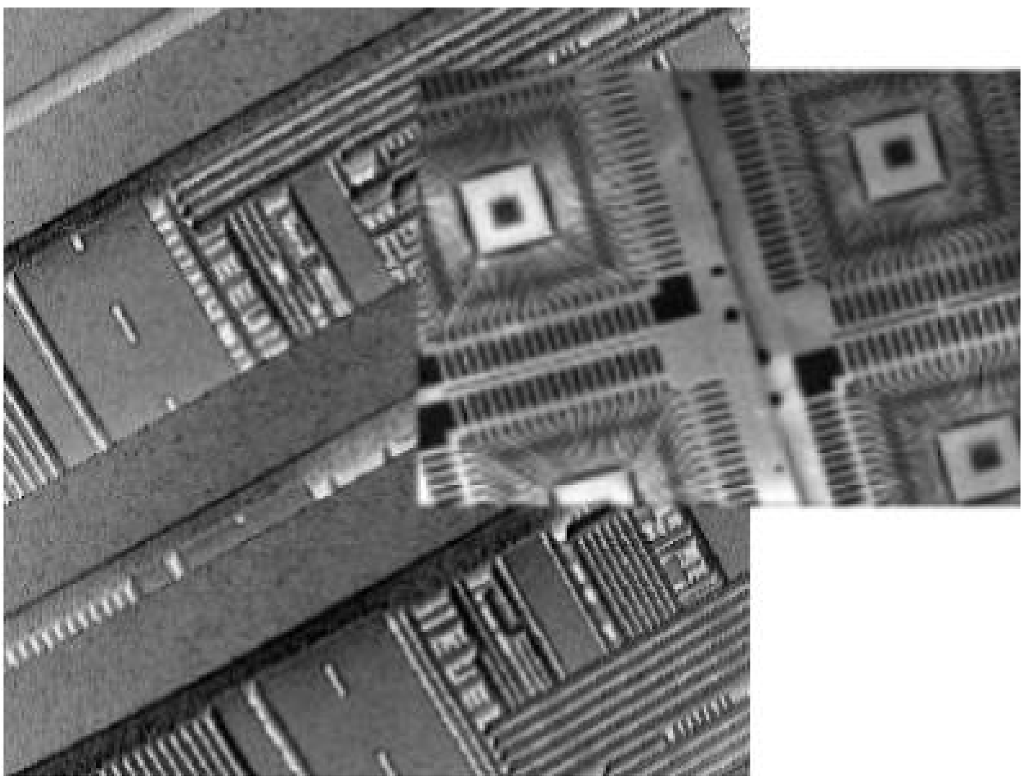
June 2003

White Paper: National Security Aspects of the Global Migration of the U.S. Semiconductor Industry



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Introduction

The U.S. is facing an imminent threat to national security as a result of foreign government actions that have capitalized on the changing composition of the semiconductor industry. Our concern is the loss to the U.S. economy of the high-end semiconductor manufacturing sector, the potential subsequent loss of the semiconductor research and design sectors, and the grave national security implications that this would entail. East Asian countries are leveraging market forces through their national trade and industrial policies to drive a migration of semiconductor manufacturing to that region, particularly China. If this accelerating shift in manufacturing overseas continues, the U.S. will lose the ability to reliably obtain high-end semiconductor integrated circuits from trusted sources. This will pose serious national security concerns to our defense and intelligence communities. Historically, shifts in manufacturing result over time in the migration of research and design capabilities. This is especially true of leading-edge industries such as advanced semiconductor manufacturing, which requires a tight linkage and geographic proximity for research, development, engineering and manufacturing activities. The economic impact in the U.S. of the loss of manufacturing, research and design has equally serious implications.

The Pentagon's Advisory Group on Electron Devices (AGED)[1] has warned that the Department of Defense (DoD) faces shrinking advantages across all technology areas due to the rapid decline of the U.S. semiconductor industry, and that the off-shore movement of intellectual capital and industrial capability, particularly in microelectronics, has impacted the ability of the U.S. to research and produce the best technologies and products for the nation and the war-fighter. This global migration has also been discussed in a recently released National Research Council/National Academy of Sciences report on the U.S. semiconductor industry[2], which details the significant growth in foreign programs that support national and regional semiconductor industries. This support is fueling the structural changes in the global industry, and encouraging a shift of U.S. industry abroad.

