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(6) Measuring Industrial Adequacy for a Surge in Military Demand: An Input-Output Approach

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PREFACE

The research described in this report is part of a larger study of the capabilities of the lower tiers of the defense industrial base. Part of this study--dealing with the adequacy of industry for the peacetime needs of the Department of Defense--has already been completed.[1] At the request of the Air Force Deputy Chief of Staff for Research and Development, the study was extended to include an evaluation of industrial capability under conditions of a surge in military demand. This report describes the methodological underpinnings and results of an analysis of the interdependencies of U.S. industry under surge conditions. It supports a companion report[2] that assesses surge needs, evaluates the requirements for industrial activity, reviews identifiable or potential vulnerabilities, and discusses remedial options.

This report should be useful to staffs responsible for conducting, planning, or regulating defense procurement activities. It should be particularly useful to the Directorates of Contracting and Acquisition Policy and Development and Programming in Headquarters USAF, and also to offices in Air Force Systems Command, as an explanation and application of a methodology for evaluating the surge capabilities of the entire defense industrial base. For this purpose, the report includes deliberately explanatory discussions and an appendix. The companion report provides an abbreviated summary of this research and

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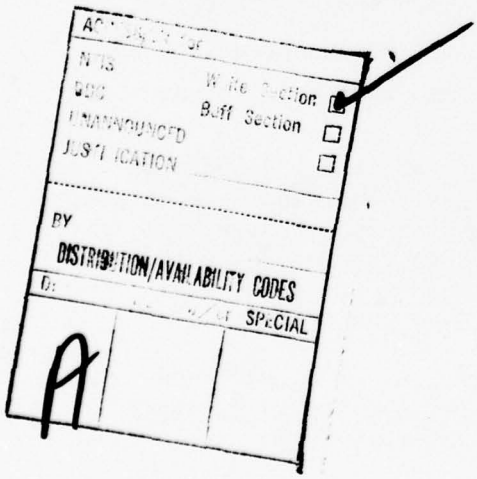
[1] See G. G. Baumbusch and A. J. Harman, Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base, The Rand Corporation, R-2184/1-AF, November 1977; and G. G. Baumbusch and A. J. Harman with D. Dreyfuss and A. Gandara, Appendixes to the Report on the Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base: Case Studies of Major Systems, The Rand Corporation, R-2184/2-AF, November 1977.

[2] See G. G. Baumbusch, P. D. Fleischauer, A. J. Harman, and M. D. Miller, Defense Industrial Planning for a Surge in Military Demand, The Rand Corporation, R-2360-AF, September 1978.

discusses the larger policy context for an evaluation of the capability of industry to meet a surge in military demand.

This work was performed under the Project AIR FORCE research project "Industrial Base Study."



SUMMARY

A major concern of the Department of Defense (DoD) is the ability of industry to respond successfully to the surge demand for its output that might accompany direct or indirect U.S. involvement in an international crisis. The production chain supporting delivery of defense materiel to the DoD can be extremely complex. A surge in demand is likely to put pressure on each sector in the chain not only to secure the necessary additional inputs but also to call on any excess production capacity to meet the added demand for its output by firms higher in the chain. Because of the obvious chain-reaction effect, concern has been expressed that there may be bottlenecks.

This report describes a methodology by which potential vulnerabilities to these bottlenecks can be identified and presents findings of a quantitative analysis (based on this methodology) to determine their existence and extent. The foundation for such an analysis rests on an understanding of the product flows connecting lower-tier defense-related industries, both with each other and with final-demand DoD prime contractors, as well as the effect on these flows of a sudden increase in DoD demand. The most useful economic tool for gaining such a detailed understanding is input-output analysis, which measures such interindustry flows and relates final demand to accommodating output. Because the economy could be subject to a drastic reordering of priorities during times of national mobilization, this report addresses only crisis situations that would fall short of requiring such a mobilization.

METHODS

Although industrial support of a military surge would involve accelerated output demands on numerous sectors of industry, the following 13 sectors (as defined by the U.S. Department of Commerce) are most crucial to combat capability:

Whole Systems

- o Complete Guided Missiles
- o Tanks and Tank Components
- o Aircraft
- o Shipbuilding and Repairing

Spares, Replacements, and Support Systems

- o Sighting and Fire Control Equipment
- o Radio/TV Communication Equipment
- o Aircraft Engines and Parts
- o Aircraft Propellers and Parts
- o Miscellaneous Aircraft Equipment

Munitions

- o Non Small Arms Ammunition
- o Small Arms
- o Small Arms Ammunition
- o Miscellaneous Ordnance and Accessories

The extent to which each of these "defense sectors" would become involved in a crisis or surge situation varies considerably, depending on duration, intensity, location, etc. It is therefore impossible to define any notion of a "typical surge." This analysis adopts a parametric approach, and DoD demand on each of these 13 defense sectors is assumed to increase 100 percent.

In responding to such an increase, each of the 13 defense sectors must not only substantially augment its own total output but must also rely on corresponding increases from each of its lower-tier suppliers. The extent of this reliance and its subsequent effect on the supplier sectors depend in part on each of the following:

- o The annual total output of each of the lower-tier supplier sectors.
- o The annual DoD purchases from each of the 13 defense sectors.

- The input-output (I/O) coefficient that measures the required output (in dollars) of each supplier sector necessary to accommodate a delivery of one dollar to the DoD by the given defense sector.

The ratio

$$\frac{100 \times (\text{I/O Coefficient}) \times \left(\begin{matrix}\text{Total DoD Purchases} \\ \text{from Defense Sector}\end{matrix}\right)}{(\text{Total Output of Supplier Sector})}$$

is calculated for each defense and supplier sector to obtain the percent increase in annual total output of each supplier sector necessary to accommodate a 100 percent increase in DoD demand on the given defense sector. If the suppliers of each defense sector are ranked according to these percent figures, it is possible to list potential supplier sector vulnerabilities. A high percentage figure indicates that the additional output requires a large increase in the supplier's total output and that a correspondingly high percentage of this output is already defense-related; therefore further expansion might be limited.

RESULTS

Results based on an across-the-board assumption of a 100 percent increase in DoD demand indicated that the potentially highest supplier sector vulnerabilities occur in:

- Aircraft industries supplying each other.
- Electronics industries supplying the communication industries.
- Nonferrous forgings industries supplying the aircraft industries.
- Scientific instruments industries supplying the aircraft industries.

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- o Optical instruments and lenses industries supplying the sighting and fire control industries.
- o Sighting and fire control industries supplying the aircraft industries.

In an actual conflict, this 100 percent increase would vary from sector to sector. Annual DoD purchases of munitions might increase much more than 100 percent and that of, say, aircraft or shipbuilding might change by substantially less than 100 percent. During the Vietnam war, for example, DoD purchases from munitions sectors increased as much as 200 percent per year; purchases from sectors producing whole systems and spares increased but never more (with one exception) than 30 percent in any given year.

The ability of a supplier sector to respond to an accelerated output demand depends in part on its ability to utilize and expand its production capacity. Comparison of published sectoral capacity utilization rates with surge demand requirements permits a crude evaluation of a sector's ability to successfully meet a request for additional output. There are many additional factors, but this analysis indicates that, almost without exception (based solely on utilization rates), there is sufficient excess production capacity in each lower-tier sector to support even a 100 percent across-the-board surge in DoD demand for combat equipment.

Of course, such a conclusion reflects the operation of an entire sector and gives no indication (except on the average) of a particular firm's ability to respond to a surge. The measurement of this latter ability is difficult, depending in part on each of the following factors:

- o Degree of specialization of labor, material inputs, and equipment.
- o Stockpiling of material inputs or finished goods.
- o Feasibility and cost of expanding labor using overtime, addition of shifts, or additional manpower.
- o Cost or lead time in procuring new equipment or activating idle equipment.

- Feasibility of subcontracting some currently in-house work or bringing in-house some currently subcontracted work.
- Ability (in terms of cost, time, etc.) to convert some non-defense production to defense production.

In addition, several conditions might limit or inhibit a firm's willingness to increase defense-related production (or to become a defense producer if it is not one):

- Requirement for specialized production process for military products.
- Burden of government paperwork.
- Uncertain prospect of continuing volume of business.
- Low profitability relative to civilian production.
- Inability to attract skilled labor on a potentially temporary basis.
- Commitment to civilian customers.

These sets of factors vary from firm to firm, and the applicability of each to a given firm can only be determined by direct contact with firms in the sectors thought to be potential vulnerabilities to a surge demand.[3] Combining the qualitative results of such a survey with the more quantitative aspects of this analysis will permit a reliable estimate of the existence, extent, and severity of vulnerabilities in these sectors and in the process develop and test a methodology that could be applied to measuring vulnerabilities to any conceivable surge.

[3] The companion report [2] details the results of such contacts with firms in Nonferrous Forgings, Optical Instruments and Lenses, and Semiconductors.

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I. INTRODUCTION

Declining competition, attrition of subcontractor involvement, rising costs, and diminishing utilization of existing capacity are a few of the many factors contributing to the concern that various aspects of the defense industrial base may be inadequate to meet both the peacetime and wartime needs of the DoD. The decreasing defense procurement expenditures of the post-Vietnam era have discouraged many firms from upgrading their equipment, facilities, and manufacturing technology, resulting in what might be construed as almost a "backward step" from preparedness.

Within the past few years, the DoD has reassessed the industrial base, using as a guideline the following peacetime and wartime objectives:[1]

- o To obtain the maximum deterrent and defense capability for each dollar allocated.
- o To ensure maximum economic efficiency within given resource constraints of money, manpower, plant, and equipment.
- o To provide for a rapid transition from peacetime to meet the military requirements of a surge or mobilization situation.
- o To encourage the maximum technological advancement for the benefit of military advancement.
- o To have a minimum of social and political effects.

An earlier phase of Rand's study [1] addressed the question of the adequacy of the lower tiers of the defense industrial base to meet the peacetime needs of the DoD.[2] A survey of 13 major system programs concluded that (with a few exceptions) the industrial base was adequate. Moreover, it was found that the major cause of reductions in the number of lower-tier firms appeared to be declining demand rather than inhibiting features of government-dictated contractual and specification practices.

The question of wartime adequacy is considerably more complex. The basic question is to what extent industry could respond to a sudden increase in demand for its output. Such a demand might be in response to advance indications of an impending conflict, to the support of a conflict, or to the need to resupply either ourselves or our allies after a conflict. The ability of industry to respond successfully to a surge demand for added output depends most directly on the extent and scope of the surge, in terms of the necessary degree of production expansion and the timetable by which this expansion is to be carried out.

Various factors contribute to the industrial demands of a given conflict:

- o Pre-conflict warning time.
- o Political constraints.
- o Intensity of conflict.
- o Duration of conflict.
- o Post-conflict recovery time.

A short, high-intensity conflict (with negligible warning time) would undoubtedly be supported by drawing down existing U.S. stockpiles and initiating a post-conflict industrial surge to resupply. However, a long, moderate-intensity conflict would perhaps be preceded by an ample warning period (or period of slowly increasing intensity) to allow industry to initiate a pre-conflict surge.[3]

This report presents the findings of a quantitative study to determine the existence and extent of lower-tier vulnerability to the accelerated DoD demand that would accompany direct or indirect U.S. involvement in an international crisis. The approach is input-output analysis, which measures intersector dependence and relates DoD demand to accommodating sector output. The primary, but not exclusive, concern is with a DoD surge demand for materiel most closely related to Air Force interests; and attention is restricted to potential crises that fall short of requiring a full national mobilization.

Under such a mobilization, the economy could be subject to a drastic shift in priorities and major reorganization and would no longer be accurately characterized by recent input-output tables.[4]

Although input-output analysis is valuable in understanding the overall operation of the defense industrial base and in obtaining a quantitative measure of each sector's potential vulnerability to surge, it is less useful in realistically evaluating the substance of this vulnerability and the ability of each sector (or firm) to respond successfully to the surge. Such response is best achieved by direct contact with firms that currently produce either defense-oriented output or related output that could (in a crisis) be channeled toward defense purposes.

Other studies using input-output analysis [4-5] have been carried out on the effects on industry of a cut in military expenditures. The primary concern is not so much urgency of response as assuring as smooth a transition as possible between defense and non-defense production (especially in redistribution of labor). A 1965 study [5], for example, revealed that if there were an across-the-board reduction of 20 percent in military purchases compensated for by a uniformly proportional increase in all non-military components of the economy, only ten of 58 major industries would suffer decreases in output and employment. Not surprisingly, these ten coincide to a great extent with the list of sectors that would be most vulnerable to a surge for military output. Although this 20 percent figure was postulated as a hypothetical reduction [5], it is in fact not a totally inaccurate measure of many of the yearly drops in DoD procurement of defense materiel following the Vietnam conflict.

NOTES TO SECTION I

1. This list is extracted from [6].

2. "Lower tiers" refer to those firms that have no contractual obligations with the DoD for either development or production of combat equipment but do produce crucial materials or goods necessary to the end production of such materiel. This includes firms that may from time to time get direct orders from the DoD

for spares to support existing systems. A given firm may be a prime DoD contractor for one aspect of its output, yet a lower-tier subcontractor for another. This is most likely to happen in the case of a large, diversified corporation.

3. For a more complete discussion of these issues, see [2].

4. The Federal Preparedness Agency does maintain modified input-output tables for use during times of mobilization.

II. METHODOLOGY

INPUT-OUTPUT ANALYSIS

W. Leontief introduced input-output analysis in the 1930s as a means of quantitatively analyzing an economy in terms of the interdependence of its various industrial sectors and the requirement to satisfy final (extra-industrial) demand. The foundation for any such analysis is the determination (by direct observation) of the product flows among all sectors of the economy. From these flow figures alone, much information can be derived about not only the extent to which the sectors depend on one another for input, but also the effect on these dependencies of changes in final-market demand.[1]

As a means of illustrating these concepts, suppose that there is an increased demand by the DoD for tanks and tank components. Such a demand will generate a series of increased demands for output on a number of related industries--not only those that supply the tank-producing industries directly but also those that supply these suppliers, and so on. An increased demand for steel will require more chemicals (such as sulfuric acid), iron, limestone, and synthetic fibers. Input-output tables permit tracing such chain-reactions and measuring the direct and indirect demands imposed upon each of the industries.

Because such tables may take several years to prepare, many applications require the simplifying assumption that the relationships established (in a base-year study) linking inputs to outputs remain stable over time. Changes do occur, but they are part of a gradual process taking considerable time before becoming sufficiently diffused to affect an industry's average input-output relationships. Although much study remains to be done on the question of stability, experts generally agree that the above assumption is tenable within reasonable limits, especially when applied to problems that require a general picture of the production function of the entire economy (see [7-10]).

Two characteristic assumptions underlie the use of input-output

analysis: (1) constant returns to scale and (2) non-substitutability among inputs. Under the first, it is assumed that the inputs of an industrial sector are directly proportional to the outputs; that is, to double its output, a sector must double its inputs. Such an assumption ignores the various constraints that govern the use and availability of a given input. Yet defenders of the assumption argue that not enough is known to suggest what type of production function (other than "simple proportions") should be used and that the simplicity of the simple proportions assumption justifies its use as the best of the available alternatives.

Non-substitutability involves assuming that only one process is (or can be) used for the production of a given output; that is, the level of output of a product uniquely determines the level of each input required. Such an assumption excludes all choices (based, for example, on cost) about the proportions in which inputs are to be combined in the production of a given output. Although many proponents of input-output analysis agree that this (and the previous) assumption is contrary to accepted economic theory, they defend its use on the grounds that even though substitution among inputs does take place, its influence on input-output ratios is minor enough to be ignored in many cases.

In addition to the basic underlying assumptions of stability, constant returns to scale, and non-substitutability, input-output analysis (as used here) adopts various conventions for treatment of secondary output and imports. The basic unit of industrial classification is the firm, classified in an industry according to its primary activity. The entire output of the firm is counted as part of the output of the industry. Because the input requirements for secondary output may differ considerably from those for primary output, a change over time in the relative importance of the two outputs might cause a change in the industry's input patterns. An additional problem resulting from secondary production is that available data generally indicate only an industry's total inputs of a given product and do not specify whether these inputs constitute

the source industry's primary or secondary output. Hence, it may not be clear what industry is actually supplying this input.

The two most frequently invoked solutions to the problems of secondary production are "redefinition" and "transfer." Redefinition involves removing secondary products from the list of an industry's output and adding them to the list of output of the industry to which they are primary. Similarly, inputs used to produce the secondary products are deleted from the primary industry and added to the inputs of the industry to which the products are primary. In concept, redefinition is the most attractive of the available solutions to the problem. Yet because available data are often inadequate to support the complex adjustments, it is seldom used.

The transfer approach leaves secondary output where it occurs but also adds it to the output of the primary industry, treating it as if sold to the primary industry, where it becomes part of the output available for distribution. The consuming industries are seen as purchasing their total requirements of a given product from a single industry. This approach has been used most successfully in the mining and manufacturing sectors, the latter being the main concern of this report.

Imports that are substitutable for domestically produced goods and services are treated similarly to secondary products. That is, their value is added to the outputs of the domestic industry producing similar goods, and they are distributed as part of the total output of this industry. Imports for which there are no domestic counterparts are treated as if purchased directly by the consuming industry.

Although input-output analyses can be conducted on local, regional, national, or even international levels, this report is concerned exclusively with applications to the U.S. economy. Under government sponsorship (in recent years, the Bureau of Economic Analysis (BEA)), full scale input-output analyses have been carried out on the U.S. economy for the years 1947, 1958, 1963, 1967, and 1972. The results are published in three volumes, each of which documents a different aspect of interindustry dependence:

- The Transactions Table (in Vol. 1) shows
  - (a) The annual sales (in dollars) of each sector of the economy to every other sector.
  - (b) The annual sales of each sector to final markets.
  - (c) The annual total output (in dollars) of each sector.
- The Direct Requirements Table (in Vol. 2) shows, for each sector, the input required (by direct shipment) from every other sector to produce one dollar of its output.
- The Total Requirements Table (in Vol. 3) shows, for each sector, the total inputs required (by both direct and indirect shipments) from every other sector to accommodate a delivery of one dollar to final demand.

This last table will be most important; if final demand is interpreted as that of the DoD, it will be possible to measure the effect on each sector of varying degrees of increase in DoD demand for combat materiel.

INDUSTRIAL CLASSIFICATION

The most commonly used scheme for classifying the U.S. economy into sectors is that of the Standard Industrial Classification (SIC), first introduced in the 1940s as a means of facilitating and making more uniform the analysis of economic data. Under this classification, the manufacturing segment of the economy is divided into approximately 20 major groups, 140 industrial groups, and 450 detailed industries.[2] Each detailed industry is identified by a four-digit number. For example, the "Aircraft Engines and Parts" industry is assigned the number 3724, the "37" indicating that it is part of the "Transportation Equipment" major group and the "2" signifying that within this group it is part of the "Aircraft" industry.

As a further step toward identifying the production of a specific product, the Bureau of the Census has taken each four-digit SIC category and assigned to each of its constituents a seven-digit identification number. For example,

SIC	Description
37	Transportation Equipment
372	Aircraft and Aircraft Equipment
3724	Aircraft Engines and Parts
37241	Aircraft Engines for U.S. Military Customers
3724114	Turbo-Jet and Turbo-Fan Engines for U.S. Military Customers

Although a great deal of Census bureau data is available for industries at this seven-digit level of disaggregation, for the most part it will not be incorporated into this analysis, because the most detailed input-output data are published only at the four-digit level. In fact, one of the problems in trying to coordinate Census bureau data with BEA input-output data is that the four-digit classification scheme used by the BEA differs slightly from that of the SIC. Under the BEA, the manufacturing segment of the economy is divided into 52 major groups and 291 detailed industries. As with the SIC, each of these industries is assigned a four-digit number. For example, under the BEA classification:

BEA	Industry
60	Aircraft and Parts
6001	Aircraft
6002	Aircraft Engines and Parts
6003	Aircraft Propellers and Parts
6004	Miscellaneous Aircraft Equipment

These classifications are constantly being updated to reflect changes and shifts in product emphasis--new sectors are created and old sectors eliminated through absorption by a related one. An example is provided by "Aircraft Propellers and Parts," which occurs as a separate sector under the 1967 SIC and BEA classifications, but has since (as technology advanced) been absorbed by "Miscellaneous Aircraft Equipment."

