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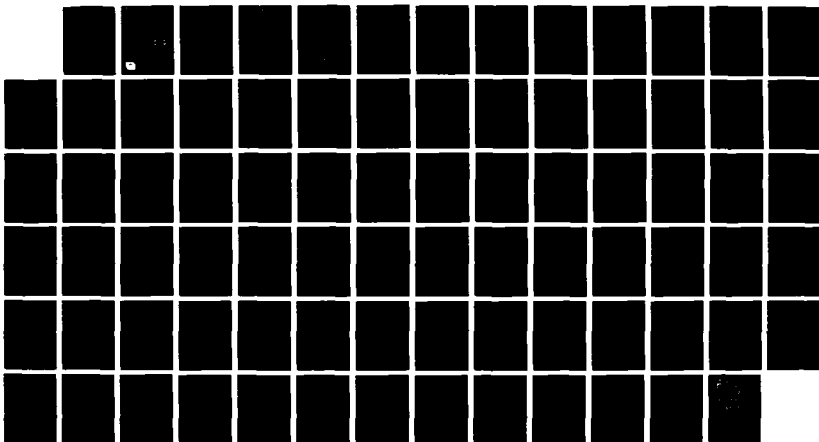
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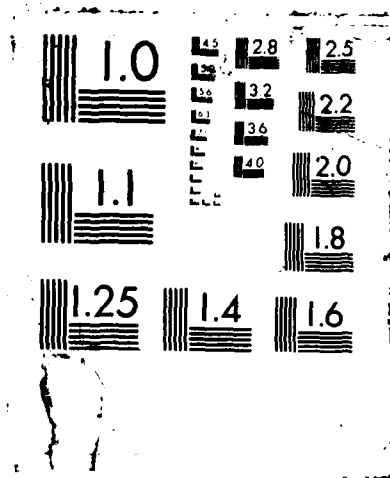
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U.S. ELECTRONICS DEPENDENCY

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Richard Van Atta
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November 1985

Prepared for
Office of the Under Secretary of Defense for Research and Engineering

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Richard Van Atta
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* Reviewers

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ABBREVIATIONS

ASPJ	Airborne Self-Projection Jammer
CIM	Computer-Integrated Manufacturing
CMOS	Complementary Metal Oxide Semiconductor
DESC	Defense Electronics Supply Center
DoD	Department of Defense
DRAM	Dynamic Random Access Memory
GPS	Global Positioning System
IC	Integrated Circuit
ICAF	Industrial College of the Armed Forces
JAN	Joint Army-Navy
JTIDS	Joint Tactical Information Distribution System
LSI	Large-Scale Integration
MOS	Metal Oxide Semiconductor
QPL	Qualified Products List
SCD	Source Control Document or Source Control Drawing
VHSIC	Very-High-Speed Integrated Circuits

EXECUTIVE SUMMARY

Concern has been expressed that National Security interests of the United States are being compromised by dependency upon foreign sources of electronics components. This concern has led to various proposals to alleviate this dependency, including the relocation of Defense electronics production. This study was chartered by the Department of Defense (DoD) to investigate the degree to which Defense electronics are dependent upon foreign sources, particularly those located in the Far East.

The Institute for Defense Analyses was tasked by the DoD to assess the question: Is the United States dependent upon foreign sources for electronic components for its defense systems? Because of urgent policy requirements an initial draft of this study had to be completed in 60 days. This short time period necessitated an approach that took advantage of available information and probed into several layers of information simultaneously. The time constraint limited the study to a fact-finding mission on the extent of dependency and did not permit questions of options for reducing potential dependency to be thoroughly evaluated.

Data for this assessment were restricted to those already available from government and industry sources and those obtained through interviews. Given the short duration of the study it was not possible to develop any new data and the coverage of the data collected was limited. During the course of the study it became clear that additional sources of information could be exploited to provide more definitive positions on the question posed, but that these would have to be explored subsequently.

In spite of the constraints noted above, the study group was able to form specific conclusions regarding the question of dependency of the United States on foreign sources for its defense electronic components. These findings are as follows:

1. The United States is dependent upon foreign assembly or production for certain categories of defense electronics components; however, for other categories of defense electronic components there is no dependency on foreign sources (for a breakout by category, see Figure S-1),

Type Of Device

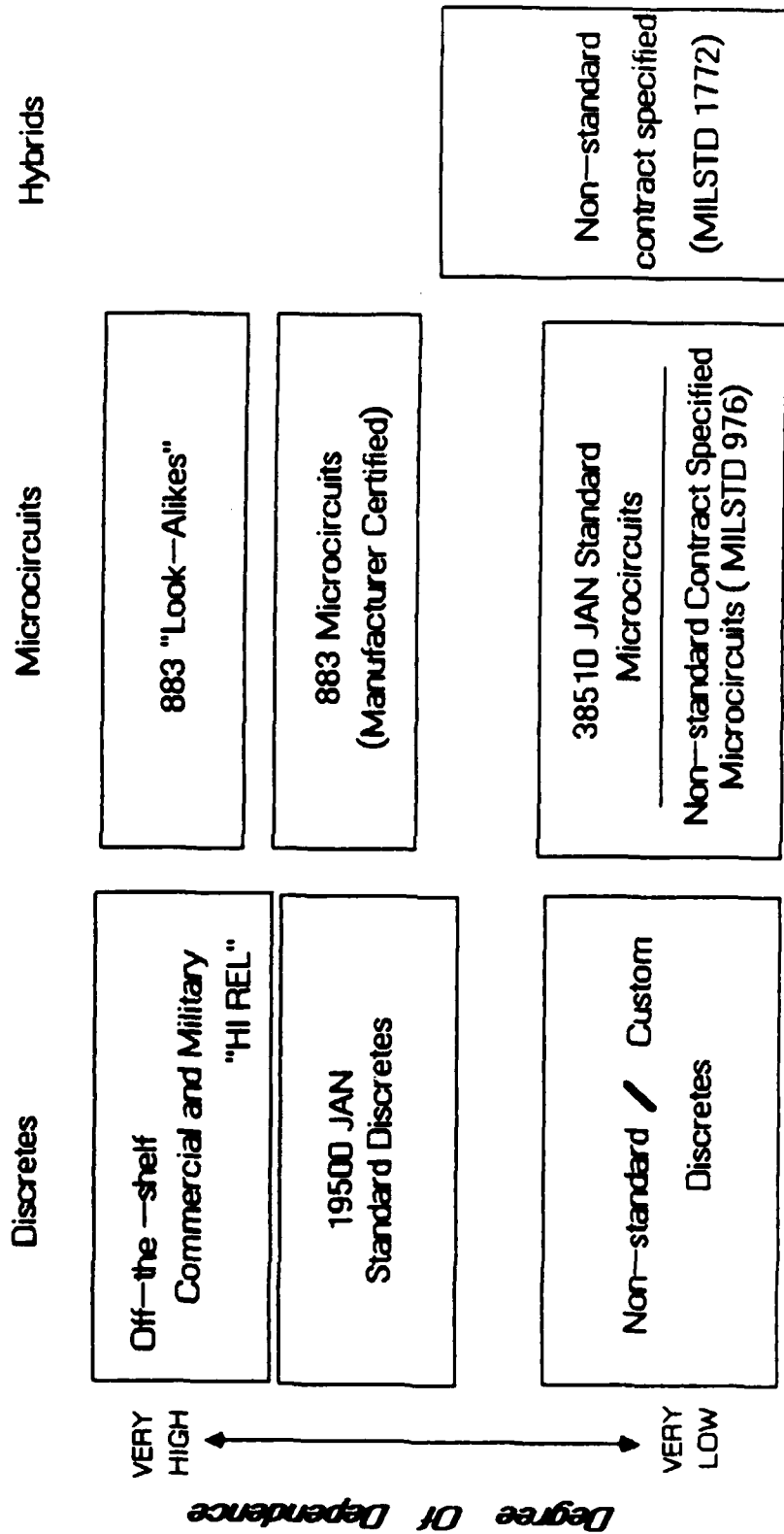


Figure S-1. Summary of Findings: Defense Electronics Dependency on Foreign Sources

2. In evaluating the question of dependency it is necessary to differentiate between types of devices--there are major differences, depending upon whether the device is a standard or non-standard one, and whether it is a discrete device, a microcircuit, or a hybrid component;
3. Statistics and data on defense electronic component assembly and production and the relationship between such components and the defense systems of which they are components are not readily available, and those that are available need to be validated carefully;
4. Given available data it is difficult to judge the proportion of devices with foreign value-added content in different defense systems, and even more difficult to assess the extent of dependency that does exist for particular categories of components.
5. Because DoD sales represent only five percent of industry dollar volume, other market considerations drive electronics industry behavior. Consequently, the DoD has little opportunity to control the industry's actions, but could increase its influence considerably by adopting incentives which take advantage of industry dynamics.
6. The bulk of offshore production, assembly, packaging, and testing facilities are presently located in East Asia. There is, however, a trend toward locating electronics facilities in Europe, particularly in Ireland and Scotland.
7. While the assembly of certain types of defense-related microelectronic devices relies on Asian facilities, these are located in a number of widely dispersed sites. There is considerable flexibility in responding to any disruption of supply from specific Asian locations, because of the wide range of alternative Asian locations which could be substituted. Moreover, analysts rate the possibility of region-wide disruption of electronics supplies to be unlikely. Therefore, the authors conclude that while distance can increase risk, there is no cause for great concern over the vulnerability of U.S. supplies of defense-related electronic devices produced in Asia over the next five years.

The study also examined two approaches for dealing with dependency on East Asian sources in times of crisis: (1) encouraging U.S. electronics firms to relocate and/or expand their offshore operations in the Caribbean and (2) relying upon domestic U.S. industrial capabilities to expand/surge domestic U.S. capabilities to meet crisis requirements. Findings in these areas include:

1. Market forces and adverse perceptions of the Caribbean labor force by U.S. industry executives work against any major shift of offshore facilities into the region.

These factors might be overcome by a carefully structured incentives package, but these incentives would have to be very significant to induce industry to move in this direction.

2. If all DoD requirements and specifications remained in force, industry executives believe that domestic capabilities to meet large DoD orders could probably achieve no more than a doubling of current defense production in most categories. These response capabilities could improve significantly, however, with the relaxation of some DoD standards and specifications.

I. THE PROBLEM

The overall objectives of this project were to determine and document the degree of U.S. dependency on offshore sources of electronic components going into U.S. military systems plus provide an assessment of the viability of encouraging firms to move to the Caribbean if foreign dependency was found to be a problem. More specifically, the Institute for Defense Analyses was assigned by the Department of Defense¹ the task of:

- Developing an overall study approach and selecting a sample of defense electronic components to examine
- Determining potential dependence on foreign sources of critical defense electronic components
- Assessing the geographic distribution of production and assembly functions for critical defense electronic components
- Integrating assessments of Caribbean capabilities to provide defense electronic components.

IDA was instructed to pursue these objectives within two major constraints. First, only readily available information was to be used. In some cases (e.g., in studying Central America and the Caribbean), specific sources were designated. The second major constraint was time--due to urgent policy requirements the project was to be completed within 60 days.

The concern over U.S. dependency on foreign sources of electronics is relatively new, stemming from more pervasive phenomena: (1) the dwindling of this country's lead in advanced technology and (2) the globalization of high-technology industry. It has become evident that the U.S. no longer dominates the electronics industry as it did even a decade ago. Competition from Japanese and more recently Korean firms has dramatically shifted the balance of trade in microelectronics. Moreover, in efforts to stay competitive with the Japanese, most U.S. firms have shifted much of their microelectronics assembly

¹This study was sponsored jointly by the Deputy Under Secretary of Defense for Research and Engineering (International Programs and Technology) and the Under Secretary of Defense (Policy).

and testing operations outside of the U.S., primarily to Asian locations. Apart from their far-reaching implications for the U.S. economy, these developments have caused concerns about increasing vulnerability of U.S. national security due to what some perceive as growing dependence on foreign sources of electronics components.

In engaging in this study some definitional issues were encountered. First and foremost is the definition of the term "dependence". The concern over foreign production of Defense-related electronics has as its primary basis the degree to which U.S. war-fighting capabilities would be impaired if foreign sources were cut off. Dependency would therefore imply major delays in U.S. weapons systems production due to the unavailability of these foreign-source components. It is difficult, without a survey of actual weapon systems, components, their supply inventory, and domestic industry flexibility to respond to supply shortages, to make a definitive statement regarding the degree to which current patterns of foreign sourcing imply dependence in the strictest sense.

An example of such dependency, as most strictly defined, is the fact that a single Japanese source, Kyocera, provides over 80 percent of all ceramic microcircuit packages. Such definitive statements regarding dependency are much more difficult to substantiate when dealing with larger questions of electronics production. For certain categories of components it can be established that assembly and testing is performed preponderantly offshore. Yet, without an assessment of domestic industrial capabilities in a wartime environment, it is not clear whether this off-shore production implies dependency for U.S. military applications. This study attempts to clarify for which aspects of Defense electronics the potential for dependency may exist; even in those cases where this was determined, ameliorating factors may reduce this potential. The limited scope of this study prevented a definitive assessment of these factors.

II. APPROACH TO ANALYSIS

A. INTRODUCTION: SCOPING THE PROBLEM

In assessing U.S. dependency on offshore sources for U.S. military electronics, it was necessary to select a subset of military electronics which was narrow enough to be covered thoroughly in the 60 days available and which also offered meaningful insights for the Office of the Secretary of Defense.

Concern for potential U.S. dependency on offshore sources of military electronics has touched on all levels of electronics; i.e., complete systems, major subsystems, and individual component parts. Although all of these areas are significant, this study focused exclusively on the sourcing of individual components parts, more particularly semiconductors. This focus was selected because of the explicit concern that had been expressed regarding dependency on such components and because analysts believed that dependency on offshore sources of component parts would, *ipso facto*, mean dependency in the other areas as well, since they are aggregated from these parts.

To collect data on U.S. dependency upon foreign sources for these electronic components two approaches were taken: (a) collecting data on components for specific, individual defense systems and (b) assessing categories of electronics components based upon DoD quality-assurance standards.

In the first approach for determining the extent of offshore sourcing of military electronics, parts lists from four specific military systems were used as an entry point into the military logistics system to identify specific devices, discover where they were manufactured or assembled, and then gauge the magnitude of the dependency problem by identifying how many different U.S. military systems incorporated those devices. Four systems, the Joint Tactical Information Distribution System (JTIDS), Airborne Self-Projection Jammer (ASPJ), NAVSTAR Global Positioning System (GPS), and the Navy Standard Airborne Computer (AN/AYK-14) were selected initially, based on their design stability, multiple prime contractors, multiple users, and relatively large procurements.

Because of time limitations, delays in data collection required dropping the latter two systems, leaving the JTIDS and the ASPJ.

A second approach to the same problem involved investigating categories of electronic components based upon military quality standards for electronic devices for the subclasses of discretes, microcircuits, and hybrids. These quality standards were an important source of information about foreign production and assembly since many of the established rules also mandated where devices could be produced and sometimes established minimum acceptable standards for the ratio of U.S.-to-foreign production and assembly operations.

