DSB Task Force on High Performance Microchip Supply

Trusted Foundry Needs of the Department of Defense

DoD and High Performance Microelectronics

- DoD has become dependent upon high performance microelectronics as its “force multiplier” –
  - Modern weapons, communications, intelligence, space and support systems all rely on complex microelectronics components to handle complex computational and communications tasks
  - Some microelectronics components are “mission-critical” and/or contain classified design elements. Such chips are susceptible to subversion by adversaries. Additionally, component lifetimes depend on subtle process parameters
  - Some system-critical chips are the hardest to obtain. They require leading edge processes, quick response and low manufacturing volume over long system lives.
- Early in the life of the IC industry DoD was an important shaping force for products and processes.
  - Now the DoD share of market is small (1-2%)
  - Its influence over commercial manufacturers is very diminished.

DoD Microelectronics Component Acquisition

- DoD has long had unique chip needs – served by captive production facilities in defense firms and in government agencies.
  - These have proven difficult and expensive to maintain at an acceptable technology level. Most have closed
- DoD and its contractors have sought to reduce their dependence on custom ICs (ASICs) by relying, as much as possible, on Commercial Off-The-Shelf components and programmable logic devices
  - The move to COTS has greatly improved and sped up system design and lowered cost, however long system life still poses replacement part problems
  - A residue remains of special functions and technologies that require unique fabrication.
- This study examines DoD's future microelectronic component acquisition challenges in the light of ongoing industry structure and technology changes

The microelectronics industry, supplier of hardware capability that underlies much of America's modern military leadership technology, is well into a profound restructuring. One unintended result of this otherwise sound industry change is the relocation of critical microelectronics manufacturing capabilities from the United States to countries with lower cost capital and operating environments. From a U.S. national security view, the potential effects of this restructuring are so perverse and far reaching and have such opportunities for mischief that, had the United States not significantly contributed to this migration, it would have been considered a major triumph of an adversary nation's strategy to undermine U.S. military capabilities.

This threat led DEPSECDEF Wolfowitz to write a memo calling for a Defenses Integrated Circuit Strategy

DEPUTY SECRETARY OF DEFENSE
1010 DEFENSE PENTAGON
WASHINGTON, DC 20301-1010

OCT 10 2003

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE
ASSISTANTS TO THE SECRETARY OF DEFENSE
DIRECTOR, ADMINISTRATION AND MANAGEMENT
DIRECTOR, PROGRAM ANALYSIS AND EVALUATION
DIRECTOR, NET ASSESSMENT
DIRECTOR, FORCE TRANSFORMATION
DIRECTORS OF DEFENSE AGENCIES
DIRECTORS OF THE DOD FIELD ACTIVITIES

SUBJECT: Defense Trusted Integrated Circuit Strategy

The country needs a defense industrial base that includes leading edge, trusted commercial suppliers for critical integrated circuits used in sensitive defense weapons, intelligence and communication systems. The purpose of this memo is to establish a strategy to ensure that such suppliers exist. The strategy has five components:

a. Facilities Identification: Identify within the integrated circuit (IC) defense industrial base those facilities that could qualify as "trusted sources" for application specific integrated circuits (ASICs) based upon special facility clearances or other government agency technical certification. This survey will identify potential sources for the production of ASICs and will assess whether sufficient capacity currently exists to supply the defense and intelligence communities requirements on a competitive basis.

b. Product Identification: Identify the products that the above facilities can produce.

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c. Near term solutions: Using data identified in (a) and (b) above, identify and adjust acquisition strategies to maximize competitive opportunities while preserving domestic capability.

d. Research Initiatives: (1) Fund research to design and test procedures to assure security concerns have been met. (2) Fund research into next generation IC design for specialized defense applications.

e. Healthy Commercial IC Industry: We should ensure the economic viability of domestic IC sources. The health of the defense IC supplier community depends on the health of the larger commercial IC base. One important enabler of the larger commercial base is balanced policies that do not unnecessarily restrict US sources from the global economic market. Therefore, the DoD will support policies that provide a level playing field internationally for the procurement of commercial products.