CRITICAL DEFENSE SECTORS

Of the 367 sectors into which the economy is classified for the most recently available BEA input-output analysis, 13 were selected as being essential to combat capability (see Table 1). These 13 sectors were chosen from the Bureau of the Census list of 94 defense-oriented industries [11] and represent sectors producing end-products most important to direct and indirect U.S. military efforts (indirect through assistance to an ally).[3] These include (with the exception of Petroleum Refining) those eight sectors with

Table 1

13 CRITICAL DEFENSE SECTORS

Sector	BEA	SIC	1975 DoD Sales ($ millions)[a]
1. Complete Guided Missiles	13.01	3761	3427
2. Non Small Arms Ammunition	13.02	3483	854
3. Tanks & Tank Components	13.03	3795	350
4. Sighting & Fire Control Equip.[b]	13.04	3662,3832	100
5. Small Arms	13.05	3484	50
6. Small Arms Ammunition	13.06	3482	116
7. Misc. Ordnance & Accessories	13.07	3489	164
8. Radio/TV Communication Equip.	56.04	3662	3595
9. Aircraft	60.01	3721	5463
10. Aircraft Engines & Parts	60.02	3724,3764[c]	2111
11. Aircraft Propellers & Parts	60.03	3728	35
12. Misc. Aircraft Equipment	60.04	3769,3728[d]	960
13. Shipbuilding & Repairing	61.01	3731	2086

[a]The 1975 sales figures are based on tables in [11].

[b]Electronic sighting and fire-control equipment is classified under SIC 3662, optical under SIC 3832.

[c]SIC 3724 includes aircraft engines and parts, and SIC 3764 includes space propulsion units and parts (these were classified together for the 1967 input-output analysis).

[d]SIC 3769 includes miscellaneous space vehicle equipment, and SIC 3728 includes miscellaneous aircraft equipment (these were classified together for the 1967 input-output analysis).

annual (1975) sales to the DoD in excess of $500 million. They also include three munitions-related sectors whose 1975 DoD sales were under $200 million. Several other sectors also have large annual sales to the DoD, but their products are less likely to be involved in any kind of crucial surge requirement. Examples are provided by Electronic Computing Equipment (with 1975 DoD sales of $272 million) and Photographic Equipment and Supplies (with sales of $174 million).[4]

For a better understanding of the extent and stability of these 13 defense sectors in defense procurement, a comparison of DoD sales is included for each of these sectors for the period 1965-1975 (App. B). These graphs clearly indicate the effect of the Vietnam war on DoD procurement. Although military buildup had already begun in the early 1960s, it was not until 1967 or 1968 that DoD purchases from each of these sectors reached a peak. Such peaks represented the culmination of the initial war surge and were followed in most cases by substantial yearly drops in procurement. In fact, for surge as some think of it, one might very well expect the change from peace to war initially to overshoot the "steady state" before leveling out at a fairly constant wartime production. Furthermore, although purchases from most of the 13 sectors increased during the first two years (1965-1967) of concentrated U.S. involvement, with the exception of the four munitions sectors, no annual increase exceeded 100 percent.

These 13 defense sectors are certainly essential to any combat effort, but the degree and extent to which supporting the war effort depends on each sector is likely to vary greatly from conflict to conflict. A long, moderate-intensity conflict (such as Vietnam) would certainly place long-term demands on all 13 sectors, but a brief conflict might put immediate demands on only a few (if any). In the latter instance, the post-conflict resupplying of either ourselves or our allies might indeed involve accelerated demands on most of the 13 sectors. To aid in differentiating among the various conflicts to which the results might be relevant, the 13 defense sectors are divided into three primary defense groups:

Whole Systems

- Aircraft
- Complete Guided Missiles
- Tanks and Tank Components
- Shipbuilding and Repairing

Spares, Replacements, and Support Systems

- Sighting and Fire Control Equipment
- Radio/TV Communication Equipment
- Aircraft Engines and Parts
- Aircraft Propellers and Parts
- Miscellaneous Aircraft Equipment

Munitions

- Non Small Arms Ammunition
- Small Arms
- Small Arms Ammunition
- Miscellaneous Ordnance and Accessories

This division is useful, not only in terms of the relative demands by category of differing potential crises, but also in relating this involvement to industrial dependence and vulnerability. An acceleration in DoD demand for munitions places somewhat different demands on industry than does a corresponding acceleration for whole systems or spares and replacements. Moreover, the rate at which products of the three groups are consumed varies greatly and is a function of the intrinsic nature of the product and the demands of the given conflict.

Appendix C indicates that during the 10-year period 1965-1975, DoD purchases of munitions ranged as high as 525 percent above its lowest level, that for spares and replacements 120 percent, and that for whole systems 80 percent. Although munitions purchases constituted only a small fraction of the DoD's expenditures in any given year, wartime requirements for them tended to accelerate much more rapidly than for whole systems and spares. This acceleration in required output carries over to the principal suppliers of the munitions sectors, namely the Steel and Chemical industries, as well as to the dozens of other

lower-tier sectors that directly and indirectly supply the munitions sectors. Table 2 indicates the percent of total DoD purchases during the years 1965-1975 that fell in whole systems, spares and replacements, and munitions.

Table 2

PROPORTION OF DOD PURCHASES BY DEFENSE PRODUCT GROUP
(Percent)

Defense Group	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Whole systems	51	51	49	48	45	48	54	51	55	58	59
Spares and replacements	45	41	39	36	36	36	37	41	37	34	35
Munitions	4	8	12	17	18	15	8	8	8	7	6

DEFENSE-RELATED SUPPLIER SECTORS

Each of the 13 defense sectors, to support its own production, must rely to varying degrees on output from each of the 367 sectors of the economy (which include, of course, the 13 defense sectors themselves). In some cases, this dependence is direct and obvious (as in Aircraft Engines and Parts supplying Aircraft); in other cases it is indirect and perhaps less obvious. Thus for example, Aircraft requires a total output of 3.7 cents from Basic Steel Products for every dollar it delivers to final demand. Yet less than 7 percent of this output is delivered directly. The majority must therefore make its way through perhaps several tiers of industry before finding ultimate end use by the Aircraft sector.

An acceleration in DoD demand on any or all of the 13 defense sectors would necessitate varying degrees of response from each of the 367 sectors. To facilitate the analysis, 99 of these 367 have been selected as being most vital to defense product end production on the following considerations:

- Only those sectors that lie in the manufacturing segment of the economy were considered. Although an acceleration in DoD demand might induce vulnerabilities in various mining, farming, construction, or service industries, measurement of these vulnerabilities using input-output techniques is much less reliable than it is for manufacturing industries.[5]
- Sectors whose total direct and indirect input into each of the 13 defense sectors is classified in the Input-Output Tables as "negligible" were not considered (Food and Kindred Products, Farm Machinery, etc.).
- Also not considered were many sectors that do not produce products likely to be involved in any kind of surge demand, even though they have non-negligible input into one or more of the 13 defense sectors. For the most part these include sectors making products used in the production of defense products rather than actually constituting part of a defense end product.[6] Examples include Household Vacuum Cleaners and Public Building Furniture, which have nontrivial inputs into the munitions and aircraft sectors respectively.
- Inasmuch as this report focuses its attention on surge for combat equipment, sectors producing products involved solely in the peripheral support of defense activity are not included--Surgical Appliances and Supplies, Uniforms, etc. Any moderate increase in DoD demand for products of these sectors could more than likely be satisfied by transferring some commercial production or delivery to defense purposes.

As seen in App. D, there are 99 manufacturing sectors, each of which produces products (raw materials, semifinished goods, or finished goods) that are important to the end production of at least one of the 13 defense sectors,[7] including, of course, the 13 defense sectors, which act not only as "prime contractors" to the DoD, but also as lower-tier suppliers for other sectors.

FOUR PERSPECTIVES OF THE DEFENSE-INDUSTRIAL BASE

At the four-digit level of aggregation, the most recent available data on annual DoD purchases and total annual sector output are those published by the Bureau of the Census for 1975 [11,13], and the most recent input-output tables are those of the BEA for the years 1963 and 1967 [14,16].[8] To identify potential industrial vulnerabilities to accelerated DoD demand, independent analyses of the defense industrial base were first run for both 1963 and 1967, using input-output data and DoD demand and total sector output figures from these years. This permits a determination of potential vulnerabilities in those years and the effect of the Vietnam war on these vulnerabilities. The war dictated various priority shifts in DoD purchase activity, which placed new and somewhat different demands on defense-oriented industries.

Although input-output coefficients and defense priorities changed between these years, the list and rank-ordering of potential vulnerabilities--necessary large percentage increases in supplier sector output--were much the same, supporting the contention that the dependencies and vulnerabilities of industry to increased defense production, even during war years, remain quite stable. The Aircraft sector will always require a substantial input from the Steel industry, munitions sectors will always depend to a large extent on the Chemical industry, etc. Of course, advances in technology might alter or eliminate existing dependencies and vulnerabilities, but such changes are slow and directly observable.

Because of this, at least one of the 1963 and 1967 tables of input-output coefficients should be reasonably representative of the current economy in terms of measuring intersector dependence and isolating potential vulnerabilities. Therefore, two additional analyses have been run, one using 1963 coefficients and one using 1967 coefficients, but <u>both</u> using 1975 DoD purchase and total sector output figures.

The following sections present results for each of four different perspectives:

- o 1967 Input-Output Coefficients
  1975 DoD purchase figures
  1975 Sector output figures
- o 1967 Input-Output Coefficients
  1967 DoD purchase figures
  1967 Sector output figures
- o 1963 Input-Output Coefficients
  1975 DoD purchase figures
  1975 Sector output figures
- o 1963 Input-Output Coefficients
  1963 DoD purchase figures
  1963 Sector output figures.

NOTES TO SECTION II

1. The mathematical foundations of input-output analysis are described in App. A.

2. These detailed industries are referred to as sectors.

3. The majority of these 94 defense-oriented industries are lower-tier suppliers of the 13 defense sectors selected for analysis.

4. These or similar products would perhaps be involved in a surge effort, but they would not play a direct role in combat capability.

5. Exclusion of "mining" industries is not intended to minimize the importance of analyzing surge capabilities of raw materials producers. Rather, in keeping with the emphasis on manufacturing, capabilities are studied through the mineral processing industries (i.e., the Primary Metals industries). For a discussion of raw materials and related stockpiling policies, see [12].

6. However, many such sectors whose output is crucial to the production process of one or more defense products have been included (e.g., Special Dies and Tools, which ranks third among input suppliers to the Aircraft Engines sector).

7. Some "important" sectors may have been left out in an attempt to narrow the analysis to manageable proportions.

8. Early in 1977, the BEA released an 85-sector 1971 update [17] of their 1967 tables, which although too aggregated for our purposes, did serve as a partial check on our results. In addition, the results of the 1972 benchmark study will be available sometime in 1978.

III. INDUSTRIAL DEPENDENCE

DEPENDENCE VERSUS VULNERABILITY

Measurement of the capability of various industries to respond to an acceleration in DoD demand for defense products requires differentiation between intersector dependencies, representing the status quo independent of a surge in DoD demand, and vulnerabilities that might arise as the result of such a surge. Thus, the Tank and Tank Components sector depends to a large degree on the Basic Steel Products sector in that it requires 21 cents of steel output for every dollar of goods it delivers to the DoD. But whether the steel industry would be adversely vulnerable to a (possibly sudden) surge in DoD demand for tanks remains to be seen and depends on such factors as (1) amount of the surge, (2) total output of the steel industry in relation to the necessary added production, (3) capacity utilization rate of the steel industry, and (4) ability and willingness of the steel industry to shift some production (if necessary) from non-defense to defense purposes. The Complete Guided Missiles sector, however, depends only a little on the Nonferrous Forgings sector in that it requires an output of only 0.3 cents from the latter to accommodate a delivery of one dollar in goods to the DoD. But the Nonferrous Forgings sector is small (in terms of both number of firms and total output), so a sudden increase in DoD demand for guided missiles might very well induce a substantial vulnerability.

For every dollar the DoD spends on combat materiel (i.e., products of any of the 13 defense sectors), how much output is required from each sector of industry? Table 3 lists the 15 highest ranking sectors among the 99 defense suppliers on the basis of this output. There is a noticeably close correlation among the four perspectives, both in the rankings and in the figures. The only significant deviations are those of Non Small Arms Ammunition and Misc. Ordnance and Accessories between 1963 and 1967. The marked increases in dependence on these

Table 3

REQUIRED SECTOR OUTPUT PER DOD PURCHASE DOLLAR

(Cents)

Supplier Sector	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Aircraft	33.8	1	25.1	2	35.9	1	27.8	2
Radio/TV Communication Equip.	22.3	2	27.8	1	24.4	2	31.5	1
Complete Guided Missiles	19.6	3	14.2	5	18.4	3	18.4	5
Misc. Aircraft Equipment	17.3	4	16.5	3	16.2	4	20.0	3
Aircraft Engines & Parts	16.5	5	16.5	4	15.9	5	18.4	4
Shipbuilding & Repairing	11.0	6	6.4	7	11.0	6	6.2	6
Basic Steel Products	5.6	7	6.1	8	5.4	8	4.9	7
Non Small Arms Ammunition	5.6	8	12.7	6	5.6	7	2.7	10
Misc. Electronics Components	5.1	9	6.0	9	4.1	9	4.8	8
Machine Shop Products	2.9	10	2.7	11	3.0	10	3.3	9
Tanks & Tank Components	2.0	11	1.3	-	2.1	11	2.3	11
Special Dies & Tools	1.9	12	1.9	14	2.0	12	2.1	13
Aluminum Rolling & Drawing	1.6	13	1.6	15	1.7	13	1.6	14
Industrial Chemicals	1.5	14	2.2	13	1.3	14	1.3	15
Metal Stampings	1.3	15	1.5	-	1.1	-	1.1	-
Misc. Ordnance & Accessories	1.0	-	4.4	10	0.9	-	2.2	12
Small Arms Ammunition	0.7	-	2.3	12	0.6	-	0.5	-
Primary Aluminum	1.2	-	1.2	-	1.3	15	1.2	-

sectors are due of course to the Vietnam war, during which sales to the DoD by these two sectors increased by as much as 700 percent and 450 percent respectively. Although the Vietnam war dictated several shifts in defense priorities (including increases in DoD purchases from all 13 defense sectors), the distribution of industrial dependence remained quite stable, with the two exceptions mentioned above.

Aside from the obvious dependence on the 13 defense sectors, the lower-tier sectors most heavily depended on (in dollar terms) for defense-related output are Basic Steel Products, Misc. Electronics Components, Machine Shop Products, Special Dies and Tools, Aluminum Rolling and Drawing, and Industrial Chemicals. However, measuring dependence strictly in terms of dollars tends to spotlight sectors that produce costly products for use in costly defense materiel, one

of the many reasons for differentiating between dependence and the more crucial notion of vulnerability.

For every dollar that the DoD spends on whole systems, spares and replacements, and munitions, how much output is ultimately required from each sector of industry? Table 4 lists the ten top-ranking sectors. Four sectors substantially support DoD purchases from each of the three defense product groups: Misc. Aircraft Equipment, Basic Steel Products, Aircraft Engines and Parts, and Misc. Electronics Components. An across-the-board surge in DoD demand might therefore place accumulated pressures on such sectors, to the point of several dependencies adding up to a potential vulnerability.

In contrast, the Industrial Chemicals sector is not a principal source of input for producers of whole systems, or spares or replacements, but it does provide 9.1 cents in output for every dollar the DoD spends on munitions. Yet because munitions purchases constitute such a small part of DoD procurement, the total dollar value of Industrial Chemicals that supports annual DoD purchases of whole systems and spares exceeds the amount that supports munitions.

As a final measure of the full industrial effect of DoD expenditures, Table 5 indicates the total sum output required of all 99 defense supplier sectors for each dollar spent by the DoD on combat materiel.

SPECIFIC INTERSECTOR DEPENDENCE

Although the broad overview of the defense industrial base in terms of the relationship between defense spending and industrial dependence is useful in understanding the base's functioning, it does not isolate sector-on-sector dependencies or permit determination of the existence of potential vulnerabilities.

Intersector dependence can be classified as either direct or total. Direct dependence measures the input required (by direct shipments) by one sector from another to produce a fixed amount of output. Total dependence measures the ultimate inputs required (by both direct and indirect shipments) by one sector from another to support a fixed delivery to final demand. For example, in 1967, the Aircraft sector

Table 4

REQUIRED SECTOR OUTPUT PER DOD PURCHASE DOLLAR, BY DEFENSE GROUP

(Cents)

Defense Group and Supplier Sector	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Whole Systems								
Aircraft	54.9	1	57.5	1	58.6	1	55.8	1
Complete Guided Missiles	32.1	2	32.9	2	30.8	2	39.5	2
Shipbuilding & Repairing	18.7	3	15.9	4	18.8	3	13.7	4
Misc. Aircraft Equipment	18.2	4	19.0	3	16.6	4	17.9	3
Basic Steel Products	5.5	5	5.2	5	5.4	6	4.9	7
Aircraft Engines & Parts	4.3	6	4.4	6	4.3	7	4.5	8
Radio/TV Communication Equip.	3.8	7	4.0	7	7.2	5	7.5	5
Tanks & Tank Components	3.4	8	3.0	8	3.5	8	4.9	6
Machine Shop Products	3.0	9	3.0	8	2.1	9	2.0	9
Misc. Electronics Components	2.6	10	2.6	10	1.7	-	1.8	-
Pipe, Valves, & Pipe Fittings	0.8	-	0.7	-	1.7	10	1.5	-
Aluminum Rolling & Drawing	1.8	-	1.8	-	1.7	-	1.8	10
Spares & Replacements								
Radio/TV Communication Equip.	56.6	1	60.0	1	56.9	1	56.1	1
Aircraft Engines & Parts	39.2	2	33.0	2	37.8	2	32.6	2
Misc. Aircraft Equipment	18.1	3	19.5	3	18.0	3	23.3	3
Misc. Electronics Components	9.9	4	10.5	4	7.6	4	7.6	4
Aircraft	4.4	5	4.6	5	4.1	7	5.1	5
Basic Steel Products	4.1	6	4.0	6	4.7	6	4.6	7
Machine Shop Products	2.9	7	2.8	7	5.1	5	4.7	6
Special Dies & Tools	2.2	8	2.1	9	2.6	8	2.5	8
Semiconductors	2.1	9	2.2	8	1.6	10	1.6	10
Complete Guided Missiles	1.8	10	1.8	-	1.0	-	1.1	-
Sighting & Fire Control Equip.	1.6	-	2.0	10	1.7	9	2.2	9
Metal Stampings	1.6	-	1.6	-	1.6	-	1.5	-
Munitions								
Non Small Arms Ammunition	86.4	1	72.5	1	86.0	1	47.0	1
Misc. Ordnance & Accessories	14.8	2	25.1	2	14.3	2	42.6	2
Basic Steel Products	13.8	3	13.6	3	9.2	4	8.5	5
Small Arms Ammunition	10.5	4	13.3	4	9.9	3	10.7	3
Industrial Chemicals	9.1	5	7.9	5	1.6	-	1.5	-
Small Arms	5.1	6	4.7	6	4.3	8	9.0	4
Aircraft Engines & Parts	3.3	7	3.1	8	0.7	-	1.6	-
Misc. Aircraft Equipment	3.1	8	3.5	7	2.5	-	5.8	6
Misc. Fabricated Metal Prods.	2.8	9	2.3	-	0.1	-	0.1	-
Misc. Electronics Components	2.6	10	2.4	10	6.9	5	4.6	7
Copper Rolling & Drawing	2.2	-	2.7	9	2.5	-	2.3	-
Aluminum Rolling & Drawing	1.7	-	1.8	-	5.2	6	3.4	8
Metal Stampings	1.8	-	2.0	-	5.0	7	3.2	9
Primary Aluminum	1.2	-	1.3	-	3.2	9	2.5	10
Semiconductors	0.9	-	0.8	-	2.6	10	1.7	-

Table 5

REQUIRED TOTAL INDUSTRIAL OUTPUT PER DOD PURCHASE DOLLAR
(Dollars)

For Each Dollar Spent by the DoD on:	1967 I/O		1963 I/O	
	1975	1967	1975	1963
Whole Systems	1.77	1.78	1.82	1.85
Spares and Replacements	1.74	1.74	1.76	1.77
Munitions	1.90	1.89	1.83	1.76
Total	1.77	1.78	1.80	1.81

depended directly on the Basic Steel Products sector for only 0.2 cents of input for every dollar of its output. Yet, for every dollar of delivery to final markets, it required more than 18 times that amount of steel output, implying a low direct dependence but high total dependence; steel products must make their way through perhaps several intermediate sectors before finding ultimate end use by the Aircraft sector.