In addition to examining the holdings of major DoD data-collection centers, the opinions of key executives in major U.S. electronics firms were solicited. Individual executives were interviewed by IDA staff members, based on a predetermined set of questions. Each person was queried about the nature of the industry, its decision processes, investment trends, and the potential responsiveness of firms to DoD desires.

For assessing the foreign regional issues (e.g., industrial capabilities of the Caribbean), the approach was mandated in the statement of work. IDA was directed to rely on existing analyses of the Defense Intelligence Agency and the Industrial College of the Armed Forces. DIA's input was primarily on security issues, whereas the Industrial College of the Armed Forces provided input for evaluating the industrial capabilities and potential of Caribbean electronics industries.

B. SYSTEM-SPECIFIC DATA

For the two defense systems identified, the JTIDS and the ASPJ, the individual program offices, selected system prime contractors, and some of their major electronic device subcontractors were contacted to link components with systems and those, in turn, with sources of supply. The companies contacted included: International Telephone and Telegraph, Singer, Hughes, Advanced Micro Devices, Hewlett-Packard, National Semiconductor, Siliconix, Fairchild, and Motorola.

Besides the program offices and contractors, the following DoD and Service activities were contacted in an effort to obtain data linking components to systems and sources of supply:

- Tri-Service Industrial Liaison Office, Alexandria, VA
- Defense Electronics Supply Center, Dayton, OH
- Air Force Logistics Center, Warner Robbins AFB, GA
- Naval Ocean Systems Command, San Diego, CA
- Naval Avionics Center, Indianapolis, IN

We discovered it is possible to select a specific program, identify the parts going into it, and identify the locations of its sources of supply. In general, it is much less feasible, however, to extrapolate from an individual part into other programs employing it. In large part, this is a result of the way data on electronic components are collected and aggregated: no DoD or Service agency is charged with the responsibility of systematically tracking which defense systems employ which electronic components. The potential seriousness of this difficulty in linking components to systems extends beyond data collection for a research study. Analysts at the Naval Avionics Center illustrate this by the example of a recent case where a major electronics manufacturer was determined to have supplied a number of devices that had not been through the proper military tests. The Navy could only send out a blanket warning notice of the problem, since it had no way of pinpointing which programs might be using the potentially defective parts. Because it is not generally possible to determine how widely a device is used, it is very difficult to gauge the order of magnitude of dependency. This difficulty can be overcome to some degree by combining available system-specific data within the wider context provided by generic, non-system-specific data. This approach is discussed next.

C. GENERIC, NON-SYSTEM-SPECIFIC DATA

The production of discretes, microcircuits, and hybrids can be categorized within several quality categories--some of which are specifically regulated by military standards and specifications. Quality levels refer to the degree of testing and quality assurance of a particular device. These quality levels and generic device types are combined into the matrix shown in Figure 1. The matrix is important since it provides a structure for later data analysis.

	TYPE OF DEVICE		
QUALITY LEVEL	DISCRETE	MICROCIRCUITS	HYBRIDS
JAN-CERTIFIED			
OTHER FEDERAL PERFORMANCE SPECIFICATIONS			
SOURCE CONTROL DOCUMENTS			
DESC DRAWINGS			
LOOK-ALIKES			
COMMERCIAL			

Figure 1. Quality Levels For Discrete, Microcircuit, and Hybrid Devices

1. Joint Army-Navy (JAN) Military Specifications

JAN electronic components meet two sets of specifications. One set is for the individual item and the other set encompasses the quality assurance and production requirements standards set forth in MIL-STD-750 ("Test Methods for Semiconductor Devices"), MIL-STD-883 ("Test Methods and Procedures for Microelectronics"), and MIL-STD-976, ("Certification Requirements for JAN Microcircuits").

The JAN marking on electronic components is a registered trademark of the U.S. Government, which assures the consumer that the JAN-marked product has met testing and certifications standards. In the case of JAN-marked microcircuits covered by MIL-M-35810, this means that the microcircuit was either manufactured in the United States or in a country with whom the United States has a reciprocal listing agreement for microcircuits on the national Qualified Products List (QPL). As of May 1985, there were no non-U.S. sources for MIL-M-38510 microcircuits, but efforts are underway to implement the

February 1983 agreement between the U.S. and Ireland for reciprocal listing on national QPLs of microcircuits.

2. Conventional Specifications

Conventional specifications for electronic components are less rigorous in comparison with the quality-assurance requirements for JAN certification. Generally speaking, conventional specifications deal with the overall performance of a discrete device or microcircuit and the kind of quality-assurance tests that will be performed. Unlike JAN-marked devices or microcircuits, the general specification devices do not come off production lines audited by DESC engineers.

3. Source-Control Documents

Source-control document parts or components are termed "non-standard parts" because they are customized for the item being procured. Non-standard source control document parts may be of the highest quality, meeting all the requirements for JAN marking, or they may be of lower quality, meeting only such quality-assurance or other requirements as are specified in the procurement contract.

4. Defense Electronics Supply Center (DESC) Drawing Parts

DESC drawing parts are based on a series of DESC documents which attempt to standardize certain families of customized IC or microcircuit functions. The goal of the DESC drawing program is to provide government-owned technical data packages to reduce costs, increase the number of potential suppliers, and provide an opportunity to improve unaudited quality-assurance procedures.

5. Microcircuit Military Specification "Look-Alikes"

Several manufacturers vend microcircuits advertised as meeting military performance requirements and packaged in accordance with relevant military standards and specifications. Such devices are not fully tested either under U.S. Government auspices or by direction and supervision of the manufacturer. According to the DESC staff, such devices should never be used in weapon systems; they are utilized from time to time with the permission of a systems project office in order to maintain a schedule. Nevertheless, these "look-alikes" have entered DoD inventories and pose serious quality control and reliability problems.

6. Commercial

Commercial discrete devices and microcircuits are found in some DoD items. The DESC staff believes that such commercial devices should never be used in DoD weapons systems. Commercial-grade components are sometimes used with the permission of a systems project office in order to maintain a schedule. In addition, such devices are commonly used in a wide range of non-weapons applications.

D. INDUSTRY SOURCES

Industry sources were solicited to obtain data on the offshore production of defense electronics. Three Industry associations, the Semiconductor Industry Association, Electronics Industry Association, and American Defense Preparedness Association were approached to identify offshore sources processing military components and to elicit general insights into the direction of future industry expansion overseas. Representatives of individual companies now making devices for DoD systems were interviewed in detail and provided a better source of specific information providing valuable insights about future industry plans, decision criteria, and potential responsiveness to DoD desires to expand the electronics industries in the Caribbean Basin.

E. AREA ANALYSIS

There were two primary sources of information in assessing regional questions. To deal with questions of regional stability and security, Defense Intelligence Agency analysts were interviewed and current regional estimates were screened. Members of the Mobilizations Studies Program at the Industrial College of the Armed Forces were also contacted and they supplied a recent student report, "Mobilization Studies Program Report: Electronics Industry and the Caribbean Basin". These sources were supplemented by questioning executives about offshore production.

F. LESSONS LEARNED

The process of gathering information raised the following points which are worth passing along to others interested in examining the question of U.S. dependency on foreign sources of electronic components for U.S. military systems.

- Data tends to be either system-specific or component-specific.
- There is no general record (or centralized agency) for linking components with systems.
- It is very difficult to acquire data about the amount of foreign value-added content of devices initially manufactured in the U.S. and to assess foreign dependency in such cases.

III. FOREIGN DEPENDENCY ASSESSMENTS

A. OVERVIEW

This section summarizes IDA's findings about the degree of U.S. defense dependency on foreign manufacture, assembly, packaging, and testing for various types of electronic components. As noted in the previous section, three broad categories of electronic components were analyzed: discrete semiconductor devices (e.g., diodes and transistors); microcircuits, and hybrid microcircuits. These classes are further subdivided into categories based on their conformance with DoD Military Specifications for both specific performance and overall quality.

The overall study findings are summarized in Figure 2. The authors conclude that foreign dependency may exist for lower-quality levels of both standard discrete semiconductor devices and standard microcircuits. In the cases of non-standard discrete devices and microcircuits the problem of foreign dependency does not now exist, due in large measure to contractual obligations imposed on prime contractors and their subcontractors by DoD. Foreign dependency also does not appear to be a problem in the case of standard microcircuits where DoD specifications required procurement of items manufactured, assembled, packaged, and tested in CONUS or other U.S.-territory plants. The United States is not dependent now on foreign fabrication of wafers. Furthermore, industry sources do not expect the United States to become dependent on foreign sources of wafers in the foreseeable future.

Quantitative data provided by the Defense Electronics Supply Center (DSEC) for production of discrete semiconductor devices from qualified U.S. and foreign lines demonstrate that foreign dependency exists for a number of military specification standard discrete semiconductor devices. Once a U.S. company has established a qualified offshore production line, production of military specification discrete devices shifts to that facility. The U.S. production line is maintained only in a "standby" capability, as required by the minimum standard of MIL-S-19500G.

Type Of Device

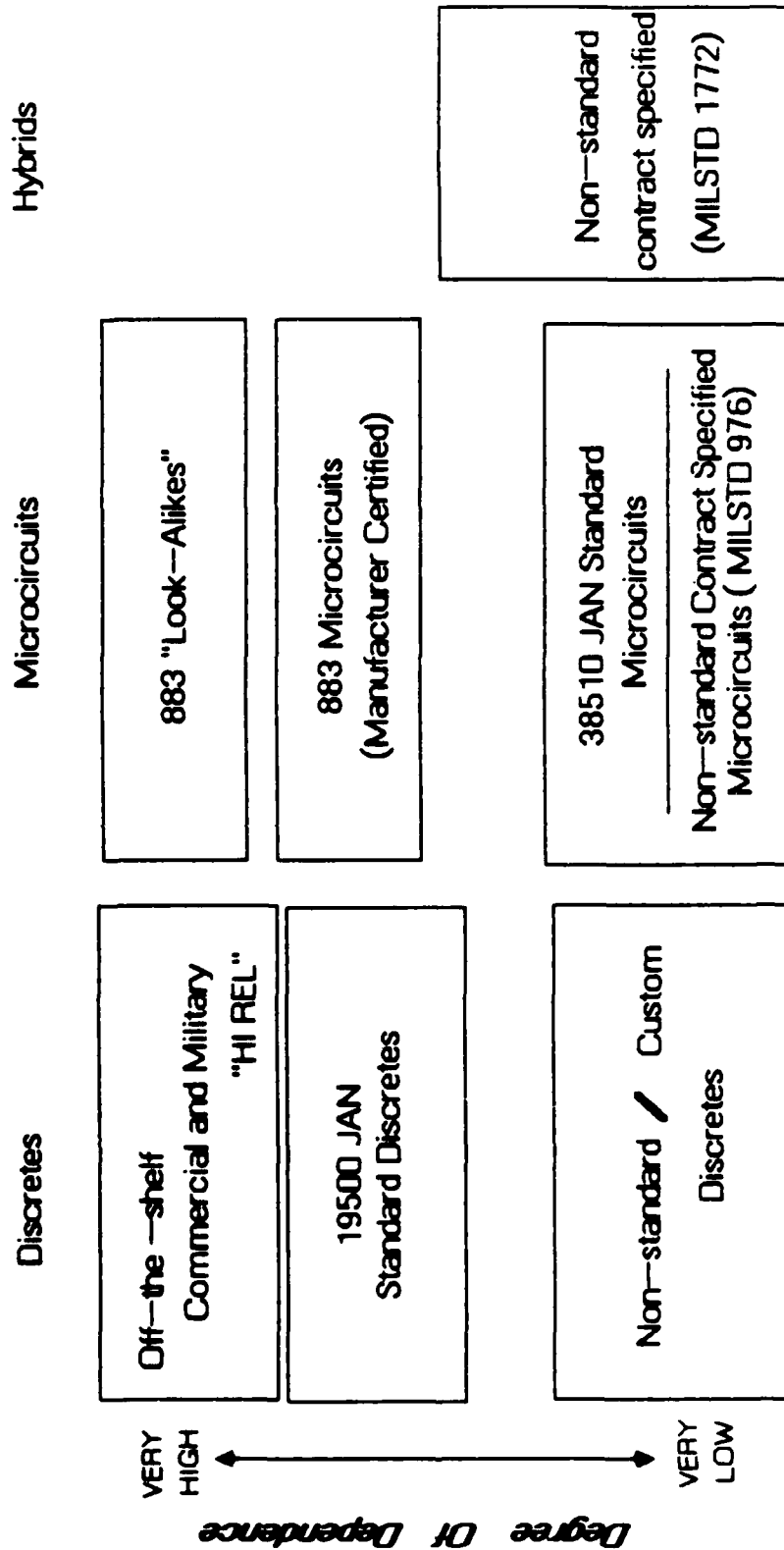


Figure 2. Summary of Findings: Defense Electronics Dependency on Foreign Sources

B. DISCRETE DEVICES

As noted in Section II, the study took the parts lists for the Airborne Self-Protection Jammer (ASPJ) and the Joint Tactical Information Distribution System (JTIDS) Class 2 Terminals as a departure point for purposes of identifying electronic components. The JTIDS parts lists were the most complete and provided substantial information regarding discrete devices.

The following is a list of discrete devices found in one or more versions of the JTIDS Class 2 terminals.

<u>Device Number</u>	<u>Device Number</u>
1N746A-1 through 1N758A-1	2N918
1N4148-1	2N2218
1N4510-1	2N2218A, 2N2218AL
1N4150-1	2N2919
1N4370A through 1N4372A	2N2219A, 2N2219AL
1N5415 through 1N5420	2N222A (JANS)
1N5550 through 1N5554	2N2920
1N5615	2N2945A
1N5617	2N3251A
1N5619	2N3501
1N5621	2N3537
1N5623	2N3716
1N5624 through 1N5627	2N3792
	2N3811
	2N4029
	2N5109

A review of this list of standard devices revealed that there were several manufacturers on the MIL-S-19500G Qualified Products List who made these devices overseas. While there were also additional manufacturers who made these devices in U.S. plants, it was clear that ITT, Hughes Aircraft, and Singer had the option of including foreign-produced semiconductor devices in their versions of the JTIDS Class 2 terminals.

A wider examination of the MIL-S-19500G Qualified Products List was undertaken. A list of all devices available from one or more manufacturer with foreign production lines was assembled. The list was constructed by reviewing actual production data for fiscal years 1982 through 1984 as reported by the manufacturer to the Defense Electronics Supply Center.

MIL-S-19500G explicitly authorizes offshore production of certain types of fully qualified semiconductor devices. The following is an excerpt of the relevant language:

"Location of manufacturer for JANS and JANTXV types

For JANS and JANTXV devices (except clear glass JANTXV diodes), wafer processing, device assembly, 100 percent screen test, and groups A, B, C, and D inspections shall be performed in the USA or its territories.

