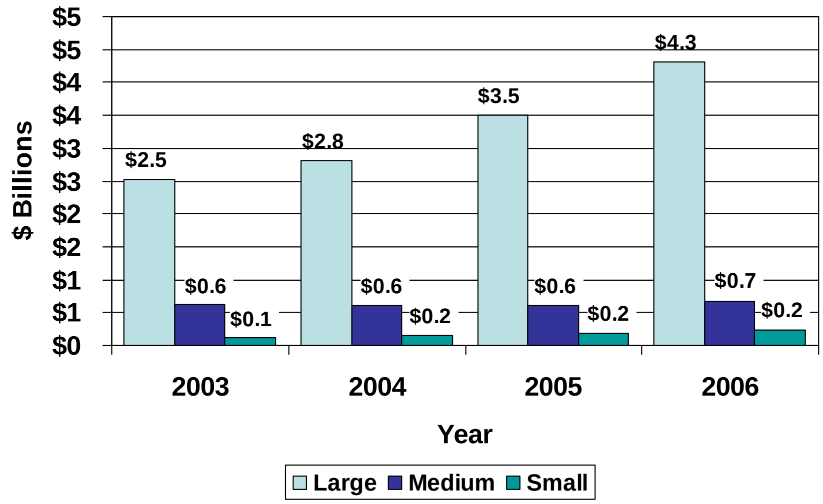
Figure XIII-15: Fabrication R&D Internal Funding



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Fabless companies also showed growth in internal R&D funding, reporting a 61 percent gain from $3.2 billion in 2003 to $5.2 billion in 2006 (see Figure XIII-16). As with the large-size IC fabrication companies, most of the internal R&D funding of fabless companies can be attributed to 10 large-size companies, which accounted for $4.3 billion, or 83 percent of funding, in 2006.

Figure XIII-16: Fabless R&D Internal Funding

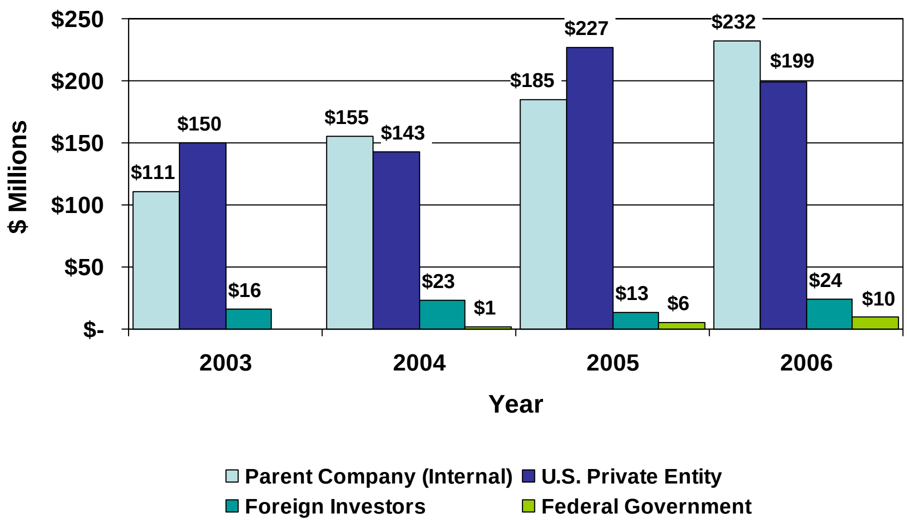


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Internal funding of R&D was sharply lower for the medium-size fabless companies at roughly $669 million in 2006 (13 percent). The small-size fabless companies reported internal R&D funding of $232 million in 2006 (4 percent).

Small-size fabless companies stand out relative to medium- and large-size counterparts in the proportion of U.S. private entity funding relative to other sources (see Figure XIII-17). In 2006, U.S. private entity funding for small-size fabless companies totaled $199.2 million, 43 percent of their total R&D funding. In comparison, medium-size fabless companies reported just $21.6 million in U.S. private entity R&D funding, three percent of their R&D funding. Large-size companies received no funds from U.S. private entities.

Figure XIII-17: Sources of R&D Funds – Small Fabless Firms



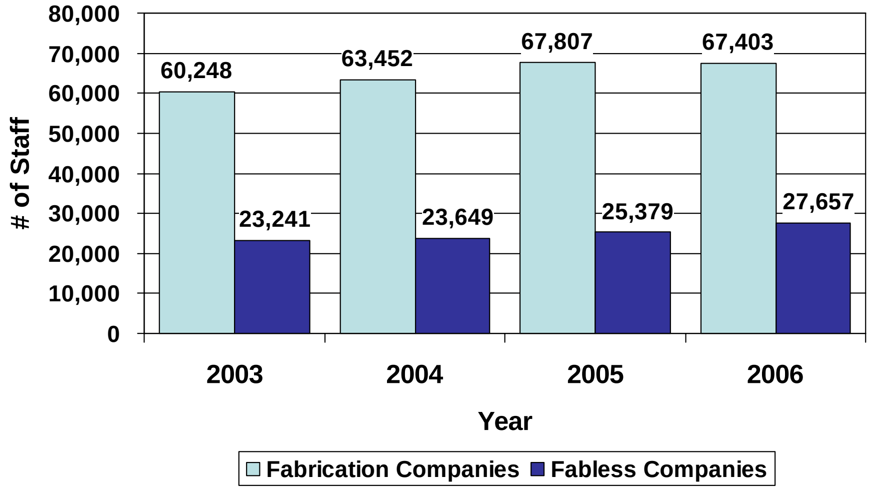
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

R&D EMPLOYMENT

R&D-related employment for fabrication and fabless firms over the 2003-2006 period mirrored the growth in R&D expenditures (see Figure XIII-18). Survey participants indicated total R&D employment rose 14 percent, from just over 83,000 in 2003 to 95,000 in 2006.[68]

[68] Figures based on responses from 107 companies – 73 designers and 34 fabricators.

Figure XIII-18: R&D Employment

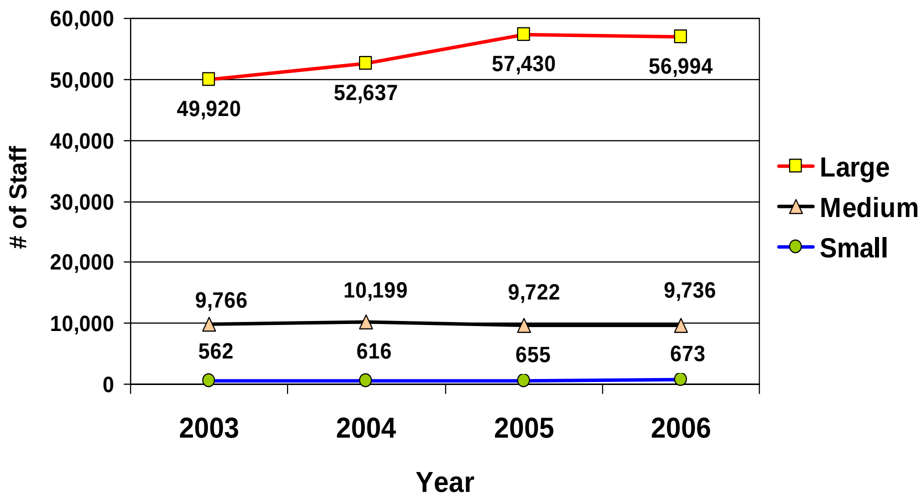


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Fabrication companies are the largest R&D employers in the industry, accounting for over 70 percent of total R&D employment in 2006. Overall, R&D employment for IC fabrication companies grew 12 percent during the 2003-2006 period, from approximately 60,000 to more than 67,000 (see Figure XIII-18).

A substantial portion of R&D employment in 2006 - nearly 51,000, or 75 percent - was concentrated in the top five IC fabrication companies. The remaining large-size companies employ another 10 percent of R&D personnel, medium-size companies 14 percent, and small-size companies accounted for only one percent (see Figure XIII-19).

Figure XIII-19: Fabrication R&D Employment – By Company Size

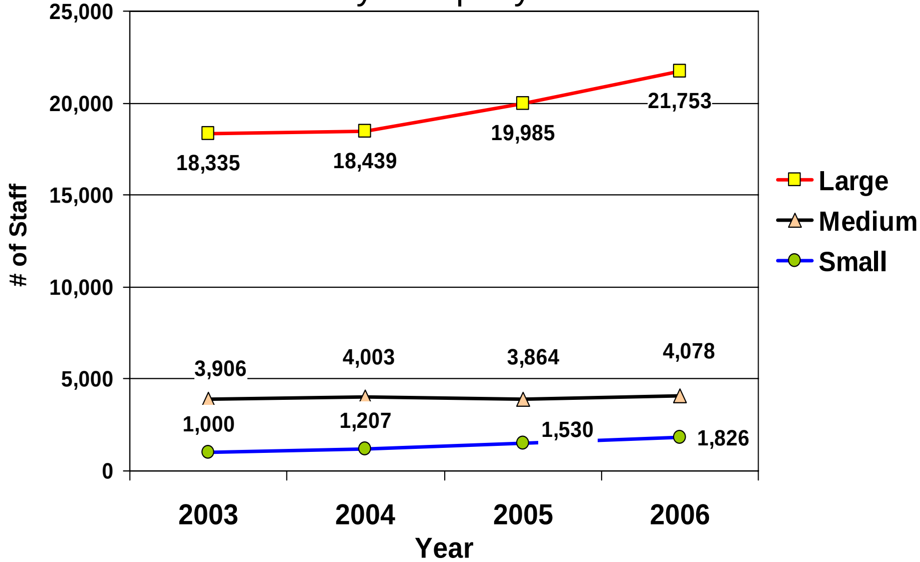


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

As with fabrication companies, R&D employment for fabless companies also grew from 2003 to 2006. Overall, R&D employment for this industry segment rose 19 percent from approximately 23,000 to more than 27,000 (see Figure XIII-18).

The vast majority of fabless R&D staff is employed by large-size companies. In 2006, these companies employed 79 percent of R&D staff (see Figure XIII-20). Medium- and small-size fabless companies employed 15 percent and six percent, respectively. Small-size fabless companies experienced the most growth, expanding their employment by approximately 83 percent during the 2003-2006 period.

Figure XIII-20: Fabless R&D Employment – By Company Size



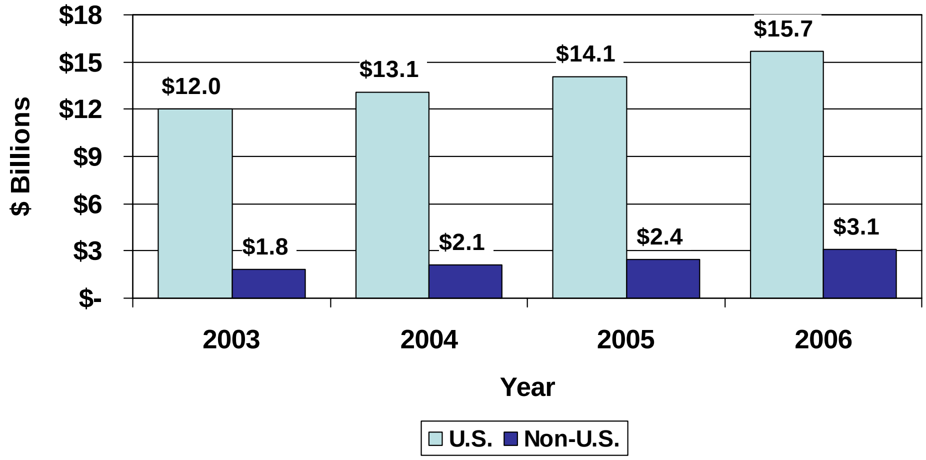
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

TOP COUNTRIES FOR R&D EXPENDITURES

In addition to conducting R&D in the United States, fabrication and fabless companies rely on research organizations in other countries to perform this work. OTE asked companies to identify the top five countries, based on total expenditures, where they fund R&D projects. Thirty countries were identified for 2006.

The United States was cited as the prime location for IC fabrication and fabless R&D spending. Some $15.7 billion in R&D activities in 2006 were conducted in the U.S., roughly 84 percent of total R&D expenditures (see Figure XIII-21). This domestic investment expanded by more than $3 billion during the 2003-2006 period, maintaining an average annual growth rate of nine percent.

Figure XIII-21: Total R&D Expenditures



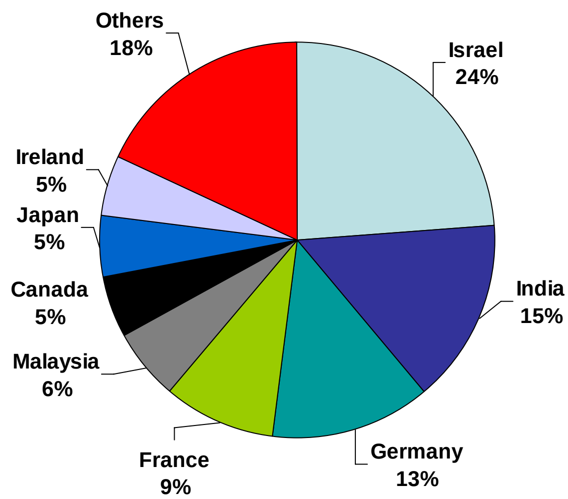
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Non-U.S. countries were recipients of a little more than $3 billion, or 19 percent of total R&D investment. While significantly lower than domestic expenditures, non-U.S. R&D investment grew at an average annual rate of nearly 19 percent over the 2003-2006 period.

In 2006, non-U.S. expenditures were concentrated in five countries: Israel ($728 million); India ($464 million); Germany ($386 million); France ($270 million); and Malaysia ($190 million).[69] Among the five, investment into India exhibited the most growth, as companies increased expenditures there annually at an average rate of approximately 47 percent (see Figure XIII-22).

[69] **Others:** Australia, Hong Kong, Thailand, United Kingdom, Italy, Switzerland, Finland, Netherlands, Sweden, Czech Republic, Denmark, Romania, Norway, Russia, Turkey, Latvia, Poland, Spain, and Egypt.

Figure XIII-22: Top Countries for Non-U.S. R&D Investment - 2006



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

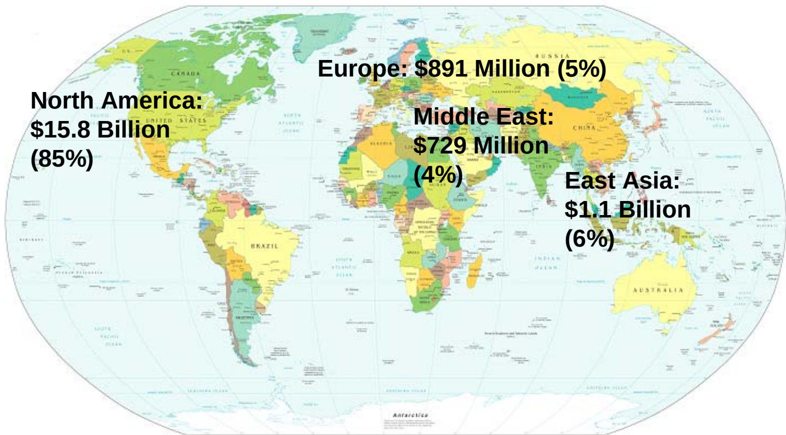
Fabrication companies disclosed making R&D investments of $2.19 billion in 2006 in numerous countries, 70 percent of all non-U.S. R&D spending by fabrication and fabless companies. The five leading countries receiving R&D investments from U.S. fabrication companies were Israel, India, France, Germany, and Malaysia.

Fabless companies reported $880 million in R&D investments in 2006, 30 percent of all non-U.S. R&D investments. The five primary recipient countries were Germany, Canada, India, Israel, and the United Kingdom.

When segmented by region, the majority of R&D investment is directed to North America, given the large sums of R&D funds spent in the United States (see Figure XIII-23). Total R&D funding for the region in 2006 nearly exceeded $15 billion, or 85 percent of total R&D expenditure. [70]

[70] **North America**: United States and Canada; **East Asia**: India, Malaysia, Japan, China, Singapore, Korea, Taiwan, Australia, Hong Kong, and Thailand; **Europe**: Germany, France, United Kingdom, Ireland, Italy, Belgium, Switzerland, Finland, Netherlands, Sweden, Czech Republic, Denmark, Romania, Norway, Russia, Turkey, Latvia, and Spain; **Middle East**: Israel and Egypt.

