This PDF is available from The National Academies Press at http://www.nap.edu/catalog.php?record_id=19263

FROM THE ARCHIVES

Foreign Production of Electronic Components and Army Systems Vulnerabilities (1985)

Pages
110

Size
8.5 x 11

ISBN
030932212X

Committee on Electronic Components; Board on Army Science and Technology; Commission on Engineering and Technical Systems; National Research Council

Find Similar Titles

More Information

Visit the National Academies Press online and register for...

- Instant access to free PDF downloads of titles from the
  - NATIONAL ACADEMY OF SCIENCES
  - NATIONAL ACADEMY OF ENGINEERING
  - INSTITUTE OF MEDICINE
  - NATIONAL RESEARCH COUNCIL
- 10% off print titles
- Custom notification of new releases in your field of interest
- Special offers and discounts

Distribution, posting, or copying of this PDF is strictly prohibited without written permission of the National Academies Press. Unless otherwise indicated, all materials in this PDF are copyrighted by the National Academy of Sciences.

To request permission to reprint or otherwise distribute portions of this publication contact our Customer Service Department at 800-624-6242.

Copyright © National Academy of Sciences. All rights reserved.

NATIONAL ACADEMY
OF SCIENCES
1863–2013
Celebrating 150 Years
of Service to the Nation

Foreign Production of Electronic Components and Army Systems Vulnerabilities

A Report Prepared by the

Committee on Electronic Components
Board on Army Science and Technology
Commission on Engineering and Technical Systems
National Research Council

PROPERTY OF
NAS-NAE
LIBRARY

Order from
National Technical
Information Service,
Springfield, Va.
22161
Order No. PB 87-137212

PROPERTY OF
NAS - NAE
JAN 09 1987
LIBRARY

NATIONAL ACADEMY PRESS
Washington, D.C. 1985

Foreign Production of Electronic Components and Army Systems Vulnerabilities
http://www.nap.edu/catalog.php?record_id=19263

UF
848
.F6
1985
c 1

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

This is a report of work supported by Contract No. DAAG29-85-C-0008 (CLIN-002) between the United States Department of the Army and the National Academy of Sciences.

Copies available from:

Board on Army Science and Technology
Commission on Engineering and Technical Systems
National Research Council
2101 Constitution Avenue, NW
Washington, DC 20418

Printed in the United States of America

Copyright © National Academy of Sciences. All rights reserved.

ccl C 181 94023

COMMITTEE ON ELECTRONIC COMPONENTS

WILLIAM C. HITTINGER (Chairman), RCA Corporation, Princeton, New Jersey
WILLIS A. ADCOCK, Texas Instruments Incorporated, Dallas, Texas
DAVID F. BARBE, Engineering Research Center, University of Maryland, College Park
ROBERT A. BURMEISTER, Materials Research Laboratory, Hewlett-Packard Laboratory, Palo Alto, California
ROBERT CATTOI, Research & Engineering, Rockwell International, Dallas, Texas
JOSEPH FEINSTEIN, Department of Electrical Engineering at Stanford University; Electronics and Physical Sciences, U.S. Department of Defense, Retired, Menlo Park, California
WILLIAM F. FINAN, Quick, Finan & Associates, Washington, D.C.
JACQUES S. GANSLER, The Analytic Sciences Corporation, Arlington, Virginia
C. LESTER HOGAN, Fairchild Camera and Instrument Corporation, Retired, Atherton, California
AUGUST F. WITT, Department of Materials, Science and Engineering, Massachusetts Institute of Technology, Cambridge
CHARLES M. WOLFE, Department of Electrical Engineering; Semiconductor Research Laboratory, Washington University, St. Louis, Missouri

Liaison with the Board on Army Science and Technology

ALFRED GESSOW, Department of Aerospace Engineering, University of Maryland, College Park

Staff

DENNIS F. MILLER, Study Director
WILLIAM RAMSAY, Senior Staff Officer, Committee on Electronic Components
SIDNEY G. REED, JR., Consultant
HELEN D. JOHNSON, Staff Associate
SHELLEY HINES, Administrative Secretary

Copyright © National Academy of Sciences. All rights reserved.

BOARD ON ARMY SCIENCE AND TECHNOLOGY

MARTIN GOLAND (Chairman), Southwest Research Institute, San Antonio, Texas
ARDEN L. BEMENT, JR., TRW Incorporated, Cleveland, Ohio
LEONARD W. CRONKHITE, JR., MCW Research Foundation, The Medical College of Wisconsin, Milwaukee
ALFRED GESSOW, Department of Aerospace Engineering, University of Maryland, College Park
JERRIER A. HADDAD, IBM, Retired, Briarcliff Manor, New York
M. FREDERICK HAWTHORNE, Department of Chemistry, University of California, Los Angeles
EARL B. HUNT, Department of Psychology, University of Washington, Seattle
WALTER B. LABERGE, Research and Development Division, Lockheed Missiles and Space Company, Palo Alto, California
CHARLES H. MCKINLEY, Vought Corporation, Dallas, Texas
WILLIAM G. MCMILLAN, McMillan Science Associates, Los Angeles, California
GORDON H. MILLAR, MOTORTECH, Daytona Beach, Florida
PETER G. OLENCHUK, United States Army, (Retired), McLean, Virginia
LUDWIG REBENFELD, Textiles Research Institute, Princeton, New Jersey
ZIVIA S. WURTELE, R&D Associates, Marina del Rey, California
NORTON D. ZINDER, Department of Genetics, Rockefeller University, New York

Liaison Members for Commission on Engineering and Technical Systems

ROBERT R. EVERETT, The MITRE Corporation, Bedford, Massachusetts
HYLA S. NAPADENSKY, Research Explosion Science and Engineering Department, IIT Research Institute, Chicago, Illinois

Staff

DENNIS F. MILLER, Executive Director
HELEN D. JOHNSON, Staff Associate
CHERYL A. WINTER, Staff Assistant

Copyright © National Academy of Sciences. All rights reserved.

PREFACE

This study is the result of a growing concern with a relatively new phenomenon that would affect the ability of the U.S. Army to produce and maintain weapons systems and with the increasing importance of production of electronic components by foreign companies or by U.S. firms operating overseas.

Recognizing the vast number of different scenarios and emergencies that might threaten its military systems, the Army asked the Board on Army Science and Technology to undertake a study on which specific component types were vulnerable and on the degree of their vulnerability (see App. A for the Statement of Task). In response, the board formed a planning panel chaired by Stuart Card; members included Gordon Millar and Arden Bement who drafted a statement of work. On the basis of these tasks, the study plan was developed for approval by the National Research Council (NRC). Once approved, a Committee on Electronic Components was created by the NRC under the Board on Army Science and Technology.

Specifically, the Army asked the committee to accomplish the following:

- Document the major trends concerning the production of electronic components for military systems and the health of the U.S. electronics industry
- Identify scenarios of events that could disrupt the supply of electronic components from overseas sources
- Describe the electronic components and their uses that the Army needs for its weapons systems
- Determine the sources of electronic components for weapons systems and the extent to which those components are vulnerable to a supply disruption
- Recommend policy actions, such as stockpiling, by which the Army can prevent or mitigate the effects of a supply disruption

The committee members included experts on the electronics industry and on Army requirements and procurement practices. Members were corporate executives and directors of research laboratories in the electronics industry, academic researchers in the field, and executives

Copyright © National Academy of Sciences. All rights reserved.

in consulting firms associated with the electronics industry. A number of the committee members had also held government positions that brought them into the planning and procurement of military systems depending on electronics.

The committee held meetings over a period of seven months. In addition to their own expertise, the committee benefited from extensive briefings by staff officials from a number of Army organizations. The briefings included information on the latest developments in weapons systems R&D that might be related to the supply of electronic components. Committee members also benefited from a number of previously published and ongoing studies on related topics.

The committee wishes to thank the many Army staff members who took the time to help. The committee especially extends its thanks to Clare Thornton, Director, and Irving Reingold, of the U.S. Army Electronics Technology and Devices Laboratory at Fort Monmouth, New Jersey, for their able support and assistance.

In addition, we wish to thank all those in and out of the military who either briefed us or sent us information, many of whom are listed in App. B. Moreover, we are particularly grateful to the investigators at the Institute for Defense Analyses who discussed the preliminary results of their related study with us.

The committee wishes to thank Dennis F. Miller, executive director of the Board on Army Science and Technology of the NRC, for his early development of this study and guidance throughout. We are grateful for the capable assistance provided by William Ramsay, senior staff officer on this project; Shelley Hines, administrative secretary; and Sidney G. Reed, Jr., consultant to the board.

WILLIAM C. HITTINGER, Chairman
Committee on Electronic Components

Copyright © National Academy of Sciences. All rights reserved.

CONTENTS

Copyright © National Academy of Sciences. All rights reserved.

Copyright © National Academy of Sciences. All rights reserved.

TABLES

Copyright © National Academy of Sciences. All rights reserved.

EXECUTIVE SUMMARY

Military weapons and the systems that support them have grown in sophistication in recent decades. So, too, have the electronic components used in those systems. Electronic components have also assumed an ever-growing importance as the U.S. Army seeks to use technology to counter the numbers advantage a likely military opponent might have on a battlefield of the future.

Today, however, a small but increasing number of those electronic components are manufactured overseas. The U.S. components industry is losing market share to foreign, particularly Japanese, companies that can offer lower prices and invest more money in research. In addition, significant U.S. manufacturing capacity has been transferred to overseas sites to compete with foreign companies.

As a result, the Army has come to depend on overseas sources whether foreignor U.S.-owned, for many of its electronic components. This makes the Army vulnerable to a cutoff in supplies in case of war or other political or economic action. The extent of the vulnerability varies widely among different component groups.

- Certain components are supplied exclusively by foreign sources. These include electronic countermeasure tubes, certain video displays (especially liquid crystal and electroluminescent types), magnetic bubble memories, and many raw materials.
- The greater vulnerability exists for integrated circuits, most of which are assembled and tested overseas.
- Also vulnerable are many semiconductors, including ceramic packages for large-scale and very-large-scale integrated circuits.
- Less vulnerable are certain magnetic materials and components, such as permanent magnets, recording heads, magnetic tape and disc memories, and microwave and millimeter wave components.
- Of low vulnerability, since domestic sources are adequate for military needs, are capacitors, resistors and resistor networks, relays, contactors, solenoids, circuit breakers, and vacuum tubes, among other components. Transistors, diodes, and thyristors are likewise made in adequate numbers in the United States, although some types are built abroad.

Copyright © National Academy of Sciences. All rights reserved.

Of particular concern are compound semiconductors, especially gallium arsenide (GaAs) devices. These will assume growing importance as electronic components in military systems now under development. Weapon systems used to detect targets and guide missiles, for example, will increasingly rely on GaAs microwave devices as well as logic and memory chips. GaAs field effect transistors are already widely used in radar, communications, and electronic countermeasure equipment.

- The U.S. Department of Defense (DOD) sponsors some research and development (R&D) on GaAs and other compound semiconductors, but little manufacturing capacity exists to make them in the United States.
- The U.S. R&D lead is slim and rapidly vanishing because the Japanese have made extensive long-term commitments to develop such technology.
- Japanese compound semiconductors have already achieved advanced performance capabilities.
- Unless current trends are reversed, Japan will become the dominant source for high-performance, compound semiconductors.

DOD now has some policies and programs in place to manage what is a limited but growing problem. Title III of the Defense Production Act of 1957, for example, provides long-term, cost-effective economic incentives to encourage domestic manufacturers of military equipment to expand their production capabilities.

A second DOD effort involves the manufacturing technology program, begun in 1985. This program provides DOD funds to qualified companies to improve their manufacturing processes and equipment to meet the nation's defense needs. In particular, it offers money in support of industrial innovation aimed at improving manufacturing technology.

Similar but more specific programs, as far as electronic components are concerned, are those designed to develop very high speed integrated circuits (VHSIC) and the GaAs technology (microwave/millimeter-wave monolithic integrated circuits [MIMIC]). Another is the industrial modernization program.

While good and to be commended, these programs by themselves are not complete answers to the Army's dependence on foreign sources for certain electronic components. For one thing, except for the VHSIC and MIMIC programs, no program addresses electronic components specifically. For another, DOD's natural desire, especially in an era of concern for budget deficits, to get the lowest possible price often encourages it to seek foreign suppliers and discourages U.S. manufacturers from risking investment capital.

Another problem is that DOD procurement policies pull against one another. Some, such as the "Buy American" Act and several internal regulations, require planners and procurement officers to develop U.S. sources for weapon systems. Others, however, seek to encourage our European allies to support a mutual defense effort by promoting joint development of weapon systems. This usually means U.S. prime contractors have to buy components from European suppliers. The

Copyright © National Academy of Sciences. All rights reserved.

benefits of these policies in terms of greater economy and strengthening the western alliance must be balanced against the concerns associated with greater offshore production.

A more serious problem is the lack of data within DOD in general and the Army in particular on how many electronic components are purchased abroad.

- An adequate data base does not exist for determining the types, quanitities, and original sources of electronic components used in weapons and other military systems.
- Nor is there any DOD policy or Army office responsible for monitoring the uses or sources of electronic components.

This lack of a data base and office on electronic components leads to a "visibility" problem in which the issue of foreign dependency is rarely considered when planning and procuring weapons.

The scope of the foreign dependency problem is currently limited and, hence, amenable to corrective actions if they are taken soon. As a first step, DOD should create a data base for electronic components. This should include:

- A program-by-program identification of electronic components used in Army systems and of their sources.
- Identification, in particular, of electronic components used for advanced systems.
- Selective horizontal aggregation of data on electronic components.
- Assignment of organizational responsibility to an existing office to create and maintain the data base.

Next, DOD should establish criteria to guide planners and procurement officers in selecting between U.S. and overseas or foreign suppliers of electronic equipment and components. Program managers should be made responsible for evaluating tradeoffs between domestic and foreign sources. For particular electronic components, the Army could:

- Begin a stockpile for certain key components that are particularly vulnerable to a supply disruption
- Redesign some weapons systems to give U.S. component manufacturers more of a competitive edge
- Target R&D funds and programs to help create a greater domestic capability for producing electronic components.

Corrective actions should also be taken now to develop domestic sources for advanced electronic components of the future. The Army should identify trends in R&D and foreign dependency, and generate

Copyright © National Academy of Sciences. All rights reserved.

1

INTRODUCTION

As military weapons and the systems that support them become ever more sophisticated, so too does the importance of electronic components for those systems. Even now, electronic components represent an estimated one-third of the total cost of new U.S. Army weapons systems. By the year 2000 this figure will rise to one-half. Indeed, although the estimates vary widely, such numbers could be low.

The problem is that the Army and its suppliers depend on foreign sources for many of these electronic components. This supply could be cut off during time of national emergency. Military action, trade wars, blockades, terrorist actions, or other events could disrupt the supply of electronic components. Such a disruption, in turn, could make it difficult to use or maintain key weapons systems in a protracted military action.

THE ELECTRONIC BATTLEFIELD

The driving force behind the proliferation of electronic components is the necessity to successfully engage likely adversaries who have greater quantities of both men and conventional weapons. A technical edge in weapons is therefore essential. Thus, Army planners must rely on electronics to secure national interests on any battlefield. New weapons or supporting systems relying on electronic components range from reconnaissance satellites and remotely piloted vehicles to receivers for battlefield vehicles, squads, individual soldiers, and such new items as night vision goggles and thermal weapons sights, pilotless reconnaissance vehicles, and "fire and forget" missiles.

Such weapons have already severely strained traditional approaches to command and control. New communications equipment is needed to allow commanders to determine what is happening on a battlefield and to send orders immediately to combat forces. Further, a significant element of new weapons systems is the collection, collation, and

Copyright © National Academy of Sciences. All rights reserved.

distribution of intelligence data, which is largely electronic in nature. The list of functions will continue to expand as systems become more and more sohisticated.

Electronic systems must be operated and maintained by available armed forces personnel. Self-diagnostic systems are therefore, becoming extremely important. A system must be able to inform an operator if that system is not functional and to assist in service. This requirement obviously adds significantly to the magnitude and complexity of the electronics package.

The U.S. Electronics Industry

From 1945 to about 1970, the U.S. electronics industry was the source of essentially all electronic components used in military hardware. During this era, the United States led the world in component research and development and in electronic manufacturing. The major sources and users of electronic components were all located in this country.

Military specifications during these years called for components performing at levels generally higher than similar consumer products. Military components were either built in facilities also producing large quantities of commercial parts or were selected from commercial lines. The military requirements for high performance led to some government-funded R&D, which in turn led to improved commercial products. The premium prices commanded by the wide temperature range, high performance, and high reliability required for military components encouraged manufacturers to invest their own resources in development.

Further, "Buy American" clauses were added to contracts. These clauses, and requirements for inspection and quality control, effectively prevented the procurement of foreign-manufactured parts and assemblies. Finally, reliability and performance were generally the overriding factors in selection of components; a premium price was not a major consideration, even if a foreign source did exist.

Starting in the 1960s and escalating significantly during the 1970s, many U.S. electronics firms moved portions of their manufacturing operations abroad, especially in the areas of consumer electronics and semiconductors. This was done to lower labor costs and, in the case of Europe, to hurdle extensive tariff and other barriers. This strategy has been a defensive one, designed to retain competitiveness with foreign manufacturers, who were increasingly penetrating U.S. consumer markets. As equipment assembly operations moved to overseas locations, the supply of components naturally tended to follow suit, thus stimulating the production of components by local sources.

This trend resulted in a greatly reduced market share for manufacturers electing to keep their assembly plants in the United States, particularly those who made components for larger items. Therefore, in order to remain in business, they also have been forced to move manufacturing operations to overseas sites, both to reduce labor costs and to be located with end-item production facilities.

Copyright © National Academy of Sciences. All rights reserved.

The Foreign Electronics Industry

At the same time U.S. manufacturers have been moving their production capacity to other countries, they are being challenged in both the U.S. and foreign markets by foreign-owned and -located companies. Foreign electronic manufacturers, especially in Japan, can design and manufacture components whose performance and reliability equals and in some cases surpasses the best U.S. manufacturers can offer. Semiconductors are probably the most obvious example. Foreign producers now supply numerous manufacturing facilities in other countries, reducing the market for U.S.-made parts and for parts produced overseas by U.S. companies.

In addition, having established a reputation for quality and low prices, foreign producers can then challenge U.S. domestic producers. This leads to a destructive spiral, in which a foreign producer's base grows larger, ability to reduce price increases, and domestic producers become steadily less competitive. Since the United States has not erected trade barriers to this component flow, the availability of either equal or superior products at lower prices has, in many instances, eliminated or greatly reduced the domestic product base.

Specific examples abound. In the personal computer business, for example, Japanese competition has all but eliminated domestic producers in the areas of disk drives, printers, and some types of semiconductor memories. The magnitude of the problem is indicated by the nation's electronics industry, long a positive contributor to the U.S. trade balance, suffering a $6.8 billion trade deficit in 1984. This massive imbalance is the first negative trade balance in the history of the U.S. electronics industry.

Although these developments occurred at first for consumer products, they had an immediate impact on the military. The explosive growth of the commercial electronics field, coupled with progressively lower quantities of individual types of military electronics, has greatly reduced the significance of the military market to major component manufacturers. Even though the amount of electronics in a given weapons system is becoming greater, a few hundred end items for a weapons systems is not significant by commercial standards.

Even specific integrated circuits are of little interest to a semiconductor manufacturer who is turning out millions of parts for consumer products if the manufacturer can inspect and package the military parts apart from the regular production of chips. This is allowed for the "MIL-883 Class B" devices. When semiconductor manufacturers move product lines overseas for competitive reasons, the products are excluded from certain aerospace and fuse applications ("MIL-M-38510"). The final U.S. inspection, test, and prestressing of devices required for some applications ("MIL-883") significantly increases the product cost with little incentive to a large-volume commercial manufacturer.

Copyright © National Academy of Sciences. All rights reserved.

One of the nation's major semiconductor manufacturers, for example, was queried about designing a microprocessor to meet a specific architecture ("MIL-STD-1750") required by the U.S. Air Force. The company replied that it had no intention of developing such a chip because it would not be worthwhile to tie up design engineering staff on the job, even if it resulted in acquiring 100 percent of the military market. Thus, some military markets are viable to U.S. manufacturers only if financial incentives are greatly increased. The outlook for such changes is problematic.

There are, however, a number of manufacturers who specialize in meeting military requirements. Yet, because of capital, cost, or inadequacy of industrial base, it is unlikely they would be capable of expanding rapidly to meet the need for surge production in an emergency.

U.S. Industry Is Facing Difficult Investment Decisions

The U.S. components industry, facing erosion of market share in many of its product areas, must now make difficult decisions about investing capital and technical resources to support domestically produced end items. Some companies are making major outlays to increase their levels of automation greatly, in the hope of countering higher domestic labor costs.

This may be an ineffective strategy. Foreign component producers are unlikely to abandon the market share they have acquired. Foreign countries, especially Japan, are generally at least as capable as the United States in applying factory automation. In addition, they have the decided advantage of much lower capital costs and, in many instances, of subsidization in one form or another by their governments. So, it appears likely that attempts in this country to become more competitive are likely to result in only a transient advantage, destined to be countered by foreign competitors at a lower cost, leaving them once again in a superior position.

Under these circumstances, there is a strong incentive for domestic manufacturers to invest in production facilities that stand a reasonable chance of competing on a cost basis. This means investing in facilities located abroad. Because of the jobs to be created, the manufacturer might also obtain foreign capital, favorable tax treatment, and other advantages they would not obtain if they invested domestically.

It is likely that R&D activities will remain centered in this country, but those in other countries will become increasingly important. U.S. research efforts generally are at least competitive with those of foreign high-technology companies. However, they are not necessarily superior. In recent years the aggressive competition initiated by foreign companies has enabled them to acquire extremely competent scientific and technical staffs, many of them trained at U.S. colleges and universities.