Location of manufacturer for JAN, JANTX, and clear glass diode, JANTXV types.

Provided the requirements of Foreign Plant Qualification Provisions...are satisfied, JAN and JANTX devices and clear glass JANTXV diodes may be assembled in a foreign country provided that the foreign assembly plant is wholly-owned or technically and quality conformance controlled by the basic plant and provided that all 100 percent screening tests and groups A, B, C, and D inspections are performed in the USA at the basic plant,...²

Appendix E to the Specification contains extensive documentation requirements necessary to support the qualification of an offshore assembly and packaging facility. Furthermore, once an offshore production facility has been qualified, its CONUS-based "parent" must retain the capability of producing a qualified device or a structurally identical device not less than once every 3 years.³

Interviews with DESC staff prompted our review of retention data for the following companies that operate domestic and foreign assembly lines:

Fairchild Semiconductor
General Instrument, Inc.
Hewlett-Packard, Inc.
Intersil, Inc.

Motorola, Inc.
Raytheon
Siliconix, Inc.
TRW Microwave

The retention data show several instances where qualified offshore production has replaced domestic production. In most instances where both domestic and offshore production lines exist, the domestic line is exercised only as often as necessary to retain qualification.

The Appendix reproduces the production data made available by DESC. Table 3 presents lot production data for three companies, illustrating the relative output of identical devices from foreign and domestic lines. The available data led the authors to conclude that there is a very strong likelihood of foreign dependency for those devices listed in the Appendix.

² MIL-S-19500G, "Military Specification, Semiconductor Devices, General Specification For," (Washington, DC: Naval Electronic Systems Command, Defense Standardization Program Branch, 16 February 1984), p. 11.

³ See Paragraph 4.5.8, *Retention of qualification* in *ibid.*, pp. 18-19 for further discussion of the retention requirement.

Table 3. Foreign and Domestic Production of Discrete Semiconductor Devices

DEVICE NUMBER	LOT PRODUCTION DATA: GENERAL INSTRUMENTS, INCORPORATED							
	HICKSVILLE NY	TAIWAN	HICKSVILLE NY	TAIWAN	HICKSVILLE NY	TAIWAN	HICKSVILLE NY	TAIWAN
	1982	1982	1983	1983	1984	1984	1984	1984
IN0483, IN0485, IN0486	1	8	0	1	0	10		
IN0645, IN0647, IN0649	1	12	1	5	2	12		
IN0645-1, IN0647-1, IN0649-1	1	12						
IN1731, IN1733, IN1734	0	2	R	R				
IN3611 THRU IN3614	0	12	0	5	1	11		
IN3957	0	12	0					
IN4245 THRU IN4247	0	12	0	5	1	10		
IN4942 THRU IN4248	0	11	1	5	1	10		
IN5415 THRU IN5420	0	9	0	5	1	9		
IN5550 THRU IN5554	0	11	1	5	1	10		
IN5624 THRU IN5627	0	7	1	5	1	8		
IN5614, IN5616, IN5618,								
IN5620, IN5622	0	12	0	5	1	11		
IN5615, IN5617, IN5619								
IN5621, IN5623	0	12	0	5	1	8		
IN5807, IN5809, IN5811	1		0		1			
IN6113 THRU IN6130,								
IN6131 THRU IN6137	1	1	0	0	0	0		

DEVICE NUMBER	LOT PRODUCTION DATA: HEWLETT-PACKARD							
	SAN JOSE	MALAYSIA	SAN JOSE	MALAYSIA	SAN JOSE	MALAYSIA	SAN JOSE	MALAYSIA
	1981	1981	1982	1982	1983	1983	1984	1984
IN5711	0	16	0	8	1	6	1	10
IN5712	0	7	0	7	0	7	0	5
IN5719	0	10	0	10	2	11	1	11

DEVICE NUMBER	LOT PRODUCTION DATA: INTERSIL, INC.							
	CUPERTINO	SINGAPORE	CUPERTINO	SINGAPORE	CUPERTINO	SINGAPORE	CUPERTINO	SINGAPORE
	1981	1981	1982	1982	1983	1983	1984	1984
2N4091, 2N4092, 2N4093	2	NQ	1	NQ	?	NQ	1	15
2N5114, 2N5115, 2N5116	6	NQ	6	NQ	?	NQ	3	6
2N4856, 2N4857, 2N4858	0	NQ	1	NQ	?	NQ	1	6
2N3823	0	NQ	0	NQ	?	NQ	3	1
2N2609	0	NQ	0	NQ	?	NQ		1

NOTES:

- * Retention requirement met by production of a structurally identical device
- R Removed from Qualified Products List
- X No production; production capabilities retained
- ? No data available from DESC
- NQ Not Qualified for military specification production

It is necessary to place the possibility of foreign dependency into a broader perspective. The MIL-S-19500G Qualified Products List contains approximately 750 discrete semiconductor devices. Of these 750, approximately 200 are produced at offshore plants. Very few are produced exclusively abroad. It therefore appears that there is foreign dependency for some discrete semiconductor devices; however, the overall proportion of foreign dependency for military specification discrete semiconductor devices is rather small.

The foregoing discussion has examined JAN-certified "military specification" devices, i.e., devices which meet all specific performance specifications, testing, and quality assurance specifications, and are produced from U.S. Government certified lines. Some other "military specification" devices are less rigorously controlled.

There are a number of semiconductor devices procured for use in DoD systems which are non-JAN-certified as having met all tests under the general as well as specific standards and specifications for semiconductor devices. Many of these non-JAN-certified devices meet the general requirements of MIL-STD-750, "Test Methods for Semiconductor Devices".

MIL-STD-750 devices enter the U.S. procurement system through a variety of mechanisms. In some instances, DoD will procure a commercial item which incidentally uses discrete semiconductor devices that have been tested in a manner which conforms to MIL-STD-750, at the option of the manufacturer. In other instances, a DoD prime contractor will request a waiver from the requirement to use JAN-certified standard devices because of a short supply situation. Under these circumstances, the contractor and the System Program Office will negotiate a change order which allows use of MIL-STD-750 devices in lieu of JAN-certified MIL-S-19500G devices. These waivers are often intended to be of limited duration, but sometimes a one-time waiver becomes routine.

DESC officials reported that they have no reliable data regarding the degree of substitution of MIL-STD-750 components for MIL-S-19500G components. They are concerned because evidence suggests that the non-JAN-certified components are qualitatively inferior. DESC officials also expressed the view that all MIL-STD-750 devices were coming from foreign sources.

If this is true, the United States may be substantially dependent on foreign sources for MIL-STD-750 semiconductor devices. The authors have not been able to verify

DESC's assertion within the limited time and resources of this study; however, interviews with industry sources tend to confirm the assertion of DESC officials.

Defense contractors frequently incorporate discrete semiconductor devices that are not available from the Qualified Products Lists in their products to perform specialized functions. These nonstandard parts are usually identified in the procurement system as "Source Control Document (SCD) parts". SCD parts are custom or semicustom parts whose description, technical characteristics, and design drawings are the sources of supply for components incorporated in the SCD part.

The usual practice of contracting officers is to restrict SCD parts to United States manufacturers. In the case of SCD discrete semiconductor devices, this practice appears to have been followed to date. Neither the JTIDS terminal nor the ASPJ parts lists indicated which, if any, discrete devices were nonstandard parts. An examination of the Navy JTIDS Class 2 Terminal Source Control Documents for nonstandard parts provided no additional information regarding incorporation of SCD discrete semiconductor devices in either the Hughes or ITT versions of the terminals.

Discussions with DESC, Naval Avionics Center, and industry sources indicate that use of foreign plants for the manufacture, assembly, packaging, and testing of nonstandard discrete semiconductor devices for significant weapon systems is highly unusual. It would appear on the basis of anecdotal information that the DoD is not dependent on foreign sources for nonstandard or "custom" discrete devices.

DESC has embarked on a program intended to reduce the number of nonstandard electronic parts entering the logistics system. The motivation for reducing the number and variety of non-standard or Source Control Drawing (SCD) parts is driven by two concerns: replacement costs and quality. DESC asserts that SCD parts are substantially more expensive and less reliable than JAN-certified standard parts.

In order to implement this program, DESC has developed standardized drawings for devices procured from SCDs. The drawings belong to the government, and are provided to various device manufacturers in an effort to introduce a degree of standardization into the SCD parts world. Currently there is no foreign dependency for DESC supplied drawing parts. The program is quite new and DESC appears to be limiting the distribution of such drawings to CONUS-based firms that carry out the actual production of devices in the U.S.

Commercial specification semiconductor devices also enter the DoD inventory from time to time in order to maintain commercial items that DoD has procured for administrative, support, and non-combat-related missions. For example, motor pools stock commercial semiconductors as replacements for devices used in commercial vehicles.

DESC had no data regarding the use of commercial semiconductor devices throughout DoD; DESC officials stated that the U.S. was dependent on foreign sources for most commercial semiconductor devices, unless the devices were either very old, obsolete technology, or very new and just entering volume production. Industry sources tended to confirm this view during interviews conducted in March, 1985.

In summary, it appears that DoD is dependent on foreign sources for a range of commercial quality to MIL-STD-750 quality discrete semiconductor devices. On the other hand, Source Control Drawing discrete semiconductor parts and DESC discrete semiconductor devices appear to be made in the U.S. from wafer fabrication through final packaging and testing. Available evidence leads to the conclusion that DoD is dependent on foreign sources for only a relatively small proportion of discrete devices which meet the requirements of MIL-S-19500G and are JAN-certified. The DoD appears to lack data that would allow quick identification of those weapon systems or other DoD items incorporating devices that passed through foreign hands during assembly, packaging, and testing. Furthermore, the DoD also lacks data that would allow an assessment of the significance of such dependence on readiness, surge capability for specific weapon systems, or other mission-critical items.

C. MICROCIRCUITS

As in the case of discrete semiconductor devices, the study used the ASPJ and the JTIDS as points of departure for analysis. These two systems provided a sample of microcircuits from which further data collection and analysis could begin.

First the potential for foreign dependency for standard microcircuits was investigated and then non-standard or "custom" microcircuits. As in the case of discrete semiconductors, a range of dependency was found.

DoD procures many quality levels of microcircuits for a variety of weapon system, command and control systems, and other items used throughout DoD. Microcircuits going into combat, combat support, combat service support items, command and control systems, and other items of relatively great importance are usually required to meet minimal

quality levels for JAN certification. In fact, the standards for JAN certification relative to other standards are quite high. Among the many requirements for JAN certification for microcircuits is the requirement that the U.S. Government inspect the production facility and quality assurance records for each lot of microcircuits.⁴

The current general specification for microcircuits, MIL-M-38510F, contains the following language regarding the country of manufacture for fully qualified microcircuits.

Country of Manufacture

All JAN microcircuits shall be manufactured, assembled, and tested within the United States and its territories except as provided by international agreement establishing reciprocal and equivalent government quality control systems and procedures.⁵

In essence, there is, by definition, no foreign dependence for microcircuits that meet both the general specifications for microcircuits and the specific subset of performance standards for each MIL-M-38510F specification.

On the other hand, the Governments of Ireland and the United States are moving to implement the 1983 agreement for the reciprocal listing of microcircuits on the respective national QPLs of each country. General Electric and Unitrode are also seeking Irish Government certification of their production facilities so that they might begin to market Irish-manufactured military specification microcircuits to DoD and DoD contractors.

There are, of course, other non-JAN microcircuits used in DoD items. One family of standard devices meets MIL-STD-883, "Test Methods and Procedures for Microelectronics." These military specification devices have the performance characteristics and packaging of a fully JAN-certified microcircuit, but come off production lines which have not been audited by the U.S. Government and may not meet other criteria established in MIL-M-38510 and/or MIL-STD-976.

⁴ See MIL-STD-976, "Certification Requirements for Microcircuits," (Griffiss AFB, NY: Rome Air Development Center) 1983, for further discussion of the JAN certification process. See also Samuel P. Miller, "Memorandum for the Record: Analysis of the Concerns Regarding Use of 'JAN' Markings by Foreign Companies," Washington, DC: Defense Materiel Specifications and Standards Office, 29 January 1985, for further discussion on JAN markings in general.

⁵ MIL-M-38510F, "Military Specification, Microcircuits, General Specification For," (Griffiss AFB, NY: Rome Air Development Center, 31 October 1983), p. 6.

Officials at DESC and industry sources state that nearly all MIL-STD-883 microcircuits are assembled in Asia; virtually no MIL-STD-883 devices are assembled in the United States.

An additional class of devices has entered the market in recent years. Termed "look-alikes" by DESC, these microcircuits have the appearance and claimed performance capabilities of MIL-STD-883 devices. Yet these "look-alikes" go through little, if any, quality assurance testing, including testing administered by the manufacturer.

According to DESC officials, nearly all of the "look-alikes" come from offshore facilities, including those marketed by major American firms who have experienced microcircuit quality control problems. These "look-alikes" enter the DoD system because of schedule and cost pressures on the system program offices; once accepted for use, even if on an interim basis, the DESC position is that "look-alikes" pose serious problems.

Nonstandard or "custom" microcircuits are a large growing portion of DoD electronics procurements.⁶ In the case of the Hughes Aircraft version of the Navy JTIDS Class 2 terminal, all of the nonstandard microcircuits are being procured from companies in the U.S. Furthermore, as part of the Hughes Aircraft contract with the U.S. Government, Hughes submitted a Specification Compliance Analysis in which it pledged to use only those microcircuits manufactured, assembled, packaged and tested in the U.S. Interviews with industry representatives, as well as discussions with various Systems Program Offices, indicate that detailed specifications for nonstandard or "custom" microcircuits generally include a prohibition against use of microcircuits that pass through offshore facilities.

DESC is also attempting to lower the costs and reduce the diversity of nonstandard microcircuits through implementation of its own SCD parts program. DESC drawing microcircuits are relatively low-volume procurement items now, but appear to hold considerable promise as a cost-effective solution to the need for relatively low cost, reliable, and semi-custom or custom microcircuits.

Finally, commercial nonmilitary specification microcircuits enter the DoD inventory, usually as replacement parts for commercial items and not for weapon systems or critical military support devices. Once in a while, mistakes are made. DESC officials

⁶ See F. Darrell Hill, "Microcircuit Acquisition Issue," (Dayton: Defense Electronics Supply Center, 1984) *passim*.

told IDA analysts that the November, 1979, tactical warning incident at the North American Aerospace Defense Command Center in Colorado Springs was triggered by the failure of a plastic-packaged microcircuit used in a Honeywell computer. DESC believes that all commercial microcircuits pass through foreign plants during their manufacture.

In summary, the study found that in the case of microcircuits complying with all aspects of military specification MIL-M-38510 (JAN-certified), the United States is not dependent on foreign sources. Government and industry sources agree that DoD is dependent on foreign sources for lower-specification-level microcircuits (MIL-STD-883) and nonspecification "look-alikes". DoD also appears to be dependent on foreign sources for commercial grade microcircuits. The implications of such foreign dependency are not clear.