Of the two notions, the most important in measuring a sector's ability to respond to a DoD surge demand is total dependence. What really matters, for example, is not how much steel the Steel industry must deliver to the Aircraft industry to produce one plane, but rather how much steel must be produced to support production in all sectors that directly or indirectly deliver to the Aircraft industry. It is these total dependence figures that will permit identification of potential vulnerabilities.

Table 6 ranks the suppliers of each of the 13 defense sectors according to the total output required of the supplier to accommodate a delivery of one dollar in goods to the DoD by the defense sector.[1] The top-ranking sectors remained nearly the same between 1963 and 1967. Among the principal exceptions to this are the larger variations in top-ranked sectors for the munitions categories, and the decline between 1963 and 1967 in the use of aluminum.

Table 6

REQUIRED SUPPLIER SECTOR OUTPUT PER DOLLAR OF DOD PURCHASES FROM DEFENSE SECTOR

Defense and Supplier Sector	1967 I/O Output	1967 I/O Rank	1963 I/O Output	1963 I/O Rank
Whole Systems				
Guided Missiles	$		$	
Misc. Aircraft Equipment	.156	1	.256	2
Aircraft	.119	2	.272	1
Misc. Electronics Components	.041	3	.016	-
Radio/TV Communication Equip.	.029	4	.088	3
Aircraft Engines & Parts	.015	-	.039	4
Tanks & Tank Components				
Basic Steel Products	.207	1	.142	1
Iron & Steel Foundries	.131	2	.105	3
Aircraft Engines & Parts	.072	3	.094	4
Non Small Arms Ammunition	.048	4	.001	-
Misc. Rubber Products	.026	-	.110	2
Aircraft				
Misc. Aircraft Equipment	.278	1	.180	1
Aircraft Engines & Parts	.072	2	.058	3
Radio/TV Communication Equip.	.060	3	.093	2
Machine Shop Products	.041	4	.025	-
Basic Steel Products	.037	-	.031	4
Shipbuilding & Repairing				
Basic Steel Products	.139	1	.151	1
Steam Engines & Turbines	.040	2	.027	-
Fabricated Plate Work	.036	3	.025	-
Pumps & Compressors	.032	4	.031	4
Power Transmission Equipment	.028	-	.044	3
Pipe, Valves, & Pipe Fittings	.017	-	.050	2
Spares & Replacements				
Sighting & Fire Control Equip.				
Radio/TV Communication Equip.	.286	1	.148	2
Optical Instruments & Lenses	.259	2	.243	1
Misc. Electronics Components	.133	3	.117	3
Photographic Equipment	.036	4	.012	-
Iron & Steel Foundries	.014	-	.031	4
Radio/TV Communication Equip.				
Misc. Electronics Components	.176	1	.132	1
Semiconductors	.038	2	.027	3
Basic Steel Products	.028	3	.031	2
Misc. Aircraft Equipment	.019	4	.016	-
Metal Stampings	.017	-	.018	4

Table 6 (continued)

Defense and Supplier Sector	1967 I/O Output	Rank	1963 I/O Output	Rank
Aircraft Engines & Parts				
Basic Steel Products	.060	1	.074	2
Machine Shop Products	.058	2	.131	1
Special Dies & Tools	.037	3	.045	3
Misc. Aircraft Equipment	.027	4	.024	-
Nonferrous Forgings	.018	-	.027	4
Aircraft Propellers & Parts				
Machine Shop Products	.155	1	.070	4
Aircraft Engines & Parts	.145	2	.083	2
Misc. Aircraft Equipment	.131	3	.049	-
Basic Steel Products	.099	4	.086	1
Aluminum Castings	.005	-	.082	3
Misc. Aircraft Equipment				
Aircraft	.230	1	.224	1
Basic Steel Products	.049	2	.046	4
Complete Guided Missiles	.040	3	.032	-
Aircraft Engines & Parts	.040	4	.067	2
Radio/TV Communication Equip.	.027	-	.047	3
Munitions				
Non Small Arms Ammunition				
Basic Steel Products	.141	1	.105	1
Industrial Chemicals	.119	2	.015	-
Aircraft Engines & Parts	.039	3	.001	-
Misc. Fabricated Metal Prods.	.037	4	.001	-
Misc. Electronics Components	.031	-	.089	2
Metal Stampings	.015	-	.067	3
Aluminum Rolling & Drawing	.017	-	.067	4
Small Arms				
Basic Steel Products	.072	1	.074	3
Motor Vehicles & Parts	.049	2	.004	-
Special Dies & Tools	.031	3	.009	-
Hardwood Dimensions & Flooring	.022	4	.087	2
Misc. Aircraft Equipment	.001	-	.097	1
Aircraft Engines & Parts	.001	-	.072	4
Small Arms Ammunition				
Basic Steel Products	.174	1	.013	-
Copper Rolling & Drawing	.173	2	.139	1
Primary Copper	.087	3	.077	3
Paperboard Containers & Boxes	.064	4	.019	-
Misc. Chemical Products	.037	-	.066	4
Primary Lead	.023	-	.084	2

Table 6 (continued)

Defense and Supplier Sector	1967 I/O Output	1967 I/O Rank	1963 I/O Output	1963 I/O Rank
Misc. Ordnance & Accessories				
Basic Steel Products	.114	1	.086	2
Misc. Aircraft Equipment	.071	2	.111	1
Non Small Arms Ammunition	.068	3	.007	-
Radio/TV Communication Equip.	.047	4	.021	-
Machine Shop Products	.017	-	.030	3
Iron & Steel Foundries	.011	-	.024	4

NOTE TO SECTION III

1. To keep the emphasis on lower-tier dependence, this table excludes cases of a defense sector supplying itself--for example, the Guided Missiles sector, which must produce $1.04 in output for every dollar in goods it delivers to the DoD.

   For the sake of completeness this table includes supplier sectors other than the 99 listed in App. D.

IV. POTENTIAL VULNERABILITIES

LOWER-TIER POTENTIAL VULNERABILITY TO SURGE

The previous section focused on the intrinsic structure of the defense industrial base in terms of the degree to which each sector relied or depended on its suppliers. This section contains an analysis of the ability of each supplier to respond to a surge demand for its output, permitting isolation of potential vulnerabilities. The conditions of dependence and vulnerability can exist quite independently of one another. Just because one sector is depended on to a great deal by another does not necessarily imply that it would be unable to successfully respond to a request for added output. Conversely, even if there is very little dependence by a given sector on another, there might very well be a potential vulnerability if the supplier sector were for some reason unable to respond to even a very small request for increased output. It is the purpose of this and the next section first to formulate means by which potential vulnerabilities can be measured, second to isolate vulnerabilities that appear potentially most critical, and third to attempt to measure how well a sector could overcome a vulnerability.

The dominant consideration in measuring such potential vulnerabilities is the extent of the surge demand--that is, how much additional output is required of a given sector in a given time period. Each potential conflict to which the results might be relevant differs in extent and scope of defense product involvement, and in the timetable by which the necessary industrial response is to be assessed. During the course of the Vietnam war, for instance, DoD consumption of non small arms ammunition increased as much as 700 percent over prewar levels, that of aircraft 40 percent, and that of ships only 15 percent. It is impossible to single out the demands of any one particular conflict and label them as representative of a typical surge.

For present purposes, it is best to assume a parametric approach--that is, DoD demand on each of the 13 defense sectors is

assumed to increase by 100 percent. This figure represents a convenient base for the parametric study and may be either an understatement or overstatement of an actual crisis surge demand (compare, for example, the surge for ammunition and ships during the Vietnam conflict). Thus, potential vulnerabilities reported as high under the 100 percent assumption might not materialize, but those reported as minimal might surface. The advantage in using input-output techniques is that modifying this 100 percent figure (or even replacing it by a specific dollar figure) permits corresponding results based on any desired degree of "surge" to be readily obtained. In fact, the ranking of potential vulnerabilities for any one defense sector will be unaffected by such changes in scale; only the dollar magnitude of the increase in supplier-sector output will change.

In satisfying such a 100 percent increase in demand, each defense sector, besides having to increase its own output, must rely on increased output from its lower-tier suppliers. Determination of the degree of this reliance and its subsequent effect on the supplier requires taking into account the following:

- The (annual) total output of each of the 99 defense-related supplier sectors.
- The (annual) DoD purchases from each of the 13 defense sectors.
- The input-output coefficient that measures the required output (in dollars) of each supplier sector necessary to accommodate a delivery of one dollar to the DoD by the given defense sector.

Computing the ratio

$$\frac{100 \times (\text{I/O Coefficient}) \times \begin{pmatrix}\text{Total DoD Purchases} \\ \text{from Defense Sector}\end{pmatrix}}{(\text{Total Output of Supplier Sector})}$$

for each defense and supplier sector yields the percent increase in annual total output of each of the 99 defense-related supplier sectors necessary to accommodate a 100 percent increase in DoD demand on a given defense sector.

Suppose that last year the DoD purchased $100 million in goods from sector A, and that for every dollar A delivers to the DoD, sector B must produce 10 cents in output. Moreover, assume that last year's total output of sector B was $50 million. If there were a 100 percent surge in annual DoD demand on sector A, sector B would have to produce an additional $10 million of output (i.e., it would have to increase its annual production by 20 percent).

In addition to measuring percent increase in supplier sector output, as just indicated, there is a second interpretation of the above ratio. Because of the 100 percent surge assumption, this ratio is also the percentage of the supplier sector's annual output required directly and indirectly by the given defense sector to support the latter's annual delivery of goods to the DoD.[1]

In general then, the suppliers of each defense sector can be ranked according to these percent figures thereby producing a list of potential vulnerabilities. The sectors of particular interest are:

- Defense sectors that place a moderate to heavy burden on several supplier sectors.
- Supplier sectors that are relied on moderately to heavily by several defense sectors.
- Supplier sectors that are relied on especially heavily by a given defense sector.

The importance of the first two in relation to the third is that many low vulnerabilities might add up to a substantial one.

Table 7 ranks each of the 13 defense sectors according to the number of its lower-tier supplier sectors in which an increase in total output of at least 2 percent is needed to accommodate a 100

Table 7

NUMBER OF SUPPLIER SECTORS REQUIRING LARGE INCREASES IN OUTPUT TO SUPPORT A 100 PERCENT SURGE ON A GIVEN DEFENSE SECTOR

Defense Sector	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Aircraft	16	1	16	1	16	1	14	2
Complete Guided Missiles	6	2	3	5	7	2	9	4
Radio/TV Communication Equip.	5	3	14	2	7	2	25	1
Aircraft Engines & Parts	5	3	8	3	6	4	12	3
Shipbuilding & Repairing	3	5	3	5	3	5	4	6
Misc. Aircraft Equipment	3	5	3	5	2	6	8	5
Non Small Arms Ammunition	1	7	4	4	1	7	0	9
Sighting & Fire Control Equip.	1	7	1	9	1	7	1	7
Misc. Ordnance & Accessories	0	9	2	8	0	9	0	9
Small Arms Ammunition	0	9	1	9	0	9	0	9
Tanks & Tank Components	0	9	0	11	0	9	1	7
Aircraft Propellers & Parts	0	9	0	11	0	9	0	9
Small Arms	0	9	0	11	0	9	0	9

percent surge in DoD demand on the defense sector.[2] The table indicates, for example, that a 100 percent DoD surge for Radio/TV Communication Equipment would potentially have had considerably less effect on this sector's suppliers in 1975 than it would have had in either 1963 or 1967. This is because of both the diminishing (since 1968) annual DoD purchases of such equipment and the annual increases in total output of many of this sector's principal suppliers. Also apparent is the effect of the multifold increase in DoD munitions purchases during the Vietnam war; whereas no munitions supplier would have required as much as a 2 percent increase in total output in 1963, by 1967, several would have.

Table 8 ranks the 99 supplier sectors according to the number of defense sectors that require at least a 1 percent increase in total output of the supplier to accommodate a 100 percent increase in DoD demand on the defense sector. Tables 7 and 8 highlight a distinction made earlier concerning the roles of a sector as both a defense prime

Table 8

NUMBER OF DEFENSE SECTORS FOR WHICH A GIVEN SUPPLIER SECTOR MUST SUBSTANTIALLY INCREASE ITS OUTPUT TO MEET A SURGE

Supplier Sector	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Nonferrous Forgings	5	1	5	2	6	1	6	1
Misc. Nonferrous Castings	4	2	5	2	0	-	1	-
Aircraft Propellers & Parts	4	2	4	-	5	2	4	-
Misc. Aircraft Equipment	4	2	3	-	3	-	4	-
Non Small Arms Ammunition	4	2	1	-	3	-	5	-
Machine Shop Products	3	-	6	1	2	-	5	5
Aluminum Rolling & Drawing	1	-	5	2	3	-	6	1
Aluminum Castings	3	-	5	2	2	-	5	5
Misc. Nonfer. Rolling/Drawing	2	-	4	-	5	2	6	1
Sighting & Fire Control Equip.	2	-	2	-	5	2	5	5
Misc. Primary Metal Products	1	-	4	-	1	-	6	1
Misc. Electronics Components	3	-	4	-	3	-	5	5
Special Dies & Tools	3	-	3	-	3	-	5	5
Primary Aluminum	2	-	2	-	3	-	5	5
Brass, Bronze, Copper Castings	2	-	1	-	2	-	5	5

contractor and as a supplier to such contractors. The increase in DoD purchases of non small arms ammunition during the Vietnam war had considerable effect on this sector's suppliers, as reflected (see Table 7) in the rise in the number of such suppliers (from 0 in 1963 to 4 in 1967) that would require at least a 2 percent increase in total output. However, Table 8 indicates that in its role as a supplier of other defense sectors, the Non Small Arms Ammunition sector was potentially less vulnerable in 1967 than in 1963, because total output had increased five-fold, and DoD purchases from sectors it supplies had increased, but to a much lesser extent.

Finally, Table 9 lists those lower-tier supplier sectors for which an increase in total output of at least 4 percent would be necessary to accommodate an increase of 100 percent in DoD demand on the given defense sector. Based on input-output considerations at least, these sectors would be potentially most vulnerable to an acceleration in military demand for the corresponding defense product. In the case of

Table 9

REQUIRED PERCENT INCREASE IN SUPPLIER SECTOR OUTPUT FOR 100 PERCENT DOD SURGE ON A GIVEN DEFENSE SECTOR

	1967 I/O				1963 I/O			
Defense and Supplier Sectors	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Whole Systems								
Guided Missiles								
Misc. Aircraft Equipment	9.4	1	5.8	1	15.3	1	15.1	1
Aircraft Propellers & Parts	4.3	2	1.4	-	13.4	2	4.7	4
Aircraft	3.7	-	2.7	-	8.3	3	12.0	2
Nonferrous Forgings	1.8	-	1.4	-	5.5	4	9.2	3
Tanks & Tank Components								
Non Small Arms Ammunition	1.7	1	0.4	-	0.0	-	0.0	-
Nonferrous Forgings	1.0	-	0.7	1	1.3	1	2.4	1
Aircraft								
Misc. Aircraft Equipment	26.5	1	17.0	1	17.2	2	11.7	1
Aircraft Propellers & Parts	22.3	2	7.2	3	39.2	1	9.6	3
Engineering & Scient. Inst.	10.9	3	9.7	2	7.2	4	7.2	5
Nonferrous Forgings	8.5	4	6.8	4	8.3	3	9.6	2
Aircraft Engines & Parts	7.3	5	5.3	5	5.9	5	4.1	6
Sighting/Fire Control Equip.	5.5	6	2.6	-	3.6	-	1.3	-
Machine Shop Products	3.9	-	4.3	6	2.4	-	3.4	-
Misc Nonfer. Rolling/Drawing	2.1	-	2.4	-	5.7	6	7.3	4
Radio/TV Communication Equip.	3.1	-	2.5	-	4.8	7	3.8	-
Mechanical Measuring Devices	0.7	-	0.8	-	3.5	-	4.0	7
Shipbuilding & Repairing								
Steam Engines & Turbines	3.2	1	4.0	1	2.2	-	3.6	-
Brass,Bronze,Copper Castings	1.3	-	0.8	-	3.8	1	2.5	-
Power Transmission Equipment	2.3	-	2.4	-	3.6	-	4.0	1
Spares & Replacements								
Sighting & Fire Control Equip.								
Optical Instruments & Lenses	2.5	1	7.2	1	2.3	1	11.8	1
Radio/TV Communication Equip								
Misc. Electronics Components	11.1	1	16.0	1	8.3	2	19.1	1
Electron Tubes	5.1	2	4.7	3	5.9	3	7.0	3
Semiconductors	4.5	3	13.7	2	3.2	-	15.4	2
Electric Measuring Instr.	2.5	-	4.4	4	2.2	-	5.3	5
Sighting/Fire Control Equip.	3.5	-	2.9	-	9.1	1	6.6	4
Primary Batteries, Wet & Dry	1.2	-	2.0	-	2.1	-	5.1	6
Coating & Engraving	0.9	-	2.2	-	1.5	-	4.7	7
Wiring Devices	1.6	-	3.1	-	2.0	-	4.4	8
Telephone/Telegraph Apparatus	1.0	-	2.5	-	1.3	-	4.0	9

Table 9 (continued)

Defense and Supplier Sectors	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Aircraft Engines & Parts								
Aircraft Propellers & Parts	17.9	1	8.2	2	24.3	1	10.3	3
Nonferrous Forgings	7.4	2	8.4	1	11.0	2	22.1	1
Machine Shop Products	2.1	-	3.3	-	4.8	3	12.1	2
Misc. Primary Nonfer. Metals	2.3	-	2.5	-	3.5	-	5.3	4
Iron & Steel Forgings	2.0	-	3.1	-	2.2	-	4.6	5
Aircraft Propellers & Parts								
Aircraft Engines & Parts	0.1	1	0.2	-	0.1	-	0.1	-
Machine Shop Products	0.1	-	0.3	1	0.0	-	0.2	-
Aluminum Castings	0.0	-	0.0	-	0.2	1	0.9	1
Misc. Aircraft Equipment								
Aircraft Propellers & Parts	7.3	1	4.4	1	11.3	1	7.6	1
Nonferrous Forgings	2.4	-	3.5	-	1.8	-	5.6	2
Aircraft	2.0	-	2.8	-	1.9	-	5.3	3
Munitions								
Non Small Arms Ammunition								
Watches, Clocks, & Parts	2.1	1	5.6	2	1.1	-	0.8	-
Misc. Fabricated Metal Prod.	1.5	-	5.8	1	0.1	-	0.1	-
Misc. Wood Products	0.9	-	4.3	3	0.0	-	0.0	-
Sighting/Fire Control Equip.	0.0	-	0.1	-	5.9	1	1.4	-
Semiconductors	0.3	-	1.8	-	1.0	-	1.5	1
Small Arms								
Hardwood Dimensions/Flooring	0.2	1	0.7	1	0.9	1	1.4	1
Small Arms Ammunition								
Copper Rolling & Drawing	0.9	1	2.9	1	0.7	-	0.6	-
Primary Lead	0.3	-	1.5	-	1.2	1	1.4	1
Misc. Ordnance & Accessories								
Non Small Arms Ammunition	1.1	1	2.0	-	0.1	-	0.4	-
Misc. Nonferrous Castings	0.5	-	2.2	1	0.0	-	0.1	-
Nonferrous Forgings	0.1	-	0.5	-	0.4	1	1.6	1

those defense sectors for which no supplier would require at least a 4 percent increase in output, the top ranking supplier has nevertheless been listed for each of the four perspectives.[3]

The potentially most serious vulnerabilities occur in sectors that supply producers of whole systems and spares and replacements, and reported potential vulnerabilities for suppliers of munitions are for the most part minimal. In addition, the top-ranking potential vulnerabilities for the four munitions sectors are in most cases quite

different from the top-ranking sectors in terms of total dependence, as presented in Table 6. This reemphasizes the importance of the distinction between the notions of dependence and vulnerability.