Copyright © National Academy of Sciences. All rights reserved.

In addition, a number of foreign countries appear to be placing more emphasis than the United States on graduating students in science and engineering. These countries may be producing a generation with a larger proportion of the population trained in innovative and advanced technical disciplines. Under these circumstances, with our historical technological lead apparently diminishing, and even disappearing in many areas, U.S. companies will tend to invest resources in the high-volume market that contributes the most to their profits.

In this, of course, they are no different from manufacturers in any free market country. Military components are produced at low volume and low profit, despite high unit cost, and involve a manufacturing cycle that continues long after the R&D investment is made. In addition, they carry a significant risk in terms of both cost and bad publicity if anything goes wrong.

As a result, most domestic component manufacturers tend to focus their R&D activities on consumer products. Further, since commercial technologies have advanced so far--largely because of competition--there is little technology advantage to be gained in the form of R&D spinoffs from military products.

Similarly, it is difficult for component manufacturers to justify the continued production of older design parts that the military needs to support systems in its inventory. In many cases, the parts cannot be used in consumer products. Or, if the parts have both military and civilian purposes, they have often been superseded in consumer markets by newer technologies, since consumer products tend to become obsolete much faster, than military ones, often in half the time or less.

Thus, manufacturers sometimes must support for the military an obsolete product far removed from the main business, one which likely has unique production and test requirements and which likely will be ordered only in small and erratic quantities for maintenance purposes. Under these circumstances, there is little incentive for manufacturers to make any capital investment to upgrade or modernize production facilities or equipment for such components. So, any capital requirement to replace depreciable parts for production is very likely to provoke a decision to terminate the product. This obviously leaves the military with the problem of either locating a substitute part or funding a redesign of a weapon system to use currently available components.

Incentives for Foreign Procurement

National policies aimed at reducing the federal budget deficit have put special pressure on the Department of Defense to increase competition and reduce costs. Prime contractors are responding in a number of ways, restricted only by the need for justification under the federal acquisition regulations, procurement specifications, and statements of work.

One of the major efforts in this area, widespread throughout the industry, is to increase greatly the degree of automation in the manufacture and test of electronic hardware. This progressively

Copyright © National Academy of Sciences. All rights reserved.

reduces the proportion of "touch labor" content of the end-item, which is clearly desirable in driving down costs. However, it also increases the percentage of end-item cost that is controlled by the cost of the components used. In a situation of mandated competition, the ability to procure the components used at a price lower by a few percent may mean the difference between winning and losing a major procurement.

Under pressure of competition, company procurement staffs become steadily more innovative in locating lower priced sources, which increasingly tend to be foreign suppliers, and design personnel attempt to accommodate unique characteristics of less expensive components. Another avenue for the introduction of foreign components is the contract modification mechanism value engineering change proposal, after a program is on contract.

Since cost has become a more important concern in military procurement, the incentives in the system all favor using as many lowerpriced components as allowed by procurement regulations and specifications. Since the quality of components produced overseas is often higher at the same or lower costs, most are actually produced abroad, while commonly being treated as an issue of little concern.

To minimize development costs and to help alleviate the imbalance between U.S. systems sold to our allies and what we purchase from them, there is strong impetus currently to procure foreign-designed equipment and systems for introduction into the U.S. military inventory. Anti-armor weapons, reconnaissance vehicles, and battlefield communications are just a few of the areas which are under for current or planned procurements of this type.

In some cases, contracts require that U.S. capability be established to produce and repair the equipment involved. While attempts are made in such cases to substitute domestically available components, which may still in fact be manufactured overseas, there are likely to be certain proprietary items in the designs that must be procured from the original vendor. This is especially true since foreign countries have much less rigid requirements for the release of design details and manufacturing rights than the United States. This results in the introduction of additional foreign-designed and -manufactured components into the operational inventory, the most critical of which may have no domestic counterparts and no provision for domestic manufacture.

In case hostilities disrupt the supply of repair parts from such a source, it would likely be difficult to substitute either domestic parts or assemblies without a major redesign of at least part of the system, which takes time. Even given a major redesign, it may be that this country would not have access to the critical performance parameters and interface requirements of the unavailable functional element. This limitation has probably been one of the major reasons the U.S. military has resisted introduction of foreign-designed weapons systems into its operational inventory. In today's environment, however, financial and political pressures are pushing strongly toward introduction of more foreign components.

Copyright © National Academy of Sciences. All rights reserved.

2

CURRENT POSITION OF THE U.S. COMPONENTS INDUSTRY

BACKGROUND

The U.S. electronic components industry faces an unprecedented challenge, with regard to its technological leadership as demonstrated in the past and also to its ability both to nurture its productive base and to invest in R&D competitively. During the past decade, Japan has dwarfed its non-U.S. international competitors in consumer electronics and thereby has come to dominate the market for electronic components. It has also aimed at strategically important markets through national policy on semiconductors, computers, computer-related equipment, and communications equipment, particularly those using fiber optics. Other East Asian and Western European countries are also increasingly competitive with the U.S. components industry.

These competitive trends will intensify as other nations seize the opportunity to create jobs, favorable trade balances, and better standards of living. Taking advantage of relatively low labor rates and other favorable economic factors, other nations are increasingly making commitments to play important roles in the continuing growth of electronics in the free world.

U.S. companies, operating in the world's largest and most open marketplace, continue to face basic economic problems that threaten the vitality of the industry. The components industry is paced by rapidly changing technology and requires a continuous high rate of capital formation, as illustrated in Table 2-1. The investment requirements in the semiconductor industry are particularly demanding and are increasing as integrated circuit technology expands. In the 1960s, $1 of capital equipment generated approximately $10 of annual sales. Today, the ratio of capital to new sales is approximately 1:1. By 1990, $1 of new capital investment is expected to generate only $0.50 of new sales.

At the same time, the risk associated with these volume-sensitive investments is increasing, because of growing market cyclicality, rapid technological advance, and uncertainty about market shares and profit margins. The issue is further aggravated on an international scale by

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-1 Electronics Manufactures: Shipments and Capital Requirements, 1977, 1980, and 1981

Industry	Industry Shipments (millions of dollars)			New Capital Expenditures (millions of dollars)			New Capital as a Percentage of Shipments		
	1977	1980	1981	1977	1980	1981	1977	1980	1981
Electronic Components (SIC 367)		27,647	30,421		2,616	2,459		9.5	8.1
Electron Tubes (SIC 3671)		2,185	2,160		61	80		2.8	3.7
Semiconductors (SIC 3674)	5,327	10,501	11,702	409	1,596	1,493	7.7	15.2	12.8
Electronic Capacitors (SIC 3675)		1,180	1,152		69	77		5.9	6.7
Electronic Resistors (SIC 3676)		794	785		50	36		6.3	4.6
Electronic Coils (SIC 3377)		700	794		21	25		3.0	3.2
Electronic Connectors (SIC 3678)		2,269	2,311		141	118		6.2	5.1
Electronic Components (SIC 3679)		10,018	11,519		678	630		6.8	5.5

SOURCE: U.S. Department of Commerce, Annual Survey of Manufactures, 1977, 1980, 1981.

Copyright © National Academy of Sciences. All rights reserved.

the relatively high cost of capital in the United States compared, in particular, to that in Japan.

Other factors, in addition to capital formation, seriously handicap the U.S. components industry relative to many foreign competitors. Lack of government support for R&D, and piecemeal allocation of what funding there is, a hands-off international trade policy, inhibitory antitrust laws, and deficiencies in our education system all contribute. A thorough discussion of these complex, interrelated matters of industrial vitality is beyond the scope of this study, but many reports are available to the interested reader (see the bibliography).

Despite recent difficulties, the U.S. components industry is still large and growing. U.S. factory sales totaled $41 billion during 1984 (Table 2-2). As discussed in the sections that follow, much of the manufacturing value of these sales is contributed by overseas assembly performed either in U.S.-owned or subcontractor facilities.

SILICON-BASED SOLID STATE PRODUCTS

U.S. factory sales of solid state products, which are essentially all silicon based, totaled $16 billion in 1984, an increase of 38 percent over 1983 sales. Integrated circuits represented more than 70 percent of such shipments. Exports totaled $5.3 billion, 22 percent over 1983 while imports increased 54 percent, from $5 billion in 1983 to $7.7 billion in 1984.

These gross export and import totals do not convey the fact that a large portion of U.S. exports is composed of wafers and chips either sent to U.S.-owned factories in other countries or to foreign contractors for test and assembly into finished products. More than $5 billion worth of U.S.-owned devices passed through such facilities in 1984, either to return to the United States or to move on for sale in third countries. Similarly, a large portion of U.S. imports consists of finished products completed in these overseas facilities and returned to this country for sale.

Table 2-3 shows 1984 exports and imports for the top 10 U.S. trade partners. Japan's share of world semiconductor shipments has grown strongly in recent years. Exports of solid state components to the United States of $2 billion (up 115 percent from 1983)--probably all finished products--exceeded U.S. exports to Japan by $1.6 billion. U.S. trade with most of the other listed countries is mostly the export of wafers and chips and the import of finished products returned from overseas assembly sites.

There is a lack of specific data relating to the end use of semiconductor devices in U.S. Army or Department of Defense (DOD) equipment. Thus, it is hard to know how many of these proportion devices are made either partly or wholly in foreign facilities. Table 2-4 shows an estimate of the current size of the military semiconductor market and Table 2-5 estimates the military market as a fraction of the worldwide market and the percent that comes from foreign sources.

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-2 Factory Sales of Electronic Components in the United States, 1975 to 1984 (millions of dollars)

Description	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Electron tubes										
Receiving tubes	152	140	144	134	105	91	100	176	62	36
Power and special purpose tubes	420	456	519	585	682	728	845	911[a]	990[a]	1,028
TV Tubes	499	637	633	732	799	959	1,069	936	1,024	1,092
Total	1,071	1,233	1,296	1,451	1,586	1,778	2,014	1,923[a]	2,076[a]	2,156
Solid state products										
Transistors	405[a]	421[a]	456[a]	508[a]	571[a]	600[a]	638	597	593	705[b]
Diodes and rectifiers	431[a]	469[a]	485[a]	548[a]	644[a]	665[a]	782	655	566	635[b]
Integrated circuits	1,712[a]	2,644[a]	2,677[a]	3,538[a]	4,717[a]	6,606[a]	6,976	7,322	7,945	11,275[b]
Other semiconductors	454[a]	777[a]	745[a]	917[a]	1,269[a]	1,218[a]	1,913	2,155	2,536	3,385[b]
Total	3,002[a]	4,311[a]	4,363[a]	5,511[a]	7,201[a]	9,089[a]	10,309[a]	10,309[a]	11,640[a]	16,000[b]
Parts										
Capacitors	470	608	744	897	1,050	1,299	1,297	1,135	1,247	1,595
Resistors [c]	447	449	477	504	647	653	636	583	638	698
Passive networks	32	47	61	82	111	118	139	138	153	226
Coils and transformers	489	485	560	654	776	852	952	842[a]	926[a]	980[e]
Connectors	734	828	986	1,286	1,674	2,018	2,203	2,148[a]	2,517[a]	2,895[e]
Switches	141	118	182	303	366	349	377	446[a]	530[a]	635[e]
Filters	71	64	81	99	126	121	124	142[a]	174[a]	190[e]
Quartz devices	209	266	197	227	201	277	413	266[a]	265[a]	290[e]
Wire and cable	*	*	*	*	789	1,066	1,176	1,304[a]	1,331[a]	1,490[e]
Relays	73	82	174	177	199	243	245	282	341	375[e]
TV and FM antennas and parts	*	*	72	84	91	84	85	83	80	72
Total	2,666[a]	2,947[a]	3,534[a]	4,313[a]	6,030[a]	7,080[a]	7,647[a]	7,369[a]	8,202[a]	9,446[e]
Other components [e]	2,969[a]	3,271[a]	4,345[a]	5,826[a]	6,549[a]	7,658[a]	8,869[a]	9,544[a]	10,846[a]	13,440[e]
Grand total	9,708[a]	11,762[a]	13,538[a]	17,101[a]	21,366[a]	25,605[a]	28,839[a]	29,565[a]	32,864[a]	41,042[e]

[a] Revised
[b] Estimated
[c] U.S. consumption
[d] Included under other Components
[e] Includes sockets, delay lines, loudspeakers, magnetic components, transducers, printed circuit boards, microwave components, other components, assemblies and parts.

SOURCES: EIA Marketing Services Department; U.S. Department of Commerce

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-3 Top 10 U.S. Trade Partners by Industry, 1984

	Trade	
Communications	Thousands of Dollars	Percentage of Total
Total U.S. Imports	3,696,821	100.0
Japan	1,730,820	46.8
Canada	472,983	12.8
Taiwan	360,911	9.8
Hong Kong	278,526	7.5
Korea	185,078	5.0
Singapore	143,693	3.9
Mexico	96,067	2.6
Sweden	94,410	2.5
Malaysia	63,627	1.7
France	50,220	1.4
Subtotal [a]	3,476,335	94.0
Total U.S. Exports	2,867,217	100.0
Canada	262,345	9.1
Mexico	261,078	9.1
United Kingdom	209,530	7.3
Saudi Arabia	204,637	7.1
West Germany	171,400	6.0
Korea	161,879	5.6
Japan	150,648	5.3
Egypt	130,466	4.6
Israel	129,310	4.5
Brazil	97,309	3.4
Subtotal [a]	1,778,602	62.0

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-3 Top 10 U.S. Trade Partners by Industry, 1984 (continued)

	Trade	
Consumer Electronics	Thousands of Dollars	Percentage of Total
Total U.S. Imports	11,765,834	100.0
Japan	7,137,726	60.7
Korea	1,060,239	9.0
Taiwan	1,030,708	8.8
Mexico	703,993	6.0
Hong Kong	629,347	5.3
Singapore	452,905	3.8
Canada	250,029	2.1
Brazil	111,275	1.0
West Germany	89,903	.8
Malaysia	83,963	.7
Subtotal [a]	11,550,088	98.2
Total U.S. Exports	1,042,525	100.0
Canada	285,216	27.4
Mexico	134,077	12.9
United Kingdom	113,883	10.9
Japan	58,205	5.6
West Germany	53,837	5.2
Netherlands	50,400	4.8
Australia	32,257	3.1
France	28,307	2.7
Taiwan	26,423	2.5
Hong Kong	26,060	2.5
Subtotal [a]	808,665	77.6

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-3 Top 10 U.S. Trade Partners by Industry, 1984 (continued)

	Trade	
Electron Tubes	Thousands of Dollars	Percentage of Total
Total U.S. Imports	342,112	100.0
Japan	153,888	45.0
West Germany	46,249	13.5
United Kingdom	21,534	6.3
Canada	19,533	5.7
Taiwan	16,944	5.0
Mexico	14,556	4.3
Ireland	10,981	3.2
France	10,645	3.1
Singapore	9,730	2.8
Korea	9,634	2.8
Subtotal [a]	313,694	91.7
Total U.S. Exports	345,781	100.0
Canada	64,786	18.7
United Kingdom	40,682	11.8
Japan	38,315	11.1
Mexico	22,271	6.4
Brazil	21,377	6.2
France	21,075	6.1
West Germany	17,070	4.9
Taiwan	12,497	3.6
Netherlands	11,345	3.3
Switzerland	10,970	3.2
Subtotal [a]	260,338	75.3

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-3 Top 10 U.S. Trade Partners by Industry, 1984 (continued)

Electron Parts	Trade Thousands of Dollars	Percentage of Total
Total U.S. Imports	5,339,959	100.0
Japan	1,879,506	35.2
Mexico	927,620	17.4
Taiwan	675,428	12.7
Canada	362,565	6.8
Hong Kong	235,730	4.4
Singapore	229,544	4.3
West Germany	178,161	3.3
Korea	134,059	2.5
United Kingdom	113,543	2.1
Malaysia	66,779	1.3
Subtotal [a]	4,802,935	90.0
Total U.S. Exports	2,614,316	100.0
Mexico	428,550	16.4
Canada	414,694	15.9
United Kingdom	264,642	10.1
Japan	170,452	6.5
West Germany	164,902	6.3
Singapore	103,661	4.0
France	102,003	3.9
Taiwan	97,612	3.7
Netherlands	65,502	2.5
Hong Kong	64,703	2.5
Subtotal [a]	1,876,721	71.8

Copyright © ~~National~~ Academy of Sciences. All rights reserved.

TABLE 2-3 Top 10 U.S. Trade Partners by Industry, 1984 (continued)

	Trade	
Industrial Electronics	Thousands of Dollars	Percentage of Total
Total U.S. Imports	11,512,754	100.0
Japan	4,849,995	42.1
Canada	1,031,618	9.0
Singapore	969,700	8.4
Hong Kong	715,892	6.2
Taiwan	693,632	6.0
West Germany	649,294	4.8
United Kingdom	549,294	5.6
Mexico	345,067	3.1
Netherlands	263,384	2.3
Korea	220,093	1.9
Subtotal [a]	10,287,969	89.4
Total U.S. Exports	19,583,904	100.0
Canada	2,920,623	14.9
United Kingdom	2,568,248	13.1
West Germany	1,752,413	9.0
Japan	1,730,909	8.8
France	1,123,581	5.7
Netherlands	1,042,857	5.3
Australia	771,227	3.9
Ireland	601,896	3.1
Italy	576,968	3.0
Mexico	560,577	2.9
Subtotal [a]	13,649,299	69.7

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-3 Top 10 U.S. Trade Partners by Industry, 1984 (continued)

	Trade	
Solid State Electronics	Thousands of Dollars	Percentage of Total
Total U.S. Imports	7,657,498	100.0
Japan	1,989,920	26.0
Malaysia	1,421,472	18.6
Philippines	838,643	10.9
Korea	827,002	10.8
Singapore	604,587	7.9
Canada	343,402	4.5
Taiwan	308,229	4.0
Thailand	225,601	2.9
Mexico	199,180	2.6
Barbados	149,854	2.0
Subtotal [a]	6,907,890	90.2
Total U.S. Exports	5,333,082	100.0
Malaysia	1,069,774	20.1
Philippines	614,315	11.5
Korea	475,652	8.9
Singapore	418,960	7.9
Mexico	365,207	6.8
Japan	363,698	6.8
Canada	311,439	5.8
United Kingdom	269,765	5.1
Hong Kong	253,315	4.7
West Germany	217,258	4.1
Subtotal [a]	4,359,383	81.7

[a] listed nations

SOURCE: U.S. Department of Commerce.

Copyright © National Academy of Sciences. All rights reserved.

TABLE 2-4 U.S. Military Semiconductor Market, 1984 and 1985 (billions of dollars)

Semiconductor Devices	1984	1985
Integrated Circuits		
Metal Oxide semiconductors	0.2	0.3
Bipolar	0.9	1.0
Total	1.1	1.3
Discretes	0.3	0.3
Total	1.4	1.6

SOURCE: Estimates by Willis Adcock, Texas Instruments, Inc.

TABLE 2-5 Features of the U.S. Military Semiconductor Market

Semiconductor Devices	1984 Military Market as Percent of Worldwide Market	1985 Military Market as Percent of Worldwide Market	1985 Percent of Military Market Foreign Owned
Integrated Circuits			
Metal oxide semiconductors	2	2	18
Bipolar	10	13	40
Total	5	7	35
Discretes	5	5	80
Total	5	7	44

SOURCE: Estimates by Willis Adcock, Texas Instruments, Inc.

Copyright © National Academy of Sciences. All rights reserved.

Many semiconductors are produced in U.S. facilities, especially those made to meet specifications on certain aerospace and fuse parts ("MIL-M-38510"), while many others, are made abroad, at least in part. For example, a certain category of devices ("MIL-883 Class B") need not be made in the United States, but instead can be attaind with commercial parts with special screening. Unfortunately, the Army lacks data on the numbers and types of semiconductor components used in military equipment that are made in foreign countries. Without such data, it is impossible to determine, quantitatively, either the degree of exposure or risk to a set of threat scenarios. This same problem exists, to some degree, with other electronic components used in military systems.

The use of foreign-produced semiconductors is an economic reality of major proportion. It is also a reality that imports from Japan are growing rapidly. Potential offsetting opportunities, such as a move to factory automation in the United States, joint R&D consortia, and the Very High Speed Integrated Circuit (VHSIC) program, are discussed in this report. However, the general trend for the U.S. silicon-based solid state industry, and hence DOD, is to continue depending on components made overseas.

GALLIUM ARSENIDE-BASED PRODUCTS

While gallium arsenide (GaAs) is a distant second to silicon (Si) in overall use as a semiconductor, its areas of application lie in high-performance systems that are critical to many military missions. In fact, the relationship of gallium arsenide to silicon in the information age has been compared to that of specialty materials, such as aluminum and titanium, to steel in the industrial era. Because of the small number of GaAs devices used in commercial products, several U.S. companies have decided not to invest in production facilities for GaAs. On the other hand, there has been no reluctance on the part of industry to absorb significant R&D funds from DOD, the National Aeronautics and Space Administration, and other government agencies.

The consequence has been a growing reliance by systems manufacturers on overseas suppliers for critical components in engineering development and production of microwave electronics systems. The degree of this reliance is indicated in a recent report of an Advisory Group on Electron Devices, which is included here as Appendix E. This group concluded that at least 80 percent of GaAs substrates and devices used in U.S. systems come from foreign sources, primarily Japanese.

ELECTRON TUBES

Electron broad tubes are a category of components of varying importance to military equipment. The U.S. industry has evolved over the years to a general position of relative stability and with far less dependence on foreign sources than the solid state industry.

Copyright © National Academy of Sciences. All rights reserved.

Receiving tubes, the most mature segment of the industry, is primarily a replacement business served largely from foreign sources. Direct government sales were 900,000 units in 1984, declining steadily each year from a level of 6.8 million in 1975.