Critical National Security Applications

Studies have shown that numerous advanced defense applications now under consideration will require high-end components with performance levels beyond that which is currently available. These cutting-edge devices will be required for critical defense capabilities in areas such as synthetic aperture radar, electronic warfare, and image compression and processing.[3] Defense needs in the near future will also be focused

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[1] C. Kirkpatrick et al, Proceedings of the Advisory Group on Electron Devices (AGED) National Technology Leadership Forum, Microelectronics Case Study, September 24, 2002; Summarized in *Manufacturing and Technology News*, vol. 10, n. 10 (Friday May 16, 2003).

[2] C. Wessner, Ed., *Securing the Future: Regional and National Programs to Support the Semiconductor Industry*, Board on Science, Technology and Economic Policy, National Research Council, 2003.

[3] B. Gilbert et al., "Assessment of Signal Processor Architecture and Integrated Circuit Device Requirements for Computing at the Trillion Device Level (DARPA/ETO Advanced Microelectronics Program, Report 1)", Special Purpose Processor Development Group, Mayo Foundation, 1997. The report lists numerous applications of advanced semiconductor designs and the vital defense needs for chips with performance beyond present capabilities.

on very high performance for missile guidance ("fire and forget"), signal processing, and radiation-hardened chips to withstand the extreme environments of space-based communications and tactical environments.[4] There are profound needs for much more advanced onboard processing capabilities for unmanned aerial vehicles undertaking both reconnaissance and attack missions, for cruise missiles and ballistic missile defense, and for the infrastructure that connects these systems.[5,6] As the military transforms to a "network-centric" force in the future, the DoD's Global Information Grid will demand extremely high-performance computation to overcome the technical barriers to a seamless communication network between terrestrial 24 and 48 color optical fiber and satellite platforms transmitting in 100+ Mbps wireless.[7] Such performance will also be necessary for "last-mile" extremely high-speed connectivity to platforms and to the soldier in the field, as well as for the high-speed encryption requirements for a secure communication system.[8] Intelligence agencies will increasingly need the most advanced chips for very high-speed signal processing and data analysis, for real-time data evaluation, for sensor input and analysis, and for encryption and decryption.[9]

As studies for DARPA have indicated, the next several generations of integrated circuits, which emerge at roughly eighteen-month intervals as predicted by Moore's Law, offer the potential for exponential gains in defense war-fighting capability.[10] It is erroneous to believe that future U.S. war-fighting capability will be derived from chips one or two generations behind current state-of-the-art technology. Many of the integrated circuits and processing platforms that are coming in to use, and which are at the heart of DoD defense strategies, are clearly at the cutting edge in their capabilities.

With the dramatic new capabilities enabled by rapidly evolving chip technologies, DoD and the intelligence agencies will need to be first adopters of the most advanced integrated circuits, and will be increasingly dependant on such chips for a defense and intelligence edge. If the ongoing migration of the chip manufacturing sector continues to East Asia, DoD and our intelligence services will lose both first access and assured access to secure advanced chip-making capability, at the same time that these components are becoming a crucial defense technology advantage. Informed elements of the intelligence community therefore have made clear that relying on integrated circuits fabricated outside the U.S. (e.g. in China, Taiwan and Singapore) is not an acceptable national security option.

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4 J. Egan, Proceedings of the Space Environmental Effects Working Group, NRO, November 4-7 2002.

5 L. Cerny, "Future Air Force Requirements for Receiver and Exciter Component Initiatives on Aerospace Platforms". Proceedings of the DARPA/Defense Science Research Council (DSRC) Conference "National Security Issues Associated with Low Volume Fabrication of Integrated Circuits in High Volume First-Tier Fabrication Facilities", December 4-5 2002.