Available evidence in the form of a sample contract and numerous interviews with industry and government personnel strongly suggest that DoD is not foreign-dependent for Source Control Drawing (SCD) microcircuits because of contractual language which generally bars offshore procurement.

D. HYBRID MICROCIRCUITS

An additional area of electronic components upon which our study touched was hybrid microcircuits. Interest in these devices was aroused by detailed discussions with ITT representatives regarding the production of their version of the ASPJ.

ITT provided the study with a detailed list of discrete semiconductor devices and microcircuits incorporated in four of the 65 hybrid microcircuits to be used in its version of the ASPJ. These four hybrids spanned the range of hybrid microcircuit technology ITT intended to incorporate in its ASPJ. Included in the accompanying Source Control Document part lists were the names and addresses of vendors, all of whom were based in the U.S. Interviews with ITT program officials revealed that ITT had conducted a worldwide search for potential producers who might be qualified to supply thick-film hybrid microcircuits for the ASPJ program. Initially, ITT was unable to find any American firms that would satisfy its production criteria. After a three-year search, reviewing over 200 manufacturers worldwide, ITT finally found three U.S. firms interested in and capable of producing thick film hybrid microcircuits to its standards and specifications.

The JTIDS contract between the U.S. Government and Hughes specified the quality assurance and site of manufacture of hybrids to be used by Hughes in its terminal.

Hughes agreed to limit itself to the general language of the existing standard for hybrids in 1983 (Appendix G of MIL-M-38510). The relevant language follows:

Country of Manufacture

All hybrid microcircuits shall be manufactured, assembled, and tested within the U.S. and its territories, except as provided by international agreement establishing reciprocal and equivalent government quality systems and procedures.⁷

Unfortunately, it is unclear whether the discrete devices and microcircuits, which when assembled together make up a hybrid microcircuit, must themselves come from certified lines. If this is the case, any potential for a dependency on foreign sources appears unlikely, given the current procurement system. If this is the case, any potential for a dependency on foreign sources appears unlikely, given the current procurement system. If there is no such requirement to use only approved components, then it is conceivable that a U.S. hybrid microcircuit manufacturer will obtain foreign-source components and complete the microcircuit manufacturing process in the U.S. using such foreign-origin devices and microcircuits in conjunction with other complete U.S.-origin components.

Evidence from interviews conducted with industry sources suggests that at present there is no problem of foreign dependency for hybrid microcircuits.

E. WAFER FABRICATION

To date, evidence was found of only very limited reliance on non-U.S. sources for production of wafers. A few U.S. firms have developed offshore wafer fabrication operations, apparently for reasons of cost. Texas Instruments Incorporated chose to produce wafers in Japan, including those for its 64K DRAM. (Some 80 percent of its worldwide need is said to be made there.) However, we identified examples of wafer fabrication facilities being established by U.S. firms in Europe as well as in Asia. This is consistent with the findings of one industry analyst who indicated that location of wafer fabrication is more likely to be influenced by market penetration motives than by the kinds of labor cost savings that make Asian locations attractive. These market-penetration motives are reinforced by reports of representatives of U.S. firms that the cost

⁷ MIL-M-38510F, *op cit.*, p. G3.

considerations in Ireland and Scotland (tax and financing concessions) are attractive features.

For the immediate future, market economics appear to be pulling some specifically defense-related wafer fabrication offshore. Under MIL-STD-38510G, DoD is committed to accepting devices produced on offshore lines which, by international agreement, have certified capabilities to produce in accordance with MIL-STD-38510 specifications. Initial interest in qualifying such lines centers on Ireland. If DoD experience with qualification of offshore facilities for productions of discrete devices can be taken as a guide, a gradual increase in DoD reliance on offshore sources for wafer fabrication could be possible.

As to the future of the overall U.S. domestic base in wafer fabrication, the economic pressures are mixed. Leaders of two major U.S. producers, Motorola and AMD, have stated publicly that they can no longer produce high volume standard devices in the U.S. and must move production offshore to compete. A third, Texas Instruments, produces over 80 percent of its high-volume 64K DRAM in Japan. If wafer fabrication should show a strong trend toward offshore migration, the survival of an independent U.S. microelectronics industry would be questionable.

Others in the industry are convinced that further progress in automating microelectronic production processes will reduce or even offset the cost advantages of moving labor-intensive processes offshore, and make it progressively more advantageous to produce in unified, computer-integrated modules, combining wafer fabrication, assembly, packaging, screening, and testing in a single line.

F. SUMMARY

To the extent that the DoD uses military specification electronic components that meet military specifications in its weapon systems and other electronic products, the current problem of foreign dependency is rather small. A small proportion of military-specification-standard discrete semiconductor devices is produced on foreign production lines; very few, if any, of these devices are produced exclusively abroad. Source Control Drawing discrete semiconductor devices appear to be produced exclusively in U.S. facilities.

Military specification microcircuits are only produced in the U.S.; Source Control Drawing microcircuits are also procured only from U.S. facilities, according to the information provided to IDA by industry and government sources.

The study also shows that electronic components that do not meet military specifications for both specific performance and quality assurance are likely to pass through foreign assembly facilities. Thus, if DoD products contain nonmilitary specification standard parts or Source Control Document parts which have not been obliged by contract to meet rigorous military specification quality assurance levels, there is a strong probability of foreign dependency.

Although dependency upon foreign-sourced components does not now appear to be a critical problem, there are some factors which in the future may lead to DoD becoming more reliant on foreign sources of electronic components. First, there is mounting pressure on DoD to introduce competition into all phases of procurement as a cost-control/cost containment measure. In one instance a Naval command authorized procurement of a Fujitsu copy of a Motorola microcircuit as an approved second source over objections of the Naval Avionics Center and DESC. The procurement of the Fujitsu microcircuit was apparently terminated when a second U.S. source for the microcircuit was found. The priority attached to multiple sources for purposes of cost control may, however, lead to further offshore sourcing of electronics components in the future.

U.S. industry's reluctance to respond to more stringent DoD standards may also force DoD to look for offshore sources of supply. Press reports in mid-1985 noted industry opposition to the new qualifications procedures for MIL-STD-1772, Hybrid Microcircuits. These reports are consistent with the comments received from industry executives that the general prospect for more DoD regulation and control would lead them to leave the military device market. Interestingly, recent DESC experience does not reflect this. Over 130 hybrid manufacturers have expressed an interest in the MIL-STD-1772 qualification process. This response may have been caused by the recent recession in the electronics device market. Therefore, if the market takes a major upturn, industry executives may well respond less favorably to DoD initiatives.

Finally, DoD may find itself facing the option of choosing from U.S. or foreign-qualified products as more nations successfully negotiate and implement agreements for reciprocal listing of electronic components on U.S. and non-U.S. national Qualified Products Lists. The implementation of the U.S.-Ireland agreement will serve as a model.

IV. INDUSTRY ANALYSIS: CROSS-SECTION OF MICROELECTRONICS INDUSTRY

A. OVERALL STRUCTURE OF MICROELECTRONICS INDUSTRY

1. Evolution

Early development of this industry owed much to the impetus provided by space and military programs. As commercial applications of microelectronic devices expanded, this space/defense spur receded in importance. Present estimates are that defense demands in recent years have accounted for approximately five percent of industry revenue.

The major forces shaping the development of the industry include:

- Technology developments: rapid and accelerating, with shortening product life-cycles and product generations;
- Automation: development of computer-aided design; automated and semi-automated assembly, testing; computer-integrated manufacturing;
- Capital costs: rapid increases with each new product generation;
- Industry structure: composed of three main elements:
 - Merchant producers dependent on venture capital and equity markets, with frequent start-up of new firms;
 - A few consumer/industrial product producers which are also major suppliers to the merchant market;
 - Larger, vertically integrated "captive" producers supplying mainly their own internal requirements (e.g., IBM);
- Foreign competition: rapid emergence of Asian competitors, forcing close attention to cost-reduction measures, including automation and offshore processing and assembly;
- Foreign product and technology leadership: developing in selected product areas.

2. Domestic Industry Structure

a. The Merchant Sector

A few firms dominate the merchant sector and are also major sources for defense microelectronic devices. Integrated Circuit Engineering's *STATUS 1985* lists the top ten IC producers as follows (with 1984 revenue estimates by Integrated Circuit Engineering):⁸

	Producer	Revenue from ICs (Thousands of Dollars)	All S/C Devices (Thousands of Dollars)
	Texas Instruments	2,230	2,350
*	Motorola	1,580	2,255
**	National Semiconductor	1,200	1,270
**	INTEL	1,170	1,170
**	Advanced Micro Devices	935	935
	Signetics	740	N/A
**	Fairchild	640	N/A
	Mostek	430	N/A
	RCA	312	N/A
	Harris	280	N/A
	Total, Top Ten	9,517	N/A

b. Captive Manufacturers

Estimates of captive producer output of microelectronic devices for 1984 are:

		Thousands of Dollars	% of Captive Output
**	IBM	3,050	66
	AT&T Technologies	480	10
	DELCO (automotive applications)	280	6
**	Hewlett-Packard	215	5
	Commodore	125	3
	Honeywell	110	2
	Digital Equipment	80	2
	Other	275	6
	Total Captive IC Manufacture	4,615	100

* IDA requested appointments, but major corporate management meetings precluded IDA visit.

** Interviewed by IDA.

⁸ Data in tables on merchant and captive manufacturers is drawn from *STATUS 1985*, Table 1-2, page 3, Table 2-1, page 17, and Table 5-6, page 98.

Based on this data it appears that captive manufacturers may account for almost one third of total U.S. microcircuit production.

c. Defense-Related Suppliers

Defense suppliers of semiconductor devices fall into four general categories:

- Merchants such as Texas Instruments, National Semiconductor, and Motorola.
- Integrated, diversified firms not known primarily for semiconductor production, but having major divisions devoted to military systems, including firms such as IBM, ITT, Hewlett-Packard, Hughes, TRW, Harris, Sanders, Westinghouse, and General Electric.
- Specialized suppliers of semiconductors used in microwave, communications and other special types of military systems. Examples are M/A-COM, Avantek and Raytheon.
- Firms that have made the military market one of their primary lines of business, such as Siliconix, which depends on the military market for 40 percent of its sales.

B. COMPETITIVE DYNAMICS OF THE WORLD MICROELECTRONICS INDUSTRY: IMPLICATIONS FOR THE U.S. INDUSTRIAL BASE

Integrated Circuit Engineering Corporation estimates that the U.S. in 1984 accounted for about 66 percent of worldwide IC production by value, and about 41 percent of discrete device output. By comparison, Japan was the world's second largest producer, accounting for 26 percent of IC output and 35 percent of discrete devices.⁹ In fact, four Japanese firms account for 63 percent of the output of the top ten world producers (excluding captives).¹⁰

The U.S. had a strongly positive balance of trade in microelectronics through 1979, when it began to decline sharply. This corresponds to the date of a major Japanese jump in market shares in the 64K RAM, positioning it for a dominant place in the 256K RAM market. These high-volume memory devices are considered cutting edge technologies that tend to set the pace in manufacturing technology for other types of devices.¹¹ At about the same time a U.S. industry leader, Texas Instruments, decided to locate its worldwide 64K

⁹ Based on *Op. cit.*, Table 1-3, page 6.

¹⁰ *Op. cit.*, page 3.

¹¹ *Op. cit.*, page 129.

DRAM production in Japan. The Semiconductor Industry Association told IDA that it expects Japan to overtake the U.S. in world market share by 1988 and to achieve reversal of the 61/29 semiconductor market share ratio by about 1990.

1. Discrete Devices

Japan's world market position in discrete devices nearly equals that of the United States. This reflects the prominent role of these devices in consumer product markets, which Japan dominates. As a more mature and stable technology, subject to intense competition from Asian producers, discretes have been subject longer than ICs to cost-shaving efforts which took a high proportion of U.S. production and assembly offshore.

2. Standard Integrated Circuits

The world facing U.S. IC producers has assumed a very different character in the past four years, beginning with the Japanese leap forward in 64K RAM devices. Combined with this new Japanese competitive threat has been the emergence of indigenous wafer fabrication capabilities in Korea, Taiwan, and Singapore. (By 1983, according to the Semiconductor Industry Association, there were 13 wafer fabrication facilities in Asia.) In addition, automation capabilities are approaching the point where it becomes more cost-effective to locate production in major markets than to achieve progressively less significant cost savings in low-cost labor locations.

The Semiconductor Industry Association is concerned that because of these commercial forces, aggravated by the prolonged overvaluation of the dollar, the U.S. is facing a major pull toward offshore wafer fabrication, like that which earlier caused emigration of much U.S. discrete device production. (Annual Semiconductor Industry Association surveys indicate that roughly eight percent of U.S. wafer fabrication capacity was offshore in 1983, virtually unchanged from the 1980 level; 1984 data are due shortly.) If this shift begins to emerge, it can be expected that cost savings from low-cost labor should be a diminishing factor, while labor-cost savings from automation are expected to make a market-oriented location strategy increasingly more cost-effective.

A market-penetration strategy, however, should not lure as high a proportion of U.S. production offshore as the labor-cost savings pull of the past. In the latter case, there was little to keep assembly and packaging in the U.S. other than the need to have an engineering line and defense product lines, because the U.S. clearly could not compete with Asian labor costs. By contrast, in the case of automation permitting market-oriented

production, the U.S. will remain the largest market and the strongest magnet for the location of such integrated and automated production facilities.

The calculus is not a simple matter of market size. Europe's high 17.5 percent tariff wall artificially attracts tariff-avoiding investment and high capital costs could prove disadvantageous to investments in the U.S. A declining dollar could increase the comparative attractions of investment in Europe. But on the other hand, continuation of serious difficulties to expanding market share in Japan is likely to draw much less U.S. investment to Japan than the size of its market would normally warrant.

However these factors may play out over the long term, expansion of offshore U.S. wafer fabrication has already become significant. A few examples of such moves are:

Texas Instruments: Japan (1968, early 1970s, 1981), Singapore (1981)

AT&T: Korea (joint venture, 1985)

Siliconix: Germany, Israel

3. Custom ICs and Other Special-Use Products

This is a field in which U.S. domination continues largely unabated, with few challenges in sight. The U.S. clearly dominates the gate array and standard cell technologies, and has a comparative advantage in full custom design. Asian challengers have concentrated on high-volume, standard devices. Japan is, however, a major competitor in developing versatile gallium arsenide devices and has a dominant position in supplying top-quality ceramic substrate and encapsulation materials. (IBM reportedly has ceramic substrate capabilities which surpass Japan's.)

4. Sheltered Production Capabilities

Commercial market and competitive forces dominate U.S. production decisions in almost all sectors of the microelectronics market, including location of facilities and choices between manufacturing, contracting, or importing. DoD's five percent share of the market is too limited to have more than a marginal influence on most investment and locational decisions made by the industry. However, some domestic U.S. production capability is sheltered, at least partially, from the full force of commercial considerations by other requirements, including:

- Company retention of U.S. design/engineering/testing lines; and
- Lines reserved or required for production of defense/space or other specialized production.