Figure XIII-23: R&D Expenditure by Region – 2006



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

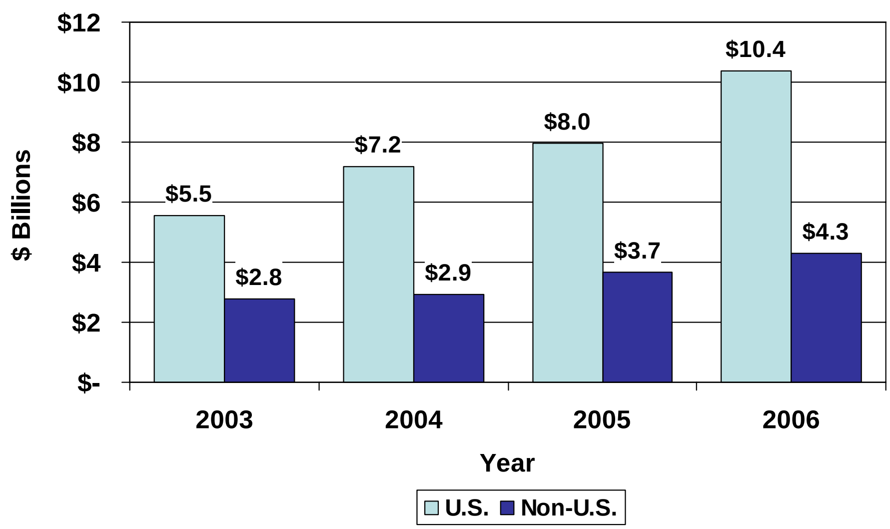
Fabrication and fabless companies reported that East Asia, led by India and Malaysia, received the second largest amount at $1.1 billion, or almost six percent of total R&D spending in 2006. Although investment in all regions grew during the 2003-2006 period, companies increasingly directed R&D funds toward East Asia, resulting in the highest average annual growth rate of 26 percent. In terms of 2006 R&D investment, East Asia was followed by Europe with $891 million, or five percent of total expenditures, and the Middle East with $729 million, or four percent.

XIV. Capital Expenditures

Investment levels of integrated circuit (IC) fabrication and fabless companies in equipment, modernization, and new facilities provide insights with respect to their competitiveness, economic health, and long-term performance. Information on fabrication and fabless company capital expenditures in the United States and in non-U.S. locations was collected and analyzed by OTE for 2003-2006.

Total capital spending by fabrication and fabless companies operating in the United States rose from $8.3 billion in 2003 to $14.7 billion in 2006 – a 76 percent increase. The vast majority of these capital outlays, 71 percent, supported business activity occurring in the United States.[71] In 2006, IC fabrication and fabless companies made $10.4 billion in capital expenditures in the United States and another $4.3 billion in non-U.S. locations (see Figure XIV-1).

Figure XIV-1: Total Capital Expenditures



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

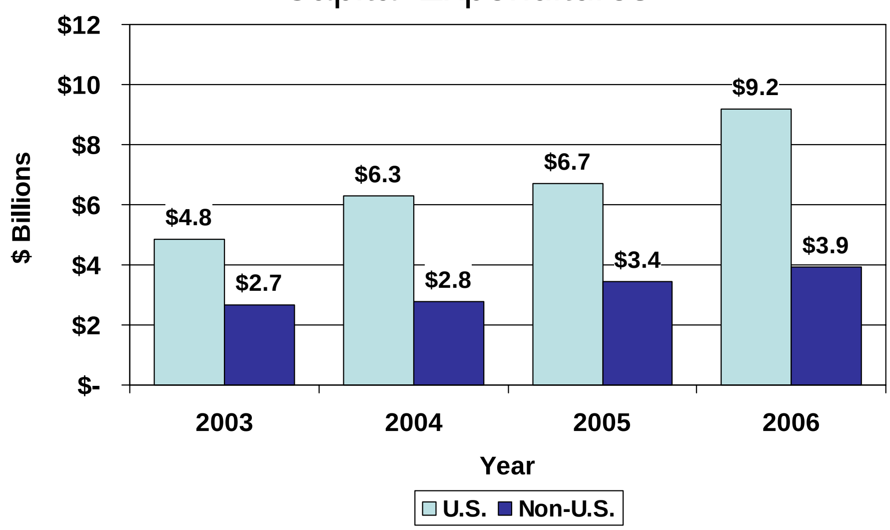
[71] This figure is from 2006 and is based on 132 company responses.

CAPITAL EXPENDITURES BY FABRICATION COMPANIES

Capital spending by fabrication companies increased steadily for the 2003-2006 period, rising 75 percent from $7.5 billion to just over $13 billion. Outlays by fabricators in 2006 constituted 89 percent of all capital expenditures by fabrication and fabless companies.

Fabricators' capital spending also expanded as a percent of net sales during the 2003-2006 period, climbing from 12 percent in 2003 to 16 percent in 2006. Roughly 70 percent ($9.2 billion) of this spending in 2006 went to improve capabilities in U.S. facilities. The balance, $3.9 billion, was used in capital investment in non-U.S. locations (see Figure XIV-2).[72]

Figure XIV-2: Fabrication Companies' Capital Expenditures

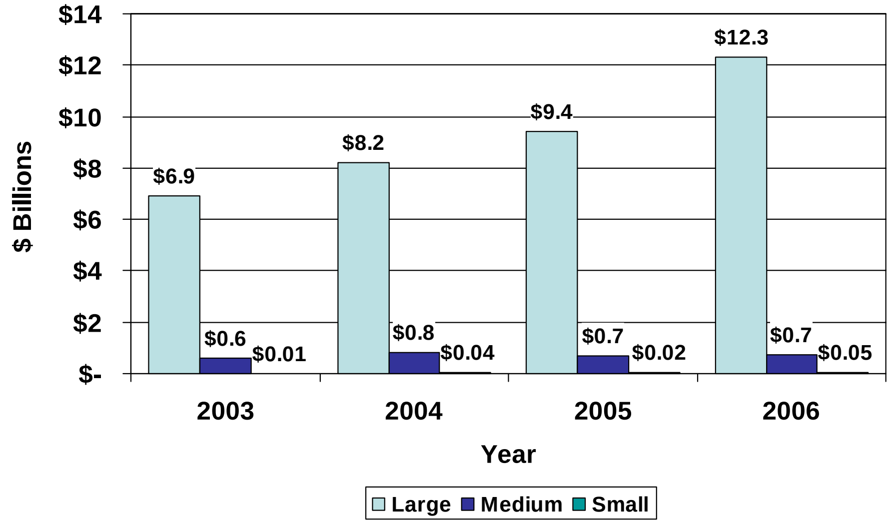


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Most of the capital spending reported by survey participants is attributable to large-size fabricators (see Figure XIV-3). These companies expended $12.3 billion of the $13 billion of total capital expenditures reported. The outlays of the top five large-size fabricators accounted for 87 percent of capital expenditures in 2006 ($11.3 billion), 69 percent of which ($7.8 billion) went to enhancing capabilities in the United States.

[72] This figure is based on 37 IC fabrication company responses.

Figure XIV-3: Fabrication Companies' Capital Expenditures



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

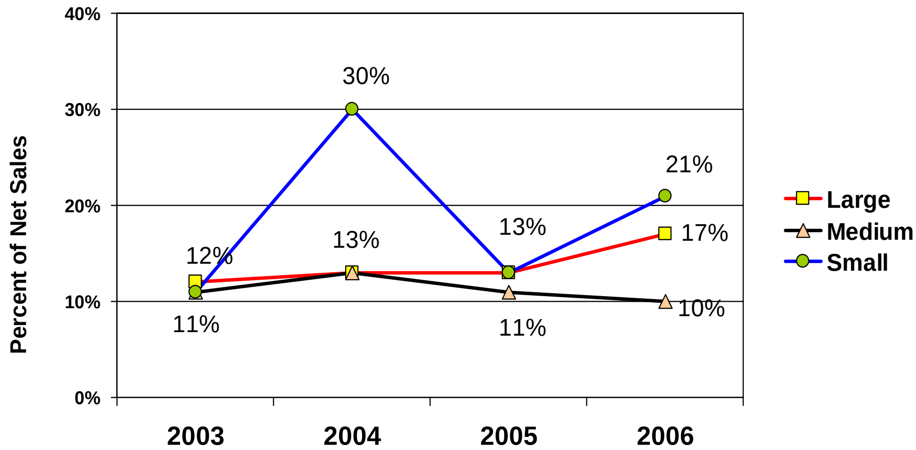
Capital expenditures for medium-size fabricators were uneven over the 2003-period. Their outlays peaked at $808 million in 2004 after rising from $594 million a year earlier.[73] Investment declined to $684 million in 2005 before rebounding to $723 million in 2006. Capital outlays in 2006 by medium-size companies represented just 5.5 percent of total capital investment by fabrication companies. Seventy-two percent of medium-size companies' 2006 capital expenditures, more than $517 million, went to enhancing domestic capability.

Capital investment by small-size fabrication companies advanced significantly in the 2003-2006 period, climbing from $10.3 million to $47 million. This spending represented less than one percent of total capital investment by fabrication companies. All of this investment went to improve company capabilities in the United States.

Capital expenditures by large-size companies as a percent of net sales were less than that for medium- and small-size companies. In 2006, large-size companies allocated 10 percent of net sales to capital expenditures compared to 17 percent for medium-size companies, and 21 percent for small-size companies (see Figure XIV-4).

[73] Medium-size companies totaled 18.

Figure XIV-4: Fabrication Companies' Capital Expenditures - By Company Size

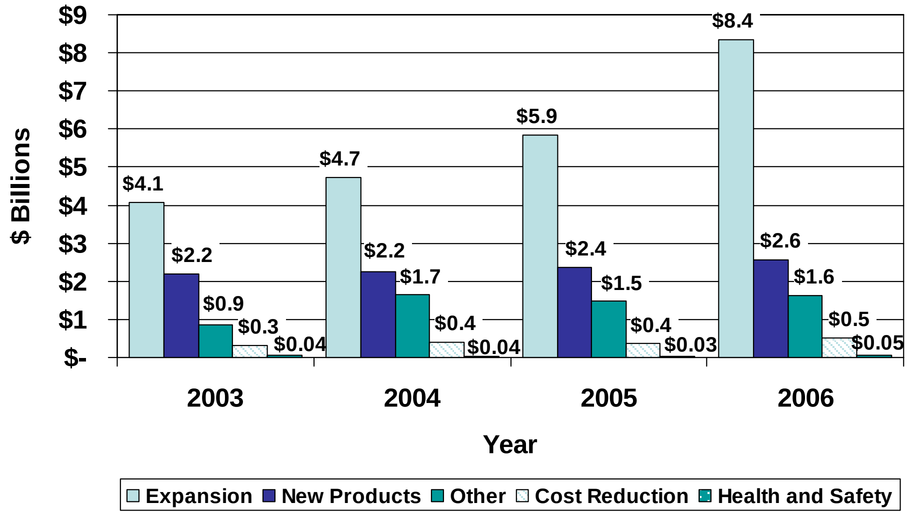


Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

ALLOCATION OF CAPITAL EXPENDITURES BY FABRICATION COMPANIES

OTE survey participants were asked to specify capital investments for expansion of existing production lines, new products, cost reduction, and health and safety. In 2006, fabrication companies allocated 64 percent of capital expenditures to the expansion and improvement of existing production lines. Overall investment in this function was just over $4 billion in 2003, a figure that more than doubled to nearly $8.4 billion in 2006 (see Figure XIV-5).

Figure XIV-5: Fabrication Companies' Allocation of Capital Expenditures



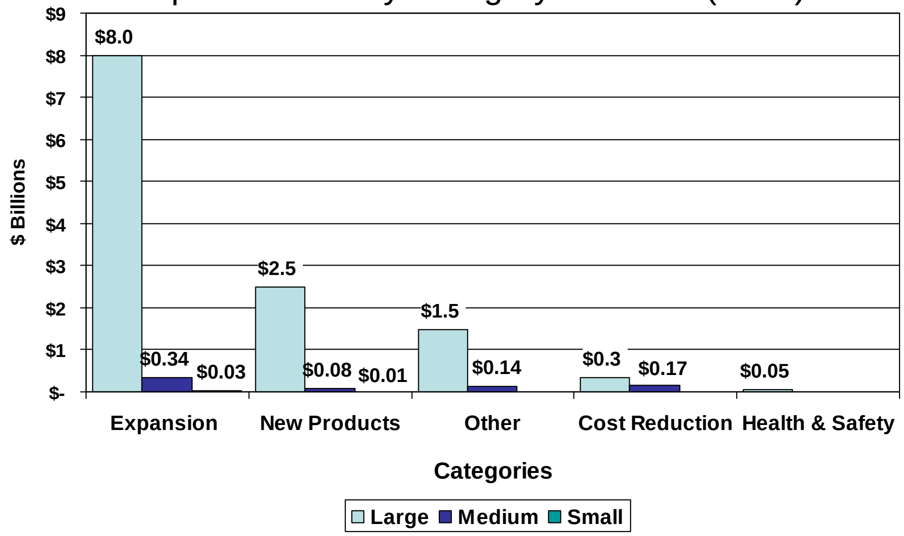
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Spending on other functions by fabrication companies was more diffuse in 2006:

- New Products - $2.6 billion (19.6 percent)
- Other - $1.6 billion (12 percent)
- Cost Reduction - $506 million (4 percent)
- Health and Safety - $52 million (0.4 percent)

Of the $12.3 billion spent in 2006 on capital expenditures by large-size fabrication companies, $8 billion was used to expand production capabilities (see Figure XIV-6). Sixty-four percent of the $8 billion ($5.15 billion) went to enhancing capability in the United States, while the remaining $2.85 billion was allocated to non-U.S. locations.

Figure XIV-6: Fabrication Companies' Capital Expenditures - by Category and Size (2006)



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Expansion of production capability was also a priority for medium-size fabricators, who spent $723 million on capital expenditures in 2006. That year, the companies devoted $336 million, or 46 percent of total capital expenditures, to this task. Two-thirds of these funds ($228.7 million) were allocated to enhancing production capability in the United States and the remaining third ($107.3 million) went toward non-U.S. capability.

Small-size companies also focused largely on the expansion of production capability. Of the $47 million these companies spent on capital expenditures in 2006, 64 percent ($32.6 million) was spent on production expansion, all of it for activity taking place within the United States.

New product development was the second largest area of capital expenditure for large-size companies. Of the $12.3 billion spent by these companies in 2006, 20 percent ($2.48 billion) went to bolster new product development. Ninety-six percent of these funds were allocated to U.S. operations.

Medium-size companies differed in their remaining priorities in 2006. They allocated 11 percent of total capital expenditures ($77.5 million) to new product development, of which $76 million (96 percent) went to U.S. operations. In the case of small-size fabricators, new product development was the second investment priority. These companies dedicated 28 percent of total 2006 capital expenditures ($13 million) to product development.

Cost reduction is a constant challenge for all IC fabricators in a world where continuing improvement is necessary for remaining competitive. Large-size companies allocated just three percent of capital expenditures ($339 million) for cost reduction activities in 2006, and 87 percent of those funds went to activities in the United States. In sharp contrast, medium-size companies expended $166 million for this activity in 2006, 23 percent of their total capital spending. Small-size fabricators spent $1 million on cost reduction activities in 2006, just two percent of their total capital expenditures.

Twelve percent of all fabrication company capital expenditures in 2006 ($1.6 billion) went toward other programs in 2006, including activities such as general administration or building maintenance. Fifty-one percent of this spending was for activity in the United States, with the balance going to non-U.S. locations. Of the $1.6 billion, 91 percent of these expenditures were made by large-size companies, while medium-size fabricators accounted for nearly nine percent.

Non-U.S. Capital Expenditures by Fabrication Companies

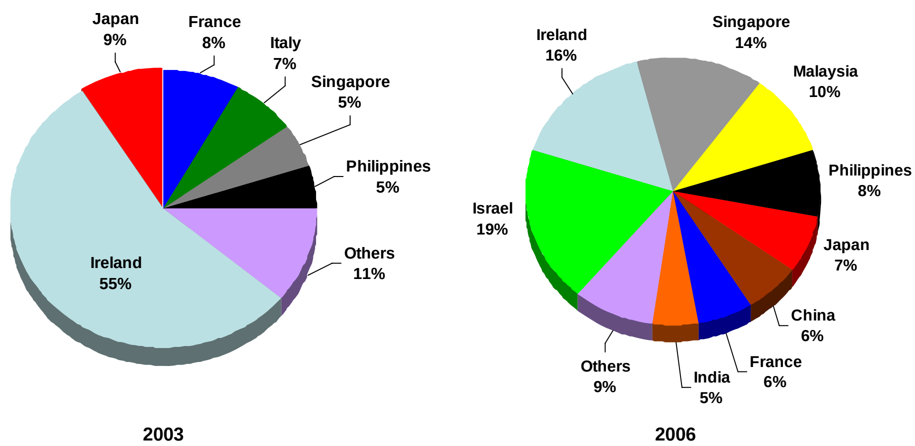
Fabricators allocated a growing amount of their capital investment to non-U.S. locations, raising spending from $2.67 billion in 2003 to $3.92 billion in 2006. However, as a percent of total capital expenditures, the offshore portion of capital spending dropped from 36 percent in 2003 to 30 percent in 2006.

A breakout shows Asia was the prime destination for non-U.S. capital investment, garnering 14 percent of the $3.4 billion (see Figure XIV-7).[74] Capital spending there reached $1.8 billion in 2006, an increase of 213 percent from 2003's investment level of $576 million. The countries attracting the most investment in 2006 were Singapore ($493 million), Malaysia ($348 million), the

[74]Figures based on responses to Question 10b of survey questionnaire, which asked respondents to identify the top five destinations of capital expenditures. There could be additional capital expenditures that are not captured by this data.

Philippines ($274 million), Japan ($223 million), China ($189 million), and Thailand ($123 million).