Certain power and special purpose tubes have important military applications. Of the total U.S. factory sales in 1984 of $1 billion, $660 million were for government defense applications. Included were high vacuum, gas, and vapor tubes ($97 million); electrooptic tubes, such as cameras, image intensifiers, light emitters, and displays ($167 million); and microwave tubes, such as klystrons, magnetrons, and traveling wave tubes ($396 million).

To maintain a stable manufacturing base for these tubes in the United States requires that DOD buy from U.S. companies in predictable patterns. There is a growing threat to this base by foreign manufacturers who are catching up in technology and are subsidized by their governments. The use of offsets in the North Atlantic Treaty Organization, as practiced in component procurements, is also a factor in potentially reducing the already narrow U.S. production base for this militarily important category.

CAPACITORS

Capacitors for military applications account for 3 percent of total U.S. factory unit sales and 8 percent of dollar sales ($500 million in 1984). The great bulk of military grade capacitors is manufactured domestically. In contrast, about one-third of nonmilitary types are produced in U.S.-owned facilities located abroad. Foreign brand imports, predominantly used in consumer and industrial applications, make up about 25 percent of U.S. consumption. Some unused U.S. capacity still exists for military types. More could be diverted from industrial grade capacity in case of emergency since many parts are the same except for testing and documentation.

There is a move toward surface-mounted and multilayer designs for commercial applications that are likely to find military use in the future.

Raw material shortages in a threat situation could quickly become a major limitation for U.S. capacitor production, since most of the tantalum and palladium used in capacitors is imported. Stockpiling is an obvious means to protect against a threat, assuming the availability of military use information.

Heavy capital demands will arise for domestic capacitor manufacturers to meet changing technology and markets. At the same time, there is the likelihood of stiff foreign competition spurred by use in consumer products. The matter of U.S. capital formation to meet these developing needs will become an important competitive issue.

Copyright © National Academy of Sciences. All rights reserved.

RESISTORS

In 1984 resistors for military uses represented less than 10 percent of the total U.S. market of $925 million. For the resistor market in general, most of the high-reliability types, including carbon film and carbon composition, are manufactured domestically. The larger volume commercial equivalents are manufactured mostly in Mexico, Taiwan, and Israel.

Very large quantities are manufactured abroad by foreign or U.S.-owned firms, particularly in Japan, and are put into consumer products imported into the United States and in boards assembled overseas in the U.S.-owned feeder facilities. Metal film and wire wound plants are located at home and abroad, with precision types for military applications produced mostly in the United States. There is a growing trend toward the use of thin and thick film resistor networks in newer equipment, including military, most of which are manufactured in the United States, although Japanese producers are very active and are becoming a factor in world markets.

Surface-mounted chip technology, requiring resistor as well as capacitor and semiconductor chips, is becoming important, especially in new computer and automotive uses. Manufacturers in Japan and the United States are engaged in research and development. It is not yet clear how extensively the technology will be used in military systems, since comprehensive reliability data have not been developed. Furthermore, it is not clear whether U.S. companies will invest in domestic volume manufacture or will manufacture overseas.

Most resistors used in military equipment are made in the United States. The industry is facing intensive foreign competition at the same time it has to make extensive capital investments to improve quality and cost-effectiveness and to take advantage of technological advances particularly in networks and surface mounting. The U.S. resistor industry thus faces many of the same competitive pressures as the solid state and capacitor industries.

SWITCHES AND RELAYS

This market, traditionally composed of electromechanical devices, is now moving toward solid state devices, particularly for newer applications. The U.S. market for total switches and relays in 1984 was $870 million. Military consumption is important, although the market is dominated by purchases for office automation, computer, industrial automation controls, and communications.

The industry is highly dispersed, reflecting the many types of products used for switching. Military products are produced almost totally in the United States. However, Japanese producers are aggressively penetrating the U.S. commercial market, particularly with subminiature types which can be mounted directly on printed circuit boards. As newer electronic systems move toward surface mounting and highly miniaturized designs, Japan is likely to become a serious

Copyright © National Academy of Sciences. All rights reserved.

competitive threat because of its large consumer electronics base. The first large-scale application of surface mounted devices, including miniaturized electromechanical and solid state relays and switches, will be in consumer products, so Japan will be able to use its experience to build a capability quickly.

CONNECTORS

The large U.S. connector industry (having factory shipments of $2.9 billion in 1984) provides a great variety of products used in essentially all electrical and electronics equipment. More than 80 percent of the market is controlled by U.S.-based companies. The top 20 U.S. connector manufacturers account for 70 percent of the market, and the largest U.S. company controls 25 percent of the market.

Although most U.S.-based connector companies have between 25 and 50 percent of their sales in international markets, most make products in the United States for domestic markets and in local markets for international sales.

The market for connector products is relatively large, but is extremely fragmented. There are very few product families with sales in excess of $50 million; the median is around $10 million. This makes connectors a very difficult market for foreign companies to target.

At the present time, there is sufficient domestic manufacturing capacity and technology to meet the needs of virtually all commercial and military requirements for the next 3 to 5 years.

Recent trends, however, suggest that the future may be different. As the transfer of electronics equipment manufacturing to overseas sites accelerates, the traditional customers of connector companies will probably start buying some of their components from plants located in foreign countries. This will alter but not drastically change the availability of connectors made in the United States.

Reviewing the present patterns and the outlook over the next 5 to 10 years, it is hard to imagine a supply problem for existing connectors made in the United States. The risk is therefore slight. Further, the problems of thousands of part numbers, rapid technology changes, and, hence, high rates of product obsolescence make stockpiling components or mothballing facilities impractical, costly alternatives. However, future products for electronic applications require significant R&D and manufacturing investment for the foreseeable move to miniaturized circuit boards of smaller dimensions, higher packing densities with VLSI and fiber optic-based systems. Although there is now no threat from overseas producers, it seems logical to assume that the Japanese will become a factor as they capitalize on their successes in solid-state silicon and fiber optic markets.

FILTERS AND QUARTZ DEVICES

The filters and quartz devices industries produced in 1984 about $480 million in factory equipment. Military applications are small in terms

Copyright © National Academy of Sciences. All rights reserved.

of units and declining, but important in application. U.S. manufacturers supply these needs from domestic sources and should be capable of meeting any likely threat scenarios.

TRANSFORMERS AND COILS

The broadly diversified group of transformers and coils products is provided by many manufacturers, including companies producing for internal consumption (roughly 30 percent of domestic output). The industry has been stagnant in recent years as production facilities have rapidly shifted to the Far East for consumer electronics and as there have been minimal changes in military demand. There appears to be no current threat to military suppliers, because most such products--with the possible exception of high performance ferrites--are manufactured domestically.

Copyright © National Academy of Sciences. All rights reserved.

3

VULNERABILITY OF MILITARY COMPONENTS

THREATENED AND NONTHREATENED KEY COMPONENTS

Silicon Integrated Circuits

Current trends toward global interdependence in the area of silicon integrated circuits will continue, with the U.S. industry highly likely to come under increasing competitive pressure.

The Japanese have taken a dominant position in dynamic random access memories (DRAMs), a leading edge product of great importance to newer electronic products. These devices are now the proving ground for technology advances aimed at increasing chip density and decreasing cycle time (increasing computing speed).

The short product life of DRAMs, the rapid decline in prices, and high investment costs have reduced the share of U.S. producers in this marketplace. Only a few major U.S. companies have announced the newest product, the one-megabit (1-M) DRAM, while most of the Japanese manufacturers are at least as advanced and are already beginning at a modest level during automated manufacturing. These Japanese companies are also working intently on bringing the next generation, a 4-M bit random access memory (RAM), to commercial status, while efforts in the United States appear to be focused at the R&D level. The Japanese will probably soon make a major effort to extend their DRAM lead to high performance, static random access memories (SRAMs)--a product of great importance to advanced military systems.

The domestic integrated circuits (IC) industry has so far retained, and probably will retain in the future, worldwide dominance in products other than RAMs, as well as a lead in processor architecture. The growing dominance of the RAMs, however, is capable of providing a very large volume base to support the investment in wafer fabrication equipment required for participation in advanced integrated circuit products.

One challenge to U.S. producers will therefore be to develop volume markets for products other than RAMs to maintain sound investments in the business for the long term. Another more difficult problem will be to face new competition in markets in which foreign producers have not

Copyright © National Academy of Sciences. All rights reserved.

yet manifested themselves. The latter problem contains many uncertainties, but the experience of the recent past is not reassuring for the future.

The Role of Submicron Fabrication of Integrated Circuits

The fabrication of modern semiconductor products requires sophisticated techniques and large, growing capital investments. This trend makes it difficult for small companies to participate as a complete production entity. The industry, as it matures, is therefore becoming increasingly concentrated and focused. The small firm still has an important role, but the market shares of "stand alone" firms have grown significantly smaller over time.

Achieving actual submicron process capability, which is within reach during this decade and will be important in achieving the advanced performance of military systems, will require enormous R&D and factory facilitation. The Japanese are driving toward this objective, as are major U.S. producers, particularly those involved in the Very High Speed Integrated Circuit (VHSIC) program. Acquiring strength in this new technology will become increasingly vital to long-term success as a manufacturer of integrated circuits. The Department of Defense (DOD) has an interest in continuing its strong support of this effort, since the industry may be hard pressed to sustain such a fast-paced effort--particularly during the current protracted industry recession.

Robotics and Other Support Industries

Support industries of various kinds are also acquiring a more foreign flavor. Overseas production of test sets for integrated circuits, for example, is increasingly important. Robotics, especially, may constitute a necessary support system for rapid progress at the technological edge.

U.S. industry is just now beginning to face the investment problems of keeping pace with the Japanese. At issue is the ability of U.S. companies to justify continuing investment at profitable returns compared with foreign competitors who do not have to meet equivalent performance standards.

Integrated Circuit Ceramic Packages

Japanese ceramic manufacturers have the major share, more than 75 percent, of the ceramic packaging market. This is because of several factors, the most important of which are quality and cost. The major Japanese supplier has established a U.S.-based manufacturing capability, which should help in the event that imports are curtailed. However, no appropriate U.S. capability exists for the complex units involved in the latest very large scale integration (VLSI) device support.

Copyright © National Academy of Sciences. All rights reserved.

Gallium Arsenide Technology

The potential advantages of gallium arsenide (GaAs) and related compounds and alloys in electronic applications have been explored in the United States and many other countries for the past 30 years. GaAs is of importance because it has a large, direct energy gap, high electron mobility, heterostructure capability with related materials, high temperature capability, and a high degree of radiation resistance.

These properties make possible the extension of electronics into optoelectronics and to operating speeds well beyond those of silicon devices. The material technology, however, is far less developed and the devices are more expensive than silicon. Therefore, it is economically desirable to use silicon components in as many electronics systems as possible. For this reason, most commercial uses to date for GaAs in the United States are in optoelectronic areas.

In contrast, current military applications for this technology require the optoelectronic and microwave capabilities as well as the radiation resistance of GaAs. Thus, supply problems exist for a number of critical military components.

Substrate Material

Almost all GaAs-related components are fabricated by epitaxial layer growth onto, or ion implantation into, single-crystal GaAs substrates. For this reason, substrate quality is of critical importance to the entire technology. The primary commercial methods for growing GaAs substrate material are the horizontal Bridgman (or gradient freeze) and the liquid-encapsulated Czochralski (LEC) techniques.

During the 1960s and 1970s, the U.S. effort was concentrated on the horizontal Bridgman technique with small-area, low-dislocation-density (10^2 to 10^3 cm^{-2}) material available from several companies, mainly Monsanto. Now, however, for commercial reasons the U.S. effort is dominated by three-inch diameter LEC technology (IEEE, 1985). The resulting material has been of relatively poor quality with high dislocation densities (10^4 to 10^5 cm^{-2}) (Rode and Roper, 1985); Japanese sources are working on four-inch and larger wafers of excellent quality.

Although the indium-doped LEC was pioneered by the Royal Signal and Radar Establishment in the United Kingdom and developed commercially by Cambridge Instruments, it has been perfected by companies in Japan. Sumitomo Electric, Nippon Electric (NEC), and several other Japanese companies have been able to obtain essentially dislocation-free (10 to 20 cm^{-2}), indium-doped GaAs LEC (IEEE, 1985; Solid State Technology, 1985b).

The quality of the Sumitomo horizontal Bridgman material is also very impressive. For example, last year more than 75 percent of the free world's supply of GaAs substrates was sold by Sumitomo. In addition, it is clear that Sumitomo intends to either maintain or

Copyright © National Academy of Sciences. All rights reserved.

increase this share of the market. The company has recently completed a fully automated facility capable of making 10 tons of GaAs crystals a year, and plans exist to expand to 50 tons per year (Solid State Technology, 1985a).

There has recently been some improvement in the quality of U.S.-made LEC GaAs substrate material. There have also been efforts to encourage more U.S. work on the horizontal Bridgman technique for growing GaAs substrate material (IEEE, 1985; Marsh, 1985). Although the R&D effort in the United States is significant, the Japanese effort in the GaAs substrate technology area is already superior to that of the United States.

Low-Noise and Power Field Effect Transistors

The market for field effect transistors (FETs) that use GaAs is dominated by military applications in the microwave and millimeter wave regions, where the high speed and radiation resistance of GaAs are required.

A study on the foreign dependency problems in this area has recently been completed (Analytic Sciences Corporation, 1985). Data on current usage were obtained from 10 companies that manufactured and seven companies that built systems using FETs made from GaAs. The study showed that about 75 percent of the material and more than 50 percent of the low-noise devices were obtained from foreign sources, mainly Japanese companies. For power transistors, more than 50 percent of both the material and the devices originate from foreign suppliers.

Thus, in addition to dominating the substrate material market, Japanese companies such as NEC and Mitsubishi dominate the market for both low-noise and power FETs. Although these devices are currently being sold in moderate volume at moderate prices, a lowering of component quality may occur when production volume increases and costs decrease. In addition, Japanese companies may decide to vertically integrate these components into their own systems rather than sell them individually.

Microwave Monolithic Integrated Circuits

The study performed by the Analytic Sciences Corporation also examined U.S. dependence on foreign sources for microwave monolithic integrated circuits (MMICs)* that use GaAs. Although no current trends were evident, it was clear that many systems companies expect to develop an in-house fabrication capability for MMICS. Historically, U.S. systems

---

*"MMIC" is the designation used by industry.

companies have often been actively involved in new electronic technologies during development. But, because of the large volume requirements foreseen in this field, multiple sources need to be developed, especially since systems firms historically have often been limited in their total volume of production. Thus, if the development of these integrated circuits comes to be dominated by systems companies, this could reduce the number of components companies entering production, and ultimately lead to a dependency on foreign companies.

Japanese companies are expected to concentrate on commercial applications for MMICS, while U.S. companies will focus on military uses. If the Japanese components are found to be suitable for military appli- cations, as many already are, the United States could become dependent on foreign services for yet another electronics component.

The Undersecretary of Defense, Research and Engineering is now beginning a new program also called "MIMIC" to push the development of microwave/millimeter-wave monolithic integrated circuits. This program, if implemented at planned levels, should help significantly in catching up with the Japanese and allow a slanting of technology development toward critical military needs.

High-Speed Digital Integrated Circuits

Although the first digital GaAs integrated circuits were made by Hewlett-Packard in 1974 (Rode and Roper, 1985), the Japanese now appear to make superior ones. Recently, for example, both Hitachi and Fujitsu have demonstrated 4K-bit static RAMs with access times of about 2 ns (Solid State Technology, 1985a,b). This performance is achieved with high electron mobility transistor structures operating at liquid nitrogen temperatures.

DOD has funded most of the U.S. research and development in this area, and DARPA has recently awarded small but significant contracts to Rockwell International and McDonnell Douglas to set up pilot production lines for GaAs. Presumably, these and similar efforts are intended to satisfy critical military requirements for digital integrated circuits in the near future.

To avoid a foreign dependency problem in the long run, however, commercial interest in this technology will probably be required. Although some have made optimistic projections for production of digital integrated circuits, these estimates may not appear sufficiently attractive to stimulate significant commercial U.S. production. In part, this will depend on the presently questionable outlook for U.S. suppliers of supercomputer systems.

Military applications for high-speed, digital integrated circuits are expected to include instrumentation, preprocessors for weapons systems, specialized logic, memory, and, possibly, the entire central processing unit in some future computers--such as those that would be required at numerous strategic defense initiative (SDI) sites.

Copyright © National Academy of Sciences. All rights reserved.

Optoelectronic Sources and Detectors

Fiber optic communications is an important commercial and military application for GaAs-based optical sources and detectors. Compared with radio communications, fiber optics is not vulnerable to radio direction finding, jamming, loss of line of sight, or electromagnetic interference/electromagnetic pulse. Compared with coaxial cable, fiber optics reduces weight, bulk, and installation time.

Therefore, various photonic technologies will likely play an increasingly important role in future military systems, and the question of foreign dependency takes on a special relevance. Although some Japanese components (particularly GaAs) may be superior to those made in the United States, there currently appears to be no problem in the availability of U.S. components for fiber optics.

However, there are virtually no U.S. sources for liquid crystal displays for computer terminals and digital readouts. If this technology should come to dominate other types, such as either cathoderay tubes or plasma, U.S. sources for display devices would be threatened.

Optoelectronic couplers and switches, containing GaAs-based sources, are used in a wide variety of civilian and military systems for isolation, level shifting, noise reduction, and other purposes. These components are produced at low cost in high volume by U.S. industry. Applications for high-power, GaAs-based diode lasers and phase-locked arrays include optical disk re- cording, high-speed laser printing, space communication, and fiber optics distribution networks and long-haul systems. With the possible exception of some single-mode lasers, the quality of U.S. and Japanese components is comparable. However, the supply of materials from foreign sources remains a critical issue.

In the long run, however, the United States may not be able to avoid foreign dependency problems in GaAs-based optoelectronic devices and integrated circuits. Japan currently has under way a $100-million, seven-year national research program involving industry, government, and academia. The research focuses on the basic technology for the mass production of optoelectronic devices and integrated circuits. NEC estimates that Japanese production of optoelectronic-related equipment will be a multibillion-dollar industry by the turn of the century. The Japanese companies will probably come to dominate this market, leaving the military dependent on foreign sources.

Magnetic Materials and Components

Magnetic materials play a vital role in modern industrial society and have a large number of military applications. They distribute electrical energy and convert it to mechanical energy in power systems. They are used to collect and store information and to process high-frequency signals in electronic systems.

Copyright © National Academy of Sciences. All rights reserved.

In spite of the importance of these materials, the United States is rapidly losing its competitive position in certain areas of this technology. This is because U.S. companies, in general, perceive no economic advantage in improving magnetic materials, while other countries, notably Japan, have decided it is in their best long-term interest to do so. As a result, U.S. systems manufacturers, and thus DOD, buy a number of critical magnetic components from foreign sources (Analytical Sciences Corporation, 1985).

Permanent Magnets

One critical area in which the United States lags far behind other countries is in new materials technology for permanent magnets. This application requires hard magnetic materials with high coercive force, such as the iron-based rare earth alloys. The rare earth metals in these magnets, however, occur together in common ores and are difficult to separate. Because of this, pure rare earth magnets are expensive.

Recently, stronger and cheaper iron-based rare earth magnets have been developed in Japan. These permanent magnets are cheaper because they use rare earth mixtures. They are now commercially available from Sumitomo and Neomax. There is some U.S. research in these materials, and some commercial supply from Japanese licensees in the United States.

Other materials being developed for permanent magnets, primarily in Italy, Holland, and West Germany (Philips), are the hexaferrites. These materials are hexagonal iron oxides, compounded with boron and strontium. They are expected to be relatively inexpensive because of the discovery of new deposits of strontium in France.

Magnetic materials that are not iron-based, such as samarium-cobalt (Sm-Co), are usually too expensive for commercial use as permanent magnets. However, they are used extensively on military and satellite traveling wave tubes. This technology was pioneered in the United States, but the narrow market has caused U.S. companies to withdraw, leaving a dependency on foreign sources.

Magnetic Tapes and Disks

For recording and storing data, hard magnetic materials with medium coercive force, such as cubic Fe_2O_3, are used. Although components made from this material are available in the United States, the highest quality ores are believed to come from England and Italy. Other materials for these applications are CrO_2, and the Co-P and Co-Fe-P alloys. Since these materials are inexpensive with high-volume applications, they are commercially available from several U.S. suppliers, such as Ampex and du Pont.

The problem appears to be in the development of new materials for high-density recording applications. Japan is leading in the development of Co-Cr alloys, with little U.S. activity. This alloy may be the

Copyright © National Academy of Sciences. All rights reserved.

material of choice for high-density hard disks in computers. There is also a substantial amount of work in Japan by Toshiba, for example, on the hexaferrite, $BaFe_{12}O_{19}$, which should be inexpensive and work very well for both tapes and disks.

Although magnetic bubble memories were originally developed in the United States, much of the production now comes from Japan. Despite the existence of at least one domestic source, much of military procurement depends on foreign suppliers.

Recording Heads

Electromagnetic recording heads are made from soft magnetic materials with low coercivity, such as some cubic ferrites and permalloy, an iron-nickel alloy. Most commercially available heads are made from ferrites, with the newer thin-film electromagnets made from permalloy. Although a significant increase in writing and reading density could be obtained with improved ferrite heads, an increase of about an order or so of magnitude can be achieved with permalloy thin film heads and disks. Because of the potentially large commercial market for high-density magnetic recording, this technology should not present a supply problem for U.S. military systems.

Microwave and Millimeter Wave Magnetic Components

Microwave circulators, isolators, filters, and phase shifters are made from soft magnetic materials with low coercive force, generally ferrites and garnets. Most of the technology in these magnetic materials was originally developed by DOD. Today, about 85 percent of the market is for military applications (IEEE, 1985). For this reason there is not expected to be a supply problem for microwave magnetic components.