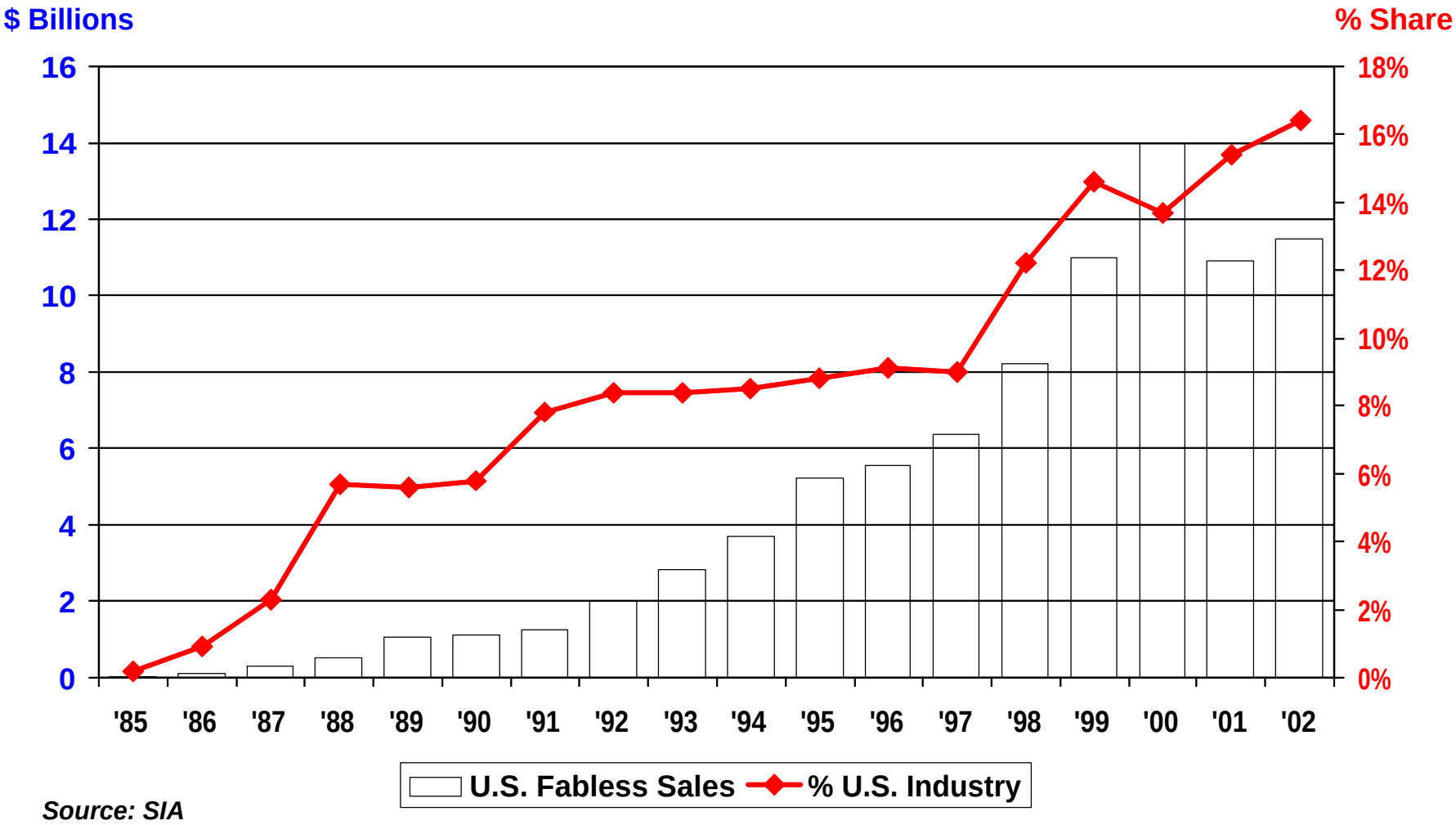
Each part of the strategy will require detailed implementation plans. Because of near-term urgency, the Intelligence Community and DoD, using the NSA Information Assurance Directorate as Executive Agent, are taking actions to preserve a current domestic supply source.

Mr. Michael W. Wynne, Acting Under Secretary of Defense (Acquisition, Technology and Logistics), will oversee implementation of the strategy. He will coordinate responses to any inquiries about integrated circuits or semiconductors. Miss Suzanne Patrick, Deputy Under Secretary of Defense for Industrial Policy; Dr. Charles Holland, Deputy Under Secretary of Defense for Science and Technology; and Mr Robert Lentz, Director, Information Assurance, Office of the Assistant Secretary of Defense for Networks and Information Integration will coordinate implementation of the strategy. Their action officer is Lieutenant Colonel Chris Warack, USAF. You may reach him by telephone at (703) 602-4323 or by electronic mail at christopher.warack@osd.mil.