To get some idea of the accumulated vulnerabilities that might arise because of a surge in DoD demand on several (or all) of the 13 defense sectors, Table 10 lists those supplier sectors for which an increase in total output of at least 7 percent would be necessary to accommodate an increase of 100 percent in DoD demand for products of all sectors lying within one of the three primary groups (whole systems, spares and replacements, munitions).

In contrast to Table 9's strict emphasis on lower-tier suppliers, Table 10 takes into account all potential vulnerabilities, including those of a defense sector responding to a surge for its own output.[4] For example, the Complete Guided Missiles sector would have to increase its total output by 78.3 percent to accommodate a 100 percent surge in DoD demand on all whole systems producers (i.e., Aircraft, Tanks, Ships, and Guided Missiles). Of this 78.3 percent, however, 76.4 percent is needed just to support the 100 percent surge on its own output.

Table 11 lists those supplier sectors for which an increase in total output of at least 15 percent would be necessary to accommodate an across-the-board increase of 100 percent in DoD demand on all 13 defense sectors. Although it is naive to think that this 100 percent across-the-board increase represents a conceivable surge demand, this table does suitably identify sectors that are potentially most vulnerable to a general acceleration in defense spending. Aside from the 13 defense sectors, the Nonferrous Forgings and Miscellaneous Electronics Components sectors appear potentially most vulnerable. Most of the potential vulnerability in the latter sector is concentrated in the supplying of one sector (Radio/TV Communication Equipment), but the vulnerability of Nonferrous Forgings is an accumulation of several individual high potential vulnerabilities.

Table 10

REQUIRED PERCENT INCREASE IN SUPPLIER SECTOR OUTPUT FOR
100 PERCENT DOD SURGE ON DEFENSE GROUP

Defense Group and Supplier Sector	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Whole Systems								
Complete Guided Missiles	78.3	1	52.4	1	75.0	1	67.5	2
Tanks & Tank Components	67.6	2	49.1	3	69.6	2	70.3	1
Aircraft	55.5	3	41.7	4	59.3	3	63.1	3
Shipbuilding & Repairing	38.3	4	50.8	2	38.6	5	58.3	4
Misc. Aircraft Equipment	36.1	5	22.9	5	32.8	6	27.0	5
Aircraft Propellers & Parts	27.1	6	8.7	8	53.6	4	14.5	7
Engineer. & Scientific Inst.	13.4	7	11.8	6	8.9	9	9.5	9
Nonferrous Forgings	11.9	8	9.2	7	15.3	7	21.3	6
Aircraft Engines & Parts	9.0	9	6.4	-	9.1	8	7.3	10
Misc. Nonfer. Rolling/Drawing	3.5	-	3.8	-	8.4	10	11.4	8
Radio/TV Communication Equip.	4.1	-	3.3	-	7.7	11	7.0	11
Spares & Replacements								
Sighting/Fire Control Equip.	75.4	1	74.4	1	82.7	1	77.6	1
Aircraft Propellers & Parts	66.1	2	52.7	3	75.8	2	56.2	4
Aircraft Engines & Parts	49.7	3	51.5	4	48.0	3	59.4	2
Radio/TV Communication Eqp.	36.1	4	53.4	2	36.3	4	57.6	3
Misc. Aircraft Equipment	21.6	5	25.4	5	21.4	5	39.0	5
Misc. Electronics Components	11.8	6	17.0	6	9.1	7	21.1	7
Nonferrous Forgings	10.3	7	12.7	8	13.1	6	28.8	6
Semiconductors	4.7	-	14.3	7	3.6	-	17.5	8
Optical Instruments & Lenses	3.0	-	8.4	9	2.9	-	14.0	10
Machine Shop Products	3.4	-	6.2	-	6.0	-	16.5	9
Misc. Nonfer. Rolling/Drawing	2.7	-	5.0	-	3.0	-	8.2	11
Electron Tubes	5.4	-	5.0	-	6.8	-	8.1	12
Misc. Primary Nonfer. Metals	3.6	-	4.2	-	4.8	-	7.9	13
Coating & Engraving	2.4	-	5.3	-	2.5	-	7.7	14
Aluminum Castings	3.1	-	5.6	-	3.0	-	7.5	15
Special Dies & Tools	3.2	-	4.3	-	3.7	-	7.4	16
Non Small Arms Ammunition	2.1	-	1.0	-	3.5	-	7.1	17
Munitions								
Non Small Arms Ammunition	105.2	1	89.6	1	104.7	1	67.5	2
Misc. Ordnance & Accessories	32.3	2	81.6	2	31.2	2	81.2	1
Small Arms Ammunition	26.0	3	72.4	3	24.7	3	40.6	3
Small Arms	10.8	4	35.0	4	9.2	4	39.7	4

Table 11

REQUIRED PERCENT INCREASE IN SUPPLIER SECTOR OUTPUT FOR 100 PERCENT ACROSS-THE-BOARD DOD SURGE

Supplier Sector	1967 I/O				1963 I/O			
	1975	Rank	1967	Rank	1975	Rank	1963	Rank
Non Small Arms Ammunition	110.6	1	91.4	1	110.2	2	76.9	3
Aircraft Propellers & Parts	93.6	2	62.0	5	129.8	1	71.0	5
Sighting & Fire Control Equip.	81.6	3	77.4	3	95.0	3	81.7	2
Complete Guided Missiles	81.3	4	56.7	8	76.5	4	69.7	7
Tanks & Tank Components	68.2	5	51.3	9	70.5	5	71.7	4
Aircraft Engines & Parts	59.5	6	59.8	6	57.3	7	67.1	9
Misc. Aircraft Equipment	58.3	7	50.2	11	54.7	8	67.1	8
Aircraft	58.3	8	45.6	12	61.8	6	69.7	6
Radio/TV Communication Equip.	40.4	9	57.5	7	44.1	9	64.8	10
Shipbuilding & Repairing	38.4	10	51.0	10	38.6	10	58.5	11
Misc. Ordnance & Accessories	37.3	11	83.9	2	31.8	11	81.9	1
Small Arms Ammunition	26.8	12	72.8	4	24.7	12	40.7	13
Nonferrous Forgings	23.0	13	24.3	14	30.0	13	52.9	12
Misc. Electronics Components	17.4	14	22.6	15	13.8	-	26.9	15
Small Arms	11.9	-	36.4	13	9.3	-	39.9	14
Semiconductors	6.4	-	18.7	16	6.0	-	23.3	17
Machine Shop Products	9.7	-	14.2	-	10.1	-	23.5	16
Misc. Nonfer. Rolling/Drawing	6.5	-	9.9	-	11.7	-	20.2	18

USE OF CAPACITY UTILIZATION MEASURES FOR ASSESSING POTENTIAL VULNERABILITY

The last section identified defense supplier sectors that would be potentially most vulnerable in terms of ability to respond to an increase in demand for its output. The measurement of this vulnerability was in terms of the amount by which total production would have to be increased. The ability of a supplier to respond to this request for added output depends on several factors, many of which do not lend themselves to precise measurement. One of the more revealing of these factors (and one that can be measured to a degree) is capacity utilization--that is, the level of operations at which an industry operates relative to the level that it could achieve within the framework of a realistic work pattern.

If a firm operates at an 80 percent capacity utilization rate, theoretically (taking no other factors into account) it could increase production by 25 percent. More generally, if CU denotes the rate (in percent) of utilization, then J = 100(100 - CU)/CU represents the percent by which total output could be increased. Table 9 computed the percent increase (I) in total output of each supplier sector necessary to accommodate a 100 percent increase in DoD demand on a given defense sector. Calculating the ratio I/J yields a measure of the responsive ability of each supplier, as given by the percent of excess capacity that would have to be utilized to meet the required demand. In particular, a ratio less than 1 indicates that (based on capacity utilization rates alone) the supplier could meet the added demand, and a ratio greater than 1 indicates that it could not.

For each of the 13 defense sectors, Table 12 ranks lower-tier supplier sectors that would need to use at least 10 percent of their available excess capacity to accommodate a 100 percent increase in DoD demand on the defense sector.[5] Of primary interest is the comparison of this table with Table 9. Sectors ranking high in both tables are potentially vulnerable to a surge demand and might also have such insufficient excess capacity as to make the vulnerability a real one.[6] An important consideration in such matters would also be the amount of excess capacity that could be channeled into defense-related production. A firm might be able to increase its overall production rate by, say, 25 percent, yet increase its defense production by much less because of problems in securing the necessary labor, equipment, facilities, raw materials, etc. Such factors are naturally not reflected in Table 12 and require a more detailed look at defense production operations.

The Industrial Patterns sector appears most often as having to utilize a large percentage of its excess capacity to accommodate a surge. Yet this sector does not appear at all in Table 9's list of the potentially highest vulnerabilities. The reported 1975 capacity utilization rate for this sector was 97 percent, indicating that

Table 12

PERCENT OF SUPPLIER SECTOR'S EXCESS CAPACITY NEEDED TO MEET A 100 PERCENT DOD SURGE DEMAND ON A GIVEN DEFENSE SECTOR[a]

Defense and Supplier Sectors	1967 I/O %	1967 I/O Rank	1963 I/O %	1963 I/O Rank
Whole Systems				
Complete Guided Missiles				
Misc. Aircraft Equipment	14	1	23	1
Industrial Patterns	11	2	12	4
Aircraft Propellers & Parts	06	-	19	2
Nonferrous Forgings	05	-	14	3
Tanks & Tank Components				
Industrial Patterns	15	1	13	1
Aircraft				
Misc. Aircraft Equipment	40	1	26	3
Industrial Patterns	39	2	30	2
Aircraft Propellers & Parts	31	3	54	1
Engineering & Scientific Inst.	30	4	20	5
Nonferrous Forgings	22	5	21	4
Machine Shop Products	17	6	10	7
Aircraft Engines & Parts	12	7	10	9
Misc. Nonfer. Rolling/Drawing	07	-	19	6
Mechanical Measuring Devices	02	-	10	8
Shipbuilding & Repairing				
Industrial Patterns	23	1	19	1
Steam Engines & Turbines	18	2	12	3
Misc. Nonmet. Mineral Prods.	18	3	01	-
Brass, Bronze, Copper Castings	06	-	16	2
Spares & Replacements				
Sighting & Fire Control Equip.				
Optical Instruments & Lenses	02	1	02	1
Radio/TV Communication Equip.				
Misc. Electronics Components	20	1	15	1
Industrial Patterns	10	2	13	2
Electron Tubes	10	3	11	3
Sighting & Fire Control Equip.	04	-	11	4
Aircraft Engines & Parts				
Aircraft Propellers & Parts	25	1	34	1
Industrial Patterns	21	2	23	3
Nonferrous Forgings	19	3	28	2
Machine Shop Products	09	-	20	4

[a]A more comprehensive version of this table may be found in App. F.

Table 12 (continued)

Defense and Supplier Sectors	1967 I/O %	1967 I/O Rank	1963 I/O %	1963 I/O Rank
Aircraft Propellers & Parts				
Industrial Patterns	00	-	01	1
Misc. Aircraft Equipment				
Aircraft Propellers & Parts	10	1	16	1
Munitions				
Non Small Arms Ammunition				
Industrial Patterns	05	1	04	-
Sighting & Fire Control Equip.	00	-	07	1
Small Arms				
Hardwood Dimensions & Flooring	01	1	02	1
Small Arms Ammunition				
Primary Copper	02	1	01	-
Primary Lead	01	-	02	1
Misc. Ordnance & Accessories				
Misc. Nonferrous Castings	01	1	00	-
Industrial Patterns	01	-	04	1

(based on this rate alone) it could increase its total production rate by only 3 percent. Although this sector is not a principal supplier of any of the 13 defense sectors, it does provide them sufficient input that its response ratios I/J are noticeably high, at least relative to its (reported) short supply of excess capacity. However, this 97 percent 1975 capacity utilization rate is qualified in [15] with an accompanying 43 percent standard error figure, casting doubt on its accuracy. (The 1974 reported utilization rate was 83 percent.)

Rather than measure a supplier sector's ability to respond to a surge demand for products of one particular defense sector, it is possible (as in Table 10) to ask for its ability to respond to a 100 percent surge demand on all sectors lying within one of the three defense groups. Table 13 lists supplier sectors that would need to use at least 20 percent of their excess capacity to meet a 100 percent DoD surge demand for products of all sectors within a given defense group.

Table 13

PERCENT OF SUPPLIER SECTOR'S EXCESS CAPACITY NEEDED TO MEET A 100 PERCENT DOD SURGE DEMAND ON A GIVEN DEFENSE GROUP

Defense Group and Supplier Sector	1967 I/O		1963 I/O	
	%	Rank	%	Rank
Whole Systems				
Complete Guided Missiles	383	1	366	1
Tanks & Tank Components	110	2	114	2
Shipbuilding & Repairing	104	3	104	3
Industrial Patterns	88	4	74	4
Aircraft	60	5	64	6
Misc. Aircraft Equipment	54	6	49	7
Aircraft Propellers & Parts	37	7	74	5
Engineering & Scientific Inst.	36	8	24	11
Nonferrous Forgings	31	9	39	8
Machine Shop Products	25	10	17	-
Misc. Nonmetallic Mineral Prod.	22	11	07	-
Steam Engines & Turbines	21	12	14	-
Misc. Nonfer. Rolling/Drawing	12	-	28	9
Brass, Bronze, Copper Castings	13	-	27	10
Spares & Replacements				
Aircraft Propellers & Parts	91	1	105	1
Sighting & Fire Control Equip.	89	2	97	2
Aircraft Engines & Parts	81	3	78	3
Radio/TV Communication Equip.	56	4	57	4
Industrial Patterns	40	5	46	5
Misc. Aircraft Equipment	32	6	32	7
Nonferrous Forgings	26	7	34	6
Misc. Electronics Components	21	8	16	-
Complete Guided Missiles	20	9	12	-
Machine Shop Products	15	-	25	8
Munitions				
Non Small Arms Ammunition	70	1	70	1
Small Arms	43	2	37	2
Misc. Ordnance & Accessories	26	3	26	3
Small Arms Ammunition	26	4	25	4

The I/J percent figures presented here for each of the 13 defense sectors reflect both the demand on excess capacity levied by those sectors it supplies and the demand that would accompany a 100 percent surge for its own defense output. Although the Complete Guided Missiles sector would need to use 383 percent of its available (in 1975)

excess capacity to accommodate a 100 percent DoD surge for all whole systems, 373 percent of this would go to meeting its own increased DoD obligations. Thus, by utilizing only 10 percent of its available excess capacity, this sector could accommodate a 100 percent surge for the remaining three whole systems producers.

Finally, Table 14 lists supplier sectors that would need to utilize at least 40 percent of their available excess capacity to accommodate a 100 percent across-the-board increase in DoD purchases. Aside from the 13 defense sectors and the Industrial Patterns sector (discussed above), each sector of industry has sufficient excess production capacity (based on capacity utilization figures and interpretation of potential vulnerability) to accommodate even a 100 percent across-the-board surge in DoD demand. Of course, such conclusions reflect the analysis of the defense industrial base at a sector-by-sector level and do not necessarily represent operation at the more important firm level.

Table 14

PERCENT OF SUPPLIER SECTOR EXCESS CAPACITY NEEDED TO MEET A 100 PERCENT ACROSS-THE-BOARD DOD SURGE

	1967 I/O		1963 I/O	
Supplier Sector	%	Rank	%	Rank
Complete Guided Missiles	397	1	373	1
Industrial Patterns	135	2	128	3
Aircraft Propellers & Parts	129	3	179	2
Tanks & Tank Components	111	4	115	4
Shipbuilding & Repairing	104	5	104	6
Aircraft Engines & Parts	97	6	94	7
Sighting & Fire Control Equip.	96	7	112	5
Misc. Aircraft Equipment	87	8	82	8
Non Small Arms Ammunition	74	9	73	10
Radio/TV Communication Equip.	63	10	69	11
Aircraft	63	11	67	12
Nonferrous Forgings	59	12	77	9
Small Arms	48	13	37	-
Machine Shop Products	41	14	43	13
Engineering & Scientific Inst.	40	15	30	-

SUMMARY OF TABLES

The most revealing tables in terms of understanding the effects of a DoD surge are Tables 6 and 9, relating total dependence and potential surge vulnerability. Table 15 summarizes these tables using data based on 1967 input-output coefficients and 1975 DoD purchase and sector output figures. Of the four perspectives discussed above, this probably is most representative of the current economy.

Table 15 reemphasizes two important observations of this study: (1) the notions of dependence and potential vulnerability can exist quite independently of one another; and (2) aside from their importance as direct suppliers of defense materiel to the DoD, many of the 13 defense sectors are also important as lower-tier suppliers of other sectors.[7]

Table 15

SUMMARY OF SECTOR DEPENDENCE AND POTENTIAL VULNERABILITY

Defense Sector	Principal Suppliers of Total Input	Supplier Sectors Potentially Most Vulnerable to Surge
Whole Systems		
Guided Missiles		
	Misc. Aircraft Equipment	Misc. Aircraft Equipment
	Aircraft	Aircraft Propellers & Parts
	Misc. Electronics Components	Aircraft
Tanks & Tank Components		
	Basic Steel Products	Non Small Arms Ammunition
	Iron & Steel Foundries	Nonferrous Forgings
	Aircraft Engines & Parts	Misc. Ordnance & Accessories
Aircraft		
	Misc. Aircraft Equipment	Misc. Aircraft Equipment
	Aircraft Engines & Parts	Aircraft Propellers & Parts
	Radio/TV Communication Equip.	Eng. & Scientific Instruments
Shipbuilding & Repairing		
	Basic Steel Products	Steam Engines & Turbines
	Steam Engines & Turbines	Power Transmission Equipment
	Fabricated Plate Work	Brass/Bronze/Copper Castings

Table 15 (continued)

Defense Sector	Principal Suppliers of Total Input	Supplier Sectors Potentially Most Vulnerable to Surge
Spares & Replacements		
Sighting & Fire-Control Equipment		
	Radio/TV Communication Equip.	Optical Instruments & Lenses
	Optical Instruments & Lenses	Radio/TV Communication Equip.
	Misc. Electronics Components	Brass,Bronze,Copper Castings
Radio/TV Communication Equipment		
	Misc. Electronics Components	Misc. Electronics Components
	Semiconductors	Electron Tubes
	Basic Steel Products	Semiconductors
Aircraft Engines & Parts		
	Basic Steel Products	Aircraft Propellers & Parts
	Machine Shop Products	Nonferrous Forgings
	Special Dies & Tools	Misc. Primary Nonfer. Metals
Aircraft Propellers & Parts		
	Machine Shop Products	Aircraft Engines & Parts
	Aircraft Engines & Parts	Machine Shop Products
	Misc. Aircraft Equipment	Misc. Aircraft Equipment
Misc. Aircraft Equipment		
	Aircraft	Aircraft Propellers & Parts
	Basic Steel Products	Nonferrous Forgings
	Complete Guided Missiles	Aircraft
Munitions		
Non Small Arms Ammunition		
	Basic Steel Products	Watches, Clocks, & Parts
	Industrial Chemicals	Misc. Fabricated Metal Prod.
	Aircraft Engines & Parts	Misc. Wood Products
Small Arms		
	Basic Steel Products	Hardwood Dimensions/Flooring
	Motor Vehicles & Parts	Tanks & Tank Components
	Special Dies & Tools	Misc. Ordnance & Accessories
Small Arms Ammunition		
	Basic Steel Products	Copper Rolling & Drawing
	Copper Rolling & Drawing	Primary Copper
	Primary Copper	Primary Lead
Misc. Ordnance & Accessories		
	Basic Steel Products	Non Small Arms Ammunition
	Misc. Aircraft Equipment	Misc. Nonferrous Castings
	Non Small Arms Ammunition	Misc. Aircraft Equipment

NOTES TO SECTION IV

1. This double interpretation of the ratio exists because of the 100 percent "surge" assumption. That is, if sector B would have to increase its total output by 20 percent to accommodate a 100 percent "surge" in DoD demand on sector A, that means that currently 20 percent of sector B's output goes ultimately to support defense production in sector A.

2. The selection in Tables 7-14 of these "minimum" percentage figures (e.g., 2 percent) is fairly arbitrary, and is made so as to best identify those cases in which potentially high vulnerabilities exist.
   The counts of Tables 7 and 8 do not include the case of one of the 13 defense sectors supplying itself.

3. Although this table does not include vulnerability figures for the 13 defense sectors supplying themselves, it does include figures for these defense sectors acting as lower-tier suppliers of other sectors. A complete list of potential vulnerability figures for all 99 supplier sectors can be found in App. E.