There are no readily available data on the capacity of such sheltered facilities. DoD should conduct an inventory of such capacity, since it would provide a measure of what minimum industrial base is available for defense needs, even if commercial capacity is unavailable.

In addition, DoD should be capable of having a greater impact on decisions by firms specializing in production of gate arrays, where military requirements are estimated to be 20 percent of the market, and in hybrids, where military demand is expected to show a concentrated growth over the next five years or more. (The potential for conflict between that basis for influence and the resistance shown by hybrid producers to MIL-STD-1772 requirements is discussed elsewhere.)

5. Technology Leadership

An assembly of leading executives of the semiconductor industry about six months ago addressed the question of trends and prospects in U.S. technological leadership in microelectronics. Taking 35 different aspects of industry technology as the focus, a majority of the executives agree that within the next five years the U.S. will lead in half.¹² However, this judgment probably gives inadequate weight to the efforts of giants such as IBM, AT&T, and Texas Instruments. Whatever its predictive value, the survey at least points to a danger that the U.S. can ignore only at its peril--that significant erosion of U.S. technology leads in commercial microelectronics could create more dependence on foreign technology in the near future, unless industry and government respond effectively to the competitive and economic challenges facing the industry.

¹² Reported to IDA by a participant at discussions organized by the Semiconductor Industry Association in late 1984.

C. OVERSEAS PRODUCTION CAPABILITIES

1. Overview

Integrated Circuit Engineering reports that 39 percent of world semiconductor production took place outside of North America in 1983. The percentage breakdown for discrete devices and ICs is as follows:¹³

	Discrete Devices, %	ICs, %	Total Semiconductors, %
North America	42	67	61
Offshore	59	34	39
	----	----	----
Japan	35	26	28
Rest of World	24	08	11

Integrated Circuit Engineering's forecast for 1985 projects no increase in the offshore percentage, but shows a one percentage point gain for Japan against the rest of the world.

2. Overall U.S.-Owned Overseas Production Facilities

The growth of U.S. offshore assembly, packaging, and testing began in the early 1970s. The greatest single increment occurred in 1974, with 10 new plants added in Asia that year. Main geographic concentrations of U.S.-owned facilities are in Asia (52 plants) and Latin America (at least 15 plants). In addition, U.S. firms use a number of contract assembly plants (at least 31 at last count in Asia; the ICAF study identified seven in Latin America; ITT consulted nine contract facilities in Mexico not included in the ICAF study.)

The authors were not able to obtain data comparing production capabilities of domestic and offshore facilities. The popular wisdom has it that about 90 percent of U.S. semiconductor assembly capability is offshore. The Semiconductor Industry Association's best guess is that roughly 15 percent of U.S.-controlled wafer fabrication is now offshore. Consistent with the market-penetration thesis about where future capacity will be located, it appears that Asia is less dominant in attracting U.S. wafer fabrication investments, and that Ireland, Scotland, Germany, Belgium, and Israel are also attractive locations, each now having one or more such U.S. facilities. One industry source interviewed expects China

¹³ Adapted from *STATUS 1985*, Table 1-3, page 6.

also to be one of the major new locations for future U.S. microelectronics investments, including fabrication.

3. Defense-Related Production Capabilities Overseas

Unfortunately, the authors were not able to get any estimates for production capacity devoted or qualified to produce or process defense microelectronic devices. Nor will either of the two studies cited above provide a breakdown between defense-related production or facilities.

V. DoD-INDUSTRY RELATIONS

An effort by the Department of Defense to minimize offshore production, assembly, packaging, or testing of critical defense electronic components should start with an understanding of the dynamics of the U.S. electronics industry and its relationship to DoD. The following discussion deals with this issue from the perspective of industry. Any effort by DoD to influence behavior should take these opinions into account in devising a strategy that speaks to industry's concerns.

A. TECHNOLOGY, INDUSTRY DYNAMICS, AND DoD

The electronics industry is one of rapidly emerging technology, fierce competition, and commercial market orientation. In this industry, the life span of state-of-the-art technology is three to five years and so industry leadership (and even survival) hinges on innovation and the image of being future-oriented. The U.S. electronics industry has great pride in its technological creativity and leadership and so shows a strong disinclination to manufacture what it considers technologically obsolete devices. At the same time, fierce domestic and international competition, coupled with the capital-intensive nature of manufacturing on the frontiers of technology, lead industry decisionmakers to be very concerned with market shares and overall market size for product lines.

One aspect of this environment is a propensity to quickly withdraw a device from production when a new item becomes available, a natural result in a commercially competitive world. This, however, plays havoc with the DoD supply system that requires a stable availability of a component over several years. An example of the impact of this process comes from the Navy's COMPRESS IMPACT data, which show that if several manufacturers are making a device, and one announces his intentions of dropping production, all of the others will quickly follow suit. To do otherwise might give the firm the image of dealing in obsolescing technology in an industry where innovation counts most. This process of market withdrawal is not only serious in and of itself, but is also troubling in that it can take place in as little as a month from the time the first firm announces its intention to the time the last company leaves the market.

Pressures to innovate continually, and to face strong challenges from other firms, leads to an industry mindset favoring relatively little regulation. In fact, the greater the regulation, the less likely a company will be interested in doing business in that area. For example, the authors were frequently told that the strict new standards imposed by newly published MIL-STD-1772 greatly dampened industry's willingness to make devices covered under the specification. (Some especially outspoken industry critics of DoD regulations claimed that they would rather not do business at all with the DoD if the amount of regulation increased any further.)

The issue is more than just the difficulty in complying with DoD structures. Complexity also means dollars. This is an especially key point in the electronics industry which, by its very nature, is capital-intensive. Consequently, every dollar invested is carefully weighed against both per-unit price and overall volume considerations. In fact, the entire industry is geared toward large production runs and resultant economies of scale. DoD's needs and approach to procurement are at odds with the dynamics of the electronics industry in several key respects. First, DoD's share of the electronics market is small. Second, DoD often needs highly specialized devices that are not of commercial interest. Also, the 20-year lifespan of most DoD systems is at odds with the 3- to 5-year life of electronics technology. Finally, DoD seeks strict oversight of production processes to ensure a standard product.

These differences between DoD's interest and that of the electronics industry undercut DoD's influence in restraining the offshore movement of defense electronics production and induce more U.S. firms to abandon the defense market.

B. SPECIFICATIONS, STANDARDS, AND PROCEDURES

DoD specifications, standards, and procurement procedures can be used to mitigate or exacerbate the problem of foreign dependency in the field of electronic components. However, using specifications, standards, and procurement procedures to reduce the likelihood of dependency must be balanced against other objectives of DoD procurement--particularly lowering the costs of electronic components and ensuring that production schedules are met. Furthermore, industry may react adversely, leaving DoD in a relatively poorer position overall with respect to available technology than it would be if foreign dependency were not addressed in a vacuum.

MIL-STD-19500G permits procurement of JAN-qualified semiconductor devices from offshore sources which have "parent" production lines in the United States.

Paragraph 4.5.8, "Retention of Qualification", allows a U.S. facility to remain qualified as long as it produces one lot of a qualified product or a structurally identical product at least once ever 3 years.¹⁴ Two advantages to DoD of this retention requirement are; (1) manufacturers are allowed to shift production of certain devices to less expensive offshore sources, thereby lowering the costs to DoD and (2) the domestic capability is retained and put to work on additional products. A disadvantage to DoD of this system is the potential loss of capacity higher order devices in the event that semiconductor devices must be manufactured on equipment which has been put into use making other devices. Additionally, recalling "retained" capability in time of crisis will not result in the same rates of output as are achieved from foreign sources because of the need to "relearn" production techniques.

As noted in Chapter III, there is a discernable problem of dependency on foreign sources for non-JAN microcircuits. From the standpoint of the DESC, the problem is one of lower reliability. DESC's proposed solution is to stiffen requirements for obtaining a waiver on the use of JAN-certified components in DoD electronic equipment. However, from the perspective of the Services and the System Project Offices, offshore procurement and possible dependency is less of a problem than lowering unit costs and maintaining product delivery schedules. Thus, stiffening requirements for waivers would be seen by these organizations as unfavorable to their primary objectives.

In the case of hybrid microcircuits, the recent DoD specification MIL-STD-1776 has been met with profound industry opposition. Industry has claimed that the requirements of this specification are too difficult to meet, that it took far too long for the specification to be promulgated and it is therefore not a state-of-the-art specification, and that it has defined a hybrid microcircuit so narrowly as to make the DoD-specific market too small to attract the capital resources necessary to attract and sustain a large number of potential vendors.

Thus, increased requirements levied by DoD specifications and standards in the area of microcircuits are met with resistance within the microelectronics industry and within DoD organizations responsible for systems procurement. It is doubtful that imposing further restrictions on offshore manufacture, assembly, packaging, and test will have the desired effect of expanding or even retaining the microelectronics production base.

¹⁴ Military Specification MIL-S-19500G, "Semiconductor Devices, General Specification For," pp. 18-19.

C. DISINCENTIVES AND INCENTIVES IN THE RELATIONSHIP

Defense purchases account for only about five percent of the total of microelectronic devices. Such a low market share strictly limits DoD influence over production continuity, technological directions and standards, and other matters of importance to DoD. The issue of market share is important in dealing with any industry, but it is especially critical vis-a-vis the electronics industry, which is highly competitive, capital-intensive, and which emphasizes market share in corporate decisionmaking. Whatever influence DoD might have is diluted by several factors:

- Fragmentation of DoD orders;
- Small production runs;
- Sales to DoD concentrated in older technologies, many of which industry considers obsolete;
- Quality specifications which some in industry consider too rigid or demanding to be worth the effort;
- Highly detailed specifications for design and production;
- Differing procedures within the Services for dealing with industry.

Although there are many powerful factors working against DoD's position with respect to the electronics industry, study findings suggest four areas of incentives that would go a long way in changing the situation:

- Procurement Practices
- Specifications
- Technology
- Economics

a. Procurement Practices

Companies interviewed suggested a number of ways in which DoD could make it more attractive for domestic producers to compete for military business:

- Consolidate device orders much more extensively both within the Service and in joint procurements;
- Convert to a two-year budget cycle to aid industry planning of production capabilities to meet expected demand;
- Ensure greater involvement by firms making state-of-the-art devices in design of systems;

- Harmonize device identification systems and possibly emulate the UK 1900 numbering system.

b. Specifications

Suggestions in this area focused on:

- Making a greater effort to qualify industry standard parts as accepted military standard devices and allocating business to firms willing to use military specifications as the quality standard for their commercial production lines (also, relevant to surge demands, see below).
- Using DESC-type mini-specifications much more extensively in lieu of very detailed source control drawing specifications.
- Adopting Japanese-style performance specifications (in lieu of too-elaborate design specifications), supported by tight quality assurance.

c. Technology

Suggestions in this area included:

- Building incentives in system design for more extensive technology insertion;
- Using design-improvement contracts more extensively;
- Coordinating VHSIC objectives with technology insertion efforts to improve joint benefits.

d. Economics

Very high per-unit prices are apparently enough to encourage at least some firms to produce even the oldest kinds of devices, but results of interviews with industry leaders suggest that the number of firms willing to do this is likely to remain small. The per-device price for military components that are commercially obsolete will remain comparatively high. Given the rather small market and the specialized nature of these products, there most likely will continue to be only very limited competition to supply this market.

D. CONCLUSIONS

DoD is in a relatively poor position to control the behavior of the U.S. electronics industry because of its relatively small share of the electronics market and because the majority of its purchases are for devices considered obsolete by industry standards. In fact, attempts to control the industry through tighter regulations and specifications are likely to have the counterproductive effect of driving U.S. companies out of the defense

electronics business or of creating a relatively small cadre of firms specializing in defense electronics but charging high unit prices. Interviews with industry officials suggest that DoD may be in a better position to influence the U.S. electronics industry by offering incentives to industry.

VI. U.S. DEPENDENCY/VULNERABILITY IN ASIA

A. GEOGRAPHIC DISPERSION OF U.S. AFFILIATED PLANTS, PRODUCTION CAPABILITIES

Based on available data, the following is a list of U.S.-affiliated Asian plants.

	U.S.-owned	Contractor	Total
Malaysia	21	?	21+
Korea	9	5	14
Hong Kong	8	5	13
Singapore	9	2	11
Philippines	?	11	11+
Taiwan	3	6	9
Thailand	1	2	3
Indonesia	1	-	1
Subtotals	52+	31+	83+

In addition, U.S. firms own a number of facilities in Japan, with responsibilities ranging from research to wafer fabrication:¹⁵

Owner	Date Established	Functions
Texas Instruments	1968	Bipolar and MOS wafer fabrication and assembly (including 64K DRAM)
Fairchild	1972	Bipolar IC assembly
Motorola	1973	CMOS wafer fabrication, automated assembly
Analog Devices	1982	Bipolar LSI

B. CORPORATE STRATEGIES IN LOCATING FACILITIES IN ASIA

In the early 1970s, many U.S. firms set up facilities in East Asia to take advantage of low wages and other cost advantages. Price competition among U.S. firms was the

¹⁵ Examples are drawn mainly from *STATUS 1985*, A Report on the Integrated Circuit Industry, published by ICE, the Integrated Circuit Engineering Corporation, Scottsdale, Arizona, 1985, Table 2-5, page 38.

initial impetus, not competition from foreign firms. This process peaked in 1974. Later, investors found rapidly rising wages and diminishing labor supplies in Singapore, Korea, and Taiwan, which resulted in dispersion of new plants to lower income countries such as Malaysia, Hong Kong, the Philippines, and Thailand.

A strong national emphasis on technical education, and the progressive development of engineering and technical skills brought by foreign investments in Singapore, Korea, Taiwan, the Philippines, and Malaysia, encouraged U.S. investors to add production activities there requiring higher skill levels. By the late 1970s what were originally simple assembly operations (bonding, encapsulation, etc.) had added screening, testing, and testing design work as well, and began to include semiautomated processing techniques. U.S. firms also discovered cost advantage beyond those originally expected, mainly because of high worker productivity and extremely low absenteeism and turnover (virtually zero in some locations).

Strategies of U.S. firms regarding investment in Asia are in transition. This is the result of several factors, including:

- Increased capital intensity of microelectronic investments;
- Progress in automation of manufacturing processes;
- Rapid evolution of technology in several Asian countries; and
- Expanded U.S. attention to foreign market penetration.

1. Increased Capital Intensity

Increased capital intensity, resulting from complexities of ever-increasing scales of integration, reduces the relative importance of labor and material cost advantages of locating in developing countries. One industry representative estimates that offshore labor cost advantages, despite 4- to 15-fold increases in wage rates, are three times as large as 20 years ago. However, since labor represents roughly 10 percent or less of product cost, it is a less important factor in location decisions than it used to be. This is because capital costs have increased several-fold with each new generation of devices.