Figure XIV-7: Non-U.S. Capital Investment by Fabrication Companies – 2003, 2006



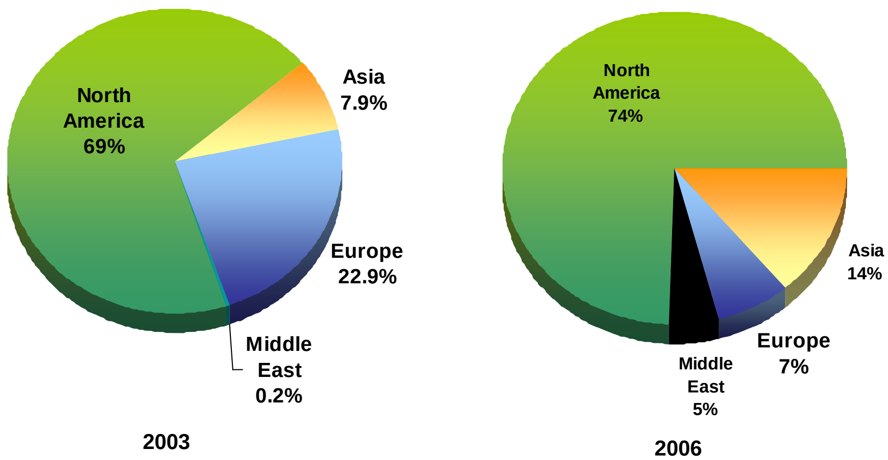
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Europe attracted $923 million of capital investment from IC fabricators in the United States in 2006, seven percent of non-U.S. capital investment. Capital spending in Europe by surveyed IC companies was cyclical over the reporting period, starting at $1.5 billion in 2003 and falling to $961 million in 2004 before rising to $1.69 billion in 2005. Ireland garnered the most in capital funds in 2006 at $528 million, followed by France ($208 million), Italy ($70.2 million), Germany ($54.7 million), and Belgium ($24 million).

Out of the 21 countries identified by surveyed IC fabrication companies as recipients of their capital spending, Israel attracted $628 million, or 19 percent of total non-U.S. fabrication capital expenditures in 2006. In North America, fabrication investment in Canada jumped from $7 million in 2003 to $19 million in 2006, an increase of 171 percent.

For the four-year period, capital expenditures increased for all geographic areas except Europe, which experienced a 45 percent decline, from roughly $1.7 billion in 2003 to $923 million in 2006 (see Figure XIV-8). Fabricators increased the amount of capital expenditures in Asia from eight percent in 2003 to 14 percent in 2006, raising investment in the region by over $1.2 billion during the period. However, North America, specifically the United States, remained the prime recipient of fabrication capital spending, capturing 74 percent of capital expenditures in 2006. In fact, fabricators nearly doubled capital investments in North America during the four-year stretch, raising spending from $5 billion in 2003 to $9.8 billion in 2006.

Figure XIV-8: Capital Investment by Fabrication Companies by Region – 2003, 2006

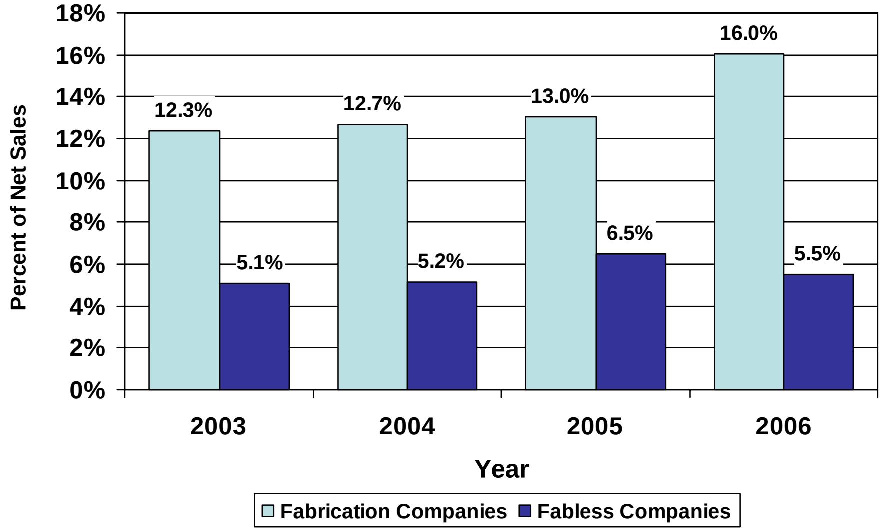


Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Capital Expenditures by Fabless Companies

The capital investment requirements of fabless companies are significantly less than those of IC fabrication companies. Data collected from 75 fabless companies for the 2003-2006 period shows capital spending as a percent of net sales averaged 5.5 percent. In contrast, IC fabrication companies' capital expenditures averaged 13.5 percent of net sales over the same period (see Figure XIV-9).

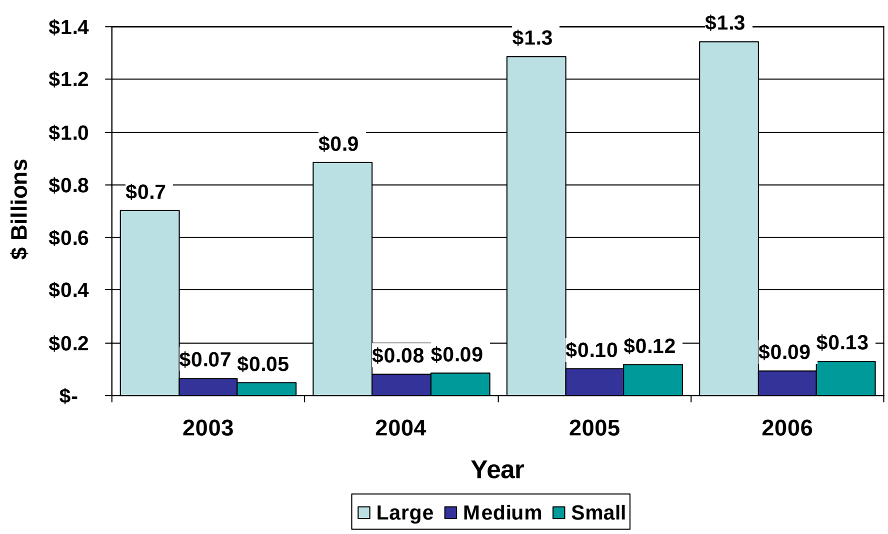
Figure XIV-9: Capital Expenditures as a Percent of Net Sales



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Although fabless company spending as a percent of net sales showed little change over four years, rising from five percent to 5.5 percent, actual expenditures increased dramatically from $817 million in 2003 to $1.57 billion in 2006. Figure XIV-10 shows this growth broken out by small-, medium- and large-size fabless firms.

Figure XIV-10: Fabless Companies' Capital Expenditures – By Company Size



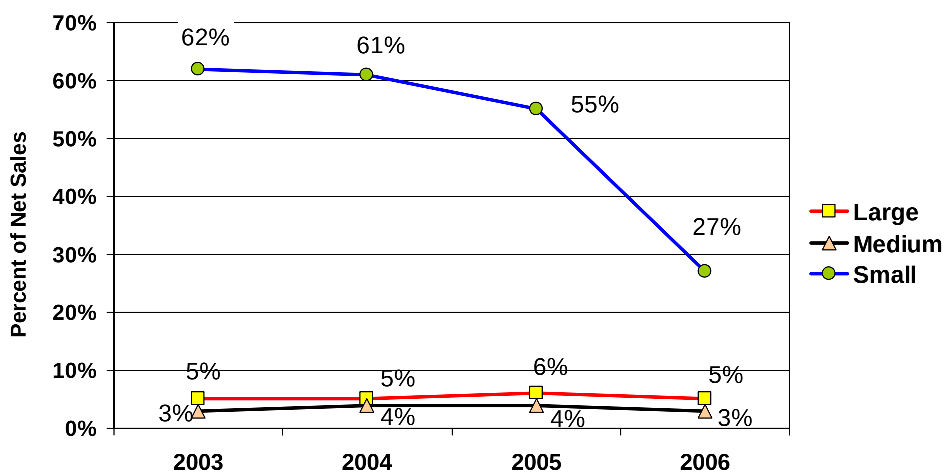
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Large-size fabless companies accounted for the majority of reported capital expenditures. Collectively, these companies allocated $1.34 billion in 2006 to capital spending, representing 86 percent of design-related capital expenditures.

Capital outlays by medium- and small-size fabless companies were substantially lower than those of large-size companies. In 2006, medium-size fabless companies reported capital expenditures of $94.6 million, an average of three percent of net sales (see Figure XIV-11). For the four-year reporting period, capital spending was low, averaging 3.5 percent.

Small-size companies in 2006 reported capital expenditures of $129.7 million, 27 percent of net sales. Capital expenditure figures for small-size companies declined from a peak of 62 percent in 2003 to 55 percent in 2005, dropping further to 27 percent in 2006.

Figure XIV-11: Fabless Companies' Capital Expenditures as a Percent of Net Sales – By Company Size



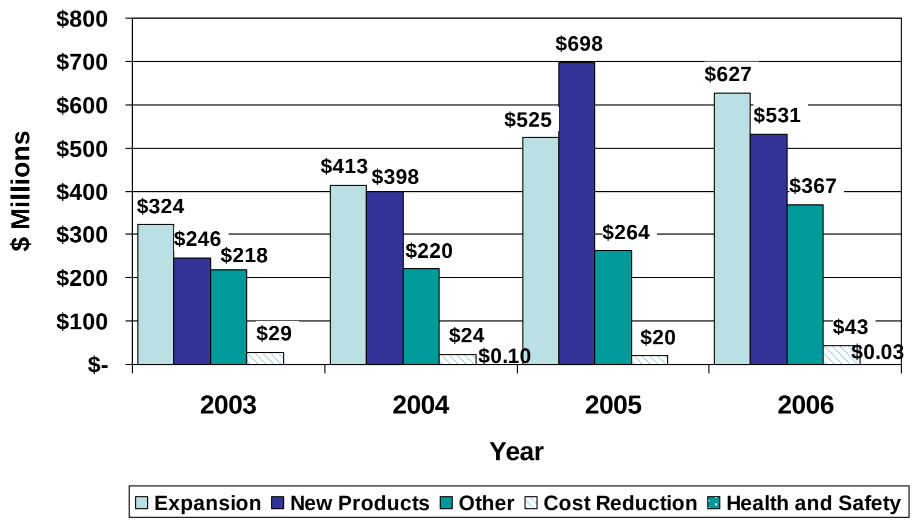
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

ALLOCATION OF CAPITAL EXPENDITURES BY FABLESS COMPANIES

Fabless companies reported capital spending practices for the expansion of existing product lines, new products, cost reduction, health and safety needs, and other activities.

The expansion of existing design production capability was a top priority for fabless companies, which increased spending for this purpose from $324 million in 2003 to $627 million in 2006 (see Figure XIV-12). Virtually all of this investment, 96 percent, was made by large-size companies for their U.S. operations. At the same time, capital spending in non-U.S. locations by fabless firms increased significantly, climbing from $4.2 million to $221 million.

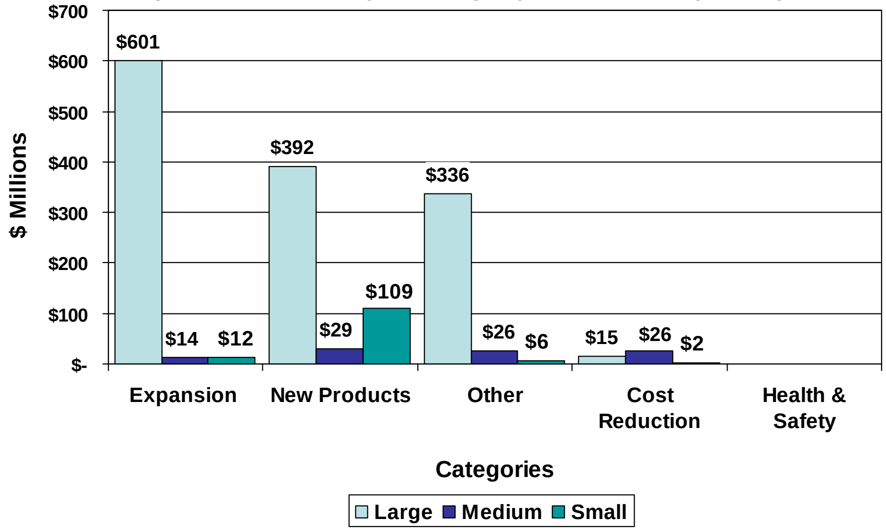
Figure XIV-12: Fabless Companies' Allocation of Capital Expenditures



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Of nearly equal importance to fabless firms is capital investment for new product development, which increased 116 percent between 2003 and 2006. In 2006, fabless companies allocated $531 million for new product development. Of the total, $475 million was expended in the United States. Capital investment in non-U.S. locations for new product development increased steadily over the four-year period, rising from $30 million in 2003 to $56 million in 2006. Seventy-four percent of the investment for new product development was attributable to large-size companies (see Figure XIV-13).

Figure XIV-13: Fabless Companies' Capital Expenditures - by Category and Size (2006)



Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

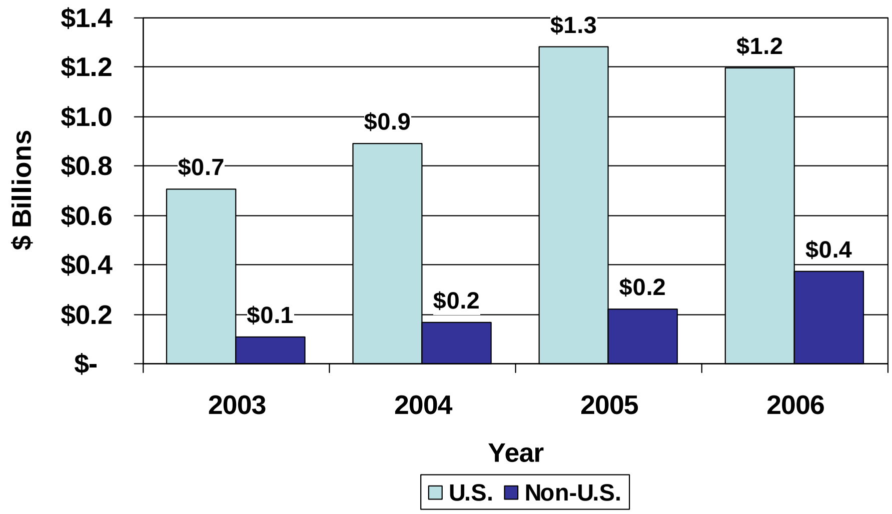
Expenditures for cost reduction accounted for $43 million, just three percent of overall fabless company capital expenditures in 2006. Spending on cost reduction, while small in overall numbers, rose 49 percent in the 2003-2006 time span. Medium-size companies accounted for 61 percent of all fabless company allocations for cost reduction. Large-size companies accounted for 34 percent of fabless company spending used on cost reduction, while small-size companies allocated five percent for this purpose.

Fabless companies provided significant funds to capital investment in other programs, which included funding for items such as information technology or laboratories. This spending totaled $367 million in 2006, or about 23 percent of capital expenditures by fabless companies. To this end, large-size companies spent $336 million, medium-size companies allocated $26 million for this activity, while small-size companies spent slightly under $6 million. Capital expenditures for health and safety were almost non-existent.

NON-U.S. CAPITAL EXPENDITURES BY FABLESS COMPANIES

Fabless firms identified 23 countries as recipients of capital investment funding. OTE survey responses highlight a large increase in non-U.S. capital expenditures by fabless companies. These expenditures rose from $98 million in 2003 to $417 million in 2006, 326 percent during the 2003-2006 period and by 90 percent between 2005 and 2006 (see Figure XIV-14).

Figure XIV-14: Fabless Companies' Capital Expenditures



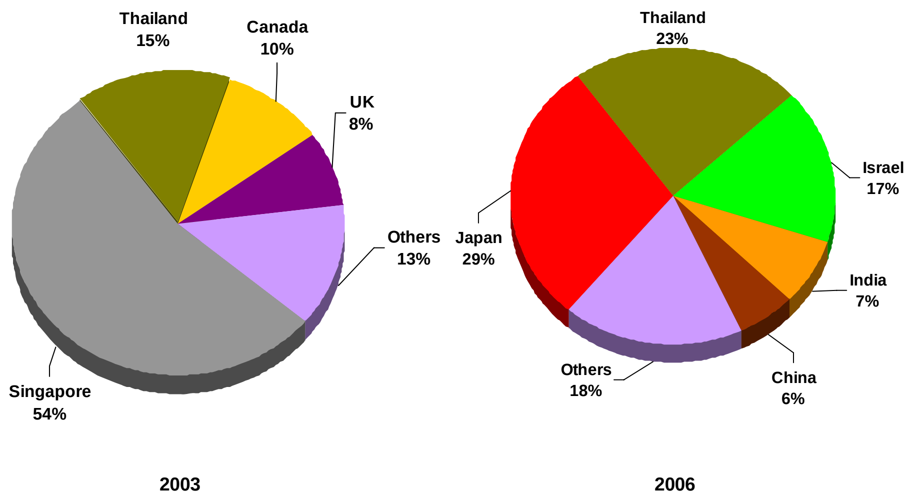
Source: U.S. Department of Commerce, Office of Technology Evaluation,
U.S. Integrated Circuit Design and Fabrication Capability Survey, November 2008.

Capital expenditures by fabless companies in 2006 were distributed in several regions:

- Asia - $310.8 million
- Middle East - $69.6 million
- Europe - $25.9 million

Not only does Asia dominate in attracting capital investment funds from U.S. IC fabless companies, spending there more than doubled from $76.5 million in 2003 to $310.8 million in 2006. Countries seeing some of the highest capital spending in 2006 for fabless activity include: Japan ($123 million); Thailand ($96 million); India ($31 million); China ($26 million); Singapore ($16 million); Malaysia ($11 million); Korea ($4 million); and Taiwan ($3 million) (see Figure XIV-15).