4. The reason the percent increase figure for Non Small Arms Ammunition is over 100 percent is that about 15 percent of this sector's output is cycled back into its own production process rather than being sold. Thus, to deliver $1 in goods to the DoD, it must produce well over $1 in output.

5. Capacity utilization rates are for the fourth quarter of 1975, and are taken from [15].

6. Sectors appearing in Table 12 but not Table 9 for the most part do not appear to be adversely vulnerable to surge in terms of percent increase in total output, but their reported capacity utilization rate is high enough to indicate little room for production expansion. Because these rates are so difficult to measure, and because they tend to change (at times rather drastically) from year to year, it is perhaps best to attach a qualitative meaning to the results of Table 12, and to rely on Table 9 for the more quantitative aspects of potential surge vulnerability.

7. Potential vulnerability in this table is measured (as in Table 9) in terms of the percent increase in supplier sector total output necessary to accommodate an increase of 100 percent in DoD demand on the defense sector.

V. CONCLUSIONS: ASSESSMENT AND QUALIFICATION

ASSESSMENT OF POTENTIAL VULNERABILITIES

The preceding analysis focused on two primary aspects of the defense industrial base: intersector dependence and potential surge vulnerability. The discussion covered means by which each of these can be measured, ranking of the defense producers and suppliers according to these measures, and an attempt (using capacity utilization data) to assess each sector's capability to overcome potential vulnerabilities. However, the results of the tables may not definitively delineate the bottlenecks that might accompany a DoD surge demand.

Interpretation of the results of the last several sections is predicated on an understanding of the various factors that account for a given sector's appearing or not appearing in a specific top ranking. Such factors are best explained by taking a closer look at the ratio

$$\frac{100 \times (\text{I/O Coefficient}) \times \left(\begin{matrix}\text{Total DoD Purchases} \\ \text{from Defense Sector}\end{matrix}\right)}{(\text{Total Output of Supplier Sector})}$$

which measures (as in Table 9) the percent of the supplier sector's total output required to support the defense sector's annual delivery to the DoD, and (at the same time) the percent increase in the supplier sector's total output necessary to accommodate an increase of 100 percent in DoD demand on the defense sector.

This latter interpretation is used to identify the supplier sector's potential vulnerability to a DoD surge demand. A large ratio indicates that the supplier sector would have to increase its output substantially to meet the surge, and results mathematically from one or more of the following:

- o A large input-output (total dependence) coefficient.
- o A large total DoD purchase figure.
- o A small supplier sector total output.

That all three conditions can occur more or less independently of one another is exemplified in the following cases.

1. The Basic Steel Products sector appears in Table 6 as a primary supplier of direct and indirect input to all but two of the 13 defense sectors. No other sector of the economy is depended on to such a widespread extent. A review of the list of potential vulnerabilities in Table 9 reveals that this sector does not appear once. The reason is that total output (for 1975) was almost $40 billion ($20 billion in 1963, $25 billion in 1967), and that only about 3 percent of this ultimately went to defense end use. Even a doubling in DoD demand for all defense products would not require a substantial increase in total output of this sector. In fact, because as much as 97 percent of the sector's output finds nonmilitary end use, any reasonable surge demand could probably be met by diverting only a small fraction of nonmilitary to military production. Of course, if military specifications required various quality controls (ranging from the grade of steel produced to the final testing procedures) that differed substantially from those for commercial production, the time factor involved in converting labor and equipment to comply with these added controls might delay the seemingly high response potential of this industry.
2. The Nonferrous Forgings sector appears in Table 9 as a source of potential vulnerability to accelerated DoD demand on six different defense sectors, more than any other sector. Yet none of these six sectors depends on Nonferrous Forgings for a substantial part of its input. The reported vulnerabilities in these cases occur because the total annual output of

Nonferrous Forgings is fairly small (only $520 million in 1975), and of this total output as much as 25 percent ultimately goes to defense end use. To accommodate a 100 percent across-the-board surge in DoD demand, this sector would either have to increase its rate of production by 25 percent or combine a lesser total increase with a diversion of some commercial production to defense production. Because such a large percent of its output is already defense-related, depending on how specialized its defense production is in terms of labor, equipment, raw materials, etc., and depending on how committed the sector might be to its commercial customers, such diversions (at least on a short-term basis) might be limited to only a fraction of what is necessary.

The Nonferrous Forgings sector as a whole reported a 1975 capacity utilization rate of 72 percent, which indicates some room for expanding production. Yet that same year, although it was operating at 72 percent of its practical capacity, it was operating at 93 percent of its preferred capacity, the level of operations it would prefer not to exceed because of cost or other considerations. Thus the cost of surge for military end-products requiring nonferrous forgings could be quite high.

3. A look at Table 9 reveals that after Nonferrous Forgings, the Aircraft Propellers and Parts sector appears as a leading potential vulnerability to the greatest number of defense sectors. In fact, its vulnerability figures far exceed those of Nonferrous Forgings, and seemingly indicate that this sector might be hard pressed to accommodate even a moderate DoD demand surge. A further look at Table 6 reveals, however, that not one defense sector depends on Aircraft Propellers for a substantial part of its input. As with Nonferrous Forgings, one of the reasons the reported vulnerabilities are so high is that the annual output of the Propellers sector is extremely low ($90 million in 1975), while DoD purchases

from those sectors it supplies are quite high.

The primary difference between the two sectors is that because of technological advances, the demand for propellers has drastically diminished since the 1960s, but that for forgings has not. The SIC classification no longer includes Propellers as a separate sector, but includes it within Miscellaneous Aircraft Equipment. Because the input-output coefficients are from 1963 and 1967 (years in which propellers were in greater demand than today), the vulnerability figures reported in Table 9 may be somewhat exaggerated. It seems reasonable to assume that current input-output coefficients would accurately reflect this diminished dependence, hence yield more reasonable looking estimates for potential vulnerability. In any case, any surge demand today that necessitated an additional output of propellers could probably be met by in-house production by one of the other aircraft-related sectors.

4. The Sighting and Fire Control Equipment sector occurs in Table 9 as a potential vulnerability under three different defense sectors: Non Small Arms Ammunition, Radio/TV Communication Equipment, and Aircraft. As in the previous two cases, dependence on this sector for lower-tier input by the defense community is minimal, as is the sector's total output. Inasmuch as many of the products of this sector are technologically quite sophisticated, the equipment, raw materials, and labor used in the production process are probably quite specialized, and unless member firms could augment their production using currently available resources, they might have difficulty responding to a sudden short-term surge request for their output.

These four cases represent in some sense the extremes of the dependence-vulnerability scale. The Basic Steel Products case involves a sector on which all defense products are substantially

dependent for input, yet that is not (according to the analysis) potentially vulnerable to a 100 percent surge in demand for its defense-related output. The other cases involve sectors whose input to defense-related sectors is minimal, but because of their low total output and high concentration of military output, they are potentially among the most vulnerable to a surge (although, as discussed above, the reported vulnerability for Aircraft Propellers might be overstated because of the data used and known trends in technology).

More in the middle of the defense-vulnerability scale are sectors both depended on to a large degree for input and potentially vulnerable to a surge in demand for their output.

1. The Machine Shop Products sector is relied on for a moderate to substantial amount of direct and indirect input by each of the four aircraft-related sectors. Vulnerabilities, as reported in Table 9, were high (over 2 percent) with regard to responding to a surge for both aircraft and aircraft engines. Because a surge for aircraft necessitates an accommodating surge for all aircraft-related materiel, the vulnerabilities for each of the four aircraft-related sectors are likely to be compounded, the result being that to support a 100 percent surge in aircraft-related products, the Machine Shop Products sector would need to increase its total output by anywhere from 7 percent to 16 percent, depending on the perspective. In recent years, the sector has been operating at slightly more than 80 percent of capacity, indicating an expansion capability of 20-25 percent. Although much of this sector's output is not as technologically sophisticated as, say, that of the Electronics industries, the machinery involved in producing aircraft valves and valve housings might be specialized to where it would be difficult to obtain such equipment on short notice. Moreover, because of the classification of output according to primary activity, many of the Machine Shop Products produced by aircraft firms are not visible in this analysis.

2. The Radio/TV Communication Equipment sector had 1975 DoD sales of $3.6 billion, more than any other sector except Aircraft. Almost one-fourth of both its direct and indirect input comes from Electron Tubes, Semiconductors, and Miscellaneous Electronics Components (of this, almost 80 percent comes from the last sector). Table 9 indicates that each of these three sectors is a potential vulnerability for a DoD surge in demand for Communication Equipment, in that each would need to increase its total production rate by a substantial amount to accommodate a 100 percent surge. However, each of these sectors reported a 1975 capacity utilization rate of about 65 percent, indicating room for considerable expansion. However, a possibly serious obstacle to such expansion is the high degree of production specialization.
3. Along with the Radio/TV Communication Equipment sector, the Optical Instruments and Lenses sector is one of the principal suppliers of input to the Sighting and Fire Control Equipment sector. In fact, since the 1967 input-output analysis, this latter sector has been reclassified and absorbed in part by each of these two major suppliers. A look at Table 9 reveals that one of the biggest potential vulnerabilities (at least for two perspectives) is that of Optical Instruments and Lenses responding to a surge for Sighting and Fire Control Equipment. There is, however, a noticeable discrepancy between the reported vulnerability figures based on 1975 DoD purchase totals and those based on 1963 and 1967. Although the potential vulnerability seems to have lessened over the years, the reclassification of this sector has made it impossible to obtain accurate DoD purchase figures. There is evidence (based on figures from previous years) to support the contention that the estimates made of these purchases (based on available related Census bureau data) are substantially lower than the actual figures. It is likely

then that the reported vulnerabilities have remained fairly constant and still in fact do represent a possible bottleneck. An important fact to consider is that for the years 1974 and 1975, the Optical Instruments and Lenses sector reported a capacity utilization rate of about 47 percent, indicating that (based on utilization figures alone) it has the capacity to more than double its current production rate and thus successfully meet even a 100 percent surge demand for its output.

4. As aircraft become more and more sophisticated, the Aircraft sector becomes more and more dependent on the Engineering and Scientific Instruments sector. Total output of this latter sector has not been increasing rapidly, however. Therefore, a larger and larger fraction of the sector's output is finding end use by Aircraft. The potential vulnerabilities as reported in Table 9 were high for all four perspectives. An important qualifying feature to keep in mind in assessing the vulnerability is that more than 85 percent of the dependence of Aircraft on Scientific Instruments is direct--that is, the latter is for all intents and purposes a first-tier supplier of the former. Because most delivery is direct, the chance of not knowing about such a bottleneck is greatly reduced; whether it would materialize depends primarily on the availability of semi-finished input and the ability of the Scientific Instruments sector to sufficiently rechannel its production.
5. To meet a DoD surge request for added military output, each of the 13 defense sectors must increase production not only to meet direct prime contract obligations to the DoD, but also to accommodate sectors that rely on its output. Especially in the case of aircraft-related sectors, these multiple demands can be substantial. Thus, a 100 percent surge in DoD demand for Guided Missiles and Aircraft would require the Miscellaneous Aircraft Equipment sector to

increase its annual production rate by 9 percent and 26 percent respectively. When these are combined with the 20 percent increase necessary to double its own DoD delivery schedule, this sector, in order to meet such an accumulated surge, would need to increase its overall production by more than one half. Although in recent years it has been operating at about 60 percent of capacity, and could theoretically increase its production rate by almost 70 percent, the lead time in achieving this expansion could be considerable.

Although Tables 9 and 12 are by no means the final word in assessing a sector's ability to respond to a surge demand, they do allow analysis of response potential in terms of the extent to which the sector would have to increase its total output to meet the demand. Numbers do change, but the conclusions to be drawn in terms of rank ordering of potential vulnerabilities remain quite stable among the four perspectives.[1] This is a reflection of the stability of the input-output coefficients as well as of the stable year-to-year structure of the defense industrial base as a whole. In interpreting numerical changes between 1963 and 1967, it is important to keep in mind that 1967 was a war year, and the scope of the Vietnam conflict dictated several shifts in defense priorities. A case in point is provided by the nearly 400 percent increase in DoD helicopter purchases between the two years. An added burden thus fell on the Miscellaneous Aircraft Equipment sector, which produces roto-blades for these helicopters. This is reflected in the rise from 11.7 to 17 percent in total output of this sector necessary to accommodate a 100 percent increase in DoD demand on the Aircraft sector.

The most noticeable effect of the war on Table 9's list of potential vulnerabilities is in the munitions category, especially the Non Small Arms Ammunition sector. DoD purchases from this sector increased from $334 million in 1965 to $3058 million in 1969, and because of this, added burdens were placed on all direct and

indirect suppliers. Prewar total output had been small, so none of these suppliers had been channeling a substantial part of its output into the sector. Moreover, many of these supplier sectors have enormous annual output (e.g., the Steel and Chemical sectors), and even after the added demands of the war, they still were not delivering a large part of their total output to Non Small Arms Ammunition. In particular, this is why none of these supplier sectors appeared in Table 9's list of potential vulnerabilities. Watches, Clocks, and Parts appeared because they had moderate input to Ammunition, which nevertheless constituted a non-trivial portion of their total output.

The basic assumption underlying the reporting of potential vulnerabilities is that of a 100 percent surge in DoD demand on each of the 13 defense sectors. As discussed earlier, this certainly does not represent a typical surge, yet as part of a parametric approach, it gives a fair picture of the relative rankings of potential vulnerabilities. The greatest number of potentially serious vulnerabilities occur in supplier sectors that deliver products to defense producers of whole systems and of spares and replacements. In contrast, the suppliers of munitions producers are for the most part potentially less vulnerable, often because a smaller part of their total output goes to munitions industries.

In an actual industrial surge situation, precipitated by U.S. preparation for, involvement in, or resupplying after a military conflict, demand for whole systems or spares and replacements is unlikely to increase by as much as 100 percent in any one year. Although a short, high-intensity crisis might require (especially in post-conflict resupplying) an immediate acceleration of production in excess of 100 percent, again, it is unlikely that this would (or could) continue to the point where producers of these systems were being asked to as much as double their annual output. During the Vietnam war, for example, sales to the DoD by sectors producing whole systems and spares increased, but by no more (with one exception) than 30 percent in any one year.[2] Hence it is likely that the 100 percent surge demand assumed for whole systems and spares and

replacements is exaggerated, and therefore that the corresponding potential vulnerabilities reported in Table 9 are greater than would be normally expected.

Munitions tend to be consumed at a far greater rate than are whole systems or spares and replacements, and DoD annual demand for them might very well increase several-fold in a moderate to long-range conflict. Demand for Non Small Arms Ammunition more than doubled between 1966 and 1967 and again between 1967 and 1968. The assumption of a 100 percent DoD surge is probably understated in the case of munitions, and the potential vulnerabilities reported in Table 9 might actually be even greater than indicated.

The effect of these observations is twofold: (1) the reduction in the potential severity of vulnerabilities indicated in Table 9 as being most critical and (2) the possible increase in severity of many vulnerabilities reported as being minimal. Even with this latter increase, however, munitions-related vulnerabilities are likely to remain small.

Although capacity utilization is just one of the many factors ultimately determining a sector's (or firm's) ability to successfully meet a surge demand for its output, it does provide a means of measuring this ability by comparing required output demand with available excess production capacity. This is precisely what is carried out in Table 12, in which it is seen that (based solely on capacity utilization considerations) every supplier sector has sufficient excess capacity to meet demands on it that would accompany a 100 percent surge in DoD demand on any one given defense sector. Moreover, Table 14 indicates that with one exception (the Industrial Patterns sector), every supplier sector has the excess capacity to meet even a 100 percent across-the-board surge for all defense materiel.[3] Even if this 100 percent figure is varied among defense sectors to more accurately reflect a conceivable conflict surge demand, it is still likely that (according to available excess capacity figures) every sector would have sufficient excess capacity to meet the demand.

Of course, these conclusions are all based on analysis of product transactions between whole sectors of the economy and are not necessarily accurate reflections of the transactions and operations of a given firm in a defense-production chain. The only reliable means of gaining information on the operation of the defense industrial base at a firm-to-firm level is by direct investigation at this level. A methodology for pursuing such an attack, as well as the results of an actual study of three defense-supplier sectors, judged by this analysis to be among the potentially most vulnerable to surge, is the subject of a companion report [2].

QUALIFICATION OF THE RESULTS

Inherent in any quantitative study such as this are questions of consistency and reliability concerning the data used, the quantities calculated, and the conclusions drawn. The most important aspects of the data analyzed are the input-output coefficients, for they indicate to what degree a given defense sector depends on each sector of the economy. These coefficients make up one of three tables that constitute the BEA's Input-Output Structure of the U.S. Economy. As described earlier, the most recent such studies at the 367-sector level of disaggregation are for the years 1963 and 1967. Many studies [7,8,9,10] have been made on the stability of these coefficients, the consensus being that changes in most cases are slow and orderly and due in part to a combination of technological changes, product mixes, capacity utilization, and current business trends. (One study [7] reports, for example, that between 1947 and 1958, the average difference in coefficients was 16 percent.)

As a hedge against possible changes in these coefficients, the analysis has been carried out from four different perspectives--two based on 1963 coefficients and two on 1967 coefficients. Although numbers do vary from year to year, the conclusions to be drawn in terms of rank ordering of sectors heavily relied on remain quite stable. There is thus evidence in support of the contention that the results are largely representative of the current economy.

In addition to the uncertainty arising from the use of input-output coefficients, similar qualifications must be imposed on the remainder of the data base. To begin with, there is the problem of trying to reconcile the two different industrial classification schemes--one used by the BEA in presenting their input-output tables, and one used by the Census bureau in presenting their total sector output, DoD sales, and capacity utilization figures. Second, for reasons of confidentiality, data on sectors whose total output comes from a very small number of firms are often not revealed in Census bureau tables. Each of these problems necessitated making various estimates and extrapolations based on alternate sources of information.

An additional problem concerned the treatment of secondary output, which varied not only between the BEA and Census bureau tables, but also from one Census bureau table to the next. In reporting 1975 shipments of $5237 million to the DoD by the Radio/TV Communication Equipment sector, the Census bureau does not distinguish between the part of the sum that was actually communication equipment, and the part that was secondary output produced by the Communication sector. At the same time, the sum does not include shipments to the DoD of communication equipment produced as secondary output by other industries. Moreover, no distinction is made between parts of the total that represent prime contract and subcontract work. To arrive at the figure of $3595 million for actual DoD purchases (as reported in Table 1), it was necessary to use prime and subcontract percentage figures as reported for the totality of this sector's federal government shipments (including shipments to DoD, NASA, ERDA, etc.).

Finally, the accuracy and reliability of the numerical results (as reflected in the tables) depend directly on the accuracy and reliability of the published data sources. This is especially true of the Census bureau tables on sector output, DoD shipments, and capacity utilization, each of which presents total sector estimates based on a small sample survey. Reported standard errors of estimate are for the most part less than 5 percent for each of the first two tables, yet at times they are disturbingly high (up to 81 percent) for the last table.

In addition to the numerical qualifications that must be imposed on the data, there are also interpretive qualifications that merit discussion. First, if DoD demand on a given defense sector increases 100 percent, then each supplier sector must increase by 100 percent the part of its output that directly or indirectly goes to the given defense sector. If the production of this output involves labor, inputs, equipment, or facilities different from that involved in its remaining output, this supplier's vulnerability might be much greater than indicated by the percent increase in total output necessary to accommodate the demand. For example, to accommodate a 100 percent increase in DoD demand on the Sighting and Fire Control Equipment sector, the Optical Instruments and Lenses sector must increase its total output by 2.5 percent. Of this total output, Sighting and Fire Control equipment products constitute only 7 percent. Thus, depending on the degree of specialization involved in producing such products, the 2.5 percent figure should more realistically be replaced by one as high as perhaps 36 percent.

A second point to consider is that the study has focused on potential lower-tier vulnerabilities and has not emphasized the possibly heavy burdens that might be placed on prime DoD suppliers (i.e., the 13 defense sectors). So although the analysis (as reported in Table 9) shows, for example, that no supplier sector required even as much as a 3 percent increase in total output to accommodate a 100 percent increase in DoD demand on the Non Small Arms Ammunition sector, such an increase would necessitate a 104 percent increase in this sector's own total output.