6 Kirkpatrick, *op.cit*.

7 C3I/CIO [DoD], "Implementing the Global Information Grid Architecture – Power to the Edge", (Jan. 2003).

8 *Ibid*.

9 R. Price, "NSA's Leading Edge Microelectronics Foundry Requirements", Proceedings of the DARPA/DSRC Conference "National Security Issues Associated with Low Volume Fabrication of Integrated Circuits in High Volume First-Tier Fabrication Facilities", December 4-5 2002.

10 Gilbert, "Assessment of Signal Processor…" *op. cit.*

Economic Importance and Changes in the Semiconductor Industry

The influence of the semiconductor industry to the U.S. economy in the last decade is difficult to overstate. The U.S. semiconductor sector currently employs 240,000 people in high-wage manufacturing jobs, and had sales totaling $102 billion in the global market in 2000 (50% of total worldwide sales). In 1999, this sector was the largest value-added industry in manufacturing in the U.S. – larger than the iron, steel and motor vehicle industries combined.[11] The productivity growth in the U.S. in the 1990s was due in significant part to the computer production and advances in information technology that depended on the semiconductor industry.[12] The economic implications of the potential migration of high-end semiconductor chip research, design and manufacturing to off-shore facilities has the potential to cause (and, it could be argued, is already causing) long-term damage to the economic growth of this country, with corresponding national security ramifications.

A fundamental change in the semiconductor industry has been, in very simplified form, that the price to performance curve has reduced revenue in the industry dramatically over the last decade. During the early 1960's, and continuing until about 1994, the compound annual growth rate in revenue of the industry was 16%. From 1994 to the present, the growth rate has been approximately 8%.[13] This situation is combined with the very large costs associated with the development of new 300mm fabrication facilities ("fabs"), as well as the increasing complexity and cost of research and design as the industry must develop methods other than the traditional scaling methods (making all aspects of the chips smaller and smaller) in order to increase performance. These factors, and the current recession, are driving the industry to consolidations. As those consolidations take place, new business models, such as fabless companies and consortia, come into play.

A Process Driven by Government Policy in Reaction to Market Forces

The principal reason that China is becoming a center of semiconductor manufacturing is the effective combination of government trade and industrial policies which have taken advantage of opportunities resulting from market forces and changes in the semiconductor industry. In a sector characterized by rapidly increasing capital costs and the need to have access to large, rapidly growing markets, such as China's, Chinese government policies and subsidies can decisively change the terms of international competition. The impact of these incentives is accentuated as a result of the multi-year recession, which has sharply reduced revenue and increased the competition for markets to absorb the industry's characteristic high fixed costs. Government policies in Taiwan were already drawing new manufacturing capability, as well as tool and equipment makers, to its science and technology park complex. However, in the last two years,

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[11] C. Wessner, "Sustaining Moore's Law and the US Economy", Computing in Science and Engineering, January-February 2003

[12] D. Jorgenson and K. Stiroh, "Raising the Speed Limit: U.S. Economic Growth in the Information Age", in *Measuring and Sustaining the New Economy*, National Research Council, 2002. See also S. Oliner and D. Sichel, "The Resurgence and Growth in the late 1990s: Is Information Technology the Story?" J. Economic Perspectives, v.14, no.4, 2000.

[13] E. Ross, Future Fab Int., Gartner Dataquest 2001

Chinese policy has resulted in a sharp upsurge in construction of fabrication facilities in that country, with plans for a great many more.[14]