In the millimeter wave region, however, microwave ferrites and garnets are not adequate because of bandwidth and frequency problems. Also, electromagnets saturate at flux densities well below those required for operation at millimeter wave frequencies where superconducting magnets are currently being used (Zensius et al., 1983). Although there is a significant amount of U.S. research and development in this area, European work, particularly in hexaferrites, may be more advanced. The future outlook for overseas dependency cannot yet be assessed.

Lithium Batteries

Lithium-based batteries are currently replacing most other batteries as the primary power sources for highly portable electrical and electronic

Copyright © National Academy of Sciences. All rights reserved.

systems and as either the secondary or backup sources for stationary systems. Since there are a large number of commercial uses for this technology, the U.S. position is expected to remain strong. There is currently a substantial R&D effort by U.S. companies, such as Rayovac and Union Carbide, on a variety of battery materials, including Li-SO_2, Li-$SOCl_2$, Li-TiS_2, and Li-CF. As a result, lithium batteries continue to develop higher current densities in smaller, cheaper packages.

The lighter weight and longer lifetime of lithium batteries is expected to enhance the effectiveness of a number of military systems. To the extent that these applications track the commercial market for lithium batteries, there should be no U.S. supply problems. Very high capacity, lithium-based batteries, however, may be limited to military use with little or no commercial market. A major current supplier is Tadiran in Israel. The supply outlook here is still uncertain.

Nonvolatile memories represent a rapidly developing application for lithium batteries (Lineback, 1985). Several U.S. companies are beginning to embed lithium cells in dual in-line packages. These can serve as a backup for static random access memories and turn standard military RAMs into long-term, nonvolatile storage systems. Lithium batteries could last as long as 50 years for such storage systems (Lineback, 1985). Requirements are not yet established and so the question of domestic versus foreign supply in this application cannot yet be resolved.

OTHER COMPONENTS, NOT THREATENED

A number of electronic components of importance to U.S. military systems are not seriously threatened by overseas sources. The following components needed to meet military specifications are adequately supplied from domestic sources and are not currently challenged in the marketplace by foreign ones:

- capacitors
- resistors, resistor networks
- relays, contactors, solenoids, circuit breakers
- meters, indicators, gauges, lamps
- connectors and associated hardware
- filters
- fuses
- switches
- transformers and coils
- quartz crystals
- transistors (except some specials)
- diodes (except some specials)
- thyristors

Copyright © National Academy of Sciences. All rights reserved.

While these items are apparently not threatened, there is little room for complacency: there are many hidden dependencies even in these areas. For example, in the case of discrete transistors, in accordance with the provision of MIL-S-19500 specifications, products categorized as "JAN" and "JANTX" may be packaged and tested abroad. Only the "JANTXV" category must be fully processed in the United States. In the case of typical military telecommunications equipment, about 35 percent of the discretes are JANTXV, with the remaining 65 percent being either JAN or JANTX. Notwithstanding the current depressed semiconductor market, lead times on MIL-S-38510 integrated circuits are running 30 to 45 weeks, a schedule constrained by packaging facilities, test equipment, and burn-in racks and sockets. If it were necessary to process all semiconductors in the United States, lead times would immediately expand to a year or more.

In the case of tantalum capacitors, which are heavily used in military equipment, the concern is the raw material. The United States does not produce tantalum ore. Canada's resources are being depleted. Africa and South America were once the main suppliers, although there has been a recent find in Australia.

Mica capacitors are still the optimum solution in a few critical areas, although their uses have been decreasing for the last 35 years, are still the optimum solution in a few critical areas. Their production depends on the availability of muscovite mica, produced primarily in India.

Traveling wave tubes will be used to a much greater extent in satellite communications terminals as the new millimeter wave military satellites enter service. Domestic production capabilities are limited. The major sources include Siemens and Telefunken in West Germany, Thomson-CSF in France, and Varian Associates, which is importing tubes from NEC in Japan. There is also concern regarding the dependence on British sources for certain millimeter wave tubes.

An underlying problem exists in a number of the basic raw materials used extensively in electronics production, such as platinum, tantalum, and palladium, where the United States is primarily or totally dependent on foreign sources.

Finally, the trend toward permissible foreign packaging and testing of certain semiconductor items, such as MIL-STD-883 integrated circuits and MIL-S-19500 JAN and JANTX discrete transistors, has established both a policy and a capability for overseas inspection. With this trend in place, and considering that many of the Japanese manufacturers of semiconductors are major corporations with high-volume production of a complete spectrum of electronic components, it will not be at all surprising if the Japanese begin to make specific targeted inroads into the market for military devices in the same manner as they have used to successfully challenge the domestic commercial producers of integrated circuits. Apparent trends in production give little reason for complacency in the future for any of the items presented on the list.

Copyright © National Academy of Sciences. All rights reserved.

4

MILITARY SYSTEMS THREATENED BY THE VULNERABILITY OF GALLIUM ARSENIDE COMPONENTS

Previous chapters have dealt with the risks to defense capabilities in times of emergency because of the dependence on foreign sources for electronic components. Virtually all modern military systems use electronic components extensively for sensors, communications, guidance, command and control, and other functions. It is the use of silicon integrated circuits that has enabled defense systems to achieve their current level of effectiveness. The acquisition and logistics commands should consider the vulnerability of U.S. defense systems to supply interruptions of silicon devices if those systems are to be available and sustainable in times of emergency.

Because of the increasing importance of silicon integrated circuits in defense systems, the Department of Defense (DOD) has funded the Very High Speed Integrated Circuits (VHSIC) program to ensure indigenous U.S. capabilities in the design and manufacture of very large scale integrated circuits.

The next advance in integrated circuits is likely to depend on a substrate material different from silicon, in particular, gallium arsenide (GaAs). It should be noted that GaAs devices are already used in microwave devices and special discrete high-speed devices. However, the increasing maturity of GaAs technology will likely make possible the wide use of both digital and analog integrated circuits, optoelectronic sources and detectors, and microwave components in defense systems fielded in the late 1990s and beyond.

CURRENT GALLIUM ARSENIDE USES

GaAs is especially important in communications, radar, missile guidance, and electronic countermeasures (see the review in Feinstein, 1982).

Copyright © National Academy of Sciences. All rights reserved.

Communications

Military needs for communications range from satellite transponders for continental distances to millimeter wave radio and fiber optic cable links for short distance and battlefield use. All high-performance microwave receivers now use low-noise GaAs field effect transistors (FETs). The low-noise stage is generally followed by several stages of amplification, all of which contain these transistors.

While discrete components in hybrid assemblies tend to make up fielded systems today, the trend toward monolithic integrated circuits is now well established in development and should appear in the field during the next decade. Typically, U.S. companies purchase field effect transistors overseas and assemble the hybrid units domestically. Such labor-intensive assembly is becoming noncompetitive with the advent of monolithics. Receivers for satellite links are located at earth stations as well as on the "birds" themselves. Ground-based transmitters must radiate high power in the kilowatt range and therefore require microwave power tubes such as klystrons and traveling wave tubes. Modern satellite transmitters operating in the 10-watt power range now use GaAs devices rather than the traveling wave tubes of older design. Power FETs for such uses are also dominated by foreign suppliers, although several U.S. companies have demonstrated capability at the laboratory level.

Millimeter wave radio is now in advanced development by the Army to provide secure communications with a battlefield. Solid state diodes based mainly on GaAs are used for mixers, local oscillators, and, in some cases, even for the transmitter. While these devices are more rudimentary than the traveling wave and other tubes, they provide adequate, short-distance signal-to-noise performance at superior reliability, lower costs, and with longer lifetime.

At present there is no production base for the high volume (hundreds of thousands) of these devices that will be required in the field either in the United States or overseas. Even the Japanese have been reluctant to invest in what appears to be a purely U.S. military market, in contrast to the commercial development they foresee for microwave links and satellite repeaters. Raw materials sources here are totally foreign.

To reduce vulnerability to electromagnetic pulse and other forms of interference, fiber optic links are now being used to connect Army battle stations. While the cable is available domestically, the transmitter, which consists of either a GaAs laser diode or light-emitting diode (LED) with modulator, is being obtained from overseas suppliers. Again, laboratory capability exists at several U.S. companies, but the production base is inadequate to be price competitive.

Radar

Radar needs range from long-range surveillance for threat analysis to short-range battlefield target acquisition, both ground and helicopter based. The short-range systems, such as STARTLE, tend to

Copyright © National Academy of Sciences. All rights reserved.

use millimeter waves to provide high resolution with small aperture, mobile antennas, while lower microwave frequencies and complex (Doppler) motion discrimination is required for threat analysis.

In all cases, GaAs components are used in the radar receivers in roles similar to those in communications. Tubes are now used to provide radar transmitter power, but solid state replacements for all new millimeter wave radars that use phased-array systems are both in an advanced stage of development. These could also use silicon impatt diodes, but superior performance would result with materials of the GaAs family.

Ultrahigh-speed signal processing of radar returns is required for quick automated decision making. While VHSIC chips based on silicon will provide this capability for the near term, a fivefold increase in digital speed of GaAs over silicon is leading to the adoption of logic using the former in the next generation of radar systems.

In view of Japan's announced intention to compete in the high-performance computer market, the Japanese will probably invest in a production capability for digital integrated circuits using GaAs. If U.S. companies again decide against significant investment because of the narrow markets for such premium products, the United States will face the same vulnerability in the digital area as it faces today in linear (microwave) components.

Missile Guidance

The increasing emphasis on "intelligent" munitions requires a system that can detect and track targets to be incorporated into the projectile. The small size of millimeter wave antenna apertures and the superior weather penetration compared with infrared makes this wavelength range attractive for such missile seekers provided the electronic components can be miniaturized and reduced in power consumption. Solid state devices are therefore ideal for this use. While the rudimentary nature of this sensor does not require the high performance of more elaborate radars, GaAs Gunn diodes will still be needed for local oscillators, varactors for frequency multiplication and mixing, and impatts for pulse power transmitters. Since device performance translates into missile lock-on range and tracking accuracy, significant compromise on quality is unacceptable.

Data links from the launching platform to the missile itself use microwave frequencies and make additional requirements on the solid state components. Several new Army systems will be of this type. In fact, one million logic devices and amplifiers will probably be required over the life of Army weapons systems.

Electronic Countermeasures

The increasing sophistication of electronic equipment has led to the term "electronic warfare" to describe the escalating battle between

Copyright © National Academy of Sciences. All rights reserved.

radar, communications, and guidance systems, and the interference and false target data aimed at them. Extremely wide-band surveillance receivers are used to detect enemy emissions and high-power jamming sources are used as a countermeasure. Recent developments in monolithic preamplifiers for GaAs field effect transistors cover a range of 2 to 20 GHz, providing an excellent front-end for surveillance. Older equipment in the field uses a frequency swept local oscillator, typically a varactor-tuned GaAs diode to achieve wide-band reception.

Jammer power requirements generally call for tubes. Even so, British sources are the major suppliers of tubes in the 20 to 40 GHz frequency band. In addition, as the trend toward solid state components replacing tubes increases, our reliance will shift to Japanese sources.

The signal coding techniques used to thwart detection of electronic countermeasures require elaborate receiver signal processing to discover intelligence buried in simulated white noise of the swept spectrum. High-speed analysis, preferably at the microwave emission frequencies, is necessary to accomplish this task quickly. Although hybrid analog methods, such as acoustooptic processing, are used today (and require a laser generally using GaAs), the trend is toward front-end, analog-digital conversion and ultrahigh-speed spectrum analysis and logic. Clearly, this is a role destined for GaAs.

FUTURE TRENDS

The rapid pace of GaAs development in analog, digital, and optical components leads to the expectation that military systems requiring state-of-the-art performance will become more dependent on such components to maintain superiority. In the analog area, the trend is clearly toward monolithic microwave integrated circuits (MMICS). This will result in the front end of the receiver through the video intermediate frequency stages being integrated on a single GaAs chip, as has already been done in Japan and for a direct broadcast satellite receiver in the United States. Because each specific use is custom designed, the capability for such chips must reside within the United States.

A second major trend is the development of all solidstate, phased-array transmitters. This approach overcomes the limited power capability of each device by adding the power of each to the radiation field. In addition, phase shifting across such an array provides an inherently fault-tolerant means for electronic scanning. Integrating of GaAs FET power amplifiers and digitally controlled phase shifters on a chip would provide modules for such an array. Arrays are now being developed for selected radar, communications, and electronic countermeasure systems. Funding has come primarily from the Air Force, with the Strategic Defense Initiative Office (SDIO) now becoming involved. Many potential Army uses can be foreseen.

The digital GaAs area is at present the least developed technology. However, the high-speed computing requirements for fast signal processing and for command and control decision making will lead to the

Copyright © National Academy of Sciences. All rights reserved.

fielded use of GaAs logic and memory chips early in the 1990s. DOD-sponsored development now emphasizes the superior radiation hardness of GaAs rather than merely its speed.

While one school of thought believes that interconnection delays rather than intrinsic device speed will ultimately determine computer performance, there are some hybrid uses such as A/D converters (directly at microwave frequencies), for which there is no substitute for GaAs. Integration of digital computation on the same chip would clearly be advantageous for a wide class of military systems. The capabilities of GaAs are leading to an entire new architecture for cost-effective systems.

The trend toward phased arrays also leads to a composite analog/digital module, where the individual transmitter and receiver FETs are controlled by digital logic. Since a large number of such modules will be required even for relatively low power systems, a U.S. production capability for high-quality GaAs components is clearly essential.

Finally, arrays of GaAs/GaAlAs laser diodes will probably replace less efficient and more cumbersome lasers. The threat posed by aggressive Japanese development plans in all the above areas is clearly indicated by a recent panel conducted under the Japanese Technology Evaluation Program of the U.S. Department of Commerce and the National Science Foundation (Bell, 1985).

Copyright © National Academy of Sciences. All rights reserved.

5

INDUSTRIAL MODERNIZATION AND PREPAREDNESS

GENERAL PROGRAMS TO SUPPORT PEACETIME PRODUCTION

Various programs have been proposed or adopted to support peacetime production of essential commodities, including electronic components. These are Title III of the Defense Production Act, the Manufacturing Technology Program, the Industrial Modernization Incentives Program, and the Department of Defense's (DOD) Production Surge Initiative.

Title III of the Defense Production Act

Creating or expanding domestic production provides greater flexibility than alternatives such as stockpiling in most cases. It also reduces stockpile goals by decreasing U.S. dependence on foreign imports, increases the gross national product, provides employment, and helps reduce our balance of payments.

If domestic capabilities are to increase, the industrial community must be convinced that profits and markets will follow from investments in new or expanded capabilities. To encourage this expansion, incentives are needed. In industries where capital formation is not difficult and marginal investments may be minimal and short term, tax incentives may be sufficient. However, industries that require large initial investment and are sensitive to market risks will generally require additional encouragement.

Title III of the Defense Production Act of 1957 provides long-term, cost-effective incentives to encourage domestic production. DOD claims that during the Korean War about $8.4 billion of industrial facilities were established with a government outlay of less than $900 million.

In its attempts to secure appropriations for Title III projects, DOD supported the Federal Emergency Management Agency (FEMA) from 1976 until 1982, and the Federal Preparedness Agency until 1978. Prior to 1979, more than 30 proposals had been developed that addressed a variety of industrial base problems. FEMA, however, was unsuccessful in obtaining approval from the Office of Management and Budget (OMB) for any projects; therefore, no appropriation requests were submitted to Congress for Title III funding.

Copyright © National Academy of Sciences. All rights reserved.

Secretary of Defense Caspar Weinberger, with FEMA concurrence, proposed legislation to OMB in May 1982 that would allow Title III programs to be funded within the DOD budget. An agreement was reached with OMB in December 1982 that established Title III program levels of $50 million (FY 1982), $200 million (FY 1983), $300 million (FY 1984), and $500 million (FY 1985 and FY 1986 each). These appropriation levels have since been revised to $25 million (FY 1985), $75 million (FY 1986), $300 million (FY 1987), and $500 million (FY 1988 and FY 1989 each). The reduction was to allow time to demonstrate the positive use of Title III through one or more small projects and to show Congress the costs and benefits of the program.

Title III is not the complete solution to our ongoing dependency on imported products. But correctly used and administered, it can provide incentives for domestic production and decrease the military's vulnerability to the threat of supply interruption.

Manufacturing Technology Program

On May 24, 1985, DOD launched its manufacturing technology program. The program relies on private sector investments and the free market to provide the manufacturing technology necessary to produce DOD materiel. The program seeks to improve the productivity and responsiveness of defense industries. DOD funds will be used only when qualified segments of industry either cannot or will not commit private funds to establish manufacturing technology for which they do not see a market. Thus, DOD funding would help ensure that manufacturing technology would be available opportunely in support of DOD's special requirements.

Further, the manufacturing technology program aims to accomplish the following:

- Aid in the economical and timely production of weapons systems and components
- Ensure that advanced manufacturing processes, techniques, and equipment are available for reducing DOD materiel acquisition, maintenance, and repair costs
- Advance manufacturing technology continually to bridge the gap from R&D to full-scale production
- Promote capital investment and industrial innovation in new plants and equipment by reducing the cost and risk of applying new or improved manufacturing technology
- Ensure that manufacturing technologies used to produce DOD materiel are consistent with safety and environmental considerations and energy conservation objectives
- Disseminate results throughout the defense industries.

In carrying out the manufacturing technology program, DOD created a computer data center called the Manufacturing Technology Program Information System. It contains information on all planned, active, and completed program investments.

Copyright © National Academy of Sciences. All rights reserved.

DOD recently established the Manufacturing Technology Information Analysis Center to collect, analyze, and disseminate information on the program. A data base will contain information on manufacturing technology projects sponsored by the Army, Navy, Air Force, and Defense Logistics Agency.

DOD also sponsors a Manufacturing Technology Advising Group (MTAG). Six technical subcommittees provide expert technical advice on the program and its initiatives. MTAG provides a technical focus for the military departments and defense contractors by reviewing proposed investments and by holding meetings to discuss issues.

Industrial Modernization Incentives Program

The industrial modernization incentives program assumes significant opportunities exist to modernize manufacturing processes for defense production. Although there are many good examples of advanced manufacturing technology uses, much of the manufacturing done on defense programs is labor-intensive and uses outdated and inefficient equipment. Batch production methods are used extensively in which quantities may be small, deliveries spread over a period of time, and engineering changes frequent.

Therefore, recent technology advances pointing to major manufacturing improvements are particularly suited to DOD needs. In particular, flexible manufacturing systems appear to offer the greatest promise. For example, computer control and integration of machines, work stations, transfer mechanisms, and tooling can make possible the production of a wide variety of products in small numbers.

Two problems have been cited most frequently as inhibiting modernization and progress in the defense production area: program uncertainties and a profit calculation policy that, in most acquisition circumstances, is based on unit cost. Uncertainty means risks are introduced that hinder investment amortization and inhibit long-term planning. DOD's cost-based profit policy means that a contractor may actually see future profits reduced as a result of efforts to improve productivity and reduce costs. DOD's desire to obtain the lowest possible price therefore often results in negotiating away the long-term benefits a contractor may see from modernization, leaving only the risks.

The industrial modernization incentives program is a response to these challenges. It is targeted at fostering increased capital investment and modernization. It relies on incentives such as shared savings rewards, contractor investment protection, and award fees to encourage contractors to invest in modern plants and equipment. DOD must see the prospect of reduced acquisition costs as a result of any business arrangement negotiated under the program. Associated benefits may result in areas such as quality, reliability, or the industrial base, and should be highlighted in proposals.

Copyright © National Academy of Sciences. All rights reserved.

DOD has already begun discussions, factory studies, framework agreement negotiations, and actual projects under the program. General Dynamics (F-16) and Westinghouse (multi-program) have received the lion's share of the publicity in terms of concept applications. However, a large number of contractors are seen to be involved when subcontractor and vendors are considered, for example, more than 100 contractors are estimated to be involved in the program, many as subcontractors.

A "strawman" policy documentation package (DOD FAR Supplement coverage, a DOD directive and guide) supporting the program was recently circulated. DOD plans to place the policy documentation in the formal coordination cycle, terminate the test phase, and move to the implementation phase in the near future.

DOD Production Surge Initiative

A "production surge" program would permit the rapid increase in sustained production of important military systems, for example, doubling peacetime rates in time of urgent need. Because of peacetime fiscal limits, the program will include only those consumables and components deemed most critical by the Joint Chiefs of Staff and the Armed Services via a time-phased, selective approach. The concept requires that surge targets be achieved within six months and then sustained indefinitely using existing facilities.

The program aims to achieve minimal net cost to DOD over the production life of the surge item, with the eventual consumption of all those long-lead component purchases that would have been made in the final years of normal production. It also seeks high payoff from invested funds in terms of a significant production capability increase added per dollar spent, flexibility of DOD options for item life-cycle support, and minimum risk of technological obsolescence of components, considered to be carried in the surge "rolling inventory" on a first-in, first-out basis.

The first DOD surge item funded by Congress was the TOW 2 missile in FY 1985 with an investment of $16.2 million. This initiative would provide a capability to increase production by 700 missiles per month within six months of any crisis and to sustain this level indefinitely. A follow-on investment of $20 million has been requested in the FY 1986 budget to add a monthly capability of 800 additional missiles for a maximum surge increase of 1,500 missiles above the 1,000 programmed peacetime production rate.

Other FY 1986 surge projects include $29.1 million to double the production of the SSQ-53B and 77A sonobuoys in three months, $9.5 million to increase Sparrow missile production by 30, $8 million to increase Sidewinder missile production by 60 within six months, and a first-stage $5-million investment (toward a total $68 million) for advancing a capability to double production output of the combined effects munition (CBU-87) within six months.

Copyright © National Academy of Sciences. All rights reserved.