Figure XIV-15: Non-U.S. Capital Investment by Fabless Companies – 2003, 2006



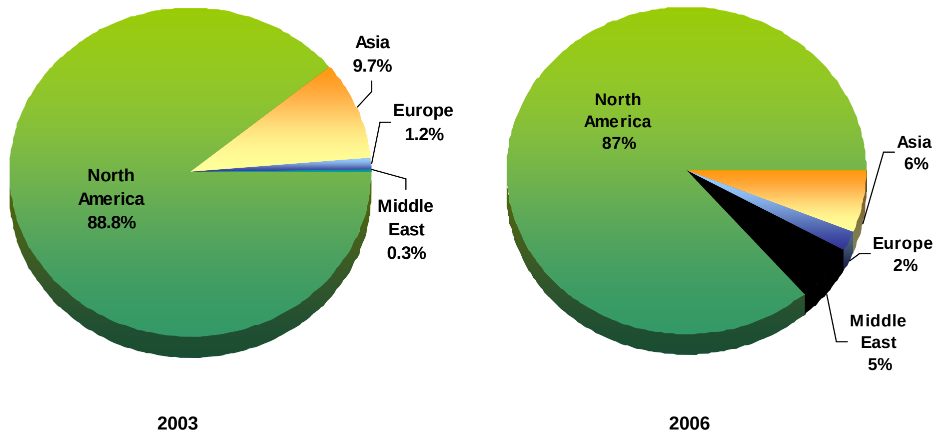
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

The ascendance of Japan as a destination for capital expenditures from U.S. fabless companies is apparent. Spending there increased from $1.2 million in 2003 to $123 million in 2006. Fabless company capital spending in Thailand also surged, climbing from $15 million in 2003 to $96 million to 2006. At the same time, survey participants reported decreased capital spending in Singapore, where inflows dropped from $53 million in 2003 to $16 million in 2006.

In the Middle East, Israel is benefiting from rising capital expenditures. Spending there by fabless companies soared from $2.1 million in 2003 to $69.6 million in 2006, a jump of over 3,000 percent. Most of this increase occurred in 2006, when capital spending rose to $66.9 million from $2.7 million in 2005.

Europe also received significant capital spending from fabless companies, with survey participants reporting $26 million in expenditures for 2006. Capital expenditures by fabless companies in Europe rose in the 2003-2006 period, increasing 169 percent from $9.6 million. Nearly all of this 2006 capital spending, 71 percent, occurred in two countries: the United Kingdom at $11.9 million and Germany at $6.6 million. The remainder was distributed in small sums across 10 other European countries.

Figure XIV-16: Capital Investment by Fabless Companies by Region – 2003, 2006



Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

APPENDIX A: SURVEY AUTHORITY

BIS/OTE performed this assessment and data collection under authority delegated to the U.S. Department of Commerce under Section 705 of the Defense Production Act of 1950, as amended (50 U.S.C. App. Sec. 2155) (DPA) and related Executive Order 12656. These authorities enable BIS/OTE to conduct mandatory surveys, study defense-related industries and technologies, and monitor economic and trade issues affecting the U.S. defense industrial base. OTE has performed assessments on a broad range of U.S. industrial and technology sectors including imaging and sensors, space systems, cartridge and propellant actuated devices, munitions power sources and the U.S. Air Force C-17 aircraft.[75] Almost all OTE assessments are conducted with the participation of the Armed Services, Congress and/or industry associations.

[75] See the U.S. DOC/BIS/OTE web site for a full listing of published reports: http://www.bis.doc.gov/defenseindustrialbaseprograms/.

APPENDIX B: GLOSSARY

Amorphous Silicon: A semiconductor material that has no definite or regular crystal structure and is used to make the thin-film transistors (TFTs).

Antimonides: A class of compound semiconductor materials that have higher peak carrier velocities than silicon, gallium arsenide and indium phosphate materials. These materials are attractive for producing high speed transistors and can be used in low-voltage systems.

Applied Research: Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met. This activity includes work leading to the production of useful materials, devices and systems or methods, including design development and improvement of prototypes and new processes.

Application Specific Integrated Circuit (ASIC): A circuit designed to suit a customer's particular requirement, as opposed to memory devices or microprocessors, which are general-purpose semiconductors.

Back-End: The series of process steps at the back-end of integrated circuit manufacturing from contact through completion of the wafer, prior to electrical test.

Basic Research: Systematic, scientific study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts.

Bulk Silicon: The silicon semiconductor material predominantly employed in the production of integrated circuit products manufactured around the world.

Capital Expenditures: Investments made by a company in buildings, equipment, property, and systems where the expense is depreciated. This does not include expenditures for consumable materials, other operating expenses and salaries associated with normal business operations.

Circuit: The connection of multiple electrical elements to accomplish a desired function.

Coprocessor: Specialized circuitry in a microprocessor that off loads specified tasks and processes them more rapidly than in possible in basic microprocessor circuitry.

Custom ASIC: These ASICs differ from standard cell ASICs in that designers have total control of the attributes of each transistor forming a logic gate, enabling them to tune the integrated circuit device for optimum operation, performance superior to that attained in other types of devices.

Development: The design, development, simulation, or experimental testing of prototype or experimental hardware or systems, to validate technological feasibility or concept of operation, to reduce technological risk, or to provide test systems prior to production approval.

Design: Activity required to implement a product concept in support of the manufacture of the Integrated Circuit product at a fabrication facility.

Die: A single integrated circuit (or chip) cut from the wafer on which it was manufactured.

Digital: The expression of information in binary code as ones and zeros.

Digital Design: Design methods employed to create integrated circuit products such as microprocessors and memory devices. Digital IC design has three major segments: electronic system level (ESL), register transfer level (RTL), and physical design.

Digital Signal Processing: Digital circuits designed to address a broad class of problems in signal reception and analysis that have traditionally been solved using analog components. DSP is used to enhance, analyze, filter, modulate or otherwise manipulate standard analog functions such as images, sounds, radar pulses, and other such signals by analyzing and transforming wave-forms (e.g., transmitting data over phone lines via modem).

Display Electronics: Integrated circuit products employed in digital displays used for entertainment and information systems.

Dynamic Random Access Memory (DRAM): A type of memory component. These active memory cells are "Dynamic" and lose their ability to retain information when power to the system is lost. Information stored in the memory cells is accessed randomly. Memory is a key component of most electronic products.

EPROM: An erasable programmable read-only memory chip that allows stored information to be erased by exposure to ultraviolet light.

EEPROM: Electronically-erasable programmable read-only memory.

EPGA: See *One-Time Electronically Programmable Gate Arrays*.

Extra Permanent Memory (XPM): Non-volatile, one-time programmable memory.

Fabless: A semiconductor company with no company-owned and operated IC fabrication capability in the United States, only product design capability.

Fabrication: The process of manufacturing an integrated circuit.

Fabrication Facility: A manufacturing plant or production facility that processes semiconductor wafers to produce integrated circuit products, or discrete electronic components such as transistors and diodes.

Field Programmable Gate Array (FPGA): A semi-custom integrated circuit chip, a gate array, containing cells with rows of transistors and resistors that are not connected. The appropriate interconnections are made to meet specific requirements of the customer using software to form a custom-designed working device. This device can be programmed in the field, outside of a factory setting.

Flash Memory: Non-volatile solid state memory. It is related to electrically erasable programmable read-only memory (EEPROM) devices.

Front-End: Integrated circuit wafer processing steps, including thermal processes, implantation, chemical vapor deposition (CVD), photolithography, etching, physical vapor deposition (PVD), polishing, process diagnostics and control (metrology), and cleaning.

Foundry: A wafer production and processing plant. Usually used to denote a facility that is available on a contract basis for companies that do not have wafer fabrication capability of their own, or that wish to supplement their own capabilities.

Gallium Arsenide: A compound semiconductor material used for making optoelectronic devices and high-frequency ICs. This material has higher electron mobility than silicon, thus having the capability of producing higher-speed devices.

Gallium Nitride: A compound semiconductor material used in the manufacture of integrated circuit products. Properties include higher operating temperatures and higher voltages than gallium arsenide.

Gate Array: Semi-custom chip IC devices containing cells with rows of transistors and resistors that are not connected. The appropriate interconnections are made to meet specific requirements of the customer using software to form a custom-designed working device.

Indium Phosphate: A compound semiconductor material used in the manufacture of integrated circuit products. The material provides faster performance in integrated circuit devices.

Insulator: Material that does not allow an electrical charge to pass through it.

Integrated Circuit (IC): A miniaturized electronic device containing multiple solid-state circuits that work in conjunction to form a complete device with defined functions, and that has been manufactured on the surface of a thin substrate of semiconductor material. In these devices many active or passive elements are fabricated and connected together on a continuous substrate, as opposed to discrete devices, such as transistors, resistors, capacitors and diodes that exist individually.

Line Width: The width of a metal interconnect in an integrated circuit.

Lithography: The transfer of a pattern or image from one medium to another, such as to a wafer.

Magneto-Resistive Electro Mechanical Memory (MRAM): A memory device that stores data using magnet charges and at higher density rates than conventional memory. It could replace other types of memory devices such as dynamic random access memory and flash memory.

Mask: A patterned plate or template used to expose selected areas of a wafer layer to light in the process of fabricating an integrated circuit.

Mask Programmable Gate Arrays (MPGA): Generic masks are used to create an array of generic base cells laid out in rows. Logic circuits are created by connecting transistors with wires within cells and connecting cells with wires. This architecture can reduce development time for IC products, but device performance is less efficient than what can be achieved in custom ASICs.

Memory: The working space used by the computer to hold the program that is currently running, along with the data it needs to run programs and process data. The main memory is built from random access memory (RAM) chips. The amount of memory available determines the size of programs that can be run, and whether more than one program can run at a time. Main memory is temporary and is lost when the computer is turned off. It is distinguished from more permanent internal read only memory (ROM) which contains the computer's essential programs, and data storage memory devices such as hard drives and compact disks.

Micro Electro-Mechanical Systems Memory (MEMS): A micro electro-mechanical system for the writing of data and reading of stored magnetic data. It has the potential in enable higher data storage because it uses mechanical positioning to define a data storage cell rather than microlithography processes.

Microlithography: A process in semiconductor fabrication that transfers a pattern from a photomask to the surface of a substrate. Microlithography involves a combination of substrate preparation, photoresist application, soft-baking, exposure, developing, hard-baking and etching.

Microprocessor: The main processing unit of a computer or information processing device. The device is capable of carrying out instructions, performing calculations, and interacting with the components used to operate a computer. The microprocessor handles the fetch, decode, and execute steps.

Mixed Signal Technologies: Integrated circuit devices that combine analog and digital circuitry.

MMIC Technologies: Monolithic microwave integrated circuits (a.k.a. micro monolithic integrated circuits) are often used as amplifiers and filters. The devices operate at microwave frequencies and can employ both analog and digital circuitry.

Nanometer (nm): One billionth of a meter; one millionth of a millimeter (10^{-9} meter).

Neutron Hardened: Integrated circuit products incorporating design features and/or physical characteristics that can withstand the damaging effects of high-speed neutrons, gamma rays, and electromagnetic pulses that accompany a nuclear weapons detonation.

Non-Affiliated Company: For the purposes of this assessment, a company that is not owned or operated by a survey respondent.

Nonvolatile Memory: A storage device whose contents are preserved when its power is off. Storage using magnetic disks or tape is normally non-volatile. Some semiconductor memories (ROM, EPROM, Flash memory) are non-volatile while other semiconductor memories (static RAM and especially dynamic RAM) are normally volatile but can be made into non-volatile storage by permanently connecting a (rechargeable) battery.

One-Time Electronically Programmable Gate Arrays (EPGA): A semi-custom integrated circuit chip, a gate array, containing cells with rows of transistors and resistors that are not connected. The appropriate interconnections are made to meet specific requirements of the customer using software to form a custom-designed working device. This device can be programmed only one time.

Organic Technologies: Classes of conducting polymers with semiconductor properties and processes that can be used to manufacture transistors and integrated circuit devices, including displays.

Original Equipment Manufacturer (OEM): A manufacturer who places his brand on a product and sells it. The manufacturer may or may not have designed or manufactured the product himself.

Phase Change Memory: Non-volatile memory that uses the crystalline and amorphous switching states of chalcogenide glass.

Photomask: A transparent blank covered with a pattern that is transferred to the surface of a substrate through photographic methods.

Polymer Memory: An emerging technology based on plastic materials with semiconducting properties.

Process Development: The creation of wafer production processes used in manufacturing integrated circuit products for a specified technology node.

Product Development: Conceptualization and development of an integrated circuit product prior to the production of IC product for customers.

RAM (Random Access Memory): Memory available on a computer for storing data and programs currently being processed. It is automatically erased when the power is turned off. Information in the RAM that needs to be stored for future use must be saved onto a disk or a tape.

Radiation Hardened: Integrated circuit products incorporating design features and/or physical characteristics that demonstrate a capability to resist radiation-induced damage from industrial sources, electromagnetic pulses, weapons systems; and/or charged particles in space that can damage circuitry and render a device inoperable.

Radiation Resistant: Integrated circuit products that are able to resist damage from given doses of radiation, including single-event effects resistant, radiation tolerant, radiation hardened, and neutron hardened devices.

Radiation Tolerant: Integrated circuit products incorporating design features and/or physical characteristics with limited capability to resist radiation induced damage from industrial sources, electromagnetic pulses, industrial sources, weapons systems, and charged particles in space that can damage circuitry and render a device inoperable.

Register Transfer Level (RTL) Design: An integrated circuit design step that converts an electronic system level (ESL) design into a description that drives the function of digital circuits and interconnections in an integrated circuit.

Research and Development: Basic and applied research in the engineering sciences, as well as design and development of prototype products and processes.

Semiconductor Materials: Elemental materials such as silicon and germanium (or compounds like gallium arsenide) that possess levels of electrical conductivity that are less than a conductor but greater than an insulator.

Semiconductor Industry Association (SIA): SIA is the leading trade association representing the integrated circuit industry. SIA represents U.S. IC product manufacturers on trade, technology, environmental protection and worker safety and health issues.

Silicon: The most common element in nature and the material used to create most transistors and integrated circuit products.

Silicon Carbide: A compound semiconductor material used in the manufacture of integrated circuit products. Properties include an ability to handle high voltages and higher temperatures.

Silicon Germanium: A semiconductor alloy material used in the manufacture of integrated circuit products. Properties include lower power consumption than bulk silicon, reduced resistance, and higher processing speeds.

Silicon-on-Insulator: A silicon wafer with a thin layer of oxide ($SiO2$) buried in it. SOI substrates provide superior isolation between adjacent devices in an integrated circuit as compared to devices built into bulk wafers.

Silicon-on-Sapphire: Similar to silicon-on-insulator except that sapphire is used as an insulator in place of silicon dioxide. Properties include radiation resistance.

Single-Event Effects Resistant: Resistant to effects caused by a single energetic particle striking an Integrated Circuit (IC) device. Performance of the IC device is not compromised to a point where it is inoperable or not reliable for executing a mission as a result of latch-up, burnout, or gate rupture.

Standard Cell ASIC: Devices that employ pre-designed logic cells laid out in rows to implement the design for a logic circuit. This approach allows for lower integrated circuit device development costs. These products often are larger and can not match the performance of custom ASICs.

Static Random Access Memory (SRAM): An integrated circuit similar to a DRAM that requires no constant refreshing or recharging. It retains stored information as long as power is applied to the computer, hastening information-retrieval process time. In contrast to ROM, SRAM is volatile and will lose data when the power is switched off. SRAM is typically faster than DRAM but usually costs more per bit because each bit requires several transistors. It is used to support speed-critical systems in computers.

Technology Node: Generally accepted manufacturing benchmarks used by fabricators for making integrated circuit products using a given generation of manufacturing technology. Sometimes referred to as a "process node" or "process technology," it represents the smallest circuit feature size that can be drawn on a chip with a microlithography tool. Circuit feature dimensions dictate how much circuit can be placed in a given area on a microchip. As technology nodes step down to smaller dimensions, circuit density can be increased, allowing for the manufacture of more complex devices.

Transistor: A type of switch that contains no moving parts and uses electricity to turn itself on and off. The device controls current flow and serves as the basic element of a computer chip. It consists of three terminals: a source, a gate, and a drain. Applying a voltage to the gate controls current flow between the source and the drain.

Trusted Access Program/Trusted Supplier Program: A program implemented by the National Security Agency and the Defense Microelectronics Activity (DMEA) to qualify Integrated Circuit design and manufacturing companies as “trusted” suppliers of Application Specific Integrated Circuit (ASIC) products required for national security applications.

United States: The term “United States” includes the fifty states, Puerto Rico, the District of Columbia, the island of Guam, Trust Territories, and the Virgin Islands.

Wafer: A thin, flat piece of semiconductor crystal (typically silicon) used in the manufacture of microprocessors and integrated circuits. Circuit components are created on the surface of the wafer through a series of manufacturing techniques that include layering and etching.

Wafer Starts Per Week: The number of semiconductor wafers that can be processed by an Integrated Circuit on production line(s) in a 7-day period.