The U.S. high-tech industry has been in a recession the last two years, with sharply reduced sales and severe losses. The number of state-of-the-art U.S. chip manufacturing facilities is expected to sharply decrease in the next 3-5 years to as few as 1-2 firms that now have the revenue base to own a 300mm wafer production fab, and likely less than a handful of firms.[15] Although the U.S. currently leads the world semiconductor industry with a 50% world market share, the Semiconductor Industry Association estimates that the U.S. share of 300mm wafer production capacity will be only approximately 20% in 2005, while Asian share will reach 65% (only 10% of this from Japan).[16] The remaining state-of-the-art U.S. chip-making firms face great difficulty in attaining the huge amounts of capital required to construct next-generation fabs. This situation stands in contrast to that in China. To ensure that they develop the ability to build the next-generation fabrication facilities, the Chinese central government, in cooperation with regional and local authorities, has undertaken a large array of direct and indirect subsidies to support their domestic semiconductor industry. They have also developed a number of partnerships with U.S. and European companies that are cost-advantageous to the companies in the short-term. The Chinese government is successfully using tax subsidies (see below) to attract foreign capital from semiconductor firms seeking access to what is expected to be one of the world's largest markets. This strategy, which is similar to that employed by the European Union in early 1990s, is a means of inducing substantial inflows of direct investment by private firms. Indeed, much of the funding is Taiwanese, driven by the tax incentives and their need for market access, especially for commodity products such as DRAMs. The strategy does not rely on cheaper labor, as that is a small element in semiconductor production.

The Chinese are, however, able to increasingly draw on substantially larger pools of technically trained labor as compared to the U.S., from the large cohorts of domestic engineering graduates.[17] Importantly, the output of Chinese universities is supplemented by large numbers of engineers trained at U.S. universities and mid-career professionals who are offered substantial incentives to return to work in China. These incentives for scientists and engineers, which include substantial tax benefits, world-class living facilities, extensive stock options taxed at par value, and other amenities, are proving effective in attracting expatriate labor. They also represent an important new dimension in an accelerating global competition for highly skilled IT labor.[18]

The immediate and most powerful incentives for a highly leveraged industry are the direct and indirect subsidies, including infrastructure needed for state-of-the-art fabs, offered by the government. For example, the Chinese central government has undertaken indirect subsidies in the form of a substantial rebate on the value-added tax (VAT)

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[14] C. Wessner, *Securing the Future… op. cit.*

[15] W.Siegle, Chief Scientist, AMD, "Deconstructing the Computer" citing Gartner,McKinsey analysis, Feb. 28, 2003

[16] Semiconductor Industry Assoc.(D.Hatano), "Fab America – Keeping U.S. Leadership in Semiconductor Technology Strong" pp. 9,15 (citing International Sematech data), May 9, 2003

[17] *Ibid.*

[18] T. Howell, "Competing Programs: Government Support for Microelectronics," in *Securing the Future: Regional and National Programs to Support the Semiconductor Industry*, National Research Council, 2003.

charged on Chinese-made chips.[19] While many believe this is an illegal subsidy under GATT trade rules, the impact of the subsidy on the growth of the industry may well be irreversible before—and if—any trade action is taken. There are a variety of other documented measures adopted by the Chinese government.[20] The development of special government funded industrial parks, the low costs of building construction in China as compared to the U.S., and their apparent disinterest in the expensive pollution controls required of fabrication facilities in the U.S. all represent further hidden subsidies. The aggregate effect of these individual "subsidies" may be only a few tens of percentage points of decrease (literally, only 20-30%) in the manufacturing costs of the chips, but in such a cost-driven industry, this difference appears to play an important role in driving the entire offshore migration process for these critical components. Essentially, these actions reflect a strategic decision and represent a concerted effort by the Chinese government to capture the benefits of this enabling, high-tech industry, and thereby threatening to be a monopoly supplier and thus in control of pricing and supply.

It is therefore important to understand that the current shift in manufacturing capacity to China is not entirely the result of market forces. It is equally important to recognize that even if some residual U.S. manufacturing capacity remains after this large-scale migration takes place, the shift of the bulk of semiconductor manufacturing will severely constrain the ability of the U.S. to maintain high-end research and development capabilities. Such directed government support has proven itself to be a severe threat to U.S. industry. For a variety of reasons, the U.S. government has never been able to provide such coordinated support. The results of this deficit have been devastating. The idea that national governments cannot contribute to the health and direction of such a "consumer based" industry is unfounded, particularly given the national security implications.