2. Automation

Automation technology has been improved and diversified to make an ever-growing range of applications possible. However, high equipment costs limit the applications of automation. One firm interviewed claims to make an annual appraisal of the extent to

which it can extend automation in IC production. It considers whether the labor-saving potential would make it economical to locate future assembly and other more labor-intensive functions in the U.S. or other industrial nations. Neither this nor any of the other firms that were interviewed seem to believe that offshore cost advantages are currently matched by realizable savings through complete automation, but several industry officials appear to believe that time is fast approaching.

3. Technological Advances

For at least the next few years, several leading firms in the industry contemplate further offshore investments, albeit of a somewhat different pattern than earlier investments. Responses to an IDA questionnaire reveal many differences in the factors that companies rank as most important in deciding about the location of incremental offshore investment over the next five years. Among the most prominent are labor productivity and availability of technical skills. Asian countries continues to rank high in those respects. Korea, Taiwan, and Singapore are top ranking in technical skill pools. Thailand, Malaysia, the Philippines, and India are among countries favored for less technically demanding operations. Asian countries generally are ranked very high on work ethics (particularly Korea and Taiwan). However, one source notes that, in times of strong demand, expansion in Chinese-dominated countries would be disadvantageous because that culture eschews a three-shift day, which is possible in Thailand, Indonesia, the Philippines, and Korea.

Asian technological advances are producing a shift of investment strategy, as indigenous entrepreneurs, particularly as Korea, Singapore, and Taiwan become competitive in wafer fabrication and a range of sophisticated manufacturing processes. A spokesman at the Semiconductor Equipment and Materials Institute stated that Korean manufacturers now have on order in the U.S. more wafer production equipment than in all of Europe. Planned Korean semiconductor investments over the next five years extend into the \$1.5 to \$2 billion range.¹⁶ A number of these projects involve technology agreements with major American producers with a wide range of products from discrete devices to very advanced and sophisticated technologies, including 2-micron geometry, 6-inch wafer fabrications, 256K RAMs and VLSI techniques.

¹⁶ This figure and the information in the next paragraph are also drawn from STATUS 1985. See pages 10-12 and Table 10-12 and Table 2-12 on page 50.

U.S. semiconductor investors have had to change substantially their concept of investment in Korea, both as to level of sophistication and competitive implications. No longer can U.S. firms presume to set the terms of U.S.-Korean business relations; Korean firms are taking competitive initiatives, in part through major investments in the U.S. market. Two of 28 new start-up investments planned in the U.S. for 1984, as identified by Integrated Circuit Engineering, are Korean investments.¹⁷

The U.S. industry strategies involving Korea today differ greatly from those of five to ten years ago. Among the new opportunities are the cost advantages of Korean manufacturing and engineering efficiencies, and their strengthened competitive positions in Asian markets through joint ventures piggybacking onto the Korean lead in market penetration in the region.

4. Market Penetration

Market penetration goals are a fourth modifier of past U.S. semiconductor investment strategies as they affect Asia. A number of firms have decided they must produce in Japan both to improve penetration of the Japanese market and to improve their competitive position vis-a-vis Japan in other markets. A number of firms in the industry believe it is only a matter of a few years before it will be cost effective to locate completely integrated production modules in major markets, such as Japan and Western Europe. Continued progress in automation of microelectronic production processes will be the main key to shifting from cost-saving locations in low-wage Asian economies into major markets using fully automated production lines.

5. Short-Term Investment Trends

According to industry sources, a pattern of investments, from 1985 to 1990, based on continuation of present economic and technology trends, would involve the following elements of U.S. investment and locational strategies in Asia:

- Modest expansions and additions to assembling, screening, and testing operations in second-tier Asian producers (e.g., Thailand, Malaysia, Philippines), tapering off toward the end of the period;
- The beginnings of U.S. investments and technology agreements in The People's Republic of China, led by the pending Hewlett-Packard project,

¹⁷ Drawn from *STATUS 1985*, page 50.

involving full production of microelectronic devices for consumer and industrial uses;

- A growing number of wafer fabrication and full product facilities in first-tier countries (Korea, Taiwan, Singapore), along with licensing and second-source agreements as well as possible tie-ups in the U.S.;
- Toward the end of the period, increased emergence of integrated production in Japan.

C. TECHNOLOGICAL DEPENDENCE

While to date it remains largely a theoretical concern, the U.S. could be approaching a time when it might want (or have) to turn to foreign sources for both products and technologies needed for defense. As previously noted, U.S. microelectronic leaders have major concerns about the erosion of U.S. technological leadership in microelectronics. These concerns raise issues that go beyond the scope of this study but are worth stating:

- How close is the U.S. to a time when Japan, Korea and other Asian countries achieve technological leadership in major defense-applicable technologies?
- In which areas is this most likely to occur?
- How much do licensing of U.S. technology and other U.S. corporate and public policies contribute to that potential shift of leadership?
- To what extent do military co-production policies contribute?
- To what degree are these policies necessary to assure our continued access to such technology leads?
- What policies should the U.S. develop to improve our access where such leads are inevitable?

D. ASIAN SECURITY CONSIDERATIONS

How vulnerable is the U.S. because of dependence on Asian sources of microelectronic production, assembly and testing? In general, IDA analysts expert in the Asian area foresee no significant threat over the next five years to U.S. defense electronic supplies from Asia.

At a country level, South Korea (because of North Korea) and Thailand (because of Vietnam) are the only two microelectronics-producing countries adjacent to potential adversaries that could inflict major damage on their industry. Continued animosity between

China on the one hand and the USSR and Vietnam on the other provides a continued check on invasion of either country, and shows little likelihood of diminishing. Political disturbances within South Korea are conceivable, but not of an order likely to cause problems for foreign investors.

The Philippines is the only microelectronics-producing country facing active internal disorder, but even there steady expansion of troubles is unlikely to put the U.S. microelectronics supply in jeopardy. U.S. companies around the world have survived insurrections intact, and only in extreme cases such as in Iran and Vietnam have they been seized or driven out (no electronics firms were involved). If the situation were to become so extreme as to disrupt normal air communications or labor and material supplies, most American firms relying on Philippine sources have at least one, and more often several, other production facilities or sources elsewhere in Asia.

Potential communal strife between Chinese and Malays continues to hang over Malaysia. After a decade of accommodation without violence, no signals of possible resumption of conflict are discernable at present. Moreover, except for brief disruptions of air traffic, there have been few examples of jeopardy to industrial plants from such internal disorders, since most damage is concentrated in communities and locales with political symbolism. Even during the Vietnam war there was almost no physical damage to, or interference with, U.S. investments there.

Of the major powers in the region, China is best situated, by virtue of its central location, to create problems. Yet, its intense preoccupation with economic development with a minimum of distraction makes it, at least for the present, a stabilizing force in the region. While attempting to relax tensions with the Soviet Union, China retains its concern over the Soviet presence in Afghanistan and support of Vietnam in Kampuchea. Indeed, China has welcomed the presence of U.S. bases in the Philippines as a counterpoise to further Soviet adventures in the region.

Even in the case of a major global conflict involving the Soviet Union, Soviet lack of land forces contiguous to any plausible targets among Asian microelectronics producer countries would give it little capability for more than harassing sea and air routes or supporting Vietnam in localized aggression. Neither of these scenarios is likely to jeopardize air transport of microelectronics. The greatest danger would be possible interruption of energy supplies which could cramp production.

One remote, but conceivable, scenario could involve animosity prompted by U.S. protectionist trade actions severely affecting Asian countries such as Japan, Korea, or Hong Kong. This could give rise to mob actions aimed at disrupting U.S. investor facilities in these countries. Such problems should have limited temporary impact, relieved by use of facilities elsewhere in the region.

E. VULNERABILITY OF ASIAN SOURCES TO INTERDICTION

The firms contacted acknowledged potential for disruption of their supplies from Asia. None, however, indicated any foreseeable risk that would cause them to reconsider their preferences for location of future production facilities. One firm admitted concentrating its testing capabilities in Singapore to such an extent that interdiction of that source would be a severe blow. Another, with five facilities in Southeast Asia, said that interdiction of all those facilities would be a disaster from which it would be hard-put to recover. The majority indicated much greater interchangeability between facilities, and alternative locations in Taiwan, Northeast Asia, and elsewhere, to which sources of supply could be shifted. Most would suffer only some delays, but could gear up quickly elsewhere to replace lost assembly capacity.

If, in an extreme case, all offshore sources in Asia were taken out, major firms like Fairchild, National, and Intel have facilities in other parts of the world, including Mexico, the Caribbean, and Latin America which could take up some of the slack. Some firms, generally the smaller ones, with few overseas facilities, would face greater jeopardy. In such an extreme case, one surprising vulnerability arises. Several sources confirmed that the concentrated development of assembly operations offshore has resulted in related development of a unique cadre of technicians experienced in installation and maintenance of bonding, lead wiring, encapsulating, screening, and testing equipment. These capabilities have become so exclusively located offshore, predominantly in Asia, that absence of such experienced technicians in the U.S. and other areas would be a significant factor, limiting the ease with which such operations could be shifted out of Asia. One firm estimated that it requires about two years of on-the-job training and experience to get technicians proficient in installation and maintenance.

The IDA representatives were unable to get an adequate sampling of industry views on one important point of debate about the future of the microelectronics industry in the United States. Several industry leaders contend that the U.S. industry is not cost-competitive in the high volume "commodity" devices on which the industry must depend

for most of its profits and capital. They conclude that the industry cannot long survive with only domestic production but must move production offshore, particularly for such commodity devices as memories, microprocessors, and microcontrollers.

Others contend that rapid advances in automation will permit U.S. firms increasingly to locate new plants in major market areas such as the U.S., Europe, and Japan. Two of the firms interviewed assigned a high probability to this scenario. While they expect further expansion and somewhat more sophisticated plants and technical tie-ups with Asia, they foresee even larger additions of new plants in the U.S. These would not reduce capacity in East Asia but would expand the relative importance of domestic production and gradually dilute the proportion of assembly and processing operations now concentrated in Asia.

Our research did, however, identify some qualifications to this proposition. Such computer-integrated manufacturing (CIM) modules lend themselves best to high-volume products and new products. The ironic implication is that defense-related devices are likely to benefit least from relocation because they are generally low-volume and older products. This further underscores the need for DoD:

- To put great emphasis on closing its technology gap;
- To make every effort to maximize defense-wide standardization and consolidation of orders; and
- To require that P3I technology insertion plans, VHSIC, and other gap-closing program give high priority to the potential for developing CIM modules, including assembly for production of these insertions.

In summary, while the assembly of certain types of defense-related microelectronic devices relies on Asian facilities, these are located in a number of widely dispersed sites. There is considerable flexibility in responding to any disruption of supply from specific Asian locations which could be substituted. These reasons lead to the conclusion that, while distance can increase risk, there is no cause for great concern over the vulnerability of U.S. supplies of defense-related electronic devices produced in Asia over the next five years.

VII. WAYS OF OVERCOMING DEPENDENCY: THE CARIBBEAN OPTION

This section assesses Caribbean regional capabilities to provide defense electronics. The underlying presumption is that greater Caribbean capabilities to supply U.S. defense electronics needs would make the U.S. less vulnerable to Soviet interdiction in the event of a major international crisis or U.S.-Soviet conventional war. The emphasis here is not on relocating existing Far Eastern electronics facilities (a delicate political issue), but rather on new expansion into Caribbean countries.

A. APPROACH

As part of the Electronics Dependency study, the authors were also asked to integrate existing studies about the Caribbean with findings about the degree of U.S. dependency on offshore suppliers. In doing this, two major sources of existing research about the problem were exploited: (1) an Industrial College of the Armed Forces (ICAF) paper which assessed the capability of the Caribbean region to perform offshore assembly and production of electronic components, and (2) open source, scholarly literature about Caribbean regional development and about the President's Caribbean Basin Initiative. Note, however, that these two sources have different thrusts. The first deals with the capabilities of the region, whereas the second focuses primarily on the desirability of promoting Caribbean development from the standpoint of U.S. economic, political, and national security interests.

In assessing the potential of the Caribbean, and as part of a broader survey, the opinions of U.S. electronics industry executives were solicited regarding the feasibility and potential responsiveness of the industry to U.S. government desires to build the Caribbean region's capabilities. This information was obtained at minimal additional effort or cost because these questions were included in the interviews that had already been scheduled to investigate the degree of U.S. dependency on offshore sources of electronic components for defense systems.

B. CAPABILITIES

A five-member ICAF study team (having technical, military and political expertise) examined existing electronics industry capabilities and their potential to expand in six countries: Costa Rica, El Salvador, Honduras, Haiti, Panama, and Mexico. The team evaluated each country based on the: (1) present state of the indigenous electronics industry, (2) business environment, (3) political climate, (4) macro and micro economic factors, and (5) social/cultural factors (e.g., work ethic, literacy rate).¹⁸

The ICAF team began its research with two basic assumptions. First, the primary motivation for any U.S. manufacturer to move offshore was low-cost labor and second, the most sophisticated U.S. electronics manufacturing industries "will never be exported into less developed countries".¹⁹ Consequently, the ICAF study concentrated on labor-intensive electronics assembly operations. Typically, such activities include cleaning, component insertion, packaging, and checking operations, all of which are labor intensive, can be performed on assembly lines, and require relatively little start-up capital.

Overall, the study concluded:

- The existing electronics industry is far larger, more sophisticated, and profitable than previously reported.
- Existing regional electronics capacity is being underutilized and, hence, there is considerable potential for expansion.
- Indigenous governments and industrial groups are extremely enthusiastic about pursuing this initiative.
- Indigenous workers generally possess the requisite skills and work ethics necessary to make U.S. electronics ventures in the region successful.
- The region's biggest drawback is an almost uniform lack of skill in how to attract investments from U.S. electronics firms.

C. DESIRABILITY

A number of different sources have recognized U.S. interest in promoting political stability in Central America through economic development. The National Bipartisan Commission on Central America (the so-called "Kissinger Commission") concluded that

¹⁸ John Bremer, Terence J. Donovan, Rufugio S. Fernandez, David G. Mein, Stanislaus R. P. Valerga, "Electronics Industry and the Caribbean Basin," The Industrial College of the Armed Forces, National Defense University, April 1985.

¹⁹ *ibid.*

regional economic, political, and social turmoil posed a serious threat to U.S. national security interests and that the U.S. should do all in its power to promote stability, especially through economic development. The conclusions of the Kissinger commission have been echoed in several professional journals as well.²⁰

Reagan Administration concern about economic growth in the region was voiced by the President in announcing the Caribbean Basin Initiative in February of 1982.²¹ Recent statements by Congressional leaders, particularly in the debates about aid to El Salvador, suggest that Congress agrees that economic aid to the region is of vital importance.