XPM: See *Extra Permanent Memory*.

Zero Capacitor Random Access Memory (ZRAM): Embedded floating body memory cell technology uses a structure based on a single transistor, an approach that allows storage density five times that of static random access memory (SRAM) devices.

APPENDIX C: LIST OF SUPPLIERS ACCREDITED BY THE DEFENSE MICROELECTRONICS AGENCY (DMEA)[76]

Supplier	Scope of Accreditation	Accredited	Expires
Aeroflex Colorado Springs	Aggregation; Design; Packaging/Assembly; Test	12/4/2007	12/4/2009
BAE Systems Information and Electronic Systems Integration, Inc.	Design; Packaging/Assembly; Foundry Services; Test	11/5/2008	12/13/2009
BAE Systems Microwave Electronics Center Nashua	Foundry Services	4/7/2008	4/7/2010
Endicott Interconnect Technologies, Inc	Packaging/Assembly	9/25/2008	9/25/2010
Honeywell Aerospace Plymouth	Design; Packaging/Assembly; Foundry Services; Test	10/22/2008	3/13/2010
Honeywell Federal Manufacturing & Technologies, LLC/Kansas City Plant	Aggregation; Design; Packaging/Assembly; Test	6/10/2008	6/10/2010
HRL Laboratories	Foundry Services	4/18/2008	4/18/2010
IBM Systems Technology Group	Mask Data Parsing; Mask Manufacturing; Foundry Services	12/13/2007	12/13/2009
Intersil Corporation	Foundry Services	7/31/2008	7/31/2010
National Semiconductor Corporation	Foundry Services	12/13/2007	12/13/2009
National Semiconductor Corporation	Aggregation	4/14/2008	4/14/2010
Northrop Grumman Electronic Systems	Foundry Services	2/25/2008	2/25/2010
Northrop Grumman Space Technology	Foundry Services	12/13/2007	12/13/2009
Pantronix Corporation	Packaging/Assembly	12/2/2008	12/2/1210
Raytheon RF Components	Foundry Services	8/28/2008	2/28/2010
Rockwell Collins, Inc.	Design; Packaging/Assembly; Test	1/15/2009	10/20/2010
Sandia National Laboratories Microsystems Science, Technology, & Components	Design	1/7/2009	1/7/2011
Sarnoff Corporation	Foundry Services	10/20/2008	10/20/2010
Teledyne Microelectronic Technologies	Packaging/Assembly; Test	1/22/2008	1/22/2010
TriQuint Semiconductor Texas	Foundry Services	12/2/2008	12/2/2010

[76] For more information on accredited suppliers, please visit http://www.dmea.osd.mil/trustedic.html

APPENDIX D: ASSESSMENT COVERAGE – SURVEY INSTRUMENT

The OTE survey instrument was structured to provide a facility-by-facility breakout for all IC fabrication and design operations across the United States. A number of large-size IC companies filled out multiple OTE surveys to fulfill this facility-level reporting requirement. In preparing the final report, OTE staff aggregated the final data submissions to protect business proprietary information. The depth and breath of the OTE IC database can be best explained by reviewing the specific sections of the survey instrument.

The OTE survey requested information pertaining to: (1) conventional integrated circuit products, which account for the majority of U.S. capabilities, and (2) radiation resistant products, including single-event effects resistant, radiation tolerant, radiation hardened, and neutron hardened products for commercial, industrial and military applications.

The OTE survey document consists of nine sections containing questions on a broad range of parameters to measure capability for IC product fabrication and design. A summary of the focus of each section follows:

Conventional IC Products - Survey Sections 2a-2e

To assess capabilities, IC fabrication and design companies were asked to describe their abilities in terms of the dimensions, materials, device types, and processing capability by wafer size. Technology node capability (nanometers) spanned 15 categories ranging from 10,000 – 6,000 nanometers down to less than 32 nanometers. These categories were grouped in four technology node ranges: 10,000 nm – 1,000 nm; 1,000 nm – 250 nm; 250 nm – 65 nm; and less than 65 nm. Wafer processing data covered five wafer sizes: 2- or 3-inch, 4-inch, 6-inch, 8-inch, and 12-inch.

Information was collected on companies' capability to design and fabricate conventional IC products using 10 material types:[77]

[77] For more information on these material types, see Appendix C.

Materials Types Included in the Survey
Standard Silicon Materials
Bulk Silicon
Silicon on Insulator
Silicon Germanium
Non-Standard Materials
Gallium Nitride
Gallium Arsenide
Indium Phosphate
Silicon Sapphire
Antimonides
Silicon Carbide
Amorphous Silicon
Source: U.S. Department of Commerce, Office of Technology Evaluation, *U.S. Integrated Circuit Design and Fabrication Capability Survey*, November 2008.

Survey participants also described their ability to design and/or fabricate 14 types of conventional IC devices:[78]

Device Types Included in the Survey	
Field Programmable Gate Arrays (FPGAs)	Digital Signal Processors
One-Time Electronically Programmable Gate Arrays (EPGAs)	Nonvolatile Memory
Mask Programmable Gate Arrays (MPGAs)	Static Random Access Memory (SRAM)
Structured Application Specific Integrated Circuits (ASICs)	Dynamic Random Access Memory (DRAM)
Standard Cell ASICs	Microprocessors/Co-processors
Custom ASICs	Micromonolithic Integrated Circuits (MMIC)
Mixed Signal ASICs	Display Electronics

[78] For more information on these device types, see Appendix C.

Organizations were asked to further describe their nonvolatile memory device fabrication and/or design capability. These 10 nonvolatile memory device types included:

Types of Nonvolatile Memory Included in the Survey	
Erasable Programmable Read-only Memory (EPROM)	Electrically Erasable Programmable Read-only Memory (EEPROM)
Flash Memory	Polymer Memory
Ferro-electric Random Access Memory (FeRAM)	One-time Programmable Memory (XPM)
Magneto-resistive Random Access Memory (MRAM)	Phase Change Memory
Zero Capacitor Random Access Memory (ZRAM)	Micro Electro-mechanical Systems Memory (MEMS)

Radiation Resistant IC Products - Survey Sections 3a-3c

Respondents were asked to provide information on their ability to design and/or fabricate four types of radiation resistant IC products: single-event effects resistant, radiation tolerant, radiation hardened and neutron hardened. The data collected from these specific categories was further segmented by technology node, material type, wafer size, and device type - the same categories used in the survey section on conventional capability.

Manufacturing Utilization - Survey Sections 4a-4c

This section focused on manufacturing capability in the context of production, facility utilization, facility availability, and projections for continued operation in the future. Capability was reported by wafer starts per week, circuit technology node, wafer size and material type. These questions covered both conventional and radiation-resistant IC products.

National Security/Trusted Foundry Access Program - Survey Sections 5a-5k

Companies and organizations were asked to state their interest and capability in designing/supplying products for current and future national security end-uses, including how much capacity they were willing to devote to national security business. Design and fabrication companies were also asked if they were certified or had interest in becoming certified for the Department of Defense Trusted Foundry Access Program.

Performance and Outsourcing of Production Functions by Fabrication Firms - Survey Sections 6a-6l

The survey requested companies and organizations to identify their current capability to perform seven manufacturing steps: mask making, wafer manufacturing (front and back ends), wafer sorting, circuit testing, packaging, and final testing. Survey participants specified those manufacturing steps that they outsource to domestic service providers and facilities at non-U.S. locations. Companies were also asked to identify the manufacturing functions they would continue to carry-out in the United States through 2011 and the functions they expect to outsource to domestic and non-U.S. locations in the future.

Performance and Outsourcing of Production Functions by Fabless Firms - Survey Sections 7a-7j

In the area of IC design, survey participants were asked to describe their current capability to carry out seven design steps: digital, analog, RTL (register transfer level) design, synthesis, physical layout, functional verification, and test vector generation. Companies were also asked to specify those design steps that they outsource to domestic service providers and to facilities at non-U.S. locations. Companies were asked to identify the design functions they would continue to carry out in the United States through 2011 and the functions they expect to outsource to non-U.S. locations in the future.

Financials - Survey Sections 8a-8f

Fabrication companies and fabless companies provided data for years 2003-2007 on their net sales. OTE used this information to understand the financial profiles of companies participating in these distinct segments of the industry. Both fabricators and fabless firms were examined by size in terms of sales and their industry position as large-, medium-, or small-size companies. In addition, OTE reviewed the financial standing of IC fabrication companies and fabless companies.

Research & Development: Expenditures, Outsourcing and Employment - Survey Sections 9a-9d

Corporate research and development (R&D) expenditures were broken into four categories: basic research, applied research, product development, and process development. Respondents were also asked about the sources of their funding: parent company/internal, federal government, state and local government, U.S. private entities, and foreign investors. R&D employment trends as well as offshore transfers of R&D expenditures were also captured at the corporate level.

Capital Investment: Expenditures and Outsourcing - Survey Sections 10a-10b

Information on fabrication and fabless company capital expenditures was collected from survey participants for the 2003-2007 period. Investment patterns of fabrication companies and fabless companies were analyzed separately. In addition to overall investment levels, the data focuses on specific aspects of capital investment, including cost reduction, replacement expansion, improvement of production capacity, and new product development. Capital investment flows for domestic versus international operations also are examined.

DEFENSE INDUSTRIAL BASE ASSESSMENT: U.S. INTEGRATED CIRCUIT DESIGN AND MANUFACTURING CAPABILITY

OMB Control Number: 0694-0119; Expiration Date: 12/30/2007

SCOPE OF ASSESSMENT

The Bureau of Industry and Security (BIS), Office of Technology Evaluation, in cooperation with the U.S. Department of Defense, is conducting an assessment of the U.S. design and manufacturing infrastructure available for producing Integrated Circuit products required for meeting U.S. national security needs. The goal of this study is to provide decision makers in the Departments of Defense, Energy, Justice, Homeland Security, and others with (1) detailed information on the health and status of Integrated Circuit design and manufacturing capabilities remaining in the United States; and (2) the outlook for maintaining these activities in the future. The scope of this effort encompasses Integrated Circuit design and production resources, including activities such as mask blank, mask making, and semiconductor wafer supply.

RESPONSE TO THIS SURVEY IS REQUIRED BY LAW

A response to this survey is required by law (50 U.S.C. app. Sec. 2155). Failure to respond can result in a maximum fine of $10,000, imprisonment of up to one year, or both. Information furnished herewith is deemed confidential and will not be published or disclosed except in accordance with Section 705 of the Defense Production Act of 1950, as amended (50 U.S.C. App. Sec. 2155). Section 705 prohibits the publication or disclosure of this information unless the President determines that its withholding is contrary to the national defense. Information will not be shared with any non-government entity, other than in aggregate form. The information will be protected pursuant to the appropriate exemptions from disclosure under the Freedom of Information Act (FOIA), should it be the subject of a FOIA request.

Not withstanding any other provision of law, no person is required to respond to nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a currently valid OMB Control Number.

BURDEN ESTIMATE AND REQUEST FOR COMMENT

Public reporting burden for this collection of information is estimated to average 9 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information to BIS Information Collection Officer, Room 6883, Bureau of Industry and Security, U.S. Department of Commerce, Washington, D.C. 20230, and to the Office of Management and Budget, Paperwork Reduction Project (OMB Control No. 0694-0119), Washington, D.C. 20503.

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

GENERAL INSTRUCTIONS		
1	DEADLINE: Your office should submit its completed survey on or about **November 9, 2007**.	
2	Please complete each section of the survey.	
TABLE OF CONTENTS		
i	**Who Must Respond To This Survey - Please Begin Survey Here**	Begin
ii	Company/Organization Information	1a-1b
iii	U.S. and Foreign Facility Locations and Customer Segments	1c-1d
iv	Integrated Circuit Design & Manufacturing Facilities Information	2a-2e
v	Rad Tolerant, Rad Hardened, Neutron Hardened Design & Manufacturing	3a-3c
vi	Manufacturing Capabilities & Production Rates	4a-4c
vii	Interest and Capability to Supply Products For National Security	5a-5k
viii	Performance of Production Functions for Integrated Circuits	6a-6l
ix	Performance of Design Functions for Integrated Circuits	7a-7j
x	Finance (Income Statement and Balance Sheet)	8a-8f
xi	Research and Development and R&D Occupation	9a-9d
xii	Capital Expenditures	10a-10b
xiii	Survey Certification	11
3	Estimates are welcome; however, please indicate such in the corresponding comments boxes if so reported.	
4	Please report all financial, production, manufacturing capacity, and similar data on a Calendar Year basis.	
5	**Questions related to this questionnaire should be directed to:**	
	Jason Bolton, Trade & Industry Analyst, (202) 482-5936 [e-mail: jbolton@bis.doc.gov] Christopher Nelson, Trade & Industry Analyst, (202) 482-4727 [e-mail: cnelson@bis.doc.gov] Mark Crawford, Senior Trade & Industry Analyst, (202) 482-8239 [e-mail: mcrawfor@bis.doc.gov] Brad Botwin, Program Director, (202) 482-4060 [e-mail: bbotwin@bis.doc.gov] BIS/OTE Fax Number: (202) 482-5361	
6	Before returning your completed Excel questionnaire via e-mail, be sure to complete the **Certification** page.	
Mr. Brad Botwin, Program Director, Office of Technology Evaluation BIS Room 1093, U.S. Department of Commerce, 1401 Constitution Avenue NW, Washington, DC 20230		

WHO MUST RESPOND TO THIS SURVEY

Select the description that most closely reflects your organization:

1	An Integrated Circuit product design, product development and manufacturing organization.	
2	A fabless Integrated Circuit product design and product development organization - *only.*	
3	An Integrated Circuit manufacturing foundry - *only*.	
4	Did your organization at any time in the last five years have a capability to design/manufacture IC products?	
5	If you selected "Yes" to any of questions 1-4 above, please continue completing this survey.	
6	If you selected "No" for questions 1-4, please complete "Exemption From Survey" below.	

EXEMPTION FROM SURVEY

If your organization's operations during the last five years did not involve Integrated Circuit product design and/or manufacturing, you may be exempt from completing this survey. Please call one of the contacts listed in *General Instructions* above to verify your status. Then complete steps 7-8 below:

7	Briefly explain the products and/or services provided by your organization in the space below:
8	Please complete and print out the "Certification" page. Return a signed copy of the "Certification" only after confirming your exemption by speaking with one of our staff. Please transmit the "Certification" to our offices via mail, express courier, e-mail, or FAX (202) 482-5361, no later than **November 9, 2007**.

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

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Section 1	**Company/Organization Information**				
		U.S. Executive Office Location			
1.a Company/Organization Name		Street Address		Country	Mailing Code
		City		Phone Number	
Website Address		State		FAX Number	
D&B Universal Numbering System (DUNS) Number		SIC (3-Digit) Code(s)*		**Primary number(s) that identify the type of product(s) or service(s) provided from this facility. To determine the appropriate codes, see the SIC and NAICS code listings at the following website: (http://www.census.gov/epcd/www/naics.html)*	
CAGE Code		NAICS (4-Digit) Code(s)*			

Point of Contact Regarding this Survey			
Name(s)	Phone	Location	E-mail Address

Instructions -- Survey Completion and Submission Method

OTE already has collected information on the locations of your company's design and/manufacturing facilities. OTE now needs detailed information about the capabilities of each of those U.S.-based facilities. A company may provide this information in one or two ways:

Option #1) Instruct each of your design and/or manufacturing facilities to complete the requested information regarding their technical and production capabilities (Survey Sections 2-4) and have them report that information directly to OTE. If your company chooses this approach, **individual facilities** should not and may not report **Interest and Capability to Supply (Section 5), Performance of Production Functions (Section 6), Performance of Design Functions (Section 7), Financial information (Section 8), Research and Development and R&D Occupational information (Section 9), and Capital Expenditures (Section 10).** Survey Sections 5 - 11 **must be** completed and submitted as a single consolidated corporate/organization response. [This approach may speed completion of the survey for companies operating multiple facilities.]

Option #2) Instruct each of your design and/or manufacturing facilities to report the requested information regarding their technical and production capabilities (Survey Sections 2-4) to a designated corporate coordinator. The corporate coordinator can submit in a consolidated filing the technical and production capabilities for each of its facilities along with the requested financial information (Section 8), research and development and R&D occupational information (Section 9), and Capital Expenditures (Section 10).

Note: OTE is sending copies of this survey to every company's U.S. corporate office and to facilities engaged in integrated circuit design and/or manufacturing work in the United States. **Be sure to coordinate with your corporate point of contact and your facilities.**

Please specify in the box whether your company will use Option #1 or Option #2 :

My company/organization is headquartered in:	
The parent of my company/organization is headquartered in:	

Parent Company/Organization Name	Address	City	State	Country

My company/organization is (public/private):	
My parent company/organization is (public/private):	

1.b One or more foreign governments have invested, directly or indirectly in my company/organization - and collectively **control five percent or more** of stockholder voting shares in my company.

If you answered **"Yes,"** please explain *(in the space below)* the nature of the investment and identify the foreign government(s).