Several Major Changes Are Well Underway In The Semiconductor Industry:

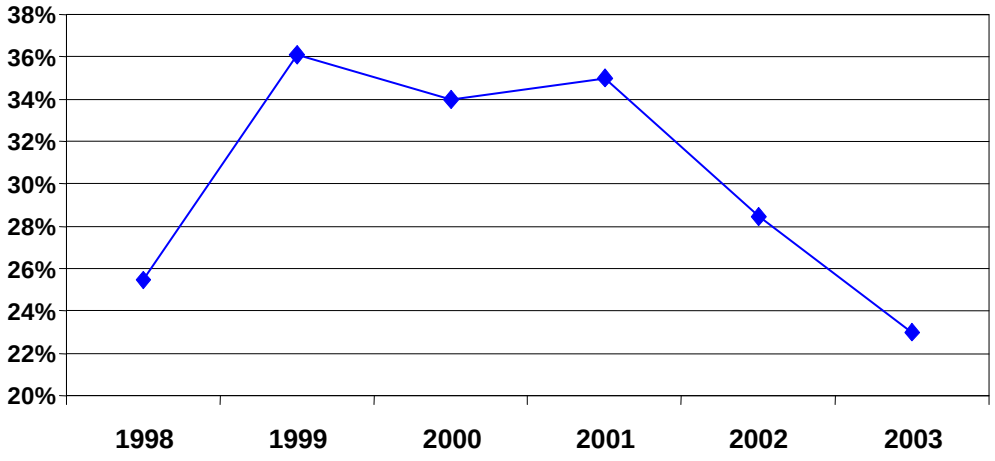
- The classical vertically integrated company is rapidly being replaced by hollow “fabless” firms that contract out manufacturing
  - Driven by dramatic increases in investment required to manufacture advanced technologies and market demand for much better returns on capital investment

The fabless/foundry business model has grown to 16% of the U.S. chip industry. The trend is strongest in the leading process technology portion of the industry



Source: SIA

U.S. industry's share of capital expenditures falling in leading edge semiconductor manufacturing capacity.



Leading Edge	< 0.4µ	< 0.3µ	< 0.3µ	< 0.2µ	< 0.2µ	<0.16

Source: SICAS/SIA

Early indications are that this trend continued downward in 2004 – this is a structural shift, not a result of short-term business fluctuations

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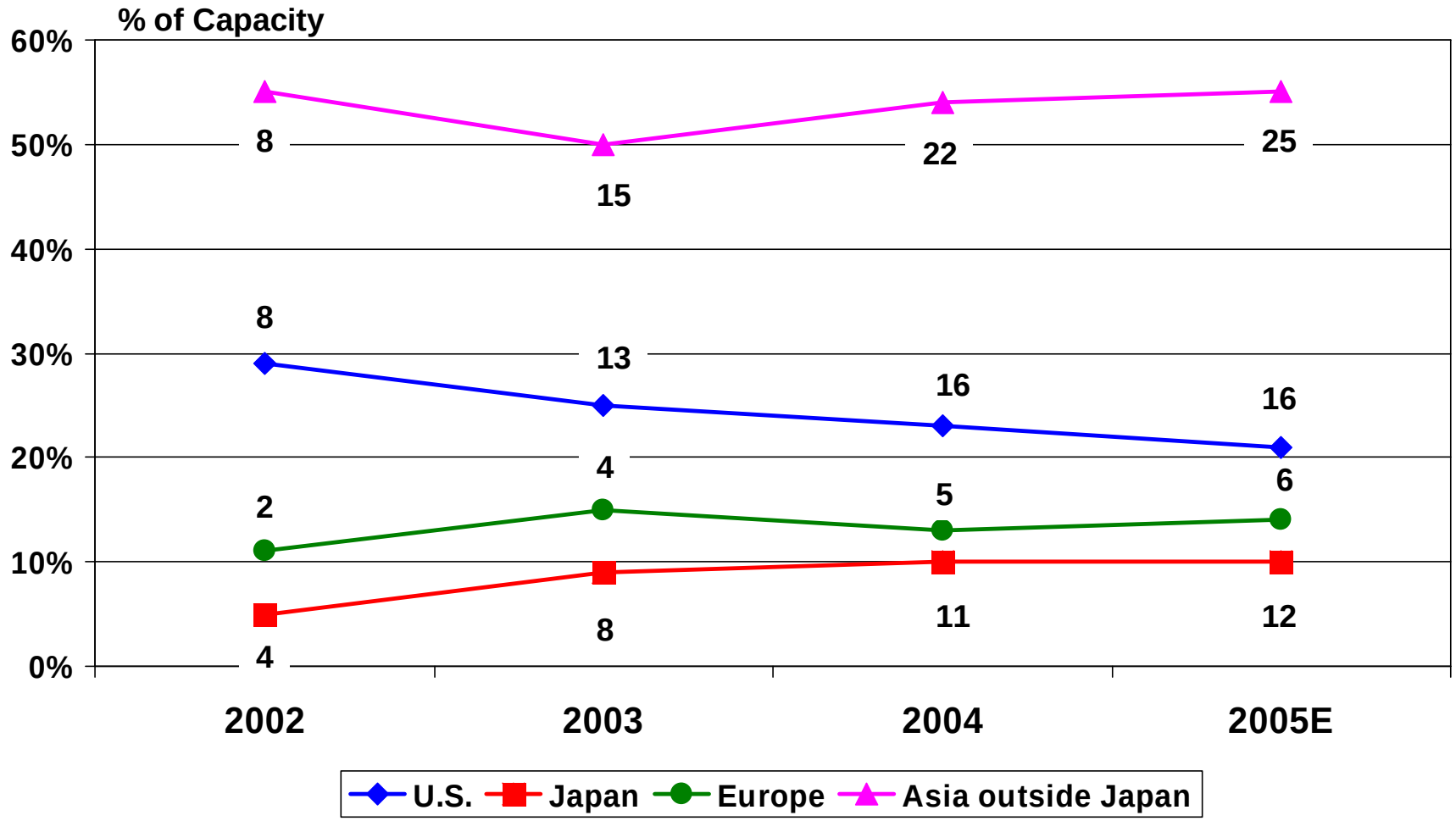
- Expensive manufacturing capacity is moving abroad, mostly to Taiwan, China and Singapore
  - Packaging and testing already well-established
  - Design is beginning to follow
  - Driven by national decisions that native semiconductor industries are strategically important, warranting strong capital investment incentives