SPECIFIC ELECTRONIC COMPONENTS PROGRAMS

There are a very limited number of initiatives related directly to electronic components. Some related basic research and exploratory development programs, however, are supported, as are the silicon-based Very High Speed Integrated Circuit (VHSIC), the new MIMIC (GaAs) programs, and those few programs involving a selected number of other specialized components. Despite the promise of these specific efforts, a serious gap in preparedness could arise if more resources are not devoted to electronic components.

Related Research Support

Some component research is funded by the three services. However, this research tends to emphasize basic electronic phenomena that could eventually provide the basis for an electronic component, rather than component research per se. Each service has an electronic devices program that provides the primary continuous source of funding explicitly directed toward electronic components. Each service tends to provide $20 to $30 million for such research.

This funding is used to develop components in three general categories: low-power devices, microwave and millimeter wave devices, and electrooptic devices. A special advisory group, called the Advisory Group on Electronic Devices, reviews all proposed projects.

VHSIC

Over the years, there have been some small advanced development efforts in components, but none on a sustained basis until the VHSIC program changed over in 1983 from exploratory development to advanced development. Thus, the VHSIC program represents a major departure from the components development strategy followed during the 1960s and 1970s.

The need for the VHSIC program arose from the perceived progress of the Soviet Union in the use of silicon integrated circuits in their military systems. It is also clear that the large and visible effort of the Japanese in very large scale integration (VLSI) heightened DOD's awareness of the importance of high-speed integrated circuits. The VHSIC program was originally planned as a $300 million program; with yield enhancement and systems insertion being added, the cost to completion is now put at nearly $1 billion.

Laissez Faire Policies and Defense Needs

Because electronics technology, with few exceptions, is driven by commercial markets, DOD has sought to avoid investment in electronics technology except where particular military uses warranted special development. As a result, most of the programs oriented toward

Copyright © National Academy of Sciences. All rights reserved.

preparedness were not applied to electronic components. It should be noted that VHSIC technology--and the fledgling microwave monolithic integrated circuits effort--are exceptions in that a manufacturing technology program is being funded to improve components. Other exceptions include components such as traveling wave tubes and radiation hardened components, where the primary application is in military equipments.

Common electronic components, such as resistors, capacitors, switches, silicon memory, and logic chips, largely escape attention from the point of view of preparedness, even though a large percentage involve foreign manufacture. It is the very pervasiveness of these components in military systems that could cause replenishment problems in time of war if supply lines are cut off and there is no stockpile and little manufacturing capability in the United States.

A plan is clearly needed, but apparently does not exist, to establish methods to obtain components of the class described above in time of war.

Copyright © National Academy of Sciences. All rights reserved.

6

CURRENT PROCUREMENT POLICIES AND PRACTICES

FOUR KEY POINTS

Four points relate to current Department of Defense (DOD)--and overall U.S.--procurement policies and practices and are critical in evaluating any future initiatives that might be taken to reduce the U.S. military's dependence on foreign services for electronic components. They are:

1. Overall, there is little DOD or U.S. government policy at the component level. Procurement policies that deal with cost factors are focused at the weapons systems level. For example, the "Buy American Act" specifically applies only to end products and does not consider individual subsystems and components.
2. Some policies, primarily at the weapons systems level, pull against one another by simultaneously encouraging DOD buyers to increase and reduce foreign dependency. This ambiguity, both for policy and procurement, allows arbitrary and often contradictory decisions to be made by each individual player.
3. There is little or no "visibility" in the form of available hard data on foreign dependency at the component level in U.S. weapons systems today. This has been demonstrated by a number of DOD and independent studies over the last few years. Further, there are no specific actions now under way to gain such visibility other than those made ad hoc.
4. There is currently no DOD or U.S. government organizational responsibility, in either the policy or procurement arena, for addressing the overall issue of growing dependency on foreign components for weapons systems. Thus, adverse trends are likely to continue in the absence of a specific institutional change.

THE FOREIGN-DOMESTIC DICHOTOMY IN CURRENT POLICIES

Policies Encouraging Self-Sufficiency

To understand better the current ambiguity in U.S. policy with regard to foreign dependency, consider two sets of essentially different (and

Copyright © National Academy of Sciences. All rights reserved.

yet concurrent) policies that now exist. These policies are administered by a wide variety of segments in DOD and the rest of the federal government. The first encourages U.S. self-sufficiency.

By explicit legislation, and the corresponding federal regulations, R&D on weapons systems is limited to U.S. sources only (DOD FAR Supplement 25.7007; based on Section 744 of the Defense Appropriations Act for FY 1973).

On very selected projects, such as the Very High Speed Integrated Circuit (VHSIC) program, DOD has explicitly excluded foreign participation. The reasons given vary from economic to strategic considerations.

DOD has explicit and implicit procedures throughout its production and mobilization planning that address foreign dependency. For example, one Army regulation (70-67) calls for an overall strategy for acquiring weapons systems. Under this regulation, the production risks are identified at each acquisition decision point and risk-eliminating actions are evaluated. Among the considerations are plans to ensure a second source to support efficient manufacturing and to provide for any required "surge" capacity. The project manager is responsible for continual evaluating the reduction of production risks and for collecting sufficient data to conduct the evaluation.

Yet another Army regulation (70-72) specifically prescribes the policies and responsibilities for production management. This regulation calls for integrating planning for industrial preparedness with that for production. Project managers are required to consider the effect that choosing foreign-made equipment or components will have on industrial preparedness.

By requiring special specifications for electronic components instead of using commercial ones, DOD has been able to indirectly control the source of components. Military specifications tend to result in far more expensive components and thus make it relatively unattractive for foreign manufacturers to produce them for commercial use. However, a recent shift allows Ireland, Austria, and Canada to be treated as U.S.-qualified sources.

The "Buy American Act" of 1933 is intended to exclude the procurement of weapons systems from foreign sources. The original objective was to protect American workers, industry, and capital, although strategic considerations have always been important. This law, quite encompassing at the prime contractor level, does not apply specifically to subsystems and components, as long as more than 50 percent of the total system costs are domestic. Thus, while the act tends to discourage foreign procurements, it does not exclude them in primarily domestically produced systems.

The Buy American Act can be waived through a bilateral memorandum of understanding between the United States and other countries, as authorized by the Culver-Nunn Amendment to the Defense Appropriation Act of 1977. Yet, there are provisions that promote self-sufficiency by not allowing this waiver if it could affect U.S. mobilization. They require that mobilization and the need for a strong domestic industrial base be considered in evaluating opportunities for international competition.

Copyright © National Academy of Sciences. All rights reserved.

Prior to initiating production, DOD requires that a detailed evaluation be made of a program's "production readiness." A manufacturing strategy is supposed to be developed as a part of the program acquisition strategy that will address dependencies on critical foreign source materials.

In addition, the production readiness review also requires that the program office consider postproduction support. This also encourages consideration of the issue of self-sufficiency. Specifically, production planning must be done to meet material requirements for the postproduction period.

Perhaps one of the greatest incentives to self-sufficiency is the continual effort made by individual congressmen to protect U.S. suppliers in their particular districts. Thus, special items are continually being added as riders to the defense appropriations bill that require purchase of items in the United States. (A frequent example is the insertion of the "specialty metals clause" requiring that all "specialty metals" be melted in the United States, even if the item using the metal is made overseas.) While always a consideration, the tendency to use such special exceptions frequently increases during periods of economic hard times or defense cutbacks.

Policies Fostering Foreign Dependence

In contrast to policies emphasizing self-sufficiency, other policies and practices have the effect of encouraging foreign dependency, especially at the component or subsystem levels. The latter policies are growing in number, a result of the reciprocity required for foreign sales of U.S. military equipment, attempts at greater economy in weapons research and acquisition, and attempts to encourage allied cooperation.

Since the mid-1970s the United States has sold many of its weapons systems abroad through the foreign military sales program. Averaging around $15 billion a year, these sales are frequently made in a competitive marketplace and thus have to be made attractive to foreign buyers.

The most common technique for doing this is to reach "offset agreements" wherein the foreign purchaser will buy a weapons system from the United States a and the United States (either the country or the company involved) will purchase a significant share of the total sales value in other goods from the foreign country. (In recent years, the percent has often exceeded the weapons system sales value.) The most common arrangement in these offset agreements is for the foreign purchaser to buy the weapons system and for U.S. firms to assist with purchases in the foreign country, particularly of subsystems and components.

Thus, for example, Raytheon Company (U.S.) and Fokker (Netherlands) signed a basic purchasing agreement in January, 1985. Raytheon agreed to buy $65 million worth of electronic equipment in the Netherlands for the Patriot antiaircraft missile during the subsequent 4 years and then

Copyright © National Academy of Sciences. All rights reserved.

an additional $50 million of logistical services over the next 11 years (Aerospace Daily, 1985). While such offset agreements obviously have a growing effect on foreign dependency, especially at the com- ponents level, sales of U.S. foreign military equipment does help the U.S. economy and national security. Thus, such agreements have been encouraged in recent years. Offset agreements are now in effect with Australia, Belgium, Denmark, the Netherlands, Norway, Switzerland, and Israel, and numerous additional offset agreements exist on a company-to-company basis.

In recognition of and to encourage our allies to contribute to a joint defense, the United States seeks to cooperate with them in developing and purchasing weapons systems. Specifically, DOD encourages the highest practicable degree of standardization and interoperability of equipment and duplication of effort. Thus, DOD seeks to select components and subsystems designed and built overseas. These policies require weapons planners to ensure that sources, in North Atlantic Treaty Organization (NATO) countries with whom the United States has signed memoranda of understanding, have an opportunity to compete with U.S. sources for DOD business.

Even stronger language is contained in policies issued by DOD's Office of International Security Affairs, which specifically encourages the maintenance of a "NATO industrial base." DOD Directive 2010.6 (Standardization and Interoperability of Weapons Systems and Equipment within the NATO states:

- The Department of Defense shall initiate and carry out methods of cooperation with its allies in defense equipment acquisition to improve NATO's military effectiveness and to provide equitable economic and industrial opportunities for all participants.
- The United States shall pursue...establishment of general and reciprocal procurement memoranda of understanding with NATO member nations. These are intended to encourage bilateral arms cooperation and establish regular review of armaments programs and trade and to make efficient use of alliance resources through expanded competition. Waiver of "Buy National" restrictions should be sought and applied wherever possible to support this objective.
- Foreign participation as subcontractors to U.S. prime contractors shall be encouraged, as well as U.S. industry performing as subcontractors to NATO prime contractors.
- Teaming, licensing, or subcontracting arrangements between firms of two or more NATO nations are desirable and encouraged. Such arrangements may be entered into prior to or after a contract is awarded.
- In R&D projects that may have application for two or more NATO nations, the acquisition strategy shall encourage NATO industrial participation at the earliest possible time. One possible strategy is to establish NATO industrial participation in the Request for Proposal (RFP) as a primary source selection factor to be considered in the evaluation of proposals, together with

Copyright © National Academy of Sciences. All rights reserved.

technical, schedule, cost, and management elements. In other circumstances, it may be appropriate to obtain an option for the government to require the prime contractor (and subcontractors) to license contractors of participating countries at a later date to manufacture the system or components thereof and, in conjunction with such license to provide the data, user rights, know-how, and other technical assistance that may be necessary to establish a viable second production source.

- DOD components (military services) shall...afford NATO contractors from countries with whom we have general and reciprocal memorandum of agreement the opportunity to compete for DOD procurements.

These policies have been encouraged and often required by congressional concern with full economic and security cooperation with our NATO allies. For example, the Culver-Nunn Amendment to the Defense Appropriations Act of 1977 requires a specific report from the DOD to Congress each year on the amount of NATO cooperation.

To encourage and make easier the U.S. purchases of foreign items (and vice versa), memoranda of understanding have been signed between the U.S. and many of its allies. These memoranda are detailed in Appendix T of the FAR Supplement. They seek to foster:

- Greater cooperation in research, development, acquisition, and production
- The most rational use of respective industrial, economic, and technological resources
- The greatest attainable military capability at the lowest possible cost
- Greater standardization and interoperability of their weapons systems.

Thus, DOD policy seeks to ensure that companies from participating countries are provided every opportunity to compete on a fair and equal basis with U.S. companies for R&D and production contracts. In this regard, all components from participating countries are treated as components mined, produced, or manufactured in the United States when determining whether the end result is a domestic product. Further, prime contracts are not to preclude participating country sources from competing for subcontracts, except when restricted by national security or mobilization considerations.

As noted above, the fact that the Buy American Act itself makes no reference to subsystems and components in essence encourages foreign purchases at the lower tiers. However, this is further encouraged by the desire to obtain the maximum performance at the lowest cost, regardless of source.

Congress has also sought to increase the amount of competition that takes place on defense contracts as a means of reducing cost and fraud. The Competition in Contracting Act of 1985 explicitly requires "full and open competition." It even requires each service to have

Copyright © National Academy of Sciences. All rights reserved.

"competition advocates," whose job it is to stimulate competition. Qualified foreign manufacturers will be encouraged to bid for defense business and, if they are the low bidder, they are more likely to be awarded contracts in the future under this new regime.

Because developing and producing new weapons systems is very costly, there is a growing tendency toward more joint ventures and "coproduction." U.S. firms are combining with more foreign firms (European, and in the future, Japanese) to jointly develop or produce weapons systems. To date, such joint ventures have primarily resulted in most of the effort at the prime contractor level being in the United States and more at the lower tiers being done by foreign sources, as the offset agreements have tended in this direction. It was not within the charter of this committee to assess the value of these provisions to national security. Rather, we note that the benefits of greater economy and cooperation among the Western allies must be balanced against concerns arising from greater dependence on offshore sources. Indeed, there is growing recognition of the implications of these joint ventures and offset agreements, but as one high-level defense official stated in July 1985: "The benefits of these agreements make additional weapons sales possible and fulfill alliance and foreign policy objectives, which outweighs the major negative effect of possible loss of domestic subcontracting" (Aerospace Daily, July 29, 1985).

There has recently been a move within DOD to allow nondomestic manufacture of Joint Army-Navy (JAN) components (DOD, 1985), as a further move toward encouraging international standards and joint production of weapons systems. This, of course, will encourage greater use of foreign electronic components.

LACK OF VISIBILITY: THE HIDDEN COMPONENTS PROBLEM

As described above, two sets of DOD and national policies are at work: the first encouraging self-sufficiency (for national security and domestic economic reasons) and the second actually encouraging foreign procurement, especially at the lower tiers (for reasons of both economic and strategic considerations).

These policies complement industry's shifting to more overseas production to meet commercial competition. While the commercial aspect applies more to "standard items" than to very specialized military ones, produced in very small quantities it increases U.S. dependency on foreign electronic components. It also makes the defense market less attractive because of the items small quantities, highly specialized nature, maximum performance requirements, and long logistics support time. Many U.S. manufacturers have stopped making devices rather than maintain an unprofitable process line.

Perhaps most significantly, there has been little visibility for this growing phenomenon. And this visibility is unlikely to improve in the future unless institutional changes are made.

Copyright © National Academy of Sciences. All rights reserved.

Given DOD's emphasis on data collection and documentation, the absence of visibility may come as a surprise. However, a review of the reporting requirements indicates why this is so. Procurement officers are required to prepare a form for contracts exceeding $25,000 that requires information on whether the contractor is a foreign concern or a domestic firm performing work outside the United States. Additionally, prime contractors with contracts exceeding $500,000 and first-tier subcontractors with contracts exceeding $100,000 are required to report all foreign-source purchases valued at more than $10,000.

This information is submitted only for DOD prime contracts and first-tier subcontracts. Weapons systems prime contractors are seldom foreign manufacturers. Furthermore, second-tier contractors are generally not components suppliers and obtain parts from many sources. Complicating this situation further is the fact that the relevant information is neither kept in a national central data base nor is it uniformly sub- mitted for all systems. The General Accounting Office reported in December 1984 on the current inadequacies of the reporting system and of DOD's efforts to improve its operation. But even if the information were available and well maintained, its usefulness and depth would be questionable because most of the foreign sourcing occurs below the third tier of contracting.

An independent look, taken specifically for this study, found that the overwhelming majority of foreign electronic components procured by U.S. defense contractors--ones that were originally made overseas--were actually bought from U.S. suppliers (sales distributors, wholesalers, or U.S. outlets of foreign firms). Thus, even accurate recordkeeping with the current reporting requirements would not show how many components actually came from foreign countries. To do that, the original country of origin would have to be indicated and the reports would have to go down to the component level for the data to be generated. Then, the data would have to be aggregated in some way. Obviously, one need not gather all component data in this manner, but only those for "critical" weapons systems and components.

Copyright © National Academy of Sciences. All rights reserved.

7

OPTIONS FOR VULNERABLE CRITICAL COMPONENTS

In considering ways to reduce or manage the number of foreign components, two broad considerations immediately came to mind. First, there are both long- and short-term actions. Changes such as new R&D programs to reduce the vulnerability are clearly long term, while creating a one-year stockpile of critical components is short term. Both, however, require immediate funding if they are to have any impact.

Second, while very real, vulnerability appears relatively limited. The number of product items involved is manageable, but growing. Thus, any corrective action should be one in which the actions are "by exception" rather than universally applied so that they bog down the full defense procurement system.

Given these two caveats, there are three principal characteristics that any set of corrective actions should have:

1. The solution should be tailored to each individual product category. Different solutions may be needed for different problems, perhaps a new R&D program in one area, with a stockpiling program in another. Solutions designed to be universal are likely to be both inefficient and ineffective.
2. Visibility is going to be required if any corrective actions are to be taken effectively. Thus, there should be some form of a selective information management system that cuts across weapons systems and aggregates information at the component level.
3. Some organization(s) should be given the responsibility for both visibility and taking corrective actions.

Within these broad guidelines exist a wide variety of options to be used (either alone or in combination) that one might select for individual products. These options fit into two broad categories: specific actions for individual programs and broader policy and institutional changes to address the dependency issue. Examples of these two categories follow:

Category I--Broader Product/Policy/Institutional Actions

- Targeted Department of Defense (DOD) investments
- Specific procurement and/or acquisition policy changes
- Establishment of visibility and responsibility

Copyright © National Academy of Sciences. All rights reserved.

Category II--Specific Program Actions

- Stockpiling of vulnerable components for critical weapons systems
- Creating onshore capacity
- Planning for substitution
- Redesign of systems to eliminate dependency

STOCKPILING

In stockpiling, one need only stockpile those components that are deemed critical. Many items are standard; for others, substitutes are readily available; and for some, their loss would not affect the nation's security. One of three approaches could be taken to the stockpiling of critical parts: rolling inventory, surge capability, and life-of-buy procurement.

All these are familiar alternatives. Their principal disadvantages are the capital investment and the risk of obsolescence should the components change during the life of the product. Nonetheless, the costs are relatively small, since the dollars involved in a few components of a major weapons system are typically a very small but unknown percentage of the total costs. Further, accounting for the risk of obsolescence represents an even smaller percentage. Thus, buying parts might lower the unit cost of high-volume, one-time procurements.

The rolling inventory approach might be used to buy either one year's or 18 months' worth of critical components in advance. Obviously, this requires knowing which items to purchase. While the initial purchases would essentially double the order, from that point on the system would work normally, always ordering one year in advance. This arrangement would have "full funding," which would have to be waived through notification to Congress of the proposed action or through a legislative amendment that would allow this to be done on all critical components that can be obtained only from foreign sources.

The surge capability approach involves buying enough components to meet the need for rapid increases in production should it be required, for example in wartime or periods of crisis. It would mean taking the same approach as in rolling inventory at greater levels of procurement, depending on the planned surge requirement. For example, to triple production over an 18-month period, DOD would have to order enough parts to match this demand and not have any concern about the interruption of foreign sources.

The life-of-buy approach goes even further and assures the purchase of enough parts for planned production quantities and logistics support needs. This raises the total cost as well as the risk of obsolescence, but it ensures that any supply interruption can be easily handled and may be desirable under certain extreme circumstances. The potential danger is that the product may no longer be made to meet increased future needs. This could seriously affect long-duration mobilization needs, unless emergency needs can be well planned in

Copyright © National Academy of Sciences. All rights reserved.

advance and components ordered along with the peacetime buyout. Nonetheless, this option is in fact commonly used by the Defense Electronics Supply Service for parts that are going out of production. Congress has approved funds for buyouts of electronic parts that will not be available in the future.

Thus, DOD has the choice of stockpiling at a variety of levels critical electronic parts that it may anticipate being unable to obtain under potential future economic or strategic conditions.

CREATING ONSHORE CAPACITY

The United States has often developed new electronic components that are later produced by U.S-owned subsidiaries overseas or by foreign firms. Thus, to counter this trend, U.S. government could subsidize domestic production of critical components. This could be done in at least four ways:

1. Direct subsidization of production
2. Government production in "arsenals"
3. Government ownership of industrial capacity in private plants
4. Purchase and maintenance of product-unique production equipment on a standby basis.

Again, each of these four approaches has been used in the past. It is a question of economics which makes the most sense under a particular set of circumstances. The direct subsidization of production can, for example, be done simply by saying to the firm that did the research and development: "We will pay you whatever it costs to produce the quantities we need as long as you produce them domestically." The component could be made solely for DOD or for commercial sales as well. The cost to DOD of direct subsidization would probably vary from component to component. No cost estimates are available.

In the second approach the government sets up its own production facilities for selected components. This would give it either a backup or direct capability to produce those components in the small quantities needed for specific military uses. For example, the Naval Ocean Systems Command now produces in its own facilities certain obsolete semiconductor parts.

The third approach for creating domestic capacity would have the government buying production equipment and placing it in a contractor's facility on a temporary basis. The contractor could be selected by competitive bidding or on the basis of which firm had done the original R&D work. In this approach, the government owns the equipment, so it is free to move it from plant to plant should there be a reason for doing so.