Corporate Level Response Only

	2003	2004	2005	2006	2011*	
1.c Please state the **number of Integrated Circuit fabrication facilities** that your company operated* in the United States for the following years:						**Project the Number of Facilities that your company anticipates operating in the United States in 2011.*
Please state the **number of Integrated Circuit fabrication facilities** that your company operated outside of the United States for the following years:						
Total	0	0	0	0	0	

1.d *Instruction:* Please specify the industry sectors that your company/facility serves through the provision of design and/or manufacturing services for Integrated Circuit products located in the United States:

(Select "Yes" or "No")

Aviation systems/Avionics		Telecommunications		**Comments:**
Automotive		Military and Space		
Consumer electronics		Other National Security systems		
Electronic Data Processing		Other *[specify in comments]*		
Industrial				

DEFINITIONS OF TERMS USED IN SURVEY

APPLIED RESEARCH – Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met. This activity includes work leading to the production of useful materials, devices and systems or methods, including design development and improvement of prototypes and new processes.

BASIC RESEARCH – Systematic, scientific study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts.

CAPITAL EXPENDITURES – Investments made by a company in buildings, equipment, property, and systems where the expense is depreciated. This does not include expenditures for consumable materials, other operating expenses and salaries associated with normal business operations.

DEVELOPMENT – The design, development, simulation, or experimental testing of prototype or experimental hardware or systems, to validate technological feasibility or concept of operation, to reduce technological risk, or to provide test systems prior to production approval.

DESIGN – Design activity required to implement a product concept in support of the manufacture of the Integrated Circuit product at a fabrication facility.

INTEGRATED CIRCUIT – Analog or digital devices that incorporate transistors, diodes, capacitors, resistors, and other circuit elements that are integrated on a single substrate (chip), typically silicon.

MANUFACTURING – The production of a working Integrated Circuit product in a fabrication facility.

NEUTRON HARDENED – Integrated Circuit products incorporating design features and/or physical characteristics that can withstand the damaging effects of high-speed neutrons, gamma rays, and electromagnetic pulses that accompany a nuclear weapons detonation. Most CMOS[1] technologies are inherently neutron hardened without any specific effort on the part of an ICs designer/manufacturer. For “minority carrier” IC devices that are affected by neutron-induced displacement damage, a level of $1X10^{14}$ n/cm2 (1MeV equivalent fluence) is the accepted standard.[2]

ORGANIZATION — A company, firm, laboratory, or other entity that owns or controls one or more U.S. establishment capable of designing and/or manufacturing Integrated Circuit products. A company may be an individual proprietorship, partnership, joint venture, or corporation *(including any subsidiary corporation in which more than 50 percent of the outstanding voting stock is owned by a business trust, cooperative, trustee(s) in bankruptcy, or receiver(s) under decree of any court* owning or controlling one or more establishment.

PRODUCT DEVELOPMENT – Conceptualization and development of an Integrated Circuit product prior to the production of IC product for customers.

Continued on Next Page

RADIATION HARDENED – Integrated Circuit products incorporating design features and/or physical characteristics that demonstrate a capability to resist radiation-induced damage from industrial sources, electromagnetic pulses, weapons systems; and/or charged particles in space that can damage circuitry and render a device inoperable. Some IC devices may be considered radiation hardened when their *total dose failure level* exceeds >300 krad.[3] A *total dose failure level* of 500krad is the standard cited in International Traffic in Arms (ITAR) regulations.[4]

RADIATION TOLERANT – Integrated Circuit products incorporating design features and/or physical characteristics with limited capability to resist radiation induced damage from industrial sources, electromagnetic pulses, industrial sources, weapons systems, and charged particles in space that can damage circuitry and render a device inoperable. Radiation tolerant would cover parts having a total dose failure level >100 krad but less than 300 krad.

RESEARCH AND DEVELOPMENT – Basic and applied research in the engineering sciences, as well as design and development of prototype products and processes.

S**EMICONDUCTOR** – Elemental materials such as silicon and germanium (or compounds like gallium arsenide) that possess levels of electrical conductivity that are less than a conductor but greater than an insulator. The properties of these materials and similar ones can be manipulated to affect conductivity through temperature and/or the use of dopants.

SINGLE-EVENT EFFECTS RESISTANT – Single-event effects caused by a single energetic particle striking an Integrated Circuit (IC) device. Performance of the IC device is not compromised to a point where it is inoperable or not reliable for executing a mission as a result of latch-up, burnout, or gate rupture.

TRUSTED ACCESS PROGRAM – A program implemented by the National Security Agency and the Defense Microelectronics Activity (DMEA) to qualify Integrated Circuit design and manufacturing companies as “trusted” suppliers of application specific Integrated Circuit (ASIC) products required for national security applications.

WAFER STARTS PER WEEK – The number of semiconductor wafers that can be processed by an Integrated Circuit on production line(s) in a 7-day period.

UNITED STATES – The term “United States” includes the fifty states, Puerto Rico, the District of Columbia, the island of Guam, Trust Territories, and the Virgin Islands.

[1] Complimentary metal oxide semiconductor (CMOS) is a class of semiconductor used in digital logic circuits employed in microcontrollers, microprocessors, memory, and other devices. The technology also is used in analog circuits in sensors, transceivers, data converters and other systems.

[2] Sandia National Laboratories. A minority carrier device is a device in which current is conducted by charge carriers of sign (positive or negative) opposite to the dopant polarity of the underlying semiconductor material. In other words, current carried by electrons (negative) in a p-type semiconductor, or by holes in an n-type semiconductor. In semiconductors, minority charge carriers are less abundant than majority charge carriers. Minority carrier devices: Bipolar junction transistors, charge-coupled devices (CCDs), solar cells.

[3] Sandia National Laboratories.

[4] ITAR Part 121 – The United States Munitions List (See *www.pmddtc.state.gov/consolidated_itar.htm*. [Microelectronic circuits are considered radiation hardened when they exceed all five of these standards: (1) Total dose of $5x10^5$ Rads (Si); (2) Dose rate upset of $5x10^8$ Rads (Si) per second; (3) Neutron dose of $1x10^{14}$ N/cm^2; (4) Single-Event upset of $1x10^{minus;7}$ or less error/bit/day; and (5) Single-Event latch-up free and having a dose rate latch-up of $5x10^8$ Rads (Si) per second or greater.]

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Section 2 **Integrated Circuit Design & Manufacturing General Information - U.S.-Based**

2.a *Instruction:* Please list the Integrated Circuit product **Design** and **Manufacturing** market types and capabilities of your company/organization in the United States in calendar year 2006. Check the appropriate boxes that describe the (1) function(s) carried out; and (2) product classes.

Include design and manufacturing facilities used to produce Radiation Tolerant, Radiation Hardened, Neutron Hardened, and Single-Event Effects resistant Integrated Circuit products.

Design and Manufacturing Facility Market Types and *Capabilities*

	(Check all that apply -- A blank response is counted as "No capability")														
Facility Type? →															
Product Capabilities	**Conventional Integrated Circuit Products**			**Single-Event Effects Resistant**			**Radiation Tolerant**			**Radiation Hardened**			**Neutron Hardened**		
Product Classes	Commercial	Industrial	Military	Commercial	Industrial	Military	Commercial	Industrial	Military	Commercial	Industrial	Military	Commercial	Industrial	Military
Yes or No? →															

Comments:

Section 2 **Integrated Circuit Design & Manufacturing - *Continued***

2.b *Instruction:* For the market types and capabilities identified in Question **2.a**, please specify your design and manufacturing capabilities that reside **in the United States**:

Minimum Technology Node Capability [nanometers]	-- by Wafer Size	Capability to Design and/or Manufacture - by Technology Node, Wafer Size & Material Type (Select all that apply -- A blank response is counted as "No Capability")												
		Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphate	Antimonides	Amorphous Silicon	MEMS* Technologies	Organic Technologies	Carbon Based Technologies
10,000 - 6,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
6,000 - 3,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
3,000 - 1,500	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
1500 - 1,000	2- or 3-inch													
	4-inch													
	6-inch													

	8-inch													
	12-inch													
1,000 - 800	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
800 - 500	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
500 - 350	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
350 - 250	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
180 - 130	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													

130 - 90	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
90 - 65	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
65 - 45	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
45 - 32**	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
32 or less**	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													

Note: 10,000 nanometers equals 10 micrometers. *Micro Electro-Mechanical Systems (MEMS) **Respond to this specification if your company expects to develop a capability to work at this Technology Node by 2011.

Section 2 **Integrated Circuit Design & Manufacturing - *Continued***

2.c *Instruction:* Please specify your company's/facility's design and manufacturing capabilities by **material type** with regard to the production of Integrated Circuit products in the United States:

DEVICE TYPES	Material Type	Capability to Design and/or Manufacture - by Device & Material Type *(Select all that apply -- A blank response is counted as "No capability")*												
		Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphate	Antimonides	Amorphous Silicon	MEMS Technologies	Organic Technologies	Carbon Based Technologies
Field Programmable Gate Arrays														
One-time, Electrically Programmable Gate Arrays														
Mask Programmable Gate Arrays														
Structured ASICs [a.k.a. Structured Arrays; Platform ASICs]														
Standard Cell ASICs [a.k.a. cell-based ASICs]														
Custom ASICs														
Mixed Signal Technologies														
Digital Signal Processors														
Nonvolatile Memory														
SRAM														
DRAM														
Microprocessors/Coprocessors														
IR*-Focal Plane Arrays														
Anti-Tamper Technology														
MMIC** Technologies														
Display Electronics														

IR=Infrared** ****MMIC= Monolithic Microwave Integrated Circuit

2.d ***Instruction:*** Please specify your company's/facility's **design capabilities** with regard to the production of specific types of **Nonvolatile Memory products** located in the United States:

Note: Do not complete this page if your company/facility does not design Nonvolatile Memory products. Proceed to Section 3

Memory Device Type	Capability to Design Nonvolatile Memory - by Device, Density, Read-Write Speed												
	Memory Density — *Select all that apply - A blank response is counted as "No capability"*						**Read Time** [Nano Seconds (ns)] — *Select all that apply -- A Blank response is counted as "No capability"*					**Write/Erase** — *[Please provide specifications]*	
												Size	**Time**
	<1 Mbit	**1-8 Mbit**	**16-32 Mbit**	**64-128 Mbit**	**256-1024 Mbit**	**>1 Gbit**	**<10ns**	**10-20ns**	**20-50ns**	**50-150ns**	**>150ns**	*Specify data size: Word, page, black, etc.*	*(Write in Spec.)*
Erasable Programmable Read-Only Memory (EPROM)													
Electrically Erasable Programmable Read-Only Memory (EEPROM)													
Flash													
Ferro Electric (FeRAM)													
Magnetoresistive (MRAM), (RRAM)													
MEMS-base (nanotube, NRAM)													
Phase Change Memory (PCM, a.k.a. PRAM)													
Polymer													
Super Permanent Memory (XPM)													
Zero Capacitor (ZRAM)													
Other *(Specify)*													
Other *(Specify)*													

Section 2 **Integrated Circuit Design & Manufacturing - Non-Volatile Memory Devices - *Continued***

2.e *Instruction:* Please specify your company's/facility's **manufacturing capabilities** with regard to the production of specific types of **Nonvolatile Memory products** in the United States:

Note: Do not complete this page if your company/facility **does not manufacture** Nonvolatile Memory products. Proceed to **Section 3**

Capability to Manufacture Nonvolatile Memory - by Device, Density, Read-Write Speed

Memory Device Type	Memory Density (Select all that apply - A blank response is counted as "No capability")						Read Time [Nano Seconds (ns)] (Select all that apply -- A Blank response is counted as "No capability")					Write/Erase [Please provide specifications]	
	<1 Mbit	1-8 Mbit	16-32 Mbit	64-128 Mbit	256-1024 Mbit	>1 Gbit	<10ns	10-20ns	20-50ns	50-150ns	>150ns	Size: *Specify data size: Word, page, black, etc.*	Time: *(Write in Spec.)*
Erasable Programmable Read-Only Memory (EPROM)													
Electrically Erasable Programmable Read-Only Memory (EEPROM)													
Flash													
Ferro Electric (FeRAM)													
Magnetoresistive (MRAM), (RRAM)													
MEMS-base (nanotube, NRAM)													
Phase Change Memory (PCM, a.k.a. PRAM)													
Polymer													
Super Permanent Memory (XPM)													
Zero Capacitor (ZRAM)													
Other *(Specify)*													
Other *(Specify)*													

Section 3 Rad Tolerant, Rad Hardened, Neutron Hardened Design & Manufacturing

3.a With regard to **radiation-tolerant**, **radiation-hardened** and **neutron-hardened** Integrated Circuits, my company/facility:

Select all that apply. (A blank response is counted as "No" capability and/or "No" interest.)

	Designing		Manufacturing*	
Currently **has capabilities** and **is now providing** in the following areas:	Radiation Tolerant		Radiation Tolerant	
	Radiation Hardened		Radiation Hardened	
	Neutron Hardened		Neutron Hardened	
	Single-Event Effects Resistant		Single-Event Effects Resistant	
Is **NOT now engaged** in this activity, but has previous experience in the following areas:	**Designing**		**Manufacturing***	
	Radiation Tolerant		Radiation Tolerant	
	Radiation Hardened		Radiation Hardened	
	Neutron Hardened		Neutron Hardened	
	Single-Event Effects Resistant		Single-Event Effects Resistant	
If called upon by the U.S. Government, ***would be interested*** in:	**Designing**		**Manufacturing***	
	Radiation Tolerant		Radiation Tolerant	
	Radiation Hardened		Radiation Hardened	
	Neutron Hardened		Neutron Hardened	
	Single-Event Effects Resistant		Single-Event Effects Resistant	

*Company/facility possesses manufacturing process technology to achieve radiation tolerance, hardening, or neutron hardening.

Section 3 **Rad Tolerant, Rad Hardened, Neutron Hardened IC Design & Manufacturing**

3.b *Instruction:* Please identify your company's/facility's capabilities to design and/or manufacture custom Integrated Circuit products that are **radiation-tolerant, radiation-hardened, neutron hardened, and/or Single-Event effects resistant** at locations in the United States.

Capability to Design and/or Manufacture - by Technology Node, Wafer Size & Material Type

(Select all that apply - A blank response is counted as "No capability")

Radiation Tolerant →														
Radiation Hardened →														
Neutron Hardened →														
Single-Event Effects Resistant →														

(Select all that apply - A blank response is counted as "No capability")

Minimum Technology Node Capability [nanometers]	**-- by Wafer Size**	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphate	Antimonides	Amorphous Silicon	MEMS Technologies	Organic Technologies	Carbon Based Technologies
10,000- 6,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
6,000 - 3,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													

3,000- 1,500	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
1,500 - 1,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
1,000- 800	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
800 - 500	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
500- 350	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
350 - 250	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
250- 180	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													

	12-inch													
180 - 130	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
130- 90	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
90 - 65	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
65- 45	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
45 – 32**	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
32** or less	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													

*Note: 10,000 nanometers equals 10 micrometers *Respond to this specification if your company expects to develop a capability to work at this Technology Node by 2011.*

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

Section 3 **Rad Tolerant, Rad Hardened IC Design & Manufacturing - Devices & Materials**

3.c *Instruction:* Please specify your company's/organization's design and manufacturing capabilities by device type with regard to the production of custom **radiation-tolerant, radiation-hardened,** and **neutron hardened** Integrated Circuit products located in the United States:

Capability to Design and/or Manufacture - by Device & Material Type

(Select all that apply -- A blank response is counted as "No capability")

Type of Device ↓	Radiation Tolerant	Radiation Hardened	Neutron Hardened	Single-Event Effects Resistant	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphate	Antimonides	Amorphous Silicon
Field Programmable Gate Arrays														
One-time, Electrically Programmable Gate Arrays														
Mask Programmable Gate Arrays														
Structured ASICs [a.k.a. Structured Arrays; Platform ASICs]														
Standard Cell ASICs [a.k.a. cell-based ASICs]														
Custom ASICs														
Mixed Signal ASICs														
Digital Signal Processors														
Nonvolatile Memory														
SRAM Memory														
DRAM Memory														
Processors														
IR Focal Plane Arrays														
Anti-Tamper Technology														
MMIC Technologies														

Display Electronics														

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

Section 4 **Manufacturing Capabilities & Production Rates**

4.a *Instructions:* Specify the ***maximum*** Wafer Start capacity **per** **week** of your organization/facility in 2007 in the United States by **circuit technology node**, **wafer size**, and **material type**.

Note: Assumes 7-day a week operations.

Wafer Starts Per Week by Circuit Technology Node, Wafer Size & Material Type

(State your wafer-start-per-week capacity -- A blank response is counted as "No capability")

Technology Node Capability [nanometers]	**-- by Wafer Size**	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphate	Antimonides	Amorphous Silicon	MEMS Technologies	Organic Technologies	Carbon-Based Technologies
10,000* - 6,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
6,000 - 3,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
3,000 - 1,500	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													

1,500* - 1,000	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
1,000 - 800	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
800 - 500	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
500* - 350	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
350 - 250	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
250 - 180	2- or 3-inch													
	4-inch													

	6-inch													
	8-inch													
	12-inch													
130 - 90	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
90 - 65	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
65 - 45	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
45** - 32	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													
	12-inch													
32** or less	2- or 3-inch													
	4-inch													
	6-inch													
	8-inch													

	12-inch													

Note: 10,000 nanometers equals 10 micrometers *Respond to this specification if your company expects to develop a capability to work at this Technology Node by 2011.

Section 4 **U.S.-Based Manufacturing Facility Utilization & Availability**

4.b Please (1) state the average **manufacturing capacity utilization rates** at your U.S. -based fabrication facility for the years 2003-2006. Then, (2) state the **maximum number of wafer starts possible per week** at your manufacturing facility; (3) state the **actual average wafer starts per week** at your facility; and (4) indicate whether this facility will be operating through 2011.