Finally, a supplier sector's ability to respond to an accelerated demand depends on many factors, not the least of which is capacity utilization. The rate of utilization, but just as important the flexibility, with which both the used and unused capacity can be distributed between commercial and defense production must be considered. Utilization rates vary (sometimes substantially) from year to year and are determined on the basis of a questionnaire survey of the larger firms in each sector. Because no definition of capacity utilization is applicable to all industries and situations, there are numerous problems inherent in its measurement.

CONCLUSION

This report had three primary objectives: to outline the underlying structure of the defense industrial base in terms of intersector dependence, paying special attention to the lower tiers and their support of final production; to suggest a methodology by which potential sector vulnerability to military surge can be measured and rank the supplier sectors of each defense sector according to this vulnerability; and to attempt (using capacity utilization) to assess these potential vulnerabilities and thus determine to what extent a sector can meet the added demands of surge.

Instead of interpreting surge in light of the demands of several different conceivable crisis scenarios, this study adopted a parametric approach and assumed (for the sake of analysis) a doubling in DoD demand for all combat materiel. To accommodate such a surge, each defense-related supplier sector must double the part of its output that supports final production of this materiel. The analysis has shown, however, that (with a few exceptions) such a doubling in output amounts to an increase in total output (defense and non-defense) of less than 10 percent.[4] Moreover (with one exception), each defense-related supplier sector has sufficient excess production capacity to accommodate a 100 percent across-the-board surge, on the assumption that all excess capacity can be used for defense-related production.

The foundation of this study has rested on the use of input-output analysis as the most revealing of the available means of describing the intersector transfer of goods within the defense industrial base. As is the case with any model that attempts to analyze a system as large as the U.S. economy, there are questions of accuracy and reliability concerning both the input-output data and all other data used and produced during the course of the analysis. Although the majority of the presentation is quantitative, it is really intended that the reader extract from each table and each discussion not only a quantitative but also a qualitative impression of the relative surge capabilities of various industries. In particular, the results show that almost without exception, the lower tiers of the defense

industrial base seem capable of supporting a substantial surge in DoD purchases of combat materiel. However, this type of overview analysis of the U.S. economy is inherently rather crude. To ensure that none of the potential vulnerabilities are real, detailed information on a firm-by-firm basis for the concerned sectors would be necessary.

NOTES TO SECTION V

1. For example, in an extended version of Table 9 (see App. E), the rankings of the 99 supplier sectors of the Aircraft sector have been compared for 1963 and 1967, and a linear correlation coefficient of approximately .90 obtained.

2. Percent increases in DoD purchases from each of the 13 defense sectors during the peak years of the Vietnam war are summarized below:

Defense Sector	Increase in 1966 DoD Purchases Over 1965	Increase in 1967 DoD Purchases Over 1966	Increase in 1968 DoD Purchases Over 1967
Whole Systems			
Complete Guided Missiles	20	28	12
Tanks & Tank Components	2	56	26
Aircraft	16	18	-1
Shipbuilding & Repairing	17	-5	-14
Spares & Replacements			
Sighting & Fire-Control Equip.	(a)	(a)	(a)
Aircraft Engines & Parts	10	17	-15
Aircraft Propellers & Parts	(a)	(a)	(a)
Misc. Aircraft Equipment	10	4	-14
Munitions			
Non Small Arms Ammunition	46	148	115
Small Arms	(a)	(a)	(a)
Small Arms Ammunition	(a)	(a)	(a)
Misc. Ordnance & Accessories	196	88	-51

[a]For reasons of confidentiality, DoD purchase figures were not reported for this sector.

3. The parametric surge assumption guarantees that some of the 13 defense sectors will appear to have insufficient excess capacity. These are not included in this comment on supplier sectors.

4. And with no exception less than 25 percent.

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Appendix A

A MODEL FOR INPUT-OUTPUT ANALYSIS

Input-output analysis was introduced by W. Leontief in the 1930s as a means of quantitatively analyzing an economy in terms of the interdependence of its various industrial sectors and the requirement to satisfy outside (extra-industrial) demand. This appendix offers a brief description of an input-output model as it might be applied to the U.S. economy.

Suppose that the national economy is divided into n sectors, each of which provides specific goods or services to both each other and to the "outside." Let x_i denote the annual output (measured in appropriate units) of sector i, and x_{ij} the amount of the product of sector i absorbed annually as input by sector j. As a measure of the interdependence among sectors, $a_{ij} = x_{ij}/x_j$ will denote the quantity of the output of sector i absorbed by sector j per unit of its total output, and A will denote the n x n structural matrix

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ & & \cdots & \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

Finally, let y_i denote the amount of the product of sector i demanded annually by the "outside."

The output of a given sector is either absorbed by other sectors (including possibly itself) or goes to satisfy outside demand. Thus

$$x_i = \sum_{k=1}^{n} x_{ik} + y_i, \quad 1 \le i \le n.$$

Replacing x_{ik} by $a_{ik}x_k$ gives

$$x_i - \sum_{k=1}^{n} a_{ik}x_k = y_i, \quad 1 \le i \le n.$$

This is a system of n equations in n variables, and can be written in vector notation as

$$(I - A)\, x = y,$$

where $x = (x_1, x_2, \ldots, x_n)$ is the output vector, I is the n x n identity matrix, and $y = (y_1, y_2, \ldots, y_n)$ is the demand vector.

The system can be solved for x:

$$x = (I - A)^{-1} y.$$

This determines each of the outputs x_i as a linear combination of the demands $y_1, y_2, \ldots, y_n$:

$$\begin{aligned} x_1 &= B_{11}y_1 + B_{12}y_2 + \ldots + B_{1n}y_n \\ &\ldots \\ x_n &= B_{n1}y_1 + B_{n2}y_2 + \ldots + B_{nn}y_n. \end{aligned}$$

The effect on x of a change in the demand vector y is readily seen. In particular, an increase of one unit in the demand y_j gives rise to an increase of B_{ij} units in the output x_i of sector i.

To guarantee that for any given demand vector y, there is a solution x for which each output x_i is positive, it is necessary that each coefficient B_{ij} be non-negative. If this is not the case, then the combined input requirements of all sectors will exceed the combined productive capabilities, and the economy will be unable to sustain itself. A necessary and sufficient condition on the structural matrix A so that all entries of $B = (I - A)^{-1}$ are non-negative is that there exist n positive numbers $c_1, c_2, \ldots, c_n$ such that

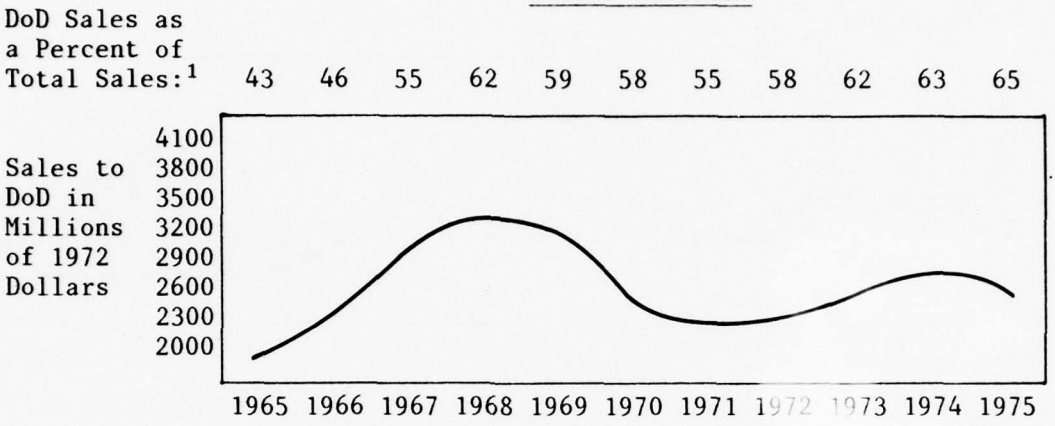
$$\sum_{j=1}^{n} c_j a_{ij} < c_i, \quad 1 \le i \le n.$$

In almost all cases in which the structural matrix A of a national economy has been determined from observed interindustry flows, this condition has been satisfied.

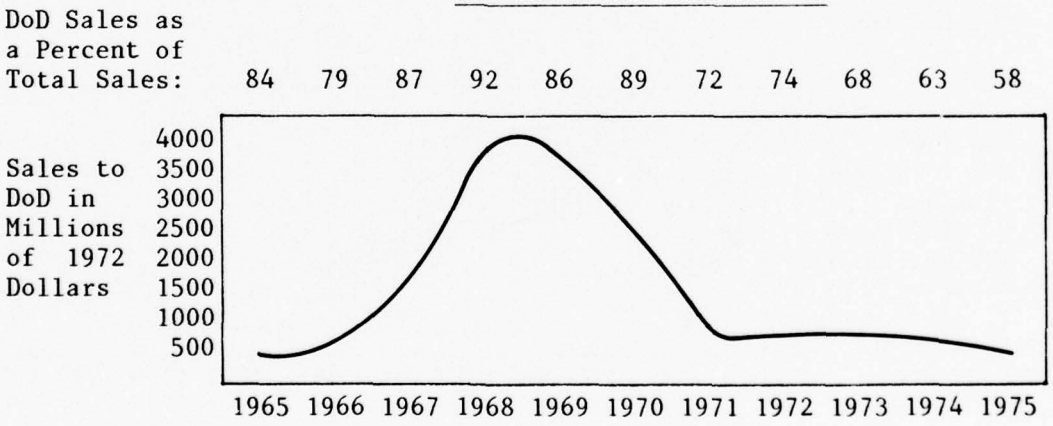
Appendix B

PRIME CONTRACT SALES TO THE DOD BY DEFENSE SECTOR, 1965-1975

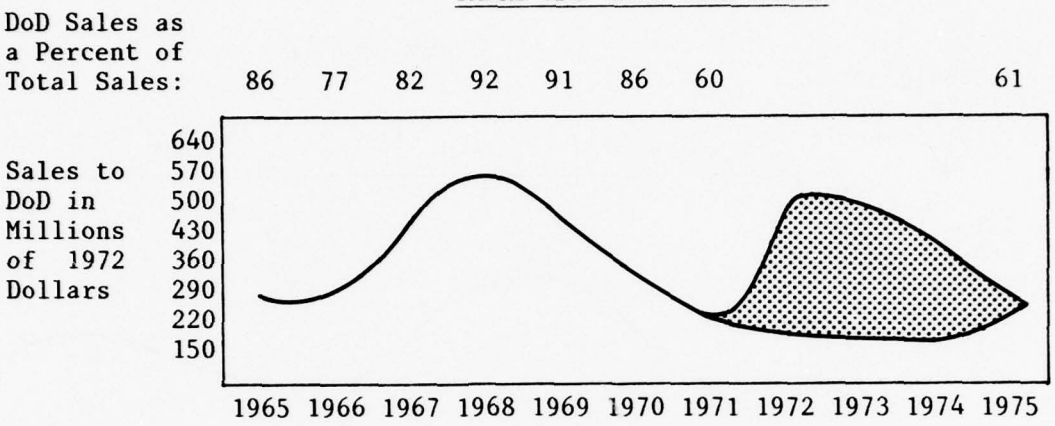
GUIDED MISSILES



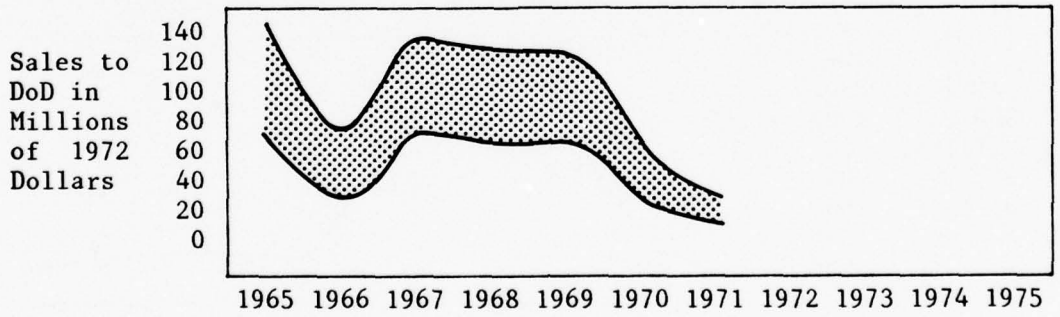
NON SMALL ARMS AMMUNITION



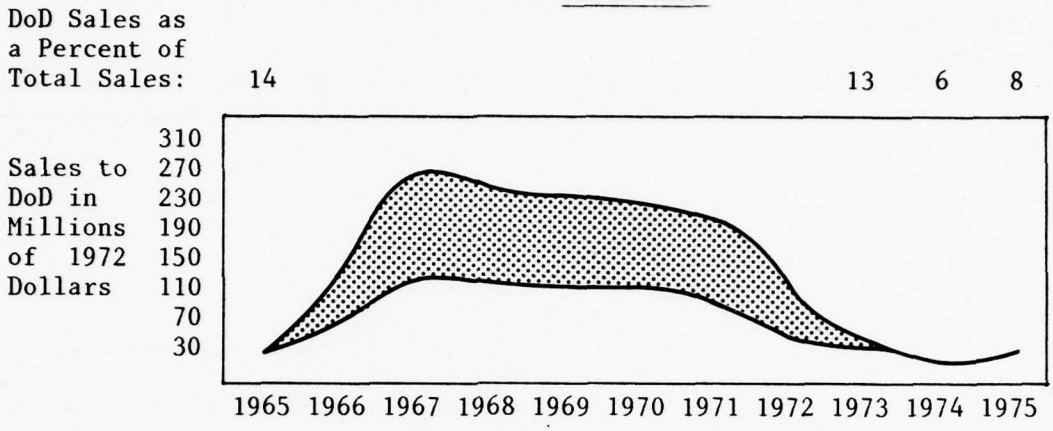
TANKS AND TANK COMPONENTS[2]



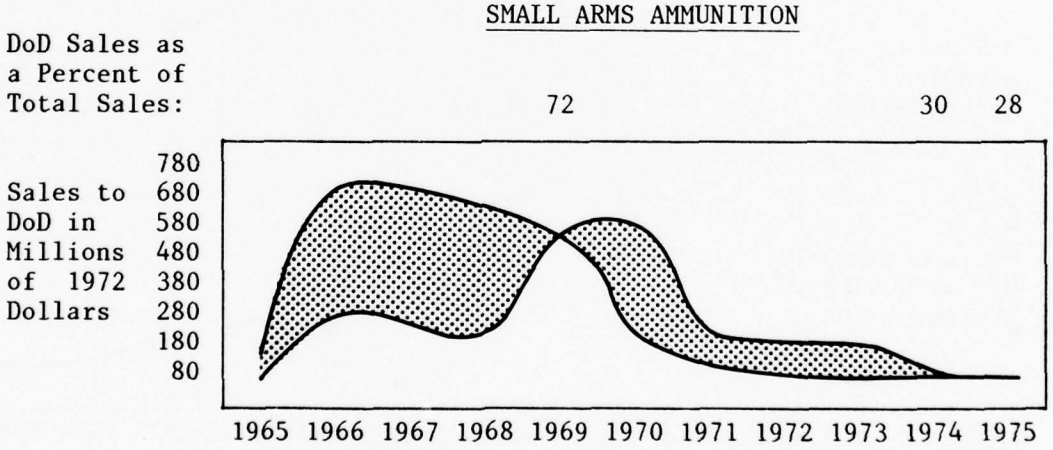
SIGHTING AND FIRE CONTROL EQUIPMENT[3]