Finally, the government could create a backup (standby) option for domestic production through purchase of any product-unique production equipment, for example, masks, which would be stored and used only when needed. The purchase could be made either by the government or by a

Copyright © National Academy of Sciences. All rights reserved.

U.S. firm purchasing the foreign component. This approach (also replying on the appropriate process specifications and methods sheets) is used in mobilization planning for many weapons systems that have gone out of production.

The problem with this approach is the volatility of the methodology, equipment, processes, and, especially, the skills required to operate the equipment. It is not uncommon for a production line to become obsolete in six months, and production processes that are years old might be difficult, if not impossible, to bring back. Nonetheless, where the production process is still in use, this approach may be an attractive alternative to maintaining a domestic production backup capability.

All four of these approaches are used in a variety of other defense production operations and are therefore clearly possible as options for selected vulnerable critical electronic components.

SUBSTITUTION

Usually by the time a military product is in production, it is relatively late to develop alternate components to substitute for specific vulnerable ones. Indeed, research on substitute components is covered below under a longer-term set of considerations. However, it would clearly be desirable to do some preliminary planning for selected critical components such that, if their supply were interrupted or threatened for extended periods, substitute components could be rapidly used, even if it meant a slight degradation in performance or life of the system.

For example, during peacetime components need a long shelf life because they may go unused for extended periods. During wartime, substitutes with a short shelf life could be used since long life is no longer important.

Thus, at least three approaches appear attractive for planning considerations:

1. Use of ordinary commercial devices that were not designed to meet military specifications
2. Use of derated devices
3. Reverse engineering of foreign components.

If plans were made to substitute either devices that did not meet military specifications or those that had been derated, then changes could be made relatively rapidly if necessary. Similarly, if enough reverse engineering were done to come up with an approximately equivalent device, then it too could be substituted in a relatively short period of time. (It might be noted, incidentally, that the Air Force, at its Sacramento, California, facility, is now doing reverse engineering and emulation for some selected electronics components.)

Copyright © National Academy of Sciences. All rights reserved.

Obviously, these approaches take some investment, either for planning or for reverse engineering, and they should undoubtedly be carried through to at least the test demonstration point. But the cost would be relatively small, and they would provide a backup approach with some lead time still required for producing the alternative components, especially if they are not currently available.

REDESIGN

It may be highly desirable to actually redesign some critical weapon systems in their development phase to eliminate those components whose only source is an overseas supplier once this information has been obtained. However, this information is generally not available today. This increases the engineering costs and may well result in the redesigned item having either reduced performance or increased production costs. In fact, in most cases this option will be prohibitively costly in both time and resources. However, in some selected applications, it may be worth these increased costs. A less severe form of this approach is to redesign the weapons system and demonstrate the alternate, but then to shelve it, so it is available should the foreign source no longer be in the future. No cost estimates are available for this approach.

TARGETED DEPARTMENT OF DEFENSE INVESTMENT

Targeted DOD investment is somewhat similar to subsidizing U.S. companies to produce selected components in this country. However, it deals more broadly with generic capability. Here, the government would make significant investments, either in R&D or manufacturing where U.S. electronics firms have not found it economic to make such investments.

For example, DOD has already invested millions of dollars in developing Very High Speed Integrated Circuits (VHSIC). It was clear that there was not a sufficiently large and early commercial market and that the investment requirements were very high. Yet, there was a very real defense need and the U.S. government had to act or the field either would not have been sponsored or would have been taken over by the Japanese.

Thus, the government made a significant investment both in the components themselves and in as R&D in the manufacturing process. In this case, DOD chose to limit the bidders to domestic sources to create a unique U.S. capability in VHSIC. However, even after the R&D has proved successful, U.S. firms may still not be able to economically compete. Production of some critical components might still end up in other countries. Thus, the government might need to invest in manufacturing equipment where it is not economically advantageous for U.S. firms to invest because of the low volume of production or the lack of a commercial market.

Copyright © National Academy of Sciences. All rights reserved.

This report identified a few critical areas in which the United States currently lags far behind or likely will lag behind in the future. Components, such as those based on gallium arsenide (GaAs) could well require future DOD focus and investment. This again requires clear visibility for the critical areas and an organizational focus, so attention can be brought to the needed corrective actions. Such steps also require added money, but as was the case with the VHSIC investment, the total dollars are likely to be relatively small compared with overall DOD budgets. Further, the return can be extremely high both in terms of improved military performance and reduced foreign dependency.

Such effort may have a spillover into commercial markets. U.S. firms may be unable to invest in R&D or production at first; but, once the government has, firms may well be very competitive in the commercial world. In many cases, comparable investments are being made, in one form or another, by governments in other countries, especially Japan.

SPECIFIC PROCUREMENT AND ACQUISITION POLICY ACTIONS

There is at present little, if any, specific policy at the component level with regard to foreign dependency. However, at least six such policies could be initiated:

1. A delivery commitment for foreign-sourced components
2. A "Buy American" policy for critical components of critical systems
3. A requirement for at least one U.S. source for critical components on critical systems
4. A requirement placed on systems contractors to guarantee component supply
5. The inclusion in the DOD production release decision (DSARC 111) of an impact analysis and a contingency plan for all critical components made solely in foreign countries
6. A shift to "common buying" for all critical components so that the decision is removed from the level of individual weapons systems to a higher level.

Each of these approaches has some costs and potential benefits that might be achieved on a selective basis. A simple and general requirement that all defense components be made in the United States would create a time lag before production could begin, dramatically increase costs, and possibly reduce the performance of the affected weapons systems. Therefore, any such change should be made on a highly selective basis and over a significant period of time.

Shifting to a "Buy American" policy for critical components would have to be restricted and phased in under clear terms to be cost-effective. For example, the policy might apply only to those items on the mobilization list of critical weapons systems and only to certain selected components that have no readily available U.S. substitutes.

Copyright © National Academy of Sciences. All rights reserved.

A compromise to this approach would be to require that U.S. sources be made available for any components made solely in foreign countries. Thus, for example, it could be required that a U.S. license be obtained for production technology for any component that the government would choose to buy abroad, recognizing the increased costs associated with such a license and the possibility that it might not be made available at a reasonable cost.

Placing the responsibility on the weapons systems contractor for guaranteeing component supply would encourage the contractor, under normal market conditions, to use U.S. suppliers, stockpile critical foreign components or both. This is unrealistic for many critical items: a question would immediately arise about the exact nature of the guarantee, since costs under some circumstances could become prohibitive. Nonetheless, this alternative might offer some added incentives--and costs--to address, and at least make the foreign-dependency issue more visible.

Requiring the dependency issue to be addressed in DOD production release decisions, for example, at the DSARC III decision point, might also gain added visibility for weapons systems. Requiring an impact analysis, as well as a plan for dealing with potential contingencies, would perhaps cause the program manager to select some of the above-noted options for individual weapons systems and to accept the increased costs associated with those efforts.

A more dramatic change would be for DOD to shift to a common buying approach for critical components. All program offices would pool their demands for such components, which would be bought in some common form. Interestingly, large industrial firms pool the requirements of their various divisions for high-cost, critical components, such as microelectronics. By combining the demands of separate divisions, which might be relatively small on their own, a large firm can increase its buying power and can lower prices.

For DOD, this could be done either Army or DOD-wide. It could be done through a variety of existing organizations, such as the Defense Electronics Supply System. Again, any such system would require visibility and could perhaps be limited to only certain types of specific components, although the idea has been proposed on a far wider scale, such as for space-based components.

Since these require extensive reliability testing and are usually bought in very small quantities, a significant advantage could be gained through standardizing and buying in common.

If such common-buying techniques were used, it might be possible to have a large enough volume to interest a U.S. supplier, whereas the single, smaller quantities from individual weapons systems are insufficient to gain that market attention. Similarly, it might be possible to create a large enough market so that a U.S. source for small quantities might be set up to act as a backup for the lower-cost foreign producers.

Copyright © National Academy of Sciences. All rights reserved.

ESTABLISHMENT OF A DATA BASE AND ORGANIZATIONAL RESPONSIBILITY

Any information created by added visibility should, if possible, build on an existing data system since DOD clearly already has too many. Further, it should operate on a principle of management-by-exception, since otherwise the data requirements would be prohibitive. Additionally, because most DOD information is developed on individual weapons systems, the data should be collected both by weapons systems and across weapons systems. Thus, one can both assess the military vulnerability as well as the overall impact of corrective actions for individual components.

It must be emphasized that gathering data, especially on older systems, will not be easy. But it can be done and is, in fact, the only way the necessary visibility can be attained. (Certainly, modern data-processing techniques make the problem much easier than in the past.)

Table 7-1 shows how such data have been gathered for the Sparrow-III missile (AIM-7). (This example was selected because it is one of the few that the committee could find, but it has the advantage that the Sparrow III guidance and control system is extremely similar to the Army's Hawk missiles.) The study from which these data are derived concluded that the absence of the 16 items listed (Joint Oversight Committee on Foreign Dependency, 1985)--all foreign sourced--would result in the missile's production being shut down for a period of 18 months. Even then, the study assumed that domestic sources could be found (or developed) without major system redesign.

The committee did not have the opportunity to review extensively all existing data systems, but is convinced that the growing interest within DOD in industrial base information will likely make such information more available if there is the appropriate demand for it and an organization to use it. However, one data system is the present plan for making MIL Standard 2096 a part of requirements for the production of all future weapons systems. It has been a Navy standard since 1983 and is intended to become a DOD standard shortly.

The original purpose was to provide visibility concerning the sources of electronic components, so the effect of a part being removed from supply because of obsolescence could be judged. This is the identical problem of interest to the foreign dependency issue. Therefore, if this data system were expanded to identify the original source of supply, it would be useful for even foreign components being bought by American parts suppliers (Note again the importance of showing the original source of the item, rather than the U.S. distributorship.)

Of course, the existence of a data system is a necessary but not sufficient condition for its use. Some DOD office or organization would have to be designated lead agency to handle all issues and actions associated with the growing dependency on foreign components. Clearly, the nature of policy issues suggests at least monitoring and perhaps active involvement by the Office of the

Copyright © National Academy of Sciences. All rights reserved.

TABLE 7-1 Foreign Sources of AIM-7 Missile Guidance and Control Section Items

Item	Offshore Involvement	Foreign Source	Number of AIM-7 Contractors/ Subcontractors
Integrated circuit	Ceramic package	Japan	6
Integrated circuit	Transistor	Japan	2
Integrated circuit	Header/wafer lids, frames ceramics, cans	Japan	3
Phase shifter	Ferrite transistor	West Germany Japan	1 1
Integrated circuit	Assembly	Japan	1
Connector	Raw material	Various	1
Ball bearing/ repair unit	Raw material	Various	2
Microcircuit	Package	Japan	4
Microcircuit	Semiconductor	Japan	2
Microcircuit	Header/wafer lids, frames, cans	Japan	2
Microcircuit	Assembly	Japan	4
Amplifier	Header, transistor	Japan	1
Integrated circuit	Package	Japan	3
Bearing unit	Raw materials	Various	1
Ball bearings	Raw material	Various	1
Prom	Assembly	Thailand	1

SOURCE: Joint Oversight Committee on Foreign Dependency, 1985.

Copyright © National Academy of Sciences. All rights reserved.

Secretary of Defense. In addition, some organization should be appointed to implement any policies at the components level. This organization would be the recipient of the data as well as the point for recommendations on actions by individual program offices and for generic actions by individual funding agencies.

Ultimately, there is one additional requirement beyond that associated with visibility and organizational responsibility; namely, that of additional dollars to address the dependency problem. However, when the specific issues are properly identified, the cost should be relatively small and thus affordable within service and, in many cases, within individual program budgets.

Copyright © National Academy of Sciences. All rights reserved.

8

CONCLUSIONS AND RECOMMENDATIONS

The U.S. Army depends on foreign sources for many electronic components. This dependency has been growing in recent years and could accelerate as U.S. manufacturers continue to lose market shares to overseas suppliers for a broad spectrum of electronic technologies with military relevance. This trend could leave some Army weapons and communications systems vulnerable to a cutoff of overseas supplies under wartime or other emergency conditions. This chapter presents conclusions and recommendations to address this problem.

CONCLUSIONS

1. An adequate data base does not exist for determining the types, quantities, and original sources of electronic components used in military systems. In the absence of such information, it is impossible to plan ways to protect the Army's ability (or that of the other services) to obtain critical electronic components in the event of supply disruptions.

2. The U.S. components industry is losing market shares to foreign, particularly Japanese, companies. Further, recent economic recessions have limited capital investments for advanced products.

- Market share losses are occurring in the area of advanced, high-density, and high-performance silicon integrated circuits, best exemplified by Japanese dominance of dynamic random access memories (DRAMs). This breakthrough is especially critical because DRAMs are the technology drivers for both newer high-density processes and for advanced product designs across a broad spectrum of device technologies.

3. A significant portion of the manufacturing capacity of U.S. components companies has been transferred in recent years to overseas sites, and will remain abroad for the forseeable future.

Copyright © National Academy of Sciences. All rights reserved.

- Many electronic endproducts, such as home electronics and communications equipment, are in part or whole manufactured in U.S.-owned facilities in other countries. This encourages foreign sourcing of electronic components for such manufacture with a consequent reduction of U.S. component production and capability.

4. Certain electronic components used in Army systems are supplied exclusively by foreign sources.

- Electronic countermeasure (ECM) tubes
- Certain video displays, especially liquid crystal and electroluminescent types
- Magnetic bubble memories (with exceptions)
- Other components in foreign sourced military systems
- Many raw materials used in domestic component manufacture.

5. The extent of the potential vulnerability of most Army systems varies widely among different component groups.

- The greatest vulnerability exists for integrated circuits, most of which are assembled and tested overseas at low-cost sites. Included are many types used in military systems as MIL-883 Class B and MIL-S-19500 devices. Of the $16 billion in total sales of U.S.-branded silicon semiconductors in 1984, about one-third of their value was added in such foreign facilities.
- Vulnerability also exists for many semiconductors because of the foreign-supplied content. Most ceramic packages for large-scale and very-large-scale integrated (LSI, VLSI) circuits are Japanese produced or controlled. Silicon substrates of superior quality are supplied in significant and growing measure by Japanese vendors.
- Less vulnerable, because of modest foreign production, are certain magnetic materials and components, such as permanent magnets, recording heads, magnetic tape and disk memories, and microwave and millimeter wave components.
- Of low vulnerability, since domestic supply is adequate for military needs, are capacitors; resistors and resistor networks; relays, contactors, solenoids, and circuit breakers; meters, indicators, gauges, and lamps; vacuum tubes; connectors; filters; fuses; switches; transformers and coils; and quartz crystals. Transistors, diodes, and thyristors are likewise made in adequate numbers in the United States, although some types are built abroad.

6. Compound semiconductors, especially gallium arsenide (GaAs) devices--of rapidly growing importance to advanced and future military systems--present a critical dependency problem.

- The Department of Defense (DOD) sponsors substantial R&D in compound semiconductors, especially those that are GaAs based, but there is little U.S. manufacturing capability.

Copyright © National Academy of Sciences. All rights reserved.

- The U.S. R&D lead is slim and rapidly diminishing--or nonexistent--primarily because of the Japanese long-term commitment.
- Japanese devices have achieved advanced performance capability.
- Unless current trends are reversed, Japan will become the dominant source for high-performance, compound semiconductor devices.

7. DOD procurement policies and practices do not address adequately the issue of the U.S. military's dependence on foreign sources for electronic components.

- There is little specific policy that deals with components.
- There are explicit but contradictory general policies that both encourage and discourage foreign dependency.

8. DOD industrial modernization and preparedness are directed mostly at strategic and critical materials stockpiling and industrial modernization for production of military systems--except for Very High Speed Integrated Circuits (VHSIC). A plan to improve domestic production of electronic components does not exist.

9. There is no effective organizational responsibility for addressing either the Army's or DOD's growing dependency on components supplied solely by foreign sources.

- There is little or no visibility concerning foreign dependency at the components level in U.S. weapon systems today.
- It is unlikely that current trends will be reversed unless specific assignments are made within DOD to attack the dependency problem.

10. The scope of the problem is limited now and hence amenable to corrective actions if they are taken soon.

RECOMMENDATIONS

Basis for the Recommendations

The needed corrective actions follow directly from these conclusions and from the detailed material substantiating them in prior chapters. Two broad areas of actions are specifically required. First, visibility is needed for the industrial base at the components and materials levels, particularly in terms of the original sources. Second, while visibility is necessary, institutional mechanisms are also needed to undertake both short and longer-term corrective actions.

Fortunately, the findings presented in this report indicate that the problems are manageable if corrective action is initiated soon. While a large share of electronic components come from foreign sources, most

Copyright © National Academy of Sciences. All rights reserved.

are of little or only moderate concern. Only a few are serious problems, for which actions need to be initiated. The others simply need to be monitored to ensure that they do not change status. For example, out of the thousands of electronic components and subsystems used to guide and control the AIM-7 antiaircraft missile, only 16 caused a foreign dependency problem. Each of those could then be addressed once recognized.

Equally important (for the issue of manageability) is the fact that the dollars required to greatly reduce--if not eliminate--the problems associated with a dangerous degree of foreign dependency appear to be within reason. Certainly the establishment of a management information system would appear to be relatively inexpensive. If corrective actions are approached from a cost-effectiveness viewpoint on a case-by-case basis, both the program-specific and product-specific costs would also appear to be quite reasonable.

The clear ties between military long-term dependency and future trends in the commercial market for electronic components should be emphasized. The amount of dependency that DOD develops will depend directly on which items are produced domestically for the large U.S. commercial electronics market. For example, if it were economically desirable to produce high-performance GaAs components domestically for commercial electronics products, then it would be much less likely that there would be a related military problem of foreign dependency.

In general, stimulation of the investments of U.S. firms in such a commercial capability lies outside the policy realm of the Army or even DOD. Such efforts rest at the national level and involve issues such as investment tax incentives, reduction of the national deficit to lower pressure on interest rates, allowance of cooperative ventures among U.S. electronics firms, and other measures affecting industry at large. However, a well-coordinated DOD program explicitly seeking to reduce foreign dependency could be effective if it reduced the risk-reward ratio for new private investments in component production. Such efforts deserve study.

Additionally, there are some broad DOD initiatives that go beyond the simple issue of foreign dependency and that have to do with the treatment accorded to large defense contractors and that accorded to component suppliers. This issue involves considerations such as R&D resource allocation (between weapons systems and new components development) and profit policy, which allows a more significant profit margin for the prime contractors than for the lower-tier suppliers. These remain largely sidelined as issues, but they have a broad and direct implication for the electronics components industry.

Finally, the need for DOD to prepare for the acquisition of foreign technology, where necessary, is clear. The first steps taken toward this process (see Appendix D) should be encouraged.

Three specific kinds of actions are therefore required to begin to address the foreign dependency issue:

1. Visibility and management at the components level
2. Short-term actions to reduce foreign dependency for current programs
3. Longer-term actions to reduce future foreign dependency.

Copyright © National Academy of Sciences. All rights reserved.

In all three cases, the step that needs to be immediately taken is to set up procedures, policies, data bases, organizational responsibility, and budgets, on a case-by-case basis. As noted above, none of this infrastructure exists at present; thus, until these changes are brought about, it is highly unlikely that the increasing tendency toward foreign dependency at the electronic components level will be reversed.

RECOMMENDATION 1: OBTAIN DATA ON FOREIGN DEPENDENCY AND CREATE A MANAGEMENT CENTER TO USE IT

An adequate data base on electronic components should be obtained. Four actions are needed: (1) program-by-program identification of components, (2) identification of components for advanced systems, (3) selective horizontal aggregation of component data, and (4) assignment of organizational responsibilities for data base maintenance.

Program-by-Program Identification

The original sources of all electronic components and the materials they contain (if they are foreign sourced) should be identified. Of particular importance is whether there is an equivalent domestic source. If not, then the part becomes identified as a critical item. What is important in this identification is to trace the source all the way back, so for example an American distributorship is not listed if the source is actually a foreign supplier. In general, DOD "rules of origin" may have to be developed, so distributors, for instance, know how much foreign content is in parts labeled as U.S. products.

Most likely, very few components will fit into this category. However, identifying these few is essential. Naturally, the initial establishment of the necessary information system will require considerable effort but the data could be made a contractual item as part of each individual program. Additionally, since these component data are a major part of any surge/mobilization planning activity, DOD should be collecting them for any proper industrial preparedness effort.

This program-by-program list would then form the nucleus of the data that would be aggregated, across programs, to determine overall DOD needs (see below). With the combination of these two lists, the proper corrective actions to reduce current foreign dependency could then be determined.

Identification of Components for Advanced Systems

As advanced systems and subsystems are being designed, it is important to consider whether the sources of the electronic components that go into these new designs are available domestically. Obviously, the best time for corrective action is at this early stage, when a U.S. supplier

Copyright © National Academy of Sciences. All rights reserved.

can be established or a domestic license obtained on a foreign item, or the system could even be redesigned to use a domestically available component or technique. To assemble such a data source, requirements could be placed on the design firm to clearly establish the original source of all components selected for new designs and to report on any that were being used that were of foreign origin. Again, this would have to be done on a program-by-program basis, but it would also be supplied to the aggregated information data base for possible combined corrective actions.

Selective Horizontal Aggregation of Component Data

Obviously, gathering all information on all electronic components on all weapons systems would be a complex and cumbersome effort. Fortunately, however, such information is neither required nor desired. Rather, it is possible to aggregate a highly selective list of components and materials for the purposes of identifying foreign dependency and establishing necessary corrective actions.

Thus, the aggregated data base might be relatively small, but this horizontal accumulation of information would provide important visibility. For example, where it might not be worthwhile to have a specific U.S. source set up for a component on an individual weapons system, it might pay to do so where that component is used on several weapon systems.