300MM Wafer Fabrication Plants



Note: Number of fabs is cumulative. These figures include R&D fabs; which operate at a much lower capacity than a production fab.
Source: International SEMATECH

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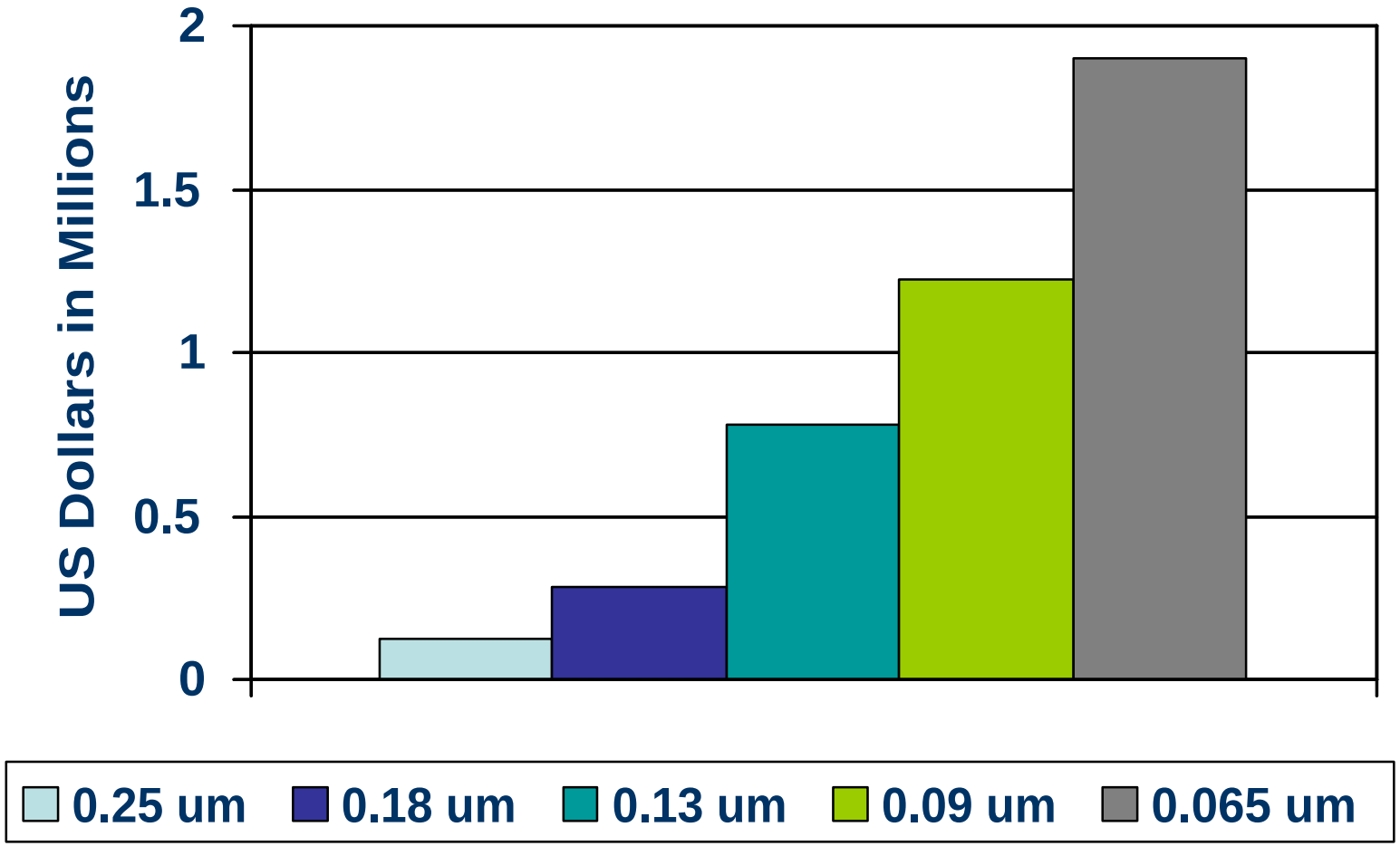
  - Driven by national decisions that native semiconductor industries are strategically important, warranting strong capital investment incentives
- Low manufacturing volume, advanced technology "ASICs" are becoming prohibitively expensive on a per unit basis
  - Total design and prototyping costs are typically $26M
  - The mask set, alone is more than $1M