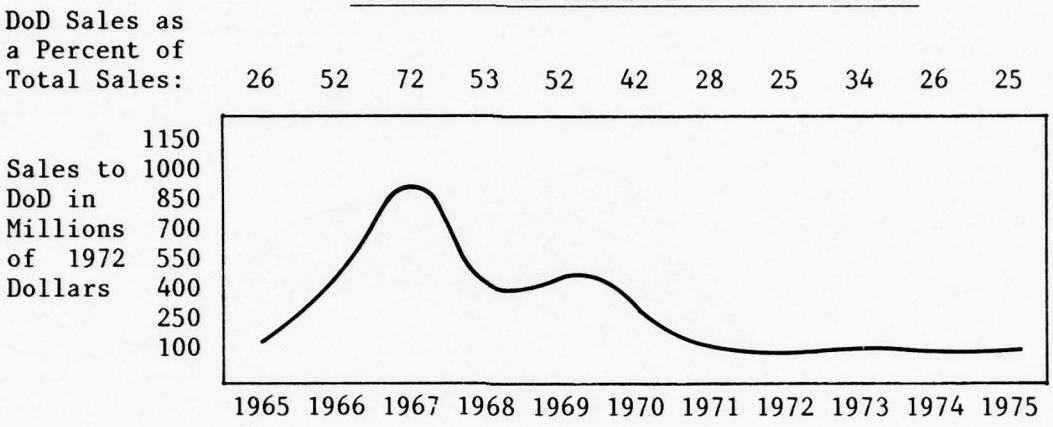
SMALL ARMS



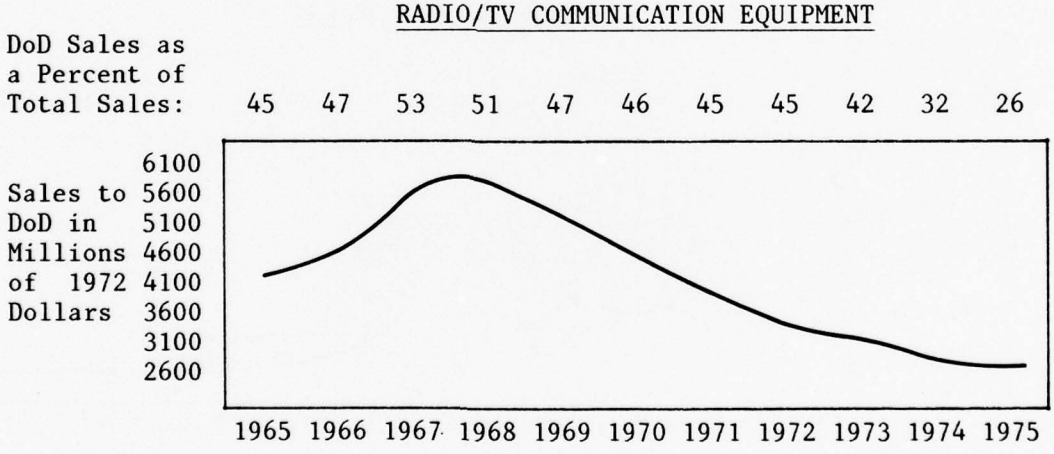
SMALL ARMS AMMUNITION



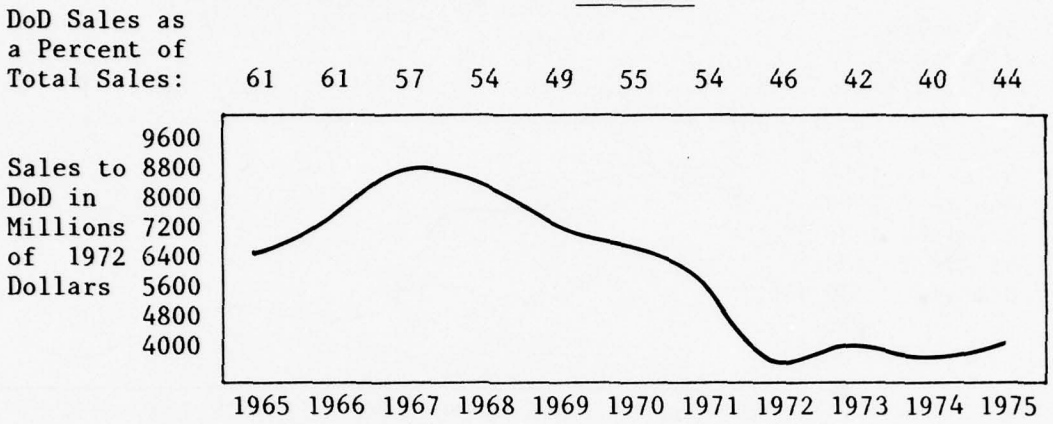
MISCELLANEOUS ORDNANCE AND ACCESSORIES



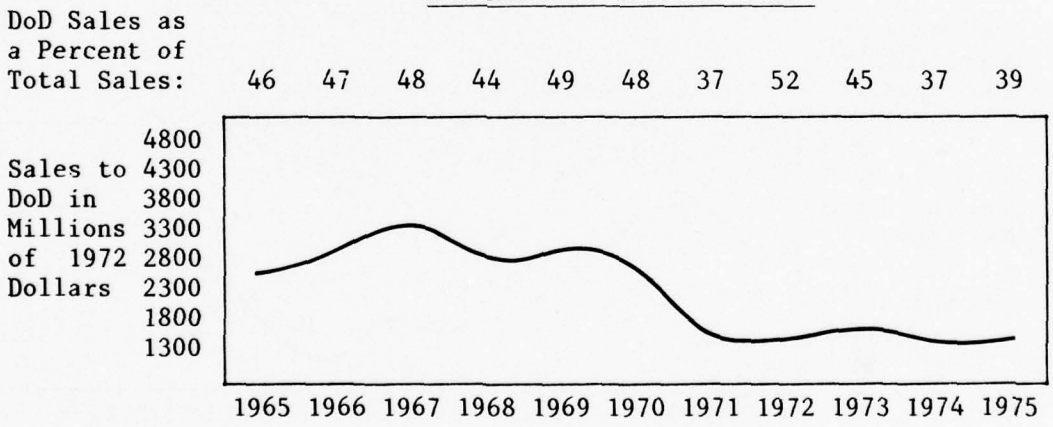
RADIO/TV COMMUNICATION EQUIPMENT



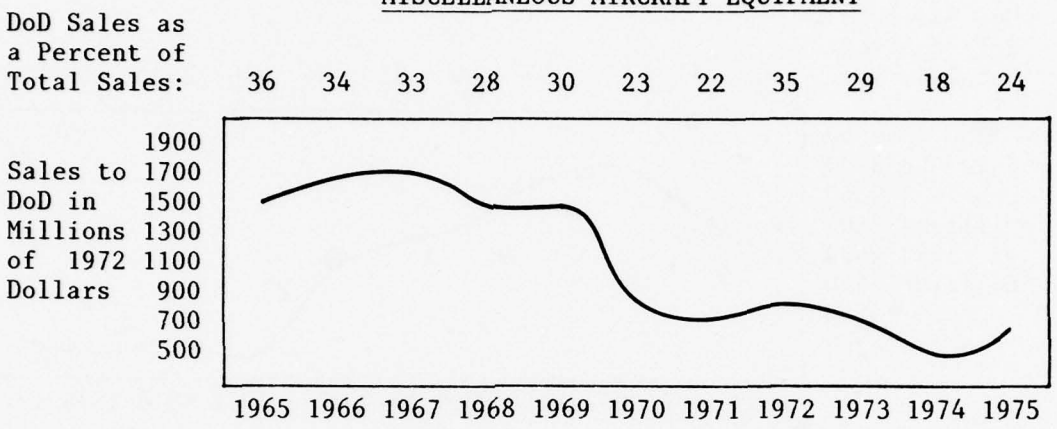
AIRCRAFT



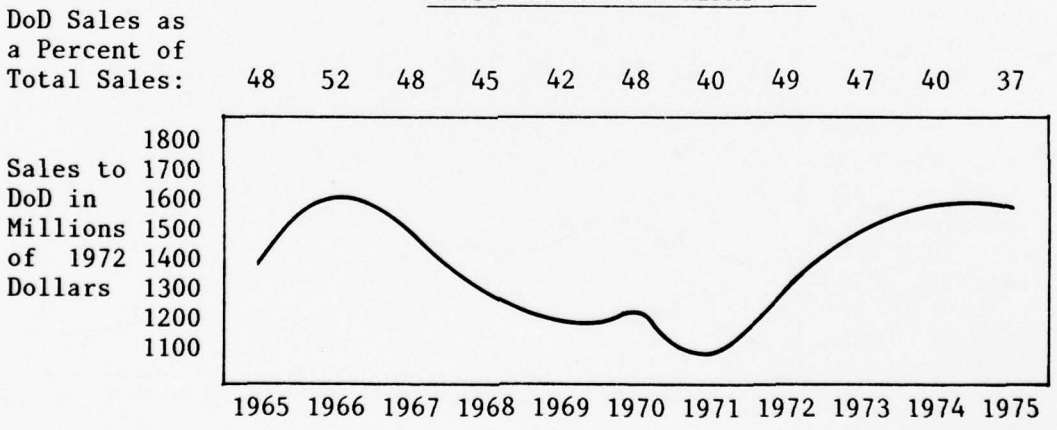
AIRCRAFT ENGINES AND PARTS



MISCELLANEOUS AIRCRAFT EQUIPMENT[4]



SHIPBUILDING AND REPAIRING



NOTES TO APPENDIX B

1. For example (to interpret the numbers along the top of the table), in 1975, 65 percent of the total output of the Guided Missiles sector was sold directly to the DoD.

2. For reasons of confidentiality, DoD purchase data for sectors whose total output comes from a small number of firms are often not revealed and are indicated only as lying between certain bounds. The shaded area in some of the graphs represents the region in which the actual DoD purchase figure is known to lie.

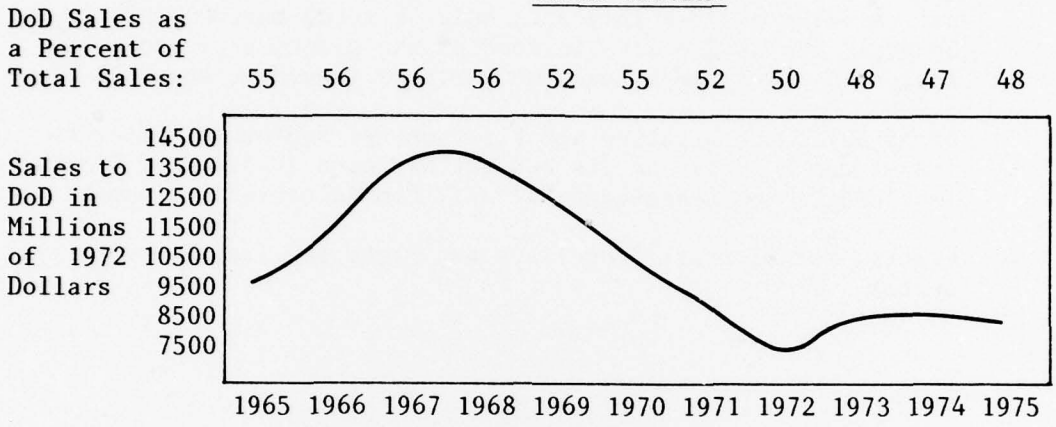
3. As of 1972, the Sighting and Fire Control Equipment sector no longer was a sector on its own but had been absorbed by Optical Instruments and Lenses and Radio/TV Communication Equipment.

4. Figures for Aircraft Propellers and Parts are included with this sector.

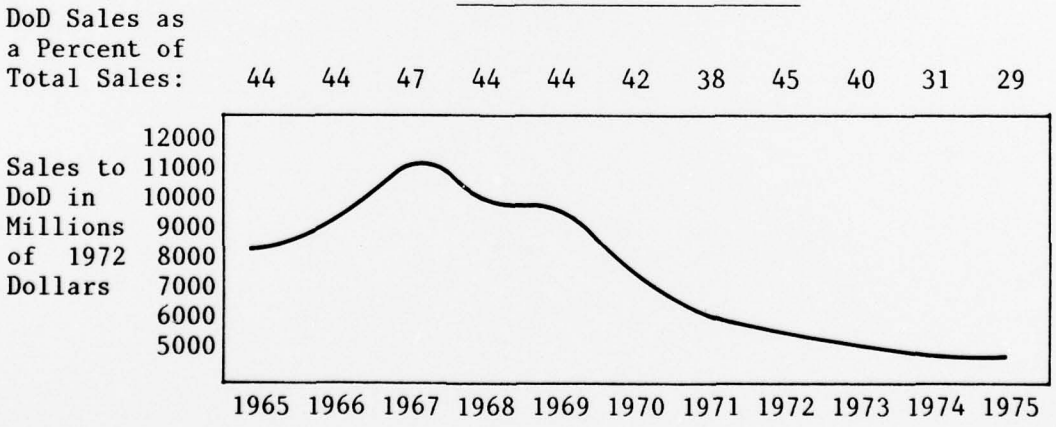
Appendix C

PRIME CONTRACT SALES TO THE DOD BY DEFENSE PRODUCT GROUP, 1965-1975

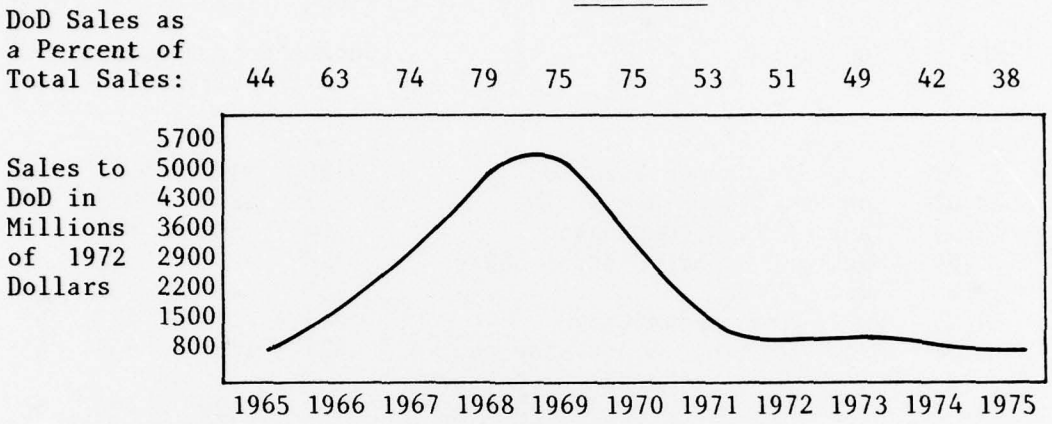
WHOLE SYSTEMS



SPARES AND REPLACEMENTS



MUNITIONS


DoD Sales as a Percent of Total Sales:
44 63 74 79 75 75 53 51 49 42 38
Sales to DoD in Millions of 1972 Dollars
5700
5000
4300
3600
2900
2200
1500
800
1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975

Appendix D

99 DEFENSE-RELATED INDUSTRIAL SECTORS

BEA	Supplier	1963 Output[a]	1967 Output[a]	1975 Output	1975 CU[b] %
		($ Millions)			
Ordnance & Accessories					
13.01	Complete Guided Missiles	4198	5127	4647	83
13.02	Non Small Arms Ammunition	565	2850	973	40
13.03	Tanks & Tank Components	504	500	573	62
13.04	Sighting & Fire Control Equip.	228	231	143	54
13.05	Small Arms	183	475	555	80
13.06	Small Arms Ammunition	213	648	477	50
13.07	Misc. Ordnance & Accessories	425	1084	542	45
Lumber & Wood Products, Except Containers					
20.03	Hardwood Dimensions & Flooring	429	429	474	68
20.09	Misc. Wood Products	976	1394	2591	76
Wooden Containers					
21.00	Wooden Containers	420	543	493	69
Chemicals & Selected Chemical Products					
27.01	Industrial Chemicals	12613	17041	25246	77
27.04	Misc. Chemical Products	2715	3889	6056	72
Plastics and Synthetic Materials					
28.01	Plastics Materials & Resins	3239	4377	8725	73
28.02	Synthetic Rubber	946	1147	1805	79
Rubber & Misc. Plastics Products					
32.03	Misc. Rubber Products	2856	647	3998	75
32.04	Misc. Plastics Products	3815	694	15572	72
Glass & Glass Products					
35.01	Glass & Glass Products	1921	548	3902	80
Stone & Clay Products					
36.08	Porcelain Electrical Supplies	137	253	321	64
36.16	Abrasive Products	745	876	1234	68
36.17	Asbestos Products	550	617	882	65
36.18	Gaskets & Insulations	323	413	802	74
36.20	Mineral Wool	400	463	1049	77
36.22	Misc. Nonmet. Mineral Products	107	118	259	87
Primary Iron & Steel Manufacturing					
37.01	Basic Steel Products	19989	25156	39906	68
37.02	Iron & Steel Foundries	3421	4657	9101	74
37.03	Iron & Steel Forgings	1182	1712	2511	79
37.04	Misc. Primary Metal Products	323	679	1086	77

BEA	Supplier	1963 Output[a]	1967 Output[a]	1975 Output	1975 CU[b] %
		($ Millions)			
Primary Nonferrous Metals Manufacturing					
38.01	Primary Copper	2163	2646	2372	78
38.02	Primary Lead	514	677	838	68
38.03	Primary Zinc	364	479	403	72
38.04	Primary Aluminum	1970	2833	3349	61
38.05	Misc. Primary Nonferrous Metals	1003	1158	1560	62
38.06	Secondary Nonferrous Metals	928	1313	2692	64
38.07	Copper Rolling & Drawing	1842	2609	2325	62
38.08	Aluminum Rolling & Drawing	2310	3130	4845	67
38.09	Misc. Nonfer. Rolling/Drawing	743	1118	1681	77
38.10	Nonf. Wire Drawing/Insulating	2376	4022	4925	69
38.11	Aluminum Castings	742	1049	1532	65
38.12	Brass, Bronze, Copper Castings	351	518	493	81
38.13	Misc. Nonferrous Castings	377	653	529	68
38.14	Nonferrous Forgings	255	493	520	72
Fabricated Structural Metals Products					
40.04	Fabricated Structural Steel	1955	2992	4553	67
40.06	Fabricated Plate Work	1839	2932	6017	76
Screw Machine Products & Metal Stampings					
41.01	Screw Machine Products	1966	2929	3931	60
41.02	Metal Stampings	3002	6384	9816	79
Misc. Fabricated Metal Products					
42.03	Misc. Hardware	1898	2499	3639	74
42.04	Coating & Engraving	836	1261	2246	77
42.05	Misc. Fabricated Wire Products	1569	2015	1855	77
42.07	Steel Springs	226	319	404	52
42.08	Pipe, Valves, & Pipe Fittings	2116	3064	5941	65
42.10	Metal Foil & Leaf	364	461	627	76
42.11	Misc. Fabricated Metal Prods.	840	1348	2049	61
Engines & Turbines					
43.01	Steam Engines & Turbines	734	1291	2583	85
43.02	Internal Combustion Engines	1674	2534	5212	72
Metalworking Machinery & Equipment					
47.01	Machine Tools (Metal Cutting)	1224	2526	2338	69
47.02	Machine Tools (Metal Forming)	547	864	1019	69
47.03	Special Dies & Tools	2719	4362	4810	73
47.04	Misc. Metalworking Machinery	854	1267	1791	78
General Industrial Machinery & Equipment					
49.01	Pumps & Compressors	1547	2402	4077	74
49.02	Ball & Roller Bearings	1031	1431	2046	75
49.03	Blowers & Fans	364	596	1244	78
49.04	Industrial Patterns	174	251	314	97
49.05	Power Transmission Equipment	1064	1486	2521	70
49.06	Industrial Furnaces & Ovens	308	536	532	73
49.07	Misc. Industrial Machinery	890	1174	1709	57
Machine Shop Products					
50.00	Machine Shop Products	2257	3940	5800	81
Office, Computing, & Accounting Machines					
51.01	Computing & Related Machines	3082	5356	9346	63

BEA	Supplier	1963 Output[a]	1967 Output[a]	1975 Output	1975 CU[b] %
		($ Millions)			
Elec. Transmission & Distribution Equip.					
53.01	Electric Measuring Instruments	939	1505	1960	62
53.02	Transformers	782	1288	1782	64
53.03	Switchgear, Switchboard Appar.	1206	1913	2480	67
53.04	Motors & Generators	1988	2888	3686	68
53.05	Industrial Controls	819	1312	1878	70
53.06	Welding Apparatus	362	515	921	51
53.07	Carbon & Graphite Products	244	343	565	61
53.08	Misc. Elec. Industrial Appar.	320	463	673	62
Electric Lighting & Wiring Equipment					
55.02	Lighting Fixtures	1243	1700	2374	71
55.03	Wiring Devices	1238	1660	2314	60
Radio/TV Communication Equipment					
56.01	Radio/TV Receiving Sets	2787	4553	3531	67
56.03	Telephone/Telegraph Apparatus	1817	2776	4738	63
56.04	Radio/TV Communication Equip.	7739	9900	10672	61
Electronic Components & Accessories					
57.01	Electron Tubes	1032	1584	1066	65
57.02	Semiconductors	720	1354	3032	66
57.03	Misc. Electronics Components	2854	5426	5702	64
Misc. Electrical Machinery					
58.01	Storage Batteries	548	597	1291	77
58.02	Primary Batteries, Wet & Dry	213	356	449	71
58.04	Engine Electrical Equipment	1095	1574	2095	84
58.05	Misc. Electrical Equipment	249	386	482	57
Aircraft & Parts					
60.01	Aircraft	6347	11264	11204	52
60.02	Aircraft Engines & Parts	4364	5637	5358	62
60.03	Aircraft Propellers & Parts	210	211	90	58
60.04	Misc. Aircraft Equipment	4751	6753	5717	60
Misc. Transportation Equipment					
61.01	Shipbuilding & Repairing	1687	2557	5513	73
Scientific Instruments & Supplies					
62.01	Engineering & Scientific Inst.	865	1301	1522	73
62.02	Mechanical Measuring Devices	1279	1687	2591	74
62.03	Automatic Temperature Controls	561	656	709	71
62.07	Watches, Clocks, & Parts	557	959	1047	67
Optical Equipment & Supplies					
63.01	Optical Instruments & Lenses	316	581	1036	47
63.02	Ophthalmic Goods	308	470	648	55
63.03	Photographic Equip. & Supplies	1936	3774	7308	79

[a] 1967 and 1963 output figures are taken from [14] and [16] respectively, and those for 1975 are taken from [13]. Because of differences in the BEA and SIC classification schemes, many of the 1975 sector output figures reported here differ slightly from those given in [13].

[b] This column lists the (fourth quarter) 1975 capacity utilization (CU) rates for each of the 99 defense-related supplier sectors. Figures are computed based on tables in [15].

Appendix E

LOWER-TIER POTENTIAL VULNERABILITY TO SURGE

This appendix presents expanded versions of Tables 9-11, incorporating results for all 99 defense-related supplier sectors, rather than for just the top-ranking ones (as given in the tables). To measure the effects of a military surge on the industrial base, it is assumed (as before) that DoD demand for products of each of the 13 defense sectors increases 100 percent. Table E.1 lists the corresponding percent increase in total output of each of the 99 supplier sectors based on each of the following three interpretations of a 100 percent surge:

- o A 100 percent surge on a particular defense sector.
- o A 100 percent surge for all defense products belonging to one of the three primary groups: whole systems, spares and replacements, and munitions.
- o A 100 percent across-the-board surge for products of all 13 defense sectors.

For example, the Complete Guided Missiles sector (13.01) would have to increase its total output by 1.7 percent to accommodate a 100 percent surge in DoD demand for Aircraft (60.01); 2.6 percent to accommodate a 100 percent surge in DoD demand for products of all five spares and replacements sectors; 81.3 percent to accommodate a 100 percent across-the-board surge in DoD demand for all combat materiel.

Finally, although the text presents vulnerability figures for four different perspectives of the defense industrial base, this appendix is restricted to figures based on 1967 input-output coefficients and 1975 sector output and DoD purchase figures. (The relative rankings for each of the four perspectives are quite similar.)[1]

[1]A listing of the 99 defense-related industrial sectors by BEA identification number can be found in App. D.