A Plan of Action

The stakes are real. The time for the country to react effectively is limited. There are things that can be done. If these steps are taken in a timely fashion, the collective impact of the measures will be more powerful in maintaining reliable first access to high-end semiconductor chip design and manufacturing in the U.S. These could include:

- **Active Enforcement of GATT trade rules**. Currently the Chinese government is providing a 14% rebate on VAT to customers who buy Chinese-made semiconductor chips, essentially providing a large subsidy of their domestic industry in clear violation of GATT rules.[14] Thus, U.S.-made chips would pay a 17% VAT, and Chinese-made chips would pay a 3% VAT. Given the tight price competition of chips and the growing importance of the Chinese chip market, this is a very significant step towards ending U.S. production. It is important to ensure that GATT rules are properly enforced in this instance, and not allow government imposed advantages for foreign competitors to damage U.S. manufacturers. DoD should insist that the U.S.

[19] Letter from the Semiconductor Industry Association to the United States Trade Representative Robert Zoellick, dated December 12, 2002.
[20] T. Howell, "Competing Programs…" *op cit*.

Trade Representative undertake prompt bilateral negotiations to remove these measures.

- **Joint production agreements**. With the current downturn in the high-tech sector, it is probable that many chip manufacturing companies will be unable to acquire the necessary capital to invest in the $3+ billion required for new 12-inch wafer advanced chip fabrication facilities, which are radically increasing in cost. Title 15 of the U.S. code (sections 4301 through 4305) gives private technology companies facing global competition the ability to enter into joint production ventures with a waiver of certain anti-trust laws. Under this provision, a group of companies could consolidate assets into a small number of chip fabrication plants, which could be jointly run by a cooperative of two to five companies. This cooperative investment in a fab could sharply reduce the risk and cost to each participating firm, and their agreements to purchase chips from the new fab could be the basis to obtain financing. The Department could encourage this kind of venture and offer contracting opportunities to meet DoD's own chip-making needs, thus being an additional guarantor of demand.
- **Business models**. A variety of creative business models exist which can help the Department and intelligence agencies obtain improved access to advanced manufacturing lines. The Department and intelligence agencies can enter into agreements with a number of U.S.-based chip manufacturers within the context of one of these models to the mutual benefit of all parties. DOD should contract with selected U.S. fabs for long-term access, using any one or more types of contractual vehicles (such as "take or pay"). DoD should also direct its aerospace end-users to employ the services of these domestic fabs. While DoD, NSA and NRO are only a very small piece of the semiconductor market, they can still use their residual contracting power to encourage retention of U.S. advanced chip manufacturing in a coordinated way. DoD and the intelligence agencies must pursue this avenue of creative government-industry cooperation, and must do so soon, as time is not on the side of the U.S. industrial base or the U.S. Government. It is important to note, however, that even a much stronger and better coordinated effort in this area alone will not resolve DoD's problems because over time without a strong domestic commercial semiconductor industrial base it will become very difficult for DoD to retain access to state of the art chips. DoD requires an industry with technology leadership, not just its own short term supply fix.
- **Encourage tax incentives for U.S. investment**. As the next generation of chip fabrication facilities can cost at least $3 billion per plant, the manufacturing sector will require assistance in acquiring the investment capital necessary to develop the manufacturing capabilities for cutting edge semiconductor chips. DoD and the intelligence agencies should work with industry and propose targeted tax incentives, possibly in coordination with state and local government financing, to assist in meeting these investment costs. As noted above, these efforts cannot be delayed into the out-years, as time is of the essence.