Average Manufacturing Capacity Utilization Rates				**2007 Maximum number** of Wafer Starts Per Week*	**2007 Average Actual** Wafer Starts Per Week**	***Will this Facility Operate Through 2011?***
2003%	**2004%**	**2005%**	**2006%**			

****Normalized to 8-inch wafer equivalents. **Assumes 7-days-a-week operations.***

Section 4 **Mask Blank Supply Practices, Inventory, & Outlook - 2006 -- *Continued***

4.c Instruction: **Complete this page only** if your company/organization has captive, in-house IC mask-making capability located in the United States that supports IC manufacturing activities, or that could be used to support IC manufacturing.

Binary Mask Blanks				***Phase-Shift Mask Blanks***			
What *percent* of your Company's/Organization's **binary mask requirements** are fulfilled by mask production performed: →		***In-House***	***by External Mask Makers***	What percent of your Company's/Organization's **phase-shift mask requirements** are fulfilled by mask production performed: →		***In-House***	***by External Mask Makers***
Average Number of Binary Mask Blanks in Inventory				Average Number of Phase-Shift Mask Blanks in Inventory			
% of Binary Mask Blank Inventory Used Monthly				% of Phase-Shift Blank Inventory Used Monthly			
Shelf Life - Binary Mask Blanks *(Weeks)*				Shelf Life - Phase-Shift Mask Blanks *(Weeks)*			
Cycle time for delivery of mask blanks from day of order. *(Weeks)*				Cycle time for delivery of mask blanks from day of order *(Weeks)*			
Percent of Company/Organization Integrated Circuit Manufacturing activity utilizing Binary Mask Blanks				Percent of Company/Organization Integrated Circuit Manufacturing activity utilizing Phase-Shift Mask Blanks			
Percent of Company's/Organization's Manufacturing Business that will require Binary Mask Blanks in 2011* *(Projected)*				Percent of Company's/Organization's Manufacturing Business that will require Phase-Shift Blanks in 2011* *(Projected)*			
Number of Suppliers Your Company/Organization Uses				Number of Suppliers Your Company/Organization Uses			
% of Total	**Supplier Names**	**Country**	**City**	**% of Total**	**Supplier Names**	**Country**	**City**

Section 4 **Mask Blank Supply Practices, Inventory, & Outlook - 2006 --** *Continued*

4.c Instruction: **Complete this page only** if your company/organization has captive, in-house IC mask-making capability located in the United States that supports IC manufacturing activities, or that could be used to support IC manufacturing.

Binary Mask Blanks			***Phase-Shift Mask Blanks***		
Does your company purchase its mask blanks directly from:	Binary Mask Blank Manufacturer	Binary Mask Blank Distributor	Does your company purchase its mask blanks directly from:	Phase-Shift Mask Blank Manufacturer	Phase-Shift Mask Blank Distributor
Does your company/organization currently have problems obtaining:	Adequate numbers of binary mask blanks	Timely delivery of binary mask blanks	Does your company/organization currently have problems obtaining:	Adequate numbers of phase-shift mask blanks	Timely delivery of phase-shift mask blanks
Is your company/organization at a competitive disadvantage due to limited supply of binary mask blanks?			Is your company/organization at a competitive disadvantage due to limited supply of phase shift mask blanks?		
Is your company/organization concerned about future availability and timely supply of mask blanks?			Is your company/organization concerned about future availability and timely supply of mask blanks?		
Does your mask blank supplier operate a Just-In-Time manufacturing process?			Does your company maintain a month or more supply of mask blanks?		
Is there a need to establish a capability to fabricate phase shift mask blanks in the United States?					

ATTENTION: If this is an **individual facility response** to the survey [not a corporate response], please **proceed to Section 11**, the CERTIFICATION Page. Facility managers **should not complete** Sections 5-10.

If this is a **corporate-level response**, please proceed to fill out **Sections 5 - 10 and the Certification Page (Section 11)**.

***Select the appropriate link below*:**

Individual Facility Response | Corporate-Level Response

Instruction: Questions in Section 5 are to be completed by **corporate offices.** Facility managers **should not complete** these sections**.**

Section 5 Interest and Capability to Supply Products for National Security

5.a Design Services

What percent of your company's/organization's U.S.-based Integrated Circuit design capacity* was utilized to help produce national security-related products in 2007?	%
What percent of your company's/organization's U.S.-based Integrated Circuit design capacity would you be willing to make available for, or otherwise commit to future national security-related work assuming fair cost and profit?	%
What percent of your company's/organization's foreign-based design capacity was utilized to perform U.S. national security-related work in 2007?	%

5.b Manufacturing Services

What percent of your company's/organization's U.S.-based manufacturing capacity* was utilized to help produce national security-related products in 2007?	%
What percent of your company's/organization's U.S.-based manufacturing capacity would you be willing to make available for, or otherwise commit to future national security-related work assuming fair cost and profit?	%
What percent of your company's/organization's foreign-based manufacturing capacity was utilized to perform U.S. national security-related work in 2007?	%

Comments:

**** Capability to perform design work***

Section 5 Interest in Certification in the Trusted Access Program - Continued

5.c Does your company/organization have in place today an **ability to design custom Integrated Circuit products in a trusted environment** located in the United States that conforms to **Department of Defense standards** for the conduct of such work?	
5.d Does you company/organization have in place today an **ability to manufacture custom Integrated Circuit products in a trusted environment** located in the United States that conforms to **Department of Defense standards** for the conduct of such work?	
5.e Has your company/organization been **certified** by DOD's Trusted Access Program Office at the National Security Agency, or by the Defense Microelectronics Activity (DMEA) as a 'trusted' supplier of Integrated Circuit products?	
5.f Is your company/organization **seeking**, or **planning to seek**, certification by DOD's Trusted Access Program Office at the National Security Agency, or by the Defense Microelectronics Activity as a 'trusted' supplier of Integrated Circuit products?	

5.g If your company/organization is **not seeking** or **not planning to seek** certification, please explain why in the space provided below.

Explanation:

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Section 5 Interest in Certification in the Trusted Access Program - Continued

5.h ***Instruction:*** If you answered "**Yes**" to Question 5.e or 5.f, please identify the **manufacturing** and/or **design facilities** for which (1) certification has been awarded, or (2) the facilities for which certification is being sought or may be sought.

If you answered "No" to Questions 5.e or 5.f, please proceed to the next survey page (5.i).

Facility Name(s)	City	State	Awarded Certification	Seeking Certification	Planning to Seek Certification

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Section 5 Outlook on Future Capability to Supply IC Products for U.S. National Security

Types of Devices

5.i ***Instruction:*** Please identify those Integrated Circuit product areas where your company's/organization's **design capabilities** in the United States are most likely to diminish or cease over the next five years:

(Select all that apply)

	Field Programmable Gate Arrays		Structures ASICs [a.k.a. Structured Arrays]		Mixed Signal ASICs		SRAM Memory
	One-time, Electrically Programmable Gate Arrays		Standard Cell ASICs [a.k.a. cell-based ASICs]		Digital Signal Processors		Processors
	Mask Programmable Gate Arrays		Custom ASICs		Nonvolatile Memory		MMIC Technologies
	IR-Focal Plane Arrays		Anti-Tamper Technology		DRAM Memory		Display Electronics

Types of Devices

5.j ***Instruction:*** Please identify those Integrated Circuit product areas where your company's/organization's **manufacturing capabilities** in the United States are most likely to diminish or cease over the next five years:

(Select all that apply)

	Field Programmable Gate Arrays		Structures ASICs [a.k.a. Structured Arrays]		Mixed Signal ASICs		SRAM Memory
	One-time, Electrically Programmable Gate Arrays		Standard Cell ASICs [a.k.a. cell-based ASICs]		Digital Signal Processors		Processors
	Mask Programmable Gate Arrays		Custom ASICs		Nonvolatile Memory		MMIC Technologies
	IR-Focal Plane Arrays		Anti-Tamper Technology		DRAM Memory		Display Electronics

5.k ***Instruction:*** Please describe, if applicable, the primary factors contributing to any projected decline in your company's/organization's manufacturing capability in the United States:

Section 6 Performance of Production Functions for the Manufacture of Integrated Circuits

Instruction: Questions in Section 6 are to be **completed by corporate offices.** Facility managers **should not complete** these sections**.** *Answer the questions on this page **ONLY** if your company/organization **operates fabrication facilities** in the United States to produce Integrated Circuit products.* *If your company does not operate Integrated Circuit manufacturing facilities in the United States, please proceed to… ……… Section 7.* ***(Select all that apply)*** →	Mask Making	Wafer Manufacturing *(Front End)*	Wafer Manufacturing *(Back End)*	Wafer Sorting	Circuit Test	Packaging	Final Test & Inspection	Other *(Specify Here)*	Other *(Specify Here)*
6.a My company/organization in 2007 ***was capable*** of performing the following Integrated Circuit manufacturing steps at facilities in the United States that it owns and operates:									
6.b My company/organization in 2007 ***was not capable*** of performing the following Integrated Circuit manufacturing steps at its own facilities in the United States. However, we employed other U.S.-based vendors to complete the following tasks at their facilities in the United States:									
6.c My company/organization anticipates for the **2008-2011** period that ***it will retain capability*** to perform the following Integrated Circuit Manufacturing Steps at facilities in the United States that it owns and operates:									
6.d My company/organization for the **2008-2011** period ***does not anticipate being capable*** of performing the following Integrated Circuit manufacturing steps at its own facilities in the United States - but will secure other U.S.-based vendors to complete these Manufacturing Steps at their facilities in the United States.									

Section 6 Performance of Production Functions for the Manufacture of Integrated Circuits - *Continued*

Instruction: Answer the questions on this page **ONLY** if your company/organization **operates fabrication facilities** in the United States to produce Integrated Circuit products. If your company does not operate Integrated Circuit manufacturing facilities in the United States, *please* ***proceed to*** *Section 7.* ***(Select all that apply)*** →	Mask Making	Wafer Manufacturing *(Front End)*	Wafer Manufacturing *(Back End)*	Wafer Sorting	Circuit Test	Packaging	Final Test & Inspection	Other *(Specify Here)*	Other *(Specify Here)*	Other *(Specify Here)*	Other *(Specify Here)*
6.e Between 2007 and 2011, my company/organization expects that its use of outsourcing for the following Manufacturing Steps will:											
6.f Between 2007 and 2011, my company's/organization's capabilities to perform the following Manufacturing Steps at facilities in the United States will:											
6.g My company/organization **outsources** the following Integrated Circuit Manufacturing Steps to facilities located **outside of the United States** that it owns and operates.											
6.h My company **outsources** the following Integrated Circuit Manufacturing Steps to facilities located **outside of the United States** that are owned and/or operated by non-affiliated foreign companies.											
Technology Node [Nanometers]											
6.i My company/organization **outsources** outside of the United States one or more of the seven Integrated Circuit Manufacturing Steps *cited at the top of this page* for products built with the following minimum Technology Nodes:		10,000-6,000		1,500-1,000		500-350		180-130		65-45	
		6,000-3,000		1,000-800		350-250		130-90		45-32	
		3,000-1,500		800-500		250-180		90-65		32 or less	

Section 6	**Performance of Production Functions for the Manufacture of Integrated Circuits - *Continued***							
6.j The primary reasons why my company/organization outsources outside of the United States one or more of the following Manufacturing Steps cited at the top of this page are: *(Please provide Yes/No response to all that apply.)*	No U.S. capability		No U.S. *contractor* found		Insufficient *U.S.* workforce			
	Foreign government subsidies - *Direct*		Foreign government subsidies - *Indirect*		*Lack* of tax/financial incentives to produce in the United States			
	Lower costs		To assure better market *access*		Competitive *pricing* pressures			
	Maximize profit		To better *serve* offshore markets		Other *(Please Specify)*			
6.k In the space provided, please identify the countries to which your company/organization outsources one or more of the Manufacturing Steps identified above:								

***INSTRUCTION**: If your company outsources any of the production steps listed above to locations outside of the United States, then your company must complete the Next Page of Section 6.*

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Section 6 **Performance of Production Steps for the Manufacture of Integrated Circuits - *Continued***

6.I INSTRUCTION: Please specify the characteristics of the IC products for which ***your company outsources*** Fabrication Steps.

If your company does not operate Integrated Circuit manufacturing facilities in the United States, please proceed to Section 7.

Outsourced Production - by Device Type, Material, & Circuit Technology Node

(Select all that apply -- A blank response is counted as "No capability")

Device Type	***Capability***				***Semiconductor Material Types***											***Circuit Technology Node [nanometers]***															
	Radiation Tolerant	Radiation Hardened	Neutron Hardened	Single-Event Effects Resistant	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphide	Antimonides	Amorphous Silicon	Carbon Based Technologies	10,000 - 6,000	6,000 - 3,000	3,000 - 1,500	1,500 - 1,000	1,000 - 800	800 - 500	500 - 350	350 - 250	250 - 180	180 - 130	130 - 90	90 - 65	65 -45	45 - 32	32 or less
Field Programmable Gate Arrays																														
One-time, Electrically Programmable Gate Arrays																														
Mask Programmable Gate Arrays																														
Structured ASICs [a.k.a. Structured arrays; Platform ASICs]																														
Standard Cell ASICs [a.k.a. cell-based ASICs]																														
Custom ASICs																														
Mixed Signal ASICs																														
Digital Signal Processors																														
Nonvolatile Memory																														

Section 6 **Performance of Production Steps for the Manufacture of Integrated Circuits – *6L Continued***

6.I INSTRUCTION: Please specify the characteristics of the IC products for which ***your company outsources*** Fabrication Steps.

If your company does not operate Integrated Circuit manufacturing facilities in the United States, please proceed to Section 7.

Outsourced Production - by Device Type, Material, & Circuit Technology Node

(Select all that apply -- A blank response is counted as "No capability")

	Capability				***Semiconductor Material Types***											***Circuit Technology Node [nanometers]***														
Device Type	Radiation Tolerant	Radiation Hardened	Neutron Hardened	Single-Event Effects Resistant	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphide	Antimonides	Amorphous Silicon	Carbon Based Technologies	10,000 - 6,000	6,000 - 3,000	3,000 - 1,500	1,500 - 1,000	1,000 - 800	800 - 500	500 - 350	350 - 250	250 - 180	180 - 130	130 - 90	90 - 65	65 -45	45 - 32	32 or less
SRAM Memory																														
DRAM Memory																														
Processors																														
IR Focal Plane Arrays																														
Anti-Tamper Technology																														
MMIC Technologies																														
Display Electronics																														

Section 7 **Performance of Design Steps for Integrated Circuits**

Instruction: Questions in Section 7 are to be completed by **corporate offices**. Facility managers **should not complete** these sections. *Answer the questions on this page* ***ONLY*** *if your company/organization* ***operates Design Facilities*** *in the United States to produce Integrated Circuit products.* *If your company/organization does not operate Integrated Circuit Design Facilities in the United States, please proceed to* Section 8. *(Select all that apply)*	Digital	Analog	RTL Design*	Synthesis**	Physical Layout***	Functional Verification****	Test Vector Generation*****	Other *(Specify Here)*	Other *(Specify Here)*	Other *(Specify Here)*
7.a My company/organization **is capable** of performing the following Integrated Circuit Design Steps at facilities in the United States that it owns and operates.										
7.b My company/organization **is not capable** of performing the following Integrated Circuit Design Steps at its own facilities in the United States. However, we employ other U.S.-based vendors to complete the following tasks at their facilities in the United States.										
7.c My company/organization anticipates for the 2008-2011 period that **it will retain capability** to perform the following Integrated Circuit Design Steps at facilities in the United States that it owns and operates.										
7.d My company/organization for the 2008-2011 period **does not anticipate being capable** of performing all of the following Integrated Circuit Design Steps at its own facilities in the United States - but we will secure other U.S.-based vendors to complete these Design Steps at their facilities in the United States.										

*Register Transfer Level (RTL) = Starting point for design;
**Synthesis = Automated way of creating a gate level representation;
***Physical layout = generation of Integrated Circuits in graphic data system (GDSII) format (by hand for custom/analog/mixed signal, automated for standard cell);
****Functional Verification = Timing and correctness checks between physical and logical;
*****Test vector generation = Input to test.

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Section 7 — Performance of Design Steps for Integrated Circuits - *Continued*

Instruction: *Answer the questions on this page* ***ONLY*** *if your company/organization* ***operates Design Facilities*** *in the United States to produce Integrated Circuit products.*
If your company/organization does not operate Integrated Circuit Design Facilities in the United States, please proceed to Section 8.