Mask Costs


US Dollars in Millions
2
1.5
1
0.5
0
0.25 um
0.18 um
0.13 um
0.09 um
0.065 um

Several Major Changes Are Well Underway In The Semiconductor Industry:

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  - Driven by national decisions that native semiconductor industries are strategically important, warranting strong capital investment incentives
- Low manufacturing volume, advanced technology "ASICs" are becoming prohibitively expensive on a per unit basis
  - The mask set, alone is ~$1M
- The rapid rate of technology change quickly makes chip designs obsolete

These Changes are not in the best interests of DoD:

- DoD requires **trusted** and **assured** sources of IC components:
  - Trusted to ensure protection of classified designs, integrity of mission-critical components and long operating life
  - Assured to guarantee access to special military technologies, quick response for time-critical designs, parts availability for the life of the system

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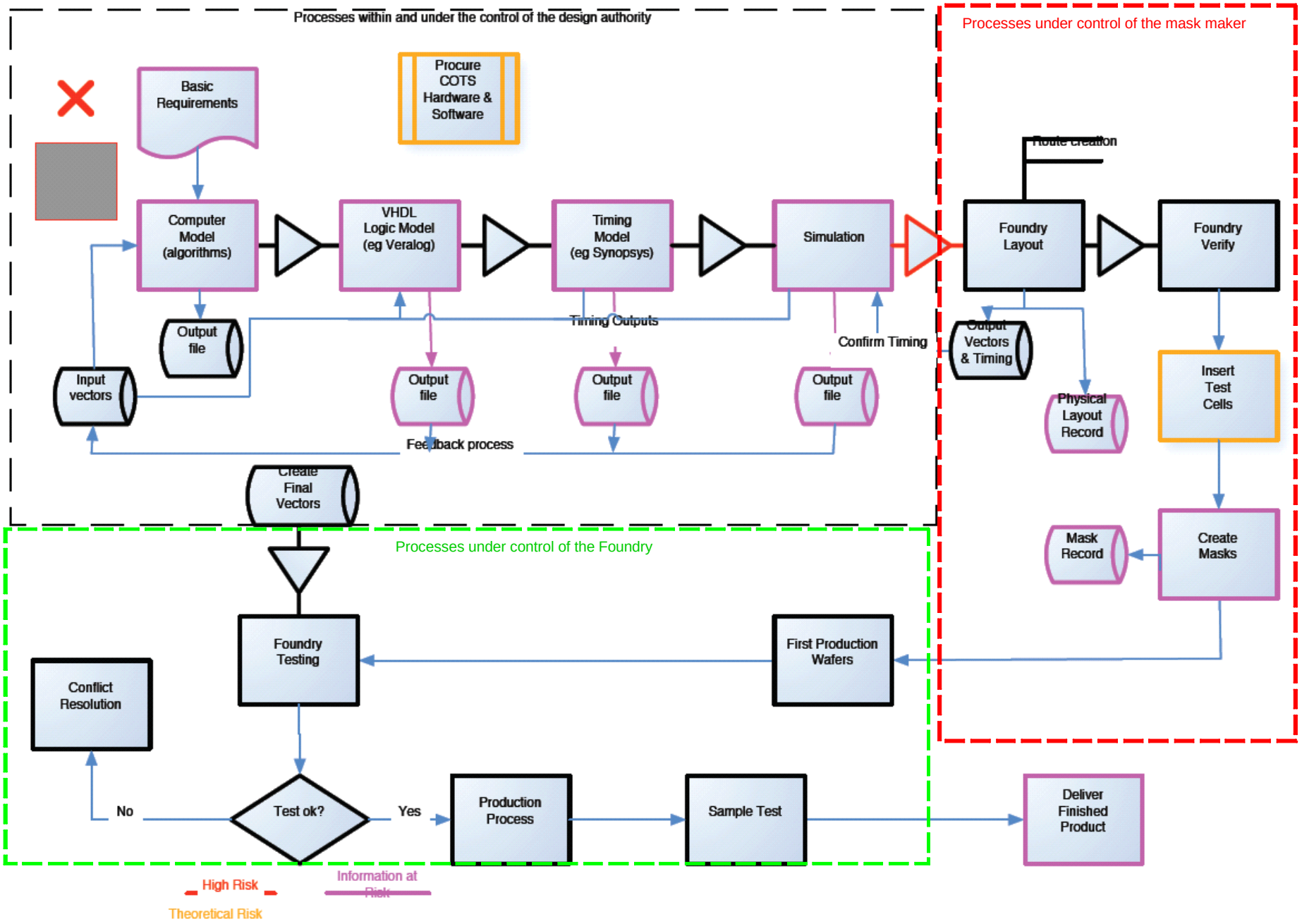
- **KEY POINT: TRUST CANNOT BE ADDED TO ICs AFTER FABRICATION (i.e., modifications to designs cannot reliably be detected)**
  - Electrical or imaging testing or reverse engineering are neither practical nor economically feasible.
  - Applies to both ASICs and COTS


Processes within and under the control of the design authority
Processes under control of the mask maker
Processes under control of the Foundry
Basic Requirements
Procure COTS Hardware & Software
Computer Model (algorithms)
VHDL Logic Model (eg Veralog)
Timing Model (eg Synopsys)
Simulation
Foundry Layout
Foundry Verify
Route creation
Output file
Input vectors
Timing Outputs
Confirm Timing
Output Vectors & Timing
Physical Layout Record
Insert Test Cells
Feedback process
Create Final Vectors
Mask Record
Create Masks
Foundry Testing
First Production Wafers
Conflict Resolution
No
Test ok?
Yes
Production Process
Sample Test
Deliver Finished Product
High Risk
Theoretical Risk
Information at Risk

DoD Has Responded To These Challenges By:

- Past reliance on the US IC industry and captive foundries for supplies of sensitive components
  - US Industry down to three on shore, leading edge IC logic fabricators (IBM, Intel, possibly TI) only one of which will accept foundry business
  - NSA, Sandia and defense contractor facilities are too costly to keep up to the state-of-the-art
- Establishing a Radiation-Hardened IC program at two US defense firms (BAE and Honeywell)
- Establishing a “Trusted Foundry” program with three tiers:
  - Tier I: leading edge – contract with IBM for take-or-pay services
  - Expanding to Tier II and III where there is more competition
- There are serious risks inherent in these ad hoc efforts

The Task Force's Conclusion:

- The Department of Defense and its suppliers face a major integrated circuit supply dilemma that threatens the security and integrity of classified and sensitive circuit design information, the superiority and correct functioning of electronic systems, system reliability, and the continued supply of long-life system and special technology components.
  - All the tools of the software "hacker" apply to IC designs and more: Viruses, Trojan Horses, and Worms in addition to process compromises
  - Software and hardware hacking threats taken together are a formidable security challenge
- The solution to this dilemma has a direct impact on the successful application of microelectronics to defense systems

Findings and Recommendations - 1

Industry Environment

- F: As indicated in the DEPSECDEF memo, the health of the semiconductor industry is a matter of national security – R&D and production go hand-in-hand; loss of one leads to loss of the other, with major military force multiplier consequences. Without a sizable production base, US component technology will lag.
- R: DoD, using the power and influence of the SECDEF, must take a strong advocacy position within the US government for polices and actions that ensure the US offers as good an environment for semiconductor investment as anywhere else in the world