In the same way, visibility from aggregated data on new systems and subsystems might also show that there is growing foreign dependency on certain types of components; for instance, high-performance GaAs devices (and raw materials). Thus, where dependency for an individual weapon may not justify a corrective action, accumulated dependency might require the establishment of U.S. programs.

Assigning Organizational Responsibility

Some organization should be made responsible for maintaining and using the data base. The organization would not only keep the information current, but would also have an input to major decisions on individual programs, the industrial base, and R&D.

RECOMMENDATION 2: TAKE CORRECTIVE SHORT-TERM ACTIONS FOR CURRENT WEAPONS SYSTEMS

Chapter 7 identified a set of possible options for corrective actions to reduce component vulnerability. These included stockpiling vulnerable components for critical weapons systems, creating a domestic or standby capacity, planning for substitution, and redesigning to eliminate dependency.

Copyright © National Academy of Sciences. All rights reserved.

For each of these options, suboptions were discussed--for example, stockpiling, or a rolling surge, or life-of-buy inventory--along with the advantages and disadvantages of each. It is necessary to determine the costs and benefits of such corrective actions for each relevant scenario of component vulnerability.

To guide the program office in this, there are two sets of information that it must have: (1) criteria, both military and economic, on which to base its determinations; and (2) acquisition policy, to provide guidance in making decisions (on timing, investment, impact of source selection, and data requirements).

Establish Military and Economic Criteria

A program manager trying to decide whether to do something about electronic components needs to know what scenarios should be considered and what dependency considerations merit concern. For example, for some products the only important scenario might be peacetime interruptions, for others, the ability to "surge" rapidly, and for still others, the long-term mobilization potential.

For some products the only pieces of equipment of concern are those that are either expendable items or spare parts, while other products may involve the full weapons system. Political considerations associated with the country from which the component originates should also be provided to the program manager. Finally, with regard to scenarios, there is the question of response time and its relative importance. For some components there may be sufficient time to allow a domestic line to be built up, while for other items there can be no allowable interruptions of supply. In terms of scenarios, it is important to emphasize that not only are military conflicts of relevance, but such considerations as economic embargoes, political instability in a country, and the like are also relevant.

The other important area of establishing criteria for use in option selection is that associated with the meaning of "dependence" in the case of the component under consideration. Simply because the component being used is purchased abroad does not mean that the United States is dependent on the source. For example, there could be an exactly equivalent component available within the United States or, in some cases, only a percentage of the total procurement of the component may come from other countries. (Perhaps a candidate criterion might be that if more than 50 percent of a given purchase comes from abroad, then that purchase is to be listed as a potentially vulnerable component.) In any case, the criteria established for relative dependency do not mean that actions need necessarily be taken, but rather that the costs and potential vulnerability impact should be assessed for all those components that fit into the vulnerability criteria.

Copyright © National Academy of Sciences. All rights reserved.

Establish Acquisition Policy

Despite the general concern about foreign dependency, the acquisition policy leads program managers simply to select the low-cost option and to treat foreign dependency as a secondary issue. Several steps could correct this.

First, program managers should be made responsible, for any system either in development or currently deployed, to explicitly identify those sources of foreign dependency--down to the component and material levels--and to assess the impact of cutoffs in supply.

Second, it should be made clear that these issues are to be addressed in each major service review of the program at the initiation of full-scale development and again at the initiation of production. Additionally, program managers should be responsible for continuing to address these issues throughout the program's life.

Third, it must be made clear that program managers are responsible for assessing the cost associated with each of the various potential options that might be taken to correct the foreign dependency.

Finally, program managers should identify what actions are to be specifically taken (as part of the program) to prevent any impact from foreign dependency on electronic components. These actions may include such considerations as having foreign dependency as one criterion in the contract award competition (source selection) for the program, as well as program actions that are taken to create U.S. sources, stockpile components, have alternate designs on standby, have U.S. licensees available for backup production, and so on.

Interestingly, the dollars involved in most of the actions considered--on a weapon-by-weapon basis--are likely to be relatively small. They can be viewed as an insurance policy--a way to ensure continuous availability of critical components for both peacetime and crisis conditions. In general, analyses of a few specific products have indicated that the level of investment will be relatively insignificant, perhaps less than 1 percent of the cost of the weapon. Thus, it seems quite practical for program managers to take actions.

RECOMMENDATION 3: TAKE ACTION TO REDUCE FUTURE DEPENDENCY FOR COMPONENTS IN ADVANCED SYSTEMS

Identify Future Dependency for Next-Generation Weapon Systems

In the future, whole classes of components might be made in foreign countries only. In fact, a whole generation of technology might be implemented exclusively abroad, and thus the United States could be totally dependent for a major share of its weapon systems. Hence, current research and development on systems, subsystems, and components, and broad, long-term trends in industrial components production and materials should all be analyzed.

Copyright © National Academy of Sciences. All rights reserved.

Generate Policies, Assign Organizational Responsibilities, and Set Criteria

In this area, one DOD research office should be made fully responsible for determining what actions are necessary to reduce or eliminate all future dependency. To date, such actions have been largely ad hoc. In some cases, the action required may well be to stimulate a totally new technology to ensure that the United States is in the forefront of the field, such as is being done in the VHSIC program.

One area that would require a major integrated program is that of advanced, compound semiconductors for future use, especially high-performance GaAs semiconductors. Other possibilities include advanced displays, lithium batteries, and magnetics. Perhaps some of the production equipment research could be funded by the DOD's manufacturing technology program, but it is also necessary to consider capital investment incentives (or purchases) once the technology is developed. Another policy option that should be considered involves assisting U.S. firms in gaining access to technological developments in other nations, especially Japan.

As for current weapons, criteria need to be established for these future advanced systems and components to evaluate the degree of foreign dependency. However, the criteria will be more general considerations. The R&D and policy leaders in the DOD--and also outside of it--should concentrate on early recognition of the importance of a domestic production capability (not just prototyping) of next-generation electronic components and the material for their fabrication.

This process frequently would entail significant investments in capital equipment and/or advanced production processes (or at least provisions for the indemnification of such equipment against possible defense contract termination). It might also involve some significant industrial strategy decisions, such as whether to have a captive production line for defense items should there be insufficient commercial demand and whether to maintain a second U.S. production line to provide for continuous competition or surge capability.

Criteria should consider that some of the investment required would be quite small, perhaps limited to the purchase of a particular piece of production equipment or the stockage of additional raw materials. However, there will be some categories (such as VHSIC and probably GaAs) where the investment required could be quite significant since there may be a need to create a subsector of an industry. Nonetheless, the total magnitude of the investment will still be extremely small relative to the overall DOD investments (where acquiring a new weapon typically costs more than $100 billion annually).

Thus, a program measured in the millions or even tens of millions of dollars, which would extract a major portion of the U.S. defense establishment from a condition of foreign dependency as well as help create a viable U.S. commercial business base in next-generation electronics technology, could well be worth the investment.

Copyright © National Academy of Sciences. All rights reserved.

Redistributing DOD Resources

Some redistribution of resource investment should be made within DOD in its overall R&D and production technology, as well as in its capital equipment investments. Because of the growing cost of producing weapons systems, DOD resources have been shifting more and more toward the monitoring and support of the weapons systems themselves, rather than the critical components that go into them (Gansler, 1980). Yet the latter often are the cause of the United States being in a position of technological superiority. A reevaluation of this overall shift in the distribution of DOD resources is appropriate.

Moreover, a move toward additional R&D component production investments could be important. Such a shift, when combined with the other recommendations detailed above, would go a long way toward reducing the problem of U.S. dependence on foreign electronic components for weapons systems.

Copyright © National Academy of Sciences. All rights reserved.

BIBLIOGRAPHY

Aerospace Daily. January 23, 1985, 116.

Analytic Sciences Corporation. 1985. A Study of the Effect of Foreign Dependency.

Electronic Industries Association, informal reports.

Federal Contracts Report. July 29, 1985, 198.

Feinstein, J. 1982. Research thrusts of the U.S. Department of Defense. IEEE Spectrum 19:91. October.

Gansler, J. S. 1980. The Defense Industry. Cambridge, Mass.: Massachusetts Institute of Technology Press.

General Accounting Office. 1984. DOD Manufacturing Technology Program--Management Is Improving But Benefits Are Hard to Measure. Washington, D.C.: General Accounting Office. November.

General Accounting Office. NSIAD-85-30. Washington, D.C.: General Accounting Office.

Grunwald, J., and K. Flamm. 1985. The Global Factory: Foreign ✓ Assembly in International Trade. Washington, D.C.: Brookings Institution.

Institute of Electrical and Electronic Engineers (IEEE). 1985. IEEE Opinions on Research Needs in Selected Areas of Electrotechnology. Unpublished report. April.

Joint Oversight Committee on Foreign Dependency, Joint Logistics Commanders. 1985. A Study of the Effects of Foreign Dependency. October.

Laser Focus. 1985. Past-deadline report 21(8):12. August.

Lawrence, R. 1984. Can America Compete? Washington, D.C.: Brookings Institution.

Lineback, J. R. 1985. Lithium batteries open door to a new class of circuit. Electronics 30. July.

Marsh, A. K. 1985. Honeywell will produce gallium arsenide chips. Aviation Week and Space Technology 124-125. May.

Copyright © National Academy of Sciences. All rights reserved.

Miller, G. W. 1983. Regrowing the American Economy. Englewood Cliffs, N.J.: Prentice-Hall.

National Research Council. 1978. Technology, Trade and the U.S. Economy. Washington, D.C.: National Academy Press.

National Research Council. 1983. International Competition in Advanced Technology: Decisions for America. Washington, D.C.: National Academy Press.

National Research Council. 1984. The Competitive Status of the U.S. ✓ Electronics Industry. Washington, D.C.: National Academy Press.

National Science Foundation. 1985. U.S. Access to Japanese Scientific and Technical Literature. Washington, D.C.: National Science Foundation. April.

Office of Technology Assessment. 1983. International Competitiveness ✓ in Electronics. Washington, D.C.: U.S. Government Printing Office.

President's Commission on Industrial Competitiveness. 1985. Washington, D.C.: U.S. Government Printing Office. January.

Rode, A. G., and J. G. Roper. 1985. Gallium arsenide digital IC Processing--A manufacturing perspective. Solid State Technology 28(2). February.

Scott, B. 1985. U.S. Competitiveness in the World Economy. Cambridge, Mass.: Harvard Business School Press.

Solid State Technology. 1985a. International Report 28(4):32. April.

Solid State Technology. 1985b. International Report 28(8):18. August.

U.S. Department of Commerce. 1985. Japanese Technology Evaluation Program. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Commerce, JTECH Panel. 1985. Report on Opto- and Micro-Electronics in Japan. Summarized in T. E. Bell. 1985. Japan reaches beyond silicon. IEEE Spectrum 22:46. October.

U.S. Department of Commerce, various informal reports on electronic components.

U.S. Department of Defense. 1984. Manufacturing Technology Program. Technical Subcommittee Membership. DOD Instruction 4200.15. Washington, D.C. November.

Copyright © National Academy of Sciences. All rights reserved.

U.S. Department of Defense. 1985. Manufacturing Technology Program. DOD Instruction 4200.15. Washington, D.C. May.

U.S. Department of Defense. 1985. Defense Financial and Investment Review. Washington, D.C. June.

U.S. Department of Defense. 1985. A Study of the Effects of Foreign Dependency. Prepared for the Joint Logistics Commanders Report. October 15.

Wade, J. P., Jr. 1985. Letter to Honorable Charles A. Browsher. July 26.

Zensius, D. P., J. L. Hauptman, and N. K. Osbrink. 1983. GaAs FET YIG oscillator times from 26 to 40 GHz. Microwaves & RF 22:129-139. October.

Copyright © National Academy of Sciences. All rights reserved.

APPENDIX A

STATEMENT OF TASK

The scope of the committee's work is described in the contract between the Department of the Army and the National Academy of Sciences. The general summary work statement made there is as follows:

> The committee will assess the extent to which foreign manufacture of electronic components places in jeopardy needed Army supplies of electronic components. In the course of this study, the committee will conduct a two-day workshop at which time experts from the Army, electronics industry, and other relevant sectors will brief the committee.
>
> Five tasks are specified:

1. Document the major relevant trends: the electronic content of military systems, increases in the offshore production of electronics, the percentage of military electronics supplied from abroad, the future health of the U.S. electronics industry in areas considered vital by the committee, technology transfer through coproduction agreements, the dwindling talent base for research and development on mature electronic components, and the impact of federal procurement policy in this area.
2. Identify and adopt for further study a small number of scenarios in which supplies would be disrupted.
3. Identify a representative list of about 20 of the major electronic components used by the Army and provide a brief description of their uses.
4. For each class of components on the list, determine (1) component requirements of Army systems (old systems, new systems, supply problems); (2) sources of supply (e.g., market share of largest competitors and their place of manufacture, importance of foreign sources); (3) maturity (rate at which components are undergoing large, rapid changes); (4) the extent to which similar components appear in commercial and military markets and are militarily unique, the relative size of those markets, and whether the components could be supplied by non-MIL-SPEC items; (5) whether each component is highly used as a

Copyright © National Academy of Sciences. All rights reserved.

consumable (e.g., a lithium battery) or as part of a system (since this distinction can be expected to be related to surge requirements and stockpiling needs); (6) vulnerability to supply disruption; (7) backups, high capacity, and other mitigations possible for each element; and (8) future trends in vulnerability.

5. Insofar as possible, determine quantities needed versus quantities stockpiled and producible under the assumed scenario. The committee will attempt to identify, at least qualitatively, interactions and more subtle effects (e.g., adequate production capability onshore that is, however, almost completely foreign owned).

Copyright © National Academy of Sciences. All rights reserved.

APPENDIX B

PRESENTATIONS AT COMMITTEE MEETINGS

MAY 14-15, 1985

CHARLES FREEMAN, Night Vision Research Division Night Vision Electrooptics Laboratory
The Electronic Components Situation as Related to Lasers, Detectors, Sensors and Image Processors

IRVING REINGOLD, Electronic Technology and Devices Laboratory, Fort Monmouth, New Jersey
Introduction to the Various Briefings on Electronic Components

RON SEBOL, Tactical Systems Branch at the Fusing Laboratory of the Harry Diamond Laboratories
The Problems of Procurement of Specialized and Obsolete Components for Fuse-Specific Components

CLARE THORNTON, Electronics Technology and Development Laboratory
Overview of the Problem and Extended Briefing on the Use of Electronic Components in Army Systems

RICHARD VAN ATTA, Institute for Defense Analyses
Production of Vital Electronic Components in Foreign Countries

HOWARD WICHANSKY, Fiber Optic Team in the Multi-Channel Transmission Division at CENCOMS
Use of Fiber Optic Components

JULY 25-26, 1985

RICHARD DONNELLY, Industrial Resources, Office of the Secretary of Defense (OSD)
Concerns of the Office of OSD, Foreign Procurements, and Various Strategies Proposed by OSD for Dealing With Obsolescence, Non-availability and Surge Problems

Copyright © National Academy of Sciences. All rights reserved.

JOHN STARNS, Study on Foreign Dependency by The Analytic Sciences Corporation
The Foreign Dependency Problem at the Procurement Level and Recommendations for the Implementation of a Procurement Strategy Methodology

ELLISON URBAN, Naval Air Systems Command
Microcircuit Obsolescence, Systems Life Cycle Analysis and Lifetime Procurement Recommendations

OCTOBER 3-4, 1985

BRUCE GILLETTE, Latin American Office, Office of the Deputy Undersecretary of Defense for International Programs and Policies
Department of Defense Activities in Support of Reducing Non-Western Hemisphere Production of Electronic Components

MICHAEL STONE, Caribbean Basin Initiative Affairs, Agency for International Development (AID)
AID Activities Related to Electronic Components Production in the Caribbean Basin

Copyright © National Academy of Sciences. All rights reserved.

APPENDIX C

THE WORLDWIDE SEMICONDUCTOR INDUSTRY

INTRODUCTION

Semiconductor devices have become the backbone of most military systems. The following account of the history and dynamics of the semiconductor industry emphasizes its current global characteristics.

The technological base of the world semiconductor industry has evolved dramatically since the industry's beginnings 35 years ago. This evolution can be divided into four periods of technological development. The first phase, which began in 1948 with the demonstration of the point-contact transistor at Bell Telephone Laboratories and continued through the 1950s, was characterized by the development of basic semiconductor technology. The second phase was ushered in with the commercial introduction of the integrated circuit in the early 1960s. During this phase, which lasted through the early 1970s, the density of semiconductor elements on a single IC chip increased to as many as 100 logic gates--a level known as medium-scale integration. This progress in the direction of miniaturization gave rise to a wide variety of new devices, including the random access memory in 1970 and the microprocessor in 1971.

The third phase, which began in the early 1970s, brought advances in large-scale integration (LSI)--conventionally defined as 100 to 1,000 logic gates or the equivalent--that resulted in a dramatic expansion in semiconductor applications and markets. Since the late 1970s, the industry has moved into a new phase--the very-large-scale integration (VLSI) era, in which tens of thousands of component elements are processed in a single chip.

These technological evolutions have spawned a world semiconductor industry that has experienced a remarkable period of growth. As shown in Table C-1, total industry sales have expanded at an average annual rate of 17 percent during the past 15 years. The industry's growth has been led by the demand for integrated circuit (IC) products, particularly metal oxide semiconductor (MOS) memory and MOS logic devices. Consumption of IC products rose more than 25 percent per year, while consumption of MOS devices grew at an annual rate approaching 50 percent.

Copyright © National Academy of Sciences. All rights reserved.

TABLE C-1 Worldwide Semiconductor Market, 1969 to 1984 (millions of dollars)

Years	MOS	Other	Total IC	Total Discrete	Total Semiconductor
1969	30	638	668	1,764	2,476
1970	100	727	827	1,749	2,626
1971	162	751	913	1,574	2,540
1972	276	969	1,245	1,796	3,148
1973	562	1,424	1,986	2,465	4,616
1974	873	1,622	2,495	2,681	5,373
1975	835	1,262	2,097	2,034	4,348
1976	1,228	1,708	2,936	2,546	5,762
1977	1,430	2,013	3,443	2,627	6,310
1978					
1979	3,594	3,419	7,013	3,805	10,810
1980	5,019	4,428	9,447	4,163	13,610
1981	4,792	4,495	9,287	4,430	13,717
1982	5,586	4,662	10,248	3,869	14,117
1983	7,440	5,897	13,607	4,433	17,770
1984	11,737	8,831	20,568	5,388	25,956
Average Annual Growth Rates (percent)					
1969-1974	96.2	20.5	30.2	8.7	16.8
1974-1979	30.7	16.1	28.0	7.3	15.0
1979-1984	26.7	20.9	24.0	7 2	19.2
1969-1984	48.9	19.2	25.7	7.7	17.0

[a] metal oxide semiconductor
[b] integrated circuit
[c] figures not available

SOURCES: Dataquest, Market Estimates, May 12, 1978; Robertson, Colman, and Stephens, Semiconductor Outlook--Part I, World Semiconductor Demand, March 22, 1985.

Copyright © National Academy of Sciences. All rights reserved.

WORLD ELECTRONICS INDUSTRY

Semiconductor products are used throughout the consumer, industrial, and military electronics industry. As noted below, semiconductors have assumed an increasingly important role in the functioning and operation of major segments in the world electronics industry--including computers, office equipment, communications productions, consumer products, industrial process control equipment, and scientific instruments. The value of electronics products consumed in the United States, Western Europe, and Japan reached $200 billion in 1983, more than doubling the 1977 level. By the late 1980s, electronics is expected to generate over $400 billion in world sales, a figure that will place electronics with automobiles and oil as one of the world's leading industries.

Data-processing systems, peripherals, and office equipment make up almost 50 percent of electronics industry sales. As shown in Table C-2, consumer electronics is the second-ranked product category (28 percent of the market), followed by communications equipment (11 percent of the market). The rapid growth of the industry has been shared approximately equally by all product lines. The market shares of each major product line have remained virtually unchanged since 1975.

The geographical distribution of electronics systems market consumption is shown in Table C-3. The United States is the dominant consumer of electronic components, accounting for slightly more than one-half of world consumption. Western Europe and Japan, the second- and third-ranking markets, accounted for one-half and one-third of U.S. consumption. Regional market shares are also noted to have remained approximately equal over the past eight years.

THE CONTRIBUTION OF SEMICONDUCTOR PRODUCTS TO THE ELECTRONICS INDUSTRY

Today, at the heart of all state-of-the-art electronics systems is the semiconductor. The dramatic improvements in semiconductor performance and efficiency, coupled with reductions in the cost and physical size of components, have been a major factor contributing to the electronics industry's rapid expansion. Such advances have enabled electronic components to be produced at lower cost and with enhanced performance. New electronic products were also made possible, such as hand-held calculators, personal computers, and word processors. Thus, although the demand for semiconductor components is derived from the combined market demand for industrial, consumer, and defense-related electronic products, there is an important synergy between the two industries.

This relationship is expected to intensify in the future as more powerful, less expensive electronics systems become available based on advances in semiconductor technology. In Table C-4 the semiconductor share of electronics equipment value is forecasted to increase from its current share of 11 percent to 15 percent by the end of the 1980s.

Copyright © National Academy of Sciences. All rights reserved.