- **Increase Science and Engineering Graduates**. The unprecedented technical challenges faced by the industry will require technically trained talent to provide solutions to these problems. In order to effectively compete against the concerted effort by the Chinese to capture the semiconductor industry, it will be necessary to counter the growing disparity of trained talent in both physical sciences and engineering between East Asia and the U.S.[21] Incentives need to be created for increasing university student training in these fields, in particular, of students who are U.S. citizens. The training over the past two decades of East Asian students in American universities, who increasingly return to their country of origin, is a partial cause of the present situation. Additionally, efforts need to be undertaken to encourage their retention in the U.S. Overall, DoD should focus on programs that increase the number of science and engineering graduates at the B.S. and M.S. level needed to provide the technical capabilities for the semiconductor industry.
- **Increases in Federal Funds for Research and Development (R&D)**. Levels of federal funding in the U.S. for research on microelectronics have been steadily decreasing, while at the same time, competitors in Asia and Europe have dramatically expanded public support for semiconductor R&D.[22] This decline in U.S. research support is of particular concern because the industry is increasingly addressing extremely complex technical challenges for which no solution is readily apparent. The following points highlight this need for restoration of funding and describe possible steps that could be taken:
    a. DARPA's annual funding of microelectronics research and development – the principle channel of direct federal financial support in this area – has declined since 1999, and is projected to decline further.[23] DoD should consider restoring this funding.
    b. SEMATECH, the private industry partnership with government which was created to help revive the weakened U.S. industry in 1987 through collaborative research and pooled manufacturing knowledge, was provided with government funds of $100 million per year, fully matched by industry funds. Since 1996, SEMATECH has no longer received any government funding. Originally an entirely U.S. endeavor, SEMATECH has now had to become "international" to remain in operation, thereby destroying its original U.S.-centric focus. DoD should consider alternative mechanisms for cooperative R&D efforts with industry in critical research areas.
    c. In the current harsh financial climate of the U.S. high-tech industry, the private sector will not be able to continue an adequate investment in research and development - there have in fact been widespread anecdotal reports of major decreases in R&D efforts in the U.S. commercial electronics industry. The need is developing for processors based on the next generation of silicon chip technology (referred to as the "90 nanometer" generation), and the U.S. could find

[21] C. Wessner, *Securing the Future… op cit.*
[22] *Ibid.*
[23] C. Wessner, *op cit.*, "Sustaining Moore's Law…"

itself without a domestic manufacturing base, as the research for that technology generation should be under way **now**. The area of non-silicon semiconductors, which offer a level of speed performance exceeding that of silicon components, is clearly under-funded. For example, research is needed on nano-electronics, such as alternatives to silicon CMOS through nanotubes and nanowires. This technology will be important for next-generation military communications and radar systems (operating in consort with advanced silicon processor chips). Here too, the DoD must find ways to assist the U.S. non-silicon semiconductor manufacturing base by further encouraging R&D appropriate to DoD requirements.

d. We urge the Department and intelligence agencies to support increased government funding for R&D of advanced chip technologies, and also to support the development of new DoD-specific chip designs within the aerospace industry, which, like the fabs, are losing their capabilities as the chip designs themselves are increasingly conducted overseas. DoD's decades-long role in the support of such research has diminished in recent years. Rejuvenation of this long-standing DoD role in advanced R&D would help to assure that U.S. industry, to the extent that it can be retained, will lead the future shifts to the most advanced chip technology which DoD will need.

- **Cooperative Research Programs**. Programs such as the Focus Research Center Program (FRCP) under the Microelectronics Advanced Research Corporation (MARCO) seek to overcome the growing challenges companies face in advancing microelectronics technologies through government-industry partnerships that focus on cutting-edge research deemed critical to the continued growth of the industry. The government's share of funding (25%) of this cooperative program has been supported through the Government-Industry Co-sponsorship of University Research (GICUR) program within the Office of Secretary of Defense. The funding targets for this program as outlined in the original ramp-up plan have not been met. In fact, this program has been zeroed out of the administration's FY 2004 budget. DoD should ensure that funding levels for this vital area of government-industry collaborative research be properly supported, and that when U.S. universities are the recipients of such funding, the training of U.S. citizens (in contrast to foreign students) is strongly emphasized.
- **Survey of Trade Practices**. DoD should survey all possible technologies that the Chinese government may be targeting for subsidies that would assist in the transfer of U.S. chip-making and related fields to China, and then develop a list of those subsidies that are in violation of GATT trade rules and seek USTR action For those that are not in violation but nonetheless create a competitive "edge" for China, The Department and the intelligence agencies will need to develop counter strategies. . The focus should aim to strengthen the entire electronics and IT "food chain" – from semiconductor manufacturing equipment to semiconductors to computers and systems. This will require broad interagency coordination and cooperation. It would

probably be necessary to form such a "tiger team" immediately, and to provide that team with the authority and resources to act to stem the deterioration of our defense-critical on-shore infrastructure.