D. VIEWS OF U.S. INDUSTRY OFFICIALS

Interviews with key executives of U.S. electronics companies uncovered several trends in industry thinking and decisionmaking criteria about foreign expansion in general. These include:

- Automation: Some see automation of domestic facilities as an alternative to offshore investment.
- Market access: Concern over market access and market share have a high priority in industry decisionmaking about where to locate new facilities. Those interviewed do not see further expansion of present Southeast Asian facilities as an attractive possibility. Instead, the People's Republic of China, Japan, and Ireland (which, as a member of the EEC, provides a customs-free stepping stone to Western Europe) are viewed as much more desirable regions for future investment. Conversely, Latin America is a relatively unattractive investment candidate from the market-penetration standpoint.
- Incentives: Positive, large-scale incentives are a major stimulus to overseas investment. The Industrial Development Authority of Ireland, for example, has done a remarkable job in creating a progressive business environment, providing significant tax relief, and offering generous cash grants to investors, thereby making The Republic of Ireland the most profitable location for industrial investment in Europe. (U.S. Department of Commerce figures indicate a 33 percent return on investment in Ireland from 1977 to 1980.) The Irish approach is especially significant since electronics is one of its top priorities.

²⁰ Victor Basiuk, "Security Recedes," *Foreign Policy*, Winter 1983-1984; David Ronfeld, *Geopolitics, Security, and U.S. Strategy in the Caribbean Basin* (Santa Monica, California, Rand Corp., November 1983, Report R-2997-AF/RC).

²¹ For details on the Caribbean Basin Initiative, see Ronald Reagan, "Caribbean Basin Initiative," U.S. Department of State Bulletin, Vol. 82 (April 1982).

- Volume: Most U.S. companies see overseas operations as a place to engage in very large production runs for mass markets.

These interviews also elicited specific information about the desirability of locating new operations in the Caribbean. For one thing, there is a widespread negative perception of Central American and Caribbean work ethics, despite the documented successes of some U.S. operations in the region. It appears that recent successes are seldom recounted, whereas past problems are legendary. Additionally, some company executives believe that, for large companies, many Caribbean nations are too small to offer the scale of operations they envision. This factor is exacerbated by a widely held belief that the Central American and Caribbean labor force lack the kind of specialized skills (e.g., equipment maintenance technicians, testing specialists) necessary for "high tech" assembly and production operations.

Surprisingly, there was little concern shown by any of those interviewed for the issue of industrial security either in the Caribbean or the Far East. Instead, respondents said sabotage and nationalization had never been a problem anywhere in the past and that they did not foresee it arising in the future. Consequently, security concerns were not a major decisionmaking criterion for assessing the potential of overseas locations for expansion.

E. CONCLUSIONS

Despite U.S. policy interests in seeing the growth of the Caribbean electronics industry, it appears unlikely that U.S. companies will respond as desired under present circumstances. Key U.S. industrial decisionmaking criteria (as expressed in the interviews) all militate against U.S. expansion into the Caribbean Basin. U.S. executives uniformly stated that they do not see Central or South America as potential major future markets and so the Caribbean has no appeal from the market penetration standpoint. Similarly, low regional wage rates have little bearing since most "high tech" electronics assembly is automated. Even where human labor is required in the production and assembly process, the Caribbean labor force is perceived as lacking the necessary technical skills. Additionally, many U.S. company officials are highly suspicious of the region's work ethics even if the requisite skills are present in the indigenous work force. Also, any major movement of U.S. industry to the Caribbean is unlikely because the level of incentives offered by local governments is not sufficiently high to overcome the combined

lure of high incentives and market-penetration opportunities offered by countries in other regions (e.g., the Republic of Ireland).

It is even less likely that U.S. defense electronics operations will be shifted to Caribbean countries. The defense electronics sector shares all the negative aspects of the civilian electronics segment, plus its production runs are typically quite small. This is important since one of the most frequently cited reasons for U.S. industry to move offshore is to conduct large-volume operations.

Clearly, these findings contrast markedly with those of the ICAF study. Why? For one thing, the IDA and ICAF research teams looked at very different segments of the electronics industry; so different, in fact, that they are virtually separate industries. This study examined "high tech" portions of the industry (i.e., device production and assembly), whereas the ICAF study focused on "low-tech" operations like packaging, component insertion, and cleaning. Also, some of the ICAF findings about current Caribbean capabilities (e.g., extent of existing electronics facilities, productivity of the labor force) indicate there is a wide gap between actual capabilities and the perceptions of them by U.S. executives. Lastly, the ICAF study concentrated exclusively on Central America and the Caribbean Basin; consequently, it did not look at the comparative advantages offered by other regions. This is important, since many other areas offer capabilities equaling or exceeding those of Caribbean nations plus better incentive plans. Viewed from this wider perspective, the likelihood of enticing U.S. electronics operations to the Caribbean appears much less bright than a study of the Caribbean alone suggests.

The differences between the two findings suggest the following overall conclusion regarding U.S. electronics and the Caribbean: Although it still appears that there is little chance of persuading companies to move "high-tech" operations to the region, there may be hope of encouraging companies to locate "low-tech" activities in Caribbean Basin countries. (It is impossible to state this more positively since this study did not address the "low-tech" sector of the electronics industry.) Therefore, to the extent that DoD wishes to encourage the growth of electronics industries in the Caribbean for policy reasons, it is probably better to concentrate on "low-tech" operations.

VIII. U.S. SURGE/EXPANSION CAPABILITY

A second approach for dealing with potential U.S. foreign dependency problems in times of crisis is to rely on the surge/expansion capabilities of domestic electronics assets needs. IDA explored this option by asking executives of nine major U.S. electronics firms about both immediate and longer-term surge response capabilities. Each source was asked about: (a) replacing existing sources that were interrupted unexpectedly, (b) a surge demand that doubled present Defense demand levels, and (c) quadrupling the present demand.

A. SHORT-TERM

The initial short-term constraint would be wafer fabrication at the front end of the process. It requires time to set up new production lines, even if equipment is available, and the process of fabrication takes many weeks. It was not clear that assembly would be a major constraint in the short run, because most firms indicated they could roughly double current production with existing plants, which maintain assembly capabilities in conjunction with both existing JAN production lines, source control products, and engineering/development lines. Several firms replied that the extent of their response capability would depend on how much national priority was involved in the surge demand.

B. LONGER-TERM RESPONSE CAPABILITY

The authors encountered much more variation, as might be expected, in how much surge/expansion firms estimated they could handle beyond a six-to-twelve-month horizon. A key factor in the industry's ability to respond would be the timing of any interdiction or increase in demand with respect to the stage at which the industry finds itself in the cyclical demand for microelectronic devices. Currently, much of the industry is operating on a four-day work week, and would happily absorb a major surge in defense demand.

To the extent that new equipment is required for meeting a long-term surge demand, longest lead times are experienced with test equipment--six months in normal times--a

period which could rapidly go to a year or more with any kind of surge in demand for this highly specialized, complex equipment.

C. FLEX POINTS IN POTENTIAL SCOPE OF INDUSTRY RESPONSE

In discussions with industry representatives it was noted that the scope of industry's ability to respond to surge requirements could be altered considerably by changes in the conditions DoD applies to procurement to meet a surge in demand. Main variables identified included:

- Moderation of selected quality parameters
- Simplification of specifications
- Modification of testing and burn-in procedures
- Selective acceptance of plastic encapsulation

1. Quality Parameters

One industry spokesman described his firm's production line as yielding a bell-shaped distribution of product quality which is highly modal, with a very small percentage meeting the extremely strict military specifications, especially the temperature specifications. However, because the distribution curve is so compressed, relatively small modifications in test parameters can produce large percentage gains in the proportion of devices qualifying. If, in a crisis, Defense gives added weight in setting its specifications to the tolerances and probability distributions of the current manufacturing processes and less to the physical extremes the devices might encounter in most severe conditions, our source implied that it could calibrate specification modifications so as to ensure the size of the production increases required.

By contrast, another individual representing a firm serving predominantly commercial markets, and known for exceptional quality, stated that even his firm's commercial product is keyed to standards largely consistent with military specifications. This firm places less emphasis on flexibility in quality standards, and argues that any firm capable of producing devices which could meet the stresses encountered by use in automobiles--the most severe everyday application it knows--should be able to produce quality suitable for military uses. Still, the proposition that DoD might need to modify its standards in a crisis to get the surge it needs may have much validity for a majority of the industry that produces for industrial and commercial end users.

2. Specifications

One approach to meeting requirements for a production surge is to simplify specifications. DESC efforts to produce more mini-specs were seen by an industry spokesman as a way of beating an impending gridlock over specification. Recent industry difficulties with the Defense Department over quality control were seen as representing not company disregard of quality assurance processes, but as difficulties in meeting the strictures of escalating specification complexity.

3. Modification of Testing and Burn-in Procedures

The test and burn-in procedures required for Defense devices were cited by some industry representatives as a major limiting factor which could be modified, if necessary, to get a major production surge. Not only does the process account for a major fraction of total production time, but it also uses equipment which is among the most expensive and which has longest lead items to produce. Defense items are particularly test-intensive. As a result, this process becomes a key limiting factor. In a crunch, it could become a bottleneck so quickly as to leave little choice but to modify the process if getting the product was critical.

4. Selective Acceptance of Plastic Packaging in Lieu of Ceramics

Industry sources differed widely on the possibility and advisability of substituting plastic packaging for ceramics to encapsulate microelectronic devices for use in Defense systems under a surge requirement. Some argued that plastic continues to have limitations which preclude its use in space and certain telecommunications applications. Others see improvements in plastics qualities and moisture resistance as making its use suitable in all but clearly extreme uses.

The subject takes on more than trivial importance since one firm, Kyocera of Kyoto, Japan, accounts for more than 80 percent of the world's supply of ceramics used for microelectronics packaging. If interdicted or preempted to any degree, this could become a major vulnerability. It is known that IBM (and possibly other U.S. firms as well) produce ceramics for their own substrate and encapsulation needs. Limits on their ability to meet needs of defense production in substitution for supplies from Kyocera would be a key to the extent that some substitution of plastic packaging would reduce vulnerability to loss of Asian sources.

IX. CONCLUSIONS

Specific conclusions regarding U.S. dependence on foreign sources for selected defense electronic components are:

1. The United States is dependent upon foreign assembly or production for certain categories of defense electronic components; however, for other categories of defense electronic components there is no dependency on foreign sources;
2. In evaluating the question of dependency, it is necessary to differentiate between type of device--there are major differences, depending upon whether the device is a standard or non-standard one, and whether it is a discrete device, a microcircuit, or a hybrid component;
3. Statistics and data on defense electronic component assembly and production and the relationship between such components and the defense systems of which they are components are not readily available, and those that are available need to be examined carefully;
4. Given available data, it is difficult to judge the proportion of devices with foreign value-added content in different defense systems, and even more difficult to assess dependency that does exist for particular categories of components.
5. Because DoD sales only amount to five percent of industry dollar volume, other market considerations drive electronics industry behavior. Consequently, DoD has little opportunity to control the industry's actions, but could increase its influence considerably by adopting incentives which take advantage of industry dynamics.
6. The bulk of offshore producing, assembling, packaging, and testing facilities are presently located in East Asia. There is, however, an emerging trend to open electronics facilities in Europe, particularly in Ireland and Scotland.
7. While the assembly of certain types of defense-related microelectronic devices relies on Asian facilities, these are located in a number of widely dispersed sites. There is considerable flexibility in responding to any disruption of supply from specific Asian locations, because of the wide range of alternative Asian locations which could be substituted. Moreover, analysts rate the

possibility of region-wide disruption of electronics supplies to be unlikely. Therefore, IDA concludes that, while distance can increase risk, there is no cause for great concern over the vulnerability of U.S. supplies of defense-related electronic devices produced in Asia over the next five years.

The study also examined two approaches for dealing with dependency on East Asian sources in times of crisis: (1) encouraging U.S. electronics firms to relocate and/or expand their offshore operations into the Caribbean and (2) relying upon domestic U.S. industrial capabilities to expand/surge domestic U.S. capabilities to meet crisis requirements. Findings in these areas are as follows:

1. Market forces and adverse perceptions of the Caribbean labor force by U.S. industry executives work against any major shift of offshore facilities into the region. These factors might be overcome by a carefully structured incentives package, but these incentives would have to be very significant to induce industry to move in this direction.
2. If all DoD requirements and specifications remained in force, domestic capabilities to meet large DoD orders could probably achieve no more than a doubling of present defense production in most categories. These response capabilities improve significantly, however, with the relaxation of some DoD standards and specifications.

APPENDIX

LOT PRODUCTION DATA

APPENDIX

LOT PRODUCTION DATA

MILITARY SPECIFICATIONS SEMICONDUCTOR DEVICES

As noted in the body of the report, MIL-S-19500G requires manufacturers to retain the ability to produce military specification devices (performance and quality) within the United States in the event that an offshore production and/or assembly facility is utilized in any step of the manufacturing process. The specification further requires detailed documentation of the processes to be performed overseas, a detailed description of the facilities, including photographs, and a highly detailed quality assurance plan.

IDA reviewed the materials filed by manufacturers with approved offshore assembly facilities for military specification semiconductor devices. The documentation filed by each manufacturer was extensive, covering in very minute detail each qualified facility. The documentation includes make, model, and serial number of individual assembly line equipment, test equipment, packaging equipment, and in some cases the names and addresses of materials suppliers. Each plan reviewed contained detailed history of American parent firm quality assurance audits, including discussions of remedial actions taken to correct deficiencies uncovered during the course of quality assurance inspections.

Semiconductor production is measured in terms of lots. Depending on the particular device being produced, a lot may contain tens to hundreds of devices. While it is not possible to determine the dependence of U.S. defense electronics industries on offshore production of semiconductor devices, based on the numbers of lots produced onshore versus offshore, the production data provides insights into production trends.

As a general rule, once a qualified production line has been established offshore, the data held by DESC (reproduced following) suggest that the U.S. production line atrophies. It appears that for the selected devices produced offshore, there is a significant likelihood of foreign dependence because of the inability of the parent U.S. firm to quickly reestablish production, even if the production line for these devices has been left in a mothballed state.

On the other hand, it should be noted that a relatively small proportion of military specification devices are produced offshore, and very few, if any, are produced exclusively offshore as of 1984.