TABLE C-2 Worldwide Electronics System Markets (billions of dollars)

	1975				1980				1983			
	Total	U.S.	Japan	Europe	Total	U.S.	Japan	Europe	Total	U.S.	Japan	Europe
Data-processing systems, peripherals, and office equipment	27.0	17.2	3.2	6.6	57.6	33.1	8.8	15.7	96.3	61.7	14.0	20.6
Consumer electronics	17.1	6.6	4.4	6.1	36.8	16.7	7.7	12.4	48.9	22.7	11.0	15.2
Communications equipment	8.1	3.0	1.3	3.8	15.6	5.7	1.6	8.3	22.4	8.3	3.0	11.1
Industrial equipment	3.5	1.4	0.8	1.3	8.2	3.3	2.3	2.6	11.6	4.5	4.1	3.0
Testing and analytical instruments	2.3	1.4	0.3	0.6	6.4	4.5	1.0	0.9	7.5	5.5	0.8	1.2
medical equipment	2.2	1.2	0.2	0.8	4.4	2.3	0.8	1.3	6.7	4.1	1.1	1.5
Automotive electronics	0.4	0.2	---	0.2	2.7	1.5	1.2	---	4.5	2.6	1.9	---
Power supplies	0.6	0.4	---	0.2	0.9	0.4	0.2	0.3	0.9	---	0.5	0.4
All equipment	61.2	31.4	10.2	19.6	132.6	67.5	23.6	41.5	198.8	109.4	36.4	53.0

SOURCE: Radio Corporation of America.

Copyright © National Academy of Sciences. All rights reserved.

TABLE C-3 Distribution of Electronics System World Market by Product Segment and Geographic Region, for 1975, 1980, and 1983 (percent)

Electronics System World Market	1975	1980	1983
Distribution by product segment			
Data-processsing systems, peripherals, and office equipment	44	43	48
Consumer electronics	28	28	25
Communications equipment	13	12	11
Industrial equipment	6	6	6
Testing and analytical equipment	4	5	4
Medical equipment	4	3	3
Automotive electronics	1	2	2
Power supplies	1	1	1
Distribution by Geographic region			
United States	51	51	55
Japan	17	18	18
Western Europe	32	31	27

SOURCE: Radio Corporation of America.

TABLE C-4 Growth of World Semiconductor and Electronics Markets

Year	World Electronics Market (billions of dollars)	World Semiconductor Market (billions of dollars)	Semiconductor Share of Electronics Equipment, Value (percent)
1968	65	2	5
1975	61	4	7
1980	133	14	11
late 1980s	60	15	400

SOURCE: Arthur D. Little, Inc.

Copyright © National Academy of Sciences. All rights reserved.

REGIONAL SEMICONDUCTOR PRODUCTION

To meet the product demands of the electronics industry, a worldwide semiconductor industry has rapidly evolved over the past 15 years. As shown in Table C-5, North American-based producers have retained dominance over European- and Japan-based producers in both integrated circuit and discrete product markets. North American producers accounted for 46 percent of the total value of all shipments in 1970. This share gradually rose to almost 60 percent by 1980 and declined in recent years to 54 percent.

Within major product sectors, however, somewhat different trends are observed. In the more rapidly expanding IC market, North American producers have accounted for, on average, 60 percent of the value of total shipments (see Table C-6). Japanese producers maintained a market share of 18 to 20 pecent from 1970 to 1975 and have steadily increased that share. European producers have seen their share erode substantially--down from a peak of 20 percent in 1975 through 1976 to 7 percent in 1984.

THE MOVE TO LOW-LABOR COUNTRIES

Foreign operations of American semiconductor companies can be grouped into three categories: (1) offshore assembly and subcontractor assembly, primarily to supply the U.S. market; (2) point-of-sale (POS) assembly, primarily to supply foreign markets; and (3) complete manufacturing (wafer fabrication, assembly, and testing). Offshore assembly affiliates are set up in a foreign country to assemble U.S.-manufactured subassemblies for export back to the United States. The U.S. market is the primary market served by an offshore assembly operation; foreign subcontractor assembly operations are included as a subclass of offshore assembly even though they are not foreign direct investment. POS facilities primarily supply foreign markets. The foreign operations with complete manufacturing are the only ones that process the silicon wafer from wafer fabrication through final testing. These operations normally only serve foreign markets. It should be noted, however, that American foreign subsidiaries performing only assembly operations frequently serve both U.S. and foreign markets. Identification of some assembly operations as either an offshore plant or a pos plant is therefore somewhat arbitrary.

The primary reason that American semiconductor companies establish offshore assembly operations is to lower direct labor costs. When assembly is transferred offshore, the lower wage rates can yield up to a 50-percent decline in total manufacturing cost. There are natural divisions between wafer fabrication, assembly, and final testing that allow the assembly phase to be located at a different facility from the remainder of the manufacturing operations. Assembly technology is quite readily transferred. There are no serious supply constraints on the location of an assembly plant other than adequate low-cost labor and electrical power. Learning economies are not significantly affected by having multiple assembly facilities.

Copyright © National Academy of Sciences. All rights reserved.

TABLE C-5 Total Semiconductor Production by Geographic Region

Product Shipments (billions of dollars)

Year	Total	North America	Japan	Western Europe	Rest of World
1970	2.6	1.2	0.8	0.6	0.0
1971	2.5	1.2	0.7	0.7	0.0
1972	3.1	1.5	0.8	0.8	0.0
1973	4.6	2.2	1.1	1.2	0.1
1974	5.4	2.6	1.2	1.4	0.1
1975	4.3	2.1	0.9	1.2	0.1
1976	5.8	2.7	1.5	1.3	0.2
1977	6.3	3.0	1.6	1.5	0.2
1978	8.9	4.8	2.5	1.4	0.2
1979	11.5	6.6	2.9	1.7	0.3
1980	14.2	8.4	3.8	1.6	0.3
1981	14.1	8.0	4.2	1.5	0.4
1982	14.2	8.0	4.6	1.3	0.1
1983	17.9	9.7	6.6	1.4	0.1
1984	26.1	14.0	9.8	2.1	0.1

Distribution (percent)

Year	Total	North America	Japan	Western Europe	Rest of World
1970	100.0	46.1	29.1	24.4	0.5
1971	100.0	45.7	26.1	27.5	0.7
1972	100.0	47.6	26.4	25.1	0.9
1973	100.0	47.9	24.7	25.9	1.6
1974	100.0	48.9	21.7	6.9	2.5
1975	100.0	49.0	21.2	27.0	2.8
1976	100.0	46.9	26.3	23.3	3.5
1977	100.0	47.9	25.6	23.5	3.1
1978	100.0	53.9	28.1	15.7	2.2
1979	100.0	57.4	25.2	14.8	2.6
1980	100.0	59.4	27.0	11.4	2.3
1981	100.0	56.9	29.6	10.9	2.6
1982	100.0	56.7	33.0	9.5	0.7
1983	100.0	54.3	37.0	7.9	0.8
1984	100.0	53.6	37.5	8.0	0.8

SOURCE: Dataquest, 1970-1977; Integrated Circuit Engineering, 1978-1981; Semiconductor Industry Association, 1982-1984.

Copyright © National Academy of Sciences. All rights reserved.

TABLE C-6 Production of Integrated Circuits by Geographic Region

Product Shipments (billions of dollars)

Year	Total	North America	Japan	Western Europe	Rest of World
1970	0.9	0.6	0.2	0.1	0.0
1971	1.0	0.6	0.2	0.2	0.0
1972	1.4	0.8	0.3	0.3	0.0
1973	2.2	1.3	0.4	0.4	0.0
1974	2.7	1.6	0.4	0.6	0.1
1975	2.3	1.4	0.4	0.5	0.1
1976	0.2	1.8	0.7	0.6	0.1
1977	3.7	2.1	0.8	0.7	0.1
1978	4.0	3.2	1.2	0.5	0.1
1979	7.0	4.7	1.8	0.6	0.1
1980	0.7	6.4	2.5	0.7	0.1
1981	0.6	6.1	2.6	0.8	0.2
1982	10.3	6.2	3.3	0.7	0.1
1983	13.4	7.6	5.0	0.7	0.1
1984	20.7	11.5	7.7	1.4	0.2

Distribution (percent)

Year	Total	North America	Japan	Western Europe	Rest of World
1970	100.0	63.5	20.3	16.2	0.0
1971	100.0	59.4	18.4	21.9	0.2
1972	100.0	60.7	19.5	19.4	1.2
1973	100.0	61.0	18.2	19.7	1.0
1974	100.0	60.9	16.2	20.6	2.3
1975	100.0	59.3	18.0	19.8	2.9
1976	100.0	56.2	21.9	17.8	4.1
1977	100.0	56.8	20.9	19.1	3.3
1978	100.0	64.0	24.0	10.0	2.0
1979	100.0	66.2	25.4	8.5	1.4
1980	100.0	65.9	25.4	7.4	1.3
1981	100.0	63.1	27.0	8.2	1.7
1982	100.0	60.4	32.1	6.7	0.8
1983	100.0	55.6	37.0	5.6	0.8
1984	100.0	55.4	37.1	6.7	0.8

SOURCE: Dataquest, 1970-1977; Integrated Circuit Engineering, 1978-1981; Semiconductor Industry Association, 1982-1984.

Copyright © National Academy of Sciences. All rights reserved.

The Southeast Asian region was the first area where American semiconductor firms located offshore assembly operations. Other American electronics manufacturers had previously located there, probably because of the low labor costs and the stable governments in the area. After first locating subsidiaries in Hong Kong and Korea, U.S. semiconductor firms established additional operations in Taiwan, Singapore, and Malaysia. The spread of U.S. companies through the area was due mainly to increasing wage levels in older offshore locations.

Fairchild Semiconductor was the first U.S. semiconductor company to establish an offshore assembly plant. It set up operations in Hong Kong in 1963 and in Korea a year later. Others quickly followed, and by 1969, 60 percent of U.S. semiconductor companies in the sample had set up an offshore operation. Today almost all U.S. firms utilize offshore assembly. Foreign firms, seeking to remain competitive with American firms, were forced to duplicate the American migration.

PRESENT STRUCTURE OF THE INDUSTRY IN THE UNITED STATES

There are three categories of semiconductor manufacturers in the United States: (1) peripheral companies that use semiconductor products, perform research and development on semiconductors, and in some cases, manufacture semiconductors for internal consumption ("captive production"); (2) large firms that manufacture semiconductors for sale on the open market; and (3) small, independent firms. The differentiation between the second and third types of firms is somewhat arbitrary. In this analysis, the division between large and small is based on the size of the entire corporation, not the semiconductor operation; furthermore, unless otherwise specified, the data based only on the commercial market.

There are well over 100 companies manufacturing semiconductors in the United States. Despite the large number of participants in the industry, the four largest firms account for 50 percent of total U.S. semiconductor shipments.

Two firms with captive capabilities are of major importance to the industry: AT&T and IBM. AT&T's research arm, Bell Laboratories, played an important role in the creation and development of semiconductor technology. So long as Bell Laboratories research objectives were compatible with the general needs of the industry, it remained the major source of new product and process technology. Bell Labs' philosophy "was to support research in those fields of current basic science that seemed to have the greatest relevance to the mission of the Bell Telephone System." This meant an orientation toward improving communications systems. As semiconductor technology broadened into new areas of applications unrelated to communications, Bell Labs' inputs into the innovative stream lessened in importance. This was a major change since Bell Labs conducted a large share of the basic and applied research relating to solid state devices. The situation was further accentuated by the AT&T breakup. Bell Labs research is now regarded more than ever by AT&T as a proprietary advantage not to be shared with the industry at large.

Copyright © National Academy of Sciences. All rights reserved.

While the importance of Bell Laboratories to the semiconductor industry has declined, that of IBM has grown. Not only does IBM carry out a substantial research and development program relating to semiconductors, it is also the single largest customer. IBM consumes over one-third of the semiconductors purchased from semiconductor firms by computer companies. Relative to IBM's market share of the computer industry this may seem small, but IBM has a large in-house production capability that supplies 80 percent of the semiconductors it consumes.

The vacuum tube companies, RCA being the sole exception, have either focused their semiconductor production on specialized products or have discontinued operations. Vacuum tube companies are not important in the domestic semiconductor industry because, as a rule, they have not recently entered fast-changing areas of semiconductor technology.

The remaining types of large firms tend to dominate all phases of established semiconductor technology. The large firms have been the main instruments through which production technology has been transferred abroad. However, the most current and advanced technology is more likely to be exploited by the small "spinoff" companies.

Small firms are differentiated by their marketing strategy rather than by the way they entered the semiconductor industry. There are three types of small semiconductor companies (other than job-shop operations): (1) second-source companies, which duplicate the successful products of other companies; (2) specialty companies, which specialize in very limited areas of semiconductor technology; and (3) innovating companies, which usually formed to exploit innovations not being aggressively pursued by larger companies.

Second sourcing a successful product acts to technology within the U.S. semiconductor industry. However, the type of firm that engages in this activity may have little other qualitative impact on the industry.

Specialty producers are not very important to the overall development of the industry since they focus only on very specific demands within a broad market for a particular technology. There is a long lag between the initial appearance of an innovative product and the appearance of these companies in the market; this also limits their importance in the industry.

The last type of small company, the innovator, is formed to exploit innovations that the larger firms either cannot or will not pursue. Some large firms deliberately let smaller firms have the early lead into new markets. This allows the larger firms to focus their resources on established, profitable markets while the smaller firms attempt to develop markets for new technology. Once the direction of the market is ascertained and the type of technology most likely to succeed in it is well defined, the larger firms turn their resources to new technology. The larger firms often cannot completely dislodge the small companies from the new markets because they lack the experience with the new process technology. On the other hand, the small firms often fail because of management or capitalization deficiencies, and few became big on their own.

Copyright © National Academy of Sciences. All rights reserved.

APPENDIX D

U.S. ACCESS TO FOREIGN TECHNOLOGY

The U.S. components industry has led the world for many years in technology and has been generous in sharing knowledge with others in the free world. A liberal policy of open publication has been instrumental in disseminating information, particularly in electron tube and solid state technology, to the benefit of other nations. Additionally, patent licenses and, occasionally, technical aid have been provided internationally at very reasonable terms.

As a consequence, other industrially developed nations, particularly many Western European countries and Japan, have developed a significant R&D capability, in many instances rivaling that of the United States.

Efforts have been under way in recent years to establish access to foreign technology for the United States. This is particularly true regarding transfer of Japanese military technology to the United States, resulting from the 1983 bilateral government agreement in which Japan made an exception to its policy of banning all such exports. This is a possible avenue for Department of Defense (DOD) to ensure that the U.S. components industry continues to be a strong competitor.

However, this bilateral approach on military technology may not be sufficient, since the military efforts of our trading partners is only a small fraction of their overall R&D efforts. A recent report by the National Science Foundation to the House Committee on Science and Technology describes the need for a very broad program to follow and utilize foreign R&D. The private sector is undertaking programs for much greater awareness and access to foreign technology. There is, for example, a trend toward joint technology ventures with foreign partners, particularly the Japanese. The Microelectronics and Computer Technology Corporation has established an International Liaison Office to disseminate the nature of R&D activities in Japan in microelectronics and computer technology research.

The recent example of IBM's success in negotiating a nonexclusive patent license with the Ministry of International Trade and Industry and large Japanese computer companies is a major change from the past, in which such agreements covered only access to U.S.-generated patents.

DOD could aid this process by continuing its efforts on military technology transfer and ensure dissemination of this information to U.S. suppliers. It could also encourage and support the efforts of government to negotiate an approach, particularly with Japan.

Copyright © National Academy of Sciences. All rights reserved.

APPENDIX E

FINAL REPORT ON GaAs FET STUDY

The Advisory Group on Electron Devices (AGED) was asked to conduct a study on GaAs material and FETs. The objectives of this study were:

- Determine current U.S. dependence on foreign suppliers for GaAs material and/or FETs
- Determine reasons for this foreign dependence
- Project future trends
- Recommend actions to assure adequate sources of supply for future DOD needs

To accomplish this study, a committee was formed, headed by Mr. Norman Pond, assisted by:

Committee Members:	Affiliation:
Mr. Jerry A. Arden	California Eastern Labs, Inc.
Captain Ralph F. DeWalt	U.S. Navy
Mr. Robert Goff	Avantek
Dr. S F. Paik	Raytheon Company
Mr. Homer Prue	Sanders Associates
Dr. T. B. Ramachandran	M/A-Com, Incorporated
Ex Officio:	
Mr. Joseph Kearney	Eaton Corporation
Dr. Joseph Saloom	M/A-Com, Incorporated

The problem was approached by segmenting the effort into three topics as follows:

- Collect current usage data on FETs and materials from users and suppliers

Copyright © National Academy of Sciences. All rights reserved.

- Project future needs by integrating forecasts by DOD, system manufacturers, and component manufacturers
- Determine reasons for foreign suppliers, i.e., cost, quality, performance.

Current usage data and projection for future needs was obtained by contact with 7 systems manufacturers and 10 component manufacturers. Those companies use 44,000 IN^2 of GaAs per year. Figure I summarizes this data:

SURVEY SUMMARY OF GaAs WAFER USAGE ESTIMATES

FIGURE I

	1984 USAGE	1989 USAGE	ANNUAL GROWTH RATE
System Manufacturer	44K IN^2	345K IN^2	51%
Components Manufacturer	82K IN^2	341K IN^2	33%
Total of Survey	126K IN^2	686K IN^2	40%

The dependence on foreign sources of supply vary with type of products Figure II indicates that for low noise FETs, approximately 75 percent of the material used on the production of low noise FETs in the U.S. comes from foreign suppliers. More than 50 percent of low noise FETs used by U.S. manufacturers come from foreign suppliers. The situation is similar in the power FET area. U.S. material is used for the majority of production of microwave diodes.

FOREIGN GaAs SUPPLY FOR U.S. PRODUCTS

FIGURE II

	GaAs MATERIAL	GaAs DEVICES
Low Noise FETs	75%	50%
Power FETs	50%	50%
Diodes	25%	10%
MMICs	No Established Trend	
Digital ICs	No Established Trend	

Copyright © National Academy of Sciences. All rights reserved.

As indicated in Figure I, the consensus of opinion is that the need for GaAsmaterial will grow rapidly over the next several years. An average projected growth rate among the 17 companies surveyed is 40 percent per year. This correlates well with other industry studies and DOD estimates (it should be noted that these figures are not projections of total U.S. needs, but the projected needs of the companies surveyed).

Several observations made during the course of making the survey and subsequent discussion include:

- Several manufacturers currently producing high production volumes of FETs do so primarily with Japanese material
- Several systems manufacturers are projecting large future productious of GaAs Monolithic Microwave Integrated Circuits or GaAs Digital ICs using U.S. GaAs material
- Successful merchant quality of U.S. manufactured FETs on premium quality Japanese material is well established; however, the success of U.S. manufactured GaAs ICs on U.S. material is relatively unproven
- The question of dependency on foreign supply of GaAs material appears more serious for premium horizontal Bridgeman material than it does for large quantities of L.E.C. material.

Projection of future trends is difficult because, in addition to the trend of increased utilization of GaAs, the trend is clearly toward greater integration of functions and the trend is towards Monolithic Microwave Integrated Circuits. Thus, to answer the question concerning the trend towards utilization of foreign material and/or components, it is necessary to think through how the MMIC area will develop. A lot of discussion was held on this problem and it is clear that many systems companies intend to have internal MMIC capability. The history of electronic components indicates that systems companies are frequently involved in new technologies as they are developed, but seldom are major suppliers to themselves or others when these products are used in production quantities. Concern was expressed that if the center of effort in this area is in the systems companies, it may hamper the development of a component oriented source of supply within the U.S. There was further concern that this scenario might lead to continued reliance on foreign sources of material and components. It is believed that Japan will concentrate on commerical Monolithic Microwave Integrated Circuit products while the U.S. effort is predominantly focused on military needs. If the Japanese technology is suitable for military requirements at the time that systems companies need production volumes and begin purchasing outside, it is possible that these purchases could go to foreign suppliers. Thereby, todays reliance on Japanese material and FETs could be replaced tomorrow by similar reliance on Japanese MMICs.

Irrespective of the concern about heavy dependence on foreign suppliers, it is clear that actions need to be taken to assure reliable, dependable, domestic sources for material, devices, and MMICs. The following actions would seem appropriate in that regard:

Copyright © National Academy of Sciences. All rights reserved.

1. **Encourage the development of a domestic producer of premium quality horizontal Bridgeman material.**

2. **Encourage the establishment of adequate U.S. GaAs material and device suppliers with procurement practices that:**

    - **Favor U.S. suppliers**
    - **Maintain a 3 tier supplier structure:**

        - **Systems manufacturers**
        - **Device/component manufacturers**
        - **Material suppliers**

    - **Foster cost reduction through yield improvements achievable by multi-year commitments and multi-program standardization by merchant suppliers.**

3. **Accelerate the practical implementation of U.S. developed and produced GaAs monolithic ICs (both digital and analog) with selective funding of high volume programs using multi-tier, multi-source, and multi-year techniques.**

N. H. Pond 6/27/84

Copyright © National Academy of Sciences. All rights reserved.

GLOSSARY

DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DRAMs	dynamic random access memories
EMI	electromagnetic interference
EMP	electromagnetic pulse
FAR	federal acquisition regulations
FEMA	Federal Emergency Management Agency
FET	field effect transistors
GaAs	gallium arsenide
IC	integrated circuits
JAN	Joint Army Navy
JTECH	Japanese Technology Evaluation Program
LEC	liquid-encapsulated Czochralski
LED	light-emitting diode
LSI	large-scale integration
MIMIC	microwave/millimeter-wave monolithic integrated circuits
MMICS	microwave monolithic integrated circuits
MOS	metal oxide semiconductor
MTAC	Manufacturing Technical Analysis Center
MTAG	Manufacturing Technical Advisory Group

Copyright © National Academy of Sciences. All rights reserved.

MTPIS	Manufacturing Technology Program Information System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NEC	Nippon Electric Company
OMB	Office of Management and Budget
POS	point of sale
RAM	random access memory
SCRAMs	static random access memories
SDIO	Strategic Defense Initiative Office
Sm-Co	samarium-cobalt
VECP	Value Engineering Change Proposal
VHSIC	Very High Speed Integrated Circuits
VLSI	very large scale integration

Copyright © National Academy of Sciences. All rights reserved.

Copyright © National Academy of Sciences. All rights reserved.