Defense Vision

- F: DoD and its prime suppliers have no comprehensive picture of their future microelectronics needs on which to base plans for supply trust, assurance and special technologies throughout the stages of system life
- R: SECDEF and the USD(ATL) should formulate a forecast-based vision on which to base transformation of the microelectronics supply environment

Size the Problem

- F: DoD has no comprehensive estimate of the size of its microelectronics needs, but the defense fraction of the world IC market is now 1 – 2%; can identify 50-60 DoD ASICs / yr, but no estimate of supplier mission-critical needs.
- R: DoD should continue DDR&E and IDA IC consumption studies and expand them to identify classes, technologies and volumes of ICs that require trusted and assured supply

Findings and Recommendations - 2

DoD Acquisition Strategy

- F: DoD's microelectronics directed acquisition efforts have been largely ad hoc – reactions to problems as they have arisen (RHOC, Trusted Foundry programs). Throughout the recent history of microelectronics, DoD has been, for the most part, a "customer of last resort." Industry competition has now dwindled to the point where there is no longer a diverse supply base of IC suppliers controlled and manufacturing in the US.
- R: DoD must been seen as a desirable customer in the future. DoD (USD(ATL), USD(IP)), working with industry, must determine how best to establish a meaningful government-industry partnership to assure DoD and its system suppliers meet their microelectronics supply needs

Custom IC Design and Production Models and Technology

- F: DoD will continue to have an irreducible need for complex, high performance, custom ICs. The current industry emphasis on mass production has made ASICs using leading edge technology prohibitive. A similar, unfulfilled industry need is now developing. Fifteen years ago DARPA had a program, MMST, addressing this issue, but with different goals.
- R: DDR&E should take another look at the economics of manufacturing limited production volume ASICs with the goal of mounting an effort, like SEMATECH, to meet the need for leading edge technology, low production volume critical parts..

SME Export Controls

- F: The current global system of semiconductor export controls is inconsistent and uncertain
- R: The US, at DoD's urging, should strengthen the Wassenaar Arrangement with bilateral agreements with major SME supplier nations and Taiwan to ensure that SME exports to potential adversary nations are suitably regulated. DoC should gather information on foreign availability of critical SME to aid in export license decision-making

Findings and Recommendations - 3

Programmable Hardware and Software

- F: Many custom, modest performance digital IC functions today are constructed using programmable logic chips (structured ASICs, FPGAs, processors and DPSs) together with memory (DRAMs, SRAMs and ROMs), storing both program instructions and circuit configurations. The logic chips have far more intricate designs and are the most critical and the hardest to verify. US companies still lead in the design of programmable logic chips, however continued US leadership in this area cannot be taken for granted.
- R: To promote continued US strength in this and other IC technologies, DDR&E should:
  - Partner with industry and other US government agencies (e.g., NSF and DHS) to support continued university research to ensure an adequate supply of skilled scientists and engineers in the field
  - Foster interchange of the best counter-tamper practices to assure integrity of government and commercial design through courseware and industry information programs
  - Institute a targeted program in the area of firmware integrity to rapidly develop, disseminate, and encourage adoption of improvements in this trust-related aspect of programmable designs, and
  - In conjunction with the above, encourage research in “Design for Trust Evaluation”

DoD-Unique Technologies

- F: Defense systems, by their nature, will continue to require special technologies for which there is no wide commercial demand. These include radiation hardening, low and high power electronics, and counter-tamper techniques. R&D to meet these needs is supported mainly through DoD mission agencies such as DTRA and NSA.
- R: DDR&E should continue special technology R&D and, in addition,
  - Reduce controls on international trade in radiation-tolerant “standard” designs that discourage commercial firms from evaluating their hardness.
  - Increase efforts to develop tamper protection technology, and
  - Develop design and production terchnologies to disguise the true function of sensitive ICs

Findings and Recommendations - 4

Adversarial Clandestine Operational Opportunities

- F: DoD and its suppliers will continue to depend on advanced technologies progressively only available offshore. Opportunities for adversaries to clandestinely manipulate designs and technology used in US critical applications are enormous and increasing at every stage of an IC product's life. Risk management is essential, since risk avoidance will be prohibitively costly.
- R: The DDR&E, working together with the intelligence community, should assemble an accurate characterization and assessment of adversaries' "dirty tricks" to facilitate developing an effective US counter-tamper strategy. They should further develop risk mitigating technical approaches to support the risk management process. DDR&E should take the lead in defining requirements and making investments to achieve security breakthroughs.