- **The Semiconductor Equipment and Materials Industry**. Over the last decade a fair fraction of US semiconductor tooling and equipments capability has migrated off shore. This has been particularly true of the "high technology" end of the business – advanced lithography. The migration has had a significant impact on our ability to guide and direct development in the chip economy as a whole. For example, when ASML (a Dutch firm) took over SVG-L (our last cutting edge lithography stepper supplier) the personnel base at the former SVG-L site, in part because of the recession, was reduced, and some advanced product development shifted to Europe. Along with the sale of SVG-L, Tinsley, an SVG-L subsidiary, which is the world's premier supplier of aspheric optical components widely used in defense surveillance systems, was also conveyed to ASML. Lithography patent battles that could affect sales and services to U.S. chip makers using equipment from either of these companies are continuing.[24] As another example, it is generally accepted throughout the industry that the photomask is a key gating element in semiconductor development today, and that mask development is one of the largest challenges currently facing the industry. The cost of photomask infrastructure development is currently outstripping available R&D resources by a factor of 4 to 5. A recent SEMATECH study indicated the shortfall at approximately $750 million. Outside the U.S., this shortfall is being met with Government sponsored development activities in hopes of taking over the market. A small number of U.S. merchant mask companies are currently spearheading an effort to establish a pre-competitive R&D activity focused on U.S. mask infrastructure development. The need, supported by SEMATECH, includes advanced tool evaluation and development, along with materials, metrology, and standards activities to improve future photomask manufacturing capability. The goal is to accelerate leading edge photomask infrastructure capability on-shore by building on prior and current mask industry investments. DoD should give full consideration to supporting this effort for a U.S. mask consortium. Overall, the "tiger team" should survey and make recommendations on what can be done to stimulate and grow what is left of the on-shore semiconductor equipment industry, including masks and lithography.

Necessity of Comprehensive Action

If DoD and the intelligence agencies lose commercial advanced chip production capability, off of which they have sharply leveraged over the past two decades to greatly reduce their costs and to improve war-fighting capability, the ability to benefit from such cost-saving relationships will be permanently lost. DoD can attempt to achieve temporary solutions, such as building its own next generation government-owned chip fabrication facility, but this is likely to be both expensive and ineffective. If the best research and

[24] United States International Trade Commission, Investigation Number 337-TA-468

design capability shifts to China along with manufacturing, this approach will not work past the next generation or two of semiconductor chip production. In addition, such temporary solutions are not only unworkable over time if the U.S. wishes to retain the best capability that is required for defense and intelligence needs, but will be far more expensive than the solutions proposed above. This is because the opportunity to leverage off the commercial sector (an approach which the DoD and intelligence community rely upon at present) for new advances and cost savings will be lost. The U.S. policy goal should not be to seek to prevent China from obtaining significant chip-making capability in the very near future. That will happen. The issue is whether the U.S. can improve its competitive position and remove unfair distortions in order to retain significant on-shore manufacturing capacity.

Conclusions and Further Action

I believe that a prompt, concerted effort by the defense and intelligence community can reverse this trend of off-shore migration of manufacturing, research and design that is now under way and that will become essentially irreversible if no action is taken in the next few months. I am requesting a report and plan of action from DoD and the intelligence community, based on the steps enumerated above, on how they will act to prevent the national security damage that the loss of the U.S. semiconductor industry will entail.

The loss goes beyond economics and security. What is at stake here is our ability to be pre-eminent in the world of ideas on which the semiconductor industry is based. Much of applied physical science – optics, materials science, computer science, to name a few – will be practiced at foreign centers of excellence. This stunning loss of intellectual capability will impede our efforts in all areas of our society.

I hope that by bringing attention to this matter, we can avoid a potential national security crisis in terms of reliable access to cutting edge technology necessary to the critical defense needs of our country. We are being confronted by one of the greatest transfers of critical defense technologies ever organized by another government and the time for action is overdue.