LOT PRODUCTION DATA: FAIRCHILD SEMICONDUCTOR
SAN RAFAEL PHILIPPINES SAN RAFAEL PHILIPPINES SAN RAFAEL PHILIPPINES

DEVICE NUMBER	1981	1981	1982	1982	1983	1983	1984	1984
IN0457-9/IN3595	0	NQ	0	NQ	0	Q	0	1
IN0747A THRU IN0759A	0	NQ	0	NQ	R	NQ	-	-
IN0753A,-1 THRU IN0759A,-1	0	NQ	0	NQ	R	Q(R)	-	-
IN0914, IN4148-1,								
IN4A54-1, IN4150-1	0	NQ	0	NQ	0	2	2	6
IN0962B,-1 THRU IN0973B,-1	0	NQ	0	NQ	R	Q(R)	X	-
IN3064/IN3600	0	NQ	0	NQ	0	Q	X	0
IN3070	0	NQ	0	NQ	0	Q	X	0
IN4306,M; IN4307,M	0	NQ	0	NQ	0	Q	1 (REJECT)	0
IN4376	0	NQ	0	NQ	0	Q	0	1
IN4620 THRU IN4626	0	NQ	0	NQ	R	NQ	NQ	NQ
IN4938-1	0	NQ	0	NQ	0	Q	X	0
IN5194, IN5195	0	NQ	0	NQ	0	Q(R)	-	-
IN6101	1	NQ	2	NQ	3	NQ	5	NQ
2N0696, 2N0697	-	NQ	-	NQ	R	NQ	-	NQ
2N0706, 2N0608	-	NQ	-	NQ	R	NQ	-	NQ
2N0718A, 2N2221A, 2N2222A	-	NQ	5	NQ	1	1	X	6
2N0720A, 2N1893	-	NQ	-	NQ	R	NQ	-	NQ
2N0869A	-	NQ	0	NQ	0	Q	X	0
2N0914, 2N0916	-	NQ	-	NQ	R	NQ	-	NQ
2N0918	-	NQ	0	NQ	R	NQ	-	NQ
2N0930, 2N2484	-	NQ	0	NQ	0	Q	X	2
2N1613, 2N2218A, 2N2219A	-	NQ	0	NQ	0	1	X	1
2N1711, 2N1890	-	NQ	-	NQ	R	NQ	-	NQ
2N2060	-	NQ	1	NQ	0	Q	X	3
2N2369A	-	NQ	0	NQ	1	Q	X	3
2N2604, 2N2605	-	NQ	0	NQ	R	NQ	-	NQ
2N2904A, 2N2905A	-	NQ	0	NQ	0	Q	X	2
2N2920	-	NQ	0	NQ	0	Q	X	0
2N3019	-	NQ	0	NQ	0	Q	X	1
2N3700	-	NQ	0	NQ	0	Q	X	2
2N1132	-	NQ	-	NQ	R	NQ	-	NQ
2N0744	-	NQ	-	NQ	R	NQ	-	NQ
2N2481	-	NQ	-	NQ	R	NQ	-	NQ

NOTES:

- * Retention requirement met by production of a structurally identical device
- R Removed from Qualified Products List
- X No production; production capabilities retained
- ? No data available from DESC
- NQ Not Qualified for military specification production

PRODUCTION DATA: GENERAL INSTRUMENTS, INCORPORATED

	HICKSVILLE NY 1982	TAIWAN 1982	HICKSVILLE NY 1983	TAIWAN 1983	HICKSVILLE NY 1984	TAIWAN 1984
DEVICE NUMBER						
IN0483, IN0485, IN0486	1	8	0	1	0	10
IN0485, IN0647, IN0649	1	12	1	5	2	12
IN0645-1, IN0647-1, IN064	1	12	*	*	*	*
IN1731, IN1733, IN1734	0	2	R	R	-	11
IN3611 THRU IN3614	0	12	0	5	1	*
IN3957	0	12	0	*	*	10
IN4245 THRU IN4247	0	12	0	5	1	10
IN4942 THRU IN4248	0	11	1	5	1	10
IN5415 THRU IN5420	0	9	0	5	1	9
IN5550 THRU IN5554	0	11	1	5	1	10
IN5624 THRU IN5627	0	7	1	5	1	8
IN5614, IN5616, IN5618, IN5620, IN5622	0	12	0	5	1	11
IN5615, IN5617, IN5619	0	12	0	5	1	8
IN5621, IN5623	1		0		1	
IN5807, IN5809, IN5811	1		0		1	
IN6113 THRU IN6130, IN6131 THRU IN6137	1	1	0	0	0	0

PRODUCTION DATA: HEWLETT-PACKARD

SAN JOSE 1981	MALAYSIA		SAN JOSE		MALAYSIA		SAN JOSE		MALAYSIA	
	1981	1982	1982	1983	1983	1984	1984	1984		

DEVICE
NUMBER

IN5711	0	16	0	8	1	6	1	10
IN5712	0	2	0	7	0	?	0	5
IN5719	0	10	0	10	2	11	1	11

PRODUCTION DATA: INTERSIL, INC.

CUPERTINO 1981	SINGAPORE		CUPERTINO		SINGAPORE		CUPERTINO		SINGAPORE	
	1981	1982	1982	1983	1983	1984	1984	1984		

DEVICE
NUMBER

2N4091, 2N4092, 2N4093	2	1	?	?	1	15
2N5114, 2N5115, 2N5116	6	6	?	?	3	6
2N4856, 2N4857, 2N4858	0	1	?	?	1	6
2N3823	0	0	?	?	3	1
2N2609	0	0	?	?	1	1

PRODUCTION DATA: MOTOROLA									
DEVICE NUMBER	PHOENIX MEXICO		PHOENIX MEXICO		PHOENIX MEXICO		PHOENIX MEXICO		MEXICO 1984
	1981	1981	1982	1982	1982	1982	1983	1984	
1N0746A - 1N0758A	4	25	22	26	6	17	1	23	
1N4370A - 1N4372A	*	*	*	*	*	*			
1N0746A-1 - 1N0758A-1	13		*		10	0	9		
1N759A	0	4	0	3	1	0	0	3	
1N759A-1	3		3		7	1	4		
1N0821 - 1N0829	0	5	0	5	1	7	0	3	
1N0935B - 1N0939B	2		4		8	0	4		
1N0941B, 1N0943B, 1N0945B	2		4		4		3		
1N0962B - 1N0984B	3	21	2	20	2	12	0	16	
1N90962B-1 - 1N0984B-1	10		13		11		10		
1N985B - 1N992B	1	5	0	2	1	7	0	6	
1N0985B-1 - 1N0992B-1	NQ		0	0			NQ		
1N4557B - 1N4562B/ RB	*		0	4	0	7	0	2	
1N2804 1N2807B/ RB	1	0	*	*	*	*	*	*	
1N2808B - 1N2837B / RB	1	3	1	7	0	1	1	2	
1N2838B - 1N2846B/RB	1	2	0	1	0	4	0	2	
1N2970B - 1N2974B/ RB	6	1	0	3	0	8	0	3	
1N2975B - 1N3004B/ RB	8	0	0	9	0	12	0	3	
1N3005B - 1N3015B/ RB	2	0	0	4	0	8	0	3	
1N3016B-1N3021B; 1N3821A-									
1N3016B-1N3021B;									
1N3821A-1N3028A	10	3	0	12	0	17	0	15	
1N3022B - 1N3043B	9	2	3	16	0	23			
1N3044B - 1N3051B	7	3	0	3	0	14	0	9	
1N3154 - 1N3157	2		1		3	0	2		
1N3305B - 1N3309B/ RB	1		0	2	0	4	0	0	
& 1N4549B - 1N4554B/ RB	1	*	*	*	*	*	*	*	
1N3310B - 1N3339B/ RB	6	0	0	4	0	8	0	5	
1N3340B - 1N3350B/RB	0	0	0	1	0	2	0	1	

DEVICE NUMBER	PRODUCTION DATA: MOTOROLA							
	PHOENIX 1981	MEXICO 1981	PHOENIX 1982	MEXICO 1982	PHOENIX 1983	MEXICO 1983	PHOENIX 1984	MEXICO 1984
IN3890, IN3891, IN3983 & R			2	0	2	0	4	0
IN3910 - IN3913			2	0	1	0	0	0
IN3993A - IN4000A & RA	4		1	5	0	7	0	3
IN4099-IN4104; IN4614-IN4627	2	20	0	21	0	18	0	22
IN4105 - IN4135	3	13	4	16	1	22	1	31
IN4565A - IN4574A	3	1	1	10	1	7	0	8
IN5283 - IN5314	10	11	2	19	0	15	2	14
IN5518B - IN5530B	2	31	3	17	3	17	0	19
IN5531B - IN5546B	2	28	1	18	0	12	0	13
IN6309 - IN6324					Q		1	

LOT PRODUCTION DATA: MOTOROLA											
PHOENIX	KOREA	PHILIPPINES	MEXICO	PHOENIX	KOREA	PHILIPPINES	MEXICO	PHOENIX	KOREA	PHILIPPINES	MEXICO
1981	1981	1981	1981	1982	1982	1982	1982	1983	1983	1983	1983
1984	1984	1984	1984	1985	1985	1985	1985	1986	1986	1986	1986

[illegible]

LOT PRODUCTION DATA: MOTOROLA

301A30

		PRODUCTION DATA: TRW MICROWAVE													
		USA		MEXICO		USA		MEXICO		USA		MEXICO		HONG KONG	
		1981		1982		1982		1983		1983		1984		1984	
DEVICE															
NUMBER															
IN5711	3	3	0	0	0	0	0	4	0	0	0	1	1	0	1
IN5712	4	4	0	0	0	0	0	1	0	0	0	1	1	0	0
IN5719	1	1	4	4	4	0	0	1	0	0	0	0	0	2	2

LOT PRODUCTION DATA: RAYTHEON CORPORATION											
MOUNTAIN PHILIPPINES			MEXICO MOUNTAIN PHILIPPINES			MEXICO MOUNTAIN PHILIPPINES			MEXICO		
VIEW	1981	1982	VIEW	1982	1983	VIEW	1983	1984	VIEW	1984	1984
DEVICE NUMBER	1981	1982	VIEW	1982	1983	VIEW	1983	1984	VIEW	1984	1984
2N0320A, 2N0329A	0	3	0	4	0	0	0	2	0	0	2
2N0497, 2N0498, 2N0536, 2N0657	0	4	0	2	1	2	2	1	0	0	1
2N0696, 2N0697	0	0	0	2	0	6	6	4	0	0	4
2N0706	0	3	0	1	0	5	5	3	0	0	3
2N0718A	0	1	0	1	0	2	2	2	0	0	2
2N0720A	0	1	0	2	0	3	3	5	0	0	5
2N0744	0	1	0	0	0	0	0	0	0	0	0
2N0757A, 2N0759A, 2N0760A	0	0	0	0	0	0	2	0	0	0	0
2N0910, 2N0911, 2N0912	0	0	0	0	0	1	1	4	0	0	4
2N0916	0	1	0	0	0	0	0	1	0	0	1
2N0918	0	6	2	7	2	11	11	9	1	1	9
2N0929, 2N0930	0	6	0	0	0	0	0	0	0	0	0
2N1131, 2N1131L, 2N1132, 2N1132L	0	2	0	3	0	3	3	4	0	0	4
2N1613, 2N1613L	0	3	0	1	0	4	4	2	0	0	2
2N1711, 2N1711S, 2N1890, 2N1890S	0	6	0	5	0	10	10	5	0	0	5
2N1893, 2N1893S	0	1	0	4	0	5	5	1	0	0	1
2N2060, 2N2060L	0	0	0	0	1	1	1	3	0	0	3
2N2218, 2N2218A, 2N2218AL, 2N2219, 2N2219A, 2N2219AL	2	6	1	7	0	10	10	4	2	2	4
2N2221, 2N2221A, 2N2222, 2N2222A	10	11	5	8	11	12	12	12	8	8	12
2N2369A	5	10	1	5	4	6	6	6	1	1	6
2N2481	0	0	0	0	0	0	0	0	0	0	0
2N2484	0	5	1	5	3	10	10	7	1	1	7
2N2604, 2N2605	0	0	0	3	1	4	4	1	1	1	1
2N2609	0	1	0	0	4	0	0	0	0	0	0
2N2708	0	0	0	0	0	0	0	0	0	0	0
2N2857	0	0	0	0	0	0	0	0	0	0	0
2N2904, 2N2904A, 2N2904AL, 2N2905, 2N2905A, 2N2905AL	2	5	1	5	0	9	9	5	0	0	5
2N2906, 2N2906A, 2N2907, 2N2907A	6	12	6	6	5	12	12	9	8	8	9
2N2919, 2N2919A, 2N2920, 2N2920L	3	2	4	3	2	0	0	0	1	1	0
2N2945, 2N2946A	0	0	2	3	2	6	6	5	0	0	5
2N3019, 2N3019S	6	2	1	5	2	2	2	7	2	2	7
2N3051A	0	0	0	0	2	2	2	0	2	2	0
2N3250A, 2N3251A	1	3	0	2	1	5	5	5	0	0	5
2N3467, 2N3467A, 2N3469, 2N3469A	1	1	1	2	1	4	4	3	0	0	3
2N3485A, 2N3486A	0	1	0	1	0	2	2	1	0	0	1
2N3498, 2N3498L - 2N3501, 2N3501L	0	5	0	0	3	3	3	3	1	1	3
2N3634, 2N3634A - 2N3637, 2N3637L	4	1	1	0	0	0	0	5	2	2	5
2N3700	3	2	2	0	1	7	7	8	1	1	8
2N3735	0	0	1	2	1	1	1	0	0	0	1
2N3737	2	1	0	0	3	1	1	0	2	2	0
2N3752, 2N3752A, 2N3753, 2N3753L	2	4	1	0	3	2	2	1	1	1	4
2N3810, 2N3811, 2N3811L, 2N3811L	0	0	0	0	0	0	0	0	0	0	0
2N3848	0	0	0	0	0	0	0	0	0	0	0
2N3860A, 2N3860A	1	0	0	0	0	1	1	1	0	0	1
2N4109	0	0	0	0	0	0	0	0	0	0	0
2N4233	0	0	0	0	0	0	0	0	0	0	0
2N4271	0	0	0	0	0	0	0	0	0	0	0
2N4554	0	0	0	0	0	0	0	0	0	0	0
2N4556 - 2N4557	0	0	0	0	0	0	0	0	0	0	0
2N4559	0	0	0	0	0	0	0	0	0	0	0
2N4553, 2N4554	1	0	0	0	0	0	0	1	1	1	1
2N4555, 2N4556	1	0	0	0	0	0	0	0	0	0	0

NOTES:

- No specified production
- Refer to Requirement Map by Production of Structurally Identical Device

PRODUCTION DATA: SILICONIX, INC.												
DEVICE NUMBER	SANTA CLARA		HONG KONG		SANTA CLARA		TAIWAN		HONG KONG		SANTA CLARA	
	1981	1981	1981	1982	1982	1982	1982	1983	1983	1983	1984	1984
2N2608				1			4			5		0
2N2609				2						0		0
2N4856 THRU 2N4861	4	6	0	6	6	3		3	0	0	7	
2N4091 THRU 2N4093		1	0		1				0	1		
2N6661								1			0	

PRODUCTION DATA: SILICONIX, INC.																
DEVICE NUMBER	SANTA CLARA		HONG KONG		SANTA CLARA		TAIWAN		HONG KONG		SANTA CLARA		TAIWAN		HONG KONG	
	1981	1981	1981	1981	1982	1982	1982	1982	1983	1983	1983	1984	1984	1984	1984	1984
2N2608				1			4				5	0			1	
2N2609				2							0	0			0	
2N4856 THRU 2N4861	4	6	0	6	6	3		3	0	0	7	0	0	2		
2N4091 THRU 2N4093			1	0	1				0	1			0	1		
2N6661								1			0					

END
DATE
FILMED
MARCH
1988
DTIC