Table E.1

REQUIRED PERCENT INCREASE IN SUPPLIER SECTOR OUTPUT FOR 100% SURGE ON A GIVEN DEFENSE SECTOR

	BEA ID #	D 13.01	E 13.02	F 13.03	E 13.04	N 13.05	S 13.06	E 13.07	S 56.04	E 60.01	C 60.02	T 60.03	O 60.04	R 61.01	S	Whole Systems	Spares	Munitions	Total
	13.01	76.4	0.2	0.0	0.0	0.0	0.0	0.2	1.0	1.7	0.8	0.0	0.8	0.2		78.3	2.6	0.4	81.3
	13.02	0.5	104.0	1.7	0.0	0.0	0.0	1.1	1.4	1.0	0.1	0.0	0.6	0.0		3.3	2.1	105.2	110.6
S	13.03	0.0	0.2	67.4	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.0		67.6	0.1	0.5	68.2
	13.04	0.6	0.0	0.0	70.9	0.0	0.0	0.0	3.5	5.5	0.4	0.0	0.6	0.0		6.2	75.4	0.1	81.6
	13.05	0.1	0.2	0.0	0.0	10.5	0.0	0.1	0.5	0.3	0.0	0.0	0.2	0.0		0.5	0.7	10.8	11.9
U	13.06	0.1	0.4	0.6	0.0	0.0	25.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.8	0.0	26.0	26.8
	13.07	0.8	0.5	0.7	0.1	0.1	0.0	31.8	0.5	1.4	0.2	0.0	0.9	0.3		3.2	1.7	32.3	37.3
	20.03	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1		0.2	0.1	0.3	0.7
P	20.09	0.1	0.9	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.5		0.7	0.2	1.0	1.9
	21.00	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.3	0.0	0.1	0.2		0.7	0.7	0.1	1.5
	27.01	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.0	0.0	0.1		0.4	0.3	0.4	1.2
P	27.04	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.1	0.0	0.0	0.1		0.4	0.3	0.2	0.9
	28.01	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.0	0.1	0.1		0.6	0.5	0.1	1.2
	28.02	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.1		0.4	0.3	0.1	0.8
L	32.03	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.5	0.9	0.2	0.1	0.1	0.1		1.5	0.8	0.1	2.4
	32.04	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.0	0.0	0.0		0.5	0.3	0.1	0.9
	35.01	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.2		0.4	0.5	0.0	0.9
I	36.08	0.3	0.1	0.0	0.0	0.0	0.0	0.0	1.5	0.5	0.1	0.0	0.1	0.1		0.9	1.8	0.1	2.7
	36.16	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.6	1.0	0.4	0.0	0.1	0.6		2.2	1.2	0.3	3.7
	36.17	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.2		0.4	0.2	0.0	0.6
E	36.18	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.8	0.0	0.3	0.3		1.3	1.3	0.1	2.7
	36.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1		0.2	0.1	0.0	0.3
	36.22	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.3	0.2	0.0	0.1	2.7		3.2	0.7	0.1	4.0
R	37.01	0.2	0.3	0.2	0.0	0.0	0.1	0.0	0.3	0.5	0.3	0.0	0.1	0.7		1.6	0.7	0.4	2.7
	37.02	0.1	0.1	0.5	0.0	0.0	0.0	0.0	0.1	0.4	0.4	0.0	0.1	0.4		1.4	0.7	0.1	2.2
	37.03	0.3	0.7	0.3	0.0	0.0	0.0	0.1	0.1	1.3	2.0	0.1	0.5	0.5		2.4	2.6	0.8	5.9
	37.04	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.6	1.6	0.7	0.0	0.5	0.5		2.5	1.8	0.2	4.5
	38.01	0.4	0.2	0.1	0.0	0.0	0.4	0.0	0.8	1.0	0.5	0.0	0.2	0.8		2.4	1.5	0.7	4.5
	38.02	0.2	0.2	0.1	0.0	0.0	0.3	0.0	0.3	0.5	0.5	0.0	0.1	0.5		1.3	0.9	0.5	2.7
S	38.03	0.7	0.3	0.2	0.0	0.0	0.1	0.1	0.9	1.7	0.9	0.0	0.3	0.8		3.4	2.2	0.6	6.2
	38.04	0.8	0.3	0.3	0.0	0.0	0.0	0.1	0.7	2.3	0.6	0.0	0.5	1.2		4.7	1.9	0.4	6.9
	38.05	0.5	0.3	0.1	0.0	0.0	0.0	0.1	0.9	1.6	2.3	0.0	0.3	1.3		3.5	3.6	0.4	7.5
E	38.06	0.3	0.1	0.1	0.0	0.0	0.1	0.0	0.3	0.8	0.4	0.0	0.2	0.5		1.6	0.9	0.3	2.8
	38.07	0.4	0.2	0.1	0.0	0.0	0.9	0.0	0.8	1.1	0.4	0.0	0.2	1.0		2.6	1.5	1.1	5.2
	38.08	0.8	0.3	0.3	0.0	0.0	0.0	0.1	0.6	2.6	0.4	0.0	0.6	0.5		4.2	1.6	0.4	6.3
C	38.09	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.8	2.1	1.4	0.6	0.6	0.6		3.5	2.7	0.2	6.5
	38.10	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.7	0.4	0.1	0.0	0.1	0.3		1.0	0.8	0.1	1.9
	38.11	0.6	0.3	0.2	0.1	0.0	0.0	0.1	1.0	1.8	1.6	0.0	0.4	0.3		3.0	3.1	0.4	6.5
T	38.12	0.5	0.1	0.1	0.3	0.0	0.0	0.1	0.9	1.2	0.5	0.0	0.3	1.3		3.1	2.0	0.2	5.4
	38.13	2.1	0.2	0.1	0.1	0.0	0.0	0.5	1.8	2.0	1.7	0.0	0.6	0.6		4.7	4.3	0.7	9.8
	38.14	1.8	0.7	1.0	0.0	0.0	0.0	0.1	0.5	8.5	7.4	0.1	2.4	0.5		11.9	10.3	0.8	23.0
O	40.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1		1.1	0.0	0.0	1.2
	40.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.2		1.3	0.1	0.0	1.4
	41.01	0.7	0.2	0.1	0.0	0.0	0.0	0.1	1.2	2.2	0.7	0.0	0.5	0.3		3.3	2.4	0.3	6.1
R	41.02	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.6	0.9	0.3	0.0	0.1	0.1		1.3	1.1	0.2	2.6
	42.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	0.1	0.0	0.1	0.1		2.4	0.3	0.0	2.7
	42.04	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.9	1.8	1.1	0.0	0.3	0.6		3.1	2.4	0.3	5.8
S	42.05	0.2	0.1	0.0	0.0	0.0	0.0	0.1	1.1	0.6	0.2	0.0	0.1	0.3		1.3	1.4	0.3	2.9
	42.07	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.1	0.0	0.1	1.2		1.8	0.4	0.1	2.3

Table E.1 (continued)

	BEA ID #	D 13.01	E 13.02	F 13.03	E 13.04	N 13.05	S 13.06	E 13.07	S 56.04	E 60.01	C 60.02	T 60.03	O 60.04	R 61.01	S	Whole Systems	Spaces	Munitions	Total
	42.08	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.6	0.3	0.0	0.1	0.6		1.5	0.5	0.1	2.1
	42.10	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.2	0.0	0.0	0.0		0.4	0.7	0.0	1.1
S	42.11	0.2	1.5	0.1	0.0	0.0	0.0	0.0	0.4	0.4	0.2	0.0	0.1	0.6		1.2	0.7	1.6	3.5
	43.01	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.2	3.2		3.7	0.5	0.0	4.2
	43.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.8		1.0	0.3	0.0	1.3
U	47.01	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.0	0.1	0.2		0.9	0.6	0.1	1.7
	47.02	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.3	0.0	0.1	0.1		1.1	0.7	0.2	1.9
	47.03	0.8	0.3	0.3	0.0	0.0	0.0	0.1	0.9	2.0	1.6	0.0	0.5	1.0		4.1	3.2	0.4	7.7
P	47.04	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.1	0.1		0.6	0.4	0.1	1.1
	49.01	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	0.1	0.0	0.3	1.6		3.2	0.6	0.1	3.8
	49.02	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.9	0.6	0.0	0.3	0.3		1.6	1.1	0.1	2.9
P	49.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3		0.4	0.1	0.0	0.5
	49.04	0.3	0.1	0.5	0.0	0.0	0.0	0.0	0.3	1.2	0.7	0.0	0.2	0.7		2.7	1.2	0.2	4.2
	49.05	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.0	0.1	2.3		2.7	0.4	0.1	3.2
L	49.06	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.3	0.0	0.1	0.2		0.7	0.5	0.1	1.3
	49.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0		0.1	0.1	0.0	0.2
	50.00	1.2	0.4	0.2	0.0	0.0	0.0	0.0	0.6	3.9	2.1	0.1	0.7	0.6		5.8	3.4	0.4	9.7
I	51.01	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0	0.0		0.2	0.6	0.0	0.8
	53.01	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.5	1.0	0.0	0.0	0.1	0.0		1.2	2.6	0.0	3.9
	53.02	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.1		0.3	0.3	0.0	0.6
E	53.03	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.3	0.1	0.0	0.1	0.2		0.7	1.4	0.0	2.1
	53.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.3	0.0	0.2	0.5		1.2	0.9	0.1	2.2
	53.05	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.9	0.4	0.1	0.0	0.2	0.7		1.4	1.1	0.1	2.6
R	53.06	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.1	0.8		1.1	0.3	0.0	1.4
	53.07	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.7	0.5	0.3	0.0	0.1	0.4		1.2	1.1	0.2	2.5
	53.08	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.1	0.0	0.0	0.1		0.5	0.9	0.0	1.4
	55.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1		0.2	0.1	0.0	0.3
	55.03	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.4	0.1	0.0	0.1	0.1		0.6	1.8	0.1	2.5
	56.01	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.2	0.0	0.0	0.0	0.0		0.3	1.2	0.1	1.6
S	56.03	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.0	0.0		0.3	1.1	0.0	1.4
	56.04	0.9	0.2	0.1	0.3	0.0	0.0	0.1	35.4	3.1	0.1	0.0	0.2	0.0		4.1	36.1	0.2	40.4
	57.01	0.4	0.1	0.0	0.2	0.0	0.0	0.0	5.1	0.8	0.1	0.0	0.1	0.0		1.2	5.4	0.1	6.7
E	57.02	0.8	0.3	0.0	0.1	0.0	0.0	0.0	4.5	0.6	0.0	0.0	0.1	0.1		1.4	4.7	0.3	6.4
	57.03	2.5	0.5	0.0	0.2	0.0	0.0	0.1	11.1	2.5	0.1	0.0	0.3	0.0		5.1	11.8	0.5	17.4
	58.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.0	0.0	0.1
C	58.02	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.2	0.0	0.0	0.0	0.0		0.3	1.2	0.0	1.5
	58.04	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.2	1.1	1.1	0.0	0.1	0.2		1.7	1.4	0.1	3.2
	58.05	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.1		0.5	0.3	0.0	0.8
T	60.01	3.7	0.1	0.0	0.0	0.0	0.0	0.0	0.3	51.8	0.4	0.0	2.0	0.0		55.5	2.7	0.1	58.3
	60.02	1.0	0.6	0.5	0.0	0.0	0.0	0.1	0.6	7.3	48.3	0.1	0.7	0.3		9.0	49.7	0.7	59.5
	60.03	4.3	0.4	0.2	0.0	0.0	0.0	0.1	0.7	22.3	17.9	40.2	7.3	0.2		27.1	66.1	0.5	93.6
O	60.04	9.4	0.4	0.1	0.0	0.0	0.0	0.2	1.2	26.5	1.0	0.1	19.3	0.1		36.1	21.6	0.6	58.3
	61.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.3		38.3	0.0	0.0	38.4
	62.01	2.4	0.0	0.0	0.1	0.0	0.0	0.0	0.5	10.9	0.1	0.0	0.6	0.1		13.4	1.3	0.1	14.7
R	62.02	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.7	0.1	0.0	0.1	0.4		1.3	0.7	0.0	2.1
	62.03	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.1	0.0	0.0	0.2		0.5	0.4	0.4	1.3
	62.07	0.1	2.1	0.0	0.0	0.0	0.0	0.0	0.7	0.4	0.0	0.0	0.0	0.0		0.6	0.8	2.1	3.5
S	63.01	0.1	0.0	0.0	2.5	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.1	0.0		0.5	3.0	0.0	3.5
	63.02	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.1		0.3	0.5	0.0	0.8
	63.03	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0		0.2	0.2	0.1	0.5

Appendix F

ASSESSMENT OF LOWER-TIER VULNERABILITY USING CAPACITY UTILIZATION MEASURES

The ability of a supplier sector to respond to a surge demand on its output depends in part on its capacity utilization rate. If CU denotes this rate, then J = 100(100 - CU)/CU represents that amount (in percent) by which total output could theoretically be increased. Table E.1 above listed the percent increase I in total output of each supplier sector necessary to accommodate a 100 percent increase in DoD demand on a given defense sector. The ratio I/J gives a measure of the ability of each supplier to respond to such a surge in terms of the percent of available excess capacity that would have to be utilized to meet the required demand, under the assumption that all excess capacity could be applied to defense-related production. In particular, a ratio less than 1 indicates that (based on utilization rates alone) the supplier could meet the added demand, and a ratio greater than 1 indicates that it could not.

Table F.1 lists these I/J ratios based on the same three interpretations of surge as used for Table E.1. For example, the Complete Guided Missiles sector (13.01) would have to make use of 8 percent of its excess capacity to accommodate a 100 percent DoD surge for products of the Aircraft sector; 2 percent of its excess capacity to accommodate a 100 percent surge for products of all four munitions sectors; 397 percent of its excess capacity to accommodate a 100 percent across-the-board surge for products of all 13 defense sectors.

Table F.1

PERCENT OF SUPPLIER SECTOR'S EXCESS CAPACITY NEEDED TO MEET A 100% SURGE ON A GIVEN DEFENSE SECTOR

	BEA ID #	D 13.01	E 13.02	F 13.03	E 13.04	M 13.05	S 13.06	E 13.07	S 56.04	E 60.01	C 60.02	T 60.03	O 60.04	R 61.01	S	Whole Systems	Spares	Munitions	Total
	13.01	3.73	0.01	0.00	0.00	0.00	0.00	0.01	0.05	0.08	0.04	0.00	0.04	0.01		3.83	0.13	0.02	3.97
	13.02	0.00	0.69	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00		0.02	0.01	0.70	0.74
S	13.03	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		1.10	0.00	0.01	1.11
	13.04	0.01	0.00	0.00	0.83	0.00	0.00	0.00	0.04	0.06	0.00	0.00	0.01	0.00		0.07	0.89	0.00	0.96
	13.05	0.00	0.01	0.00	0.00	0.42	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.00		0.02	0.03	0.43	0.48
U	13.06	0.00	0.00	0.01	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.00	0.26	0.27
	13.07	0.01	0.00	0.01	0.00	0.00	0.00	0.26	0.00	0.01	0.00	0.00	0.01	0.00		0.03	0.01	0.26	0.30
	20.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.01	0.01
P	20.09	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02		0.02	0.01	0.03	0.06
	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00		0.02	0.02	0.00	0.03
	27.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00		0.01	0.01	0.01	0.04
P	27.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.01	0.00	0.02
	28.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00		0.02	0.01	0.00	0.03
	28.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00		0.02	0.01	0.00	0.03
L	32.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00		0.04	0.02	0.00	0.07
	32.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00		0.01	0.01	0.00	0.02
	35.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.01		0.01	0.02	0.00	0.03
I	36.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00		0.02	0.03	0.00	0.05
	36.16	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.01		0.05	0.03	0.01	0.08
	36.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.00	0.00	0.01
E	36.18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.01	0.01		0.04	0.04	0.00	0.08
	36.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.00	0.00	0.01
	36.22	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.02	0.01	0.00	0.00	0.18		0.22	0.05	0.00	0.27
R	37.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.02		0.03	0.01	0.01	0.06
	37.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01		0.04	0.02	0.00	0.06
	37.03	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.07	0.00	0.02	0.02		0.09	0.10	0.03	0.22
	37.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.02	0.00	0.02	0.02		0.09	0.06	0.01	0.15
	38.01	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.03	0.04	0.02	0.00	0.01	0.03		0.08	0.05	0.02	0.16
	38.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01		0.03	0.02	0.01	0.06
S	38.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.02	0.00	0.01	0.02		0.09	0.06	0.01	0.16
	38.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.00	0.01	0.02		0.07	0.03	0.01	0.11
	38.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.00	0.01	0.02		0.06	0.06	0.01	0.12
E	38.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01		0.03	0.02	0.00	0.05
	38.07	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.02		0.04	0.02	0.02	0.08
	38.08	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.00	0.01	0.01		0.09	0.03	0.01	0.13
C	38.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.05	0.00	0.02	0.02		0.12	0.09	0.01	0.22
	38.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01		0.02	0.02	0.00	0.04
	38.11	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.00	0.01	0.01		0.06	0.06	0.01	0.12
T	38.12	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.04	0.05	0.02	0.00	0.01	0.06		0.13	0.09	0.01	0.23
	38.13	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.04	0.04	0.00	0.01	0.01		0.10	0.09	0.02	0.21
	38.14	0.05	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.22	0.19	0.00	0.06	0.01		0.31	0.26	0.02	0.59
O	40.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02		0.02	0.00	0.00	0.02
	40.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04		0.04	0.00	0.00	0.04
	41.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.00	0.01	0.00		0.05	0.04	0.00	0.09
R	41.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.00	0.00	0.00		0.05	0.04	0.01	0.10
	42.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00		0.07	0.01	0.00	0.08
	42.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.04	0.00	0.01	0.02		0.10	0.08	0.01	0.19
S	42.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.01	0.00	0.00	0.01		0.04	0.05	0.01	0.10
	42.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01		0.02	0.00	0.00	0.02

Table F.1 (continued)

	BEA ID #	D 13.01	E 13.02	F 13.03	E 13.04	N 13.05	S 13.06	E 13.07	S 56.04	E 60.01	C 60.02	T 60.03	O 60.04	R 61.01	S	Whole Systems	Spares	Munitions	Total
	42.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01		0.03	0.01	0.00	0.04
	42.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00		0.01	0.02	0.00	0.03
S	42.11	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01		0.02	0.01	0.02	0.05
	43.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.18		0.21	0.03	0.00	0.24
	43.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02		0.03	0.01	0.00	0.03
U	47.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00		0.02	0.01	0.00	0.04
	47.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00		0.02	0.01	0.00	0.04
	47.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.05	0.04	0.00	0.01	0.03		0.11	0.09	0.01	0.21
P	47.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00		0.02	0.01	0.00	0.04
	49.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.05		0.09	0.02	0.00	0.11
	49.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.01	0.01		0.05	0.03	0.00	0.09
P	49.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01		0.01	0.00	0.00	0.02
	49.04	0.11	0.05	0.15	0.01	0.00	0.00	0.01	0.10	0.39	0.21	0.00	0.08	0.23		0.88	0.40	0.06	1.35
	49.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05		0.06	0.01	0.00	0.08
L	49.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00		0.02	0.01	0.00	0.04
	49.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
	50.00	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.17	0.09	0.00	0.03	0.02		0.25	0.15	0.02	0.41
I	51.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00		0.00	0.01	0.00	0.01
	53.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.00		0.02	0.04	0.00	0.06
	53.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.01	0.00	0.01
E	53.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00		0.01	0.03	0.00	0.04
	53.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01		0.03	0.02	0.00	0.05
	53.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.02		0.03	0.03	0.00	0.06
R	53.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01		0.01	0.00	0.00	0.01
	53.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01		0.02	0.02	0.00	0.04
	53.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00		0.01	0.01	0.00	0.02
	55.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.01
	55.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00		0.01	0.03	0.00	0.04
	56.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00		0.01	0.02	0.00	0.03
S	56.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00		0.00	0.02	0.00	0.02
	56.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.05	0.00	0.00	0.00	0.00		0.06	0.56	0.00	0.63
	57.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.00	0.00	0.00		0.02	0.10	0.00	0.12
E	57.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.00	0.00	0.00		0.03	0.09	0.01	0.12
	57.03	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.20	0.04	0.00	0.00	0.01	0.00		0.09	0.21	0.01	0.31
	58.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
C	58.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00		0.01	0.03	0.00	0.04
	58.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.06	0.06	0.00	0.01	0.01		0.09	0.07	0.00	0.17
	58.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.00	0.00	0.01
T	60.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.02	0.00		0.60	0.03	0.00	0.63
	60.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.12	0.79	0.00	0.01	0.00		0.15	0.81	0.01	0.97
	60.03	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.31	0.25	0.55	0.10	0.00		0.37	0.91	0.01	1.29
O	60.04	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.40	0.02	0.00	0.29	0.00		0.54	0.32	0.01	0.87
	61.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03		1.04	0.00	0.00	1.04
	62.01	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.30	0.00	0.00	0.02	0.00		0.36	0.03	0.00	0.40
R	62.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.01		0.04	0.02	0.00	0.06
	62.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00		0.01	0.01	0.01	0.03
	62.07	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00		0.01	0.02	0.04	0.07
S	63.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.03	0.00	0.03
	63.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.01	0.00	0.01
	63.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00		0.01	0.01	0.00	0.02

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