(Select all that apply)

	Digital	Analog	RTL Design*	Synthesis**	Physical Layout***	Functional Verification****	Test Vector Generation*****	Other *(Specify Here)*	Other *(Specify Here)*	Other *(Specify Here)*	Other *(Specify Here)*
7.e Between 2007 and 2011, my company expects that its use of outsourcing for the following Design Steps will:											
7.f Between 2007 and 2011, my company's capabilities to perform the following Design Steps facilities in the United States will:											
7.g My company ***outsources*** the following Integrated Circuit Design Steps to facilities located **outside of the United States** that it owns and operates:											
7.h My company ***outsources*** the following Integrated Circuit Design Steps to facilities located **outside of the United States** that are owned and/or operated by non-affiliated foreign companies:											

7.i In the space provided, please identify the countries to which your company outsources the one or more of the Design Steps identified above:	

INSTRUCTION: ***If your company outsources any of the Design Steps listed above to locations outside of the United States, then your company must complete Question 10 of this survey section.***

****Register Transfer Level (RTL) = Starting point for design;***
*****Synthesis = Automated way of creating a gate level representation;***
******Physical layout = generation of Integrated Circuits in graphic data system (GDSII) format (by hand for custom/analog/mixed signal, automated for standard cell);***
*******Functional Verification = Timing and correctness checks between physical and logical;***
********Test vector generation = Input to test.***

Section 7 **Performance of Design Functions for Integrated Circuits - *Continued***

7.j ***INSTRUCTION:*** Your company indicated on the previous survey page that it outsources one or more of the following Integrated Circuit **Design Steps** to locations outside of the United States. ***Please Specify*** the characteristics of the IC products for which **your company outsources** Design Steps.

Outsourced Design Steps - by Device Type, Material, & Circuit Technology Node

(Select all that apply -- A blank response is counted as "No capability")

	Capability				*Semiconductor Material Types*											*Circuit Technology Node [nanometers]*														
Device Type	Radiation Tolerant	Radiation Hardened	Neutron Hardened	Single-Event Effects Resistant	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphide	Antimonides	Amorphous Silicon	Carbon Based Technologies	10,000 - 6,000	6,000 - 3,000	3,000 - 1,500	1,500 - 1,000	1,000 - 800	800 - 500	500 - 350	350 - 250	250 - 180	180 - 130	130 - 90	90 - 65	65 - 45	45 - 32	32 or less
Field Programmable Gate Arrays																														
One-time, Electrically Programmable Gate Arrays																														
Mask Programmable Gate Arrays																														
Structured ASICs [a.k.a. Structured arrays; Platform ASICs]																														
Standard Cell ASICs [a.k.a. cell-based ASICs]																														
Custom ASICs																														
Mixed Signal ASICs																														
Digital Signal Processors																														
Nonvolatile Memory																														
SRAM Memory																														
DRAM Memory																														

Section 7 **Performance of Design Functions for Integrated Circuits – *7j Continued***

7.j *INSTRUCTION:* Your company indicated on the previous survey page that it outsources one or more of the following Integrated Circuit **Design Steps** to locations outside of the United States. ***Please Specify*** the characteristics of the IC products for which **your company outsources** Design Steps.

Outsourced Design Steps - by Device Type, Material, & Circuit Technology Node

(Select all that apply -- A blank response is counted as "No capability")

	Capability				***Semiconductor Material Types***											***Circuit Technology Node [nanometers]***														
Device Type	Radiation Tolerant	Radiation Hardened	Neutron Hardened	Single-Event Effects Resistant	Bulk Silicon	Silicon on Insulator	Silicon Germanium	Silicon on Sapphire	Gallium Nitride	Silicon Carbide	Gallium Arsenide	Indium Phosphide	Antimonides	Amorphous Silicon	Carbon Based Technologies	10,000 - 6,000	6,000 - 3,000	3,000 - 1,500	1,500 - 1,000	1,000 - 800	800 - 500	500 - 350	350 - 250	250 - 180	180 - 130	130 - 90	90 - 65	65 - 45	45 - 32	32 or less
Processors																														
IR Focal Plane Arrays																														
Anti-Tamper Technology																														
MMIC Technologies																														
Display Electronics																														

Instruction: Questions in Section 8 are to be **completed by corporate offices**. Facility managers should not complete these sections.*

Section 8 FINANCIALS - Income Statement for *Integrated Circuit Business Unit*

8.a *Instructions:* Businesses and organizations that are part of a larger company with non-related business operations should provide an income statement ***only for their Integrated Circuit Business Unit.***

My company/organization operates on a:		*(in Thousands of Dollars, i.e., $12 = $12,000.00)*				
		2003	**2004**	**2005**	**2006**	**2007 (est)**
	Net Sales *(and other revenue)*					
	Cost of goods sold					
	Gross Profit	$ -	$ -	$ -	$ -	$ -
	Selling, general and administration expenses					
	Depreciation					
	Total Operating Expenses	$ -	$ -	$ -	$ -	$ -
	Operating Income	$ -	$ -	$ -	$ -	$ -
	Interest Expense					
	Other non-operating expenses					
	Interest Income					
	Other non-operating income					
	Total Non-Operating Expenses	$ -	$ -	$ -	$ -	$ -
	Income before income taxes	$ -	$ -	$ -	$ -	$ -
	Provision for income taxes					
	Net Income	$ -	$ -	$ -	$ -	$ -

Comments:

****Non-profit laboratories or non-profit RDT&E organizations need not complete Section 8.***

Section 8 FINANCIALS - Income Statement for *Integrated Circuit Business Unit - Cont.*

8.b *Instructions:* Companies/organizations whose sole focus is the design and/or production of Integrated Circuit products should provide an income statement for **Corporate**-wide activities.*

My company/organization operates on a:		*(in Thousands of Dollars, i.e., $12 = $12,000.00)*				
		2003	**2004**	**2005**	**2006**	**2007 (est)**
	Net Sales *(and other revenue)*					
	Cost of goods sold					
	Gross Profit	$ -	$ -	$ -	$ -	$ -
	Selling, general and administration expenses					
	Depreciation					
	Total Operating Expenses	$ -	$ -	$ -	$ -	$ -
	Operating Income	$ -	$ -	$ -	$ -	$ -
	Interest Expense					
	Other non-operating expenses					
	Interest Income					
	Other non-operating income					
	Total Non-Operating Expenses	$ -	$ -	$ -	$ -	$ -
	Income before income taxes	$ -	$ -	$ -	$ -	$ -
	Provision for income taxes					
	Net Income	$ -	$ -	$ -	$ -	$ -

Comments:

Non-profit laboratories or non-profit RDT&E organizations need not complete Section 8.

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Section 8 FINANCIALS - Balance Sheet for *Integrated Circuit Business Unit*

8.c ***Instructions:*** Businesses and organizations that are part of a larger company with non-related business operations, should provide balance sheet data **only for their Integrated Circuit Business Unit.**

			2003	2004	2005	2006	2007 (est.)
Current Assets			***(in Thousands of Dollars, i.e., $12 = $12,000.00)***				
	Cash						
	Marketable securities						
	Accounts receivable, net						
	Inventories						
	Prepaid Expenses						
	Other current assets *(please specify)*						
	Total Current Assets		$ -	$ -	$ -	$ -	$ -
Non-Current Assets			***(in Thousands of Dollars, i.e., $12 = $12,000.00)***				
	Property, facility and equipment*		$ -	$ -	$ -	$ -	$ -
	Instruction: Break out capital expenditures [**Do not double count** PP&E in 'Total Non-Current Assets.']	Property & Land					
		Plant/Buildings					
		Machines & Equipment					
	Less accumulated depreciation						
	Net fixed assets		$ -	$ -	$ -	$ -	$ -
	Investments						
	Intangibles *(patents, trademarks, goodwill)*						
	Other non-current assets *(please specify)*						
	Total non-current assets		$ -	$ -	$ -	$ -	$ -
	Total assets		$ -	$ -	$ -	$ -	$ -
Liabilities and Owners' Equity							

Current Liabilities		(in Thousands of Dollars, i.e., $12 = $12,000.00)				
	Accounts payable					
	Estimated tax liability *(e.g. income taxes payable)*					
	Accrued expenses					
	Long-term debt *(Current portion)* due in one year					
	Other current liabilities *(please specify)*					
	Total current liabilities	$ -	$ -	$ -	$ -	$ -
Non-Current Liabilities		***(in Thousands of Dollars, i.e., $12 = $12,000.00)***				
	Long-term debt *(less current portion)*					
	Deferred income taxes					
	Other long-term liabilities *(please specify)*					
	Total non-current liabilities	$ -	$ -	$ -	$ -	$ -
	Total liabilities	$ -	$ -	$ -	$ -	$ -
Owners' Equity		***(in Thousands of Dollars, i.e., $12 = $12,000.00)***				
	Common stock					
	Additional paid-in capital					
	Total paid-in capital	$ -	$ -	$ -	$ -	$ -
	Retained earnings					
	Less treasury stock *(stock repurchase)*					
	Total owners' equity	$ -	$ -	$ -	$ -	$ -
Total Liabilities and Owners' Equity**		$ -	$ -	$ -	$ -	$ -
Comments:						

*PP&E should be reported at original acquisition cost. ****Attention:** Please report any significant one-time events on the next page of this survey instrument .

Note: Non-profit laboratories or non-profit RDT&E organizations need not complete Section 8.

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Section 8 FINANCIALS - Balance Sheet for *Integrated Circuit Business Unit - Continued*

8.d Reporting of Significant One-Time Events

Year	***Instruction:*** Please provide an explanation of any significant one-time events that would skew assessments of the economic performance of your company/organization.
2003	
2004	
2005	
2006	
2007 (est.)	

Section 8 FINANCIALS - Balance Sheet for *Corporate Parent Operations*

8.e ***Instructions:*** Businesses and organizations that are part of a larger company with non-related business operations, should provide balance sheet data **for corporate-wide activities**

			2003	2004	2005	2006	2007 (est.)
Current Assets			*(in Thousands of Dollars, i.e., $12 = $12,000.00)*				
	Cash		$				
	Marketable securities		$				
	Inventories		$				
	Prepaid Expenses		$				
	Other current assets *(please specify)*		$				
	Total Current Assets		$	$ -	$ -	$ -	$ -
Non-Current Assets			*(in Thousands of Dollars, i.e., $12 = $12,000.00)*				
	Property, facility and equipment*		$	$ -	$ -	$ -	$ -
	Instruction: Break out capital expenditures [**Do not double count** PP&E in 'Total Non-Current Assets.']	Property & Land	$				
		Plant/Buildings	$				
		Machines & Equipment	$				
	Less accumulated depreciation		$				
	Net fixed assets		$	$ -	$ -	$ -	$ -
	Investments		$				
	Intangibles *(patents, trademarks, goodwill)*		$				
	Other assets *(please specify)*		$				
	Total non-current assets		$	$ -	$ -	$ -	$ -
	Total assets		$	$ -	$ -	$ -	$ -
Liabilities and Owners' Equity							
Current Liabilities			*(in Thousands of Dollars, i.e., $12 =*				

		$12,000.00)				
	Accounts payable	$				
	Estimated tax liability *(e.g. income taxes payable)*	$				
	Accrued expenses	$				
	Long-term debt *(Current portion)* due in one year	$				
	Other current liabilities *(please specify)*	$				
	Total current liabilities	$	$ -	$ -	$ -	$ -
Non-Current Liabilities		***(in Thousands of Dollars, i.e., $12 = $12,000.00)***				
	Long-term debt *(less current portion)*					
	Deferred income taxes	$				
	Other long-term liabilities *(please specify)*	$				
	Total non-current liabilities	$	$ -	$ -	$ -	$ -
	Total liabilities	$	$ -	$ -	$ -	$ -
Owners' Equity		***(in Thousands of Dollars, i.e., $12 = $12,000.00)***				
	Common stock					
	Additional paid-in capital					
	Total paid-in capital	$	$ -	$ -	$ -	$ -
	Retained earnings	$				
	Less treasury stock *(stock repurchase)*					
	Total owners' equity	$	$ -	$ -	$ -	$ -
Total Liabilities and Owners' Equity**		$	$ -	$ -	$ -	$ -
Comments:						

* PP&E should be reported at original acquisition cost.

****Attention:** Please report any significant one-time events on the next page of this survey instrument.

Note: Non-profit laboratories or non-profit RDT&E organizations need not complete Section 8.

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Section 8 FINANCIALS - Balance Sheet for *Corporate Parent Operations - Continued*

8.f Reporting of Significant One-Time Events

Year	***Instruction:*** Please provide an explanation of any significant one-time events that would skew assessments of the economic performance of your company/organization.
2003	
2004	
2005	
2006	
2007 (est)	

Instruction: Questions in Section 9 are to be **completed by corporate offices**. Facility managers **should not complete** these sections.

Section 9 Integrated Circuit Product R&D - Expenditures by Function

9.a ***Instructions:*** Companies/organizations whose sole focus is the production of Integrated Circuit products should report **Corporate**-wide R&D expenditure figures for the table below. Those businesses and organizations that are part of a larger company with other non-related business operations should report R&D expenditure figures **only for their Integrated Circuit Business Unit.**

R&D Expenditures Supporting Design and/or Manufacturing Operations
(Corporate or Integrated Circuit Business Unit)

(Thousands of Dollars, i.e., $12 = $12,000.00)

Category	Year →	2003	2004	2005	2006	2007 (est.)
Basic Research						
Applied Research and Development						
Product Development						
Process Development						
	Total R&D	$ -	$ -	$ -	$ -	$ -

Section 9 Integrated Circuit Product R&D - Funding Segmented by Source

9.b ***Instructions:*** Companies/organizations whose sole focus is the production of Integrated Circuit products should report **Corporate**-wide R&D funding figures for the table below. Those businesses and organizations that are part of a larger company with other non-Integrated Circuit related business operations should report R&D funding figures **only for their Integrated Circuit Business Unit**.

R&D Funding Supporting Design and/or Manufacturing Operations
(Corporate or Integrated Circuit Business Unit)

(Thousands of Dollars, i.e., $12 = $12,000.00)

Category	2003	2004	2005	2006	2007 (est.)
Parent Company *(Internal)*					
Total Federal Government					
State and Local Government					
U.S. Private Entity *[includes industry, universities, and all other non-government funding]*					
Foreign Investors *[includes private, industry, governments, and universities]*					
Other (Please Specify)					
Total R&D	$ -	$ -	$ -	$ -	$ -

Comments:

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Section 9 — U.S. R&D Occupational Breakdown

9.c *Instruction:* Please break-out R&D employment.	**Numbers of Employees - Full Time Equivalent***				
Occupation	**2003**	**2004**	**2005**	**2006**	**2007** *Projected*
U.S. Citizens or Green Card Holders:					
Development Staff (e.g., Engineers)					
Research Staff (e.g., Scientists)					
All Other Staff					
Non-U.S. Citizens/Foreign Nationals:					
Development Staff (e.g., Engineers)					
Research Staff (e.g., Scientists)					
All Other Staff					
Total	0	0	0	0	0

**** Full-time equivalent refers to part-time workers, who in the aggregate, work a 35-40 hour work week.***

Section 9 **Integrated Circuit-Related R&D Expenditures 2003-2007 - Top Five Countries**

9.d ***Instructions:*** For years 2003-2007, please state the five top countries *(based on total dollars)* in which your company funded research and development activities.*

Total R&D Expenditures Supporting Design and/or Manufacturing

(Thousands of Dollars, i.e., $12 = $12,000.00)

		Top Five Countries for IC-Related R&D Investment				
Ranking		**2003**	**2004**	**2005**	**2006**	**2007 (est.)**
1	**Country**					
	R&D Expenditure					
2	**Country**					
	R&D Expenditure					
3	**Country**					
	R&D Expenditure					
4	**Country**					
	R&D Expenditure					
5	**Country**					
	R&D Expenditure					

**** Corporate or Integrated Circuit Business Unit***

Section 10 Integrated Circuit-Related Capital Investment

10.a *Instructions:* For years 2003-2007, please break down *(based on total dollars)* your company's capital expenditures **1)** by purpose and **2)** by location (U.S., Non-U.S.) using the five categories provided in the table below.

Expenditures Supporting Design and/or Manufacturing Operations (Corporate or Integrated Circuit Business Unit)

(Thousands of Dollars, i.e., $12 = $12,000.00)

Category	2003		2004		2005		2006		2007 (est.)	
	U.S.	Non-U.S.	U.S.	Non-U.S.	U.S.	Non-U.S.	U.S.	Non-U.S.	U.S.	Non-U.S.
Cost Reduction & Replacement										
Expansion & Improvement of Existing Production lines										
New Products										
Health, Safety and/or Pollution Control										
Other *(Please Specify)*										
Total Capital Expenditures	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Section 10 Integrated Circuit-Related Capital Expenditures 2003-2007 - Top Five Countries

10.b ***Instructions:*** For years 2003-2007, please state the five top countries *(based on total dollars)* in which your company made capital expenditures.

Total Capital Expenditures Supporting Design and/or Manufacturing

(Thousands of Dollars, i.e., $12 = $12,000.00)

		Top Five Countries for IC-Related Investment				
Ranking		**2003**	**2004**	**2005**	**2006**	**2007 (est.)**
1	**Country**					
	Captial Expenditure					
2	**Country**					
	Capital Expenditure					
3	**Country**					
	Capital Expenditure					
4	**Country**					
	Capital Expenditure					
5	**Country**					
	Capital Expenditure					

CERTIFICATION

The undersigned certifies that the information herein supplied in response to this questionnaire is complete and correct to the best of his/her knowledge. It is a criminal offense to willfully make a false statement or representation to any department or agency of the United States Government as to any matter within its jurisdiction. [18 U.S.C.A. 1001 (1984 & SUPP. 1197)]

Company Name

Company's Internet Address

Name of Authorizing Official

Title of Authorizing Official

Email

Phone Number

Ext.

Date

If Point-of-Contact is same as above, select here

Point-of-Contact Name

Title

Email

Phone Number

Ext.

Would you like a copy of the final report?