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

DEC 18 2003

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board Task Force on High Performance Microchip Supply

You are requested to form a Defense Science Board Task Force on High Performance Microchip Supply.

The migration of semiconductor manufacturing and design capability to foreign countries imposes significant challenges upon the United States. The movement of manufacturing capability may leave the Department of Defense without an assured supply or access to emerging new designs. Failure to assure supplies may lead to future critical parts shortages at inopportune times, an inability to access new microchip designs in a timely manner during the design of new systems, or compromise sensitive national security information embedded in chip designs. In addition, the offshore movement of manufacturing and design capability could lead to inability to assure design function. The failure to assure design function could result in the intentional insertion of unknown vulnerabilities into vital pieces of equipment and result in the exploitation by a foreign government. A careful analysis of the implications associated with the movement to offshore manufacturing and design facilities is warranted.

The Task Force should assess the implications of the movement of manufacturing capability and design for three scenarios. As a minimum, the Department of Defense needs to address their ability to obtain radiation hardened microchips, the ability to produce limited quantities of special purpose microchips in a timely and secure manner, and the ability to produce microchips in a timely manner to meet emerging needs.

While investigating these scenarios the Task Force should address the following:

a. What are the root causes associated with the migration of the manufacturing capability of high performance semiconductors? Are there policies or technology investments that DoD, either alone or in conjunction with other US government agencies, can pursue which will influence the migration of manufacturing to foreign shores?

b. Do alternatives to the creation of trusted foundries based on US territory exist? Is testing a viable alternative and if so, what level of assurance will testing provide to guarantee that only intended functions are built into the microchip?

c. Are there alternative manufacturing techniques which will allow overseas fabrication of the microchips and subsequent interconnect development in the US? Can field programmable gate array (FPGA) microchips provide suitable performance capabilities for DoD's specialized needs?

d. Finally, are there future technologies which the US may invest in to replace the current microchip technology?

The Study will be co-sponsored by me as the Acting Under Secretary of Defense (Acquisition, Technology, and Logistics), the Director, Defense Research and Engineering, the Deputy Under Secretary of Defense (Industrial Policy), and the Assistant Secretary of Defense (Networks and Information Integration). Dr. William Howard will serve as the Task Force chairman. Dr. Chuck Byvik will serve as Executive Secretary and LTC Scott Dolgoff, USA, will serve as the Defense Science Board Secretariat representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, United States Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Michael W. Wynne
Acting

Task Force Members

Howard	William	Dr.	**Chairman**	Consultant
Dolgoff	Scott	LTC	**DSB Secretariat**	DSB OUSD(AT&L)
Byvik	Chuck	Dr.	**Executive Secretary**	USD(AT&L)

Members

Bandy	Bill	Mr.	Member	Matrics, Inc.
Betza	Steven	Mr.	Member	Lockheed Martin
Fisher	Christine	Ms.	Member	ODSD Industrial Policy
Gosler	Jim	Mr.	Member	Sandia National Laboratories
Hart	Tom	Mr.	Member	Quicklogic Corporation
Hartwick	Thomas	Dr.	Member	Consultant
Howell	Thomas	Mr.	Member	Dewey Ballantine
Marshall	Travis	Mr.	Member	Consultant
Tennenhouse	David	Dr.	Member	Intel Corporation
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Cerny	Charles	Dr.	Government Advisor	AFRL
Clark, USAF	Anne	Maj	Government Advisor	DTRA
Emily	Dave	Mr.	Government Advisor	NAVSEA, Crane Division
Hannah	Barry	Dr.	Government Advisor	Navy Strategic Systems
Jones	Robert	Mr.	Government Advisor	Space and Sensor Technology
Keogh	Joe	Mr.	Government Advisor	U.S. Government
Kosinki	John	Dr.	Government Advisor	Intel & Info Warfare Center
Price	Ray	Mr.	Government Advisor	NSA
Ridgley	Richard	Mr.	Government Advisor	OGA
Thompson	Mark	Mr.	Government Advisor	CIA
VanDyk	Steven	Mr.	Government Advisor	
Warach	Chris	LtCol	Government Advisor	OSUSD(IP)
Zimmerman	John	CDR	Government Advisor	ODUSD(IP)
Zolper	John	Dr.	Government Advisor	DARPA

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